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Exploring three strategies for the prevention of hospital-acquired clostridium difficile infection in NYS acute care hospitals: structure-process-outcome model of quality improvement

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EXPLORING THREE STRATEGIES FOR THE PREVENTION OF HOSPITAL-ACQUIRED
CLOSTRIDIUM DIFFICILE INFECTION IN NYS ACUTE CARE HOSPITALS—
STRUCTURE-PROCESS-OUTCOME MODEL OF QUALITY IMPROVEMENT

by

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ABSTRACT

Those receiving medical care are at risk for developing serious hospital-acquired conditions (HACs), which include infections (HAIs) and other harm while receiving medical care. Pay for performance programs initiated by the Centers for Medicare and Medicaid Services (CMS), and private payers, linking reimbursements to quality of care, have created financial incentives for hospitals to address these HACs. The most common HAI in the United States, causing almost half a million infections, with 29,000 deaths within 30 days of diagnosis, results from Clostridium difficile. Infection with this bacterium leads to deadly diarrhea, and disproportionately impacts patients 65 and older, representing 80% of C. difficile deaths. People contract C. difficile infection (CDI) in an acute care setting in a variety of ways: risk of CDI is 7-10 times more likely while taking antibiotics and during the month after; coming into contact with unclean surfaces contaminated with feces from an infected person; and inadequate or improper hand hygiene of healthcare workers.

Using the structure, process, outcome model of quality improvement, which asserts poorly designed systems, and not people, to be the root cause of harm resulting from medical care, this project investigates structural interventions that address each of these three risk factors with the goal of uncovering potential strategies to prevent this deadly infection. Using difference-in-differences analysis, we evaluate the impact on hospital-acquired CDI (HA-CDI) rates of a NYS Antibiotic Stewardship Collaborative aimed at improving antibiotic prescribing practices (Chapter 2); using time-series regression analysis with a fixed-effects approach we assess the relationship between HA-CDI rates and emergency department wait times and patient-reported room cleanliness scores in NYS hospitals (Chapter 3); and through administration of a survey
and trend-analysis, we explore the proliferation of electronic hand hygiene monitoring systems within NYS hospitals and the impact of these systems on HA-CDI rates (Chapter 4)
CHAPTER 1: BACKGROUND AND INTRODUCTION

The problem. The Centers for Disease Control and Prevention (CDC) estimates that on any given day, about one in 25 hospital patients has at least one hospital-associated infection (HAI)\(^1\), described as “infections patients can get while receiving medical treatment in a healthcare facility–a major, yet often preventable, threat to patient safety”\(^1\). In 2011, this was estimated by a multistate point-prevalence survey to be 648,000 patients with 721,800 HAIs in U.S. acute care hospitals, with about 75,000 of these patients dying during their hospitalization.\(^2\) These infections are also costly; it is estimated $9.8 billion is spent each year treating HAIs. For the top 5 HAIs, surgical site infections contribute the most to overall costs (33.7%), followed by ventilator-associated pneumonia (31.6%), central line–associated bloodstream infections (CLABSIs; 18.9%), Clostridium difficile infections (15.4%), and catheter-associated urinary tract infections (CAUTIs; <1%).\(^3\) Clostridium difficile is the most common HAI in the United States, causing almost half a million infections, with 29,000 deaths within 30 days of diagnosis.\(^4\) Infection with this bacterium leads to deadly diarrhea, and disproportionately impacts patients 65 and older, representing 80% of C. difficile deaths.\(^5\) The excess health care costs related to C. difficile infection are estimated to be as much as $4.8 billion for acute care facilities alone.\(^2\)

Hospital-acquired infections are a type of preventable adverse event, or “an injury caused by medical management rather than the underlying condition of the patient,”\(^6\) which are the result of medical errors. There are four different types of medical errors—diagnostic, treatment, preventative, and other—as described in the table below.\(^7\)
Types of Errors

The culture of medicine creates an expectation of perfection and often attributes errors to carelessness or incompetence, while concerns for liability discourage the reporting of errors and communicating about how to correct them. However, according to the Institute of Medicine, preventing errors and improving safety for patients require a systems approach in order to modify the conditions that lead to errors.6 “People working in health care are among the most educated and dedicated workforce in any industry. The problem is not bad people; the problem is that the system needs to be made safer”6. The idea of approaching quality improvement from a systems perspective, using a scientific approach to design waste out of processes, is not new. Although, history of healthcare quality prior to 1960 is a fragmented set of events, deliberate quality improvement efforts were emerging in industries other than healthcare between 1860 and 1960.8

Quality improvement before 1960. At the turn of the twentieth century, Frederick Taylor wrote The Principles of Scientific Management, which, among other tenets, called for the standardization of work.9 “Managers with the help of researchers must find the best way for any
task and make sure that the task for any job is done accordingly”. According to Taylor, the “best way” required designing processes that were as efficient as possible, which he believed required removing as much human decision-making as possible from the shop floor. He was fond of saying, “In the past, the man has been first; in the future the machine must be first,” and was criticized by many for treating employees as merely cogs. However, by focusing on the system to minimize the human element, Taylor’s principles led to consistent and reliable production. Swapping efficiency for safety, these elements have been adopted by high-risk industries, such as nuclear power and aviation, where reliability is a significant concern.

Expanding upon Taylor’s scientific management principles, Walter Shewhart discovered some variation is inherent in all systems, which he termed common-cause variation, and the goal should be to bring a process into a state of statistical control, or the absence of special-cause variation, to reduce waste and improve quality. According to Shewhart, “Through the use of the scientific method, extended to take account of modern statistical concepts, it has been found possible to set up limits within which the results of routine efforts must lie if they are to be economical. Deviations in the results of a routine process outside such limits indicate that the routine has broken down and will no longer be economical until the cause of trouble is removed”. To correct special-cause variation, and to improve processes generally, Shewhart developed the Plan, Do, Study, Act cycle. This cycle is used to make changes that lead to improvement in a manner of continuous quality improvement. Statistical process control and PDSA cycles are still used today in many industries.
Combining these theories, we understand from Taylor, performance is a property of the system, and from Shewhart, if a system is stable, the performance is predictable. As such, “performance is determined by the design of the system, and systems are perfectly designed to achieve the results they get”\textsuperscript{10}, to borrow words from W. Edwards Deming, who is considered one of the fathers of quality improvement and was heavily influenced by Shewhart.\textsuperscript{10} In practical application, the infection rate for patients in a hospital is a property of the system(s) that have been designed or have evolved. If we are not satisfied with the current infection rate, changing this system provides the mechanism to change the result. However, when performance features are understood to be system properties, we come to realize most problems in organizations do not come from individual workers; they arise from the structure of the system itself—policies, processes, organization, operating rules, and culture.\textsuperscript{13}

\textit{Quality improvement enters healthcare.} Though Taylor’s systems-thinking, as well as Shewhart’s statistical process control and continuous quality improvement tools, are often used in healthcare quality improvement today, they would take about three-quarters of a century and considerable patient harm before becoming standard practice. For most of the past 50 years, US federal and state health policy initiatives have focused primarily on increasing access and containing costs. In 1965, Congress passed legislation establishing the Medicare and Medicaid programs as Title XVIII and Title XIX of the Social Security Act, which came with a set of “Conditions for Participation” deemed necessary for hospital operation—staff credentials, 24-hour nursing services, and utilization review. While the system of review held promise for monitoring performance, it was largely ineffective, mostly due to an absent association between the review process and the identification of ways to improve care, formal evaluation criteria to
guide providers’ decision making, and mechanisms to adjust payment based on the quality of care.\textsuperscript{8}

Attempts to address the first two of these three limitations were introduced throughout the 70s and 80s, which included Medicare’s Professional Standards Review Organizations (PSROs) established in 1972, considered unsuccessful in both improving quality and containing costs, and Peer Review Organizations (PROs), which were established during the implementation of the hospital prospective cost-per-case, diagnosis-related groups (DRGs) model. PROs were tasked with “validating assignments to the DRGs, reducing unnecessary admissions and readmissions, and reducing complications, and mortality rates, and were considered successful in achieving the intended goals of quality enhancement and cost containment\textsuperscript{8}; as a result they have continued to play a considerable role under the new Centers for Medicare and Medicaid Services (CMS) label of Quality Improvement Organizations (QIOs).\textsuperscript{8}

Also, during this time period, quality improvement efforts were undertaken by leaders in academic medicine and non-profit organizations. In 1951, the Joint Commission on Accreditation of Hospitals (JCAH), now The Joint Commission, was established as a non-profit organization with the intended function of providing voluntary accreditation of hospitals based on a rubric of defined minimum quality standards. In 1989, the Agency for Health Care Policy and Research—currently known as the Agency for Healthcare Research and Quality (AHRQ)—was established by Congress in response to data revealing wide geographic variations in practice patterns without supporting clinical evidence, and reports of misuse and overuse of procedural treatments. The National Committee for Quality Assurance (NCQA) was established in 1990, a
nonprofit organization tasked with managing accreditation programs for individual physicians, health plans, and medical groups. It measures accreditation performance through the administration and submission of the Healthcare Effectiveness Data and Information Set (HEDIS) and the Consumer Assessment of Healthcare Providers and Systems (CAHPS) survey.\textsuperscript{14}  

Concurrent to the introduction of these programs, efforts to address healthcare quality began in the 1960s, with the groundbreaking contributions of Avedis Donabedian, often considered the founding father of this discipline.\textsuperscript{15} In 1966, he published “Evaluating the Quality of Medical Care,” a highly useful model that relies upon the elements of structure, process, and outcomes to examine the quality of care delivered.\textsuperscript{16} According to Donabedian's model, improvements in the structure of care should lead to improvements in clinical processes that should in turn improve outcomes, which is not unlike Taylor’s systems approach to quality. Donabedian expanded this work further, outlining seven attributes of healthcare that define its quality. These Seven Pillars of Quality included, “(1) efficacy: the ability of care, at its best, to improve health; (2) effectiveness: the degree to which attainable health improvements are realized; (3) efficiency: the ability to obtain the greatest health improvement at the lowest cost; (4) optimality: the most advantageous balancing of costs and benefits; (5) acceptability: conformity to patient preferences regarding accessibility, the patient-practitioner relation, the amenities, the effects of care, and the cost of care; (6) legitimacy: conformity to social preferences concerning all of the above; and (7) equity: fairness in the distribution of care and its effects on health”\textsuperscript{17}. 
Shortly after Dr. Donabedian’s transformative contribution to the field of healthcare quality, The National Academies of Science established the Institute of Medicine (IOM) in 1970, which has since launched numerous concerted efforts focused on evaluating, informing, and improving the quality of healthcare. In the early 90s, quality became a much larger focus in health policy initiatives, as several notable studies highlighted inconsistencies in the quality of care\textsuperscript{18-21}, which led to two landmark reports from the IOM. *To Err Is Human: Building a Safer Health System*, sets forth a national agenda for reducing medical errors and improving patient safety through the design of a safer health system\textsuperscript{6}, and *Crossing the Quality Chasm*, which highlighted six core aims for the 21st-century healthcare system: to deliver care that is safe, effective, patient-centered, timely, efficient, and equitable\textsuperscript{22}.

According to the IOM, achieving these six aims for improvement would require significant redesign efforts, changing the structures and processes of the environment in which health professionals and organizations function. They recommend four main areas of focus for redesign: applying evidence to healthcare delivery, using information technology, preparing the workforce, and aligning payment policies with quality improvement, the latter of which was strongly emphasized in both reports as a mechanism for making care safer and controlling costs.\textsuperscript{6,22} Specifically, in *To Err is Human*, the IOM states, “The committee’s strategy for improving patient safety is for the external environment to create sufficient pressure to make errors so costly in terms of ability to conduct business in the marketplace, market share and reputation that the organization must take action. The cost should be high enough that organizations and professionals invest the attention and resources necessary to improve safety”\textsuperscript{6}. 
Payment structures and behavior. This idea of paying for performance certainly did not originate in healthcare. Revisiting Taylor’s work, he recommended a strict wage system to fairly pay employees based on their level of productivity and quality of work. His system had three components: setting high standards for any given task, hiring or transferring the right people to perform those tasks at the expected standards, and paying them more according to the value added to the system, and company, through their work. While Taylor was applying pay for performance principles at the individual level, the intent was similar to its current application in healthcare—aligning incentives, as the IOM suggested.

Evidence that providers have responded to changes in Medicare and Medicaid payment policies in the past suggests they do alter their behavior according to incentive structures. In the early 1980s, average lengths of stay were increasing in the Medicare population but these trends reversed after implementation of a prospective payment system in acute care hospitals in 1983. Additionally, the change in provider behavior was directly related to the portion of their Medicare patient volume—hospitals that were more dependent upon Medicare patients showed a larger change in observed behavior than hospitals with a smaller proportion of Medicare patients. A 1996 study examining skilled nursing facilities found those with cost-based Medicaid payment structures tended to have more registered nurses than licensed practical nurses, compared to those with flat-rate payments.

Introduction of pay for performance. However, up until the 1990s, the task of ensuring healthcare quality was left, for the most part, to the medical profession and hospital accreditation organizations. Government and healthcare agencies focused on increasing access and reducing
costs through inputs or structural factors, such as physicians licensing and hospital accreditation, shying away from intruding on what they viewed as the professional domain of physicians. Medical associations successfully established and defended that professional autonomy throughout most of the twentieth century. In contrast, pay for performance programs, as recommended by the Institute of Health, include a focus on process measures, which assess quality of care through the ways in which doctors and hospitals provide medical care to patients—scrutinizing the tests, procedures, and treatments administered to patients with specific diseases, explicitly to check for errors or missed care.25

Thomas and Caldis define pay for performance as, “an approach used to provide incentives to physicians and health care provider organizations to achieve improved performance by increasing quality of care or reducing costs”26, essentially rewarding providers who foster the six quality aims set forth in the IOM’s Crossing the Quality Chasm to improve health outcomes, while using resources judiciously. The rationale for these programs is, at the most basic level, that improving care requires changes in the behavior of providers, and by paying for improved performance or penalizing poor performance, providers would be properly incentivized to make these changes. Additionally, pay for performance programs have the potential to improve the environment of care, as it makes it attractive for both providers and healthcare organizations to invest in improved structures and systems, which, in a Donabedian sense, should change processes and produce higher quality of care.27

The Centers for Medicare and Medicaid services (CMS) has utilized pay for performance strategies to incentivize providers and healthcare organizations to reduce hospital-acquired
infections. The Deficit Reduction Act (DRA) of 2005 identifies conditions that are: (a) high cost or high volume or both, (b) result in the assignment of a case to a DRG that has a higher payment when present as a secondary diagnosis, and (c) could reasonably have been prevented through the application of evidence-based guidelines. In accordance with this program, hospitals, as of October 1, 2008, do not receive additional payment for discharges in which one of the selected conditions was not present on admission, and includes hospital-acquired infections like surgical site infections (SSI), catheter-associated urinary tract infections (CAUTI), and central line-associated bloodstream infections (CLABSI). Also, the Affordable Care Act (ACA) introduced two additional pay for performance programs aimed at improving the quality of care provided to Medicare beneficiaries and administered by CMS: the Hospital Value-Based Purchasing (HVBP) Program and the Hospital Acquired Conditions (HAC) Program.

In its Hospital Value-Based Purchasing Program (HVBPP), cost savings are guaranteed through across-the-board reductions in hospital reimbursement, and hospitals are then able to earn back a portion of the lost reimbursement through performance on quality measures. In this program, performance is based on an approved set of measures and dimensions grouped into specific quality domains, each weighted equally: safety, clinical care, efficiency and cost reduction, and patient and caregiver-centered experience of care. The safety domain assesses performance in five infection areas—CAUTI, CLABSI, Clostridium difficile infection (CDI), SSI, Methicillin-resistant Staphylococcus aureus (MRSA)—and two safe care measures—early elective delivery (PC-01) and AHRQ’s adverse event composite score (PSI-90).
The ACA has also used pay for performance to incentivize reduction in hospital-acquired infections with the introduction of its Hospital-Acquired Condition Reduction Program (HACRP), which began in 2015. The HACRP aims to reduce what Medicare pays to hospitals that rank worst among other hospitals for how often their patients get hospital-acquired conditions, in an attempt to reduce the incidence of preventable adverse events that occur during hospitalizations in the United States. Hospitals in this program are evaluated according to 2 domains. Domain 1 constitutes 35% of the total score and is solely based on the Agency for Healthcare Research and Quality’s (AHRQ) Patient Safety for Selected Indicators (PSI)-90 composite measure. Domain 2 accounts for the remaining 65% of the total score and consists of an average of 5 hospital-acquired infections: CLABSI, CAUTI, SSI, MRSA, and CDI. Beginning on October 1, 2014, hospitals scoring in the lowest quartile had Centers for Medicare & Medicaid Services’ (CMS’) payments reduced by 1%, totaling approximately $373 million nationally.

This project. These programs impart fiscal consequences in an effort to incentivize providers and healthcare organizations to take the necessary steps to reduce the number of HACs they experience. Understanding foundational theories and frameworks of quality improvement, improving organizational structures as a strategy for meeting pay for performance targets should lead to greater and more sustainable change. This project will explore and evaluate structural interventions that address the three main pathways of CDI risk and spread, which is a key metric of federal pay for performance programs.

- **Chapter 2** evaluates an Antibiotic Stewardship Collaborative, which aimed to assist hospitals with implementing the infrastructure necessary to address improperly
prescribed antibiotics—people on antibiotics are 7-10 times more likely to get C. difficile while on the drugs and during the month after. The aim of this study was to determine if the hospitals in the collaborative experienced a reduction in hospital-acquired CDI (HA-CDI) rates greater than those facilities not participating in the collaborative during its first year (2016) compared to the five-year period leading up to the collaborative (2011-2015). If the findings support this hypothesis, it will suggest an Antibiotic Stewardship Collaborative of this nature to be a promising structural intervention for preventing HA-CDI.

- **Chapter 3** examines if there is a relationship between a hospital’s rate of hospital-acquired CDI and their ED wait times and patient-reported room cleanliness scores—C. difficile is capable of forming spores that contaminate hospital room surfaces. The aim of this study was to determine if a facility’s average emergency department wait time before a patient is admitted is a significant predictor of that facility’s annual HA-CDI rate. Similarly, this study aimed to determine if the percentage of patients at a facility indicating their room is “always,” “usually,” or “sometimes/never” clean is a significant predictor of that facility’s annual HA-CDI rate. If a positive relationship is found with the former and a negative with the latter, it would suggest structural or process changes aimed at reducing ED wait times, improving ED cleanliness, and/or encouraging patient and family empowerment to advocate for increased environmental services, could prove impactful for reducing HA-CDI rates.

- **Chapter 4** evaluates the experiences and perceptions of New York State hospitals in regards to electronic hand hygiene monitoring systems (EHHMS), a structural intervention to address inadequate or improper hand hygiene of healthcare workers, one
of the primary modes of CDI transmission.\textsuperscript{33} The aim of this study was to examine the extent of the proliferation of this technology in New York State hospitals, the reasons some hospitals have not pursued an EHHMS, and the experiences of hospitals currently utilizing an EHHMS, to gain insight into the efficacy of these systems for improving hand hygiene compliance rates and subsequent HA-CDI. If hospitals with an EHHMS report positive experiences with these systems, in terms of improved hand hygiene rates, which is also supported by a corresponding reduction in HA-CDI rates, it would suggest these systems to be an effective structural intervention.
CHAPTER 2: EVALUATION OF AN ANTIBIOTIC STEWARDSHIP

COLLABORATIVE AIMED AT ANTIBIOTIC USAGE SURVEILLANCE IN NYS HOSPITALS
INTRODUCTION

Every year in the United States, at least 2 million people become infected with bacteria that are resistant to antibiotics, and at least 23,000 people die as a direct result of these infections, with many more dying of conditions complicated by an antibiotic-resistant infection. Antibiotic-resistant infections can happen anywhere, but most deaths related to antibiotic resistance happen in healthcare settings. Antibiotic resistance is the ability of bacteria to resist the effects of an antibiotic, and occurs when bacteria change in a way that reduces the effectiveness of drugs, chemicals, or other agents designed to cure or prevent infections. Resistance develops when antibiotic therapies fail to kill the strongest of the harmful bacteria, allowing them to survive and multiply, passing on their resistance and causing more illness. These resistant organisms, such as Clostridium difficile, emerge through administration of antibiotics in humans, but also through antibiotic use in animal agriculture; they are passed from animals to humans in the food supply, but also when human carriers contaminate surfaces and staff within healthcare facilities.

Inappropriate and overuse of antibiotics has caused the C. difficile bacterium to mutate overtime into strains that are resistant to specific antibiotics. In the 1970s, overuse of clindamycin (CLI) in hospitals led to CLI resistant strains and as a result, policies were implemented to control their use. In its place, cephalosporins (CFs) became widely used in the 1980s and 90s, and these drugs quickly became the antibiotics with the highest relative attributable risk of C. difficile infection (CDI). This resistance led to the use of fluoroquinolones (FQ), and subsequently, the emergence and rise of FQ-associated CDI. Over this same time period, strains have become highly virulent, with higher rates of recurrence and mortality. As such, duration of antibiotic course and administration of multiple antibiotics have been found to be significant risk factors for both C.
difficile carriage and diarrhea. Antibiotic therapy leads to disruption in the normal gastrointestinal flora, which enables ingested spores of toxigenic C. difficile to colonize the colon and produce toxins, leading to deadly diarrhea. In 2011, C. difficile was responsible for almost half a million infections and was associated with approximately 29,000 deaths.

While over-prescribing of antibiotics has certainly contributed to resistance, this occurs much more frequently in outpatient settings. Acute care settings contribute to the promotion of resistant bacteria primarily through inappropriate prescribing, as opposed to overprescribing. Studies have shown that treatment indication, choice of agent, or duration of antibiotic therapy is incorrect in 30% to 50% of cases. Incorrectly prescribed antibiotics have questionable therapeutic benefit and expose patients to potential complications. For example, one U.S. study reported that a pathogen was defined in only 7.6% of 17,435 patients hospitalized with community-acquired pneumonia (CAP). In such cases, broad-spectrum antibiotics are favored, as opposed to more targeted treatment options, damaging healthy flora and contributing to the spread of resistant organisms.

In response to this threat, the National Healthcare Safety Network, a data tracking system developed and maintained by the Centers for Disease Control and Prevention (CDC) for healthcare-associated infections, developed an Antimicrobial Use and Resistance (AUR) Module, focused on reporting of antimicrobial use (AU) and antimicrobial resistance (AR). Reporting in this module is currently voluntary, but many policy experts believe it soon will be mandated by the Centers for Medicare and Medicaid Services (CMS). To assist hospitals in preparing for compulsory reporting of antibiotic use, in September 2015, the Healthcare
Association of New York State (HANYS)—the statewide hospital and continuing care association in New York providing advocacy, education, data analytics, operational assistance, and quality improvement initiatives for member not-for-profit and public hospitals, nursing homes, and other healthcare organizations—formed an Antibiotic Stewardship Collaborative.

This is a voluntary collaborative provided as a benefit to HANYS’ member hospitals aimed at supporting these facilities as they advance their focus on antibiotic stewardship: providing tools and resources to reduce drug-resistant organisms, prevent C. difficile infections (CDI), and prepare for reporting in NHSN's AUR module. Participating hospitals are asked to:

1. Submit data monthly to HANYS on their prescribing practices for specific antibiotics, receiving a comparative report in return indicating how their antibiotic usage compares to similar hospitals participating in the collaborative, and
2. Attend educational webinars on a variety of topics related to antibiotic stewardship and drug-resistant organisms.

To learn more about the factors associated with voluntary participation in the collaborative and the effects of participation on outcomes, we compared HANYS’ acute care member hospitals participating and not participating in the collaborative on several different dimensions. First, we examined factors associated with participation in the collaborative to determine if differences emerged to indicate a “type” of facility that chooses to self-regulate in the area of antibiotic stewardship by joining a voluntary collaborative. It was thought larger facilities, with greater resources to devote to antibiotic stewardship, and those with higher rates of hospital-acquired CDI, were more likely to join the collaborative. Additionally, we conducted a difference-in-
differences analysis comparing these same participating and non-participating facilities to assess the impact the first year of the collaborative (2016) had on reducing hospital-acquired C. difficile infections (HA-CDI). We hypothesized those hospitals participating in the collaborative would have significantly lower HA-CDI rates after the collaborative was implemented, compared to those facilities not participating. This analysis was supplemented with semi-structured interviews with personnel responsible for antibiotic stewardship at these facilities to gain insight regarding their decision to join or not to join the collaborative, successes and lessons learned from participating in the collaborative, and suggestions for how to improve the collaborative.

**Hypothesis 1**: Larger facilities and those with higher rates of HA-CDI were more likely to join the collaborative.

**Hypothesis 2**: Hospitals participating in the collaborative experienced a greater reduction in HA-CDI rates during the first year of the collaborative compared to hospitals who did not participate.

**METHODS**

**Dependent Variable**

*Rates of hospital-acquired C. difficile infection*
Monthly hospital-acquired C. difficile infection counts, which represent the number of CDI cases not present on admission at each facility each month, and total monthly discharges, each from the period of January 2011-December 2016, were extracted from the Statewide Planning and Research Cooperative System (SPARCS), New York State’s comprehensive all-payer data reporting system. The Healthcare Association of New York State has access to this system for the purposes of regular business operations and research projects. These variables were used to calculate a monthly facility CDI rate (number of CDI/1000 patient discharges), the dependent variable. The codes ICD-9-CM 008.45—Intestinal infection due to Clostridium difficile, prior to October, 2015, and ICD-10-CM A04.7—Enterocolitis due to Clostridium difficile, after October 2015, indicated as the principal or secondary diagnoses were used to identify appropriate claims. The “present-on-admission” indicator was set to “no” to limit the extraction to only hospital-acquired CDI.

**Independent Variable**

*Participation in the collaborative*

Our primary independent variable of interest in this analysis was the interaction between an indicator variable for participation in the collaborative (1 if the hospital participated in the collaborative, 0 if otherwise) and an indicator variable for the time period post-implementation of the collaborative (1 if the time period was on or after January 2016, 0 if otherwise), which is the difference-in-differences (DD) estimator. The implications of the DD estimator is described in more detail below. Despite differences in the consistency of participation across facilities in collaborative activities, monthly data submissions and attendance at educational events, this was
an intention to treat analysis, with participation defined as a signed memorandum of understanding (MOU) by the facility signifying their enrollment in the collaborative. According to this definition, we classified 44 hospitals as participating in the collaborative.

**Control Variables**

*Clinical predictors of C. difficile infection*

Payer profile and other clinical characteristics were also extracted from SPARCS to serve as control variables in the analysis. This included total discharges and total Medicare discharges, which was converted to a percent of total discharges, serving as a proxy for advanced patient age. Clinical characteristics included average length of stay (ALOS), a mean calculated by dividing the sum of inpatient days by the number of patient admissions with the same diagnosis-related group classification, and the all patient refined-diagnosis related group case mix index (APR-DRG CMI). CMI reflects the diversity, clinical complexity, and resource needs of the hospital’s patient population, and the APR-DRG CMI specifically takes into account patient age and severity of illness.

*Non-clinical hospital characteristics*

Hospital non-clinical characteristic data was extracted from the Centers for Medicare and Medicaid (CMS) Healthcare Cost Report Information System (HCRIS) by the Economics, Finance, and Information (EFI) division of the Healthcare Association of New York (HANYS). This data included urban/rural designation, teaching status (major teaching, minor teaching, and non-teaching, as calculated from the intern- and resident-to-bed ratio (IBR)), and
disproportionate share hospital (DSH) patients (transformed as high, medium, low, and none), which represents the percentage of low-income patients the hospital sees not supported by Medicare, Medicaid, the Children’s Health Insurance Program (CHIP), or other payer\textsuperscript{53}. Classifications of facility type (acute care and critical access), region (Central New York, Western New York, Northeastern New York, Rochester Area, Long Island, Northern Metropolitan Area, and New York City, as determined by zip codes), and upstate/downstate designation were also provided by HANYS and are designations set by the organization for the purposes of their regular business operations.

**Analytic Methods**

**Comparative analysis**

Extracting monthly data for all New York State hospitals for 2011-2016 resulted in a sample of 202 facilities. Of these, 12 facilities were omitted due to incomplete SPARCS data resulting from mergers or closures that occurred during the study period (N=190). The focus of the project was on acute care facilities and as such, specialty hospitals (2 cancer, 1 rehabilitation, 1 children’s, and 2 long-term care) were removed to prevent confounding, resulting in a total sample size of N=184, with 44 participating in the collaborative and 140 not participating. We first examined characteristics of interest—non-clinical characteristics: urban/rural designation, region, upstate/downstate designation, DSH patient percentage, facility type, and teaching status; payer profiles: percent Medicare; and clinical characteristics: total discharges, hospital-acquired CDI rate (CDI counts/1000 patient discharges), ALOS, and APR-DRG CMI—for the 184 hospitals in the cohort, comparing the 44 hospitals participating in the collaborative to the 140 non-
participating using the $\chi^2$ test for categorical variables and the student’s t-test for numeric variables, as outlined in Table 1 of the Appendix. These factors were examined to determine whether certain types of hospitals were more inclined to participate in the collaborative based on their clinical and non-clinical characteristics.

**Difference-in-differences analysis**

To assess changes in outcomes, we conducted a linear regression analysis with a difference-in-differences (DD) approach to compare changes over time in hospital-acquired CDI rates (dependent variable), for hospitals participating in the collaborative to those not participating. The DD estimator represents the difference between the hospital-acquired CDI (HA-CDI) rate, the dependent variable, for hospitals participating in the collaborative in the five-year period before its implementation (2011-2015), and after the first year of the collaborative (2016), compared with these same differences in the control group (non-participating hospitals). This difference represents the amount of change attributable to participation in the collaborative beyond what would have otherwise occurred in the environment following temporal trends. In addition to the difference-in-differences estimator, we included as control variables non-clinical characteristics, as well as percent Medicare discharges—a proxy for advanced age$^{39,48,49}$, average length of stay (ALOS)$^{39}$, and APR-DRG case mix index (CMI)$^{39}$, known predictors of hospital-acquired C. difficile infections, and ran models with (Model 1) and without (Model 2) regional granularity. Regression models have been provided below. Robust standard errors were used to control for heteroskedasticity in the models. Before completing the difference-in-differences analysis, we conducted a test of trend to ensure the two groups (participating and non-
participating hospitals) were not already trending in significantly different directions before implementation of the collaborative.

**Model 1:** HA-CDI rate\(_i\) = \(\alpha_0 + \beta_1\text{Participation in the Collaborative}_i + \beta_2\text{1st Year of the Collaborative}_i + \beta_3\text{Participation*1st Year of Collaborative}_i + \gamma_1[\text{clinical characteristics}]_i + \gamma_2[\text{non-clinical characteristics with region granularity}]_i + \varepsilon_i\)

**Model 2:** HA-CDI rate\(_i\) = \(\alpha_0 + \beta_1\text{Participation in the Collaborative}_i + \beta_2\text{1st Year of the Collaborative}_i + \beta_3\text{Participation*1st Year of Collaborative}_i + \gamma_1[\text{clinical characteristics}]_i + \gamma_2[\text{non-clinical characteristics without region granularity}]_i + \varepsilon_i\)

*Key informant interviews*

The primary focus of our study was the quantitative analysis. However, to provide greater context for the program being assessed, we conducted 9 semi-structured telephone interviews with antibiotic stewardship personnel at facilities participating (N=7) and not participating (N=2) in the collaborative. Hospitals participating in the collaborative were further categorized as highly consistent in their participation in collaborative activities (N=4) and less consistent in their participation in collaborative activities (N=3), to ensure a variety of perspectives were captured. This categorization was made according to a consistency index, which was simply the total number of collaborative activities within the study period the facility took advantage divided by the total number of opportunities available (12 possible months of antibiotic usage data submissions and 10 educational webinars), with data provided by HANYS and collected for the purposes of managing the collaborative. These interviews elicited reasons for joining or
declining to join the collaborative, successes and lessons learned from participating in the collaborative, and suggestions for how to improve the collaborative.

Interview participants (10 participating and 10 non-participating) were selected randomly within each strata of size, region, and teaching status, and in the case of hospitals participating in the collaborative – the consistency index, from a deidentified list of facilities to achieve a representative sample. HANYS’ staff from the Quality, Advocacy, Research and Innovation division, responsible for oversight of the Antibiotic Stewardship Collaborative, were consulted to identify the specific person at each facility to contact via email for the purposes of coordinating an interview. Nine facilities agreed to an interview, 7 participating facilities and 2 non-participating facilities. Responses from facilities within each group were similar and no additional interviews were sought.

One-on-one telephone interviews followed an interview guide with approximately 5 to 7 open-ended questions intended to gain a deeper understanding of each facility’s experience with the collaborative (see Item 1 of the Appendix for the Interview Guide). The questions were developed to address the areas where clarification was desired (such as perceived challenges and successes) and reviewed by the HANYS research team to ensure interpretability. These were highly interactive and dynamic interviews, with a flexible agenda driven by participant responses. Notes were transcribed by hand, omitting identifying information. Key informants were assured that the names of their organizations would remain anonymous to reduce social desirability bias and protect their confidentiality. Recurring themes, defined as similar responses provided by 2 or more interviewees, were identified for each question category. Study
recruitment stopped after 9 interviews because all respondents described similar factors. All coauthors reviewed the synthesis of findings to provide feedback on interpretation. To ensure the thematic analysis captures the key informants’ statements as intended, the draft manuscript will be provided to interviewees for respondent validation.55

RESULTS

Comparative analysis
As shown in Table 1, hospitals participating in the collaborative represented approximately 24% of the total sample of hospitals. Total average annual discharges (2011-2016) were significantly higher in the cohort of hospitals participating in the collaborative ($P<0.001$, 2-tailed test) compared to those not participating in the collaborative, with approximately 6,400 additional discharges per year in participating hospitals. Over three-quarters of hospitals participating in the collaborative were from urban areas, and more specifically, approximately 28% were located in New York City, which was a significantly higher representation compared to the population of hospitals not participating in the collaborative ($P=0.03$, 2-tailed test). Other notable differences between the participating and non-participating cohorts included a greater percentage of major teaching hospitals and a greater percentage of hospitals with a higher percent of disproportionate share hospital (DSH) patients participating in the collaborative, though these were not found to be statistically significant differences.
Additionally, hospitals in the collaborative had slightly higher average hospital-acquired CDI rates than hospitals not participating in the collaborative, and the total population of hospitals, from 2011-2016 (Table 1). When we conduct a more detailed analysis comparing hospital-acquired CDI rates for the cohort of hospitals that joined the collaborative to the cohort that did not, before the collaborative (pre) was implemented and after the first year of the collaborative (post), we begin to understand this difference. In the 5-year period leading up to the collaborative, as shown in Figure 1 of the Appendix, there were notable differences in rates of hospital-acquired CDI for the collaborative and non-collaborative cohorts of hospitals from 2011 to Q2 2012 and again beginning in 2014 until Q3 of 2015, with rates for the collaborative cohort appearing slightly lower overall, despite both groups experiencing a similar downward trend in rates overall. However, during the first year of the Antibiotic Stewardship Collaborative, we see participating hospitals began at a lower rate of hospital-acquired CDI, as compared to their non-participating peers, with these rates decreasing only slightly over the duration of the collaborative’s first year. Over the same period, the hospitals not participating in the collaborative saw a greater reduction in rates of hospital-acquired CDI. Based on this preliminary analysis, it would appear the Antibiotic Stewardship Collaborative did not result in a greater reduction of hospital-acquired CDI in its first year compared to trends already occurring in the environment.

**Conclusion 1:** Larger hospitals were more likely to join the collaborative; hospitals with higher rates of HA-CDI were not more likely to join the collaborative.

*Difference-in-differences analysis*
The above preliminary analysis only assesses the impact of the collaborative at a superficial level, without controlling for known contributors to hospital-acquired C. difficile infection (CDI). As indicated in Table 2 of the appendix, the test of trend revealed the cohort of hospitals participating in the collaborative were not trending in any significant way (Model 1: $P = 0.46$, Model 2: $P = 0.46$), compared to the population of hospitals who elected not to join, which allowed us to proceed with the difference-in-differences analysis. Table 3 of the Appendix reports the results of the two linear regression models—with (column 1) and without (column 2) region classifications included. The coefficient of interest is the interaction term (Participation in the Antibiotic Stewardship Collaborative $\times$ Implementation of Collaborative), which is the difference-in-differences (DD) estimator. These models also include the control variables. As indicated by the DD estimator in both models, hospitals participating in the collaborative experienced a greater decrease in their rates of hospital-acquired CDI during the first year of the collaborative than the cohort of hospitals not participating in the collaborative (Model 1: $\beta = -0.153$, Model 2: $\beta = -0.152$). This was not found to be a statistically significant change (Model 1: $P = 0.191$, Model 2: $P = 0.194$).

**Conclusion 2**: Hospitals participating in the collaborative did not experience a greater reduction in HA-CDI rates during the first year of the collaborative compared to hospitals who did not participate.

However, it may be clinically significant. The margins of the two models have been graphed in Figure 2 of the Appendix. These graphs illustrate the predicted change in rates of hospital-acquired CDI, before and after year one of the collaborative, if the entire sample had been in the
collaborative (red), or if the entire sample had not been in the collaborative (blue). The models predict that if all hospitals had participated in the collaborative, rates of hospital-acquired CDI (HA-CDI) would have decreased from approximately 2.38 to 1.96, in model 1, or 2.35 to 1.94, in model 2, an average decrease of 0.42 cases of HA-CDI/1000 patient discharges, during the first year of the collaborative; the predicted decrease had there not been any participation in the collaborative is far less substantial. If all hospitals had participated in the collaborative, rates of HA-CDI would have decreased from approximately 2.33 to 2.06, in model 1, or 2.34 to 2.08, in model 2, an average decrease of 0.26 cases of HA-CDI/1000 patient discharges.

Reviewing the control variables across models, the known predictors of CDI—APR-DRG CMI; ALOS; percent Medicare population, as a proxy for the age of the patient population, and total discharges—are expectedly positively associated with rates of CDI and significant in both models (Table 3). Additionally, we see teaching status as an indicator variable for teaching or non-teaching is also positively associated with CDI rates and significant, as shown in model 2, but not when it’s further broken down into major and minor teaching categories. Being a rural hospital, compared to urban facilities, is associated with significantly lower rates of CDI, in both models. Interestingly, having disproportionate share hospital (DSH) patients, low-income and uninsured, whether a high, medium, or low percentage, is associated with higher rates of hospital-acquired CDI, compared to hospitals who do not see DSH patients, in model 1; however, in model 2, having a high percentage of DSH patients is associated with lower rates of HA-CDI. Also, time period is negatively associated with CDI and significant in both models, indicating CDI rates have been decreasing over time, which is consistent with the preliminary analysis. Region, whether it is rolled up to simply downstate hospitals compared to upstate
hospitals or broken out into specific areas of New York State, is positively associated with CDI rates and significant. This means, downstate hospitals have a greater incidence of CDI, compared to upstate hospitals, with the Long Island region contributing the most to this. When all the regions are compared to the Northeastern New York State area, a primarily rural subset of New York State, we see Long Island contributes the most to CDI rates of all the regions examined.

*Key informant interviews*

Key informants praised several aspects of the Healthcare Association of New York State’s (HANYS) Antibiotic Stewardship collaborative and described some challenges and ideas for improving the program in the future. These reports differed based on the consistency the facility has demonstrated in completing collaborative activities (submitting monthly data and attending educational webinars), as summarized in Table 4 of the Appendix. Additionally, those not participating in the collaborative provided insight into why they opted not to join.

The most celebrated aspect of the collaborative from almost all informants participating in the program were the comparative reports on antibiotic usage—HANYS compiles all monthly data submissions from hospitals and issues a report to each facility illustrating how their usage of specific antibiotics compares to peer hospitals. Respondents heralded the awareness these reports have brought to their existing antibiotic stewardship efforts with one interviewee stating, “it definitely makes us more conscious of where we are in terms of using specific antibiotics—if we’re under- or over-utilizing.” However, one facility with lesser consistency in the program believes the reports do not compare like facilities in some areas; “antibiotic usage will differ
based on population needs and at times the reports are comparing ‘apples to oranges’ for some antibiotics.”

Putting the necessary information technology (IT) and pharmacy infrastructure into place to provide HANYS monthly antibiotic usage data to generate these comparative reports was the most commonly cited challenge from participating hospitals, though many down-played this as a necessary first hurdle that was well-worth the investment. “We had to have our IT department write, develop, and integrate into our EMR a new report in order to submit our data to HANYS, and that was a lot to tackle at first, but now things are easy; the data is generated automatically.”

This impediment to data reporting was the main reason hospitals opted not to join the collaborative, according to respondents. With competing priorities and initiatives, these facilities could not get the necessary buy-in from leadership to move forward with the infrastructure improvements necessary to provide HANYS with monthly antibiotic usage data. One facility stated, “a more formal and concerted push from HANYS regarding the importance of joining the collaborative would have helped get the buy-in we needed—if it was somehow a mandate, or more like a mandate, it would have potentially provided the leverage needed to get the necessary resources allocated.”

The educational webinars were also believed, by those facilities with consistent participation in collaborative activities, to have been very helpful for getting hospital antibiotic stewardship efforts off the ground and a great place to hear what other hospitals have done, share experiences, and ask questions of the larger collaborative community, which included many
subject matter experts. However, many respondents reported the value of these events waned over time, with the primary criticism that the programming did not advance as hospitals’ antibiotic stewardship programs progressed from the implementation phase to fully operational; it was suggested HANYS offer more forward-thinking content from new speakers. Additionally, some facilities mentioned it was challenging to attend the educational events with competing priorities and initiatives.

DISCUSSION

Summary

We analyzed participation in the Healthcare Association of New York State’s (HANYS) Antibiotic Stewardship Collaborative to determine what type of facility joins a voluntary program aimed at monitoring and improving antibiotic usage and educating hospitals on antibiotic stewardship programs and infection prevention for C. difficile and other multi-drug resistant organisms. The notable differences between the two cohorts of hospitals, those participating and those not participating in the collaborative, were a significantly higher number of total discharges and facilities from the New York City Region, an area characterized by high saturation of acute care providers, as well as a greater percentage of major teaching hospitals and facilities with a high percentage of DSH patients, though the latter of these were not found to be statistically significant. Interviews with facilities participating in the collaborative revealed the greatest hurdle associated with joining the collaborative to be the initial investment required to implement the necessary IT solutions to track and report antibiotic usage. However, the
resulting comparative reports issued by HANYS illustrating how each facility’s prescribing practices compares to their peers were believed by most to be well-worth the effort. Hospitals that elected not to join the collaborative cited concern for their ability to get the necessary reporting capabilities in place as their main justification for opting out of the program.

The impact of participation in the first year of the collaborative on HA-CDI rates was examined and those facilities participating in the collaborative experienced a larger decrease in HA-CDI rates than those not participating, though this was not found to be statistically significant. However, plotting the predicted margins of the two groups indicated a much larger reduction in HA-CDI rates would have likely occurred if all facilities had participated in the collaborative than if there had been no participation in the program. We believe a significant change in this measure as a result of collaborative efforts requires a longer study period to manifest, considering hospitals first needed to develop antibiotic usage reporting capabilities, begin tracking and analyzing prescribing practices, and then make any necessary changes accordingly. HANYS has plans to repeat this analysis again in the future, once a longer time period can be evaluated.

The collaborative approach to addressing healthcare quality issues—bring many organizations together to work toward a common goal—has been used extensively at the national and state-level to reduce hospital-acquired infections, with significant clinical impact. These have most commonly been aimed at improving hand hygiene, and reducing specific infections such as catheter-associated urinary tract infections, central line-associated blood stream infections, and ventilator-associated pneumonia. In response to the growing health crisis posed
by antibiotic resistance and resistant bacteria, collaboratives have also emerged to address CDI, specifically.\textsuperscript{62,63} A collaborative implemented in the New York metropolitan area and administered in partnership between the regional healthcare association, Greater New York Hospital Association (GNYHA), a private non-profit health services research organization, United Hospital Fund, and the New York State Department of Health, resulted in a significant reduction in hospital-onset CDI rates.\textsuperscript{62} Additionally, a hospital participating in the Florida Department of Health Clostridium difficile Prevention Collaborative experienced a 52\% reduction in CDI rates. Our findings are consistent with the literature which supports the collaborative model as an effective approach for improving clinical measures such as hospital-acquired infection rates.

For approaching antibiotic stewardship, emphasis has been placed on the implementation and evaluation of antibiotic stewardship programs within hospitals, following the CDC’s Core Elements of Hospital Antibiotic Stewardship Programs\textsuperscript{64}, and the role of state healthcare associations in facilitating these programs has been growing. The State of Minnesota has launched an antibiotic stewardship collaborative, a partnership between the Minnesota Department of Health, Minnesota Department of Agriculture, Minnesota Pollution Control Agency, and Minnesota Board of Animal Health, to 1) improve use of antibiotics in human and animal health, and 2) to prevent development of resistance.\textsuperscript{65} Additionally, the Alaska Antimicrobial Stewardship Collaborative has emerged as a partnership of acute care and long-term care hospitals in this State, dedicated to ensuring appropriate antibiotic use. It appears this collaborative is aimed at promoting implementation of the CDC’s Core Elements of Antibiotic Stewardship.\textsuperscript{66}
Similarly, the New Jersey Hospital Association Institute for Quality and Patient Safety has instituted the New Jersey Antimicrobial Stewardship Learning Action Collaborative, which is working with New Jersey hospitals to promote the use of the appropriate agent, dose, duration and route of administration of antimicrobial agents, in acute and post-acute care settings, to reduce inappropriate antimicrobial use. They are also achieving this aim through the promotion of the CDC’s Core Elements. A recent review of the evidence base for hospital antibiotic stewardship programs revealed these programs to be effective at improving a variety of clinical measures related to Antibiotic Stewardship. However, many of the reviewed studies suffered from poor study design.

Limitations

Our analysis has limitations. Much of the Antibiotic Stewardship Collaborative efforts were focused on assisting hospitals with developing the ability to report and analyze their antibiotic prescribing practices, with education on infection prevention a secondary goal. However, we were not able to evaluate changes in antibiotic usage patterns as the outcome for this study, as the prescribing data does not exist for hospitals outside the collaborative. Additionally, the data is more nuanced than simply looking for an overall decrease in antibiotic prescribing; the goal is also to improve the appropriateness of prescribing, which means a specific antibiotic may be prescribed less while another one is prescribed more, and this could indicate improvement. As an alternative, this analysis evaluates the impact of the collaborative on the secondary goal, a reduction in HA-CDI rates.
Also, the educational programming provided by the collaborative was not exclusively attended by hospitals considered participating in the collaborative, as defined as having a signed memorandum of understanding (MOU) signifying enrollment. While marketed as educational opportunities provided by the HANYS Antibiotic Stewardship Collaborative, no hospital was excluded from attending any of the educational events. It is possible hospitals attending these events who opted not to participate in the collaborative, by not signing a memorandum of understanding, implemented the lessons provided in the programming at their facilities. This could have led to a decrease in their facility’s rate of HA-CDI, which would lessen any discernable impact of the collaborative when comparing the participating and non-participating groups.

Additionally, a federally contracted program between HANYS and the Centers for Medicare and Medicaid Services (CMS), New York State Partnership for Patients, which aims to decrease a number of hospital-acquired conditions including CDI, was happening somewhat concurrently to the first year of the Antibiotic Stewardship Collaborative. CMS added CDI as a project area with the renewal of the contract in 2015 and NYSPFP chose to approach improvements in CDI through the umbrella of Antibiotic Stewardship. However, many months of planning occurred before the intervention was initiated and it was rolled out in several stages. Full implementation did not occur until the end of 2016.

With a small sample size, N = 184 (44 participating in the collaborative, 140 not participating), power was low for conducting hypothesis tests comparing characteristics of the two cohorts. Other notable differences between the two groups, while not significant, may be important.
Furthermore, using SPARCS billing data may not capture all instances of CDI. When data gets submitted to SPARCS from hospitals, if anything is incorrect on the claim, it goes through various stages of edits and is returned to the facility. Hospitals then have the option of correcting the claim or not, and can retroactively edit claims from as far back as the 1990s, and only those claims that are approved by SPARCS make it into the master file. Understanding this, it is possible the extracted data is incomplete in terms of total instances of CDI. Additionally, the data was extracted using specific ICD-9 and 10 codes, and it is possible some instances of CDI were not captured, or were coded incorrectly. However, a recent study concluded, “C. diff ICD-9 codes closely approximate true C. diff infection…and can therefore be used as a reasonable alternative to microbiological data for tracking purposes,” and the ICD-9 code is a direct crosswalk to the ICD-10.

Conclusion

We find evidence to suggest larger hospitals in areas with high competition for acute care services, like New York City, are more likely to engage in a voluntary Antibiotic Stewardship Collaborative aimed at addressing inappropriate prescribing of antibiotics and prevention of hospital-acquired CDI. Additionally, participation in such a collaborative may result in a downward trend in HA-CDI rates for participating hospitals, however we cannot make this claim definitively at this time; an evaluation timeframe greater than 12-months for future studies is recommended. The HANYS Antibiotic Stewardship Collaborative is innovative in its emphasis on preparing hospitals to report antibiotic usage and the leaders of this initiative believe before appropriate prescribing can be achieved, hospitals need to put the infrastructure in place to
enable consistent surveillance of antibiotic prescribing. It is expected, this will in turn lead to improved appropriateness of prescribing and a sustainable reduction in infections from antibiotic resistant organisms in the long-term, while simultaneously preparing hospitals for state or federal mandates requiring regular reporting of this data.[11] Our early results indicate this approach may prove effective, and add to the limited literature evaluating the impact of collaboratives aimed at addressing antibiotic stewardship; however, additional research is needed.
CHAPTER 3: EMERGENCY DEPARTMENT WAIT TIMES AND PATIENT-REPORTED ROOM CLEANLINESS IN NYS HOSPITALS ON PREVALENCE OF HOSPITAL-ACQUIRED CLOSTRIDIUM DIFFICILE INFECTION
INTRODUCTION

C. difficile is a drug-resistant organism and the most common hospital-acquired infection, with almost a half million cases and approximately 29,000 deaths in 2011.\(^4\) The excess healthcare costs related to C. difficile infection (CDI) are estimated to be as much as $4.8 billion for acute care facilities alone.\(^2\) One of the main pathways for the spread of CDI is vulnerable patients coming into contact with contaminated surfaces in acute care settings, or inadequate handwashing of healthcare workers that have come into contact with infected patients or contaminated surfaces.\(^69\)

C. difficile is shed in the fecal matter of infected individuals and capable of sporulating when environmental conditions no longer support its continued growth. This capacity to form spores enables the organism to persist in the environment (e.g., on dry surfaces) for extended periods of time, even months.\(^70\) These endospores are resistant to many sterilization and disinfection measures including heat and 70% ethanol (the main component in hand sanitizers).\(^34\) As a result, this bacterium can be found on bedpans, bedpan hoppers, floors of utility rooms, toilet seats, floors at the bedsides of patients infected with C. difficile, and the hands of hospital personnel.\(^69\) Studies have shown that room assignment is important in transmission, with patients placed in a room where a previous occupant was infected with CDI having a significantly increased risk of contracting the illness.\(^71\) Unfortunately, consistent testing of C. difficile spore contamination in patient rooms would be resource intensive and impractical for already time-constrained patient-care and environmental services staff. However, recent studies, demonstrating a strong correlation between patient-reported room cleanliness scores, collected in the in-patient setting,
and a facility’s rate of hospital-acquired infections, indicate regular microbial testing may not be necessary.\textsuperscript{72}

Contamination of surfaces with \textit{C. difficile} is not just limited to in-patient units. A recent study conducting a point–prevalence culture survey to assess the frequency of \textit{C. difficile} contamination in outpatient settings found, of 84 clinic and emergency department rooms cultured, 12 (14\%) had 1 or more contaminated environmental sites. Specifically, toxigenic \textit{C. difficile} was detected in 2 of 3 emergency departments tested.\textsuperscript{73} Infection prevention remains a major challenge in the fast-paced, high-volume setting of emergency care. Patients seeking evaluation and treatment in the emergency department (ED) not only have the potential to spread communicable infectious diseases to healthcare personnel and other patients, but are vulnerable to acquiring new infections associated with the care they receive.\textsuperscript{74} In terms of CDI, emergency departments are a primary access point for patients who are unable to wait for primary care, and as a result, many patients with diarrhea are seen in emergency departments. This contributes to higher levels of \textit{C. difficile} contamination in the emergency department, compared to other areas of the hospital.\textsuperscript{70} Additionally, a recent study found greater room square footage increased the risk of acquiring CDI in the hospital setting, likely due to increased environmental contamination and difficulties in effective disinfection.\textsuperscript{75} This could also be a contributing factor to higher levels of \textit{C. difficile} bacterium in emergency departments. Complicating matters, hand hygiene compliance is often lowest in emergency departments, than other areas of the hospital.\textsuperscript{34}

Understanding the tendency for \textit{C. difficile} bacterium to persist in the environment, especially in the emergency room, and poor hand hygiene compliance of emergency department personnel,
this study examines if there is a relationship between how long patients wait in the emergency
department (ED) before being admitted to a floor, and overall hospital-acquired C. difficile
infection (HA-CDI) rates. Additionally, it explores the possible relationship between patient-
reported room cleanliness and hospital-acquired CDI, to determine if how consistently hospital
rooms are cleaned, according to patients, is a reflection of their microbial cleanliness, after
controlling for known predictors of CDI. If a relationship exists between these measures and
hospital-acquired CDI rates, it could point to new possible opportunities for prevention through
targeted disinfection efforts in emergency departments and patient engagement in care on in-
patient units. It was expected facilities with longer emergency department wait times and higher
percentages of patients reporting their room was “never” kept clean would be associated with
higher HA-CDI rates, and higher percentages of patients reporting their room was “always” kept
clean would be associated with lower HA-CDI rates

**Hypothesis 1**: Hospitals with longer ED wait times have higher rates of HA-CDI than
hospitals with shorter average ED wait times.

**Hypothesis 2**: Hospitals with a higher percentage of patients indicating their room was
“always” kept clean have lower rates of HA-CDI than hospitals with a lower percentage.

**Hypothesis 3**: Hospitals with a higher percentage of patients indicating their room was
“sometimes” or “never” kept clean have higher rates of HA-CDI than hospitals with a
lower percentage.
METHODS

Dependent Variables

Rates of hospital-acquired C. difficile infection

Total monthly (January 2013-December 2016) hospital-acquired C. difficile infection (HA-CDI) counts at the facility-level were extracted from the Statewide Planning and Research Cooperative System (SPARCS), New York State’s comprehensive all payer data reporting system, to which the Healthcare Association of New York State has access for the purposes of regular business operations and research projects. These were extracted in two ways to address each of the research questions—total monthly facility-level HA-CDI counts for examining patient-reported room cleanliness in the inpatient setting, and monthly HA-CDI counts restricted to those patients entering through the emergency department, for examining emergency department wait times. Total monthly discharges were also extracted to calculate two monthly facility CDI rates (number of CDI/1000 patient discharges) for total HA-CDI and HA-CDI restricted to patients entering through the ED, the dependent variables. The codes ICD-9-CM 008.45—Intestinal infection due to Clostridium difficile, prior to October, 2015, and ICD-10-CM A04.7—Enterocolitis due to Clostridium difficile, after October 2015, were used to identify appropriate claims.47 The “present-on-admission” indicator was set to “no” to limit the extraction to only hospital-acquired CDI.

Independent Variables
Emergency department wait times

Hospital Compare is the Centers for Medicare & Medicaid Services’ (CMS) Hospital Quality Initiative public domain database of hospital quality measures, which includes overall ratings, timely and effective care measures, measure of complications and deaths, use of medical imaging, survey of patients’ experiences (HCAHPS), and payment and value of care measure. This database was used to extract emergency department wait times and patient-reported room cleanliness scores for the study period. Annual average time in minutes from emergency department arrival to emergency department departure for admitted patients (indicated as ED1 in CMS documents) was extracted for the following time periods—2013: Q2-2013 - Q1-2014, 2014: Q2-2014 - Q1-2015, 2015: Q2-2015 - Q1-2016. These are averages calculated from a random sample of patient charts. This data is originally submitted by hospitals to the Quality Improvement Organization (QIO) Clinical Data Warehouse through the CMS Abstraction and Reporting Tool (CART), then made available on hospital compare.

Patient-reported room cleanliness

Additionally, annual percent of patients who reported their room and bathroom were "Always," "Usually," and "Sometimes/Never" clean (indicated as H-CLEAN-HSP-A-P, H-CLEAN-HSP-U-P, H-CLEAN-HSP-SN-P in CMS documents), was extracted for the following time periods: 1/2013 - 12/2013, Q2-2014 - Q1-2015, Q2-2015 - Q1-2016. This data was originally captured through administered Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) surveys conducted by hospitals, then made available on Hospital Compare.
HCAHPS is administered to a random sample of adult inpatients between 48 hours and six weeks after discharge, typically through mail.\textsuperscript{76}

Control Variables

Clinical predictors of \textit{C. difficile} infection

Payer profile and other clinical characteristics were also extracted from SPARCS to serve as control variables in the analysis. This included total discharges and total Medicare discharges, which was converted to a percent of total discharges, serving as a proxy for advanced patient age\textsuperscript{39,48,49}. Additionally, average length of stay (ALOS), a mean calculated by dividing the sum of inpatient days by the number of patient admissions with the same diagnosis-related group classification\textsuperscript{39}, and the all patient refined-diagnosis related group case mix index (APR-DRG CMI), were also included. CMI reflects the diversity, clinical complexity, and resource needs of the hospital’s patient population, and the APR-DRG CMI specifically takes into account patient age and severity of illness.\textsuperscript{50}

Non-clinical hospital characteristics

Hospital non-clinical characteristic data was extracted from the Centers for Medicare and Medicaid (CMS) Healthcare Cost Report Information System (HCRIS) by the Economics, Finance, and Information (EFI) division of the Healthcare Association of New York (HANYS). This data included urban/rural designation\textsuperscript{51,52}, teaching status (major teaching, minor teaching, and non-teaching, as calculated from the intern- and resident-to-bed ratio (IBR))\textsuperscript{52}, and disproportionate share hospital (DSH) patients (transformed as high, medium, low, and none)\textsuperscript{53}. 

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Classifications of facility type (acute care, critical access, cancer, long-term care, and children’s hospital), region (Central New York, Western New York, Northeastern New York, Rochester Area, Long Island, Northern Metropolitan Area, and New York City, as determined by zip codes), and upstate/downstate designation were also provided by HANYS and are designations set by the organization for the purposes of their regular business operations.

**Sample**

*Data extraction*

Extracting monthly data for all New York State hospitals for 2013-2016 resulted in a sample of 202 facilities. Of these, 12 facilities were omitted due to incomplete SPARCS data resulting from mergers or closures that occurred during the study period (N=190). The focus of the project was on acute care facilities and as such, specialty hospitals (2 cancer, 1 rehabilitation, 1 children’s, and 2 long-term care) were removed to prevent confounding (N =184). Data from SPARCS is organized at the facility level, with each hospital assigned a New York State Permanent Facility Identifier (PFI), while data from the CMS Hospital Compare site is organized according to Medicare and Medicaid billing arrangements, which are catalogued by CMS Certification Number (CCN); some facilities in the same hospital system report data to CMS under the same CCN number. The data extracted from SPARCS was “rolled up” from the PFI level to the CCN level, using a crosswalk provided by the Economics, Finance, and Information (EFI) division of HANYS, to reflect the CMS groupings; for facilities sharing a CCN, data was combined to align with the extracted Hospital Compare and Healthcare Cost Report Information System (HCRIS) data. Rolling up to the CCN level reduced the total number of facilities from 184 to 151, as
outlined in Table 5 of the Appendix. Three annual time periods with 151 hospitals each resulted in 453 total observations.

Analytic Methods

Fixed-effects regression

We conducted a time-series analysis, common for assessing changes in hospital-acquired infections\textsuperscript{77-79}, using a fixed-effects approach, with separate regression models examining:

1. Emergency department wait times and hospital-acquired C. difficile infection (HA-CDI) rates, limited to patients entering through the emergency department.
2. The percentage of patients indicating their room was “always” kept clean and facility HA-CDI rates.
3. The percentage of patients indicating their room was “sometimes/never” kept clean and facility HA-CDI rates.

Using a fixed-effects model allows us to control for both “unit-specific” and “time-specific” effects that are unobserved but may be impacting the outcome. In other words, this model accounts for individual heterogeneity, controlling for the unique, time-invariant characteristics at the hospital-level that we cannot observe or measure, like cultural factors or differences in operational procedures, and variables that change over time but not across hospitals, like state and federal policies or initiatives, that could be impacting HA-CDI rates.\textsuperscript{80}
Additionally, our model controls for percent of discharges where Medicare was the payer—a proxy for advanced age\textsuperscript{39,48,49}, average length of stay (ALOS)\textsuperscript{39}, and APR-DRG case mix index (CMI)\textsuperscript{39}, known predictors of HA-CDI. Because the non-clinical hospital characteristics are time-invariant, for the duration of our study period, they would have been dropped by the model and were therefore excluded; these variables have been used to describe the hospital sample. Regression equations for these three models have been provided below.

**Model 1:** HA-CDI rates\textsubscript{it} = α\textsubscript{1} + β\textsubscript{1}Emergency Department Wait Time\textsubscript{it} + γ\textsubscript{1}[Clinical Characteristics]\textsubscript{it} + ν\textsubscript{i} + ε\textsubscript{it}

**Model 2:** HA-CDI rates\textsubscript{it} = α\textsubscript{1} + β\textsubscript{1}Patient Room “Always” Kept Clean\textsubscript{it} + γ\textsubscript{1}[Clinical Characteristics]\textsubscript{it} + ν\textsubscript{i} + ε\textsubscript{it}

**Model 3:** HA-CDI rates\textsubscript{it} = α\textsubscript{1} + β\textsubscript{1}Patient Room “Sometimes” of “Never” Kept Clean\textsubscript{it} + γ\textsubscript{1}[Clinical Characteristics]\textsubscript{it} + ν\textsubscript{i} + ε\textsubscript{it}

Standardized coefficients were calculated for each variable to determine effect size and assist with interpretability. The formula for calculating standardized coefficients has been provided below.

\[
\text{Effect Size} = \frac{\text{Coefficient of } X \times \text{Standard Deviation of } X}{\text{Standard Deviation of } Y}
\]

**RESULTS**
Descriptive Analysis

Sample
As shown in Table 5, 78.2% of hospitals in the population were from urban areas of New York State, with the greatest representation from the New York City and Central New York regions, with average annual discharges of 15,132, 42.9% of which were supported by Medicare. The majority, 93.4%, of hospitals in the sample were acute care facilities, with the addition of 10 Critical Access Hospitals (CAH). Hospitals with a low percentage or no disproportionate share hospital (DSH) patients made up 55% of the sample, with a similar proportion of teaching hospitals, categorized as major and minor. Average length of stay at these facilities was 5.24 days, with an average APR-DRG case mix index of 1.33. Rates of hospital-acquired CDI were 2.27/1,000 patient discharges (range: 0-10.20), and 1.69/1,000 patient discharges (range: 0-5.99) when counts were limited to patients entering through the emergency department.

Scatter plots
Scatter plots (average values for the study period), as provided in Figure 3 of the Appendix, supported our hypotheses regarding emergency department wait times and patient-room cleanliness scores. Descriptively, there appears to be a negative relationship between the percentage of patients indicating their room was “always” kept clean and HA-CDI rates; in other words, the higher the number patients indicating their room was “always” kept clean, the lower that facility’s HA-CDI rates. Additionally, there appears to be a positive relationship between emergency department wait times and the percentage of patients indicating their room was
“sometimes” or “never” kept clean; the longer patients wait in the emergency department, the higher that facility’s rate of HA-CDI for patients entering through the emergency department, and the higher the number of patients indicating their room was “sometimes” or “never” kept clean, the higher the facility’s rate of HA-CDI.

**Fixed-effects Regression Analysis**

*Emergency department wait times*

However, this exploration does not control for known predictors of hospital-acquired C. difficile and the unobservable factors within the organizations and external environment that may also be contributing to infection rates, as well as changes over time. Table 6 of the Appendix depicts the results of the fixed effects multiple regression models for each of the four variables of interest, controlling for the known predictors of HA-CDI, with each column representing a different model—emergency department wait times (1), and percentage of patients indicating their room was “always” (2), and “sometimes/never” kept clean (3).

As indicated in column 1, we see emergency department wait times have a significant and positive relationship with HA-CDI rates, with an additional .003 cases of HA-CDI/1,000 patient discharges with every additional minute patients spend in the emergency department on average ($P < .001$).

**Conclusion 1**: Hospitals with longer ED wait times do have higher rates of HA-CDI than hospitals with shorter average ED wait times.
Additionally, percent of discharges where Medicare is the payer is also significant. Every percentage point increase in Medicare discharges at a facility is associated with an increase in HA-CDI rates of 2.17 cases per 1,000 patient discharges \((P < .001)\). Average length of stay is also significant, with an increase of 0.10 cases of HA-CDI/1,000 patient discharges with every additional day of in-patient stay.

The standardized coefficients (indicated as Stand. \(\beta\) in Table 6) allow us to interpret these variables according to their effect size in the model. We see that for every standard deviation unit increase in emergency department wait time, HA-CDI rates increase by .310 standard deviation units. This is the largest effect size in the model, indicating emergency department wait times explain more of the variance in HA-CDI rates for patients entering through the emergency department than some of the best-known predictors of HA-CDI. Percent of discharges that are Medicare is the closest second, with each standard deviation unit increase associated with a standard deviation unit increase in HA-CDI of .231. Average length of stay, APRDRG case mix index, and total discharges have the third (.123), fourth (.097), and fifth (.074) largest effect sizes, respectively.

**Patient-reported room cleanliness—“always” kept clean**

As indicated in column 2, the percentage of patients indicating their room was “always” kept clean has a significant and negative association with hospital-acquired C. difficile infection (HA-CDI) rates, with .032 fewer cases of HA-CDI/1,000 patient discharges for every percentage point increase in the number of patients rating their room as “always” clean \((P < .001)\).
Conclusion 2: Hospitals with a higher percentage of patients indicating their room was “always” kept clean do have lower rates of HA-CDI than hospitals with a lower percentage.

Additionally, in this model, percent of discharges where Medicare is the payer is also significant. Every percentage point increase in Medicare discharges at a facility is associated with an increase in HA-CDI rates of 2.82 cases per 1,000 patient discharges (P < .001). Average length of stay is also significant, with an increase of 0.37 cases of HA-CDI/1,000 patient discharges with every additional day of in-patient stay. Lastly, total discharges is also significant; each additional 1,000 discharges is associated with .032 additional cases of HA-CDI.

Again, the standardized coefficients allow us to interpret these variables according to their effect size in the model. We see that for every standard deviation unit increase in the percent of patients indicting their room was “always” kept clean, HA-CDI rates decrease by .146 standard deviation units. However, this is only the fourth largest effect size. Average length of stay, total discharges, and percent of discharges where Medicare is the payer have the first (.366), second (.350), and third (.245) largest effect sizes, which means these variables explain more of the variance in HA-CDI rates than the percentage of patients indicating their room was “always” kept clean.

Patient-reported room cleanliness—“sometimes” or “never” kept clean

In column 3, we see the percentage of patients indicating their room was “sometimes” or “never” kept clean is positively associated with hospital-acquired C. difficile infection (HA-CDI) rates (β = .029), though this was not found to be statistically significant (P = .13).
Conclusion 3: Hospitals with a higher percentage of patients indicating their room was “sometimes” or “never” kept clean do not have higher rates of HA-CDI than hospitals with a lower percentage.

Similar to the previous model, average length of stay (β = .378, P < .001), total discharges (β = .033, P < .001), and percent of discharges where Medicare is the payer (β = 2.80, P < .001) all have a significant and positive association with HA-CDI rates. Also like the prior model, we see these variables have the largest effect size, in the aforementioned order, as indicated by the standardized coefficients.

DISCUSSION

Summary
We evaluated the relationship between hospital-acquired C. difficile rates, and emergency department (ED) wait times and patient-reported room cleanliness scores, for New York State hospitals, using time series analysis with a fixed effects approach. Consistent with our preliminary hypotheses, we found a significant, positive relationship between emergency department wait times and rates of HA-CDI for the subset of patients entering through the emergency department. After standardizing coefficients, we found emergency department wait times explain more of the variance in HA-CDI rates for patients entering through the ED than some of the best-known predictors of HA-CDI, average length of stay, percentage of discharges
that are Medicare, and total discharges. Additionally, we found significant relationships between the percentages of patients indicating their room was “always” kept clean and HA-CDI rates, with the former negative and the latter positive. Though, these were not found to be as substantive in explaining the variance in HA-CDI as the known predictors. Lastly, the relationship between the percentage of patients indicating their room was “sometimes” or “never” clean was found to be negative but not significant.

Research examining the relationship between emergency department wait times and contraction of hospital-acquired infections is limited. Many studies support the emergency department, characterized by high patient turnover, fast paced medical care, poorer hand hygiene rates, and crowding, as a place with great potential for bacterial contamination. Recently, a retrospective cohort study of adult hospitalized patients, by Carvour et al. (2018), found patients in the emergency department have the highest odds of a positive CDI assay, especially compared to the intensive care unit, which had the lowest odds. This study has the advantage of examining patient-level data and the predictors of CDI, as opposed to aggregated facility-level counts.

However, it only includes one facility in the analysis. Our results suggest this relationship between time spent in the ED and HA-CDI may not be unique to the facility studied by Carvour et al. These studies begin to shed light on how time spent in the emergency department, as the gateway to inpatient care, contributes to the propensity of patients to eventually develop a C. difficile infection during their stay. The findings support efforts to reduce average ED wait times.
before patients are admitted to an in-patient room, or more rigorous environmental cleanliness strategies in emergency departments, as possible avenues for C. difficile prevention.

Research regarding the use of patient satisfaction surveys as tools for quality improvement has been on-going for more than two decades. A recent review of these studies indicates research in this area has primarily examined what factors determine a patient’s level of satisfaction with their medical care, and not whether or not patient satisfaction scores accurately predict hospital quality. Because research is lacking to determine if these scores predict hospital quality, like rates of hospital-acquired conditions, patient satisfaction measures have often been dismissed in the medical community as biased and thus poor reflections of actual care received, especially by physicians. However, studies are beginning to emerge offering evidence to support patient satisfaction scores as important predictors of quality of care.

A recent review of the literature examining the patient experience and healthcare quality found better patient care experiences are associated with better clinical outcomes and better patient safety within hospitals. More specifically, facilities with higher patient satisfaction have been found to have lower 30-day risk-standardized hospital readmission rates and 30-day mortality rates. Recently, Press Ganey, an organization that assists healthcare facilities improve safety, quality, and experience of care through performance analytics and strategic advisory solutions, examined the relationship between patients’ perceptions of environmental factors, using the HCAHPS measures, and specific safety, quality, and experience outcomes, including C. difficile infection rates. This study found a strong, negative correlation between HA-CDI and perceptions of cleanliness.
However, Press Ganey’s analysis did not control for known predictors of HA-CDI and confounding factors. This study expands upon the work of Press Ganey with a more sophisticated analysis of the relationship between patient-reported room cleanliness scores and rates of HA-CDI. Our findings support their assessment and suggest a greater role for patient and family engagement in the prevention of C. difficile infection; patients and families should be empowered to advocate for additional environmental services when the in-patient room does not appear to be clean, as the significance found implies observable cleanliness is indicative of microbial cleanliness.

Limitations

Our analysis has some limitations. This study compares emergency department (ED) wait times and HA-CDI counts for patients entering through the emergency department at the facility level; patient-level details were not available to assess emergency department wait times of patients who eventually develop HA-CDI. Additionally, some people who become infected with C. difficile through the ED may not be captured, depending on how long it takes for symptoms to develop and diagnosis; some patients could be discharged from the hospital before a C. difficile diagnosis is made. However, our findings suggest a relationship does exist between ED wait times and HA-CDI, which indicates further investigation is warranted.

Furthermore, response rates for HCAHPS surveys are very low due to how it is administered; the average response rate for administered surveys is 26.6%. Understanding that people are more likely to provide feedback on negative experiences, this should result in a conservative
estimate, which strengthens the likelihood of a relationship given the statistical significance we found at the “always” and “usually” levels of patient-reported room cleanliness. With access to only data from New York State hospitals, having to omit facilities that were missing data due to mergers and closures, and “rolling-up” our data from facility- to billing-level made for a small sample size (N = 453, 151 facilities over 3-years). Though, we believe our analysis still offers valuable insights, providing direction for future research.

Additionally, using SPARCS billing data may not capture all instances of CDI. When data gets submitted to SPARCS from hospitals it goes through various stages of edits, if anything is incorrect on the claim it is returned to the facility. Hospitals then have the option of correcting the claim or not, and can retroactively edit claims from as far back as the 1990s, and only those claims that are approved by SPARCS make it into the master file. Understanding this, it is possible the extracted data underestimates total instances of CDI. However, this would strengthen our findings. Additionally, the data was extracted using specific ICD-9 and 10 codes, and it is possible some instances of CDI were not captured, or were coded incorrectly. However, a recent study concluded, “C. diff ICD-9 codes closely approximate true C. diff infection…and can therefore be used as a reasonable alternative to microbiological data for tracking purposes”47, and the ICD-9 code is a direct crosswalk to the ICD-10.

Lastly, we were unable to control for antibiotic usage—multiple antibiotic therapies, duration of treatment, and usage of specific high-risk antibiotics—which has been found to be an important predictor of CDI rates in the in-patient setting in several studies.39,40,48,81 Aggregated facility-level counts of high-risk antibacterial agents for New York State hospitals were unavailable for
this study. It would also be problematic to include facility-level counts of specific antibiotics, as higher usage rates of high-risk antibacterial agents may not be indicative of inappropriate prescribing but reflective of the hospital’s patient population.

Conclusion

Longer emergency department wait times and lower patient-reported room cleanliness scores are associated with higher rates of hospital-acquired C. difficile infection. This suggests further investigation is needed to better understand these potentially promising opportunities for HA-CDI prevention, which include a reduction in the time patients wait in the emergency department before being admitted to an in-patient floor, or concerted efforts to improve environmental cleanliness in emergency departments, and patient and family engagement strategies that encourage advocating for additional environmental services when patient rooms appear unclean.
CHAPTER 4: ADOPTION OF ELECTRONIC HAND HYGIENE MONITORING
SYSTEMS AND THE ASSOCIATED IMPACT ON HOSPITAL-ACQUIRED
CLOSTRIDIUM DIFFICILE RATES IN NEW YORK STATE HOSPITALS
INTRODUCTION

With almost a half million cases and approximately 29,000 deaths in 2011, Clostridium difficile has become the most common hospital-acquired infection. The excess health care costs related to C. difficile infection (CDI) are estimated to be as much as $4.8 billion for acute care facilities alone. In response to growing rates of CDI and other hospital-acquired conditions, the Affordable Care Act (ACA) established the Hospital-Acquired Condition (HAC) Reduction Program, in an effort to reduce the incidence of preventable adverse events that occur during hospitalizations in the United States. Hospitals scoring in the lowest quartile of this program have their Centers for Medicare & Medicaid Services’ (CMS’) payments reduced, which in 2014 totaled approximately $373 million nationally.

Proper hand hygiene is the single most important, simplest, and least expensive means of reducing the prevalence of hospital-acquired infections and the spread of antimicrobial resistance. By extension, improving hand hygiene rates could contribute to lower costs of care and greater reimbursements for hospitals through reduced hospital-acquired infections. However, hand hygiene compliance rates are typically at or below 50% for most U.S. healthcare facilities, and much lower for busier units like the ICU or emergency department. This is further complicated by the Clostridium difficile bacterium, for which transfer to the patient via the hands of healthcare workers is thought to be the most likely mechanism of exposure, as the spores survive routine environmental cleaning with detergents and hand hygiene with alcohol-based gel hand sanitizers. Washing with soap and water is required to remove C. difficile spores from hands.
McGuckin et al. (2009) demonstrate hand hygiene performance can be improved through audit and feedback.\textsuperscript{89} Yet, interventions aimed at improving rates of hand hygiene compliance are often only minimally effective\textsuperscript{91}, as it is difficult to measure hand hygiene compliance facility-wide considering the World Health Organization’s (WHO) benchmark of five moments of hand hygiene—before patient contact, before aseptic task, after body fluid exposure risk, after patient contact, after contact with patient surroundings\textsuperscript{92}—and the limitations of traditional methods of monitoring. The method currently considered the gold standard by the Joint Commission for measuring handwashing compliance is using human observers: nurses or other health care workers who roam halls and patient rooms with a clipboard, recording who does and does not wash their hands. However, all observation schedules capture at best 3.5% and at worst 1.2% of all daily opportunities for handwashing.\textsuperscript{93}

In an attempt to address this, electronic hand hygiene monitoring systems (EHHMS) have emerged to not only record compliance but also promote it. A recent review of these technologies to uncover challenges in implementation revealed there are several different systems on the market or in development.\textsuperscript{94} All include one or more of the following components: “dispensers for soap (antiseptic or plain) or alcohol-based hand-rub, patient zone indicators in doorways or around beds, and healthcare worker tags (eg. badges, wrist bands, or pager cases) that communicate with the dispensers or the patient zone indicators or both” (Conway, 2016). These systems use a combination of technologies, including radiofrequency identification (RFID), ultrasound, infrared, Wi-Fi, remote video monitoring, or alcohol vapor-sensing technologies to collect and exchange information. Systems differ in their complexity,
ranging from the simplest, where dispensers record each time they are activated (called a hand hygiene event), to the most complex, which sense healthcare worker entry and exit into patient areas and if a hand hygiene event has occurred, as well as issue a prompt if needed, providing immediate feedback to the healthcare worker visible to coworkers and patients.94

Recent studies indicate these systems can increase hand hygiene compliance rates to 75%95, though additional studies show compliance rates exceeding 8596,97, and even 95%98 in a short time after implementation. However, little has been published regarding the cost-effectiveness of these systems, in terms of hospital-acquired infection prevention and the resulting cost savings. One study showed a 40% decrease in infections in the first quarter after installation of the electronic hand hygiene monitoring system, and significant cost savings well-over the cost of the initial investment (estimated cost per infection = $126,034 x 4 infections prevented = $504,136 - the cost of the system $72,800 = $431,336).98 Though, this study did not indicate if these were savings that were directly realized by the hospital, in terms of amounts that would otherwise have been expended and not reimbursed, or savings to the healthcare system generally.

Despite these promising findings, implementation of EHHMS can prove challenging, disrupting a healthcare facility’s infrastructure and healthcare staff workflow, and it can be difficult to gain employee buy-in and trust. Additionally, there can be inconsistencies and inaccuracies inherent in these systems.94 The initial investment required to implement these systems can seem too costly for some hospitals, and implementation too complex, with evidence on efficacy so far limited.99 However, hospitals could have strong financial incentives to implement new
technology if a system proves effective, considering recent changes to Medicare and Medicaid reimbursements for hospital-acquired infections.31

The aim of the present study was to assess the proliferation of and experiences with electronic hand hygiene monitoring systems (EHHMS) in New York State hospitals, and the reasons some facilities have elected not to pursue this technology, through the administration of a state-wide survey of Healthcare Association of New York State (HANYS) members. We also conducted a trend analysis on the New York State facilities that have implemented an EHHMS to determine the impact this technology has had on their rates of hospital-acquired CDI, supplemented by perspectives shared during telephone interviews with facilities with and without an EHHMS. We hypothesized for those facilities that have not implemented an EHHMS, the primary reason for not doing so would be the initial investment of capital required to procure and implement the system. Additionally, we hypothesized facilities with an EHHMS would have lower hospital-acquired CDI rates than hospitals without these systems, characterized by a notable decline in rates pre- and post-implementation of the system.

**Hypothesis 1**: The initial investment of money and staff resources required to implement the system is the primary reason hospitals do not pursue an EHHMS.

**Hypothesis 2**: After implementation of an EHHMS, hospitals experience lower HA-CDI rates than hospitals without an EHHMS.
METHODS

Hospital Survey

Survey design. A short survey was developed in consultation with the Healthcare Association of New York State (HANYS) to assess barriers to the adoption of electronic hand hygiene monitoring systems (EHHMS) and their proliferation across the state, the challenges associated with their implementation, and their relative effectiveness. HANYS is the statewide hospital and continuing care association in New York State providing advocacy, education, data analytics, operational assistance, and quality improvement initiatives for member hospitals, nursing homes, and other healthcare organizations. The survey was constructed using Survey Monkey and consisted of 11 questions in total, beginning with two general questions assessing the level of the respondent’s familiarity with EHHMS, and whether their facility has implemented this technology. Response logic was built into the survey directing participants to three additional questions if their facility has not pursued an EHHMS, five additional questions if their facility has implemented an EHHMS, and one additional question if the facility has implemented or is in the process of implementing an EHHMS. All respondents were asked at the close of the survey if they would be willing to speak more in-depth with a researcher regarding their responses to serve as a possible case study for this study, and to provide an email address if interested.

The question pertaining to a hospital’s reasons for not pursuing an EHHMS—implementation costs, ability of these systems to improve infection and hand hygiene rates, maintenance costs, and employee push-back—and the series of questions assessing a hospital’s experience with this
technology—ease of implementation, return on investment, impact on infection rates, and employee response—were drafted based on known concerns and challenges with implementation of these systems. Facilities that have not pursued an EHHMS were also asked to respond to two questions of interest to HANYS, what their current approach to hand-hygiene surveillance is and if they have plans for revisiting EHHMS implementation in the future. Additionally, those facilities that have implemented an EHHMS were also asked if they believe this technology to be a source of competitive advantage, defined as the leverage a business has over its competitors, which can be gained by offering clients better and greater value. See Item 2 of the Appendix for the survey instrument.

Reliability testing. To refine the survey instrument and assess inter-rater reliability, the survey instrument was administered to HANYS staff members in the Quality, Advocacy, Research, and Innovation (QARI) division, the department overseeing the project, and select employees from Island Peer Review Organization (IPRO), which provides healthcare assessment and improvement services and partners with QARI on other quality initiatives. The HANYS staff members completed the survey and provided feedback, and the survey instrument was edited accordingly. After these changes, the survey instrument was administered to employees of IPRO, and further adjustments were made to the survey instrument according to the outcome of these tests.

Sampling methodology. An institutional electronic newsletter, under the Healthcare Association of New York State (HANYS) branding, explaining the research project and containing the survey link, was distributed via email to 217 Infection Control Directors representing
HANYS’184 acute care and critical access member hospitals. This was a convenience sampling approach appropriate for the small sample size. The survey was launched on March 12th, 2018, and closed on April 6th, 2018. A follow-up reminder email was sent after the survey was in the field two-weeks to encourage participation.

*Data preparation.* The survey results were extracted from Survey Monkey into an Excel file, and reformatted where necessary to prepare for analysis. The survey responses were reviewed to identify instances of multiple responses from a single facility; where there were multiple responses from the same facility (N = 6) that differed, the participants were contacted, and their responses remediated into a single, cohesive answer. Descriptive statistics were then performed on the survey results, and in some instances, paired with sample characteristic data (described in more detail below), to better illustrate how different types of hospitals responded.

*Matching payer profile and clinical and non-clinical characteristics.* To get a better understanding of the sample of hospitals who completed the survey, clinical, and non-clinical characteristics, as well as payer profile, were compiled and compared to the full cohort of acute care and critical access hospitals, as provided in Table 1 of the Appendix. Non-clinical characteristic data was extracted from the Centers for Medicare and Medicaid (CMS) Healthcare Cost Report Information System (HCRIS) by the Economics, Finance, and Information (EFI) division of the Healthcare Association of New York (HANYS). These data included urban/rural designation, teaching status (major teaching, minor teaching, and non-teaching, as calculated from the intern- and resident-to-bed ratio (IBR)), and disproportionate share hospital (DSH) patients (transformed as high, medium, low, and none). Classifications of facility type (acute
care, critical access, cancer, long-term care, and children’s hospital), region (Central New York, Western New York, Northeastern New York, Rochester Area, Long Island, Northern Metropolitan Area, and New York City, as determined by zip codes), and upstate/downstate designation were also provided by HANYS and are designations set by the organization for the purposes of their regular business operations.

Payer profile and clinical characteristic data was extracted from the Statewide Planning and Research Cooperative System (SPARCS), New York State’s comprehensive all payer data reporting system, to which the Healthcare Association of New York State has access for the purposes of regular business operations and research projects. This included total discharges and total Medicare discharges\textsuperscript{39,48,49}, the latter of which was further broken down into total Medicare managed care and non-managed care discharges; total Medicare discharges and its subsections were each converted to a percent of total discharges. Clinical characteristics included monthly hospital-acquired C. difficile infection counts, which represent the number of CDI cases not present on admission at each facility each month, and total monthly discharges from the period of January 2011-December 2016. These were used to calculate a monthly facility CDI rate (number of CDI/1000 patient discharges). The codes ICD-9-CM 008.45—Intestinal infection due to Clostridium difficile, prior to October, 2015, and ICD-10-CM A04.7—Enterocolitis due to Clostridium difficile, after October 2015, were used to identify appropriate claims.\textsuperscript{47} The “present-on-admission” indicator was set to “no” to limit the extraction to only hospital-acquired CDI. Additionally, average length of stay (ALOS), a mean calculated by dividing the sum of inpatient days by the number of patient admissions with the same diagnosis-related group classification\textsuperscript{5}, and the all patient refined-diagnosis related group case mix index (APR-DRG
CMI), were also included. CMI reflects the diversity, clinical complexity, and resource needs of
the hospital’s patient population, and the APR-DRG CMI specifically takes into account patient
age and severity of illness.[20]

Trend analysis. For hospitals indicating on the survey they have implemented an electronic hand
hygiene monitoring system (EHHMS) to monitor and improve hand hygiene compliance we
conducted a pre- and post-implementation trend analysis on hospital-acquired CDI rates. First,
hospital websites were searched, and organization press releases revealed the implementation
timeline. Second, facility rates of hospital-acquired CDI/1000 patient discharges (HA-CDI), as
described above, were graphed from January 2011-December 2016, with separate data series for
pre- and post- implementation. For comparison purposes, HA-CDI rates for the entire population
for the same time periods were also graphed. Trend lines were added to determine how rates of
HA-CDI have changed over time. Additionally, percent change was calculated for each facility
with an EHHMS comparing a 3-month baseline period 1-year before implementation of the
system and a 3-month comparison period 1-year after implementation.

Case Study Interviews. The Infection Control Directors at the hospitals identified by the survey
as having an electronic hand-hygiene monitoring system (EHHMS) were contacted for semi-
structured interviews aimed at uncovering additional insights into why they adopted the system,
and their experiences with the system to date. Additionally, for a vastly different perspective, we
reached out to the critical access hospitals (CAH) that completed the survey to request an
interview. Critical access is the designation assigned by the Centers for Medicare and Medicaid
Services to small, rural facilities with less than 25 total beds, and often limited resources for investing in non-essential technology.\textsuperscript{101}

The interview guide was prepared in advance, with approximately 5-7 open-ended questions intended to gain a deeper understanding of the findings from the survey and trend analysis (for hospitals with an EHHMS). Each interview was conducted one-on-one, over the telephone, with responses transcribed in note form by hand. They began with a general discussion of electronic hand-hygiene monitoring systems and less-complicated interview questions to gain a rapport with the interviewee. These conversations were also highly interactive and dynamic, with a flexible agenda driven by participant responses. The interview transcripts were analyzed according to conventional content analysis techniques, with the help of indexing, to identify major themes and ideas.\textsuperscript{54} Refer to Item 3 of the Appendix for the Interview Guide.

RESULTS

Hospital Survey

Survey sample
As illustrated in Table 7, hospitals participating in the survey represented approximately 30\% (N = 56) of the total population of hospitals (N = 184). Respondents from urban and rural areas of New York State represented 64.3\% and 35.7\% of the sample, respectively, which translates to 14\% more facilities from rural areas compared to the total population. Additionally, there were
some regional differences, with a greater percentage of respondents from Northeastern New York and the Rochester Area, and fewer from Long Island and the Northern Metropolitan Area, than the total population of hospitals. Also, there was less representation from major and minor teaching hospitals, and thus a greater number of non-teaching hospitals, in the survey sample compared to the total population. Lastly, hospitals completing the survey have substantially fewer average annual discharges than the full population of hospitals.

State of adoption

The survey revealed a very small number of facilities in the sample have elected to implement an electronic hand hygiene monitoring system (N = 2), though five additional hospitals are either in the process of implementing an EHHMS (N = 3) or have a system identified that will be procured and implemented soon (N = 2), as shown in Table 8 of the Appendix. The most popular EHHMS solution selected by these facilities was BioVigil\textsuperscript{102}. Of the 56 survey respondents, 16\% and 50\% indicated they either thoroughly or briefly considered pursuing an EHHMS and decided against implementation, respectively, while the remaining 21\% disclosed they were unfamiliar with such technology. When these responses are paired with clinical characteristics no noteworthy patterns emerge, except the hospitals that have implemented an EHHMS have approximately 2,000 additional annual discharges on average than hospitals that have decided against implementation. However, the facilities unfamiliar with the technology are of similar size, and the five hospitals on the path to an EHHMS are much smaller.

Hospitals without an EHHMS
A sample that is characterized by a greater number of rural and non-academic facilities, with fewer annual discharges, might account for the small number of hospitals that have implemented an EHHMS. These systems are commonly thought of as prohibitively expensive, and therefore likely perceived to be out of reach for facilities with fewer resources to allocate to non-essential investments. As illustrated in Table 9 of the Appendix, an overwhelming number of respondents, 39 out of 49 participants asked (79.6%), selected “these systems require too much initial investment of money and staff resources” as a reason their facility has not implemented an EHHMS. The next most commonly selected reason for not pursuing an EHHMS was “the ability of such systems to accurately monitor hand hygiene is questionable,” at 28.6% of respondents, which was followed by “we are not familiar with such technology,” at 24.5% (the same number of facilities who identified in this manner in the first survey question). However, many facilities identifying as being unfamiliar with EHHMS also believed these systems to be too expensive (N = 8), and a few believed the accuracy of EHHMS was questionable (N = 2) and that getting buy-in from leadership to pursue this technology was not possible (N = 3).

**Conclusion 1:** The initial investment of money and staff resources required to implement the system is the primary reason hospitals do not pursue an EHHMS.

**Hospitals with an EHHMS**

Of the two hospitals that indicated they have implemented an electronic hand hygiene monitoring system (EHHMS), only one completed the survey questions regarding their experience with this technology. This hospital felt the system was as expected to implement, not overly challenging nor easier than expected. They also reported staff members are unhappy with
the change and infection rates have only improved minimally since implementation. It has also been their experience that implementation and up-keep costs have been outweighed by savings from reduced infections; on net the system is not saving the facility money. However, this hospital also believes this system to be a source of competitive advantage over competitors. This facility agreed to be interviewed about their experience, which offered an opportunity for them to elaborate on these answers; an account of this conversation has been provided below.

Case Studies

For the purposes of this analysis and to maintain anonymity for the facilities examined, Hospital A is the name given to the hospital with an implemented EHHMS that completed the full survey questions and agreed to an interview; Hospital B is the name given to the second hospital indicating they have an EHHMS who declined to share their experience via the survey and one-on-one interview.

Trend analysis and interview—Hospital A

According to the representative from Hospital A, their experience with an electronic hand hygiene monitoring system (EHHMS) began with a six-month free trial where they piloted the product on two units beginning in spring 2014. During the trial period, the system captured a substantially greater number of hand hygiene events than was achieved with direct observation. Additionally, it revealed hand hygiene compliance rates to be considerably lower than anticipated, especially considering the WHO’s 5 moments for hand hygiene. This data was used to create a business case for procuring the system—estimating the number of infections the
system could help prevent and translating that into a monetary value—that made it easier to get support from executive leadership. After the trial period, Hospital A negotiated the contract and the system was installed on most in-patient units and in the emergency department within a month, around October 2015.

Hospital A decided on an approach with the goal of minimizing employee push back, first allowing the system to collect a baseline set of hand hygiene compliance data and then using that data to inform staff of the current state, followed by education on the WHO’s 5 moments for hand hygiene and identification of a champion on each unit to promote best practices and keep engagement high. As illustrated in Figure 4 of the Appendix, this approach appears to have been successful in the short-term. Hand hygiene compliance on units, according to the representative from Hospital A, improved dramatically in the months following organization-wide implementation of the EHHMS, increasing from 50-60% to over 80% on most units. Correspondingly, hospital-acquired CDI (HA-CDI) rates plummeted during this same time period from an average of 2.84 in Q3, 2014 to 0.865 in Q4, 2014. These low rates were maintained for about 12-months, reaching 0.415 in Q3, 2015, the lowest facility rate in over 4-years. This is even more impressive considering Hospital A was experiencing a slight upward trend in HA-CDI rates in the time period before implementation of the EHHMS; over this same pre-implementation time period, the full population of hospitals was experiencing a slight decrease in HA-CDI rates.

However, maintaining these high rates of hand hygiene compliance for the long-term has proved challenging for Hospital A, according to the hospital representative. They attribute declining
compliance over time to staff turnover, which shifted the hand-hygiene culture established when the EHHMS was implemented, resulting in less staff buy-in for the system and belief in its importance. This facility consciously selected a system that aggregated total hand hygiene surveillance, as opposed to tracking individual compliance, which many systems can do, to make adoption of the EHHMS more palatable for employees, and this has made it impossible to target persistent offenders. Interestingly, Hospital A’s rates of hospital-acquired CDI (HA-CDI) began trending upward a year after implementation of the EHHMS and maintained this trajectory through December 2016, as illustrated in Figure 4; over this same post-implementation time period, the full population of hospitals continued to experience a downward trend in HA-CDI rates.

Despite their struggles to maintain the success experienced in the short-term after implementation of an EHHMS, Hospital A remains a staunch advocate of these systems. “People are fooling themselves when they think direct observation is accurately capturing hand hygiene compliance – it’s definitely not capturing the 5 moments – it’s a small snapshot in time that only captures [staff] coming in and out of the room,” said Hospital A’s representative. They believe manually collected data through direct observation is extremely limiting, as it only collects a few moments, typically during the day shift, which results in estimating hand hygiene compliance rates from a small percentage of opportunity; electronic systems, conversely, offer 24-hour surveillance. However, they understand these systems to be only one piece of the puzzle; “improving hand hygiene takes a multi-pronged approach and staff commitment.” According to Hospital A, hand hygiene compliance culture is also crucially important and is difficult to maintain with staff turnover and without the ability to target the individuals contributing most to
declining hand hygiene rates. They also caution against the annual fee that accompanies these systems, which becomes very difficult to justify when hand hygiene rates are declining.

**Trend analysis—Hospital B**

The second hospital with an implemented electronic hand hygiene monitoring system (EHHMS) declined to answer the survey questions regarding their experience and did not respond to requests to be interviewed. According to hospital press releases, the system was piloted on two units in January 2015, and was eventually implemented throughout the hospital by early 2016. The trend analysis conducted on Hospital B’s hospital-acquired CDI (HA-CDI) rates, from January 2011 to December 2016, suggests their experience with an EHHMS (developed by a different company) differed from that of Hospital A.

As illustrated in Figure 5 of the Appendix, the facility was already experiencing a downward trend in HA-CDI rates greater than that experienced by the full population of hospitals before the EHHMS was piloted. After the EHHMS was tested, HA-CDI rates were volatile, spiking in Q3, 2015 to 2.91 and falling to 2.01 in Q4, 2015. Just as the EHHMS was being implemented facility-wide, HA-CDI rates decreased again, reaching a facility low of 1.33 for the 6-year time period in Q2, 2016. This drop in HA-CDI may be attributable to the EHHMS. However, shortly after the system was implemented across all units, HA-CDI rates began to trend upward again, reaching 2.77 in Q3, 2016 and 3.13 in Q4, 2016. Overall, during the 2-year period when the EHHMS was being piloted and fully implemented, HA-CDI rates experienced an upward trend at Hospital B, while the full population of hospitals experienced a downward trend in rates.
Unlike Hospital A, the implementation of an EHHMS at Hospital B does not appear to have had any attributable impact on HA-CDI rates that can be discerned by the trend analysis.

**Hypothesis 2:** *It is unclear if after implementation of an EHHMS, hospitals experience lower HA-CDI rates than hospitals without an EHHMS.*

*Interview—Critical Access Hospital*

Of the 56 hospitals participating in the electronic hand hygiene monitoring systems (EHHMS) survey, only 3 were of the critical access hospital (CAH) designation. All three were contacted to request their participation in a one-on-one telephone interview and one consented. The facility interviewed is very small in size, approximately 70 monthly total discharges on average, and has not implemented an EHHMS, according to their infection control representative, because the cost is prohibitive. “If I brought it up to [leadership] I might be crucified” given the budget at their facility is already tight; anything that requires purchasing something new and non-essential would most definitely “get shot down.”

However, without such a system, their hand hygiene rates are about 90%, according to their representative, which is supported by their extremely low HA-CDI rates of 3 total infections in five years (2011-2016). To monitor and improve compliance, they have an infection prevention team made up of staff from all departments, including laboratory and housekeeping, on all shifts, that collect hand hygiene observation data. Additionally, they conduct patient surveys of staff hand hygiene practices, asking questions like, “in the past 24 hours, what did you see your staff do: use sanitizing gel, wash at the sink, etc.,” and patients in the emergency department also get
surveyed. When the patient surveys were implemented in the ED, there was concern the data would upset their high compliance rates, but this data only proved to support the existing numbers. “We have a very strong culture around hand hygiene,” stated the representative when asked how they manage to achieve such high compliance rates; “we do regular education and training” and all departments are involved in infection prevention.

DISCUSSION

Summary

We explored the adoption of electronic hand hygiene monitoring systems (EHHMS) in New York State acute care hospitals, through administration of an online survey, and examined the impact those systems have had on hospital-acquired C. difficile infection (HA-CDI) rates at facilities that pursued implementation, using trend analysis of state-wide billing data. Inconsistent with our preliminary expectations, proliferation of these systems appears to be low, according to our survey, with only two facilities reporting having an implemented system and five facilities in the procurement or implementation process, despite many more considering pursuing an EHHMS, at least briefly. Overwhelmingly, facilities indicated the initial investment of money and staff resources required to implement an EHHMS to be the main reason hospitals have declined this intervention.
Additionally, an interview with a hospital representative from a facility with an implemented EHHMS confirmed the system was very effective at improving hand hygiene compliance rates, at least in the short term, due to vastly improved data collection, which served as a catalyst for renewed attention and focused improvement efforts. They emphasized the importance of having a strong hand hygiene culture to maintain the improved rates the system helps facilitate, which can easily be dismantled through staff turnover and once the newness of the system dissipates. The trend analysis supported this experience, revealing a sharp decline in HA-CDI rates following implementation, which persisted for approximately 12-months before regressing. However, the trend analysis for the second hospital with an implemented EHHMS, that declined to be interviewed, showed limited impact on HA-CDI rates pre- and post-implementation of the system.

The conversation with a critical access hospital (CAH), the CMS designation for small, rural hospitals characterized by financial vulnerability, revealed perceptions that electronic hand hygiene monitoring systems (EHHMS) are, and will likely remain, prohibitively expensive for facilities with significant resource constraints. However, this facility reported great success with traditional hand hygiene monitoring techniques, using patient surveys and direct observation through an intra-departmental infection control team, and attributed their high rates of hand hygiene compliance to their robust hand hygiene culture.

While research is limited evaluating the effectiveness of EHHMS, our results are supported by the existing literature. Other studies corroborate the perception of Hospital A that electronic hand hygiene monitoring systems are a reliable, and in some cases superior, alternative to traditional
hand hygiene monitoring techniques, such as direct observation and product utilization, and the experience of Hospital B in that the higher compliance achieved does not necessarily translate into a reduction in hospital-acquired infections. Additionally, like the experience of Hospital A, a recent study of three community hospitals with an implemented EHHMS found these systems to be an effective tool for improving hand hygiene compliance rates, achieving greater than 85% on average. However, the authors also cited consistent and constant messaging and staff empowerment as key drivers of success, and noted empowering and inspiring staff to be crucial components for releasing the full benefits of an EHHMS. This is further reflected in a 2014 systematic review of studies examining the issues that affect health care workers' compliance with hygiene guidelines, which identified organizational culture as a key factor. Specifically, where a lack of organizational commitment existed, healthcare workers felt disempowered to correct poor compliance. In contrast, where the hospital culture was supportive, hand hygiene compliance improved.

**Limitations**

Our analysis has some limitations. Due to the small population size of acute-care facilities in New York State, the survey sampling methodology was based on convenience, to ensure adequate responses. However, the response rate was only 33%, which resulted in a sample that may not be representative of the entire population. Furthermore, there were only two hospitals who identified as having an EHHMS, and only one that shared their experience on the survey and in an interview, which makes this evidence somewhat anecdotal and potentially not representative of other facilities’ experiences with an EHHMS. Also, while it was stressed that each acute-care hospital should only provide a single response to the survey, some facilities
provided multiple responses that had to be remediated into a single answer; though, we believe this improved the accuracy of those responses.

Administering the survey through a Healthcare Association of New York State (HANYS) branded newsletter aimed to increase the legitimacy of the study but may have led to response bias; facilities with responses they perceive as being more favorable to HANYS, such as those who have implemented electronic hand-hygiene monitoring systems, may have been more likely to respond. This may have had a similar influence on the interviewees. However, HANYS strives to position itself as a non-regulatory entity with the sole purpose of serving its members so the effect was likely minimal. Additionally, using trend analysis in combination with the survey data and interviewee reports appeared to confirm representative responses.

Lastly, using SPARCS billing data may not capture all instances of CDI, which was used to conduct the trend analysis. When data gets submitted to SPARCS from hospitals it goes through various stages of edits, if anything is incorrect on the claim it is returned to the facility. Hospitals then have the option of correcting the claim or not, and can retroactively edit claims from as far back as the 1990s, with only those claims that are approved by SPARCS making it into the master file. Understanding this, it is possible the extracted data underestimates total instances of CDI. However, this would strengthen our findings. Additionally, the data was extracted using specific ICD-9 and 10 codes, and it is possible some instances of CDI were not captured, or were coded incorrectly. However, a recent study concluded, “C. diff ICD-9 codes closely approximate true C. diff infection…and can therefore be used as a reasonable alternative to microbiological data for tracking purposes”47, and the ICD-9 code is a direct crosswalk to the ICD-10.
Conclusion

Adoption of electronic hand hygiene monitoring systems (EHHMS) appears to be low in acute care facilities in New York State and hospitals with these systems are experiencing mixed results in terms of improved hand hygiene compliance and number of related hospital-acquired infections. While these systems proved very effective at one hospital for improving hand hygiene rates, which translated to a reduction in HA-CDI, the results were difficult to maintain long-term. It was emphasized by multiple facilities that having a strong organizational culture in support of hand hygiene is essential to achieving high rates of compliance. It seems an EHHMS could be a powerful tool for igniting that culture, though hospital staff need to be diligent in their efforts to maintain the initial enthusiasm.
CHAPTER 5: CONCLUSION

In response to the growing rate of hospital-acquired infections (HAI), pay-for-performance programs have emerged to incentivize providers and healthcare organizations to take the necessary steps to improve healthcare quality and safety.\textsuperscript{30} Under the structure, process, outcome model of healthcare quality, hospital-acquired conditions are understood not to be the result of human error, but the product of systems and structures, which determine processes, and lead to certain outcomes.\textsuperscript{15,16} This project aimed to address the burden of hospital-acquired Clostridium difficile infection (HA-CDI) in New York State Hospitals, the most common HAI and a target of federal PFP programs, by examining three potential structural interventions for its prevention: (1) evaluation of an Antibiotic Stewardship Collaborative aimed at improving antibiotic prescribing practices, (2) assessment of the relationship between facility HA-CDI rates and emergency department wait times and patient-reported room cleanliness scores, and (3) examination of the proliferation of electronic hand hygiene monitoring systems and their relationship to HA-CDI rates. Through a summary of these study objectives and findings, recommendations for future practice and further research will be identified, indicating a body of work that offers a unique contribution to healthcare quality field, and that has developed the professional acumen of the researcher in a number of ways.

Summary of findings

Chapter 2 evaluated the impact of an Antibiotic Stewardship Collaborative aimed at improving antibiotic prescribing practices, which also provided education on the elements of antibiotic stewardship programs and prevention of drug-resistant organisms, such as Clostridium difficile,
for New York State Hospitals. A difference-in-differences analysis was conducted to determine if there was a significant change in hospital-acquired Clostridium difficile infection (HA-CDI) rates for the cohort of hospitals participating in the collaborative, over the first year of the collaborative, compared to the population of hospitals opting not to participate. This quantitative analysis was supplemented with informal interviews with hospital representatives responsible for carrying out the collaborative activities at their facilities, to gain a better understanding of the successes and challenges faced by collaborative participants; some facilities not participating were also interviewed to determine the reasons for abstaining.

The analysis indicated that while HA-CDI rates for participating hospitals decreased more than hospitals not participating during the first year of the collaborative, this was not found to be significant. However, HA-CDI rates are a lagging variable that may take additional time to change in response to efforts aimed at improved antibiotic prescribing; hospitals had to first develop the infrastructure necessary to begin tracking prescribing data, receive and analyze comparison reports, and then implement necessary interventions to improve prescribing before any subsequent changes in HA-CDI rates were likely to be seen. Despite these findings, hospital representatives offered considerable praise for the collaborative, specifically mentioning the comparative antibiotic usage reports and early educational sessions as highly valuable.

**Chapter 3** assessed the relationship between rates of hospital-acquired CDI at New York State acute care hospitals and their average emergency department (ED) wait time and patient-reported room cleanliness scores. A time series, fixed effects regression analysis was conducted and determined average ED wait time to be a significant predictor of a facility’s HA-CDI rate; this
was found to explain more of the variance in HA-CDI rates for patients entering through the emergency department than some of the best-known predictors of HA-CDI, with percent of discharges that are Medicare being the closest second. Additionally, the percentage of patients indicating their room was “always” kept clean was found to have a significant and negative association with hospital-acquired C. difficile infection (HA-CDI) rates. The percentage of patients indicating their room was “sometimes” or “never” kept clean was found to have a negative association with hospital-acquired C. difficile infection (HA-CDI) rates, though this was not statistically significant.

**Chapter 4** explored the proliferation of, and experiences with, electronic hand hygiene monitoring systems (EHHMS) within New York State acute care hospitals. A brief survey was administered to determine the number of hospitals that have implemented an EHHMS and what their experience has been in terms of changes in hand hygiene compliance and subsequent infection rates. Additionally, the survey sought to determine the reasons facilities have elected not to pursue this technology. For hospitals with an operating EHHMS (N=2), a trend analysis was conducted to see if a discernable change in HA-CDI rates could be detected post-implementation. These trend analyses were supplemented with informal conversations with one of the hospitals identified as having an EHHMS and, for a vastly different perspective, a critical access hospital that has not pursued this technology due to financial constraints.

The analysis revealed minimal adoption of EHHMS across New York State hospitals, with those that have not pursued the technology citing the high associated costs as the most common reason, and a mixed impact on HA-CDI rates for hospitals with an implemented system. The facility
with an EHHMS that participated in the interview reported a substantial improvement in hand hygiene compliance rates after implementation of the system. Additionally, according to a trend analysis, this improvement in hand hygiene compliance appears to be associated with a substantial decrease in HA-CDI rates. However, improvement in both of these metrics proved difficult to maintain in the long-term. While the hospital representative praised the ability of EHHMS to track a greater number of hand hygiene opportunities, they stressed the importance of having a strong organizational culture around hand hygiene to maintain the improved compliance the system helps facilitate. This was echoed in the conversation with the critical access hospital, who reported hand hygiene compliance rates greater than 90% using traditional hand hygiene monitoring techniques, emphasizing their robust hand hygiene culture as the greatest contributor to this success.

**Implications for future practice**

The findings of these studies have implications for future practice. Despite not finding a significant change in hospital-acquired Clostridium difficile infection (HA-CDI) rates during the first year of the collaborative for participating hospitals in Chapter 2, all hospitals participating in the collaborative managed to develop the infrastructure necessary to begin tracking and reporting antibiotic prescribing data, which is a significant success considering impending state and federal mandates that may soon require regular submission of this usage activity. This suggests a collaborative of this nature is a successful strategy for preparing hospitals for meeting the challenge of these regulations, and should be considered by other state hospital and healthcare associations.
The findings from Chapter 3 suggest a reduction in rates of HA-CDI for patients entering through the emergency department (ED) may be realized through a concerted effort to reduce the time patients wait before being admitted to an in-patient room. Alternatively, this research suggests improved environmental cleanliness in the ED might also yield a similar result, which may prove to be a more feasible approach. Additionally, the findings from Chapter 2 suggest empowering patients and families to request additional environmental services if their room or bathroom does not appear clean, as a mechanism for reducing HA-CDI.

Lastly, the findings from Chapter 4 suggest that while electronic hand hygiene monitoring systems can be an effective tool for improving hand hygiene compliance, those results may not be sustainable in the long-term if they are not accompanied by a strong organizational culture around hand hygiene. For hospitals that can afford this technology, an EHHMS might be the perfect impetus for igniting that culture; for hospitals where non-essential technological upgrades are out of reach, high rates of hand hygiene compliance can still be achieved with traditional hand hygiene monitoring methods if these efforts are based on an organizational-wide commitment to superior hand hygiene practices.

Areas for future research

The results of these studies suggest important areas for future research. Specifically, understanding hospital-acquired CDI rates to be a lagging outcome variable when evaluating an antibiotic stewardship collaborative aimed at improving antibiotic prescribing practices, repeating the analysis in Chapter 2 with additional data from year two of the collaborative could
yield different results. This data has recently become available and this expanded analysis will be conducted immediately following the completion of this project.

While the findings in Chapter 3 have interesting implications, they are limited in their design, comparing aggregated facility rates of HA-CDI to aggregated facility averages of emergency department (ED) wait times and patient-reported room cleanliness scores. Further research should be conducted at the patient-level to determine if the supposed relationship between these variables continues. However, this could prove challenging, as patient-level data is subject to the Health Insurance Portability and Accountability Act (HIPAA) and laws governing the use of protected health information (PHI). This analysis could be strengthened in a more feasible manner by adding additional years of data from Hospital Compare, once it becomes available. This expanded analysis is on my agenda for future work.

Finally, the analysis in Chapter 4 is limited by the small number of hospitals with an electronic hand hygiene monitoring system, which makes this evidence somewhat anecdotal. However, the survey revealed many hospitals are in the process of implementing an electronic hand hygiene monitoring system (EHHMS). This study may be worth repeating in a few years to gain some additional perspectives that may be more representative of the true impact of an EHHMS on hand hygiene compliance and HA-CDI rates. This subsequent analysis will be conducted if there is interest from the partnering organization, HANYS.

*Contribution to the healthcare quality field*
Each of the preceding chapters discussed the contributions of their respective study to the Clostridium difficile infection (CDI) prevention body of knowledge. As such, this section has been reserved for discussing the contribution this project in its entirety makes to the advancement of the healthcare quality field.

The recent rise in pay-for-performance programs that penalize hospitals with high rates of hospital-acquired conditions through reduced reimbursements has resulted in a newfound focus on the prevention of adverse events.29 However, it has been shown that approximately 70% of adverse events are preventable19 and 30% can be attributed to negligence20. Largely responsible for these rates is the complexity inherent in the systems and processes that characterize hospitals and health systems, with prominent healthcare research agencies emphasizing the need to improve teamwork and standardize work procedures.6 This echoes the recommendations of Avedis Donabedian, the founding father of healthcare quality, from many years before (originally published in 1966), describing a structure, process, outcome approach to improving healthcare quality.16 Donabedian asserted structural components have an impact on processes, and processes determine outcomes; in other words, in order to improve outcomes, structural components of the system should be examined to understand how they shape processes.15

Through the lens of Donabedian’s seminal work, this project examined the potential for three structural interventions to reduce rates of hospital-acquired CDI:

(1) Chapter 2: If infrastructure is developed to track and report antibiotic usage data, does HA-CDI decrease as a result of improved prescribing practices?
(2) Chapter 3: Do prolonged emergency department (ED) wait times contribute to higher rates of HA-CDI, and could empowering patients to advocate for additional environmental services when their in-patient room does not appear clean improve HA-CDI rates?

(3) Chapter 4: If an electronic hand hygiene monitoring system (EHHMS) is implemented to provide consistent monitoring and tracking of hand hygiene moments of healthcare workers, are hand hygiene compliance rates improved and is there a subsequent reduction in HA-CDI rates?

The findings from the preceding chapters suggest Donabedian’s model remains highly applicable even in today’s modern healthcare landscape, as two of the three aforementioned structural interventions proved effective strategies for reducing hospital-acquired Clostridium difficile (HA-CDI) rates (Chapters 3 & 4). Chapter 2 did not find the Antibiotic Stewardship Collaborative to have a significant impact on HA-CDI rates. However, the collaborative has been tremendously successful in other ways—providing the impetus for participating hospitals to develop the infrastructure necessary to begin monitoring and reporting their antibiotic usage, which is fueling improvement efforts—and HA-CDI is a lagging outcome variable, which may take time to manifest the true impact of the collaborative.

**Contribution to researcher growth**

A secondary but equally important contribution of this project has been the development and refinement of my skills in conducting scholarly healthcare research. More specifically, this project allowed me to learn best practices for conducting academic research with a collaborating
external organization, develop abilities for effectively communicating with key informants, and
gain experience with new statistical approaches for evaluating healthcare interventions. This
experience has provided me with the preparation necessary to assume a faculty appointment
within a variety of university departments, while serving as a shining reflection of the rigorous
curriculum that distinguishes Rockefeller College of Public Affairs and Policy’s PhD program in
Public Administration.
## APPENDIX

### Table 1
Characteristics of Antibiotic Stewardship Collaborative (ASC) Participating and Non-Participating Hospitals 2011-2016 (N=184)

<table>
<thead>
<tr>
<th>Non-Clinical Characteristics</th>
<th>ASC hospitals (n = 44)</th>
<th>Non-ASC hospitals (n = 140)</th>
<th>P Value</th>
</tr>
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<tbody>
<tr>
<td><strong>Urban/Rural</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>81.8%</td>
<td>77.1%</td>
<td>0.512</td>
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<tr>
<td>Rural</td>
<td>18.2%</td>
<td>22.9%</td>
<td>0.512</td>
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<tr>
<td><strong>Region</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central New York&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.4%</td>
<td>15.0%</td>
<td>0.546</td>
</tr>
<tr>
<td>Western New York&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.4%</td>
<td>12.9%</td>
<td>0.794</td>
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<tr>
<td>Northeastern New York&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>11.4%</td>
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<tr>
<td>Rochester Area&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Long Island&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6.8%</td>
<td>13.6%</td>
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<tr>
<td>Northern Metropolitan Area&lt;sup&gt;f&lt;/sup&gt;</td>
<td>6.8%</td>
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<td>New York City&lt;sup&gt;g&lt;/sup&gt;</td>
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<td><strong>Upstate/Downstate</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Upstate</td>
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<td>47.1%</td>
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<tr>
<td>Downstate</td>
<td>54.6%</td>
<td>52.9%</td>
<td>0.845</td>
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<td><strong>DSH Patient Percentage</strong></td>
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<tr>
<td>High</td>
<td>27.3%</td>
<td>20.7%</td>
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</tr>
<tr>
<td>Medium</td>
<td>52.3%</td>
<td>53.6%</td>
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<td>Low</td>
<td>15.9%</td>
<td>20.0%</td>
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<tr>
<td>No</td>
<td>4.6%</td>
<td>5.7%</td>
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<tr>
<td><strong>Type</strong></td>
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<tr>
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<td>Non-Teaching</td>
<td>29.6%</td>
<td>39.3%</td>
<td>0.243</td>
</tr>
</tbody>
</table>

### Clinical Characteristics

| * Total Discharges          | 17671.25               | 11252.16                      | 0.001   |
| ** ALOS**                   | 5.345                  | 5.434                         | 0.796   |
| ** APR-DRG CMI**            | 1.156                  | 1.097                         | 0.195   |
| *** Adjusted CDI (CDI/1000 disch) | 2.528       | 2.245                         | 0.257   |

### Payer Profile (of total discharges)

| * % Medicare               | 40.93%                 | 41.52%                        | 0.818   |
| * % Medicare Managed Care  | 15.29%                 | 13.87%                        | 0.443   |
| * % Medicare Non-Managed Care | 25.63%            | 27.65%                        | 0.390   |
1 Federal Healthcare Cost Report designation (E-A, line 21)
2 HANYS region classifications by county
   a Broome, Cayuga, Chenango, Cortland, Herkimer, Jefferson, Lewis, Madison, Oneida, Onondaga, Oswego, St. Lawrence, Tioga, Tompkins
   b Allegany, Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans, Wyoming
   d Chemung, Livingston, Monroe, Ontario, Schuyler, Steuben, Wayne, Yates
   e Nassau, Suffolk
   f Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, Westchester
   g Bronx, Kings, New York, Queens, Richmond
3 HANYS classification, regions above (upstate) or at or below (downstate) the Northern Metropolitan Area
4 HANYS classification of DSH patient percentage: high > 75%, medium 25-75%, low 0-25%, no = 0%
5 NYS designation in SPARCS
6 HANYS classification for teaching status: major = IBR ≥ .25 or residents > 100, minor = IBR 0 - .25 or residents < 100, non = no residents
* Annual average
** Monthly averages
*** Adjusted CDI = (average annual CDI counts/average annual discharges) * 1,000
Item 1: Key Informant Interview Guide

Interview Guide for Key Informants

1) **Explanation of the purpose of the interview; informed consent and confidentiality; get permission to take notes.**

Before we start, I would like to thank you for taking the time to speak with me. I know that you are very busy, and I really appreciate your willingness to do this interview.

In partnership with the Quality Advocacy, Research and Innovation division at HANYS, I am working to assess hospitals' experience with HANYS Antibiotic Stewardship Collaborative, and the effectiveness of the program thus far in preventing *C. difficile* infection. This evaluation project will make up a portion of my PhD dissertation at Rockefeller College of SUNY Albany. As a part of this project, I am conducting interviews with several NYS hospital representatives both in and outside the Collaborative to gather insights into why hospitals chose to join the Collaborative or not, as well as successes, challenges, and lessons learned of those in the program. We want to find out if the Collaborative is still meeting the needs of members, and if there are ways in which we can keep the program relevant and ensure the value. Also, this will provide background and context to support the quantitative analysis I am doing. We will also plan to share in a publication for other practitioners in the field to learn from.

I expect this interview will last about 20 minutes. Any information that is obtained through this study will remain **strictly confidential**. All data will be reported in aggregate form only, and we will ensure that you or your hospital will not be identified in the final report. Your participation is strictly voluntary. You may stop the interview at any time and you have the right to decline to answer any question.

I will take notes as we speak, so please be patient if I seem to pause for a bit, and only I will see these notes.

**Do you have any questions up to this point about interview logistics?**

2) **Warm up questions—building rapport**

Before we dive into the main questions, I wanted to start by asking you some questions about your role at your hospital.

- What is your position with XXX hospital?
- What is your role in Antibiotic Stewardship at your facility?
- Has your hospital joined HANYS' Antibiotic Stewardship Collaborative? (if "no," skip to 4)
- When did you become involved with HANYS' Antibiotic Stewardship Collaborative, and what has been the context of your involvement?

3) **Implementation & Experience**
I would now like to gather more specific information on your hospital's experience in the Collaborative.

- How was the decision to join the Collaborative made: organizational push or single champion?
- What do you think is the value in joining a collaborative such as this?
- What has been the response from other hospital staff in regards to your facility's involvement in the Collaborative?
- Did you experience any challenges in executing Collaborative activities?
- What do you think are the most important "lessons learned" from your facility's participation in Collaborative activities?
- Has participation in the collaborative influenced your facility’s Antibiotic Stewardship efforts? How?
- What do you think is the most valuable aspect of the collaborative? (i.e. - antibiotic prescribing data collection, data reports, education, etc.)

4) Not Participating

I would like to get a better understanding of your hospital's decision not to join the Collaborative.

- In your opinion, what do you think is the main reason your facility opted not to join the Collaborative?
- What do your current antibiotic stewardship efforts involve? Formal/informal?
- What do you think would have made joining the Antibiotic Stewardship Collaborative more attractive to your facility (if anything)?

5) Conclusion

- Before we finish our discussion, do you have any other comments on the Antibiotic Stewardship Collaborative you'd like to share?
- I hope that I can get back to you with additional questions if they arise. Is that okay with you?
Figure 1: Graph of Quarterly Average Hospital-Acquired CDI Rates for Participating and Non-Participating Hospitals Pre (2011) and Post-Collaborative Implementation (2016)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Participation in Collaborative</td>
<td>0.093 (0.104)</td>
<td>0.053 (0.105)</td>
</tr>
<tr>
<td>**Month (2011-2015)</td>
<td>-0.013 (0.002)</td>
<td>-0.013 (0.002)</td>
</tr>
<tr>
<td>**Month x Participation</td>
<td>-0.002 (0.003)</td>
<td>-0.002 (0.003)</td>
</tr>
<tr>
<td>Total Discharges</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>Percent Medicare Discharges</td>
<td>2.973 (0.222)</td>
<td>3.315 (0.207)</td>
</tr>
<tr>
<td>Average Length of Stay</td>
<td>0.142 (0.037)</td>
<td>0.134 (0.037)</td>
</tr>
<tr>
<td>APRDRG-Case Mix Index</td>
<td>1.541 (0.135)</td>
<td>1.349 (0.136)</td>
</tr>
<tr>
<td>Critical Access Hospital</td>
<td>-</td>
<td>-1.061 (0.159)</td>
</tr>
<tr>
<td>Teaching Status1</td>
<td>-</td>
<td>0.438 (0.084)</td>
</tr>
<tr>
<td>Major Teaching Hospital^2</td>
<td>0.118 (0.103)</td>
<td>-</td>
</tr>
<tr>
<td>Minor Teaching Hospital^2</td>
<td>0.132 (0.090)</td>
<td>-</td>
</tr>
<tr>
<td>Rural Hospital^3</td>
<td>-0.470 (0.110)</td>
<td>-0.408 (0.109)</td>
</tr>
<tr>
<td>High % DSH Patients^4</td>
<td>0.507 (0.167)</td>
<td>-0.610 (0.067)</td>
</tr>
<tr>
<td>Medium % DSH Patients^4</td>
<td>0.929 (0.150)</td>
<td>-</td>
</tr>
<tr>
<td>Low % DSH Patients^4</td>
<td>1.041 (0.167)</td>
<td>-</td>
</tr>
<tr>
<td>Low % DSH Patients or No DSH Patients^5</td>
<td>-</td>
<td>0.333 (0.090)</td>
</tr>
<tr>
<td>Downstate^6</td>
<td>-</td>
<td>0.204 (0.062)</td>
</tr>
<tr>
<td>Long Island Region^7</td>
<td>1.500 (0.116)</td>
<td>-</td>
</tr>
<tr>
<td>Central New York Area^7</td>
<td>0.766 (0.113)</td>
<td>-</td>
</tr>
<tr>
<td>New York City Area^7</td>
<td>0.525 (0.116)</td>
<td>-</td>
</tr>
<tr>
<td>Northern Metropolitan Area^7</td>
<td>0.410 (0.108)</td>
<td>-</td>
</tr>
<tr>
<td>Rochester Area^7</td>
<td>0.708 (0.130)</td>
<td>-</td>
</tr>
<tr>
<td>Western New York Area^7</td>
<td>0.430 (0.122)</td>
<td>-</td>
</tr>
</tbody>
</table>

*Indicator variable for participation in the collaborative (1 if in the collaborative, 0 if otherwise)

**Continuous variable for month

^1Indicator variable for teaching facilities (includes major and minor), non-teaching omitted as reference category

^2Indicator variables for major and minor teaching facilities, non-teaching omitted as reference category

^3Indicator variable for rural facilities, urban omitted as reference category

^4Indicator variables for DSH patient percentage, no DSH patients omitted as reference category

^5Indicator variable for low DSH patient percentage or no DSH patients, high and medium DSH patient % omitted as reference category

^6Indicator variable for downstate facilities, upstate omitted as reference category

^7Indicator variables for regions, Northeastern New York State omitted as reference category

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Participation in Collaborative</td>
<td>0.047 (0.052) 0.37</td>
<td>0.009 (0.052) 0.865</td>
</tr>
<tr>
<td>**1st Year of Collaborative (2016)</td>
<td>-0.268 (0.095) 0.005</td>
<td>-0.261 (0.094) 0.006</td>
</tr>
<tr>
<td>Participation x Collaborative (2016)</td>
<td>-0.153 (0.117) 0.19</td>
<td>-0.152 (0.117) 0.194</td>
</tr>
<tr>
<td>Time Period (monthly, 2011-2016)</td>
<td>-0.002 (0.000) &lt;.01</td>
<td>-0.002 (0.000) &lt;.01</td>
</tr>
<tr>
<td>Total Discharges</td>
<td>0.000 (0.000) &lt;.01</td>
<td>0.000 (0.000) &lt;.01</td>
</tr>
<tr>
<td>Percent Medicare Discharges</td>
<td>2.832 (0.197) &lt;.01</td>
<td>3.158 (0.184) &lt;.01</td>
</tr>
<tr>
<td>Average Length of Stay</td>
<td>0.144 (0.032) &lt;.01</td>
<td>0.137 (0.031) &lt;.01</td>
</tr>
<tr>
<td>APRDRG-Case Mix Index</td>
<td>1.492 (0.119) &lt;.01</td>
<td>1.321 (0.119) &lt;.01</td>
</tr>
<tr>
<td>Critical Access Hospital</td>
<td>- - -</td>
<td>-0.876 (0.199) &lt;.01</td>
</tr>
<tr>
<td>Teaching Status(^1)</td>
<td>- - -</td>
<td>0.348 (0.074) &lt;.01</td>
</tr>
<tr>
<td>Major Teaching Hospital(^2)</td>
<td>0.057 (0.091) 0.53</td>
<td>- - -</td>
</tr>
<tr>
<td>Minor Teaching Hospital(^2)</td>
<td>0.117 (0.079) 0.14</td>
<td>- - -</td>
</tr>
<tr>
<td>Rural Hospital(^3)</td>
<td>-0.452 (0.095) &lt;.01</td>
<td>-0.409 (0.095) &lt;.01</td>
</tr>
<tr>
<td>High % DSH Patients(^4)</td>
<td>0.402 (0.192) 0.036</td>
<td>-0.565 (0.058) &lt;.01</td>
</tr>
<tr>
<td>Medium % DSH Patients(^4)</td>
<td>0.787 (0.183) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Low % DSH Patients(^4)</td>
<td>0.875 (0.193) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Low % DSH Patients or No DSH Patients(^5)</td>
<td>- - -</td>
<td>0.270 (0.079) 0.001</td>
</tr>
<tr>
<td>Downstate(^6)</td>
<td>- - -</td>
<td>0.199 (0.055) &lt;.01</td>
</tr>
<tr>
<td>Long Island Region(^7)</td>
<td>1.291 (0.103) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Central New York Area(^7)</td>
<td>0.710 (0.105) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>New York City Area(^7)</td>
<td>0.465 (0.102) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Northern Metropolitan Area(^7)</td>
<td>0.414 (0.097) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Rochester Area(^7)</td>
<td>0.598 (0.113) &lt;.01</td>
<td>- - -</td>
</tr>
<tr>
<td>Western New York Area(^7)</td>
<td>0.333 (0.106) 0.002</td>
<td>- - -</td>
</tr>
</tbody>
</table>

*Indicator variable for participation in the collaborative (1 if in the collaborative, 0 if otherwise)
**Indicator variable for the 1st year of the collaborative (1 if time period was during 2016, 0 if otherwise)
\(^1\)Indicator variable for teaching facilities (includes major and minor), non-teaching omitted as reference category
\(^2\)Indicator variables for major and minor teaching facilities, non-teaching omitted as reference category
\(^3\)Indicator variable for rural facilities, urban omitted as reference category
\(^4\)Indicator variables for DSH patient percentage, no DSH patients omitted as reference category
\(^5\)Indicator variable for low DSH patient percentage or no DSH patients, high and medium DSH patient % omitted as reference category
\(^6\)Indicator variable for downstate facilities, upstate omitted as reference category
\(^7\)Indicator variables for regions, Northeastern New York State omitted as reference category
Figure 2: Predictive Margins of Difference-in-Differences Model 1 and Model 2

Model 1

Predictive Margins with 95% CIs

Linear Prediction - CDI/1000 Patient Discharges


Pre- to Post-Antibiotic Stewardship Collaborative Implementation

Non-Collaborative  Collaborative  As observed

Model 2

Predictive Margins with 95% CIs

Linear Prediction - CDI/1000 Patient Discharges


Pre- to Post-Antibiotic Stewardship Collaborative Implementation

Non-Collaborative  Collaborative  As observed
Table 4: Key Informant Interview Responses for Hospitals with Consistent Participation, Inconsistent Participation, and Non-Participating Facilities

<table>
<thead>
<tr>
<th>Consistent participation</th>
<th>When did you become involved with HANYS' Antibiotic Stewardship Collaborative, and what has been the context of your involvement?</th>
<th>How was the decision to join the Collaborative made: organizational push or single champion?</th>
<th>What do you think is the value in joining a collaborative such as this?</th>
<th>What has been the response from other hospital staff in regards to your facility's involvement in the Collaborative?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Our facility has been involved since the program began; we frequently attend webinars and disseminate the information to hospital staff. We also discuss the antibiotic usage reports with physicians.</td>
<td>I am not sure… I believe it was an organizational push; our facility is an active member in other HANYS’ programs.</td>
<td>It is great to hear what other hospitals are doing; it’s good to hear other ideas and successes and challenges, sharing with other facilities—we’ve used ideas we’ve heard on the webinars at our facility with great success.</td>
<td>Our staff have found the education to be valuable.</td>
</tr>
<tr>
<td></td>
<td>Our facility has been involved since the program began. We submit our data to HANYS monthly and attend all the educational webinars.</td>
<td>It was an organization decision – many of our top administrators were very interested in joining the program.</td>
<td>Definitely makes us more conscious of where we are in terms of using our antibiotics – if we’re over or under utilizing” – and provided awareness to where we are compared to peers; we have used this information to do further investigation to assess appropriateness</td>
<td>Staff response has been positive – no challenges here – everyone is on board; the education has been very useful.</td>
</tr>
</tbody>
</table>
and have educated our providers. The data is encouraging...it's motivating when we see the numbers trending down for some antibiotics we’ve been working to reduce over use of.

<table>
<thead>
<tr>
<th>Our facility joined the collaborative in 2017, once I started in this role. I thought it was a really great program and pushed us to move forward with it.</th>
<th>It was a single champion that pushed the program forward; they believed it was a good idea and that the data would be really useful.</th>
<th>It is nice to see how we’re doing compared to other hospitals in the state – not sure how we would know this otherwise.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our facility has been involved since the Collaborative began. We created a stewardship team of pharmacists and some hospitalists to coordinate Collaborative activities, such as arranging for attendance at webinars and dissemination of.</td>
<td>Both. There was pressure from management given then new Joint Commission standards around antibiotic stewardship; they felt strongly it was time to make antibiotic stewardship a priority—then someone identified the HANYS Collaborative as a good.</td>
<td>The webinars have been very helpful...specifically, hearing from other facilities that had problems we shared. We all had common problems but everyone had a different perspective on how to approach them; we also had some more unique.</td>
</tr>
<tr>
<td>We are happy we are monitoring our usage and reporting to someone in somewhat of a “monitoring” capacity...and happy there is an organization helping us to know if we’re doing things right.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It has been a multidisciplinary effort– which has improved buy-in; on webinars we would have a variety of individuals attending. I would say the Collaborative has been fully embraced at this point, but there was some initial push back.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inconsistent participation</td>
<td>Our facility has been involved since the beginning of the Collaborative. We collect and send data to HANYS, attend webinars as we can, and have presented about their experience with stewardship at educational events.</td>
<td>It was mostly a single champion, the combined efforts of myself and the quality department pushed to get the executives on board with joining the collaborative; once executives were supportive, it provided the leverage required for IT to develop the necessary solutions to do the data reporting...they had otherwise been “dragging their feet.”</td>
</tr>
<tr>
<td>Our facility joined the Collaborative at the start. We have been submitting data throughout and spoke on a webinar to share</td>
<td>It was an organization-wide priority, for sure.</td>
<td>It has been really valuable just being able to get a sense of what is happening at other facilities in terms of antibiotic usage</td>
</tr>
</tbody>
</table>
what has worked for us in our antibiotic stewardship efforts.

<p>| We have been involved with the Collaborative since the beginning; unfortunately due to staffing issues, we are behind on submitting data. | Organization push. | The collaborative has helped our facility build the receipt of therapy data – but some of the antibiotics are not ones we use, and comparative data is sometimes comparing “apples to oranges”...antibiotic needs are different due to population differences. | Data reports have been helpful for providing some data but webinars are not new information – it’s the same people talking about the same things in different forums; mostly this is not relevant for those facilities with stewardship programs already in place – and we don’t want to hear from people with “perfect programs,” we want to hear from people with imperfect programs coming up with innovative solutions to make the best use of the resources they have. . .it has all been a little “cookie cutter”. . .this is one of the main reasons, in my opinion, people have lost engagement in the |</p>
<table>
<thead>
<tr>
<th>Did you experience any challenges in executing Collaborative activities? (reporting prescribing data to HANYS, attending webinars)</th>
<th>What do you think are the most important &quot;lessons learned&quot; from your facility's participation in Collaborative activities?</th>
<th>Has participation in the collaborative influenced your facility’s Antibiotic Stewardship efforts? How?</th>
<th>What do you think is the most valuable aspect of the collaborative? (i.e. - antibiotic prescribing data collection, data reports, education, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consistent participation</strong></td>
<td>We've experienced push back from physicians regarding the usage data – “those are not peer hospitals,” etc.; we've also had some issues with getting the IT in place to reflect correct populations (excluding pediatrics).</td>
<td>It’s been great for hearing other hospitals’ approaches to Antibiotic Stewardship and C. difficile prevention; it’s great to stay up on current practices.</td>
<td>Prior to the collaborative, we were using strategies and tips from all over the place, and now we have a more streamlined place for education (proven strategies directly from people who’ve actually used them).</td>
</tr>
<tr>
<td></td>
<td>Everything was brand new to us in terms of the requirements for data reporting but our IT Pharmacist was on top of it – they did a lot of research and were able to come up with the necessary solutions to be able to generate the data automatically.</td>
<td>Joining the collaborative gave us a new perspective on our prescribing practices...it gave us some important questions to ask... things that were very helpful that without the collaborative we wouldn't have known to ask; the comparative reports allow us to see</td>
<td>The collaborative has changed our approach tremendously through incorporation of the data reports into our existing program.</td>
</tr>
<tr>
<td></td>
<td>The collaborative has</td>
<td></td>
<td>All aspects are great and valuable! The education in the beginning was great – it allowed us to build a a good foundation; the data reports allow us to know if we’re headed in the right direction.</td>
</tr>
</tbody>
</table>
our progress over time, which is very valuable.

We had to have IT write, develop, and integrate a report into the EMR to be able to report our data to HANYS, and that was difficult...a lot at first to tackle...but now things are easy; I have not really attended any ASP events...however, I went to one on Sepsis that was really great. We haven’t really learned anything all that ground-breaking...it was nice to see that we’re not over-prescribing drugs, compared to others...we learned we use the same trio of antibiotics, which are the standard of care and on our order sets...this lets us know the docs are following both of these, which is good; sometimes no news is good news. Not really, no...we actively review the reports and are prepared to respond if we notice an issue, but so far we are doing well. It’s the awareness of where we stand compared to other facilities that the reports provide; it’s nice to be able to take a good look at yourself and what others are doing. If you do this, you’re bound to find out something, whether it’s good or bad, or just confirming you’re on the right track...this is important stuff and no one should be sitting idly by...staying out in front is important to making sure problems don’t arise.
We had a piecemeal IT system where each component – pharmacy, billing, etc. – is a different software solution, making it very difficult to get the infrastructure in place. It took about 8-10 days’ worth of work for an IT professional and pharmacist; though, we’ve heard that with other EMRs it is much faster…and we are in the process of switching to EPIC; the organization quickly recognized we were very far behind on stewardship and made it a priority, which led us to find the collaborative – specifically, we had a C. diff issue; however, we’ve decreased many of our antibiotic offenders by one third.

We learned there’s no “one way” to do anything when it comes to Antibiotic Stewardship – we had some common problems and we had unique problems – and we all learned from each other…we wouldn’t be where we are today without the collaborative.

It really has! In the beginning, our antibiotic stewardship efforts were limited and very siloed to just pharmacy – the collaborative helped us to understand the importance of pulling in other providers.

Everything! If I had to pick one thing, it would be the comparative data. We now have our own goals we track monthly all based on the comparative numbers HANYS provides; we used to be an outlier, now we are close to the gold standard. When we saw we were an outlier, we did some deep dives – our zosyn rates were twice that of peer hospitals – we developed a multidisciplinary team that meets daily to evaluate appropriateness of zosyn prescriptions and limited prescribing to 3 days – as well as did massive education. We’ve reduced our use by 34%.
<table>
<thead>
<tr>
<th>Inconsistent participation</th>
<th>Competing priorities make it difficult to attend webinars at times; we've experienced challenges reporting data to HANYS on a timely manner recently because our financial department recently changed systems.</th>
<th>I knew what needed to happen at our facility and had a gut feeling of where we were in terms of prescribing but needed data to facilitate discussions with providers; this collaborative provided programmatic structure for getting leadership buy-in to move in the right direction; once leadership was supportive of our facility joining the collaborative, it was all I needed to get IT moving on putting the necessary infrastructure solutions in place to begin reporting prescribing data.</th>
<th>It has changed it tremendously; it has provided the tools necessary to convince docs to change prescribing behavior and provided some serious data to share with physicians.</th>
<th>In the beginning it was the data reports to see where we were with certain drugs, and then it became benchmarking, then it became access to subject matter experts – each component has incredible value, not just one element.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No specific challenges; once the reporting capabilities were put into place, which took minimal building in the EMR, reporting has gone smoothly.</td>
<td>Thanks to the comparative reports, we were able to look at utilization rates compared to others in the Collaborative; we noticed overuse of a particular antibiotic compared to other</td>
<td>Not that much – it has provided targets to work towards and the comparative data is great to offer as an additional data source, but it has been integrated into existing efforts.</td>
<td>The reports are good; webinars were especially helpful early on but not so much as of late.</td>
<td></td>
</tr>
</tbody>
</table>
facilities and looked into ways to improve it.

It has been difficult attending webinars with competing priorities – and the education has not been very good; multiple initiatives makes it hard to give full attention to the program.

We would advise you to talk to your stakeholders that are already in the program and find out what they need, and who they would like to hear from – variety is important. For example the webinar “A look at the AUR module” back in 2017...we all know the module is super complicated and needs IT support so this is not very helpful – it should have focused on “how do we go to leadership to ask for this;” figure out what people need when they join (or even now) so you can offer a variety of webinars that would be valuable to participants at all levels; it’s the same roster of subject matter experts being recycled by all organizations (HANYS, GNY, etc.) on stewardship – offer some variety – maybe

The collaborative really hasn’t impacted our approach but we felt it would look bad if we didn’t join a HANYS initiative, and the usage reports were enticing; but it has been hard to get the staffing to provide this data to HANYS (it’s the interviewee’s responsibility for all facilities) so now we're considering just reporting to the AUR so we can get comparative data from NHSN, given some of the problems with the HANYS comparisons. The reporting in the AUR modules requires hospitals to provide data in a specific structure, which is very different from the excel file we provide to HANYS...so we feel how the collaborative prepares hospitals for reporting

Data reports are the most valuable – and recently they have been better, now that they have taken into consideration hospital size and other characteristics. However, they still compare facilities that are not alike even with the addition of these characteristics (for example, some facilities with drastic differences in the number of residents, as well as specialty floors like oncology). In addition, recent shortages for some antibiotics have introduced further complexity into the comparative data.
look out of state for new perspectives? Perhaps create tiers to reflect different points hospitals might be on their stewardship journey and offer content classified according to the tiers and provide something for all levels.

<table>
<thead>
<tr>
<th>How would you describe your familiarity with the Antibiotic Stewardship Collaborative and its activities?</th>
<th>In your opinion, what do you think is the main reason your facility opted not to join the Collaborative?</th>
<th>What do your current Antibiotic Stewardship efforts involve? Formal/informal?</th>
<th>What do you think would have made joining the Antibiotic Stewardship Collaborative more attractive to your facility?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Not participating</strong></td>
<td>We submitted some data a few years ago and explored the collaborative but decided not to pursue it because of capabilities lacking in the pharmacy EMR.</td>
<td>The necessary reports for data reporting prescribing practices were not built into the pharmacy EMR.</td>
<td>We look at specific antibiotics, restricted or not, to determine if they are being used appropriately. We also provide education by the pharmacy. We consider it a formal program at our facility but we're not following any prescribed guidelines (such as the CDC's Core Elements of a Hospital Antibiotic). We have a lot items “on our plate;” it is very difficult for hospital staff to attend and participate in the collaborative activities given their other duties and concurrent initiatives (NYSPFP). We believe there are a lot of great initiatives out there but many are duplicative to what our facility is already doing. However, we do feel the</td>
</tr>
<tr>
<td>We thoroughly considered joining and researched what would be required and felt we could not give what was necessary in terms of data; however, we try to attend all webinars related to Antibiotic Stewardship.</td>
<td>There are reporting requirements we were not set up to provide and we didn’t have the resources to put them in place; we only had an interim pharmacist for a long time that did not want to participate in the collaborative, as they didn’t feel like they could handle what was required for the collaborative in addition to their daily job responsibilities. Now we have a new pharmacist who is overwhelmed with correcting things resulting from the management of the interim pharmacist. At our current staffing</td>
<td>We recently started a committee on antibiotic stewardship, which has formalized our efforts somewhat. However, we recently proposed an escalation policy but cannot get buy-in for it. We have done some reviews and “look backs”....I would describe it as pretty informal overall; because we are a smaller facility we don’t use many antibiotics, as critical patients get transferred to larger facilities...so it’s never been put in the budget to assign a leadership role to antibiotic stewardship efforts,</td>
<td>A more formal and concerted push from HANYS regarding the importance of joining the Collaborative would help get the buy-in we need—if it was somehow a mandate...or more like a mandate...we could use it as leverage to potentially get the necessary resources allocated.</td>
</tr>
</tbody>
</table>
capacity, taking time out to review an antibiotics use report, or preparing to report antibiotic usage data is impossible – we would like to put the infrastructure in place but that requires the support of pharmacy and not enough resources have currently been allocated. which makes it difficult to prioritize.
Table 5: Sample Characteristics of New York State Acute Care Hospitals and Systems by CMS Certification Level Number (CCN) Q2, 2013-Q1, 2016 (N=151)

<table>
<thead>
<tr>
<th>Non-Clinical Characteristics</th>
<th>Total Hospitals (n = 151)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/Rural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>33</td>
<td>21.9%</td>
</tr>
<tr>
<td>Urban</td>
<td>118</td>
<td>78.2%</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central New York(^a)</td>
<td>24</td>
<td>15.9%</td>
</tr>
<tr>
<td>Western New York(^b)</td>
<td>15</td>
<td>9.9%</td>
</tr>
<tr>
<td>Northeastern New York(^c)</td>
<td>18</td>
<td>11.9%</td>
</tr>
<tr>
<td>Rochester Area(^d)</td>
<td>16</td>
<td>10.6%</td>
</tr>
<tr>
<td>Long Island(^e)</td>
<td>20</td>
<td>13.2%</td>
</tr>
<tr>
<td>Northern Metropolitan Area(^f)</td>
<td>23</td>
<td>15.2%</td>
</tr>
<tr>
<td>New York City(^g)</td>
<td>35</td>
<td>23.2%</td>
</tr>
<tr>
<td>DSH Patient Percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>34</td>
<td>22.5%</td>
</tr>
<tr>
<td>Medium</td>
<td>34</td>
<td>22.5%</td>
</tr>
<tr>
<td>Low</td>
<td>74</td>
<td>49.0%</td>
</tr>
<tr>
<td>No</td>
<td>9</td>
<td>6.0%</td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>141</td>
<td>93.4%</td>
</tr>
<tr>
<td>Critical Access Hospital (CAH)</td>
<td>10</td>
<td>6.6%</td>
</tr>
<tr>
<td>Teaching Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Teaching</td>
<td>50</td>
<td>33.1%</td>
</tr>
<tr>
<td>Major Teaching</td>
<td>37</td>
<td>24.5%</td>
</tr>
<tr>
<td>Non-Teaching</td>
<td>64</td>
<td>42.4%</td>
</tr>
</tbody>
</table>

Clinical Characteristics

| * Total Discharges                             | 15132                     |
| * % Medicare                                   | 42.9%                     |
| ** ALOS                                        | 5.24                      |
| ** APR-DRG CMI                                 | 1.33                      |
| *** Adjusted CDI (CDI/1000 disch)              | 2.27                      |
| *** Adjusted CDI (CDI/1000 disch) - ED Admits Only | 1.69                   |

\(^1\) Federal Healthcare Cost Report designation (E-A, line 21)

\(^2\) HANYS region classifications by county

\(^a\) Broome, Cayuga, Chenango, Cortland, Herkimer, Jefferson, Lewis, Madison, Oneida, Onondaga, Oswego, St. Lawrence, Tioga, Tompkins

\(^b\) Allegany, Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans, Wyoming
d Chemung, Livingston, Monroe, Ontario, Schuyler, Steuben, Wayne, Yates
c Nassau, Suffolk
d Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, Westchester
g Bronx, Kings, New York, Queens, Richmond
3 HANYS classification of DSH patient percentage: high > 75%, medium 25-75%, low 0-25%, no = 0%
4 NYS designation in SPARCS
5 HANYS classification for teaching status: major = IBR ≥ .25 or residents > 100, minor = IBR 0 - .25 or residents < 100, non = no residents
* Annual average
** Monthly averages
*** Adjusted CDI = (average annual CDI counts/average annual discharges)*1,000
Figure 3: Scatter Plots of Main Variables of Interest and Their Relationship to HA-CDI Rates
HCAHPS: room "sometimes" or "never" kept clean

Fitted values

CDI Rate
Table 6: Parameter Estimates for Fixed Effects Models of Emergency Department Wait Times (Q2, 2013 - Q1, 2016) , N = 432, and Patient-Reported Room Cleanliness in New York State Hospitals. (12/2013 - Q2, 2016), N = 444

| Variable | (1) ED Wait Times | | | (2) Patient Reported Room Cleanliness | | | (3) Patient Reported Room Cleanliness | |
|----------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|          | β (SE) | Stand. β | P     | β (SE) | Stand. β | P     | β (SE) | Stand. β | P     |
| * Emergency Department Wait Time (Minutes) | 0.003 (0.001) | 0.310 | <.001 | - | - | - | - | - | - |
| ** HCAHPS: % of patients who indicated their room was "always" clean<sup>1</sup> | - | - | - | - | - | - | - | - | - |
| ** HCAHPS: % of patients who indicated their room was "sometimes" or "never" clean<sup>2</sup> | - | - | - | - | - | - | 0.029 (0.019) | 0.071 | 0.13 |
| Response Rate | - | - | - | - | 0.023 (0.010) | 0.123 | 0.02 | 0.021 (0.010) | 0.109 | 0.047 |
| Total Discharges | 0.000 (0.000) | 0.074 | 0.38 | 0.000 (0.000) | 0.350 | <.001 | 0.000 (0.000) | 0.369 | <.001 |
| Percent Medicare Discharges | 2.165 (0.464) | 0.231 | <.001 | 2.815 (0.570) | 0.245 | <.001 | 2.796 (0.576) | 0.244 | <.001 |
| APRDRG-Case Mix Index | 0.163 (0.121) | 0.097 | 0.18 | 0.000 (0.000) | 0.026 | 0.67 | 0.000 (0.000) | 0.026 | 0.67 |
| Average Length of Stay | 0.100 (0.052) | 0.123 | 0.05 | 0.366 (0.060) | 0.366 | <.001 | 0.378 (0.060) | 0.378 | <.001 |

*Emergency department wait time is on a Q2-Q1 schedule (4/2013-3/3014, 4/2014-3/3015, 4/2015-3/3016); control variables from SPARCS have been calculated to reflect these time periods

**HCAHPS measures are on the following schedule: 1/2013-12/2013, 4/2014-3/2015, 4/2015-3/2016; control variables from SPARCS have been calculated to reflect these time periods

<sup>1</sup>"Usually" and "sometimes" or "never" omitted as reference categories

<sup>2</sup>"Always" and "usually" omitted as reference categories
Item 2: Survey Instrument—NYS Hospital Adoption of Electronic Hand Hygiene Monitoring Systems

In collaboration with Rockefeller College of Public Affairs and Policy, HANYS’ Division of Quality, Advocacy, Research and Innovation seeks your input on the following survey questions for a research project assessing statewide proliferation of electronic hand-hygiene monitoring systems, and the efficacy of such systems.

GENERAL QUESTIONS

1. Please select your facility from the list below. [DROP-DOWN LIST]

2. Please select the statement that best describes your facility's experience with electronic hand-hygiene monitoring systems.
   - o We are not familiar with such technology
   - o We briefly considered pursuing such technology and decided against implementation
   - o We thoroughly considered pursuing such a system and decided against implementation
   - o We have a system identified and will procure and implement it soon
   - o We are in the process of implementing such a system
   - o We have implemented such a system and are using it to monitor and improve hand hygiene compliance rates

HAVE NOT IMPLEMENTED AN ELECTRONIC HAND HYGIENE MONITORING SYSTEM

3. Please indicate why your facility has NOT implemented an electronic hand hygiene monitoring system (select all that apply).
   - o We are not familiar with such technology
   - o There is not enough evidence to support how effective they are in reducing infection rates
   - o There is not enough evidence to support how effective they are in improving hand hygiene compliance
   - o These systems require too much initial investment of money and staff resources to implement
   - o These systems do not provide a good return on investment
   - o Employees would not respond well to having their hand hygiene constantly monitored
   - o We already have enough technological systems to manage and maintain; we did not want to add to that burden
   - o We were not able to get enough buy-in from executive leadership
   - o The ability of such systems to accurately monitor hand hygiene is questionable
   - o OTHER: ________________________________________
4. Please select the description that best matches your current approach to hand-hygiene surveillance.
   ○ Direct observation of staff hand-hygiene
   ○ Monitoring product use
   ○ Conducting staff hand-hygiene surveys
   ○ A combination of one or more of the above
   OTHER: ________________________________________

5. Please select the statement below that best represents your plans for implementing an electronic hand hygiene monitoring system in the future.
   ○ We do not plan to revisit this again - these systems will never be right for our facility
   ○ We plan to revisit this again in 5-10 years
   ○ We plan to revisit this again in 3-5 years
   ○ We plan to revisit this again in 1-3 years
   ○ We plan to revisit this again in < 1 year
   ○ Not sure

HAVE IMPLEMENTED AN ELECTRONIC HAND HYGIENE MONITORING SYSTEM

6. Please select the statement below that best represents your experience with implementation of an electronic hand-hygiene monitoring system.
   ○ The system was much more difficult to implement than expected
   ○ The system was somewhat more difficult to implement than expected
   ○ The system was as expected to implement
   ○ The system was easier to implement than expected
   ○ The system was much easier to implement than expected

7. Please select the statement below that best represents your experience in terms of staff acceptance with implementing an electronic hand-hygiene monitoring system.
   ○ Staff members are very unhappy with the change
   ○ Staff members are unhappy with the change
   ○ Staff members are neither happy, nor unhappy with the change
   ○ Staff members are happy with the change
   ○ Staff members are very happy with the change

8. Please select the statement below that best represents your experience in terms of infection rates after implementation of an electronic hand-hygiene monitoring system.
   ○ Infection rates worsened
   ○ Infection rates remained the same
   ○ Infection rates improved minimally
   ○ Infection rates have improved moderately
   ○ Infection rates have improved greatly

9. Please select the statement below that best represents your experience in terms of return on investment after implementation of an electronic hand-hygiene monitoring system.
We have not recuperated any of the implementation costs, and the costs of keeping up the system drive losses higher

We have recuperated some or all of the implementation costs, but the costs of keeping up the system put us at a loss

Implementation and up-keep costs of the system have been equally outweighed by savings from reduced infections

We have recuperated all costs and are seeing a moderate return on investment in the form of reduced infection rates

We have recuperated all costs and are seeing a significant return on investment in the form of reduced infection rates

10. Do you believe your facility's implementation of an electronic hand-hygiene monitoring system to be a source of competitive advantage?
   o Yes
   o No

NAME OF SYSTEM

11. Please indicate below the name of the system you will be implementing or have implemented.
   [TEXT BOX]

CLOSING

12. Would you be interested in speaking to one of our researchers in greater detail about this topic? The interviews will be conducted over the phone and should last only about 20 minutes. Responses will be aggregated; individual responses will not be shared. These interviews will help us to add more context to the survey findings.
   o Yes
   o No

13. If yes, please provide the following information
   Name [TEXT BOX]
   Email Address [TEXT BOX]
Table 7
Comparison of Characteristics of Full Population of Acute and Critical Access Hospitals in New York State and EHHMS Adoption Survey Respondents

<table>
<thead>
<tr>
<th>Non-Clinical Characteristics</th>
<th>EHHMS Survey Respondents (n = 56)</th>
<th>All Acute and CAH Hospitals (n = 184)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Urban/Rural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>64.3%</td>
<td>78.3%</td>
</tr>
<tr>
<td>Rural</td>
<td>35.7%</td>
<td>21.7%</td>
</tr>
<tr>
<td>2Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central New Yorka</td>
<td>14.3%</td>
<td>14.1%</td>
</tr>
<tr>
<td>Western New Yorkb</td>
<td>12.5%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Northeastern New Yorkc</td>
<td>19.6%</td>
<td>10.9%</td>
</tr>
<tr>
<td>Rochester Aread</td>
<td>16.1%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Long Islandd</td>
<td>5.4%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Northern Metropolitan Areaf</td>
<td>5.4%</td>
<td>13.6%</td>
</tr>
<tr>
<td>New York Cityg</td>
<td>26.8%</td>
<td>27.7%</td>
</tr>
<tr>
<td>3Upstate/Downstate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upstate</td>
<td>62.5%</td>
<td>46.7%</td>
</tr>
<tr>
<td>Downstate</td>
<td>37.5%</td>
<td>53.3%</td>
</tr>
<tr>
<td>4DSH Patient Percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>21.4%</td>
<td>22.3%</td>
</tr>
<tr>
<td>Medium</td>
<td>55.4%</td>
<td>53.3%</td>
</tr>
<tr>
<td>Low</td>
<td>17.9%</td>
<td>19.0%</td>
</tr>
<tr>
<td>No</td>
<td>5.4%</td>
<td>5.4%</td>
</tr>
<tr>
<td>5Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>94.6%</td>
<td>94.6%</td>
</tr>
<tr>
<td>Critical Access Hospital (CAH)</td>
<td>5.4%</td>
<td>5.4%</td>
</tr>
<tr>
<td>6Teaching Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Teaching</td>
<td>19.6%</td>
<td>23.4%</td>
</tr>
<tr>
<td>Major Teaching</td>
<td>35.7%</td>
<td>39.7%</td>
</tr>
<tr>
<td>Non-Teaching</td>
<td>44.6%</td>
<td>37.0%</td>
</tr>
</tbody>
</table>

Clinical Characteristics

* Total Discharges 10961.72 14461.71
* ALOS 5.41 5.39
* APR-DRG CMI 1.09 1.13
** Adjusted CDI (CDI/1000 disch) 2.13 2.39

Payer Profile (of total discharges)
* % Medicare 42.76% 41.2%
  % Medicare Managed
* Care 14.73% 14.6%
  % Medicare Non-
* Managed Care 28.03% 26.6%

1Federal Healthcare Cost Report designation (E-A, line 21)
2HANYS region classifications by county
  aBroome, Cayuga, Chenango, Cortland, Herkimer, Jefferson, Lewis, Madison, Oneida, Onondaga, Oswego, St. Lawrence, Tioga, Tompkins
  bAllegany, Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans, Wyoming
  dChemung, Livingston, Monroe, Ontario, Schuyler, Steuben, Wayne, Yates
  eNassau, Suffolk
  fDutchess, Orange, Putnam, Rockland, Sullivan, Ulster, Westchester
  gBronx, Kings, New York, Queens, Richmond
3HANYS classification, regions above (upstate) or at or below (downstate) the Northern Metropolitan Area
4HANYS classification of DSH patient percentage: high > 75%, medium 25-75%, low 0-25%, no = 0%
5NYS designation in SPARCS
6HANYS classification for teaching status: major = IBR ≥ .25 or residents > 100, minor = IBR 0 - .25 or residents < 100, non = no residents
*Monthly averages
**Adjusted CDI = (average monthly CDI counts/average monthly discharges)*1,000
6) **Explanation of the purpose of the interview; informed consent and confidentiality; get permission to take notes.**

Before we start, I would like to thank you for taking the time to speak with me. I know that you are very busy, and I really appreciate your willingness to do this interview.

In partnership with the Quality Advocacy, Research and Innovation division at HANYS, I am working to assess NYS hospitals’ experience with using electronic hand hygiene monitoring systems (like badges with RFID tags) to improve hand hygiene compliance. This assessment project will make up a portion of my PhD dissertation at Rockefeller College of SUNY Albany. As a part of this project, I am conducting interviews with several NYS hospital representatives - both with and without experience using EHHMSs, to gather insights into the extent to which hospitals in the state have or have not pursued these systems, and their experiences implementing and using them; these interviews will supplement findings from a recent survey on the same subject. Our intent is to compile and share experiences with EHHMSs from across the state to assist member hospitals in determining if these technologies are right for them. Your participation in this interview will help make this possible. Our plan is to pool the insights provided and share with member hospitals (as aggregated data) in a publication.

I expect this interview will last about 20 minutes. Any information that is obtained through this study will remain **strictly confidential**. All data will be reported in aggregate form only, and we will ensure that you or your facility will not be identified in the final report. Your participation is strictly voluntary. You may stop the interview at any time and you have the right to decline to answer any question.

I will take notes as we speak, so please be patient if I seem to pause for a bit, and only I will see these notes.

**Do you have any questions up to this point about interview logistics?**

7) **Warm up questions—building rapport**

Before we dive into the main questions, I wanted to start by asking you some questions about your role at your facility.

- What is your position with XXX hospital?
- What role do you play in infection control at your facility?
- What are your thoughts on the new technology that is emerging to help improve hand hygiene monitoring and hand washing rates?
Has your facility implemented an electronic monitoring system for hand hygiene, or are currently pursuing implementation of such a system? (if "no," skip to 4)

8) Implementation

I would now like to gather more specific information on how the program was implemented.

- Please describe the electronic monitoring system your facility is using for hand hygiene (brand/company?). Has it been implemented facility-wide or on just specific units? Was there a trial or pilot program done before full implementation?
- How was the decision made to pursue an electronic monitoring system for hand hygiene?: top-down organizational push or single champion?
- How long did it take your facility to implement this technology - from procurement to a fully operational system?
- Have you experienced a return on investment since implementing this new system? If no, do you expect to?
- What has been the response of leadership and/or staff since the system was implemented?
- What have been the greatest successes, challenges, or “lessons learned” to date from using this system?
- What advice do you have for other hospital administrators considering adoption of an electronic monitoring system for hand hygiene?

9) Not Using Hand Hygiene Technology

- What do you think are the main reasons your facility did not pursue electronic monitoring systems for hand hygiene after considering it?
- Do you think you will reconsider such systems again in the future? Why?
- How does your facility currently monitor hand hygiene rates and improve compliance?

10) Conclusion

- Before we finish our discussion, do you have any other comments on electronic monitoring systems for hand hygiene?
- I hope that I can get back to you with additional questions if they arise. Is that okay with you?
<table>
<thead>
<tr>
<th>Electronic Hand Hygiene Monitoring System</th>
<th>Number of Facilities (n = 56)</th>
<th>Average Monthly Discharges</th>
<th>Average CDI Rate*</th>
<th>Average Length of Stay</th>
<th>APR-DRG CMI</th>
<th>We have implemented such a system and are using it to monitor and improve hand hygiene compliance rates.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioVigil (1), Deb Med (1)</td>
<td>2</td>
<td>1,022.28</td>
<td>2.73</td>
<td>5.71</td>
<td>1.11</td>
<td>2</td>
</tr>
<tr>
<td>BioVigil (2), Versus (1), Undecided (2)</td>
<td>3</td>
<td>835.69</td>
<td>2.25</td>
<td>4.41</td>
<td>1.58</td>
<td>3</td>
</tr>
<tr>
<td>BioVigil (2)</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>We are in the process of implementing such a system.</td>
<td>3</td>
<td>835.69</td>
<td>2.25</td>
<td>4.41</td>
<td>1.58</td>
<td>3</td>
</tr>
<tr>
<td>BioVigil (2)</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>We have a system identified and will procure and implement it soon.</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>BioVigil (2)</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>We thoroughly considered pursuing such a system and decided against implementation.</td>
<td>9</td>
<td>874.40</td>
<td>2.24</td>
<td>5.96</td>
<td>1.07</td>
<td>9</td>
</tr>
<tr>
<td>BioVigil (2)</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>We briefly considered pursuing such technology and decided against implementation.</td>
<td>28</td>
<td>811.63</td>
<td>1.90</td>
<td>5.24</td>
<td>1.07</td>
<td>28</td>
</tr>
<tr>
<td>BioVigil (2)</td>
<td>2</td>
<td>866.83</td>
<td>1.16</td>
<td>8.55</td>
<td>0.93</td>
<td>2</td>
</tr>
<tr>
<td>We are not familiar with such technology.</td>
<td>12</td>
<td>1,098.02</td>
<td>2.43</td>
<td>4.68</td>
<td>0.99</td>
<td>12</td>
</tr>
</tbody>
</table>

*Adjusted CDI = average monthly CDI counts/average monthly discharges
Table 9
EHHMS Survey Responses to, "please indicate why your facility has NOT implemented an electronic hand-hygiene monitoring system"*

<table>
<thead>
<tr>
<th>Reason</th>
<th>Counts</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is not enough evidence to support how effective they are in reducing infection rates.</td>
<td>4</td>
<td>8.2%</td>
</tr>
<tr>
<td>There is not enough evidence to support how effective they are in improving hand hygiene compliance.</td>
<td>9</td>
<td>18.4%</td>
</tr>
<tr>
<td>These systems require too much initial investment of money and staff resources to implement.</td>
<td>39</td>
<td>79.6%</td>
</tr>
<tr>
<td>Employees would not respond well to having their hand hygiene constantly monitored.</td>
<td>2</td>
<td>4.1%</td>
</tr>
<tr>
<td>We already have enough technological systems to manage and maintain; we did not want to add to that burden.</td>
<td>5</td>
<td>10.2%</td>
</tr>
<tr>
<td>We were not able to get enough buy-in from executive leadership.</td>
<td>11</td>
<td>22.4%</td>
</tr>
<tr>
<td>The ability of such systems to accurately monitor hand hygiene is questionable.</td>
<td>14</td>
<td>28.6%</td>
</tr>
<tr>
<td>We are not familiar with such technology.</td>
<td>12</td>
<td>24.5%</td>
</tr>
</tbody>
</table>

Other:
- Concern for the need to support more network infrastructure
- Prevention is not their [executive leadership's] priority
- Expensive but very infection prevention compliant
- Maintenance costs; there is discussion on piloting the technology at a sister facility
- The system we looked at did not measure hand washing with soap and water
- The system we looked at needed the employee to wear a badge, currently nurses wear Vocera and a locator badge
- We currently use the Joint Commission TST to monitor HH compliance
- We just evaluated an electronic system and the annual cost is extremely high; systems will count hand hygiene observation even if the room is unoccupied
- Strictly movement into and out of the room is counted [with the system we considered]; I do not think we could get administrative support

*49 out of 56 hospitals were asked to respond to this question, respondents were asked to select all that apply
Figure 4: Quarterly Average HA-CDI Rates for Hospital A Pre- and Post-Implementation of an Electronic Hand Hygiene Monitoring System (EHHMS) Compared to all NYS Acute Care Hospitals (N = 184)
Figure 5: Quarterly Average HA-CDI Rates for Hospital B Pre- and Post-Implementation of an Electronic Hand Hygiene Monitoring System (EHHMS) Compared to all NYS Acute Care Hospitals (N = 184)
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