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The impact of an electronic medical record nudge on reducing testing for hospital-onset *Clostridioides difficile* infection

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Abstract

Objective: To determine the effect of an electronic medical record (EMR) nudge at reducing total and inappropriate orders testing for hospital-onset *Clostridioides difficile* infection (HO-CDI).

Design: An interrupted time series analysis of HO-CDI orders two years before and two years after the implementation of an EMR intervention designed to reduce inappropriate HO-CDI testing. Orders for *C. difficile* testing were considered inappropriate if the patient received a laxative or stool softener in the previous 24 hours.

Setting: Four hospitals in an academic healthcare network.

Patients: All patients with a *C. difficile* order after hospital day three.

Intervention: *C. difficile* orders in patients administered a laxative or stool softener in <24 hours triggered an EMR alert defaulting to order cancellation (“nudge”).

Results: Of the 17,694 HO-CDI orders, 7% were inappropriate (8% pre- vs. 6% post-intervention, $p < 0.001$). Monthly HO-CDI orders decreased by 21% post-intervention (level change rate ratio [RR]: 0.79; 95% confidence interval [CI] 0.73–0.86) and the rate continued to decrease (post-intervention trend change RR: 0.99; 95% CI 0.98–1.00). The intervention was not associated with a level change in inappropriate HO-CDI orders (RR: 0.80; 95% CI 0.61–1.05), but the post-intervention inappropriate order rate decreased over time (RR: 0.95; 95% CI 0.93–0.97).

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Conclusion: An EMR nudge targeted to minimize inappropriate ordering for *C. difficile* was effective at reducing HO-CDI orders, and likely contributed to decreasing the post-intervention inappropriate HO-CDI order rate.

Introduction:

Clostridioides difficile infection (CDI), with an estimated annual incidence of 149 cases per 100,000 population leading to 29,000 deaths per year in the United States, continues to be a major public health concern.^{1–3} *C. difficile* is the most common healthcare-associated pathogen and approximately two-thirds of CDI cases are healthcare-associated.^{2,4} However, since an estimated 8–15% of hospitalized patients are asymptomatic carriers of *C. difficile*, positive test results must be interpreted in the context of clinical symptoms.^{5,6} Inappropriate testing can lead to overdiagnosis, unnecessary treatment, and financial penalties as hospital-onset CDI (HO-CDI) is a nationally reported hospital quality metric.³

The 2018 Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA) CDI clinical practice guidelines recommend not testing for CDI if patients have diarrhea clearly attributable to another cause, and advise against testing patients who have recently received a laxative.³ However, laxatives are frequently prescribed in hospitalized patients, and studies have found that 19%–44% of all *C. difficile* tests may be inappropriately ordered on patients receiving laxatives.^{7–10} This scenario provides an opportunity for intervention.

“Nudging,” a behavioral science concept popularized by Richard Thaler, is a means to reliably modify people’s choices by restructuring their environment without eliminating options or imposing financial penalties.^{11,12} This concept is effective in many areas of healthcare including smoking cessation, appropriate antibiotic prescribing, and hand hygiene compliance, and can be leveraged when designing electronic medical record (EMR) interventions.^{13–15} In this study, four hospitals within one academic healthcare network implemented a simple EMR nudge to encourage providers to cancel *C. difficile* orders on patients who received a laxative or stool softener in the prior 24 hours. Using a quasi-experimental design with an interrupted time series analysis, we sought to examine the impact of this EMR notification on reducing rates of HO-CDI diagnostic testing.

Methods:

Study setting, population and design

We conducted a retrospective study at four hospitals (designated A, B, C, and D) in the same academic healthcare network, comprising approximately 1600 inpatient beds. Hospital A is 511-bed hybrid academic-community tertiary care hospital. Hospital B is a 587-bed academic tertiary care hospital that performs solid organ and hematopoietic stem cell transplantation. Hospitals C and D are 410-bed and 110-bed community hospitals, respectively.

The study population included all hospitalized patients who had a *C. difficile* order placed after hospital day three and were therefore eligible to be included in the Centers for Disease

Control and Prevention (CDC) HO-CDI metric. At the patient level, we extracted age, race, hospital location, comorbidities included in the Charlson comorbidity index, dates of hospital admission and discharge, dates and times of all laxatives or stool softeners administered, and dates and times of all *C. difficile* orders placed from the EMR. Additional hospital level variables included the monthly number of CDC defined HO-CDI laboratory-identified (LabID) events, and the number of total inpatient-days per month. We analyzed a two-year period pre- (2/1/2015–1/31/2017) and post-intervention (2/1/2017–1/31/2019).

Clostridioides difficile testing and definitions

C. difficile testing was performed by polymerase chain reaction (PCR) (Xpert *C. difficile* PCR assay, Cepheid, Sunnyvale, CA) at all study hospitals throughout the study period. The microbiology laboratory routinely rejects formed stools and repeat specimens collected within seven days of a previous test. HO-CDI orders were defined as *C. difficile* orders placed on patients after hospital day three. A HO-CDI LabID event was defined, according to CDC criteria, as a positive *C. difficile* test in a patient hospitalized for more than three days, without any prior positive *C. difficile* tests from the same location in the last 14 days.

For this study, a *C. difficile* order was defined as “inappropriate” if placed within 24 hours after a patient received a laxative or stool softener based on the bar-coded administration time stamp in the EMR. The laxatives and stool softeners included in the EMR notification and our analysis were alvimopan, bisacodyl, docusate, sodium bisphosphate-sodium phosphate, glycerin, lactulose, magnesium citrate, methylnaltrexone, mineral oil, polyethylene glycol 3350, polyethylene glycol electrolyte solution, senna and sorbitol.

Primary and secondary outcome measures

The primary outcomes were the changes in the rates of total and inappropriate HO-CDI orders per 1,000 patient-days, comparing the pre- and post-intervention periods. The secondary outcome assessed the change in rate of HO-CDI LabID events per 1,000 patient-days before and after the intervention. A subgroup analysis also evaluated the primary and secondary outcomes stratified by individual hospital.

Intervention

On February 1, 2017, all study hospitals implemented a pop-up notification in the EMR (PowerChart Millennium, Cerner Corporation, North Kansas City, MO) triggered when providers entered a *C. difficile* order on a patient who received a laxative or stool softener within the last 24 hours. The default option of clicking “okay” without any further steps closes the pop-up and cancels the order, nudging the provider to cancel potentially inappropriate orders. However, providers can also choose to override the notification by checking a box that states, “continue with the order,” before clicking “okay.” No additional standardized, systemwide interventions to decrease HO-CDI testing were implemented during the study period. However, approximately one month prior to the EMR intervention (January 2017), hospital B started an audit of all HO-CDI orders in which the hospital epidemiologist could stop the lab from processing inappropriate *C. difficile* tests. Orders halted through this process were cancelled after they were entered into the EMR, and therefore this intervention did not affect tracking of our primary outcome. Additionally, in

May and August 2016, hospitals C and D, respectively, adopted a paper-based, nursing-driven *C. difficile* testing algorithm which encouraged early testing during the first three hospital days on any patient with loose stools, followed by a more conservative approach on or after hospital day four. A similar algorithm was implemented in select units in hospital B in May 2017. Compliance with these initiatives could not be confirmed or quantified, and they were not included in modeling due to sample size limitations.

Statistical analysis

We performed χ^2 tests for categorical variables, and means with standard deviation (SD), medians with interquartile ranges (IQR), Wilcoxon rank sum tests, or Student's t-tests as appropriate for continuous variables, to compare patient and *C. difficile* order characteristics pre- and post-intervention. We compared the median monthly rate of total and inappropriate HO-CDI orders pre- and post- intervention with the Wilcoxon rank sum test.

Using an interrupted time series design, we analyzed monthly rates of total and inappropriate HO-CDI orders as well as HO-CDI LabID events before and after the intervention, with changes expressed as rate ratios (RR). We used a segmented regression model with a negative binomial distribution since the data was overdispersed. In the models, the outcomes were the number of *C. difficile* orders (total or inappropriate) or HO-CDI LabID events per month, and the main exposure was a binomial variable indicating if the order, or LabID event, was before or after the intervention. The model also included an offset for the monthly total number of inpatient person-days, a time variable to account for time throughout the entire study period, and a "time after" term to account for time after the intervention. The binomial exposure variable allows for detection of an immediate "level change" in the primary outcome following the intervention. The time variable allows for control of unmeasured trends in ordering practices over the entire study period (baseline trend) and the time after variable allows for assessment of a slope or "trend change" in the order rate after the intervention.¹⁶ Autocorrelation was assessed using the Durbin-Watson test in SAS for the primary and secondary outcomes. All analyses were completed using SAS version 9.4 (SAS Institute, Cary, NC) and R (R Core Team, 2018).

Human Subjects

The Emory University Institutional Review Board approved this study with a waiver of patient's informed consent.

Results:

Patient and *C. difficile* order characteristics

Among 36,195 *C. difficile* orders, 17,694 (49%) assessed for HO-CDI in 9,846 patients and 11,143 admissions (Table 1). A little more than half the patients with HO-CDI orders were female (51%) and white (54%) with a mean age of 60.5 (SD 16.0) years. Comparing pre- and post-intervention periods, patients with orders testing for HO-CDI in the post-intervention period more frequently had a Charlson comorbidity index > 4 (46% vs. 51%, $p < 0.001$) and a longer median length of stay (15.1 [IQR: 9.3–23.9] vs. 16.0 [IQR: 10.4–25.1] days, $p < 0.001$).

There were 10,686 HO-CDI orders placed pre-intervention and 7,008 placed post-intervention. The median number of HO-CDI orders placed per an individual's hospital admission was 1 (IQR: 1–2), with a median time between admission and HO-CDI order of 10 (IQR: 6–16) days. The most common laxative or stool softener administered in the 24 hours prior to an inappropriate HO-CDI order was docusate (387, 30%) followed by bisacodyl (185, 14%) and lactulose (161, 13%). The intervention was associated with a significant decrease in the proportion of inappropriate HO-CDI orders (8% pre- v. 6% post-intervention, $p < 0.001$).

Total and inappropriate hospital-onset *C. difficile* order rates

The median monthly HO-CDI order rate per 1,000 patient-days pooled across all four hospitals decreased from 10.9 (IQR: 10.5–11.6) to 7.0 (IQR: 6.4–7.6, $p < 0.001$) after implementation of the intervention (Table 2). Using an interrupted time series analysis which controlled for unmeasured changes in ordering practices throughout the study period, and change in slope after the intervention, the EMR notification significantly decreased the HO-CDI order rate (level change RR: 0.79; 95% confidence interval [CI] 0.73–0.86). There was also a modest continuing decline in order rate after the intervention (trend change after intervention RR: 0.99; 95% CI: 0.98–1.0) (Table 3, Figure 1).

For inappropriate orders, the median monthly order rate per 1,000 patient-days was 0.8 (IQR: 0.8–1.0) pre- and 0.4 (IQR: 0.3–0.6) post-intervention ($p < 0.001$, Table 2). In the interrupted time series analysis, the intervention was not significantly associated with an immediate decrease in the inappropriate HO-CDI order rate (level change RR: 0.80; 95% CI: 0.61–1.05). However, after the intervention, the order rate significantly decreased with time (trend change after intervention RR: 0.95; 95% CI: 0.93–0.97) (Table 3, Figure 2).

We also assessed HO-CDI order rates stratified by hospital, given differences in patient population, baseline *C. difficile* incidence, and hospital-specific *C. difficile* testing initiatives. The two largest hospitals paralleled the overall trend with a decrease in the HO-CDI order rate associated with the EMR intervention (hospital A level change RR: 0.67; 95% CI: 0.56–0.80; hospital B level change RR: 0.85; 95% CI: 0.77–0.94). Hospital D showed a similar pattern of decline in order rate but did not reach statistical significance (level change RR: 0.73; 95% CI: 0.52–1.03). Hospital C demonstrated a significant decrease in HO-CDI order rate throughout the entire study period (RR: 0.95; 9% CI: 0.93–0.96) but was not influenced by the EMR intervention (level change RR: 0.75; 95% CI: 0.53–1.06) (Supplementary Figure 1). Similarly, for inappropriate HO-CDI orders, the trend in order rates was comparable to the composite primary outcome in hospitals A, B and D with a significant decrease in the trend change after the EMR intervention (Supplementary Figure 2).

Hospital-onset *C. difficile* laboratory-identified events

In a secondary analysis, the composite rate of HO-CDI LabID events per 1,000 patient-days decreased after the implementation of the EMR intervention (level change RR: 0.74; 95% CI: 0.60–0.91) (Table 3, Figure 3). However, in the per hospital assessment, only hospital B, which also instituted a HO-CDI audit process one month prior to the EMR intervention, had

a significant decrease in LabID events associated with the EMR intervention (level change RR: 0.65; 95% CI: 0.49–0.87).

Discussion:

A simple EMR notification to nudge providers away from testing for *C. difficile* in patients who received a laxative or stool softener within the last 24 hours decreased HO-CDI orders by 21%, an effect sustained for two years after implementation. In addition, inappropriate HO-CDI orders significantly decreased in the post-intervention period. Our results are consistent with previous literature demonstrating that educational campaigns and EMR order sets can decrease the proportion of inappropriate *C. difficile* orders placed on patients who recently received laxatives.^{7,8} Additionally, a large academic hospital recently demonstrated decreased rates of HO-CDI by using real-time electronic tracking of bowel movements and laxative administration and instructing laboratory technicians to cancel inappropriate orders directly.¹⁷ However, having to fill out cumbersome clinical decision support order sets can be onerous for healthcare providers and real-time electronic tracking is often unrealistic given the significant time, effort and personnel required for implementation and maintenance which may limit generalizability. We posit that EMR nudges may represent a simpler, more palatable strategy to reduce HO-CDI orders, especially in healthcare systems with concurrent or competing quality improvement initiatives.

While our EMR nudge was associated with an immediate decrease in the total HO-CDI order rate, the effect on the inappropriate HO-CDI order rate was more gradual. Providers who were initially skeptical of the new EMR notification may have acclimated to the nudge with repeated exposure and awareness. This may in part explain why there was a continued significant downward trend in the inappropriate order rate post-intervention. The relatively low inappropriate order rate also likely contributed to the immediate level change effect not reaching statistical significance. The EMR notification may have also influenced providers to alter their overall *C. difficile* ordering practices, even on patients not receiving laxatives or stool softeners, which could have contributed to the decrease seen in total HO-CDI orders. Lastly, there has been increasing awareness of diagnostic stewardship and appropriate *C. difficile* testing at our institution and broadly in the field of academic medicine in the last two years, which may have also contributed to the continued downward trend in total and inappropriate HO-CDI order rate after the intervention.

In a per hospital analysis, the EMR intervention was effective at decreasing total and inappropriate HO-CDI orders in three out of four study hospitals, which encompassed both community and academic practices. Hospital C was a notable outlier. We believe this is because they initiated a nursing-driven testing algorithm prior to the intervention which encouraged testing for *C. difficile* during the first three hospital days followed by a more conservative approach on or after the fourth hospital day. This resulted in a substantially lower baseline total and inappropriate HO-CDI order rates at the time of the EMR nudge, which may have limited any potential impact of this intervention, but we were unable to model this at the hospital level due to sample size.

In a secondary analysis, the EMR nudge was also associated with a significant reduction in composite HO-CDI LabID events, however this was driven by the largest hospital in this study (hospital B), where more than half of all orders testing for HO-CDI were placed. The intervention did not have a significant effect in reducing HO-CDI LabID events at the other three hospitals. Hospital B's decline in HO-CDI events may also be attributable to the audit of orders performed by the hospital epidemiologist that was initiated at a similar time as the EMR nudge, making it difficult to differentiate between the effect of these two interventions. EMR nudges may therefore help improve diagnostic efficiency and reduce excess spending (the estimated material cost of a *C. difficile* PCR assay is \$33, excluding labor and processing costs),¹⁸ but alone may not be enough to improve HO-CDI rates.

This study has some limitations. First, the study was retrospective and did not have a control group. A segmented regression analysis allows for theoretical control of unmeasured trends in ordering practices over time, including unique hospital initiatives, but cannot account for all confounding factors. We were not able to specifically control for the nursing-driven testing algorithm instituted in hospitals C and D before the EMR nudge, highlighting real-world challenges in analyzing quasi-experimental data, including difficulty in accounting for the impact of process improvement initiatives which can rely on paper-based audits. Although it included four hospitals, our study was limited to a single healthcare network, and may not be generalizable to other healthcare systems or hospitals, particularly those with different or older EMRs. We were also not able to track provider-level accept or decline rates for the pop-up notification, which could be a more direct measure of efficacy. Lastly, while our EMR notification alerts providers when a patient has received a laxative in the last 24 hours, the IDSA guidelines now suggest that orders placed up to 48 hours after laxative administration can be inappropriate.³ By restricting the time frame to 24 hours we may have underestimated the effect on the inappropriate order rate.

A simple EMR nudge reduced *C. difficile* orders that may have been otherwise classified as HO-CDI by 21%. After the intervention there was also a significant decrease in the number and proportion of orders that were considered inappropriate based on recent laxative or stool softener use. Although the intervention was not associated with an immediate decrease in the inappropriate HO-CDI order rate, there was a significant decreasing trend in the inappropriate order rate each month following the intervention. Implementing an EMR nudge can be a relatively simple method to help healthcare systems improve diagnostic efficiency and limit the number of *C. difficile* tests ordered. However, depending on individual hospital practices this may not be sufficient to reduce HO-CDI event rates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. 2015 Annual Report for the Emerging Infections Program for Clostridium Difficile Infection. Centers for Disease Control and Prevention website. <https://www.Cdc.Gov/Hai/Eip/Annual-CDI-Report-2015.Html>. Accessed Mar 25 2018.
2. Lessa FC, Mu Y, Bamberg WM, et al. Burden of Clostridium difficile Infection in the United States. *N Engl J Med* 2015;372(9):825–834. [PubMed: 25714160]
3. McDonald LC, Gerding DN, Johnson S, et al. Clinical Practice Guidelines for Clostridium difficile Infection in Adults and Children: 2017 Update by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA). *Clin Infect Dis* 2018;66(7):e1–e48. [PubMed: 29462280]
4. Magill SS, O’Leary E, Janelle SJ, et al. Changes in Prevalence of Health Care–Associated Infections in U.S. Hospitals. *N Engl J Med* 2018;379(18):1732–1744. [PubMed: 30380384]
5. Zacharioudakis IM, Zervou FN, Pliakos EE, Ziakas PD, Mylonakis E. Colonization with toxinogenic *C. difficile* upon hospital admission, and risk of infection: a systematic review and meta-analysis. *Am J Gastroenterol* 2015;110(3):381–390. [PubMed: 25732416]
6. Alasmari F, Seiler SM, Hink T, Burnham C-AD, Dubberke ER. Prevalence and Risk Factors for Asymptomatic Clostridium difficile Carriage. *Clin Infect Dis* 2014;59(2):216–222. [PubMed: 24755858]
7. White DR, Hamilton KW, Pegues DA, Hanish A, Umscheid CA. The Impact of a Computerized Clinical Decision Support Tool on Inappropriate Clostridium difficile Testing. *Infect Control Hosp Epidemiol* 2017;38(10):1204–1208. [PubMed: 28760168]
8. Buckel WR, Avdic E, Carroll KC, Gunaseelan V, Hadhazy E, Cosgrove SE. Gut Check: Clostridium difficile Testing and Treatment in the Molecular Testing Era. *Infect Control Hosp Epidemiol* 2015;36(2):217–221. [PubMed: 25633006]
9. Rock C, Pana Z, Leekha S, et al. National Healthcare Safety Network laboratory-identified Clostridium difficile event reporting: A need for diagnostic stewardship. *Am J Infect Control* 2018;46(4):456–458. [PubMed: 29305285]
10. Dubberke ER, Han Z, Bobo L, et al. Impact of Clinical Symptoms on Interpretation of Diagnostic Assays for Clostridium difficile Infections. *J Clin Microbiol* 2011;49(8):2887–2893. [PubMed: 21697328]
11. Thaler RH, Sunstein Cass R. *Nudge: Improving Decisions about Health, Wealth, and Happiness*. New Haven, CT: Yale University Press; 2008.
12. Vaughn VM, Linder JA. Thoughtless design of the electronic health record drives overuse, but purposeful design can nudge improved patient care. *BMJ Qual Saf* 2018;27(8):583–586.
13. Sunstein CR. Nudging Smokers. *N Engl J Med* 2015;372(22):2150–2151. [PubMed: 25970008]
14. Meeker D, Knight TK, Friedberg MW, et al. Nudging Guideline-Concordant Antibiotic Prescribing: A Randomized Clinical Trial. *JAMA Intern Med* 2014;174(3):425–431. [PubMed: 24474434]
15. Caris MG, Labuschagne HA, Dekker M, Kramer MHH, van Agtmael MA, Vandenbroucke-Grauls CMJE. Nudging to improve hand hygiene. *J Hosp Infect* 2018;98(4):352–358. [PubMed: 28974467]
16. Penfold RB, Zhang F. Use of Interrupted Time Series Analysis in Evaluating Health Care Quality Improvements. *Acad Pediatr* 2013;13(6):S38–S44. [PubMed: 24268083]
17. Truong CY, Gombar S, Wilson R, et al. Real-Time Electronic Tracking of Diarrheal Episodes and Laxative Therapy Enables Verification of Clostridium difficile Clinical Testing Criteria and Reduction of Clostridium difficile Infection Rates. *J Clin Microbiol* 2017;55(5):1276–1284. [PubMed: 28250001]
18. Sharp SE, Ruden LO, Pohl JC, Hatcher PA, Jayne LM, Ivie WM. Evaluation of the C.Diff Quik Chek Complete Assay, a New Glutamate Dehydrogenase and A/B Toxin Combination Lateral

Flow Assay for Use in Rapid, Simple Diagnosis of Clostridium difficile Disease. J Clin Microbiol 2010;48(6):2082–2086. [PubMed: 20375230]

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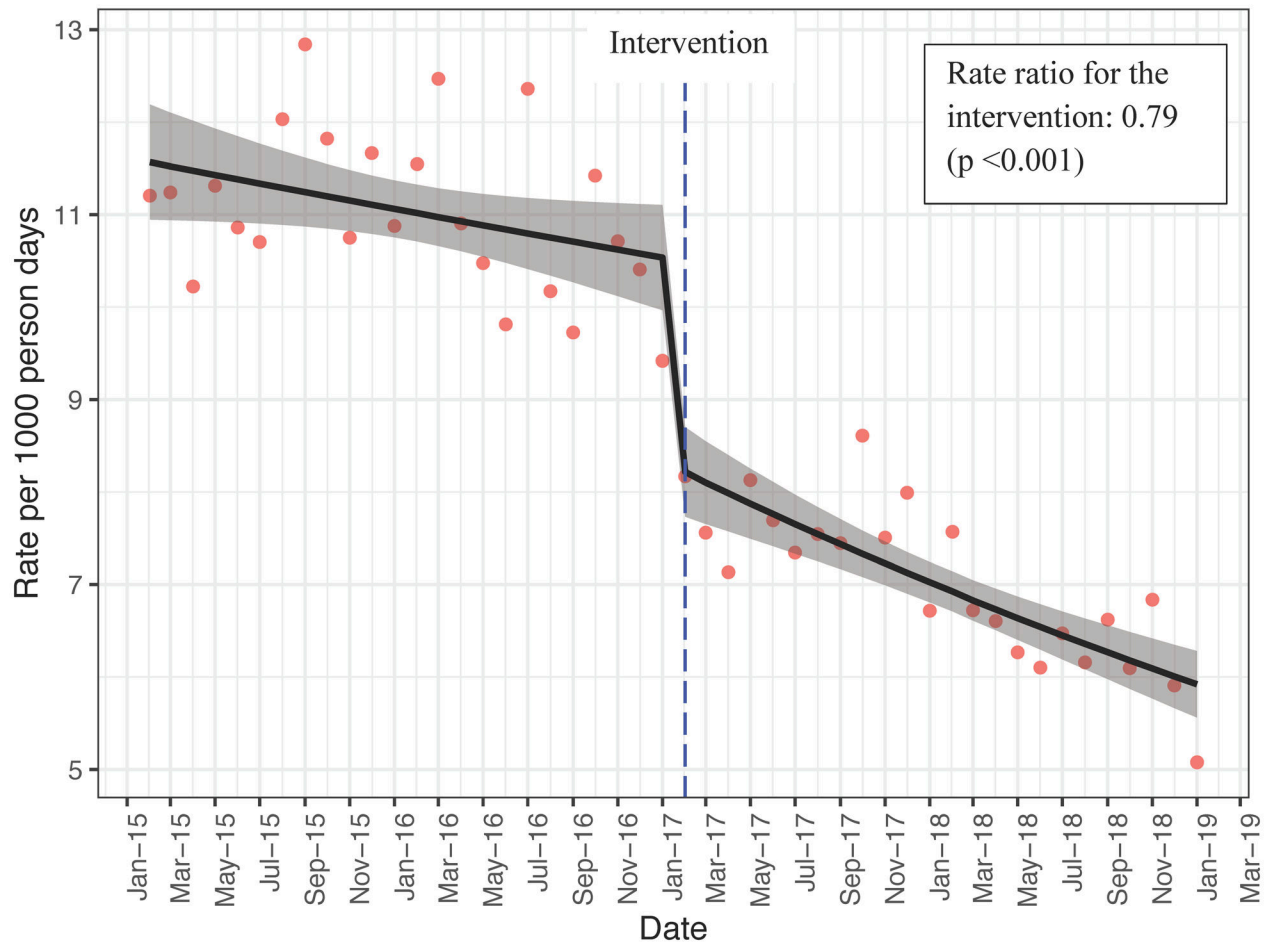


Figure 1:

Trend in hospital-onset *C. difficile* order rate per 1,000 patient-days before and after the intervention (dashed line). The data points (circles) represent the observed rates and solid line represents the predicted rates from the regression model, with a 95% confidence interval shaded in grey.

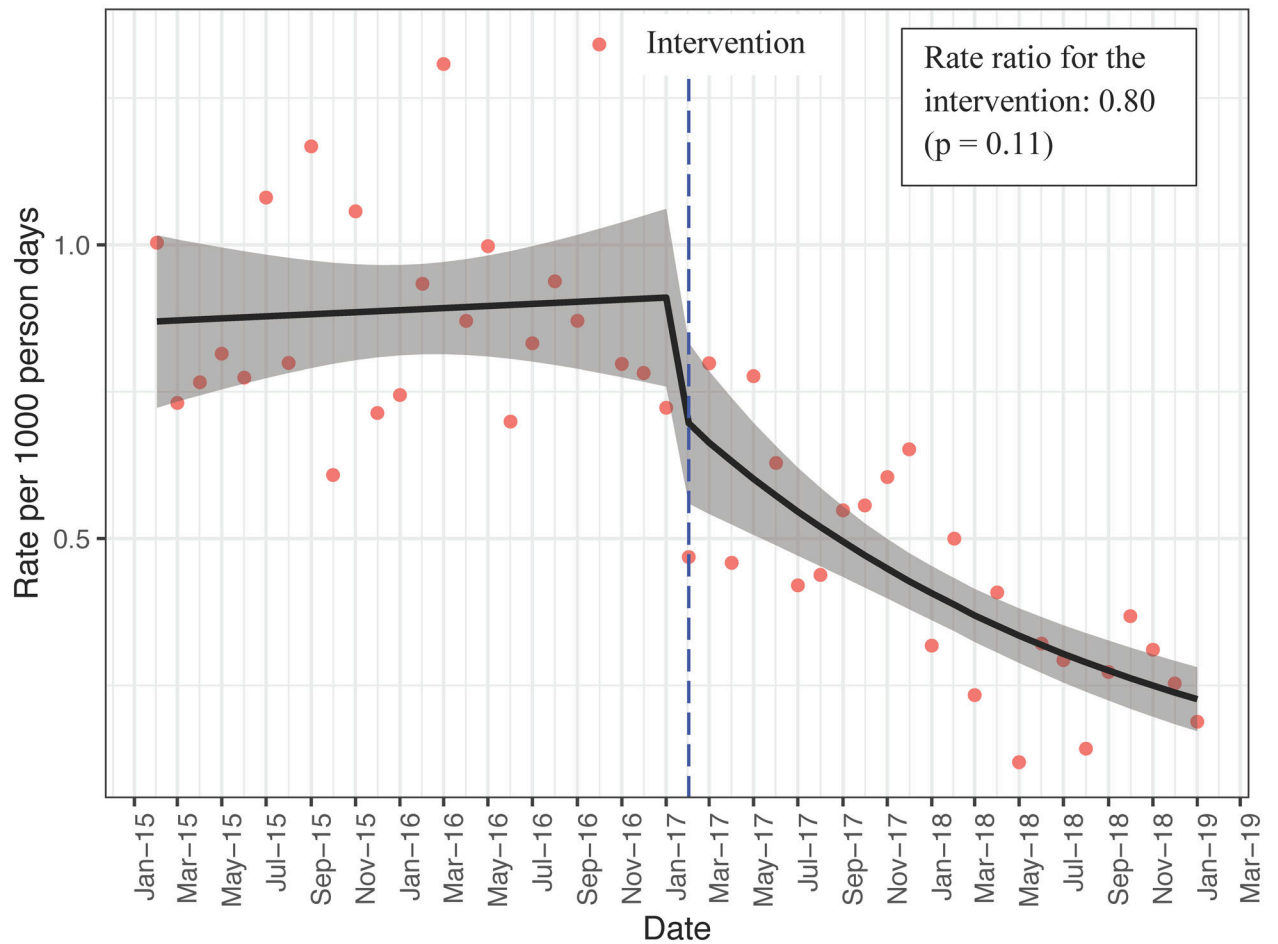


Figure 2:

Trend in the inappropriate hospital-onset *C. difficile* order rate per 1,000 patient-days before and after the intervention (dashed line). The data points (circles) represent the observed rates and solid line represents the predicted rates from the regression model, with a 95% confidence interval shaded in grey.

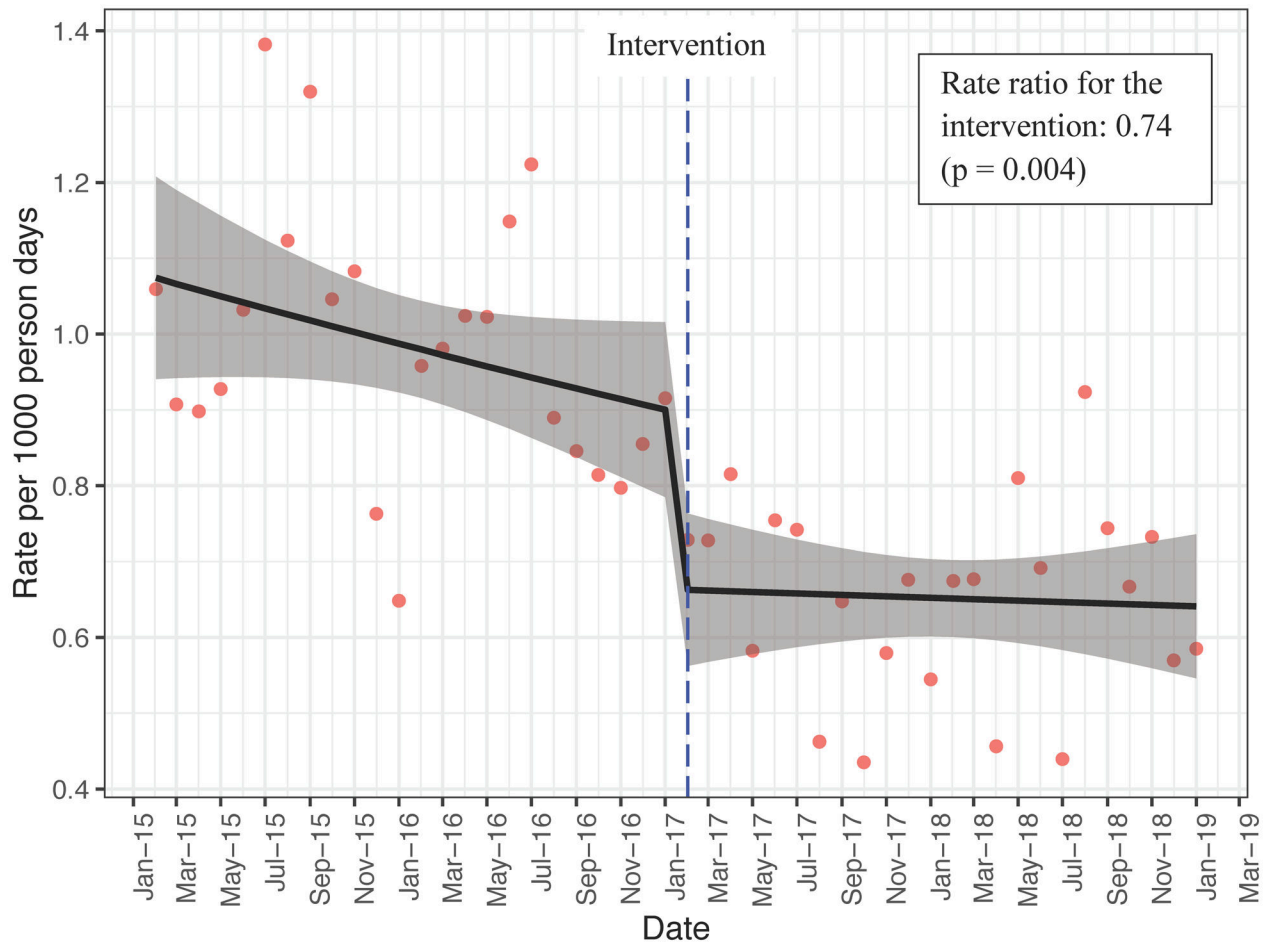


Figure 3:

Trend in hospital-onset *C. difficile* laboratory-identified events per 1,000 patient-days before and after the intervention (dashed line). The data points (circles) represent the observed rates and solid line represents the predicted rates from the regression model, with a 95% confidence interval shaded in grey.

Table 1:Characteristics of patients who had a hospital-onset *Clostridioides difficile* order^a

	Total (n = 9,846)	Pre-intervention (n = 5,753)	Post-intervention (n = 4,093)	P Value ^b
Age (years), mean (SD)	60.5 (16.0)	60.6 (16.2)	60.3 (15.7)	0.31
Length of admission (days), median (IQR)	15.6 (9.7–24.3)	15.1 (9.3–23.9)	16.0 (10.4–25.1)	<0.001
Male, n (%)	4816 (49)	2811 (49)	2005 (49)	0.90
Hospital, n (%)				
A	2272 (23)	1307 (23)	965 (24)	<0.001
B	5747 (58)	3170 (55)	2577 (63)	
C	1216 (12)	877 (15)	339 (8)	
D	611 (6)	399 (7)	212 (5)	
Ethnicity, n (%)				0.98
White	5270 (54)	3095 (54)	2175 (53)	
Black	3839 (39)	2227 (39)	1612 (39)	
Other	303 (3)	177 (3)	126 (3)	
Unknown or unreported	434 (4)	254 (4)	180 (4)	
Charlson Comorbidity Index > 4	4723 (48)	2651 (46)	2072 (51)	<0.001

Abbreviations: SD, standard deviation; IQR, interquartile range

^aIf a patient had more than one hospital-onset *C. difficile* order placed, only characteristics associated with the first order were included^bComparison of pre- vs post-intervention: χ^2 tests were performed for categorical variables and Wilcoxon rank sum or Student's t-tests were used for continuous variables

Table 2:Characteristics of hospital-onset *Clostridioides difficile* orders pre- and post-intervention

	Total (n = 17,694)	Pre-intervention (n = 10,686)	Post-intervention (n = 7,008)	P Value ^a
Inappropriate orders ^b , n (%)	1278 (7)	861 (8)	417 (6)	<0.001
Monthly order rate ^c , median (IQR)	9.0 (7.1–10.9)	10.9 (10.5–11.6)	7.0 (6.4–7.6)	<0.001
Monthly inappropriate order rate ^{b,c} , median (IQR)	0.7 (0.4–0.8)	0.8 (0.8–1.0)	0.4 (0.3–0.6)	<0.001

Abbreviations: IQR, interquartile range

^aComparison of pre- vs post-intervention: A χ^2 test was used to compare the proportion of inappropriate orders. Wilcoxon rank sum tests were used to compare median monthly order rates pre- and post-intervention.

^bAn order was defined as inappropriate if placed within 24 hours after administration of laxative or stool softener.

^cPer 1,000 patient-days

Table 3:

Interrupted time series analysis of the monthly rate of total and inappropriate hospital-onset *Clostridioides difficile* orders as well as hospital-onset *C. difficile* laboratory-identified events

	Rate Ratio	95% CI	P value
All HO-CDI orders			
Baseline trend over study period	1.00	0.99–1.00	0.05
Level change with the EMR intervention	0.79	0.73–0.86	<0.001
Trend change after the EMR intervention	0.99	0.98–1.00	0.001
Inappropriate HO-CDI orders			
Baseline trend over study period	1.00	0.99–1.01	0.76
Level change with the EMR intervention	0.80	0.61–1.05	0.11
Trend change after the EMR intervention	0.95	0.93–0.97	<0.001
HO-CDI LabID events			
Baseline trend over study period	0.99	0.98–1.00	0.11
Level change with the EMR intervention	0.74	0.60–0.91	0.004
Trend change after the EMR intervention	1.01	0.99–1.02	0.40

Abbreviations: CI, confidence interval; HO-CDI, hospital-onset *C. difficile* infection, EMR, electronic medical record; LabID, laboratory-identified