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Research Brief

Cost Analysis of Computerized Clinical Decision Support and Trainee Financial Incentive for *Clostridioides difficile* Testing

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Clostridioides (formerly *Clostridium) difficile* infection (CDI) is the most common cause of healthcare-associated infections, leading to increased morbidity, mortality, length of hospital stay, and costs.[1,2] CDI contributes an estimated $5.4 billion to US healthcare annually.[2] In an era of highly sensitive molecular testing, overdiagnosis of CDI is also suspected to be common, and up to half of inpatients with a positive *C. difficile* nucleic acid amplification test (NAAT) may not require treatment.[3]

Overdiagnosis may be due to testing patients with low pretest probability for disease. Improving test utilization through diagnostic stewardship has the potential to reduce unnecessary testing and diagnostic error.[4] Various strategies have been proposed for *C. difficile* testing, including computerized clinical decision support (CCDS).[4] We previously reported implementation of a CCDS tool (as part of a multifaceted bundle of interventions to reduce National Healthcare Safety Network (NSHN)–defined hospital-onset CDI [HO-CDI])[5] in our institution that led to significantly reduced testing and fewer HO-CDI events.[6] Here, we present a cost analysis of this intervention.

Methods

The CCDS tool was implemented after internal auditing suggested that testing for *C. difficile* might not have been indicated in up to 67% of HO-CDI cases in our institution.[6] A detailed description of the decision support algorithm, including a video demonstration of the CCDS tool, has previously been published.[6] House staff were involved with an educational campaign that preceded CCDS implementation and offered a 0.8% salary bonus at the end of the academic year if testing fell by ≥ 25%.

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PREVIOUS PRESENTATION: Data from this study were presented in part as an abstract at the 2018 Society for Healthcare Epidemiology of America meeting on April 19, 2018, in Portland, Oregon (abstract #327).

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The financial incentive, funded jointly by the UVA Office of Graduate Medical Education and UVA Health System, was part of a recurring incentivized annual quality improvement project led by trainees, for which *C. difficile* testing was chosen as the subject for the 2016–2017 academic year. Real-time monitoring of test utilization, with unit and service attributions, was available through an electronic portal as feedback during the intervention period.

A retrospective cost analysis was performed that included cost savings from reduced test utilization and fewer HO-CDI events (based on estimated attributable costs for hospitalized patients with CDI),[1,7,8] in addition to costs of building the CCDS tool and house staff financial incentives.

Results

Hospital census remained relatively constant during the study period, with 156,154 and 159,094 patient days during the pre-intervention (December 2015 – November 2016) and post-intervention (December 2016 – November 2017) periods, respectively. Total laboratory cost (materials and labor) was estimated at $31.36 per test (Table 1). Based on the literature, the estimated attributable cost per hospitalized CDI case was between $3,669[1] and $9,197;[7] the median, $6,326,[8] was chosen for purposes of our analysis. The 0.8% house-staff financial incentive was based on house staff salaries (median, $61,669; range $54,107–$71,167). The technology-associated cost involved with creating the CCDS tool (ie, developing question algorithm, software building, testing, migration through environments, etc) was estimated to be $1,000.

In total, the CCDS tool was associated with a net $61,524 annual cost savings, largely attributable to estimated reductions in unnecessary inpatient CDI treatment and laboratory diagnostics (Table 2).

Discussion

Diagnostic stewardship was successfully applied to *C. difficile* testing through implementation of a CCDS tool coupled with a financial incentive. The intervention not only reduced testing and

Table 1. Impacts of the *Clostridioides difficile* Computerized Clinical Decision Support (CCDS) Tool and Incentive on Testing and Infection Events

	Total Tests/HO-CDI		
Component	Pre	Post	% Reduction
Prevented tests[a]	0	959	…
Completed *C. difficile* NAAT tests	3243	1893	41.6
Negative	2649	1541	41.8
Duplicate negative[b]	80	23	71.3
Positive	502	325	35.3
Duplicate positive[c]	12	4	66.7
HO-CDI LabID events	190	129	32.1

Note. NAAT, nucleic acid amplification test; HO-CDI, hospital-onset *C. difficile* infection; Pre, preintervention period; Post, postintervention period.
[a]Identified as a test order opened by a provider, triggering the CCDS, but without a completed order.
[b]Within 3 days following a previous negative result.
[c]Within 14 days following a previous positive result.

Table 2. Cost Analysis

			Annual Component Costs		
Component	Component Volume, No.	Unit Cost/Wages	Pre	Post	Cost Savings, $
C. difficile NAAT	Pre: 3,243 Post: 1,893	$31.36 per test	$101,700	$59,364	$42,336
Laboratory cost	3 min per test	Lab technologist: $27.60/h[10]	$4,475	$2,612	$1,863
HO-CDI LabID events	Pre: 190 Post: 129	CDI attributable cost: $6,326	$1,201,940	$816,054	$385,886
Financial incentive	775–800 House staff	0.8% salary bonuses: $433–569	…	$367,561	−$367,561
CCDS technology build	10 h	Programmer: $100/h	…	$1,000	−$1,000
		Total	$1,308,116	$1,259,244	$61,524

Note. NAAT, nucleic acid amplification test; HO-CDI, hospital-onset *C. difficile* infection; Pre, preintervention period; Post, postintervention period; h, hours.
Cost differences reflect preintervention minus postintervention periods with the exception of technology-associated build time, which was factored under the postintervention period for this analysis.

HO-CDI (previously reported)[6] but resulted in a significant overall savings for the health system despite the considerable initial cost of the incentive. Cost savings could be considerably greater in subsequent years without the expense of the bonus, if the tool remains effective in guiding test utilization. Nonetheless, the study has several limitations.

First, the primary goal of our intervention was to improve patient care by reducing inappropriate tests and potential harm attributable to overtreatment, which accounted for the largest proportion of estimated savings. However, it is imperative to understand not only the benefits but also the potential harms of reduced *C. difficile* testing. Further studies are needed to explore the overall effectiveness and safety of the diagnostic stewardship interventions for *C. difficile* assessment.

Second, HO-CDI events were chosen as a convenient estimate for reduction in treatment for CDI; however, reductions in HO-CDI did not necessarily reflect prevention of CDI treatment in all patients and may have over- or underestimated savings. For example, we did not factor community-onset or recurrent CDI, which may cost up to $10,580 per case.[9] Other "hidden" costs, such as added provider time and administrative/quality improvement efforts, were not included. Also, savings associated with avoidance of reimbursement penalties or improved institutional reputation/rankings were not factored in the analysis.

Finally, pharmaceutical costs were not calculated separately from estimated attributable costs because nearly all patients were treated with oral vancomycin compounded by the hospital pharmacy.

The cost analysis of a CCDS diagnostic stewardship tool like ours will be impacted by institutional decisions regarding *C. difficile* infection testing and alternative treatment protocols. As such, this report should not be viewed as a cost-effectiveness analysis but rather as an assessment of costs and estimated cost savings of the CCDS tool at our institution. A financial incentive may not be feasible at other institutions; however, the specific contribution of the bonuses to this diagnostic stewardship intervention is unknown. Reduced testing has been sustained for at least 12 months following distribution of the 1-time financial incentive for trainees in June 2017. In addition, trainees comprised only about half of the prevented tests; other ordering providers received no incentive.

Although experimental and financial evidence support the use of diagnostic stewardship to improve *C. difficile* diagnostic

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utilization, further studies are required to establish patient safety and to generalize our findings at other institutions.

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Conflicts of interest. All authors report no conflicts of interest relevant to this article.

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