Reducing Inappropriate Testing for the Evaluation of Diarrhea Among Hospitalized Patients

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ABSTRACT

BACKGROUND: Diarrhea is one of the most common illnesses in the United States. Evaluation frequently does not follow established guidelines. The objective of this study was to evaluate the effectiveness of a computerized physician order entry-based test guidance algorithm with regard to the clinical, financial, and operational impacts.

METHODS: Our population was patients with diarrheal illness at a tertiary academic medical center. The intervention was a computerized physician order entry-based test guidance algorithm that restricted the use of stool cultures and ova and parasites testing of diarrhea in the adult inpatient location vs nonintervention sites, which were the emergency department, pediatric inpatient and adult and pediatric outpatient locations. We measured stool culture, ova and parasites, and Clostridium difficile testing rates from July 1, 2012 to January 31, 2016. Additionally, we calculated advisor usage, consults generated, accuracy of information, and cost savings.

RESULTS: There was a significant decrease in stool culture and ova and parasites testing rates at the adult inpatient (P = .001 for both), pediatric (P < .001 for both), and adult emergency department (P < .001; P = .009) locations. The decrease at the intervention site was immediate, whereas the other locations showed a delayed but sustained decrease that suggests a collateral impact. A significant increase in the rate of stool culture and ova and parasites testing was observed in the outpatient setting (P = .02 and P = .001). We estimate that $21,931 was saved annually.

CONCLUSIONS: A point-of-order test restriction algorithm for hospitalized adults with diarrhea reduced stool testing. Similar programs should be considered at other institutions and for the evaluation of other conditions.

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There has been an appropriate focus within the medical community in recent years on raising awareness of reducing the incidence of unnecessary medical tests, treatments, and procedures. Eliminating this waste is an important patient safety intervention, as excessive testing can lead to inappropriate diagnoses (eg, attributed to false-positive results in the setting of low pretest probability) and unnecessary therapies that carry their own risk of adverse events and side effects. For common medical symptoms and conditions in particular, addressing this waste can have a marked positive impact on patients by reducing harm and lowering costs.
Diarrhea is one of the most common chief complaints for patients seeking health care, with an estimated 211 million cases of acute gastroenteritis occurring in the United States annually. It is estimated that in 2010 in this country, there were 3.7 million emergency department visits and 1.3 million inpatient hospitalizations with a diagnosis of infectious enteritis or gastrointestinal symptoms suggesting foodborne illness. The economic impact of acute diarrhea is substantial, being estimated at $23 billion in the United States alone in 1988. Diarrhea can be caused by a wide array of infectious and noninfectious etiologies, many of which have their own specific diagnostic testing, which can make the initial assessment of the patient with acute diarrhea very challenging. Consequently, guidelines were developed to aide clinicians in the evaluation of patients with diarrhea; however, adherence to these recommendations is often suboptimal, resulting in increased costs without clinical benefit and waste of laboratory resources. Two specific tests utilized in the diagnosis of diarrhea are bacterial stool cultures and stool examination for the presence of ova and parasites. In certain clinical situations, however, the utility of these tests in the diagnostic evaluation of diarrhea is poor. For example, many laboratories will reject specimens sent for these tests in hospitalized patients admitted for more than 3 hospital days (known as the “Three-Day Rule”), given the very low incidence of these pathogens in this setting. Voluntary implementation of the “Three-Day Rule” has been shown to reduce inappropriate stool testing, improve diagnostic yield, and increase cost-effectiveness.

In addition to clinical guidelines and policies, novel tools that target ordering physicians to provide education and feedback, as well as using computerized physician order entry (CPOE)-based interventions, can markedly reduce unnecessary testing. Use of such interventions to reduce unnecessary testing for *Clostridium difficile* infection among hospitalized patients has been reported, but broader tools to address the additional testing among patients hospitalized with diarrhea are less prevalent. In response to variability in diarrheal testing practices among clinicians at Vanderbilt University Medical Center (VUMC), the Vanderbilt Antimicrobial Stewardship Program, in conjunction with the VUMC Microbiology Laboratory leadership, developed a CPOE-based testing algorithm for adult inpatients with diarrhea based on published guidelines and patient-specific characteristics. The approach of using a CPOE-based testing guidance algorithm is not well described in the literature, although there are suggestions that this strategy could be useful. Following the implementation of the testing algorithm, the Vanderbilt Antimicrobial Stewardship Program team conducted an evaluation of the tool’s impact in the adult inpatient units, as well as an examination of any collateral impact in other clinical areas of the medical center where the intervention was not explicitly activated (eg, inpatient and emergency pediatric, adult emergency department, and adult and pediatric outpatient locations). The results of this assessment are described below.

### CLINICAL SIGNIFICANCE
- Diarrhea evaluation frequently does not follow established guidelines, leading to unnecessary testing and treatment.
- A point-of-order test restriction algorithm for hospitalized adults reduced unnecessary stool testing, including a collateral impact at nonintervention sites.

### METHODS

#### Study Design

This study is a retrospective, interrupted time series analysis examining rates of diarrhea-related test ordering and the impact of a novel test algorithm and restriction strategy ("testing advisor"). It was approved by the institutional review board at VUMC as a quality improvement investigation.

#### Intervention

The diarrhea testing advisor (Figure 1) is a clinical decision tool that is incorporated in the electronic order entry system. It was developed after examining institutional testing practices and a review of the relevant literature, with a basis in the logic of the “modified Three Day Rule.” Specific goals of the advisor were to reduce orders for bacterial stool culture and stool ova and parasites testing and to guide clinicians to seek consultation with subspecialty consultation for more complicated patients. For the initial implementation, adult inpatient units were included. When a provider orders a stool culture, stool ova and parasites, and several other specialized stool tests for suspected infectious diarrhea on an inpatient in these locations, they are automatically directed into the advisor. A series of questions are then posed to the provider to capture details of the clinical illness and underlying patient characteristics (eg, symptom duration, travel history, presence of immunocompromise, and presence of hematochezia). The appropriate tests or consults are recommended depending on the information entered. For example, the advisor directs the use of bacterial stool cultures and stool ova and parasites examinations to specific patients with acute diarrhea of community onset (ie, patients with history of hospitalization of ≤3 days). If the clinician wishes to order a restricted test for a patient who does not meet the defined criteria, then approval by the infectious diseases or gastroenterology services is required. The advisor does not restrict *C. difficile* testing, as a CPOE-based tool to direct appropriate *C. difficile* testing (ie, limits testing to unformed stools, prohibits repeat testing in patients for 7 days) was already in place.

#### Evaluation of Advisor Impact

In order to assess the impact of the advisor, the monthly testing rate of bacterial stool cultures and stool ova and parasites examinations were assessed. Because *C. difficile* testing could
be ordered independent from the advisor, rates of testing were assessed as a surrogate for changes in the incidence of patients presenting with diarrhea during the study period.

The intervention was activated in mid-October 2014, and time period for this analysis was July 1, 2012 to January 1, 2016, divided into the preintervention (July 1, 2012 to October 31, 2014) and postintervention (November 1, 2014 to January 31, 2016) time periods. Because the advisor was activated only in the adult inpatient area, we assessed whether there was any collateral impact in other clinical areas of the medical centers. Specifically, testing rates were examined by the location of the patient at the time the order was placed, which included the adult inpatient (the intervention unit) and the 3 control locations: the adult emergency department, pediatric hospital, and adult and pediatric outpatient locations. Testing rates were calculated per 1000 patient days for the inpatient locations and per 1000 visits for the outpatient and emergency department locations. To examine whether the advisor may have prohibited appropriate testing of patients, we examined the absolute number and rate of positive cultures during the study period, calculated as number of positive stool cultures and ova and parasites tests in a given month out of the total number of tests sent. We hypothesized that if the advisor was too restrictive, the test positivity rate would be significantly reduced after implementation of the intervention. The sources of data for this analysis were the VUMC Enterprise Data Warehouse and the electronic medical record.

Because subspecialty consultation was required for some branches of the advisor, an analysis of the number of infectious diseases and gastroenterology consults that resulted from the advisor was also performed. Finally, the financial impact of the advisor was evaluated by determining the change in the number of stool bacterial cultures and ova and parasites examinations between the preintervention and the postintervention periods at the adult inpatient location. The difference between these rates was multiplied by the cost for each test, which was determined from cost data previously calculated by the VUMC Microbiology Department. These costs included the laboratory costs of the reagents and labor involved in the stool testing. Costs related to patient length of stay, nursing time, collection supplies, and antibiotic use were not included in this analysis.
**Statistical Analysis**

An interrupted time series analysis with Newey-West standard errors was used to compare diagnostic testing rates over the course of the study period. The 2-sample $t$ test was used for comparison of absolute stool testing rates and positivity rates. A $P$-value of $<.05$ was considered to be statistically significant. Hypothesis testing was 2 sided. Stata version 14 (StataCorp, College Station, Texas) was used for data analysis.

**RESULTS**

**Diarrhea Testing Advisor Utilization**

During the time period after the advisor was implemented, it was activated 704 times and completed 238 times. There were 26 infectious diseases consultations and 13 gastroenterology consultations generated during this time as a result of the advisor. The majority of the infectious diseases consults (81%) were prompted by the patient being immunocompromised.

**Stool Testing Rates**

Following activation of the diarrhea testing advisor, there was a significant immediate decrease in test orders and a significant continued decrease in the testing rate over time for both stool cultures and ova and parasites at the adult inpatient location (Figures 2A and 3A, Table, $P = .001$). In the control units, while there was not an immediate impact of the advisor activation, there was a significant collateral decrease in the rate of stool culture and ova and parasites testing in both the pediatric hospital units ($P < .001$) and the adult emergency department ($P < .001$; $P = .009$) in the period after activation of the advisor in the adult inpatient units despite the fact that the intervention was not activated at these sites (Figures 2B and C and 3B and C). Conversely, a significant increase in the rate of stool culture and ova and parasites testing (Figures 2D and 3D) was observed in the outpatient setting during the period after activation of the advisor in the adult inpatient units ($P = .02$ and $P = .001$, respectively).

**Test Positivity Rate Impact**

There was a statistically significant decrease in the number of positive tests per month (1.63 vs 0.67 tests per month
preintervention and postintervention, respectively; $P = .0188$) in the adult inpatient location associated with advisor implementation; however, there was no statistically significant difference in test positivity rate (positive tests/total tests) prior to and after the intervention (2.1% vs 2.4%; $P = .69$). A similar decrease in the number of positive stool cultures per month was also seen in the pediatric (6.25 vs 2.56; $P = .0006$), adult emergency department (.92 vs .11; $P = .004$), and outpatient (4.83 vs 2.44; $P = .018$) settings. There was no significant change in the number of positive tests per month for ova and parasites examinations in relation to the advisor activation at the adult inpatient location (0.19 vs 0.067; $P = .38$).

![Figure 3](image-url)

**Figure 3** (A-D) Interrupted time series analysis of stool ova and parasite testing rates in relation to implementation of the diarrhea advisor algorithm, which occurred only at the adult inpatient location (panel A).

<table>
<thead>
<tr>
<th>Table</th>
<th>Change in Test Ordering Over Time After Intervention by Site and Test</th>
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<tbody>
<tr>
<td>Location</td>
<td>Test</td>
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<td>Adult inpatient</td>
<td>Culture</td>
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<td></td>
<td>Ova and parasites</td>
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<td></td>
<td><em>Clostridium difficile</em></td>
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<td>Pediatric</td>
<td>Culture</td>
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<td><em>Clostridium difficile</em></td>
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<td>Emergency department</td>
<td>Culture</td>
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<td><em>Clostridium difficile</em></td>
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*All values are per 1000 patient days for the pediatric and adult inpatient locations and per 1000 patient visits for the emergency department and outpatient locations.
†All values are per 1000 patient days per month for the pediatric and adult inpatient locations and per 1000 patient visits per month for the emergency department and outpatient locations.
‡Denotes statistically significant result with $P < .05$. 

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Cost Analysis
An estimated $21,931 was saved in laboratory costs annually based on the decrease in stool culture and ova and parasites testing at the adult inpatient location after implementation of the diarrhea testing advisor.

DISCUSSION
The use of a computerized testing advisor to guide clinicians on the appropriate testing for hospitalized patients with diarrhea led to a significant and immediate reduction in the rate of bacterial stool culture and stool ova and parasites testing in adult inpatients. This impact was sustained following implementation. It is difficult to know with certainty what part of the algorithm is responsible for the majority of the impact; however, we found that the “three-day rule”-based restrictions limited 43% of attempted orders, with the remaining 57% being filtered into testing by other aspects of the advisor. Interestingly, a positive collateral impact occurred in other areas of the medical center where the advisor was not activated. Namely, there was a significant decrease in testing rates at the emergency department and pediatric inpatient locations. This effect may have been related to the presence of clinicians who work in both the intervention and control units, raising awareness of testing appropriateness that affected habits in other locations. Specifically, in the adult emergency department, a substantial proportion of patients are admitted and awaiting an available bed in an inpatient unit. These patients are cared for by clinicians from these locations who would be aware of the testing algorithm and have received education from the tool on appropriate testing. In addition, emergency residents rotate on adult inpatient clinical services, where they would have been exposed to the advisor. The pediatric inpatient units have less cross-over of clinicians, but adult emergency department clinicians, medicine-pediatric residents, and some surgical housestaff also rotate in the pediatric units, which may have led to more awareness of recommended testing strategies. Supporting the hypothesis that clinician crossover led to the collateral impact in nonintervention units is the fact that many clinicians who would perform diarrhea testing in the outpatient setting (eg, primary care and internal medicine providers) either do not care for patients once they have been admitted (due to a very robust hospitalist service in the adult inpatient units) or do not perform the actual test ordering in the adult inpatient units (ie, this task is performed by the housestaff on the team). The significant increase in testing rates among outpatients compared with the other areas is also interesting. Multiple factors may have contributed to this effect, but one of the strongest may have been the large number of outpatient clinicians who do not order tests on adult inpatients, which suggest a diminished opportunity for the collateral impact noted in the other areas. There was also a decrease in C. difficile testing in some areas despite this test not being restricted by the advisor. This is likely due to increased provider awareness of reducing unnecessary testing from our education efforts during the rollout of our intervention and from continuing reinforcement of awareness of overuse of diarrhea testing from interaction with the advisor. However, the decrease was modest and it is possible that there was simply a reduction in the number of cases of diarrhea seen in these locations.

This analysis did note a small but statistically significant decrease in the number of positive stool culture tests per month following implementation of the advisor, amounting to ~1 fewer positive stool culture a month. It is unclear if this was due to the advisor, as a similar decrease in the number of positive stool cultures was also seen at the nonintervention sites. If this was an effect of the intervention, the clinical impact is unclear but likely to be small for several reasons. First, the sickest patients (such as immunocompromised persons or those with fever) are recommended for infectious disease consultation in the algorithm, so it is unlikely that clinically significant positive tests in this group would have been missed. For patients without concerning symptoms, it is likely that even with a positive culture, treatment would not have been indicated or would have been of minimal benefit.17,19

The financial impact of reduced stool testing, while modest at $21,931 a year, is likely underestimated, given that reduced nursing workload, decreased need for collection supplies, and a reduction in other indirect costs anticipated as a result of less testing were not included in the analysis. To put this value in context, a CPOE-based intervention targeted at reducing redundant B-type natriuretic peptide orders was estimated to save $92,000 yearly, and another intervention designed to limit repetitive C. difficile testing saved an estimated $21,650 annually.12,20 Our cost savings estimate included only the intervention site and may have been greater if the effects seen at the other sites were included. Finally, the impact in the reduction of unnecessary antibiotic use and subsequent risk of C. difficile infection and contribution to the development of multi-drug-resistant organisms is important to acknowledge, even if this is not able to be quantified.

This intervention and analysis does have some limitations. First, it encompasses patients and clinicians at a single academic medical center, where testing rates and the underlying patient characteristics may differ from that of other acute care facilities. Second, the advisor guidance relies on the entering of accurate information about the patient’s clinical presentation. Clinicians could enter false data in order to obtain a desired test. To assess this, investigators reviewed a subset of cases to assess whether responses on the duration-of-symptoms question were accurate when compared with the clinical documentation. This question was completed by all advisor respondents, making it a uniform assessment of data validity. In a review of 67 patients (12.6% of the total), 76% of responses reported a duration of symptoms that matched the clinical documentation. This relatively low rate is not particularly surprising, as it has been noted in studies of physician self-report of sepsis bundle compliance and documentation of clinic visits that inaccuracies are common.21,22 If this had been closer to 100% accurate, the impact on testing may have been even more pronounced. Perhaps most concerning is that some providers would enter the advisor multiple times for
the same patient and provide different answers, likely to obtain their desired test and bypass the recommendations. This issue should be considered in any future testing algorithms that are designed. Third, our test positivity rate analysis assumes that the test characteristics remained stable over time. However, it is possible that if the test performed differently over time (ie, a higher or lower sensitivity/specificity), this was responsible for the changes observed in the number of positive stool cultures monthly, as opposed to the effect of the advisor.

Another limitation of this study is that we were unable to collect data on noninfectious etiologies of diarrhea. Finally, this study does not address the ongoing transition from conventional culture and microscopy-based methods of pathogen identification to newer molecular techniques. We believe that the concepts included in this study, namely, the restriction of diagnostic testing, provide a basis for the application of similar algorithms, including multipathogen molecular testing. We would expect similar high rates of inappropriate testing with these platforms if implemented without restriction; although, their role in the evaluation of hospitalized patients with diarrhea is not precisely defined at this time.

In conclusion, a point-of-order testing advisor algorithm for hospitalized adults with diarrhea was effective in reducing bacteriologic stool cultures and ova and parasites testing, leading to substantial cost and time savings. This effect occurred in areas where the advisor was directly employed, as well as in other clinical areas that did not have access to the tool. The method of test restriction used in this study is different from those described previously, as it directly impacts the provider’s ability to order the studies rather than relying on rejection of already collected specimens that do not meet testing criteria. In an era of medicine where the reduction of unnecessary treatment and testing is recognized as an important goal, projects such as this are crucial. Future efforts to expand this work to other health care systems and for the evaluation of other disease states should be considered.

References

SUPPLEMENTARY DATA
Supplementary data accompanying this article can be found in the online version at doi:10.1016/j.ajmmed.2017.10.006.
Supplementary Figure 1  Interrupted time series analysis of C. difficile testing rates in relation to implementation of the diarrhea advisor algorithm, which restricted only stool culture and O & P testing at the adult inpatient location.