ORIGINAL ARTICLE

The Impact of a Computerized Clinical Decision Support Tool on Inappropriate *Clostridium difficile* Testing

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OBJECTIVE. To evaluate the effectiveness of a computerized clinical decision support intervention aimed at reducing inappropriate *Clostridium difficile* testing.

DESIGN. Retrospective cohort study.

SETTING. University of Pennsylvania Health System, comprised of 3 large tertiary-care hospitals.

PATIENTS. All adult patients admitted over a 2-year period.

INTERVENTION. Providers were required to use an order set integrated into a commercial electronic health record to order *C. difficile* toxin testing. The order set identified patients who had received laxatives within the previous 36 hours and displayed a message asking providers to consider stopping laxatives and reassessing in 24 hours prior to ordering *C. difficile* testing. Providers had the option to continue or discontinue laxatives and to proceed with or forgo testing. The primary endpoint was the change in inappropriate *C. difficile* testing, as measured by the number of patients who had *C. difficile* testing ordered while receiving laxatives.

RESULTS. Compared to the 1-year baseline period, the intervention resulted in a decrease in the proportion of inappropriate *C. difficile* testing (29.6% vs 27.3%; $P = .02$). The intervention was associated with an increase in the number of patients who had laxatives discontinued and did not undergo *C. difficile* testing (5.8% vs 46.4%; $P < .01$) and who had their laxatives discontinued and underwent testing (5.4% vs 35.2%; $P < .01$). We observed a nonsignificant increase in the proportion of patients with *C. difficile* related complications (5.0% vs 8.9%; $P = .11$).

CONCLUSIONS. A *C. difficile* order set was successful in decreasing inappropriate *C. difficile* testing and improving the timely discontinuation of laxatives.

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Clostridium difficile is common, accounting for 12.1% of all healthcare-associated infections.[1] In recent decades, the rate of *C. difficile* infections has risen coinciding with increasing use of antibiotics in some populations.[2] The rate of *C. difficile* infections in US hospitals doubled from 1996 to 2003, increasing from 31 to 61 infections per 100,000 patients.[3] In 2008, *C. difficile* infections in acute-care settings cost between $1 billion and $4.8 billion.[4] The 30-day mortality rate following *C. difficile* infection was recently estimated to be 9.3% in patients with healthcare-onset *C. difficile*.[5]

Research is increasingly focusing on asymptomatic carriage of *C. difficile*. Studies looking at rates of asymptomatic carriage of toxigenic *C. difficile* in hospitalized patients have found rates ranging between 9% and 15%.[6–8] Patients who are asymptomatic carriers may be misdiagnosed as having *C. difficile* infections if they undergo testing that is not clinically indicated. One such example is *C. difficile* testing in patients who experience diarrhea resulting from other causes such as the use of laxatives rather than infection. A study of hospital-onset *C. difficile* infections at an academic tertiary-care hospital found that 14.8% of patients with a positive *C. difficile* test did not meet an indication for testing.[9] Treatment of asymptomatic carriers increases the risk of side effects and costs of care.

We hypothesized that a computerized clinical decision support (CCDS) tool could reduce inappropriate testing for *C. difficile* among patients receiving concurrent laxative therapy. In this study, we examined the impact of such a CCDS tool integrated into a commercial electronic health record

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PREVIOUS PRESENTATIONS: These data were presented as a poster at the Society of Hospital Medicine Annual Meeting on March 30, 2015, in National Harbor, Maryland, and at the 8th Annual Mid-Atlantic Healthcare Informatics Symposium, October 23, 2015, Philadelphia, Pennsylvania.

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system across inpatient settings in a multihospital academic health system.

METHODS

The Intervention

We defined an inappropriate *C. difficile* test as a stool specimen tested for *C. difficile* from a patient who received laxatives in the 36 hours prior to the ordering of the test. All other *C. difficile* tests were considered appropriate. We created a computerized clinical decision support (CCDS) tool in the form of a *C. difficile* order set in the inpatient electronic health record. Providers were required to use the order set to order testing for *C. difficile* in all inpatient settings. The order set automatically identified patients receiving laxatives within the previous 36 hours and displayed the following message: "In patients who do not have severe illness, stop laxatives and reassess diarrhea in 24 hours before sending a *C. difficile* test." In such cases, the names, doses, frequency, and route of each laxative administered to the patient in the previous 36 hours were displayed, along with the last date and time of administration. Users had the following options: (1) discontinue the laxatives directly from the order set without ordering *C. difficile* testing, (2) discontinue the laxatives and proceed with ordering *C. difficile* testing, or (3) proceed with ordering *C. difficile* testing without discontinuing any laxatives (Supplement Figure 1). If a patient received a laxative within the previous 36 hours, the order set defaulted to option 1. If a patient did not receive laxatives within the previous 36 hours, then the order set only displayed the *C. difficile* test order (Supplement Figure 2). The order set went live on March 11, 2014.

Clostridium difficile Testing

Our *C. difficile* testing algorithm includes enzyme immunoassay (EIA) for glutamate dehydrogenase and toxins A/B (Techlab C. Diff Chek Complete; Alere, Orlando, FL), followed by a nucleic acid amplification test (NAAT) (Illumigene, Meridian Bioscience, Cincinnati, OH; changed to BD Max, Becton-Dickinson, Sparks, MD, in August 2013) for discordant EIA results (glutamate dehydrogenase positive but toxin A/B negative).[10] *Clostridium difficile* testing is restricted to stool specimens that are semiformed to liquid (Bristol score of ≥5), and testing cannot be repeated for 9 days to reduce inappropriate *C. difficile* testing.

Cases of *C. difficile* were documented in the surveillance program Theradoc (Hospira, Salt Lake City, UT), as well as Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) database for mandatory state public reporting requirements. For positive *C. difficile* assays sent ≥48 h after hospital admission and from patients readmitted within 14 days of a previous discharge, we determined whether NHSN criteria were met for each event.[11] Adjudicated *C. difficile* infections (CDI) were classified as complicated if associated with ICU transfer, colectomy, or death attributed to CDI within 30 days.[12]

Setting

The CCDS intervention was developed, implemented, and evaluated in an academic healthcare system comprised of 3 acute-care teaching hospitals—Hospital of the University of Pennsylvania (HUP), Penn Presbyterian Medical Center (PPMC) and Pennsylvania Hospital (PAH)—with a combined capacity of more than 1,500 beds and 70,000 annual admissions. In the preintervention period, 224 encounters with hospital-acquired CDI and 407 encounters with non–hospital-acquired CDI occurred, for a total baseline CDI rate of 0.91% (631 of 69,362 encounters). The tool was used across all adult inpatient units, where resident physicians are responsible for most orders placed. All hospitals within the healthcare system used Sunrise Clinical Manager version 5.5 (Allscripts, Chicago, IL) as the inpatient EHR for order entry. An e-mail message communicating the implementation of the tool was distributed to all faculty and staff across the healthcare system, including attendings, trainees, nurses, and administrators. In addition, broadcast screensavers communicating the implementation of the tool were displayed on all computer workstations on all units across the healthcare system, excluding patient rooms.

Study Population

The study population included all adult patients who were hospitalized at the 3 health system hospitals during the study period. The preintervention period spanned 12 months prior to implementation of the CCDS tool (March 1, 2013–February 28, 2014). The postintervention period spanned a 12-month period after the implementation of the CCDS tool (April 1, 2014–March 31, 2015). Patients hospitalized between March 1, 2014, and April 1, 2014, were excluded to allow for a wash-in period.

Primary and Secondary Outcomes Measures

The primary outcome measure of this study was the change in proportion of inappropriate *C. difficile* tests sent, defined as any *C. difficile* stool assay ordered on a patient receiving laxatives in the preceding 36 hours. Additional outcome measures included the number of patients who had laxatives discontinued within 15 minutes from the time the order was placed, and proportion of patients with *C. difficile* tests sent, positive *C. difficile* tests, positive tests in patients receiving laxatives (which we classified as false-positive *C. difficile* tests), and *C. difficile* related complications (ICU transfer, colectomy, or CDI-related death) for those with adjudicated hospital-acquired infections. For those with complications associated with hospital-acquired CDI, we also examined whether *C. difficile* testing was "delayed" more than 24 hours as a result of the CCDS tool (ie, *C. difficile* testing was delayed because the patient was receiving a laxative). The delay duration was measured as the difference between the first instance of a *C. difficile* order placed but not performed because of active laxative use and the first instance where the *C. difficile* order was placed and performed.

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TABLE 1. Characteristics of Patients in the Two Study Periods

Characteristic	Preintervention (N = 69,362), No. (%)[a]	Postintervention (N = 67,814), No. (%)[a]	*P* Value
Mean age, years	54.3	54.5	.071
Sex, female	39,606 (57.1)	38,858 (57.3)	.556
Mean body mass index	29.0	29.1	.051
Race/Ethnicity			
White	34,982 (50.4)	34,014 (50.2)	.214
Black	26,684 (38.5)	26,157 (38.6)	
Other	7,696 (11.1)	7,643 (11.3)	
Median length of stay (IQR), days	3 (2–6)	4 (2–7)	<.001
Median DRG weight, (IQR)	1.18 (0.81–1.93)	1.17 (0.82–2.04)	<.001
Hospital admissions			
HUP	35,452 (51.1)	33,898 (50.0)	<.001
PPMC	14,667 (21.1)	15,015 (22.1)	
PAH	19,243 (27.7)	18,901 (27.9)	
Admission type			
Elective	19,828 (28.6)	18,930 (27.9)	<.001
Emergency Department	27,504 (39.7)	26,976 (39.8)	
Transfer	21,977 (31.7)	21,888 (32.3)	
Discharging Service			
Medicine	16,429 (26.5)	15,868 (26.6)	<.001
Surgery	18,729 (30.2)	17,855 (30.0)	
Mixed	14,033 (22.7)	13,242 (22.2)	
Women's health	10,089 (16.3)	10,140 (17.0)	
Critical care	2,659 (4.3)	2,484 (4.2)	
Top 5 major diagnostic categories			
1–Circulatory system	10,972 (29.6)	10,426 (28.4)	<.001
2–Pregnancy, childbirth and puerperium	9,048 (24.4)	9,357 (25.5)	
3–Musculoskeletal system and connective tissue	7,239 (19.5)	7,169 (19.5)	
4–Digestive system	5,563 (15.0)	5,455 (14.8)	
5–Nervous system	4,269 (11.5)	4,336 (11.8)	

NOTE: IQR, interquartile range; DRG; diagnosis-related group; HUP, Hospital of the University of Pennsylvania; PPMC, Penn Presbyterian Medical Center; PAH, Pennsylvania Hospital.
[a]Unless otherwise specified.

Statistical Methods

Data were analyzed using χ^2 and *t*-test statistics to compare dichotomous and continuous outcomes, respectively, before and after the CCDS intervention was implemented. Table 1 was generated using χ^2 analysis for categorical data and Mann-Whitney U for continuous variables. All analyses were performed with the use of Stata 12.1 software (Stata Corp, College Station, Texas, USA). The study received expedited approval and a Health Insurance Portability and Accountability Act waiver from our institutional review board.

RESULTS

In total, 69,362 hospital admissions occurred and 4,498 *C. difficile* tests were ordered in the preintervention period and 67,814 hospital admissions occurred and 4,396 tests were ordered in the postintervention period. Compared to the preintervention period, small but statistically significant differences were observed in the distributions of admissions between hospitals, discharging service, and major diagnostic categories. The median length of stay was longer during the intervention period (Table 1).

The *C. difficile* CCDS tool was associated with a decrease in the proportion of inappropriate *C. difficile* testing sent (preintervention vs postintervention: 29.6% vs 27.3%; $P = .02$) (Figure 1). In 2 of the hospitals, HUP and PAH, the proportion of inappropriate testing decreased (32.5% vs 29.9%; $P = .03$; 26.1% vs 22.6%; $P = .11$), while in PPMC, a nonsignificant increase was observed (21.1% vs 21.7%; $P = .8$).

We observed increases in the proportion of instances in which patients had their laxatives discontinued at the time of an intended *C. difficile* order with no testing sent during that order (preintervention vs postintervention: 5.8% vs 46.4%; $P < .01$) and where patients had their laxatives discontinued with *C. difficile* testing sent during that order (5.4% vs 35.2%; $P < .01$) (Table 2). There were no significant changes in the overall proportion of patients with *C. difficile* testing (6.5% vs 6.5%; $P = .99$), positive *C. difficile* tests (14.0% of tests vs 13.7%; $P = .67$), and false-positive *C. difficile* tests (27.6% of positive *C. difficile* tests vs 26.2%; $P = .62$). In addition, for those with hospital-acquired *C. difficile*, we observed a nonsignificant

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increase in the proportion of patients with *C. difficile* related complications between the preintervention and postintervention periods (5.0% vs 8.9%; $P = .11$) (Table 2). Among those with complications associated with hospital-acquired CDI in the post period, we observed only 1 case in which *C. difficile* testing was "delayed" more than 24 hours because of the CCDS tool.

DISCUSSION

In this large quality-improvement study, we examined the impact of a CCDS tool on the testing of *Clostridium difficile* across a heterogeneous patient population in diverse inpatient clinical settings. This intervention resulted in a statistically significant decrease in inappropriate *C. difficile* testing.

The CCDS tool led to a substantial increase in discontinuation of laxatives both in patients with diarrhea who had *C. difficile* testing sent and in patients with diarrhea who did not have *C. difficile* testing sent. As a result, patients with diarrhea were less likely to continue receiving laxatives, potentially preventing patient discomfort and dissatisfaction. Additionally, the proportion of patients who had *C. difficile* testing was identical during the 2 study periods, suggesting that overall the tool did not discourage appropriate and timely testing. Notably, we observed a small but nonsignificant increase in the overall proportion of patients who experienced a *C. difficile*–related complication (eg, ICU transfer, colectomy, or death) for those with hospital-acquired *C. difficile* in the postintervention period. Possible explanations for this increase include an increase in virulent strains of *C. difficile* or improved documentation of complications by infection preventionists responsible for *C. difficile* surveillance activities. The order set seems to be a less likely cause, as only 1 of the cases with complications had *C. difficile* testing delayed more than 24 hours.

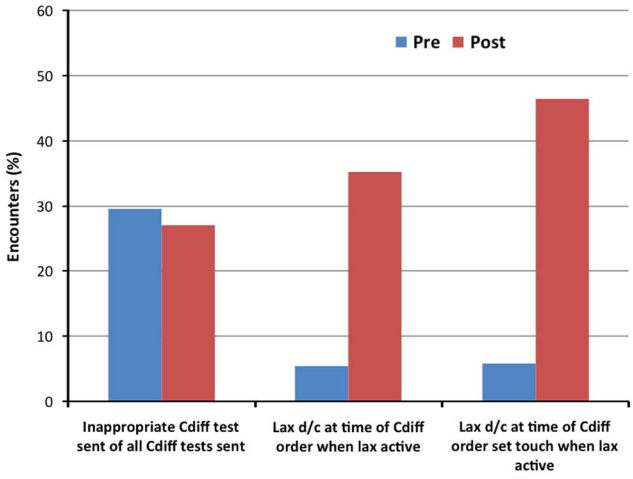


FIGURE 1. Pre-post Analysis of Impact of Tool on Process Measures
NOTE: Cdiff, *C. difficile*; D/c, discontinue; Lax, laxative; Pre, 12-month preintervention period; Post, 12-month postintervention period.

The strengths of this study include the size and diversity of the patient population included. Many examinations of quality-improvement initiatives are limited to single units or service lines and by study population and duration. These restrictions can limit generalizability. By contrast, this study population was comprised of all inpatients hospitalized across a multientity academic hospital system over a multiyear period.

Nonetheless, this study has several limitations. First, our pre- and postintervention design does not control for cultural changes in testing and does not employ a control group. Second, we were not able to capture providers who viewed the order set and as a result did not order testing but did, in viewing the order set, benefit from the decision support provided. Third, we were unable to separate patients who received laxatives and had *C. difficile* testing ordered but also met other clinical criteria concerning for *C. difficile* infections and would thus be considered high-risk patients. Fourth, other inappropriate indications for *C. difficile* testing could theoretically be addressed by a CCDS tool that our current tool did not address, including repeated testing for *C. difficile* within a limited period and testing for cure. Adding such features could increase the impact of a CCDS tool on inappropriate testing for *C. difficile*.

Future studies should explore the generalizability of this intervention to nonacademic centers. A similar tool could also have an impact in long-term-care facilities where

TABLE 2. Complications of Patients with Hospital-Acquired *Clostridium difficile* Infection (CDI) in the Two Study Periods

Complication	Period[a]	Proportion of CDI patients with complication, No. (%)	*P* Value
1–ICU transfer for CDI complication	Preintervention	9/218 (4.2)	.18
	Postintervention	15/212 (7.1)	
2–Surgery for CDI complication	Preintervention	2/218 (0.9)	.24
	Postintervention	5/212 (2.3)	
3–CDI contributed to death	Preintervention	3/218 (1.4)	.45
	Postintervention	5/212 (2.4)	
1 or 2 or 3	Preintervention	11/218 (5.0)	.11
	Postintervention	19/212 (8.9)	

NOTE: ICU, intensive care unit.
[a]Preintervention and postintervention periods each spanned 12 months.

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asymptomatic carriage is estimated to be 14.8% and as high as 30% in facilities with a prior *C. difficile* outbreak.[13] A prospective, randomized study could help determine the impact of similar tools on *C. difficile*–related complications.

In conclusion, this study suggests that a CCDS tool targeting inappropriate *C. difficile* testing in patients receiving laxatives can decrease inappropriate *C. difficile* testing and can improve the timely discontinuation of laxatives, but such a tool may not influence the overall rate of *C. difficile* orders or positive *C. difficile* tests.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/0.1017/ice.2017.161.

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