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Major Article

Health care worker perceptions toward computerized clinical decision support tools for *Clostridium difficile* infection reduction: A qualitative study at 2 hospitals



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Key Words:

Clostridium difficile infection
computerized clinical decision support
antibiotics
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Background: *Clostridium difficile* infection (CDI) is associated with significant morbidity and mortality. Computerized clinical decision support (CCDS) tools can aid process improvement in infection prevention and antibiotic stewardship, but implementation and health care workers (HCWs) uptake of these tools is often variable. The objective of this study was to describe HCWs' perceptions of barriers and facilitators related to uptake of CCDS tools as part of a CDI reduction bundle.

Methods: We conducted a qualitative study among HCWs at 2 acute care hospitals in Maryland. Semi-structured interviews and structured surveys were completed by HCWs to evaluate their perception to CCDS tools at 2 different stages: predevelopment and preimplementation. Emergent themes and patterns in the data were identified and condensed.

Results: Gaps in CDI-related knowledge and in communication between HCWs were identified throughout the evaluation. HCWs agreed on the potential of the tools to improve CDI diagnosis, prevention, and control. An important barrier for uptake was the perceived loss of autonomy and clinical judgment, whereas standardization and error reduction were perceived advantages.

Conclusions: These observations shaped the development and implementation of the CDI reduction bundle. Qualitative findings can provide valuable contextual information during the development stages of CCDS tools in infection prevention and antibiotic stewardship.

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BACKGROUND

Despite prevention efforts, *Clostridium difficile* infection (CDI) rates have remained high across the United States, suggesting that new interventions are needed.¹ Electronic health record–based computerized clinical decision support (CCDS), a technology that uses patient-specific data to provide relevant pieces of knowledge at the point of care, has been used to optimize infection control and antibiotic stewardship activities.^{2–6} However, the use of CCDS specifically for CDI prevention and control has been more limited.^{6–9} Although studies report improved user performance when CCDS tools are implemented,^{3,10} health care workers' (HCW) uptake is not guaranteed.^{11,12}

This study is part of an initiative implementing and assessing the impact of a CCDS-based bundle for reducing hospital CDI rates. This study aimed to describe HCWs' perceptions of barriers and facilitators related to uptake of computerized tools for CDI reduction.

MATERIALS AND METHODS

We conducted a qualitative study among HCWs at 2 acute care hospitals in Maryland to explore the perceived barriers and facilitators related to the uptake of a CDI reduction bundle.

Data collection

The CCDS tools used as part of the CDI reduction bundle were evaluated at 2 different time points: (1) predevelopment of the electronic tools and (2) preimplementation of the electronic tools (Fig 1).

For the pre-development evaluation, we conducted in-person semi-structured interviews with a convenience sample of HCWs including physicians, nurses, pharmacists, radiology technicians, and environmental services (EVS) workers in December 2016. The interviews were composed of 2 different sections: (1) a structured section to assess CDI-related knowledge, and (2) a semi-structured section with open-ended questions to assess their perceptions of, and agreement with, the tools included in each of the CDI bundle components. For each interview, the HCWs' occupation determined the components to be addressed (Table 1). An example of an asked open-ended question is the following:

The *C difficile* reduction bundle is planning to generate an automatic order for contact precautions that is coupled to *C difficile* testing. In other words, when you order a *C difficile* test in the system, automatically a contact precautions order will be generated for this patient.

- Would you agree with this measure? Why or why not?
- Do you think this tool will facilitate the health care provider's ordering of contact precautions?
- Would you prefer if the system allow you to opt out of the automatic contact precautions ordering? Why or why not?

To reduce potential interviewer bias, research team members (epidemiologist, nurse practitioner) with no association to either hospital acted as interviewers. The interviewees were informed the interview was anonymous and voluntary.

For the pre-implementation evaluation, a self-administered structured survey was completed by a convenience sample of 13 HCWs (physician or physician assistant role only) in September 2017 to evaluate the level of agreement toward the electronic tools ready for implementation. The survey included screenshots for each of the new electronic tools, including alerts, hard stops, and order sets. This study was approved by the Institutional Review Board at the University of Maryland, Baltimore.

Data processing and analysis

All interviews were audio-recorded and transcribed verbatim. Both interviews and surveys were anonymous and de-identified. For the CDI knowledge section, we calculated percent agreement with each CDI-related statement, stratified by occupation. For the pre-implementation stage survey, medians of agreement levels were estimated.

Nvivo 11 (QSR International, Burlington, MA) was used to analyze the open-ended questions and to guide the thematic analysis. Three research team members (N.B., G.L.R., and L.M.O.) performed conventional content analysis on 4 randomly selected interview transcripts to create an initial coding scheme that was later refined. Two of these 3 reviewers independently coded each transcript to ensure consistency of coding. Emergent themes and patterns in the data were identified. Through reviewer consensus, themes were condensed into overarching categories and subthemes which were supported with the strongest direct quotations (subsequently reported in results section).

RESULTS

Pre-development stage

CDI-related knowledge among HCWs

Of the 34 HCWs (17 from each hospital) who participated in the structured interviews, 11 were nurses, 9 were physicians, 3 were pharmacists, 4 were radiology technicians, and 7 were EVS workers.

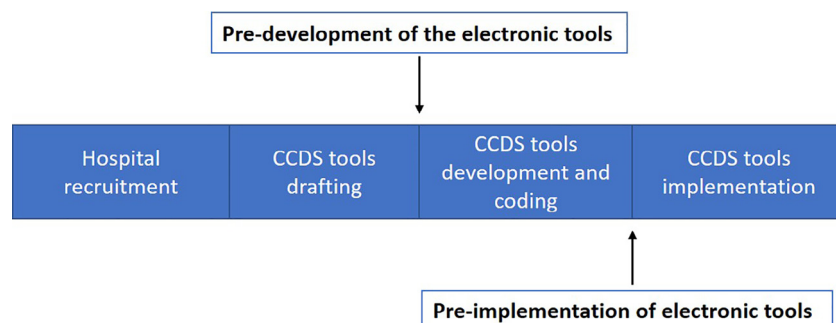


Fig 1. Graphic representation of study timeline. CCDS, computerized clinical decision support.

Table 1
Clostridium difficile infection reduction bundle components and tools

CDI bundle components	Problem statement	Evaluated interventions	HCWs interviewed
Optimize timely initiation of enteric contact precautions	Based on current guidelines, suspected CDI patients should be placed on contact precautions as soon as <i>Clostridium difficile</i> is suspected. However, HCWs tend to wait for a positive test result before placing the patient on contact precautions, even though infected patient would be shedding high levels of spores during this period. ¹³	Link contact precautions order with CDI test order	Nurses Physicians
Optimize diagnostic testing for <i>C difficile</i>	Overdiagnosis has implications for unnecessary treatment of the patient, cost, and false elevation of the hospital's CDI rates. Promoting appropriate indication-based testing has been associated with a decrease in potential false-positive results. ^{9,14–18}	Provide a hard stop or alert for <i>C difficile</i> testing with recent laxative use, repeated <i>C difficile</i> testing, and not meeting the diarrhea definition	Nurses Physicians
Reduce unnecessary use of PPIs	PPIs use has been associated with both the development of the initial CDI episode and recurrent episodes. ¹⁹	Record a mandatory indication for PPIs prescribing	Physicians Pharmacists
Reduce use of selected high-risk antibiotics associated with CDI	Fluoroquinolones, clindamycin, and third- and fourth-generation cephalosporins are considered high CDI risk antibiotics. Several studies have shown that reducing use of these high-risk antibiotics can significantly reduce CDI rates. Furthermore, concurrent use of PPIs and antibiotics leads to higher risk of CDI. ^{20–22}	Alert prescribers to high-risk antibiotics at time of order placement Switch high-risk for lower-risk antibiotics for the shortest duration recommended in hospital guidelines Create a single antibiotic order set by type of infection for ease of use	Physicians Pharmacists
Ensure consistent environmental disinfection with a sporicidal agent	<i>C difficile</i> spores are resistant to killing by most hospital disinfectants. Bleach used for room and surface cleaning has been shown to be useful in reducing CDI rates. Similarly, some hospitals use UV light and hydrogen peroxide vapor as part of their room terminal cleaning after CDI patients are discharged. ¹³	Notify housekeepers on the floor of patients' <i>C difficile</i> status through an automated daily list Provide an alert associated with transport order for procedures performed off the floor	Nurses EVS Radiology technicians

CDI, *Clostridium difficile* infection; EVS, environmental services; HCW, health care worker; PPI, proton-pump inhibitor; UV, ultraviolet.

Table 2
Clostridium difficile infection knowledge assessment by type of health care worker

Statement/topic	Agreement with statement per type of health care worker					Total
	Nurses (n = 11)	Physicians (n = 9)	Pharmacists (n = 3)	Radiology technicians (n = 4)	EVS workers (n = 7)	
<i>Clostridium difficile</i> is important as an HA pathogen	11	9	3	4	7	34
<i>C difficile</i> is highly infectious	11	9	3	4	7	34
Antibiotic use is an important risk factor for CDI development	11	9	3	-	-	23
Antibiotic stewardship is important to reduce <i>C difficile</i> rates	11	9	3	-	-	23
PPI use is an important risk factor for CDI	7	7	3	-	-	16
Presumptive <i>C difficile</i> cases should be placed under contact precautions or contact precaution orders for <i>C difficile</i> should not wait for test results	10	9	3	-	-	22
Patients can be asymptomatic carriers	10	9	3	-	-	22
The proper selection of patients for <i>C difficile</i> testing based on clinical symptoms and risk factors is essential for proper <i>C difficile</i> diagnosis	10	9	3	-	-	22
Daily and terminal cleaning of <i>C difficile</i> -positive rooms with a sporicidal agent such as bleach can help limit transmission of <i>C difficile</i> in the hospital	11	8	3	4	7	33

NOTE. Values are n.

CDI, *Clostridium difficile* infection; EVS, environmental services; HA, healthcare associated; PPI, proton-pump inhibitor.

All EVS workers correctly responded to their CDI knowledge assessment. All interviewed HCWs (EVS excluded) agreed on the association between antibiotics and CDI development (n = 23; 100%); however, the same was not observed for the association between proton-pump inhibitors (PPIs) and CDI (n = 16; 70%). Pharmacists tended to agree more on the association of PPIs with CDI (n = 3; 100%), whereas nurses agreed the least (n = 7; 64%). Nearly all HCWs were in agreement on the importance of placing presumptive CDI cases on contact precautions without waiting for laboratory results (nurses: n = 10, 91%; physicians: n = 9, 100%; pharmacists: n = 3, 100%). Because of the small sample size, the differences across HCWs were not statistically analyzed (Table 2).

HCWs' perceived barriers and facilitators

The main themes that emerged from the interviews were classified into the following 5 categories in order of priority (based on

frequency): (1) knowledge, (2) automation, (3) standardization, (4) transmission prevention, and (5) quality of documentation (Fig 2). We presented here the strongest quotes that best captured each perspective. Additional quotes were summarized in Supplementary Table S1.

1. Knowledge

We identified gaps in knowledge and communication that could impact HCWs' attitudes toward the interventions in the CDI reduction bundle as follows.

- Optimize timely initiation of enteric contact precautions

CDI guidelines recommend placing presumptive CDI patients under enteric contact precautions because patients with active

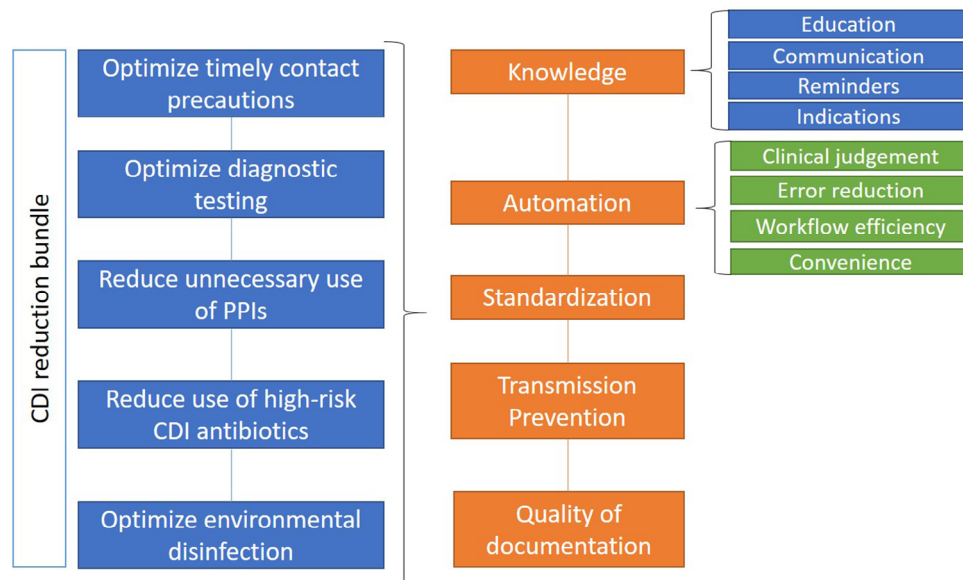


Fig 2. Graphic representation of main themes identified in health care workers' interviews. CDI, *Clostridium difficile* infection; PPI, proton-pump inhibitor.

diarrhea are considered highly infectious.¹³ Therefore, the CDI reduction bundle will link the order of initiation of contact precautions with the CDI test order prior to test result.

Some physicians preferred the option to opt out:

Sometimes I mean—whenever a patient has diarrheawe go ahead and order C. diff. That's the first thing that comes to our mind. But then most of the times. . . patient might have diarrhea, but then it doesn't fit C. diff. So in that case it is unnecessary. You know like if I have an option to opt out, then it would be good so I don't have to place like contact precautions for that patient.

- Optimize diagnostic testing for *C difficile*

Similarly, CDI guidelines do not recommend the use of a test of cure²³ because patients successfully treated may still test positive. Likewise, given the prevalence of asymptomatic colonization and high sensitivity of molecular testing for *C difficile*, patients with a prior negative CDI test in the last 5–7 days should not be retested.²⁴ The CDI reduction bundle will alert HCWs if the patient has a prior CDI test during a specific time period and alert them that repeat testing is not recommended. However, we detected a gap in knowledge on this issue among both nurses and physicians.

According to a nurse,

If the patient was positive then it is always good to retest to make sure they are either, if it's negative now or you know like it's helpful to know if they still have it currently or are they done?

While a physician argued,

I mean you know if I have seen a patient has the symptoms, I don't care that they had it before. . . or oh they didn't have it or something. I'm gonna go and just do the check for C. diff.

It is also recommended that patients who have received laxatives in the last 48 hours should not be tested for CDI because the diarrheal symptoms may be attributable to those laxatives and the presence of *C difficile* in stool may simply represent colonization of hospitalized patients.^{9,18,23} The CDI reduction bundle will alert HCWs when ordering a CDI test if the patient has received laxatives in the last 48 hours of hospitalization and not allow them to proceed with the test order.

HCWs disagreed on the importance of screening for laxative use when considering CDI.

A physician argued the following:

. . . it is something we think about because we don't want to give patients with suspected C. diff infections things like Imodium, but it is not maybe something we actively screen for when we are at the point of diagnostic testing.

- Reduce unnecessary use of PPIs

Likewise, to improve PPI prescription, the CDI reduction bundle will require the selection of an appropriate PPI indication when completing the prescription order. Physicians were divided about this measure.

Some physicians supported the tool:

. . . the list that makes you choose forces you to think about it more. So I think it would be a good measure.

Other physicians were more hesitant:

. . . the human mind is always better than the system, you know? If something. . . if I need to use it for something, I should be able to.

Pharmacists strongly agreed on how useful this tool could be:

I think this is absolutely necessary, particularly my doctor, who's over there with me today. He puts PPIs on just about everybody, and. . . a lot of people think that just the patient being on steroids is enough for that, for PPI, so I think if they had to select from an appropriate indication and saw that the indication they're trying to use it for isn't appropriate, that might flag them.

- Reduce use of selected high-risk antibiotics associated with CDI

The CDI reduction bundle will switch from high CDI risk antibiotics to low CDI risk antibiotics when appropriate. The bundle will also create a single order set for antibiotic prescription by type of infection, which will prioritize low CDI risk antibiotics for appropriate duration of therapy.

Pharmacists were in agreement with this component:

I think product selection is pretty important for specialty physicians, maybe people who are not necessarily so ID [infectious diseases] focused. . . So that definitely can help with antimicrobial stewardship and that sort of thing and then in general it is just good patient care I mean to have you know a link towards the specific antibiotics for the specific infection that they are treating.

Physicians also tended to agree that it would benefit patients:

So it's always good to—I mean deescalate the antibiotics. So it's good for everybody.

- Ensure consistent environmental disinfection

We also identified a communication gap (or transfer of knowledge) between HCWs that could impact infection prevention efforts. Because *C difficile* spores are resistant to killing by most disinfectants, the use of bleach during daily and terminal cleaning of CDI patients is recommended.^{23,24} To improve efficiency and compliance with this process, the CDI reduction bundle will provide EVS with a daily list of all patients with a positive *C difficile* or order pending.

Nurses generally agreed with the measure:

It would be helpful because currently EVS don't necessarily know which patients are *C. diff* positive or isolated for *C. diff*, they rely on asking clinicians what the isolation is for.

Similarly, the CDI bundle will create a disinfection alert with off-the-floor transport of patients with suspected or known *C difficile*, with the goal of closing the communication gap between HCWs caring for the patient during off-the-floor procedures and bedside nurses.

Radiology technicians agreed with this tool:

A lot of times when the patients come down here on the ticket to run it says they are in isolation, but it doesn't always say why they are in isolation. So if we have some kind of red flag stating why they are in isolation that would help us better to know how to clean the room.

2. Automation

One of the perceived benefits of CCDS tools was the automation of certain infection prevention and control processes. Automation can potentially reduce errors and improve workflow efficiency^{11,12,25} because these tools provide the HCWs with data at the point of action (ie, when prescribing antibiotics, ordering a CDI test), instead of relying on the HCW to actively look up relevant guidelines or review the medical records for history.

When asked about hard stops for CDI testing, nurses argued the following:

It would save clinician time and also laboratory time because they typically currently call us and let us know that they're not going to do the test because there was one done within the last seven or fourteen days.

Likewise, pharmacists agreed with a tool requiring a PPI indication when prescribed because it has the potential to streamline their daily workflow:

Well, I mean, it just helps prevent, you know, the perpetuation of it. As pharmacists. . . one of our interventions that we look at every day is PPI use in the hospital. . . I do review those every day, and I try to intervene on those every day, and this would auto-

matically get rid of them for me, so that would reduce my workload a lot.

Despite the potential benefits of automation, many physicians expressed concern regarding a perceived loss of autonomy and clinical judgment:

Yeah. Alarm would be fine and then you know I can you know make a decision but I don't want the system to make a decision for me.

Similarly, regarding automated hard stop for *C difficile* ordering in the presence of laxative use:

. . . I do not want to take this risk of *C. diff* patient now. I have too many in the ICU. Nurses will say. . . the patient is on lactulose. I said "well, it doesn't make him the first constipated patient in the hospital."

Physicians also expressed concern about alert fatigue and the burden of additional documentation. For example, a physician mentioned the following:

Most of my patients are on PPI. It's going to actually increase the number of ticks for the physicians.

Pharmacists defended the tools as follows:

I know there's always alert fatigue but we've been calling. . . to try to get rid of some of these fluoroquinolones and I will give my spiel about *C. diff* and then they just kind of are. . . move past that.

3. Standardization

Another perceived advantage associated with CCDS tools was their ability to aid with the standardized implementation of hospital guidelines and standard of care across patients and HCWs.

A physician stated the following when discussing the antibiotic component of the bundle:

A lot of clinicians tend to pick antibiotics just based on their experience or their comfort and that necessarily doesn't follow guidelines.

Similarly, a nurse made the following statement:

. . . usually we don't do the isolation unless they've had three [diarrheal episodes] but sometimes they'll have like one and then the doctor will want to send the next one. But it's not really like the three that we've kind of used as our golden rule.

Even though this gap was observed, HCWs tended to agree on the importance of standardization of hospital guidelines.

Physicians argued the following when discussing contact precautions:

Every physician or clinician is very different. . . so I think the variation is so high, it's better just to standardize it.

4. Transmission prevention

Another perceived benefit of the CDI reduction bundle tools is the potential to reduce *C difficile* transmission in the hospital.

When discussing the contact precaution component, a nurse stated the following:

I think if you are suspicious of somebody having *C. diff*, I think they should be under precaution just in case. It may take a little bit long to get the test results back, and so I think just in case, until we get the results back, that it's a no or whatever, I think that they should be on it.

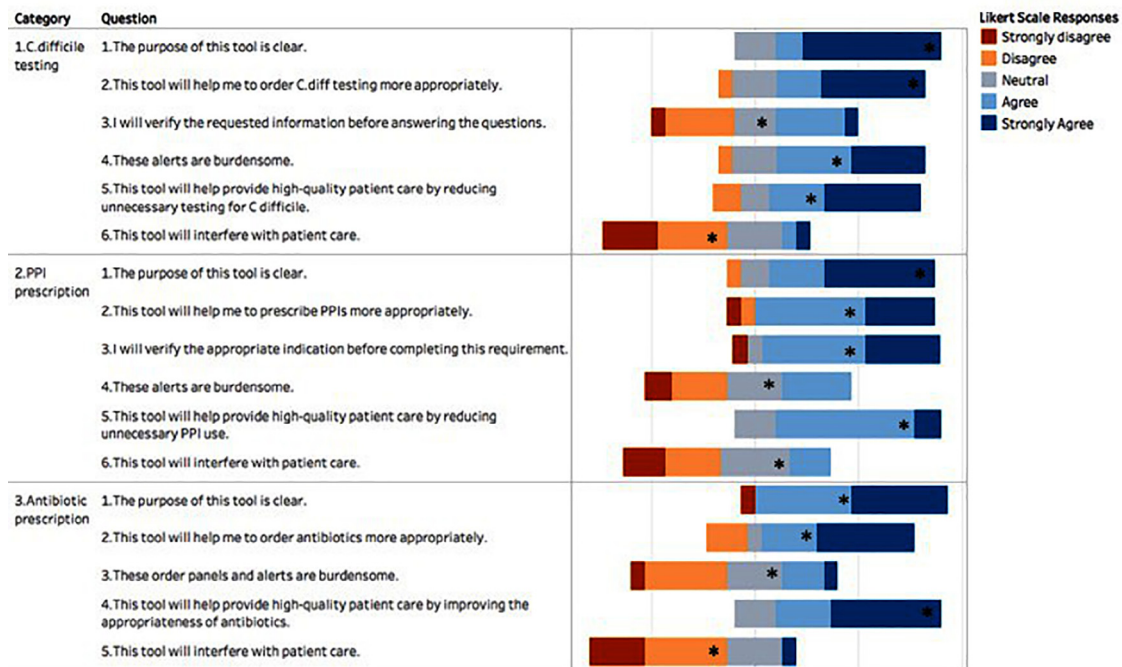


Fig 3. Divergent bar chart representing the level of agreement with the *Clostridium difficile* infection reduction bundle at time of implementation. Survey questions were broken down by evaluated component. Positive responses are stacked to the right and negative responses are stacked to the left of the chart. Asterisks represent the median response for each question. Shading represent responses, and missing values were excluded from the graph. C.diff, *C. difficile*; PPI, proton-pump inhibitor.

Likewise, when discussing the disinfection component, a radiology technician stated:

The more people that know about C. diff the better. I mean I feel like everybody should be aware and know and not just walk into a room and just see your isolation that they know it's specifically enteric and not just contact. Cause all they see when they walk in the room is you wearing a gown like say if somebody helped you lift. Well if there was some kind of sign or something that let them know that this person's actually C. diff and not just regular isolation you would know to clean/wash your hands instead of using the alcohol.

5. Quality of documentation

The final topic discussed during the HCWs interviews was the quality of documentation, particularly the documentation of stool output. The CDI bundle intends to directly inform the HCWs if the patient meets diarrhea criteria or to remind them to check the patient's stool output documentation in the previous 24 hours before ordering the CDI test.

Physicians tended to disagree with this measure because of the current poor quality of documentation:

I don't agree because of... sometimes I don't believe that all is documented. So if I feel clinically that the patient is having diarrhea and I want to order that test, I should be able to do it.

Pre-implementation stage

Overall, HCWs agreed that the evaluated tools were clear and that they have the potential to aide CDI test ordering and antibiotic and PPIs prescribing. HCWs also agreed that these tools could help them to improve the quality of patient care. Importantly, most HCWs interviewed did not feel that the proposed tools would

negatively interfere with patient care. Finally, HCWs were mostly neutral on how burdensome these tools can be (Fig 3).

DISCUSSION

We identified important gaps in CDI-related knowledge and communication between HCWs. HCWs agreed on the potential of the evaluated CCDS tools to improve CDI prevention, control, and diagnosis. They expressed concern regarding a perceived loss of autonomy and clinical judgment, but also conveyed an appreciation for the perceived benefits associated with CCDS tools such as standardization and automation. Previous work on non-CDI CCDS tools confirmed our observations of perceived threats to professional autonomy and perceived benefit of workflow efficiency.^{11,12,26,27} Finally, most HCWs agreed the tools in the CDI reduction bundle could help them improve the quality of patient care.

Unsurprisingly, we observed discrepancies between HCWs' knowledge and their perceived behaviors. For example, 100% of physicians agreed that *C. difficile* testing based on clinical symptoms and risk factors is essential for proper *C. difficile* diagnosis, still it is clear from the interviews that some physicians do not consider the proper diarrhea definition, previous testing, or laxative use before ordering the test. This gap between knowledge and behavior has been previously described among HCWs, where intolerance to uncertainty or loss aversion may explain these behaviors.^{28–30}

Our study observations helped shape the CCDS-based tools portion of our CDI reduction bundle. For instance, the research team decided to eliminate the proposed alerts regarding antibiotics and PPIs to limit alert fatigue and avoid alerts to be perceived as a nuisance that could be dismissed. Instead, we focused on incorporating desired practices into standardized order sets. Similarly, interview results informed the HCWs' education gaps that would need to be addressed to improve uptake of the different tools as lack of familiarity can act as a barrier of adherence to clinical practice guidelines.²⁶

The end users were also engaged from the beginning of the tool development process, which can influence clinician acceptance and adherence to the tool as well.²⁶

Our study was strengthened by the inclusion of a variety of HCWs whose roles are crucial for the control of CDI in the hospital and whose daily workflows will be impacted by these CCDS tools. Nevertheless, this study included a limited number of participants from only 2 acute care Maryland hospitals. The small sample size restricted our ability to perform additional statistical analyses and to generalize these results to other hospitals. At this point, we are unaware of how these perceptions will link to the actual impact of the CDI reduction bundle. We aim to explore this in future studies.

Qualitative studies are often lacking as part of the implementation of intervention studies. We think that qualitative findings, such as those presented here, can provide valuable contextual information to develop, implement, and evaluate CCDS tools to strengthen hospital infection prevention and antibiotic stewardship initiatives.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.ajic.2018.04.204>.

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