Multidisciplinary Approach to *Clostridium difficile* Infection in Adult Surgical Patients

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BACKGROUND: In 2017, our hospital was identified as a high outlier for postoperative *Clostridium difficile* infections (CDIs) in the American College of Surgeons NSQIP semi-annual report. The Department of Surgery initiated a CDI task force with representation from Surgery, Infectious Disease, Pharmacy, and Performance Services to analyze available data, identify opportunities for improvement, and implement strategies to reduce CDIs.

STUDY DESIGN: Strategies to reduce CDIs were reviewed from the literature and the following multidisciplinary strategies were initiated: antimicrobial stewardship optimization of perioperative order sets to avoid cefoxitin and fluoroquinolone use was completed; penicillin allergy assessment and skin testing were implemented concomitantly; increased use of ultraviolet disinfectant strategies for terminal cleaning of CDI patient rooms; increased hand hygiene and personal protection equipment signage, as well as monitoring in high-risk CDI areas; improved diagnostic stewardship by an electronic best practice advisory to reduce inappropriate CDI testing; education through surgical grand rounds; and routine data feedback via NSQIP and National Healthcare Safety Network CDI reports.

RESULTS: The observed rate of CDIs decreased from 1.27% in 2016 to 0.91% in 2017. Cefoxitin and fluoroquinolone use decreased. *Clostridium difficile* infection testing for patients on laxatives decreased. Terminal cleaning with ultraviolet light increased. Handwashing compliance increased. Data feedback to stakeholders was established.

CONCLUSIONS: Our multidisciplinary CDI reduction program has demonstrated significant reductions in CDIs. It is effective, straightforward to implement and monitor, and can be generalized to high-outlier institutions. (J Am Coll Surg 2019;228:570−582. © 2019 Published by Elsevier Inc. on behalf of the American College of Surgeons.)

Clostridium difficile is a preventable nosocomial infection that results in significant healthcare burden, leading to increased healthcare costs and poor patient outcomes. In postoperative patients, *C difficile* infections (CDIs) developed at a rate of 0.4% per year, with an increased risk of morbidity and mortality.[1] *Clostridium difficile* infections also represent a significant healthcare burden, leading to significant morbidity and increased healthcare costs.[2-4] In 2011 alone, there were 500,000 infections leading to 30,000 deaths.[3] In 2008, CDIs were estimated to increase hospital length of stay by up to 3 days and cost the healthcare system $4.8 billion. Controlling CDIs in postoperative patients presents an optimal opportunity to decrease healthcare costs.[2,5] In addition, elevated CDIs necessitate use of specific terminal cleaning processes and decreases use of rooms due to the need for isolation. This results in decreased throughput of the hospital.

As our healthcare system moves toward value-based healthcare, CDI rates are used as a quality metric. The Centers for Medicare and Medicaid Services uses CDI rates as part of their Hospital-Acquired Condition

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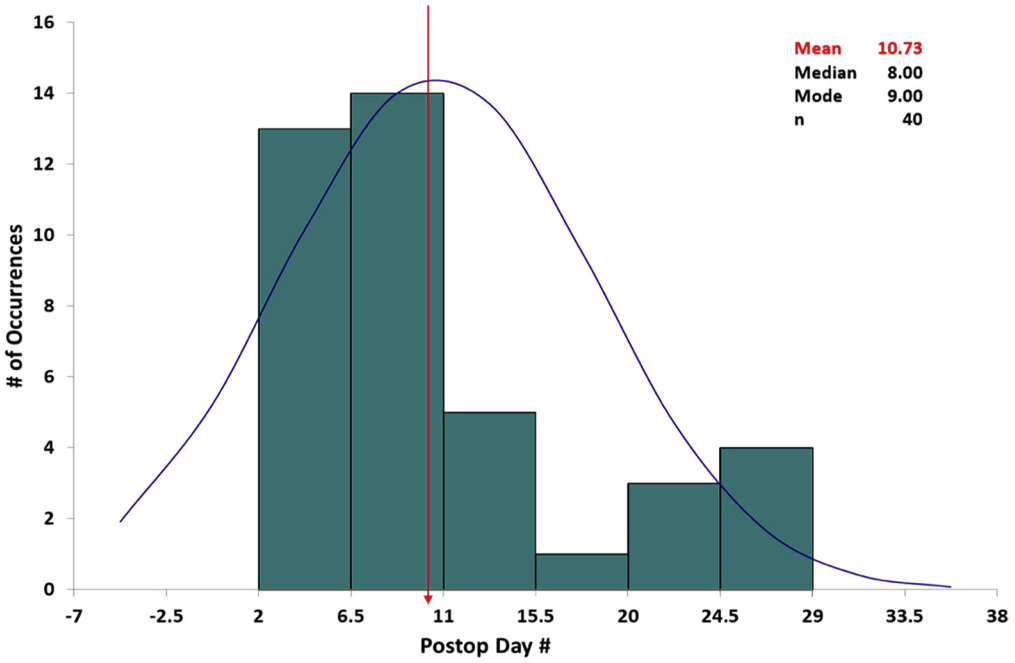

Figure 1. Postoperative (Postop) day of *Clostridium difficile* infection diagnosis. Distribution of *C difficile* infection occurrences based on postop day.

Reduction Program, which decreases reimbursement for programs failing to meet quality metric standards. For example, hospitals in the top 75% of hospital-acquired conditions have their payments reduced by 1%.[6] The Agency for Healthcare Research and Quality also measures and imposes a financial penalty for hospitals with high rates. In 2016, our institution was designated as a high outlier in NSQIP, with CDI rates at 1.29%. Due to our high-outlier status, we organized a multidisciplinary task force to generate and implement interventions to decrease CDI rates within our hospital and improve quality of care for our surgical patients.

METHODS

Development of a multidisciplinary task force

A multidisciplinary task force was formed to implement a quality improvement program to reduce our CDI rate, as measured by NSQIP. The National Healthcare Safety Network defines hospital-onset CDI as a positive test on or after day 4 of admission. To confirm CDIs were hospital-acquired, we examined the number of days postoperatively our patients were diagnosed.[3] Our average diagnosis date was between postoperative days 8 and 10 (Fig. 1). Additionally, the surgical service on which each CDI occurred was tabulated to better allocate resources (Fig. 2). Finally, the physical location of CDI occurrences was evaluated by generating heatmaps to localize high-risk wards of infection transmission (Fig. 3). Allocation of environmental services resources was determined based on the highest-risk wards.

Surgical staff

A senior faculty member was selected as team and administrative leader, based on his role as the NSQIP Surgical Champion and his experience in quality improvement within the Department of Surgery on work in bundle implementation.[7] Representation from the surgical ICU

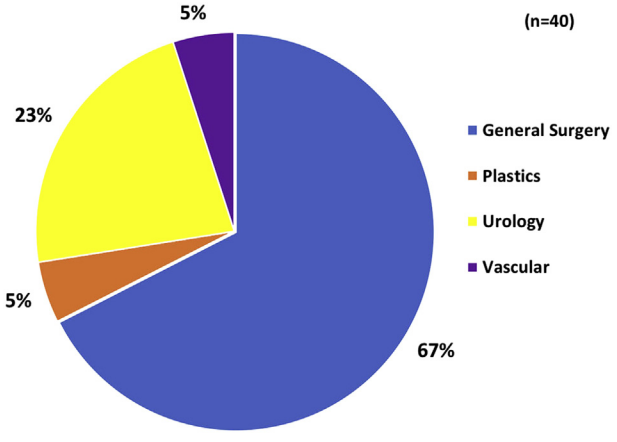

Figure 2. NSQIP *Clostridium difficile* infection occurrences. NSQIP *C difficile* infection percentages by surgical specialty from July 2015 to December 2016.

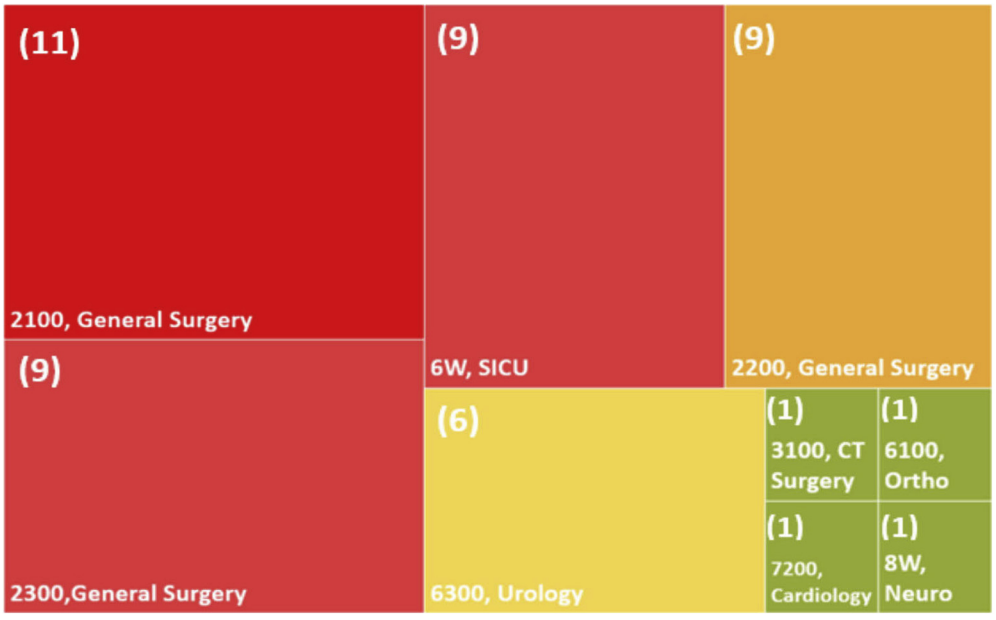

Figure 3. Postoperative location for patients with *Clostridium difficile* infections. Heatmap of *C difficile* infection occurrences by physical location within the hospital from July 2015 to December 2016. CT, cardiothoracic; Neuro, neurology; Ortho, orthopaedics; SICU, surgical ICU.

was provided by a junior faculty member in critical care as a component of his research and quality improvement position. A surgical resident member was included as a way to disseminate the ongoing interventions and findings to the surgical trainees within the department. The resident served on the task force during their designated research time and their clinical term.

Infection control

A board-certified infectious disease specialist with dedicated interest in the prevention of *C difficile* was recruited to participate in the task force. Her role was instrumental in interpreting the existing literature surrounding CDI prevention. She provided guidance for the implementation of best practices based on the current deficiencies identified within our hospital system to improve antibiotic guideline adherence. The clinical operations director for the institution's Center for Antimicrobial Stewardship and Infection Prevention served on the task force, assisting in identifying the epidemiology of CDIs specific to the hospital's geography. His position allowed for collaboration and dissemination of data across infection control groups within the hospital system.

Pharmacy

A board-certified clinical pharmacist with residency training in infectious diseases was dedicated to the task force as a component of her role in the institution's Antimicrobial Stewardship Evaluation Team, a part of the Center for Antimicrobial Stewardship and Infection Prevention. She provided interpretation of current antibiotic use by the surgical services and made recommendations to reduce use of antibiotics associated with high risk for *C difficile*. In addition to the targeted review and recommendations here, antimicrobial stewardship activities are well established throughout the hospital and the program has received the honor of being an Antimicrobial Stewardship Center of Excellence from the Infectious Diseases Society of America. Context was provided to surgeons during surgical grand rounds for recommendations on prescribing practices and other antibiotics stewardship projects within the hospital system.

Performance Services

Performance Services is a division within the health system that is funded by the hospital, with the goal of supporting quality initiatives. The division has access to data repositories, including Agency for Healthcare Research and Quality Patient Safety Indicators, NSQIP, and institutional metrics from data generated internally. The task force members from Performance Services were able to extract and analyze data from these data sets to determine baseline and improvement metrics during the course of the intervention. The communication lines for this data feedback are established within the

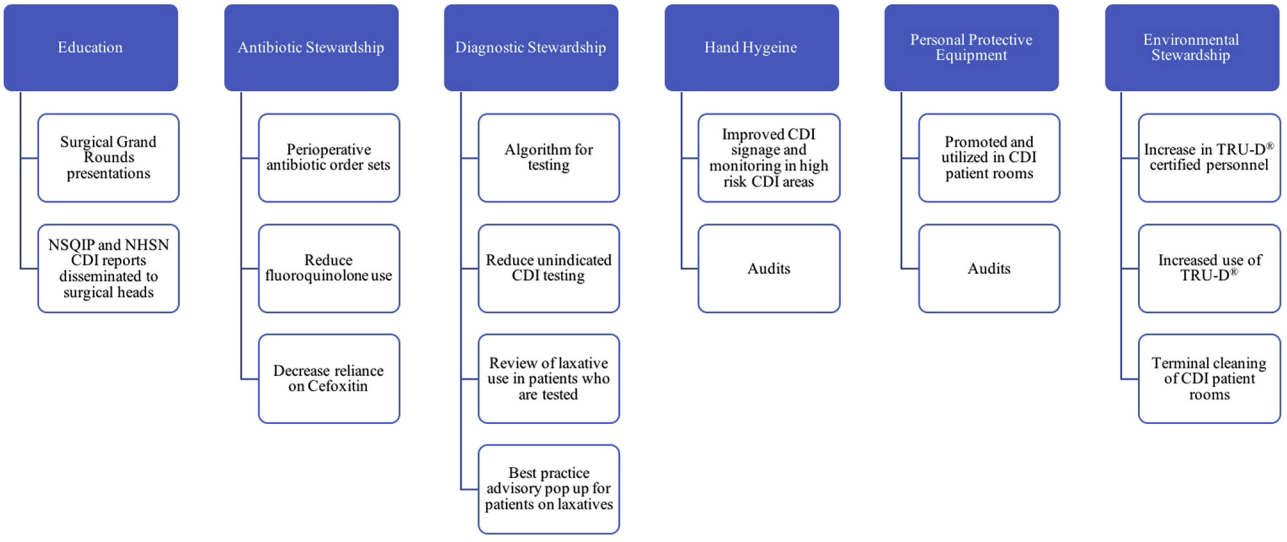

Figure 4. Bundled approach to reducing *Clostridium difficile* infections (CDI). Overview of bundled interventions across the multidisciplinary task force. NHSN, National Healthcare Safety Network.

institution by way of quality champions, by division, specialty, and ward.

Department of Surgery administration

The administrative member of the task force was essential in providing perspective on resource availability and allocation. Our representative served as the Director of Clinical Operations for the Department of Surgery.

Once established, the task force generated 4 aims to reduce the risk of CDIs in the hospital. The aims were to analyze the available data, identify opportunities for improvement, implement strategies, measure compliance and improvement data, and reflect data back to the stakeholders. Available data included Agency for Healthcare Research and Quality Patient Safety Indicators, NSQIP sample *C difficile* rates, and institutional data. The institutional data include overall *C difficile* rates, hand-hygiene compliance, personal protection equipment compliance, antibiotic-prescribing practices, *C difficile* testing rates, and environmental services cleaning audits. All data reviewed and analyzed were established metrics within the hospital system before the initiation of the task force. The opportunities for improvement were outlined as follows: education, antibiotic stewardship, environmental cleaning, hand hygiene, personal protective equipment, diagnostic stewardship, and routine data feedback.

Implementation of strategies to reduce *Clostridium difficile*

Opportunities for improvement within the hospital system were identified through discussion among the members of the task force, as well as review of current metrics from established data lines within the hospital. The current literature in CDI, infection prevention, bundled implementation, and data feedback was reviewed.[8-13] From this review, evidence-based practices were selected for implementation for each of the opportunities for improvement (Fig. 4). Our primary end point of interest was reduction in overall *C difficile* rate. Our secondary outcomes included compliance with interventions across domains, as described in the sections that follow.

Education

Education and dissemination of information is a crucial component of generating systemic change within the hospital system. This opportunity was undertaken through presentations at surgical grand rounds. Surgical grand rounds at our institution are held weekly, with attendance by residents, on-service medical students, advance practice providers, and faculty. The presentations are 1 hour in length and feature nationally renowned speakers on contemporary surgical topics. The content from our project was presented in this forum by the surgical leaders of the task force highlighting the metrics used for success, the initiatives, and the implementation plans with preliminary results.

Antibiotic stewardship

A cornerstone of CDI prevention is the judicious use of antibiotics. In the perioperative setting, antibiotics are required to prevent surgical site infection and organ space infections and should not be omitted. Given this, collaboration with the Antimicrobial Stewardship Evaluation Team allowed for evaluation of current prescribing practices of perioperative antibiotics and use of antibiotics in

the time before operation to assess for opportunities for optimization. This review revealed overuse of cefoxitin in the perioperative setting, where alternative lower-risk antibiotics were possible, postoperative redosing, and frequent fluoroquinolone prescriptions with long durations before operation.[14] Electronic evidence-based perioperative antibiotic order sets were optimized to eliminate cefoxitin, fluoroquinolones where possible, perioperative antibiotics for perianal procedures, and postoperative antibiotic redosing. Providers could override the default if their patient needed broader or longer coverage. Fluoroquinolone default 10-day durations were eliminated from discharge and ambulatory care prescriptions and a link to duration guidelines was included in the prescription. Finally, audit and feedback on surgical inpatient areas was enhanced.

Environmental cleaning

Environmental cleaning of the hospital space is paramount in preventing spread of infection among patients and providers.[15] We reviewed the terminal cleaning policies for rooms occupied by patients with known CDIs once they were discharged from the hospital, Additionally, success eliminating *C difficile* through the established terminal cleaning was verified through an auditing process. However, the audit demonstrated that there was variability and ineffective cleaning practices within the hospital system. These deficiencies were largely due to lack of environmental services staff and staff trained in Tru-D technology (Tru-D SmartUVC), a system that uses an ultraviolet light cleaning system to denature the spores of *C difficile*. The data provided a basis for requesting the hiring and training of additional environmental services staff. Expanded training for terminal cleaning was used for the Tru-D technology system. This provided more effective terminal cleaning.

Hand hygiene

The best way to prevent transmission of *C difficile* from known patients to providers and the environment is through soap and water hand hygiene. Signage for special enteric precautions was placed on the doors of patient rooms with instructions for soap and water hand washing. Sinks in close proximity to patient rooms were available and stocked with soap and hand towels. Enforcing hand hygiene and audits of appropriate washing were increased during this study, specifically in high-risk areas, such as the surgical ICU.

Personal protective equipment

Personal protective equipment was made available per standard protocol, and increased audits were promoted in high-risk areas. The standard protocol includes wearing a disposable gown and gloves on entry to each room, with a waste bin to place doffed items inside of the high-risk area.

Diagnostic stewardship

Our institution identifies patients with *C difficile* using a highly sensitive polymerase chain reaction assay. The current algorithm recommends *C difficile* testing for patients with profuse diarrhea, leukocytosis, and fever. Our review of diagnostic ordering patterns revealed that patients were commonly tested for *C difficile* for the indication of isolated diarrhea while the patient was on laxative therapy. The use of hospital resources in this fashion might overdiagnose asymptomatic carriers, resulting in false positives. Given this, a best practice alert was developed to be triggered when a *C difficile* polymerase chain reaction was ordered when the patient has received laxatives (Fig. 5). It prompts removal of the laxatives and a cue to order the test in 24 hours if diarrhea has not resolved. The prompt allows for override by the ordering provider and a verification of leukocytosis, fever, or abdominal pain.

Routine data feedback

As a participating institution in NSQIP, there are established lines of communication for quality improvement between our NSQIP Champion and surgical leadership. The division leadership meets quarterly to review the quality data from NSQIP, National Healthcare Safety Network patient safety indicators, and institution-specific metrics described here. These meetings are held for the review of the data, discussion of areas for improvement, and potential changes in policies. Data are shared quarterly between divisions within the Department of Surgery, and semiannually with the institutional leadership, including the Chief Executive Officer and President of the hospital system.

RESULTS

Our overall observed CDI reductions based on our NSQIP report went from a mean of 1.27% (October 2015 to March 2017) to 0.91% (April 2017 to June 2018) ($p = 0.04$) (Fig. 6).

Education

With regard to education, 250 attendees from surgical and urologic grand rounds participated. Representation was from all training levels, including medical students, residents, advanced practice providers, and faculty. The presentation included background in CDIs, as well as implemented quality projects. Resident education was

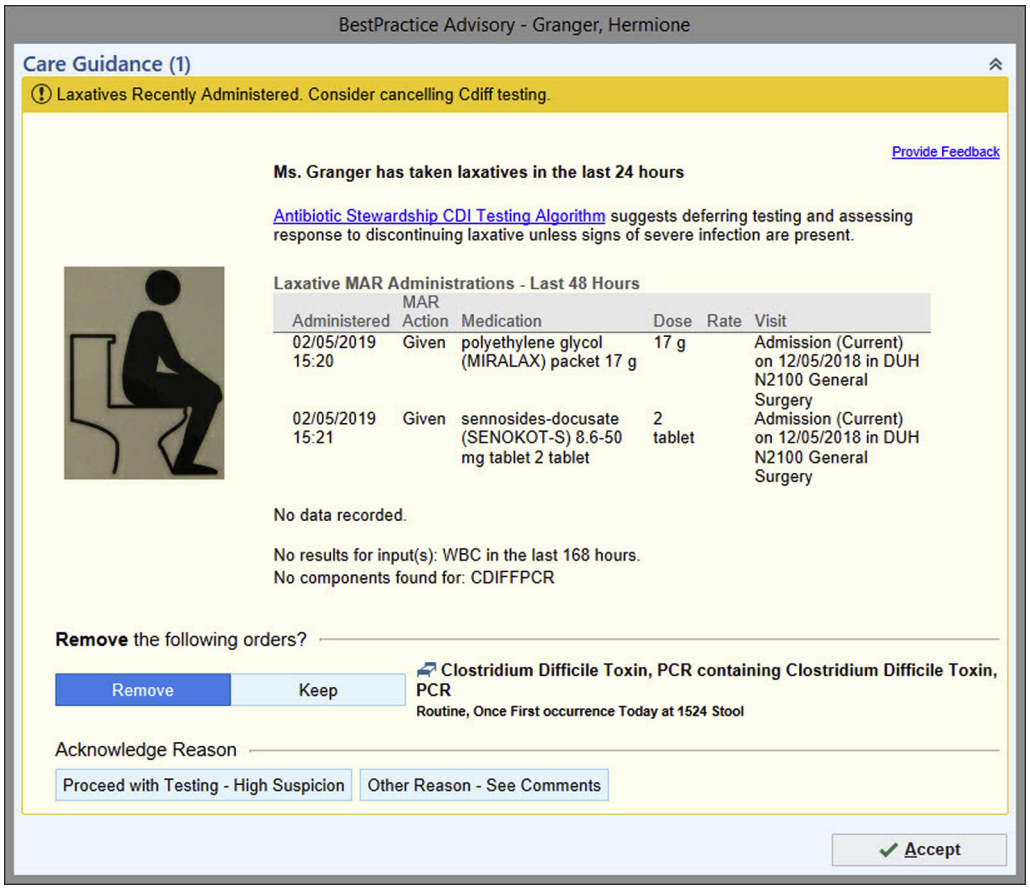

Figure 5. Emergency medial record pop-up. Best practice advisory pop-up to decrease unnecessary *Clostridium difficile* infection testing.

promoted at the intern boot camp before starting on the wards. Advance practice provider outreach was a component of their monthly meeting.

Antibiotic stewardship

Our antibiotic stewardship program revised the default antibiotic order sets for cystectomies, nephrectomies,

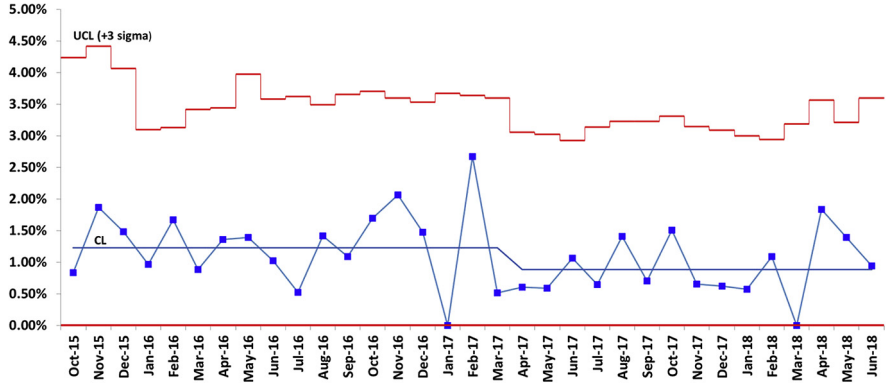

Figure 6. Observed *Clostridium difficile* infection rate based on NSQIP reporting. Blue line represents the mean observed rate for that time period, with shift in the mean after process change in April 2017. Red (upper) line represents the upper control limit (+3 sigma) for each data set (data point) and the X axis represents 0.0% infection. UCL, upper confidence level.

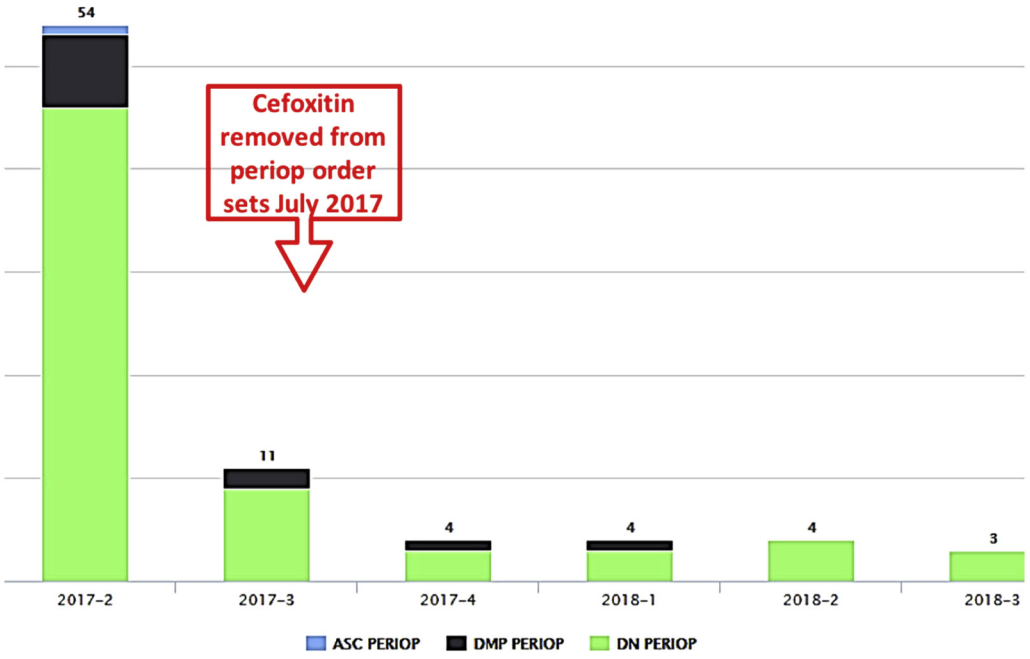

Figure 7. Perioperative cefoxitin exposure over time by operative space. ASC, ambulatory surgery center; DMP, Duke Medical Pavilion; DN, Duke North; PERIOP, perioperative.

hepatectomy, pancreatectomy, and prostatectomy. These changes produced dramatic decreases in cefoxitin exposure (Fig. 7), as well as days of therapy associated with fluoroquinolones in the perioperative areas (Fig. 8).

Environmental cleaning

Appropriately trained Tru-D technicians increased in number after the initiative, from 2 in 2017 to 7 in 2019. This increase in technicians allowed for an increase in terminal cleaning by Tru-D ultraviolet therapy from 30% in March 2017 to 100% in September 2018 (Fig. 9). Audits of the cleaning practices have continued.

Hand hygiene

Increased hand-hygiene compliance was observed in many wards of the hospital (Fig. 10). Increased audits allow for more accurate reporting of compliance.

Personal protective equipment

Audits of effective use of personal protective equipment are ongoing, but have not produced meaningful results at this time.

Diagnostic stewardship

The best practice advisory has been correlated with an overall decrease in testing patients taking laxatives for CDIs (Fig. 11).

DISCUSSION

This retrospective study examined the effect of a multidisciplinary approach to reducing postoperative CDI rates at a large academic center. With the implementation of evidence-based practices, we achieved a reduction of our hospital's NSQIP CDI rates from 1.27% to 0.91% between 2016 and 2018. This translates from "needs improvement" to "as expected." Secondary outcomes of our study included improvements in the domains of education; antibiotic stewardship, with decreased duration of use of fluoroquinolones and reduction in cefoxitin use; increased complement of environmental service employees; increased use of Tru-D technology for terminal cleaning of isolation rooms; increased hand-hygiene audits; reduction of diagnostic testing in patients on laxatives; and improved data feedback on CDI quality metrics to stakeholders. Additionally, the CDI rates reported through the National Healthcare Safety Network also decreased during the study period.

Hospital-acquired *C difficile* infections remain a clinical challenge faced by institutions worldwide.[3] Our study relied on contemporary literature to generate a multidisciplinary approach of multiple intervention implementation to decrease CDIs within the hospital. Similar to other institutions, we saw a decrease in CDI rates using a multidisciplinary approach.[7] Established recommendations to prevent and decrease CDIs include patient isolation, proper personal protective equipment and dedicated

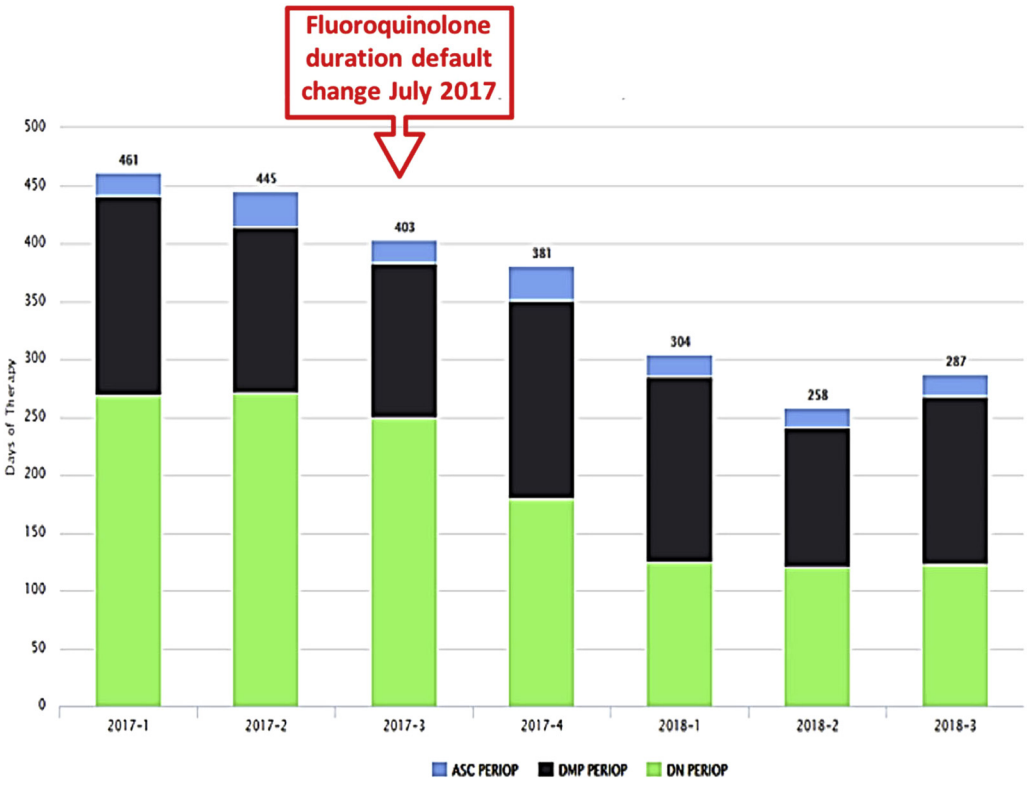

Figure 8. Perioperative fluoroquinolone use. Days of therapy over time. ASC, ambulatory surgery center; DMP, Duke Medical Pavilion; DN, Duke North; PERIOP, perioperative.

equipment, and hand-washing compliance.[8] These aspects of CDI prevention are embedded into our hospital workflow and culture. Therefore, we focused our intervention on expanding our prevention efforts through education, antibiotic stewardship, environmental cleaning, diagnostic stewardship, and routine data feedback. Although identification of a single most impactful component of CDI reduction is desired, both the literature and this study demonstrate the importance of the synergy achieved with multidisciplinary interventions.

Antibiotic stewardship remains crucial to the reduction of CDIs and other hospital-acquired infections. However, stewardship interventions might be met with resistance from surgeons, given fears surrounding potential implications toward rates of surgical site infection, organ space infection, and mortality. In a recent Cochrane review, Davey and colleagues[16] again highlighted the safety of antibiotic stewardship programs, demonstrating no change in mortality and a likely reduction in hospital length of stay. Although this review provided only low-certainty evidence for reductions in CDIs, other studies have demonstrated a substantial reduction in CDI rates with antibiotic stewardship programs,[14,17] making these programs a critical arm in our CDI reduction clinical practice guidelines.[8] After the implementation of cefoxitin and fluoroquinolone reduction programs at our institution, there have been no increases in mortality or surgical site infections. This remains an important aspect of our data feedback to our stakeholders.

In studies of antimicrobial stewardship, a component of infection control through hand hygiene is strongly recommended for a synergistic effect in CDI reduction.[9,18] Although prevention of CDIs is multifactorial, hand hygiene is essential. The CDC endorses hand washing as the most important component of infection control for

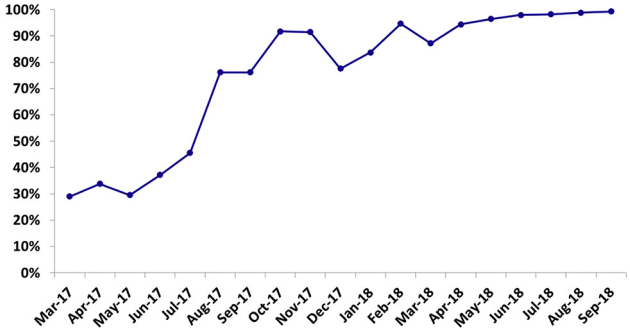

Figure 9. Tru-D ultraviolet light cleaning system. Percentage of isolation rooms treated with the Tru-D technology system.

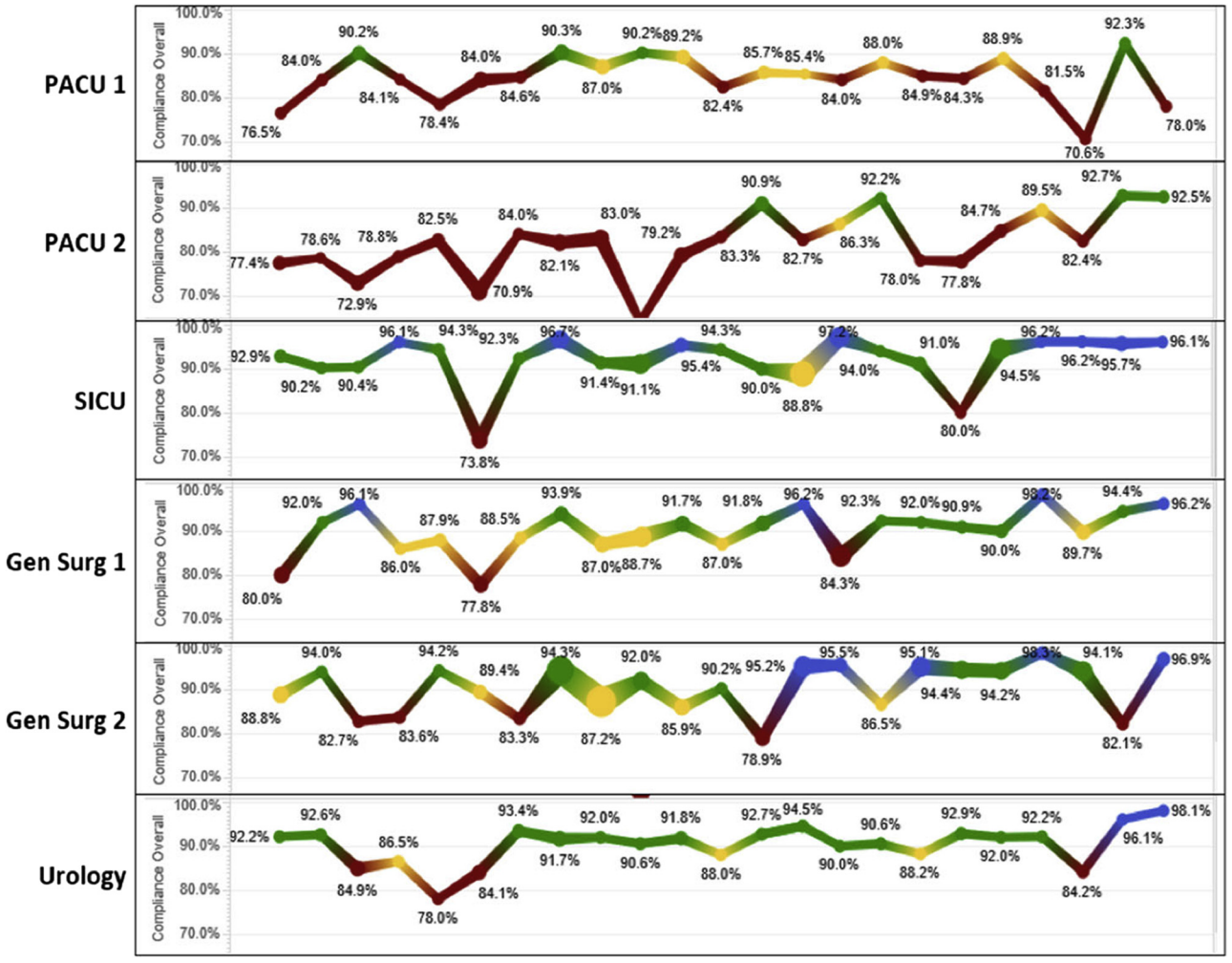

Figure 10. Hand hygiene. Compliance by ward. PACU, pre- and post-anesthesia care unit; SICU, surgical ICU.

all pathogens.[19] Institutions struggle with compliance overall, and efforts to improve compliance include clear metrics for success, auditing, and feedback.[20]

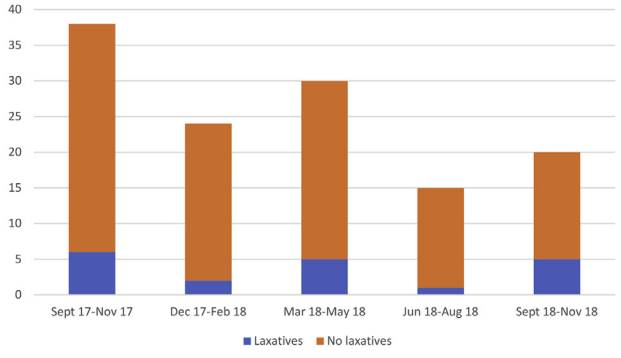

Figure 11. *Clostridium difficile* infection testing. Number of patients with positive *C difficile* infection tests by month segmented by those taking laxatives.

An important feature of our project's ongoing success was early identification and use of quality metrics to understand the benefit of our interventions. In their 2017 systematic review, Barker and colleagues[10] identified CDI prevention bundled intervention projects and evaluated the success based on 10 components of intervention: antibiotic stewardship, contact precautions, dedicated equipment, staff education, patient education, environmental cleaning, hand hygiene, isolation and/or cohorting, proton-pump inhibitor stewardship, and systems and workflow changes. Within the 26 studies, there was a decrease in CDI with bundled intervention. However, the lack of reporting metrics from each aspect of the intervention limited the conclusions that could be drawn from the studies in aggregate.[10] For our study, each aim had measurable outcomes to demonstrate baseline values and incremental progress. Generated data were reflected back to stakeholders to evaluate the contributions of

each individual intervention to the overall goal of CDI reduction. This data feedback allowed for iterative allocation of resources throughout the project, while emphasizing the synergy in the effect of reducing CDI.

To promote sustainability and reduce the financial impact of the multidisciplinary task force, many of the interventions were incorporated into the established process lines of the hospital. Our institution currently uses isolation, personal protection equipment signage, and hand-washing audits for several infectious diseases. The healthcare analytics team maintains thousands of data points on the hospital compliance processes and National Healthcare Safety Network and NSQIP reportable metrics. The Antimicrobial Stewardship Evaluation Team and Center for Antimicrobial Stewardship and Infection Prevention have policies and strategies established through other antimicrobial stewardship and infection control projects that were easily translatable to CDI. Assembling the leadership from each of these groups to discuss CDI allowed for easy translation of established quality improvement projects and expansion to other services and regional hospitals.

This study has several limitations. First, the appropriate way to understand prevalence of CDIs remains to be established, and bundled implementation limits individual component contribution interpretation and overall generalizability of the multidisciplinary project.[21] The implementation of multiple interventions simultaneously limits the interpretation of each component's contribution to the effect size. Each of the interventions have been established for efficacy within the existing literature, and the success of bundled implementation has been established in multiple infection control domains.[7,10] Duration of follow-up is a limitation of this study, and the sustainability of CDI reduction remains to be seen. Generalizability of our results can be limited in applicability to other hospitals. Our institution has a robust infrastructure for quality improvement that other institutions might not have established. However, this bundled program is easy to implement, inexpensive, has measurable quality metrics within established data sets, and is cost effective. As transparency of quality healthcare to the public continues to be emphasized, it is imperative for each hospital to incorporate multidisciplinary CDI prevention strategies.

CONCLUSIONS

We found our bundled approach to a CDI reduction program has demonstrated significant reductions in CDI. This multidisciplinary approach is effective and straightforward for providers and hospital systems to implement and monitor. In addition, it can be generalized to high-outlier and at-goal hospitals to meet important quality metrics to better serve patients to improve outcomes.

Author Contributions

Study conception and design: Turner, Behrens, Webster, Huslage, Smith, Wrenn, Woody, Mantyh

Acquisition of data: Turner, Webster, Huslage, Woody, Mantyh

Analysis and interpretation of data: Turner, Behrens, Webster, Huslage, Smith, Wrenn, Woody

Drafting of manuscript: Turner, Behrens, Mantyh, Woody, Mantyh

Critical revision: Turner, Behrens, Webster, Huslage, Smith, Wrenn, Woody, Mantyh

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Discussion

DR JONATHAN EFRON (Baltimore, MD): Dr Turner and her colleagues have nicely described their successful efforts at reducing the rates of *Clostridium difficile (C diff)* infection at the Duke University Medical system, specifically in the wards where the department of surgery patients were housed. *Clostridium difficile* remains a constant and costly infection for all medical systems, and the systematic approach that the Duke team used and described to address this issue generated significant improvement. That approach is one that other delivery systems should consider using when faced with similar infection-control issues.

This was a bundled intervention and it is not really possible to isolate 1 approach, but I wonder if there are 1 or 2 of those that you can comment on that you think really made a big difference. In other words, the significant changes that you saw in those, were they either changing the antibiotics or doing the deep cleans? Were they ones that may have moved the line for you? Would you also please comment on which aspect of this initiative was most difficult to implement, as others of us are trying to do some of this at our hospitals? Was there difficulty related to the culture change or perhaps the finances or the personnel?

Given the success that was seen here in the department of surgery for this issue, is the department planning on using this same methodology, this same cross-team methodology to solve other problems within the department and within the hospital, whether they be infection-control issues or other initiatives? In other words, is this a standardized technique that may be replicated for change management regardless of the issues faced?

DR JOHN SCARBOROUGH (Madison, WI): You primarily use your institution's NSQIP submission as your data source for comparing pre- and post-intervention *C diff* rates. Did a review of your hospital audit data confirm that reduction across the surgical services, the same reduction that you observed in your NSQIP sample?

It is difficult, if not impossible, to determine which of the strategies you implemented. It might have had the greatest impact on your *C diff* rates but, as Dr Efron has asked, can you offer a recommendation or at least an educated guess as to which one of these strategies should be prioritized? Not every hospital can afford all the extra environmental services personnel and increase their Tru-D investment while still ensuring that they have a sufficient supply of hand soap and yellow gowns.

My third question has to do with the concept of diagnostic stewardship. Given the growing importance that hospital-acquired conditions have on reimbursement, it is understandable to want to only report those patients who actually have clinically relevant *C diff* infection as opposed to those patients who are asymptomatic carriers. Nevertheless, it does seem reasonable to wonder if the reduced *C diff* infection rate that you have observed might be due to the fact that you have been more restrictive in your testing for *C diff*. What proportion of *C diff* patients in the pre-intervention phase of your study had clinically relevant infection as opposed to just colonization? And did that proportion change in the postintervention phase of your study?

The value of any quality improvement intervention is a function of both its effect on outcomes and the cost required to implement that intervention. In this era of shrinking reimbursement and narrow operating margins, hospitals are going to have to be increasingly selective in choosing which interventions they choose to implement and which complications they choose to target. To this end, do you have an estimate of how much this complete bundle costs both in terms of direct expenditures and in terms of the opportunity cost of the many hours spent devising and implementing the bundle?

The absolute number of *C diff* infections that you appear to have prevented, while sufficient enough to change your NSQIP status from "needs improvement" to "as expected," is probably, absolutely speaking, a handful of patients. Do you think that the cost of implementation was worth it?

DR HIRAM POLK (Louisville, KY): Surgical self-criticism is the way most of the things we get right have turned out, and this is a