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Assessing Targeted Funding to State Health Departments: Can Federal Funding Develop Capacity for the Prevention of Healthcare-associated Infections?

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Abstract

Background

Healthcare-associated infections (HAIs) contribute to increased morbidity, mortality and healthcare costs in the United States and recently have gained attention as a national public health threat. A call to action has been issued by federal agencies to encourage incentives, research, surveillance, and the employment of evidence-based practices to forward progress towards the elimination of HAIs. Federal initiatives, including a Department of Health and Human Services action plan, Center for Medicare and Medicaid Service pay for performance incentives, and the American Recovery and Reinvestment Act (ARRA) funding to state health departments have supported an atmosphere of HAI awareness, surveillance, and prevention. To improve HAI prevention capacity, valid surveillance must be conducted to monitor ongoing rates and successes of prevention programs.

Methods

This project evaluates the HAI prevention capacity developed in the first year of ARRA funding at the state health department. Factor analysis is used to determine state health department characteristics before the receipt of ARRA funding that constitutes baseline capacity for HAI prevention. Descriptive statistics are used to quantify successes and barriers for each of the three targeted funding areas: Infrastructure, Surveillance, and Prevention Collaboratives. Finally, longitudinal mixed effects models are used to monitor state and national trends in participation in the National Healthcare Safety Network (NHSN).

Results

A factor analysis of capacity indicators extracted from state funding application materials revealed three distinct factors characterizing baseline HAI prevention capacity: Human Capital and Expertise, Campaigns and Trainings, and Collaborative Efforts. States receiving ARRA funding met programmatic goals in year one for all three targeted funding areas; however, all states reported barriers to implementation of activities. Longitudinal modeling of NHSN participation for facilities reporting CLABSIs in their ICUs in states without reporting mandates showed significant increases in rates of participation during the ARRA time period for states funded to improve surveillance capabilities.

Conclusions

Targeted federal funding appeared to successfully achieve programmatic year one goals for the development of state health department capacity for the prevention of HAIs. Future work should focus on continued programmatic success, as well as attempt to quantify outcomes such as infections prevented, deaths averted, and costs saved.

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Introduction

Healthcare-associated infections (HAIs) are potentially devastating complications for patients receiving medical care. The Centers for Disease Control and Prevention (CDC) defines HAIs as 'infections that patients acquire during the course of receiving healthcare treatment for other conditions', and estimates that one out of every 20 hospitalized patients will contract an HAI (Centers for Disease Control and Prevention, 2010a). These infections are caused by bacteria, fungi, and viruses that patients are exposed to while receiving their medical care. The World Health Organization (WHO) expresses concerns for HAIs across nations and healthcare facilities, and claim many obstacles to surveillance and prevention (World Health Organization, 2009). CDC estimates 1.7 million HAIs occurred in hospitals in 2002, and were associated with 99,000 deaths (Klevens et al., 2007). HAI death rates are higher than several of the top ten leading causes of deaths reported in vital statistics, and HAIs cause more deaths than any current notifiable disease (Klevens et al., 2007). CDC reports the cost estimates of HAIs to exceed $30 billion, with the most expensive HAI being surgical site infections (SSI) with a per annum cost in the range of $3.2-10.1 billion (Scott, 2009).

Public health leaders have deemed these numbers unacceptable (Cardo et al., 2010). A call to action has been placed by several partners along with the CDC to move towards elimination of HAIs (Cardo et al., 2010). Elimination, the maximum reduction of a disease's incidence and infection, has been successfully attained for diseases including polio, syphilis, and tuberculosis. Following in these footsteps, consistent and sustained action can support the elimination of HAIs. Four inter-dependent pillars have been recognized as necessary to create successful elimination: financial incentives, innovation and research, response to emerging threats (data for action), and evidence-based prevention practices (Cardo et al., 2010).

Evidence-based prevention practices, formed by scientific evidence, supported by financial incentives, and monitored by real-time surveillance will serve as the basis for large-scale elimination efforts. These practices are recommendations based on research conducted by experts in the field of infection prevention (Cardo et al., 2010). To facilitate the implementation of evidence-based practices, guidelines have been made available from several leading organizations including CDC, Society of Healthcare Epidemiology of America (SHEA), Infectious Disease Society of America (IDSA), and the Association for Professionals in Infection Control (APIC). CDC evidence-based guidelines are developed and monitored by the Healthcare Infection Control Practices Advisory Committee (HICPAC), a 14 member federal advisory group that primarily forms recommendations for the prevention and controls of HAIs (Centers for Disease Control and Prevention, 2010d). These organizations, including CDC and HICPAC, focus on promoting best practices to help reduce the general burden of HAIs.

From these recommendations, strategies for preventing HAI transmission have emerged including vigilant adherence to hand hygiene, injection safety, use of personal protective equipment, and environmental controls (Siegel et al., 2007a). For example, recommended practices for hand hygiene include specific indications for hand hygiene throughout the course of patient care and guidance for when to use specific products (e.g., soap and water versus alcohol-based handrubs) (Boyce and Pittet, 2002). Alcohol-based hand rubs are known to quickly and effectively kill microorganisms on hands (World Health Organization, 2009) and are an option for surgical hand hygiene (Boyce and Pittet, 2002). When implementing hand hygiene practices in healthcare facilities, it is important to be mindful of the complexity of both the institution (healthcare facility) and the individual (healthcare worker) (Boyce and Pittet, 2002). To improve adherence to practices such as hand hygiene, a three-part combination approach involving

education, motivation, and patient empowerment is needed. Educational approaches need to increase knowledge of how, when, and why to perform hand hygiene. Motivation can be promoted through role modeling, peer pressure, and constant visual reminders throughout the healthcare unit. Finally, patients should be empowered and systems changed both structurally and philosophically, with full support of healthcare leadership (Whitby et al., 2007). To minimize HAIs caused due to environmental (room or hospital level) exposures, recommendations are in place including appropriate use of cleaners/disinfectants, appropriate medical equipment maintenance, following water-quality for dialysis, ventilation standards in operating and isolation rooms, and management of water leaks (Sehulster and Chinn, 2003).

More specific guidelines exist for healthcare facilities and workers that detail which precautions (e.g., personal protective equipment use) are necessary for given infections or conditions (Siegel et al., 2007a). Guidance for prevention practices to reduce several HAIs is also made available from CDC for a breadth of common device associated, procedure associated, and general HAIs (Centers for Disease Control and Prevention, 2010c). Device-associated infections include central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and ventilator-associated pneumonia (VAP). Preventing device-associated infections would decrease financial costs and improve patient outcomes. Recommendations for the prevention of device-associated infections include education, performance assessment and feedback, adherence to basic infection control recommendations such as hand hygiene and isolation precautions, device insertion and maintenance, and ensuring proper staffing.

For prevention of CLABSI, education should emphasize appropriate central line use, strict adherence to central line insertion practices, sterile maintenance of central lines and

appropriate selection of sites (O'Grady et al., 2002). Another common area for HAIs is the urinary tract, which is estimated in US hospitals to account for 32% of all infections (Klevens et al., 2007). CAUTI guidelines have been available since 1981, and were updated in 2007 to include important recommended practices for the utilization of catheters only when necessary (not routinely), and using proper techniques for insertion and maintenance (Gould et al., 2010). For example, hand hygiene, gloving, and other sterile techniques are necessary and insertion and maintenance should only be performed by trained staff (Gould et al., 2010).

Other types of HAIs include procedure-related infections, which are infections that follow an operative procedure (either inpatient or outpatient) (Centers for Disease Control and Prevention, 2010g). SSIs occur after a surgical procedure and can vary from mild skin-deep infections to more invasive infections in the organs, and even occur inside the body on the surgically implanted material (Centers for Disease Control and Prevention, 2010b). SSIs are preventable through practices such as proper hand hygiene and aseptic surgical techniques (Centers for Disease Control and Prevention, 2010b). SSIs widely vary in location of infection on body, types of pathogens causing infection, risk factors for patients (e.g., age, smoking status, diabetes), and operating environment (e.g., cleanliness of operation and room) (Mangram et al., 1999). Recommended practices for prevention of SSIs include pre-operative techniques such as adhering to proper hair removal, antimicrobial prophylaxis use, and hand hygiene (Centers for Disease Control and Prevention, 2010b). Abiding by recommended intraoperative procedures (e.g., proper protocols, attire, ventilation) as well as adhering to postoperative recommendations (e.g., aseptic wound care), are critical for SSI prevention (Mangram et al., 1999).

Guidelines also are available for preventing the emergence and proliferation of multidrug resistant organisms (MDROs) that are ‘epidemiologically important’ in healthcare facilities.

These are organisms that tend to have high levels of transmission in healthcare facilities, and are difficult to treat due to their patterns of resistance (both natural and acquired) (Siegel et al., 2007b). Example organisms include, methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and *Clostridium difficile* (Siegel et al., 2007a, b). Guidelines to reduce antimicrobial resistance in healthcare settings use an evidence-based approach with four strategies: infection prevention, accurate and prompt diagnosis and treatment, prudent use of antimicrobials, and prevention of transmission. In a review of the management of MDROs in healthcare settings, studies successfully able to control MDROs were generally employing seven to eight different interventions in a bundled format (Siegel et al., 2007b). The seven categories of intervention types to improve practices were: administrative measures with adherence monitored, MDRO education, judicious antimicrobial use, surveillance of MDROs, infection control precautions to prevent transmission, environmental measures, and decolonization (however, this was not routinely recommended) (Siegel et al., 2007b). Bundling, the grouping together of evidence-based practices, have shown effectiveness not only for MDROs but other HAIs such as CLABSI and ventilator associated pneumonia (VAP) (Siegel et al., 2007b). Researchers believe that reducing the burden of these other diseases will reduce antimicrobial usage, which will help to alleviate the problem of MDROs (Siegel et al., 2007a).

With the knowledge of best practices for prevention gained from guidelines and recommendations, working in collaboration is needed to correctly measure increased adherence and incentivize personal and institutional accountability (Cardo et al., 2010). CDC defines a prevention collaborative as: 'facilities engaged in an effort to improve an outcome (reduction of HAIs) through a common approach, and regular sharing of lessons learned for the benefit of the group' (Centers for Disease Control and Prevention, 2010f). Collaboratives consist of multiple

facilities implementing evidence-based practices, with an emphasis on the sharing (collaborating) between hospitals to spread effective implementation solutions (Jernigan, 2009). In addition to adhering to best practices and improving organizational culture, collaboratives require monitoring and feedback of HAI rates, using data collected through standardized definitions and case finding methods. Successful collaboratives share data and experiences with other facilities and other outside stakeholders such as state health departments, payers, quality improvement organizations (QIOs), and hospital associations (Cardo et al., 2010). An example of joining organizations together for HAI prevention was the 2004 launch of the 100,000 Lives Campaign where the Institute for Healthcare Improvement (IHI) coordinated joint efforts between multiple stakeholders and hospitals (Berwick et al., 2006).

When IHI announced the 100,000 Lives Campaign, they had a simple goal: save 100,000 lives in 18 months. 'Saving lives' was measured by the number of patients with successful discharges from the hospital who, without changes from the interventions in this Campaign, would not have survived (Berwick et al., 2006). This Campaign overlapped with several other organizations efforts including: Institute of Medicine, Joint Commission on Accreditation of Healthcare Organizations, Agency for Healthcare Research and Quality (AHRQ), Centers for Medicare and Medicaid Services (CMS), Surgical Care Improvement Project (SCIP) and The Leapfrog Group (a quality improvement group) (Berwick et al., 2006). These organizations share common goals such as reducing the risk of HAIs, creating healthcare cultures of safety, prevention and surveillance of HAIs, and the implementation of best-practices (Berwick et al., 2006). The IHI Campaign promoted prevention targets that included: CLABSIs, SSIs, and VAP through the evidence-based intervention guidelines and practices promoted by CDC (Berwick et al., 2006). Almost immediately following the conclusion of the 100,000 Lives Campaign, in an

effort to avoid impeding progress, an extension called the 'Five Million Lives' Campaign was announced by IHI in December of 2006. The goal was expanded to prevent five million incidents of medical harm in two years. In addition to existing partners from the earlier Campaign, IHI was now collaborating with payers, families, and patients (McCannon, Hackbarth and Griffin, 2007). It created national and local (state-based) networks to encourage learning, feedback, and sharing of best-practices. This Campaign emphasized the importance of hospitals partnering together and with other stakeholders. Along with the original targets from the 100,000 Lives Campaign, IHI added new targets that included: reduction of MRSA, reduction of surgical errors (through the implementation of SCIP best practices) and 'getting boards on board' (i.e., creating organizational change and engaging leadership at the hospital level) (McCannon et al., 2007).

IHI's project promoted networks within states and large hospital systems to create groups where hospitals could join together in a collaborative manner for feedback and sharing of best-practices, implementation strategies, and barriers to interventions. These collaborative activities encouraged facilities with successes to 'mentor' less successful hospitals (McCannon et al., 2007). In addition to support for coaches and hospitals, IHI provided tools for several other key stakeholder groups including boards, unit leaders, quality managers, frontline providers and the patients (McCannon et al., 2007).

Another example of facilities and stakeholders joining together in a concerted HAI reduction effort was the Michigan Keystone Intensive Care Unit (ICU) Collaborative. This project launched in 2003 though invitations to all Michigan hospitals, and formed a state wide collaborative with the Quality Safety Research Group at the Johns Hopkins University, the Michigan Hospital Association's Keystone Center for Patient Safety and Quality, and 103

participating ICUs dedicated to prevention of CLABSIs. (Pronovost et al., 2006). The goals of this collaborative were the improvement of safety culture, optimization of ICU physician staffing, reduction of CLABSI, and increased use of the VAP bundle (Pronovost et al., 2008). The specific intervention used to reduce rates of CLABSI was a bundle of five evidence-based procedures recommended by CDC (Pronovost et al., 2006). Data, including the number of CLABSIs (numerator for rate) and the number of 'catheter-days' (denominator for rate), were collected using standardized definitions by 103 ICUs both before and after the intervention. After the intervention, a median infection rate of zero was observed and sustained for 15 months of follow-up, and decreases were seen in all rates of CLABSIs compared to baseline (Pronovost et al., 2006). Demonstrating feasibility and success, the Michigan Keystone ICU Project was one of the first large scale (state-wide) prevention collaborative projects focused on reducing incidence of CLABSI. The model for change involved engagement, education, execution, and evaluation through defining clear expectations for hospital leaders, team leaders and ICU staff members and having resources available to manage organizational change (Pronovost et al., 2006). This collaborative showed data supporting interventions with evidence-based practices, resulting in substantial and sustainable reductions of HAIs; in this study up to a 66% reduction in CLABSIs was noted for the 18 month study period (Pronovost et al., 2006).

A significant part of the Michigan Keystone collaborative included improving safety culture in the ICU through the Comprehensive Unit-based Safety Program (CUSP). CUSP is a six-step process that follows a model for organizational change: engage, educate, execute, evaluate (Pronovost et al., 2008). The six steps of CUSP (performing a safety culture assessment, educating staff on the 'science of safety', having staff identify safety issues, using teamwork tools to learn from one defect a month, and finally reassessing safety culture) were

implemented. CUSP has been associated with an improved safety climate, including the improved teamwork in the unit, and this was again demonstrated in Michigan through improved scale scores, measured via surveys administered to staff in the ICU (Pronovost et al., 2008). After initially completing the survey of safety culture and exposure assessment, CUSP monitored standardized data collected about the number of infections, number of exposed-days, and the completion of the team check-up (an educational tool) monthly. Since the original Michigan intervention, The Johns Hopkins University's Quality Safety Research Group, the American Hospital Association and the Michigan Health and Hospital Association have teamed together to spread the CUSP program nationally to 45 other states (Pronovost, Marsteller and Goeschel, 2011).

Another large-scale prevention collaborative was demonstrated through the Veteran's Affairs (VA) hospitals initiatives against MRSA. In 2006 a successful intervention using an industrial-engineering approach to implementing infection control practices was able to reduce the incidence of MRSA infections in a VA hospital (Muder et al., 2008). The intervention included four approaches (standard precautions, contact precautions, active surveillance, and application using the Toyota Production System [TPS]) (Muder et al., 2008). To implement TPS a designated team leader nurse identified obstacles and engaged staff in problem-solving, while an industrial engineer taught and provided consultations to process improvement (Muder et al., 2008). The system had the team work together to: identify the specific need, observe how the tasks were completed pre-intervention, identify the cause of error, propose changing one variable, implement the change, and monitor the effect of change to continuously repeat the process until the identified need was met (Muder et al., 2008). Through active surveillance (swabbing patients for MRSA at admission, 48 hours after admission, and at discharge) staff

were involved with ongoing data collection and sharing, and measured infection rates in each unit. This programs success was attributed to the real-time feedback of data to staff, real-time problem solving, involving front-line healthcare workers in intervention designs, and monitoring the data showing intervention outcomes. Infection rates tracked in this study showed reduction in MRSA transmission and infection is possible, even in endemic settings (Ellingson et al., 2011; Muder et al., 2008).

Building on the success of the VA hospital's TPS initiative to prevent MRSA, a multi-center collaborative began in August 2006 with 17 VA hospitals, called 'beta sites', implementing a similar MRSA intervention with four components: active surveillance, contact precautions, hand hygiene, and culture change (Garcia-Williams et al., 2010). Measurement is a critical component to MDRO control programs, for both detection of new pathogens and the monitoring of trends, and can be done a number of ways (Siegel et al., 2007b). Due to the successes observed at the beta sites, the MRSA bundle was then implemented nationwide to all VA hospitals in 2007 (Jain et al., 2011). After a retrospective data collection of healthcare-associated MRSA infections to establish baseline rates, infection data were measured after the intervention and for the 33 months following through active surveillance testing. Significant declines in healthcare-associated MRSA were observed throughout the large healthcare system. The data collected for this collaborative (which is thought to be generalizable to other MDROs) showed increasing MRSA screening rates at admission and discharge, and that a bundled approach of proactive efforts to prevent transmission of MRSA is associated with reduction in healthcare-associated MRSA infections (Jain et al., 2011). To measure the levels of success in collaboratives, such as the VA collaboratives, standardized and consistent data collection of both

outcome and process measures is imperative to the determination of rates of compliance and infections, and for tracking of progress in HAI prevention.

To further measure and expand the momentum towards elimination of HAIs through ongoing work like the IHI, Michigan Keystone Projects and the VA collaboratives process and outcome surveillance, in addition to prevention activities, are supported by national and state policies. Large federal initiatives such as the 2009 Department of Health and Human Services (HHS) action plan are able to guide, enhance, and support states (and their unique legislative requirements) with HAI surveillance and prevention (Cardo et al., 2010). The HHS action plan promotes prevention through research, information systems and technology, incentives and oversight, outreach, and evaluations (Department of Health and Human Services, 2009). HHS identified six categories of infection targets to move forward towards elimination of HAIs: CLABSIs, CDI, CAUTI, MRSA, SSIs, and VAP (Department of Health and Human Services, 2009). A major component in the creation of the action plan was identifying metrics for process and outcome measurements that can accurately quantify and compare successes. The action plan was created with the support of key national partners including SHEA, IDSA, and the National Quality Forum. Sharing common goals allows for all HAI prevention efforts made by any organization to be individually and collectively effective and complementary to reaching the national targets (Department of Health and Human Services, 2009). The HHS action plan prioritized improving the use and quality of the metrics used to assess HAI prevention progress. Considering this, the first tier of the HHS goals included five targets (CLABSI, CDI, CAUTI, MRSA and SSI) and two process measures (adherence to central-line insertion practices [CLIP] and surgical care measures) with five-year national metrics that could be quantified through measures of progress tracked using the National Healthcare Safety Network (NHSN), a

voluntary surveillance system managed by the Division of Healthcare Quality and Promotion (DHQP) at CDC.

HAI surveillance has been available through the CDC since the 1970's, first through the National Nosocomial Infections Surveillance System (NNIS) until 2004 when the system switched to the current NHSN. There are many benefits to having a standardized national surveillance system that is open to all types of healthcare facilities for no fee (Centers for Disease Control and Prevention, 2010e). The standardization of definitions across facilities and regions allows the CDC the unique ability to measure infection rates nationally by facility type, location, or size. Within its patient safety component, NHSN has four modules: a device associated module (tracks infections such as CLABSI, VAP, CAUTI, dialysis events and adherence to CLIP), a procedure-associated module (measures SSIs and post procedure pneumonias), the MDRO/CDI module (monitors infection surveillance, automatic laboratory ID [Lab ID] event reporting, and process measures [including hand hygiene, contact precautions such as gowning/gloving, and active surveillance testing]), and a vaccination module (Centers for Disease Control and Prevention, 2010e). Facilities can choose infections (e.g., CLABSIs, CAUTIs, SSIs, or VAP) and locations (e.g., critical care/ICUs, specialty care areas, acute stroke wards, orthopedic trauma wards, labor wards, or pulmonary wards) to report. To further understand the kinds of facilities reporting, facility information is collected on location and population such as bed-sizes, teaching-status, and care for adults, children and pediatrics. In addition to providing a means for data collection for the facility, NHSN provides tracking of national and facility rates, and sharing of data between facilities and with other defined groups of users, such as state health departments and hospital associations (Centers for Disease Control and Prevention, 2010e). CDC utilizes NHSN data to publish aggregate reports, to estimate burden of

HAIs within hospitals, and because of the longevity of the surveillance data, to monitor HAI rates longitudinally, looking for trends and shifts. Both NNIS and NHSN have been used by increasing number of facilities for voluntary reporting of HAIs. With the availability of national surveillance data from sources such as NHSN, a strong momentum towards legislation surrounding HAI information was driven largely by consumer demand for more transparency in healthcare.

Because surveillance is also the monitoring tool for prevention, several states are mandating the use of surveillance systems, commonly NHSN, to track infection rates. Recognizing this, HICPAC formed recommendations for guidance on regulations involving public reporting of HAIs in 2005 (McKibben et al., 2005a). This report was not model legislations, but simply a framework for policy makers that included recommendations such as the use of established surveillance methods, a multi-disciplinary advisory panel monitoring and overseeing the reporting systems, choosing appropriate measures based on facilities and phase in measures to allow facilities to adjust, and providing feedback to participants (McKibben et al., 2005a). HICPAC strongly advocated for only publicly reporting validated data, and also explained the importance of risk adjustment for comparisons between hospitals (McKibben et al., 2005a). At the beginning of 2011, 33 states and the District of Columbia had passed HAI-related regulations, which include 29 states with mandatory reporting of infections to the state, and 28 states that report the data publicly. Other legislation for HAI reporting has different requirements, such as voluntary reporting, or mandatory use of the NHSN Patient Safety Component. In addition to differences in pathogens, infections, units, and types of facilities these mandates affect, the data reporting including risk-adjustments, and data validations required by these policies vary by state (Association of State and Territorial Health Officials,

2011b). While there are large variations in state policy, the Association of State and Territorial Health Officials (ASTHO) recommend state advisory groups to be proactive in their reporting for targets likely to be mandated by federal agencies in the future. Beginning in January 2011 CMS imposed rules mandating ICUs in acute care facilities report their CLABSIs through NHSN in order for hospitals to receive payment. These rules will expand to other infections continually, followed shortly by mandatory reporting of CAUTIs in ICUs and SSIs after colon and abdominal hysterectomy in January 2012 (Centers for Medicare and Medicaid Services, 2011). In addition to acute care facilities, requirements are beginning to appear for dialysis centers and inpatient rehabilitation facilities in 2012-2013 (Centers for Medicare and Medicaid Services, 2008).

Supporting overall HAI prevention, and both existing and forthcoming federal requirements and state policies, the American Recovery and Reinvestment Act of 2009, Public Law 11-5 (ARRA) was signed into law on February 17, 2009. ARRA allocated $50 million to CDC to endorse states in the prevention and reduction of HAIs. This funding was then directed to states through the Epidemiology and Laboratory Capacity for Infectious Diseases (ELC) and the Emerging Infections Program (EIP) to promote increased HAI prevention capacity through infrastructure, surveillance, and collaboratives (Centers for Disease Control and Prevention, 2011). The intent of ARRA was the establishment and expansion of state health department capacity to improve surveillance and accountability for the prevention of HAIs (Centers for Disease Control and Prevention, 2011). Grantees of the program were states and territories who applied for funding using a written project narrative explaining their current HAI prevention background and need for support, accomplishments and proven capacity in HAI prevention, project work plan, performance measures, and evaluation plan (Centers for Disease Control and

Prevention, 2011). The ARRA funding ranged between $174,358 and $2,596,434 per grantee and was provided for a 28-month project period (August 30, 2009 through December 31, 2011) to 51 applicants (49 states, DC, and Puerto Rico) for any combination of three activities:

A- "Infrastructure"- funded basic staffing and expertise, promoted the beginnings of collaborations through the gathering of an HAI Advisory Group and assisted the beginning development of a HAI prevention program.

B- "Surveillance"- increased participation of and supported hospitals in NHSN through enrollment, trainings, and technical assistance. Also encouraged validation of data collected, and the state health department involvement in data analysis and use.

C- "Prevention collaboratives"- supported prevention collaboratives and encouraged the state to enhance and/or expand current prevention efforts previously supported by state health departments or other partners, and initiated new collaboratives.

After the receipt of funding, all funded state health departments were required to submit to CDC a state plan outlining their activities and prevention targets. Infrastructure, Activity A, funding was provided to establish HAI program leadership and HAI infrastructures within the state health departments. It provided funding for HAI coordinators, advisory group creation and meetings, and other positions/activities that may not have otherwise existed in the state health department (Centers for Disease Control and Prevention, 2011). Surveillance, Activity B, funding was given to promote NHSN enrollment, and encouraged ongoing NHSN user support, validation of surveillance data, and the usage and reporting of surveillance data by the state health department (Centers for Disease Control and Prevention, 2011). Surveillance funding was provided to support expanding NHSN participation in a facility such as increasing the number of infections reported and/or units in the facility reporting. Prevention funding, Activity C,

supported partnerships with hospitals for active prevention efforts through the establishment or continuation of prevention collaboratives. CDC provided toolkits and 'cookbooks' using evidenced-based practices to assist in the establishment of prevention efforts (Centers for Disease Control and Prevention, 2010f, 2011). Funds could also be used to support existing collaboratives funded by other entities including the CUSP work through the state Hospital Associations and the 'Scope of Work' programs through the Quality Improvement Organizations (QIOs). All funding activities aimed to support capacity for improved collaboration, evaluation, and communication efforts (Centers for Disease Control and Prevention, 2011). Successful implementation of these activities required interaction between key stakeholders and other agencies to work in unison instead of singularly for the promotion of these elimination efforts through collaborative prevention, and vigilant HAI surveillance.

Statement of Research Objectives

The purpose of this research project is to assess the influence of ARRA funding on the prevention of HAIs and the development of capacity at the state health department. The research questions assessed in this work include:

1. What state health department activities/characteristics constitute 'baseline capacity' for HAI prevention funding?
2. What was the influence of targeted ARRA funding to the state health department on Infrastructure, Surveillance and Prevention collaborative development through year 1?
3. How did ARRA funding support or enhance ongoing surveillance efforts, noting the influence of other elements and factors on surveillance efforts, specifically assessing the impact of ARRA Surveillance funding on enrollment in NHSN device-associated infection modules over time?

Methods

Data Sources

Abstraction from 'in-house' sources

Data sources available included the grant application materials, quarterly performance measures, and NHSN module-specific participation data by state. Project narratives, consisting of sections explaining background and need, accomplishments and proven capacity, project work plan, performance measures, and a plan for evaluation were submitted with the grant application in response to the funding announcement. Narratives were written by leaders at the state health department and were due to CDC on June 29, 2009. Although application guidance was provided by CDC, each application was unique, and the narratives varied in content, writing style, and length. Quarterly performance measures were questionnaires administered by each state's specific Public Health Analyst (PHA), a CDC-liaison to each state providing technical assistance related to ARRA funding, assessing their activities and barriers to implementation of HAI Infrastructure, Surveillance, and Prevention collaboratives. The first four quarterly reports (capturing activities occurring Sept 1, 2009-Sept 30, 2010) were different open-ended questionnaires with state-specific prompts administered through email correspondence via state HAI coordinators. The fifth report collected (capturing activities occurring Oct 1, 2010- Dec 31, 2010) was administered through a standardized questionnaire with close-ended questions and the option to elaborate in free text fields.

To measure baseline capacity the project narratives were mined by two abstractors for information based off a conceptual logic model. The logic model was created to demonstrate ideal flow of inputs (focusing on the funding from CDC to state health department) through short-term, intermediate, and long-term outcomes. This logic model reflected increases in state

health department development towards sustainable prevention capacity. From this model there were four categories of information extracted from the project narrative: HAI staffing (number of staff, expertise, type, presence of coordinators and free quotes), HAI planning activities (funding, state plans, trainings, contextual factors, and free quotes), HAI prevention efforts/resources (partnerships, laboratory information, state health department resources, campaigns, collaboratives, surveillance system activities, and prevention quotes), and HAI advisory groups (membership, governance, and involvement). The free text describing the different activities within these categories was entered into an Access database. Training and ongoing guidance for abstraction protocols included meetings with outside evaluators as needed. To ensure compatibility between the two abstractors, narratives mined together and separately were compared and discrepancies resolved. The evaluation team (composed of a behavioral scientist, physician, economist, epidemiologist, program evaluator, and MSPH student), qualitatively analyzed the abstracted database of text to create variables and construct a standardized baseline database quantifying the baseline status of each state according to their grant applications.

To create standardization throughout all five quarterly reports, the first four unstandardized reports were retrospectively mined to fit the standardized quarterly performance measures form by two data abstractors. Six randomly selected applications were abstracted by both abstractors to ensure reliability in data coding and entry techniques. Meetings between abstractors, team members, and PHA's were held to clarify confusions or discrepancies in data collected. Because not all questions were addressed throughout the time period, gaps and missing information were coded as unknown, opposed to assuming activities were not conducted or resources did not exist. The quarterly reports requested feedback from all 51 state health departments on progress measures to allow CDC to provide technical assistance for the

successful implementation of their funding. The reports varied based on activities each state health department was funded for (Infrastructure, Surveillance, and/or Prevention collaboratives). Those funded for Infrastructure were administered questions about staffing, advisory group formation, meetings and activities, and any barriers encountered to maintenance of infrastructure. Surveillance funded states were asked to report surveillance activities, state health department data uses, barriers to NHSN data access, status of NHSN enrollment, and validation studies (targets, status, facilities, protocols, partners, and funding use). Finally, those funded for prevention collaboratives were requested to describe barriers to collaborative implementation, and collaborative specific information including targets, status, use of ARRA funds, number and types of facilities participating, collaborative activities, and the presence of 'key attributes' recommended by CDC (multi-disciplinary advisory group, staffing, communication strategy, and outcome measurement system- NHSN or other). All sections had areas for additional comments of free-text.

NHSN Data

Two types of NHSN data were available for the analysis of NHSN participation over time. First, the number of hospitals enrolled by state was provided quarterly from September 2009 to December 2010 as part of the evaluation metrics for ARRA funding. This number was standardized by the reported number of hospitals from the American Hospital Association's 2008 report. Second, NHSN participation data that included locations reporting CLABSI, CAUTI, and VAP from 2006- 2010 was provided for analysis from DHQP, CDC. Information about state-level mandates and policies for mandatory reporting to NHSN was provided by the surveillance branch of DHQP/CDC (the monitoring group for NHSN).

Analysis

Descriptive Statistics

Baseline and quarterly data were collected and managed in a Microsoft Access database, and all analyses were conducted using SAS v9.2. Descriptive statistics were used to quantify baseline and year one outcomes from application materials, quarterly reports, and NHSN.

Factor Analysis

To better understand the information collected at baseline, a factor analysis was performed to explore the relationship of the 47 finalized baseline variables (29 dichotomous variables measuring existence of a variable in state, and 18 'scored' variables [with ranges between 0-4] measuring intensity of existence of a variable in state) with a determined number of factors. An exploratory, orthogonal factor analysis was performed to determine if a rotated factor pattern could produce a small number of factors that show a linear combination of the variables weighted by the influence they have on a particular factor (Johnson, 2002).

A factor model expresses each of the *p* variables (*y*'s) as a predictor of *m* underlying common factors with the goal of $m << p$. The factor loadings (λ_{ij}) are weights, showing how each observation, y_i, depends on the factors ($f_1, .., f_m$) that are modeled for any observation y as follows:

$$\begin{aligned} y_1 - \mu_1 &= \lambda_{11}f_1 + \lambda_{12}f_2 + \cdots + \lambda_{1m}f_m + \varepsilon_1 \\ y_2 - \mu_2 &= \lambda_{21}f_1 + \lambda_{22}f_2 + \cdots + \lambda_{2m}f_m + \varepsilon_2 \\ &\vdots \\ y_p - \mu_p &= \lambda_{p1}f_1 + \lambda_{p2}f_2 + \cdots + \lambda_{pm}f_m + \varepsilon_p \end{aligned}$$

$$\text{Or: } \boldsymbol{y} - \boldsymbol{\mu} = \boldsymbol{\Lambda f} + \boldsymbol{\varepsilon},$$

Where $\boldsymbol{y} = (y_1, y_2, .., y_p)'$, $\boldsymbol{\mu} = (\mu_1, \mu_2, \ldots, \mu_p)'$, $\boldsymbol{f} = (f_1, f_2, \ldots, f_m)'$, $\boldsymbol{\varepsilon} = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_p)'$

$$\boldsymbol{\Lambda} = \begin{pmatrix} \lambda_{11} & \lambda_{12} \ldots & \lambda_{2m} \\ \vdots & \vdots \ddots & \vdots \\ \lambda_{p1} & \lambda_{p2} \ldots & \lambda_{pm} \end{pmatrix}$$

We assume for j=1,2,..,m E(f_j)=0, Var(f_j)=1, and cov(f_j,f_k) = 0. Communalities (h_{ij}^2) are calculated from the sum of the squared factor loadings (i.e. $h_{ij}^2 = \lambda_{1j}^2 + \ldots + \lambda_{mj}^2$). The eigenvalues of the correlation matrix **R** account for the proportion of variance each factor represents (Johnson, 2002).

The art of the factor analysis comes from the decision to choose the number of factors, *m*, that represent the data wisely. Ideally the choice of *m,* consolidates data and is still representative of the sample (Di Iorio, 2005). One of the techniques used to choose *m* in this report was an analysis of the scree plot. A scree plot shows the eigenvalues for each variable in the model. Examining this plot of the eigenvalues, an attempt is made to identify the scree, or the place where the eigenvalues in the plot drop sharply and then level off, creating a straighter portion of the line. Using this technique, *m* is chosen based off the number of eigenvalues before the 'leveling off' of the slope, which is before the straighter line begins, leaving room for interpretation.

Orthogonal rotation rotates the rows of $\boldsymbol{\Lambda}$ for easier interpretation. When *m*>2, this rotation is most commonly done through varimax rotation. This method of rotation attempts to maximize the variance of the squared loadings in each column of $\boldsymbol{\Lambda}^*$(newly rotated matrix). Because often times an unrotated factor matrix is difficult to determine unique loadings on specific factors, maximizing the variance allows for improved distinction of the factors, thus

allowing for easier interpretation and discrimination between the factors. Varimax rotation creates $\mathbf{\Lambda^*}$ by the formula $\mathbf{\Lambda^* = \hat{\Lambda}T}$, where the orthogonal matrix **T** maximizes the squared loadings. Varimax rotation relies on the fact that if the loadings on a factor are nearly equal, the variance is close to 0 and 1. As the squared loadings approach 0 and 1, the variance approaches a maximum. Using these maximums, varimax rotation makes the loadings appear larger or smaller to allow for clearer distinctions between factors (Johnson, 2002).

Scores were created for each state on the determined factors, and overall. State factor scores were created by summing the existence of each activity in that factor by state. An overall baseline score was created for summing all of the factor scores.

NHSN Participation Denominator

A key objective of this evaluation is to quantify a measure that monitors facility and unit level participation in NHSN as a surveillance system by states. This will measure the impact of ARRA funds in increasing HAI surveillance activities at the state level. Making comparisons of NHSN enrollment counts between states is challenging at the least, due to differences in size, locality, and the spread of locations in facilities eligible for reporting in the states. Adding another complication to the problem, one facility can have multiple locations eligible for reporting. Because of these issues, there is not readily available 'denominator data' at the state level for the expected number of locations or facilities eligible for NHSN participation. These issues do not allow for ease of comparisons across states, where the number of hospitals reported by the American Hospital Association in 2008 alone can range from 12 to 580 per state.

Furthermore, the number and types of locations reporting, and the infection types all vary in each hospital. To quantify percentage of facilities validated in 2010, denominators were

measured through counting the unique facilities reporting CLABSIs and CAUTIs at any time in 2010 by state, and determining validation coverage percent's for each state based on the number of facilities validated, self-reported by the HAI program.

In 2011, new rules from CMS mandated all ICUs in acute care facilities report their CLABSIs to NHSN. With this mandate in place nationally, the expected number of ICUs reporting can be calculated for each state. This expected number of ICUs reporting, determined by the subset of ICU's that reported CLABSI infections to NHSN in 2011, allows for longitudinal comparisons between the states. For this denominator and analysis, only ICUs reporting CLABSIs (determined by location both reporting blood stream infections in plan and having non-missing central line days) in the year 2011 were included. For consistency, ICUs reporting CLABSIs before, but not during, 2011 were excluded from this analysis. Using this denominator, we were able to calculate a percentage of ICUs reporting each month over the time period of analysis that includes both pre-ARRA measurements (January 2008 through August 2009) and during-ARRA measurements (September 2009- December 2010), facilitating a measure of readiness for the implementation of mandatory reporting in January of 2011.

Piece-wise Linear Modeling

To determine the impact of ARRA funding on NHSN participation rates for ICUs reporting CLABSIs for individual states, piece-wise linear models were used to compare rates of enrollment before and after ARRA funding. This state-level analysis was stratified on the receipt of surveillance funding and on ever having a mandate for CLABSI reporting.

General linear regression models use parameters to predict an outcome, Y_i, for each i^{th} observation in the dataset. The general form for the linear model is

$$Y_i = \beta_0 + \sum_{j=1}^{j=p} \beta_j X_{ij} + \varepsilon_i,$$

where *i* ranges from 1 to n (where n is the number of subjects), and j ranges from 1 to the number of parameters, p. In this model, β_0 represents the intercept, and ε_i, are the random error for each subject, which are normally distributed with a mean of zero and variance σ^2 (i.e. $\varepsilon_i \sim N(0, \sigma^2)$. Using maximum likelihood estimators for the β terms in the model provides unbiased, minimum variance estimates for each predictor (Kutner et al., 2005).

A piece-wise linear model jointly fits two linear models to a dataset simultaneously (Smith, 1979). The two groups are separated by an indicator function, which has a value if the data is in the group indicated, and is zero otherwise. Two indicator functions fit two separate lines to a dataset. The key to fitting a piece-wise linear model is that the two lines must connect. In a model including a time variable fitting two lines (e.g., pre-intervention and post-intervention) a regression spline connects at the intervention period, called the knot. This line is fit by having the pre and post intervention indicators equal each other. In this intervention example, to determine if there is a change in the slopes pre and post interventions, the estimates of the slopes were compared. If the difference in the two slopes equals zero, then the conclusion would be no change after the intervention.

Two variables are defined to fit a piece-wise linear model, one for a pre-intervention period, and one for a post-intervention period. For example the variables could be defined as:

$$\text{time0} = \text{time} * \mathbf{1}(\text{time} < Intervention)$$

$$\text{time1} = \text{time} * \mathbf{1}(\text{time} \geq \text{Inteverntion}).$$

The values for time increase by a steady increment (generally one unit of time) from the initial measurement to the final measurement, spanning across the intervention time.

For each observation a model created would be:

$$Y_i = \beta_0 + \beta_1 time0i + \beta_2 time1_i$$

where Y represents the outcome variable of interest and time0 and time1 measure the slope of change before and after the intervention. A significant value for the value of β_2-β_1 would imply that there was a significant change in the rates of enrollment. This modeling strategy was used for each state (creating 52 models) to measure for a significant increase in the slope of NHSN participation during ARRA in each state by itself.

Longitudinal Mixed Effects Modeling

Longitudinal models are developed to better understand the progression of a variable over time, and can be modified by different effects. Longitudinal studies are distinctly noted by the measurement of the same individuals repeatedly through time. These studies are uniquely able to separate two types of effects, in population studies called cohort and age effects (Diggle, Liang and Zeger, 1994). When drawing repeated observations on the same subject, special statistical methods must be employed to ensure intercorrelation between measurements is accounted for, or the scientific inferences drawn could be invalid (Diggle et al., 1994). More complicated models can account for both random effects and repeated measures. A random variable Y_{ij} denotes the response of interest, for the i^{th} individual measured at time t_{ij} where $i = 1, \ldots, N$ and $j = 1, .., n_i$. In this situation

$$\mathbf{Y}_i = X_i\beta_i + Z_i\mathbf{b}_i + \varepsilon_i.$$

Here $X_i\beta_i$ is the appropriate (n_i x p) matrix of covariates, $Z_i\mathbf{b}_i$ represents the variability between subjects, with regression coefficients specific to subject i, and ε_i represents the random error for subject i. This model allows for variation both between and within subjects measurement. This model has repeated measures on each subject where some parameters are population specific (meaning they are the same for all subjects measured) and other parameters are subject-specific (meaning they vary for each subject measured). Random effects included in a regression model allow for natural differences between subjects for predicting the outcome of interest. Linear mixed models satisfy four requirements:

1. $\mathbf{Y}_i = X_i\beta_i + Z_i\mathbf{b}_i + \varepsilon_i$
2. $\mathbf{b}_i \sim N(\mathbf{0}, D)$
3. $\varepsilon_i \sim N(\mathbf{0}, \sum_i)$
4. All $\mathbf{b_i}$ and ε_i are independent.

Mixed models that do not assume variability in subject specific slopes (i.e., all subjects have the same slope, and varying intercepts) are called random intercepts models. This model produces subject-specific profiles that are linear with varying intercepts, yet the same slope thus producing subject specific parallel predictive lines. The random effect for intercept allows different subjects to have different starting points in time. Significant effects for the slope terms would imply a non-zero slope, which is an increasing or decreasing rate of change over time.

Mixed models that assume variability in subject specific slopes have random intercepts and random slopes. This model allows for a random effect for both the intercept and slope for each subject. Random effects in this model account for unmeasured differences in subjects, including external factors that could affect the outcome of interest.

Inference for the Mixed Effects Model

Significant fixed effects from the marginal model can be assessed using the Wald test, with the null hypothesis being there is no significant effect and the alternative being that the effect is significant (thus, H_0: $\beta = 0$ vs H_a: $\beta \neq 0$). The Wald test statistic is calculated W $=(\widehat{\beta_{\boldsymbol{\iota}}}/\widehat{\text{Standard Error}}(\beta_{\boldsymbol{\iota}})$. The Wald test statistic follows a chi-squared distribution with one degree of freedom. This inference is particularly useful in random-intercept only models.

Inference from the random effects, $\mathbf{b_i}$, can determine specific subject deviance from the overall group. Assuming the four assumptions stated above are appropriate is often justified, particularly when between subject variability is large compared to within subject variability. The best linear unbiased prediction (BLUP) for linear combination of interest, $u = \lambda_\beta'\hat{\beta} + \lambda_b'\widehat{\boldsymbol{b_\iota}}$, where λ_β and λ_b are known vectors and can be written as:

$$\hat{u} = \lambda_\beta'\widehat{\boldsymbol{\beta}}(\boldsymbol{\alpha}) + \lambda_b'\widehat{\boldsymbol{b_\iota}}(\widehat{\boldsymbol{\beta}}(\boldsymbol{\alpha}), \boldsymbol{\alpha}).$$

Here $\widehat{\boldsymbol{\beta}}(\boldsymbol{\alpha}) = (\sum_{i=1}^{N} X_i'W_iX_i)^{-1}(\sum_{i=1}^{N} X_i'W_i\boldsymbol{y}_i)$ where W_i is the inverse variance matrix, and $\widehat{\boldsymbol{b_\iota}}(\boldsymbol{\beta}, \boldsymbol{\alpha}) = E\ [\boldsymbol{b_i}\ |\boldsymbol{Y_i} = \boldsymbol{y_i})]$**.** This inference is useful with both random intercepts and random effects (slopes) in the model.

Longitudinal mixed effect models were used to determine if there was an increase in NHSN participation rates for ICUs reporting CLABSIs during the ARRA time period. The use of these mixed effects models allows for each state to have unique participation amounts (prior to ARRA funding). Allowing for a random effect of state, we can determine if the intervention (ARRA funding) affected some states more than others. In this project, three models were created to compare different effects. First, a longitudinal model with random intercepts was

developed to measure overall change in slopes for NHSN participation rates for ICUs reporting CLABSIs after ARRA for the 14 states that did not have a mandate and received Surveillance (Activity B) funding to support NHSN participation and validation. Next, two different mixed models were compared for the 31 states that did not have a reporting mandate. One assumed only random intercepts and uniformed slopes for each state in the model, while the other assumed random intercepts and random slopes for each state. This was done to account for deviances in states baseline capacity (i.e., the number of ICUs enrolled prior to ARRA), and other unknown factors that could affect each states NHSN participation over time. When assuming random slopes, the estimates for slopes before and after interventions (and the changes in slope) assume equal weight for each state, and are calculated by using means. Since the last two models contain both states funded for Surveillance (Activity B) and not, these models can be used to quantify a significant increased effect in the states who received this additional funding.

Results

ARRA funding was provided to 51 state health department grantees, here onto collectively referred to as 'states', that included 49 states (all states except Wyoming), the District of Columbia, and Puerto Rico for any combination of activities: Infrastructure (Activity A), Surveillance (Activity B), and Prevention Collaboratives (Activity C). Infrastructure funding was provided to the most, 48, states (94%), while Surveillance funding only went to 31 states (61%) and even fewer (27, 53%) received Prevention Collaboratives. However, the most common funding combination was for all three activities (received by 22, 43% of states). One-third (17) of the states received only funding for Infrastructure (Activity A). Infrastructure and Surveillance funding (Activities A and B) went to six states, Infrastructure and Prevention Collaboratives (Activities A and C) was provided to three states, Surveillance and Prevention Collaboratives (Activities B and C) given to two states, and only Surveillance (Activity B only) funding to one state (Figure 1).

Baseline

All of the 51 state health department applicants for ARRA funding were considered in the baseline assessment including stakeholder engagement and leadership, staffing, surveillance activities, and prevention activities.

Stakeholder engagement and leadership were measured through the number and types of potential collaborators (i.e., collaborators mentioned in funding proposal) and formal partners (i.e., formalized partnership or history of active collective engagement in HAI-related activities). All (51) states had a minimum of one potential collaborator and 50% of states had three or more, with the maximum state having ten collaborators. More developed 'formal partnerships' were acknowledged by 17 (33%) states, with the number of formal partners ranging from one to four, yet over half of the states with formal partnerships had only one partner. The most frequent partners and collaborators were the state hospital association, APIC, Academia, the QIO, and community coalitions for healthcare quality (e.g., state or local quality initiatives) (Table 1).

At baseline, two-thirds of the states reported staff either hired or available to hire for HAI-related activities. Less than half of the states (n=22, 43%), however, had staff dedicated fully or partially to HAI activities at baseline. However in these states with staffing, the median number of staff hired was 2.5 (range 1-9). The types of staff available in the state health department had PhD/MD level expertise (n=21, 41%), and MPH/nurse epidemiologist level expertise (n=20, 39%, Table 2). In addition to staffing, infrastructure development was measured through existing HAI Advisory groups, which were reported by 30 states (59%), and the existence of a HAI coordinators were reported by six states (11%).

A large portion of the state health departments (73%) discussed already having at least one hospital participating in NHSN in their application materials. HAI surveillance systems that were not NHSN were reported by 14 states (28%). Few states reported sharing or validation for either system (Table 3).

At baseline, prevention collaboratives were reported by 33 states. However, only two of these collaboratives were spearheaded by the state health departments (i.e., internally led). When states reported collaborative involvement, they reported participating in up to six collaboratives, however over half of the states were participating in two or less. The most common collaborative targets included partnerships with other key stakeholders in HAI prevention, such as CLABSI through the CUSP program with the Hospital Association (n=18) and MRSA through the QIO's 9th Scope of Work (n=15). Several other prevention topics were reported such as VAP, CDI, CAUTI, MDRO's and SSIs. Externally-coordinated prevention campaigns were reported by seven states (13.7%), and internally coordinated campaigns by five states (9.8%). The two most commonly reported prevention campaign topics were antimicrobial stewardship and hand hygiene (n=6 for both, Table 4). Trainings were reported in over half of the states (n=28, 55%), with half (n=14) of the trainings externally-led and the other half (n=15) internally led (one state preformed both internal and external trainings). The most popular topics for trainings were NHSN and General Infection Prevention (Table 4).

Other contextual factors or planning items measured include state health department laboratory capacity, electronic health data initiatives, state health department reports of the EIP, high-profile outbreaks within a state, mentions of HAIs as a state or funding priority, and reports of HAI websites, or state plans (Table 5).

Year One Results

In this project 'year one' has been defined as five quarters beginning with the initialization of the funding period on August 30, 2009, and ending December 31, 2010. Programmatic activities and comparisons to baseline are assessed individually for Infrastructure, Surveillance, and Prevention collaborative activities based on types of funding received. Information was not collected on activities that fall outside of each state's funding.

Infrastructure Funding (n=48 states funded)

Infrastructure Accomplishments

By the end of year one, all (100%) states had a designated HAI coordinator in the state health department (compared to 8% at baseline) (Figure 2), and most (98%) had convened a designated HAI advisory group at least once (compared to 56% at baseline) (Figure 3).

Throughout the first year the most commonly reported activities of HAI advisory groups were writing a state plan for HAI prevention (n=41, 85%), planning for HAI surveillance activities (n=39, 81%), and providing education and training about HAI topics (n=35, 73%). Advisory group activities were grouped together to create four levels of activity: setting goals and targets (initializing), planning surveillance and prevention activities (planning), active recruitment, training, or implementation of activities surrounding HAIs (acting), and reviewing HAI surveillance data for action (reviewing). These activities were compared by state for the entire year, and as a snapshot of what was happening at the end of year one (Table 6). In year one, a high percentage of states were initializing their group (94%) and planning activities (98%). Fewer states (85%) were actively recruiting or guiding activities, and even less (27%) were actually using 'data for action' and reviewing outcomes.

Infrastructure Barriers

Turnover in the HAI coordinator position was reported by 16 states (33%), with three states (6%) reporting more than one change in coordinator. Many states reported some difficulty in establishing or maintaining infrastructure at some point in year one (n=39, 81%), and cited various reasons for their difficulties (Table 7), especially spending or contract limitations (44%), human resource delays (33%), and problems finding qualified people (31%).

Surveillance Funding (n=31 states funded)

Surveillance and Validation Accomplishments

Almost all (n=30, 96.8%) Surveillance funded states reported some type of active support for surveillance activities in the first year through NHSN trainings, technical assistance, and NHSN user support. Within the first year of funding 1,557 more hospitals were participating in NHSN compared to before ARRA. Of these additional hospitals, 1,042 (66.9%) were from states with Activity B funding.

At the end of year one, a small portion (n=5, 16%) of states reported having no access to NHSN surveillance data, or having access but not using data (n=6, 19%). However, the majority (n=21, 68%) of state health departments reported accessing NHSN surveillance data for a variety of uses. The data was accessed for sharing both internally through detection of outliers and internal reporting (55%), and externally (58%) for reports for the public and feedback to specific hospitals, with 15 states (48%) sharing both internally and externally (Table 8).

At baseline only four (13%) states reported performing validation of surveillance data, contrasted with 26 (84%) states reporting planned, underway or completed validation studies at the end of year one. While two states had completed validation studies, 13 states reported a validation study was underway, and 13 states reported a study in planning. Half (n=13) of the validating states reported multiple validation targets, and the most common target was CLABSI (n=23 states, Table 9). While states validation styles varied, 20 states cited using other states shared templates for design of their validation studies. In these 26 states validating data, a range from one to 179 facilities validated was reported. ARRA funds contributed to 36% of CLABSI data in NHSN, and 17% of CAUTI data reported to NHSN in 2010 coming from validated facilities.

Surveillance and Validation Barriers

While NHSN surveillance was increasing, some state health departments were having difficulty accessing NHSN data for action. Of the 31states funded for Surveillance, 61% (n=19) reported having some barriers to NHSN access at the end of year one (via the quarterly report ending December 2010). Concerns were most commonly technical difficulties (n=13, 42%), but also a lack of cooperation from facilities (n=9, 29%), and lack of protection for facilities (n=5, 16%, Table 10).

Prevention Collaborative Funding (n=27 states funded)

Prevention Collaborative Accomplishments

In the baseline period, 20 (of 27 states) reported any prevention collaboratives (19 externally-led, and 2 internally-led). At the end of year one, all (n=27) states reported collaboratives, with 19 (70%) states reporting the initiating at least one ARRA-funded prevention collaboratives, and 15 (56%) states reporting using ARRA funds to enhance or expand prevention collaboratives.

By the end of year one, states reported 53 collaboratives with the status defined as planning, active (either new or ongoing), or completed (Table 11). Most collaboratives (n=43, 81%) were past the planning stages and active or completed at the end of year one. Over half of these collaboratives (n=29, 55%) reported they were initiated by ARRA funds. Most (44, 83%) collaboratives implemented all four CDC recommended key attributes (multi-disciplinary advisory group, dedicated staffing, communication strategy and an outcome measurement system). An outcome measurement system was used by 48 (91%) of the collaboratives, NHSN used by 37, and another system by 23 (Table 11). Collaboratives varied by number of facilities (median = 25, range 3-134), and types of facilities, although most (n=49, 93%) involved acute care facilities. Collaboratives also involved critical access centers (n=15, 28%), long term care (n=5, 9%), long term acute care (n=4, 8%) and other types of facilities (Table 12). A variety in targets, such as CLABSI and CLABSI/CUSP (n=17), CDI (n=15), SSI (n=12), MRSA (n=10) or CAUTI and CAUTI/CUSP (n=10) were reported (Table 13). Activities in the collaboratives varied by 'stage' (planning, new, ongoing, and completed) and are reported by these strata for the final quarter of 2010 (Table 14). Half or more of the planning collaboratives were most commonly doing activities such as strategizing, recruiting, and training. New collaboratives were

most commonly recruiting and enrolling facilities, providing training or implementing prevention strategies in addition to activities like strategizing, and performing baseline assessments. In over half of the new collaboratives the state was involved in providing feedback to the collaboratives. In addition to 70% of ongoing collaboratives providing training, over half were meeting to share experiences, and half were receiving feedback from the state program and participating in CDC calls as well. Only one collaborative was completed, and its only ongoing activity was receiving feedback from the state program.

Prevention Collaborative Barriers

Barriers to implementation of collaboratives were reported by 17 states (63%) in four main domains: insufficient facility resources (n=11, 44%), insufficient state resources (n=9, 33%), facility reluctance to share data (n=7, 26%), and maintaining facility participation (n=3, 11%).

Factor Analyses

A factor analysis was run on 47 variables collected at baseline to identify a smaller number of "factors" that help establish baseline capacity. To determine the number of factors to use, an analysis of the scree plot (Figure 4), showed an appropriate construct of three or four factors. The four factor construct would contain all unrotated eigenvalues greater than three. However, after further comparing both factor patterns it became evident that the four-factor construct was parallel to the three-factor construct. The third and fourth factors (in the four-factor construct) were a direct decomposition of the third factor (in the three-factor construct), thus for parsimony and simplicity the three-factor construct was chosen as the model construct. The rotated three factor model had eigenvalues 5.31, 4.84, and 4.7, translating to the three factors explaining 31.6% of the variance (Factor 1: 11.3%, Factor 2: 10.3%, and Factor 3: 10.0%, Figure 4).

To further the 'art' of the factor analysis, the three factor constructs were characterized and named: Collaboratives, Campaigns/trainings, and Human capital/expertise based on the groupings and types of variables that represented each factor. The Collaboratives factor contained variables such as external collaboratives, the number of collaboratives, types of collaboratives, specific collaborators (hospital association, academics, QIOs), specific trainings (external trainings, MRSA 9SOW trainings, and NHSN trainings), HAI advisory groups, HAI priorities in the state health department, and NHSN enrollment. The Campaigns/trainings factor included the number of and existence of internal, external, and specific campaigns (hand hygiene, general infection control, antimicrobial stewardship, and infection specific campaigns), the number of and existence of internal trainings, state lab, and APIC collaborator. Finally, the Human capital/expertise factor contained variables about the number of staff, types of staff

(PhD/MD and nurse/masters-level, IPs), number and types of collaborators/formal partners (other state or local health departments, community coalitions for healthcare quality, additional stakeholders [i.e. insurers, consumers, patient safety organizations, other healthcare associations], additional experts [CDC, or professional societies]), and the ability to establish contracts and other contextual factors (Appendix One).

NHSN Denominator

The NHSN denominator measured for each state was the expected number of ICUs to report CLABSIs by CMS 'pay for performance' mandates that were enacted in 2011. The median denominator overall was 114.5. Comparisons between denominators for states with and without Surveillance (Activity B) funding showed significant deviance (p = .0029, Table 15).

ICUs Reporting CLABSIs to NHSN

In December 2010, the final month before reporting mandates required all ICUs to report CLABSIs to NHSN, there were significant differences in the percentage of ICUs reporting between those funded for Surveillance (Activity B) and those not. In this month, states with Surveillance funding had an average of 64.4% of facilities (standard deviation: 28.02%) reporting ICUs to CLABSI, with a range from 11.9% to 98.8% of CMS-mandated locations reporting (Table 16). This significantly contrasts (p=0.0003) with an average of 34.0% of ICUs reporting CLABSIs to NHSN in states without Surveillance funding, and a range of 0% to 91.2% of necessary facilities reporting (Table 16). This relationship was also seen when only looking at states that do not have a mandate (p=.0451). Notably, the mean percent of ICUs reporting CLABSIs to NHSN was also significantly different from Surveillance funded states in January 2008 (baseline) and at the start of ARRA (September 2009) (Table 16). When only considering states without mandates, this relationship disappears in January 2008, however holds true for the start of ARRA in September 2009 (p=0.3743 and p=0.0451 respectively).

Piece-wise Linear Regression Models

Individual Model for each state (Model 1)

NHSN participation was modeled using the percent of ICUs reporting CLABSIs for 35 months in each state and state individually. In this study baseline data were collected at a state level from January 2008 until ARRA funding (September 2009) to determine if ARRA funding (i.e., the treatment variable) caused a change in the rate of NHSN enrollment by the end of year one (December 2010). Two variables were created to distinguish the piece-wise model: a pre-intervention term, mon0, and a post-intervention term, mon1. Both mon0 and mon1 are an interaction of time with an indicator variable such that:

$$\text{mon0} = \text{time} * \mathbf{1}(\text{months} < \textit{September}\ 2010)$$

$$\text{mon1} = \text{time} * \mathbf{1}(\text{months} \geq \text{September}\ 2010).$$

The values for months ranged from as low as -20 (at the first month in the study period, January 2008) and increased by an increment of one each month to 15 (for the first month of ARRA funding September 2009). For data points collected before ARRA funding mon1 always equaled zero and mon0 had values ranging from -20 to 0, increasing for each month closer to ARRA funding. For data points collected after ARRA funding mon0 consistently had a value of zero, and mon1 ranged from 0 to 15, increasing for each month after ARRA funding.

The model fit for each state was

$$Y_i = \beta_0 + \beta_1 mon0_i + \beta_2 mon1_i + \varepsilon_i,$$

where Y_i is the estimate of the percent of ICUs reporting CLABSIs for the given state in month i. β_1 is the term for the slope before ARRA funding, and β_2 is the term for the slope after ARRA

funding. Differences from the pre-ARRA and post-ARRA slopes (β_2-β_1) were used to measure changes in participation between the two time periods.

Estimates for the 52 models are provided in Table 17. Of the 31 states without mandates, 24 (77%) saw significant estimates, that is an increased rate in the number of ICUs reporting CLABSIs in the post-ARRA time period compared to the baseline period (Table 18). No states saw a decreased rate. However, no significant differences in the proportion of states with increased participation between those funded for surveillance and those not (χ^2 =2.5 p=0.11).

Of the states with mandates, only 19% had increased rates of participation, with another 19% having non-significant changes and the remaining 62% seeing decreases in rates of new participation (Table 18). This would imply not that the participation rates had decreased, just that the rates of enrollment had 'flat-lined' or failed to continue to grow.

Mixed Effect Models

Piece-wise linear model with random intercepts for Surveillance funded states without mandates (Model 2)

In an effort to quantify the impact of ARRA funding overall on NHSN participation, a piece-wise linear model was used to determine changes in rates of increased NHSN participation in the 14 states that did not have any mandates for CLABSI reporting and received Surveillance (Activity B) funding to improve surveillance efforts. This model used similar piece-wise notation (mon0 and mon1) as Model 1 with the knot of the regression spline at the start of ARRA (September 2009). This model for fourteen states allowed each state to have its own intercept, but had an overall estimate for the slopes; one slope before ARRA and one slope after ARRA. When visualizing this model it would appear as several parallel lines with each state having a random intercept. In these 14 states, the model created was (Model 2):

$$Y_i = \beta_0 + \beta_1 mon0 + \beta_2 mon0 + b_{0i} + \varepsilon,$$

where β_1 represents the slope before ARRA funding and β_2 represents the slope after ARRA funding. In this model the outcome, Y_i is the estimate for the percent of ICUs reporting CLABSIs in month i.

From January 2008 to just before the receipt of ARRA funding in September 2009, NHSN participation was increasing at a rate of 0.27% per month, and after ARRA funding through December 2010, NHSN participation was increasing at a rate of 1.24% per month (Table 19). Both slopes were significantly greater than zero, showing a positive increase in number of ICUs reporting CLABSIs NHSN participation before and after ARRA funding.

Piece-wise linear model with random intercepts for all states without mandates (Model 3)

A piece-wise linear mixed model was developed to monitor changes in percent of ICUs reporting to NHSN over time in the 31 states without a mandate. Like earlier models, this piece-wise model also accounted for changes before and after ARRA funding. Similar notation as described above was used for mon0 and mon1. In these models 14 states have received Surveillance (Activity B) funding, and 17 states have not. To address this, an indicator variable was created as a function for receipt of Surveillance funding such that:

$$(\text{ActB} = \mathbf{I}_{\text{actb}} = \begin{cases} 1, & funded\ for\ Surveillance\ (Activity\ B\ ) \\ 0, & otherwise \end{cases}).$$

To account for unmeasured factors that caused variance in the states intercepts, a random intercept term, b_{0i}, was included in the model. To test for significant effect modification due to the receipt of Surveillance funding, the term ActB was included in the model as a main effect, and interaction term. This model was of the form (Model 3, estimates: Table 20):

$$Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + b_{0i} + \varepsilon_{ij}$$

In this model β_0 is the overall (population average) intercept, and b_{0i} is the random deviation from the population average intercept for subject i. As above, the outcome variable here Y_{ij} represents the estimate for the percent of ICUs reporting CLABSIs in month i for subject (state) j. The estimates for β_1 represent a significant slope (rate of change) of 0.11% increase each month in ICUs reporting CLABSIs to NHSN before ARRA, and β_2 represents a significant slope of 0.87% increase each month during ARRA. The estimate for β_3 represent a marginally significant (p=0.07) overall increased effect of 7.2% (throughout the time period measured,

January 2008-December 2010) in the states with Surveillance funding. The estimate for β_4 represents a significant additional increase of 0.16% for the monthly changes in slopes, (i.e. rate of change) for ICU participation in the states funded with Surveillance before ARRA funding. The significant estimate for β_5 represents an additional 0.37% increase in slopes, in the states funded with Surveillance during ARRA funding.

Piece-wise linear model with random intercepts and random slopes for all states without mandates (Model 4)

To allow for each state to have unique intercepts (starting points) and varying slopes (rates of change) both before and after the disbursement of ARRA funding, a piece-wise linear mixed model with both random intercepts and random slopes was created. This model includes the mon0 and mon1 notation described above, in addition to the main effects and effect modification of Surveillance funding through the indicator variable ActB. This model (Model 4, Estimates: Table 21) was of the form:

$$Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + \left(b_{0i} + b_1 mon0_{ij} + b_2 mon1_{ij}\right) + \varepsilon_{ij}$$

This model provides the same effect estimates as Model 3, however allowing each state to have its own variations in slope and intercept causes the standard error to be much greater in this model and fewer degrees of freedom. This model allows for variation within starting points (intercepts) and rates of enrollment (slopes) for each state. Unlike Model 3 which had all significant fixed effect parameters (except for β_3 for the ActB variable), Model 4 has only one significant fixed effect parameter (Table 22), β_2 for the mon1 (the slope after ARRA funding was distributed).

Inference from the Mixed Effects Model

States without Surveillance funding had significant differences in participation rates for both the model containing random intercepts only, and the model allowing for random intercepts and slopes (Table 22). The significant estimate for the increased rate of participation during the ARRA time period for states without Surveillance funding was 0.76% per month (Table 22).

States with Surveillance funding also saw an increased rate of participation during the ARRA time period, regardless of model chosen. The effect of ARRA funding is an increased participation rate of 8.21% per month in the two random effects models that contain both Surveillance funded and non-funded states (Table 23). A lower (yet still significant) effect of 0.98% increased rate of participation per month was identified for the random intercepts model that only included the 14 states funded for Surveillance (Table 23).

An increased effect of the Surveillance funding in the post intervention time period was measured by testing for a significant difference in the interaction terms, and not found in either Model 3 or Model 4 (Table 24).

Discussion

Healthcare-associated infections are a common and preventable complication occurring in an estimated one in 20 hospitalized patients. Momentum towards the elimination of HAIs has been increasing in recent years through financial incentives, research and innovation, collecting data to monitor emerging threats, and employing evidence based prevention practices (Cardo et al., 2010). This momentum is evident in ongoing development of guidelines, monitoring of HAI rates through surveillance activities, and implementation of prevention collaboratives (Jain et al., 2006; Pronovost et al., 2006). Through a baseline assessment, as reported in this thesis, it was determined that there is varying capacity at the state level for HAI prevention that could be summarized through three major domains: Collaborative efforts, Campaigns and trainings, and Human capital and expertise. ARRA funding distributed to 51 state health departments through CDC appeared to have programmatic successes in year one for state's development of Infrastructure, Surveillance, and Prevention collaboratives. Increased surveillance capabilities also were examined through increased rates of NHSN participation.

Because of the need for surveillance of HAI rates as 'data for action' to monitor prevention, states and federal partners are both beginning to mandate HAI monitoring. HICPAC recommendations for states wishing to implement legislation for HAIs include using established surveillance methods, and working with a multi-disciplinary advisory panel to oversee and report data from the monitoring system (McKibben et al., 2005b). At the beginning of 2011, 33 states and the District of Columbia all had passed HAI legislations (Association of State and Territorial Health Officials, 2011a). Federal initiatives have supported HAI prevention, including the 2009 HHS Action Plan which promoted research, technology, oversight, outreach, and evaluation of HAI prevention strategies (Department of Health and Human Services, 2009). This action plan

focused on metrics for six infection targets. In addition to federal initiatives, CMS began imposing reporting rules in 2011 for facilities to continue receiving reimbursements. The first of these rules mandated that all ICUs in acute care facilities report CLABSIs to NHSN (Centers for Medicare and Medicaid Services, 2011).

Supporting the atmosphere of HAI monitoring and prevention, ARRA funding was allocated in September 2009 to 49 states, D.C. and Puerto Rico (Centers for Disease Control and Prevention, 2011). ARRA funding was to support HAI prevention through three activities; the establishment of state health department Infrastructure, increased HAI Surveillance, and HAI Prevention collaboratives. This research determined which state health department activities or characteristics developed baseline capacity, the influence of targeted ARRA funding at the state health department in three areas (Infrastructure, Surveillance and Prevention collaborative development), and how ARRA funding supported NHSN enrollment and surveillance efforts considering other influential factors.

To measure states at the time of funding, baseline capacity scores were created. Using a factor analysis three factors were determined as measures of a state's baseline HAI capacity: Collaborative efforts, Campaigns and trainings, and Human capital and expertise. These three constructs were developed from analyzing states application materials, and similarly a cross-walk with the ARRA framework. The first element of baseline capacity, Human capital and expertise, would be addressed by ARRA funding through infrastructure development as supported by Infrastructure (Activity A) funding. Campaigns and trainings are promoted through all activities of ARRA funding; through the advisory groups established with Infrastructure funding, promotion of NHSN enrollment and related trainings from Surveillance funding, and promotion of collaborative specific trainings and undertakings using the Prevention

Collaborative funding. The third construct from our baseline capacity assessment was Collaborative efforts; distinctly matching with Prevention Collaborative (Activity C) funding. In the factor analysis, surveillance did not create its own construct; however it seemed to place itself across all three constructs. This implies that Surveillance efforts are a part of having human capital, and participating in campaigns, trainings, and collaborative efforts, and is important for monitoring HAI rates for evaluation of HAI prevention programs and capacity. Higher overall and collaborative baseline capacity were associated with advisory groups planning surveillance and prevention activities. Human capital and expertise baseline scores also had a significant association with advisory groups reviewing HAI data in year one. States who more staffing available had before ARRA funding may have been able to more quickly utilize their advisory group for the analysis of HAI surveillance data than states with less staffing prior to funding. Further research is needed to determine the impact of staffing on HAI Surveillance and Prevention.

For those states with Infrastructure funding, ARRA was able to place coordinators in all states, an increase of 44 coordinators from the baseline assessment, and convene 47 (out of 48 funded) multidisciplinary advisory groups in one year. These measures are an example the programmatic goals of ARRA being achieved. Other Infrastructure funding successes include all states completing a state plan, and most states reporting their advisory group contributing to its creation. These advisory groups also were involved with planning activities in year one (98% of states), however, 27% of states did report their advisory group's reviewing NHSN outcomes data submitted to the state. Ideally as ARRA funding progresses into year two, more states are able to achieve these higher level outcomes in addition the programmatic outputs.

For the 31 states with Surveillance funding, states were funded to increase surveillance efforts, and expand validation schemes. Notably, 97% of states listed providing some type of active support to the states through trainings, user support, or technical assistance for NHSN in the first year of funding, again showing success at achieving specified program goals in the first year of funding. In addition, 68% of states reported their health department's HAI program specifically involved with promoting or assisting with NSHN enrollment, in year one. By the end of year one most (68%) states were accessing NHSN data to prepare some kind of internal or external shared report. This represents state HAI programs using data for action, a key pillar towards the elimination of HAIs (Cardo et al., 2010). During the ARRA period the number of facilities and the number of locations reporting both increased. Many states also were able to reach higher goals, such as becoming actively involved in NHSN enrollment or applying more or new validation schemes.

Validating NHSN data was an important contribution and goal of ARRA funding. Validation confirms correct entry, use of definitions, and prevents the system for being played. Validation is important when convincing facilities for public reporting, and allows for local, state, and federal partners to justifiably compare facilities. Prior to ARRA funding only four state health departments discussed their roles in validation. However, at the end of year one, 84% of the states funded for Surveillance activities had validation studies planned, underway, or completed. States were most commonly validating CLABSI, matching the first infection to have a national reporting mandate by CMS. ARRA funding has allowed for more states to have validated data in NHSN, benefitting CDC's ability to accurately understand rates of infections, and assisting CMS as they begin to use NHSN data for reimbursement calculations.

Prevention collaborative states (Activity C recipients) were funded to promote collaborative prevention activities within their state, and all reported at least one prevention collaborative in the first year, showing further success in achieving programmatic goals. Notably, 70% of these states reported at least one state health department initiated collaborative. This is much higher than the two state health departments who reported initiating prevention collaboratives at baseline. ARRA funding allowed state health departments the ability to support healthcare facilities in a more central leadership role. Over half of the states (56%) reported enhancing or expanding other prevention collaboratives, with the state health departments taking a participatory role in collaboratives with outside agencies using ARRA funding, including 15 collaboratives with the CUSP program demonstrating expanded partnerships with state hospital associations.

Collaboratives were created in each state with guidance from CDC, yet allowed for much interpretation for states. This allowed each state to create a collaborative in a fashion most conducive to work ongoing in their state. Thus, collaboratives varied in many aspects including size, targets, and starting times. At the end of year one, most collaboratives were ongoing, however, some were still in the planning stages and others had already completed. Activities of the collaborative often varied by stage of the activity. CDC recommended four key attributes for these collaboratives, and 23 (85%) states implemented all four of these attributes in at least one collaborative. Key attributes of the collaboratives were designated staffing, outcome measurement system, a communication strategy, and a collaborative specific multidisciplinary advisory group. Several of these key attributes are supported by Infrastructure (Activity A) funding (staffing, advisory groups) and Surveillance (Activity B) funding (70% of the collaboratives reported NHSN as their outcome measurement system). This is one example

where funding types are not clearly distinguishable, and successes in one activity could lead to success in another.

To tease out the effects ARRA funding had specifically on NHSN participation, our analysis excluded states who had state level reporting mandates for CLABSI prior to 2011 and showed that when controlling for random intercepts (or starting places) the percentage of ICUs reporting CLABSIs to NHSN was increasing over time both before and after ARRA funding overall (regardless of receiving Surveillance funding). While Surveillance funding was focused on increasing surveillance capabilities, it was not randomly distributed, but intentionally given to states that had shown success. These states had significant differences in the number of ICUs (used as the denominator for modeling). Some of these Surveillance funded states already had up to 100% of their ICUs reporting CLABSIs, and had a mean of 50% participation at the start of ARRA. Comparatively, the maximum participation at the start of ARRA was 81.8% in states that were no funded by Activity B, but the mean participation was only 15.5% (Table 17). To account for some of this, the modeling analysis was restricted to only states that did not have a mandate.

Surveillance funded states had increased participation rates compared to those states without surveillance funding both before and after the distribution of ARRA funds (about a 0.16% /month increase before ARRA and a 0.34%/month after ARRA). However, our models showed there were no significant effects indicating an increased effect of Surveillance funding during the ARRA time period in those states who have received Surveillance funding. However for Activity B states without mandates, a mean of 40 % of ICUs were already meeting reporting deadlines in December 2010, compared to a mean of just 24% in non-mandate non-Activity B states (Table 16). This shows these states were still better prepared for accepting mandatory

reporting requirements. Being enrolled in NHSN before the mandated period may allow for better quality data because facilities are given time to adjust to the reporting requirements, and become more proficient at tracking infections using the system. This shows how the first year of ARRA funding may have helped facilities prepare for and respond to CMS rules, and possibly improve quality of their data. Policy makers should be mindful that this additional funding was provided to states during the beginning of reporting requirements from CMS.

Limitations

Within the scope of this study there are several notable limitations, including the data sources themselves. All data except for NHSN participation was self-report from the states. To mediate this guidance was provided from a public health analyst at CDC who worked closely with the state to verify information accuracy. The baseline capacity scores were defined from grant application materials. While states were asked to provide detailed information of their HAI programs, they may not have always provided an exhaustive list of all of ongoing HAI activities in the state. It is important to note also that the first four quarters of data were collected on a unstandardized open-ended questionnaire that updated each quarter, with only the last quarter of year one having information collected in a more standardized close-ended way.

ARRA funding was given in three activities to help create an overall HAI prevention program, based on stated need and proven HAI capacity. Funding amount and type was not randomly assigned; it was targeted to give states the most chance to succeed. While the funding categories Infrastructure, Surveillance, and/or Prevention collaboratives were distinct, the funding distribution was given in several different ways. Some states had all three, while others just had one or some combination of two. Because of this it is difficult to measure successes in

one funding category without accounting for baseline status, and other types of funding provided.

ARRA funding was assigned to target three main building blocks of developing HAI prevention capacity, with the overall goal of the reduction of HAIs at a time where HAIs began gaining attention as a specific public health problem. It is hoped that with the state target ARRA funding that HAI rates begin to drop, however these measure are often difficult to quantify, especially immediately after the receipt of funding. It is also difficult to attribute lower HAI rates to one specific program without acknowledging the entire HAI landscape including emerging HAI policies, and increased awareness by facilities and other partners. For example, policies, such as state and federal reporting mandates, significantly drive NHSN participation, and must be considered when trying to track NHSN participation increases. To mediate this, ARRA specific goals were measured and overall the states appeared to have achieved some programmatic successes. This project also assessed capacity specifically at state health departments, however acknowledges the importance and influence of working with other key partners in the state such as QIOs, Hospital Associations, in addition to specific facilities.

When measuring NHSN enrollment, it is often difficult to compare crude numbers of facilities enrolled between states. However it is also difficult to find a standardized number of comparisons. To have an accurate count of ICUs in each state for this project, the number of ICUs reporting to NHSN in 2011 (mandatory for reimbursement by CMS) was used as the overall denominator for ICUs in each state. This number does have a few potential flaws, including that the number of ICUs in each state could fluctuate by month throughout the time period of 2009 to 2011, and that some ICUs may have chosen to not report their data to CMS despite the mandatory rules.

When modeling this data, an important consideration was of modeling the percentage of facilities participating so that the numbers were more comparable amongst states. This may make it difficult to use this model for facilities that here is not a known denominator (or ultimate goal) for enrollment. A major flaw of the models used in this analysis is that they are limited to states that did not have previous reporting mandates. This unevenly eliminated 21 states from our analysis, of which 17 had Surveillance (Activity B) funding, and only four were not Surveillance funded. This occurred because funding was purposefully given to higher performing states, and not randomly distributed among states. This analysis was unable to monitor participation changes in over half of the Surveillance funded states.

Future Work

While considering the limitations and difficulties within this work, it is important recognize the need for continued analyses. As this thesis focused on short term (one year) outcomes, two year and overall outcomes need to be assessed at the close of time limited ARRA funding. With these later analyses, it will be informative to see if these early successes or barriers continue or even predict future successes and failures within a state. From these lessons of success and failure, new recommendations can be provided to help lower achieving states improve efforts and overcome barriers. These recommendations serve as tools for policy makers as they continue to develop ways to support federal and state based initiatives to eliminate HAIs.

Infrastructure funding was provided to states to establish capacity at the state health department. Once time limited ARRA funding has been exhausted, sustainability of the developed HAI capacity at the state level should be measured. Surveillance funding at the state level promoted NHSN participation and validation, and for continued progress, it will be

important to determine what is considered a successful NHSN participation and validation level in each state. Future work should develop clear guidelines and recommendations for this, understanding that 100% NHSN participation and validation coverage may be unnecessary and an improper use of limited resources. As more facilities and locations continue to enroll and expand their reporting programs, future projects analyzing NHSN enrollment may have to find creative ways, such as in this project, to look beyond simple facility level participation rates. However it is important for these analyses to consider that 100% reporting for every infection may not be the ultimate goal. Experts in HAI surveillance and prevention should provide reporting and validation guidance and recommendations for specific infections and locations. As it was previously decided that CLABSIs should be reportable for all ICUs, the same may not hold true for all wards in the facility, or all infections. As more mandates continue to be passed, such as reporting of CAUTIs in ICUs, and CLABSIs in dialysis facilities mathematical models like those used in this work can be used for prediction to determine which states will have the most difficulties reaching participation goals, and for association to determine relationships between increased funding or other support and increased NHSN participation.

When comparing state level data, longitudinal models, such as the models developed in this project, have a distinct advantage in being able to analyze trends over time. When analyzing longitudinal models it is important to recognize and account for correlation for having repeated measures on one subject in order to make correct inferences (Cannon et al., 2001). The mixed effects models developed in this paper allowed for state based random effects, and did not assume uniform starting points (intercepts), or equal change (slopes) across the United States. These models are superior to traditional longitudinal modeling because random variation between the states is accounted for through a random term for intercept and/or slope. Future

development of these mathematical models should better account for mandate status, and attempt to attribute and distinguish successes to the effects of both mandates and programs. As the primary goal of the ARRA funding to states was to reduce or eliminate HAI, it will be important to understand the effects this program has had on HAI rates. The primary tool for this will be analyzing the surveillance data collected for HAI rates in NHSN. It will be important to understand the effect of several ARRA inputs on HAI rates including increased NHSN enrollment, NHSN validation efforts, and prevention collaboratives. The models developed in this project should be expanded not only to quantify short term programmatic goals such as monitoring NHSN participation trends, but also to better understand more long term outcomes, such as longitudinal trends in HAI rates at the state level.

Prevention collaboratives funded through ARRA were encouraged to monitor successes throughout the funding time period. Next steps should include an individual and aggregate analysis of the effectiveness of these collaboratives by analyzing both inputs (time and money) and outputs (lowered HAI rates). When monitoring HAI rates over time it will be important to limit analyses to facilities where the ARRA funding was directly utilized so that true effects of the program can be analyzed. ARRA collaboratives have the ability to help create new standards for effective evidenced-based practice recommendations to states in need of help establishing their own prevention collaboratives. Ideally, these prevention collaboratives can be analyzed to determine infections averted, or 'lives saved' and create numbers that can be truly attributable to ARRA funding.

With the entire evaluation of ARRA, it is important for public health officials at the state and federal level to continuously monitor successes. When best practices from these collaboratives are identified it will be important to recognize and disseminate this material to

other facilities looking to achieve similar goals and amplify the effects of a successful program. While some goals are unable to be measured immediately, process measures like the activities assessed here can provide insights as to the successes and barriers of a program, and allow for real-time feedback and improvement for ongoing activities. As these later findings are quantified, distal outcomes should be compared with process measures to determine which early successes and barriers are able to predict long term accomplishments in HAI prevention. With the evaluation of ARRA, it is imperative to consider that it was time limited funding, and monitor sustainability and continuation of the successes state HAI programs developed in the two year period. Without sustainability of these programs and efforts it will be impossible to measure long term successes of the ARRA program.

Tables and Figures

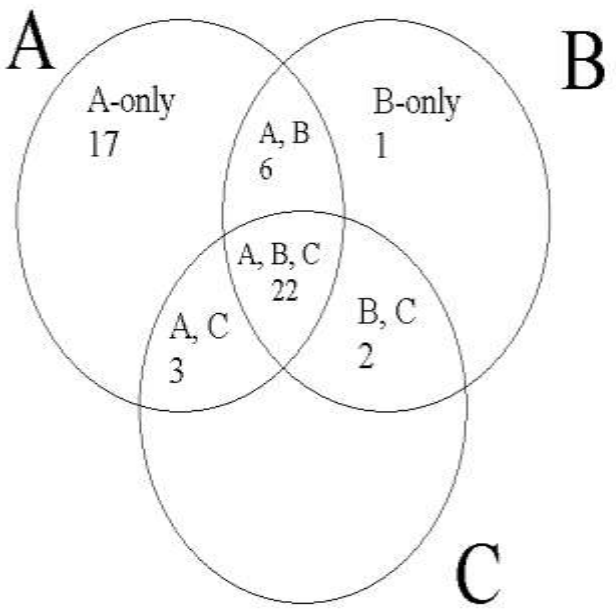

Figure 1: Number of states with unique ARRA funding distributions for Infrastructure (Activity A), Surveillance (Activity B), and Prevention Collaboratives (Activity C). The most common funding distribution was for all three activities, with 22 states.

Table 1: Number of states working with specific collaborators and formal partners (n=51) as reported at baseline in application materials prior to the receipt of ARRA funding.

Organizations	**States with Collaborators**	**States with Formal Partnerships**
Hospital Association	35 (69%)	5 (19%)
QIO	29 (57%)	3 (12%)
APIC	23 (45%)	3 (12%)
Academia	19 (37%)	3 (12%)
Community coalitions for healthcare quality	19 (37%)	2 (8%)
Professional Society Medical	11 (22%)	2 (8%)
Healthcare Association- Other	8 (16%)	2 (8%)
Insurers	8 (16%)	0 (0%)
Consumers	7 (14%)	1 (8%)
Other State Office	6 (12%)	1 (8%)
Professional Society- Infection Control	6 (12%)	1 (8%)
Survey and Certification	6 (12%)	1 (8%)
CDC	4 (8%)	1 (8%)
Patient Safety Organization	2 (4%)	0 (0%)
Professional Society- Infectious Disease	2 (4%)	1 (8%)
Local health departments	1 (2%)	0 (0%)

Table 2: Staffing at the state health department with knowledge of healthcare-associated infections, as reported at baseline in application materials prior to the receipt of ARRA funding.

	Staffing with HAI Knowledge	**States**
Staffing	*Hired*	22 (43%)
	Available	20 (39%)
	Hired and/or Available	34 (67%)
Staffing Level (Hired/ Available)	*PhD or MD*	21 (41%)
	Masters or Nurse	20 (39%)
	Infection Preventionist	16 (31%)

Table 3: Surveillance systems utilized for the monitoring of healthcare-associated infections in the state as reported by the state health department at baseline in the application materials prior to the receipt of ARRA funding.

	Activity	**States**
NHSN	*Utilized*	*37 (73%)*
	Sharing	5
	Validation	4
Other System	*Utilized*	*14 (28%)*
	Sharing	3
	Validation	1

Table 4: Topics of prevention activities (campaigns, trainings and collaboratives) ongoing at the state health department as reported at baseline in application materials prior to the receipt of ARRA funding.

	Topic	**States (n=51)**
Campaign	*Antimicrobial Stewardship*	6 (12%)
	Hand Hygiene	6 (12%)
	Infection Specific	2 (4%)
	General Infection Control	1 (2%)
Training	*NHSN*	16 (31%)
	General Infection Prevention	13 (26%)
	MRSA 9th Scope of Work	5 (10%)
	Other	4 (8%)
Collaborative	*CLABSI/CUSP*	18 (35%)
	CLABSI	5 (10%)
	MRSA 9th Scope of Work	15 (29%)
	MRSA	6 (12%)
	SSI	4 (8%)
	Other	10

Table 5: Presence of state lab and other contextual factors ongoing at the state health department as reported at baseline in application materials prior to the receipt of ARRA funding.

Lab and Other Contextual Factors	**States (n=51)**
Lab- Exists	22 (43%)
Lab- Isolate Typing	10 (20%)
Lab- Outbreaks Assistance	9 (18%)
Electronic Health Data Initiatives	16 (31%)
EIP	5 (10%)
Outbreaks (high-profile)	8 (16%)
Mention of HAI as a priority	4 (8%)
HAI Website	21 (41%)
State HAI Plan	10 (20%)
HAI Funding Priorities	13 (26%)

Year one

Infrastructure achievements and barriers (Activity A) for the 48 funded states

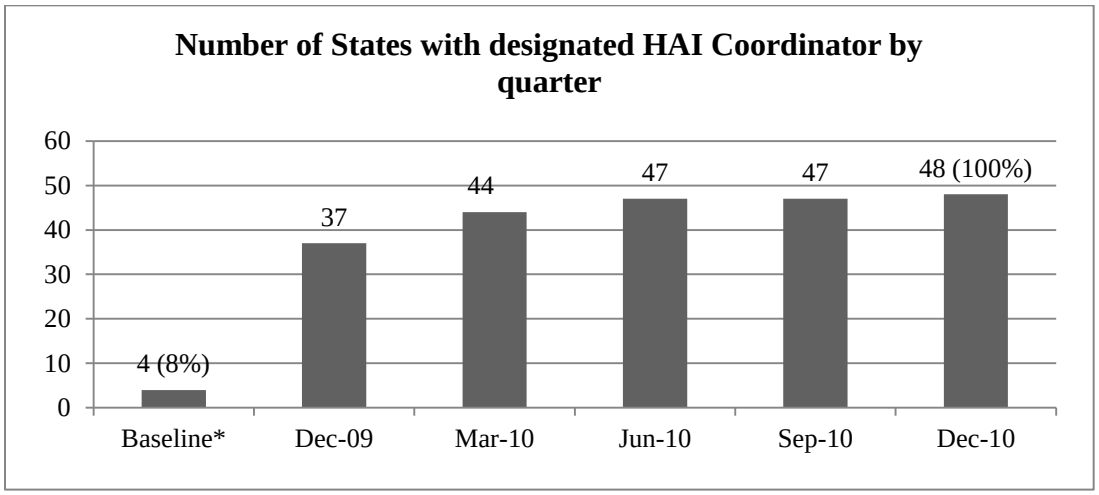

Figure 2: The number of states funded for Infrastructure reporting a designated healthcare-associated infections coordinator in each quarterly report during ARRA funding (baseline measurements are as reported at baseline in application materials prior to the receipt of ARRA funding).

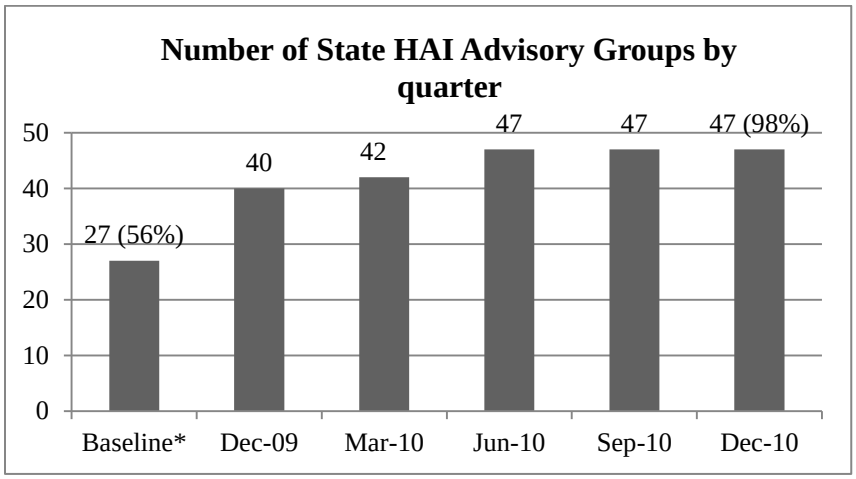

Figure 3: The number of states funded for Infrastructure reporting a designated healthcare-associated infections (HAI) advisory group in each quarterly report during ARRA funding (baseline measurements are as reported at baseline in application materials prior to the receipt of ARRA funding).

Table 6: Different activities of designated healthcare-associated infections (HAI) advisory groups, as reported by the states funded for infrastructure in quarterly reports. Activities reported as participated in 'any year one report' were reported in at least one quarterly report during ARRA funding. Activities reported as participated at 'End of Year One Report' were reported in the quarter capturing activities between October 1, 2010 and December 31, 2010.

		Any Year 1 Report	**Any Year 1 Report**		**End of Year One Report**	
	Activities	States	States doing *any* activity	States doing *all* activities	States doing *any* activity	States doing *all* activities
Initialize	Setting goals and objectives for state HAI program	27 (56%)	45 (94%)	6 (13%)	26 (54%)	4 (8%)
	Developing the state HAI plan	41 (85%)				
	Selecting infection targets or process measurement targets	31 (65%)				
Plan	Initiating contact with facilities related to HAI program activities	22 (46%)	47 (98%)	20 (42%)	39 (81%)	12 (25%)
	Planning for surveillance activities (i.e., enrollment , training, or validation)	39 (81%)				
	Planning for prevention activities (i.e., collaboratives)	35 (73%)				
Active	Recruiting hospitals for NHSN enrollment	22 (46%)	41 (85%)	8 (17%)	38 (78%)	6 (13%)
	Recruiting hospitals for prevention collaboratives	16 (33%)				
	Guiding or participating in education/training activities related to surveillance or prevention	35 (73%)				
Review Outcomes	Reviewing NHSN outcomes data submitted to the state HAI program	13 (27%)	13 (27%)		13 (27%)	

Table 7: Difficulties reported by states funded for Infrastructure to the establishment of healthcare-associated infection infrastructure at the state health department reported in a quarterly report at any time in year one of ARRA funding.

Infrastructure Establishment Difficulties*	**States (n=48)**
Spending/Contract Limitations	21 (44%)
HR Delays	16 (33%)
Problems finding qualified people	15 (31%)
Hiring Freeze	11 (23%)
Other(e.g. turnover, time)	14 (29%)

Surveillance achievements and barriers (Activity B) for the 31 funded states

Table 8: State health department uses of National Healthcare Safety Network (NHSN) data at the end of year one of ARRA funding, as reported in the quarterly reports ending December 2010 by states funded for Surveillance.

	Reported use of NHSN Data	**States (%)**	**States (%)**	**Reporting both Internal and External**
Internal	Used data to detect outlier facilities (with extremely low or high rates)	13 (42%)	17 (55%)	15 (48%)
	Prepared data reports for internal consumption	16 (52%)		
External	Prepared data reports for sharing with the public	13 (42%)	18 (58%)	
	Prepared data reports for feedback to hospitals	14 (45%)		

Table 9: Number of states with Surveillance funding validating National Healthcare Safety Network (NHSN) data for different infections as reported in the quarterly reports in year one. The median number and percent, and the range of facilities validated in each state are presented, in addition to the overall percentage of NHSN facilities that were validated from ARRA funding.

Infection Validated	# of States Validating	Mean number of facilities	Range of facilities	Median % of NHSN facilities validated in each state	IQR	Overall percentage of NHSN facilities validated
CLABSI	20	46.1	1-195	95%	43-100%	36%
SSI	6	57.17	26-99			
CAUTI	5	44.8	13-99	95%	36-100%	17%
CDI	2	115.5	52-179			
MRSA	2	2.5	2-3			
HH	1	36	36			

Table 10: Barriers to state health department access of National Healthcare Safety Network (NHSN) data at the end of year one of ARRA funding, as reported in the quarterly reports in the quarter ending December 2010 by states funded for Surveillance.

Barriers to NHSN Access	**States (%)**
No barriers to obtaining and accessing data from reporting facilities	12 (39%)
Technical difficulties	13 (42%)
Lack of cooperation from facilities	9 (29%)
Lack of protection for facilities	5 (16%)

Prevention Collaborative achievements and barriers (Activity C) for the 27 funded states

Table 11: Summary of the ARRA support, status, key attributes and outcome measurement systems of the 53 collaboratives reported in the quarterly reports by Prevention collaborative supported states throughout year one.

	Activity	**Collaboratives Reported**
		(n=53)
ARRA Funding	Initiated	29 (55%)
	Enhanced or Expanded	23 (43%)
Status at year one	Planning	10 (19%)
	Active (New or Ongoing)	42 (79%)
	Completed	1 (2%)
Key Attributes	Multi-disciplinary Advisory Group (MAG)	45 (85%)
	Staffing	45 (85%)
	Communication	49 (93%)
	Outcome Measurement	48 (91%)
Outcome Measurement System	NHSN Only	27 (51%)
	Other Only	11 (21%)
	Both	10 (37%)
	None	5 (9%)

Table 12: Types of facilities participating in the 53 collaboratives reported in the quarterly reports by Prevention collaborative supported states throughout year one of ARRA funding.

Facility Type	**Collaboratives (%,n=53)**
Acute Care	49 (93%)
Critical Access Center	15 (28%)
Long Term Care Facility	5 (9%)
Long Term Acute Care	4 (8%)
Ambulatory Care	3 (6%)
Dialysis Center	1 (2%)
Other Facility (e.g. correctional facilities, home health, rehabilitation, psychiatric)	6 (11%)

Table 13: Targets of the 53 collaboratives and 27 states as reported in the quarterly reports by Prevention collaborative supported states throughout year one of ARRA funding.

Target	**Collaboratives Reported (%, n=53)**	**States (%, n=27)**
CDI	15 (28%)	13 (48%)
SSI	12 (23%)	12 (44%)
CLABSI/ CUSP	10 (19%)	10 (37%)
MRSA	10 (19%)	8 (30%)
CLABSI	7 (13%)	5 (19%)
CAUTI /CUSP	5 (9%)	5 (19%)
CAUTI	5 (9%)	3 (11%)
MDRO	2 (4%)	2 (7%)
Acinetobacter	1 (2%)	1 (4%)
VAP	1 (2%)	1 (4%)
Avoiding/preventing hospitalization	1 (2%)	1 (4%)
Hand Hygiene	1 (2%)	1 (4%)

Table 14: Most common activities of ARRA supported prevention collaboratives as reported in the quarterly report ending December 2010 status, stratified by collaborative status (planning, new, ongoing, and completed).

Planning Collaboratives	**Collaboratives (%, n=10)**
Multidisciplinary advisory group met to strategize	6 (60%)
Recruited facilities for prevention collaborative participation	6 (60%)
State HAI program provided training on Core or Supplemental Prevention strategies	5 (50%)
New Collaboratives	**Collaboratives (%, n=9)**
Recruited facilities for prevention collaborative participation	7 (78%)
Enrolled hospitals/facilities in collaborative	7 (78%)
State HAI program provided training on Core or Supplemental Prevention strategies	7 (78%)
Facilities implemented Core Prevention strategies	6 (67%)
Multidisciplinary advisory group met to strategize	5 (56%)
Performed baseline prevention practices assessment	5 (56%)
Letters of commitment received from facilities	5 (56%)
State HAI program provided feedback to collaborative facilities	5 (56%)
Ongoing Collaboratives	**Collaboratives (%, n=33)**
State HAI program provided training on Core or Supplemental Prevention strategies	23 (70%)
Collaborative hospitals/facilities met to share experiences	18 (55%)
State HAI program provided feedback to collaborative facilities	16 (49%)
State HAI program (or affiliates) participated in CDC-led calls relevant to collaborative	16 (49%)
Completed Collaboratives	**Collaboratives (%, n=1)**
State HAI program provided feedback to collaborative facilities	1 (100%)

Factor Analysis and Factor Scores

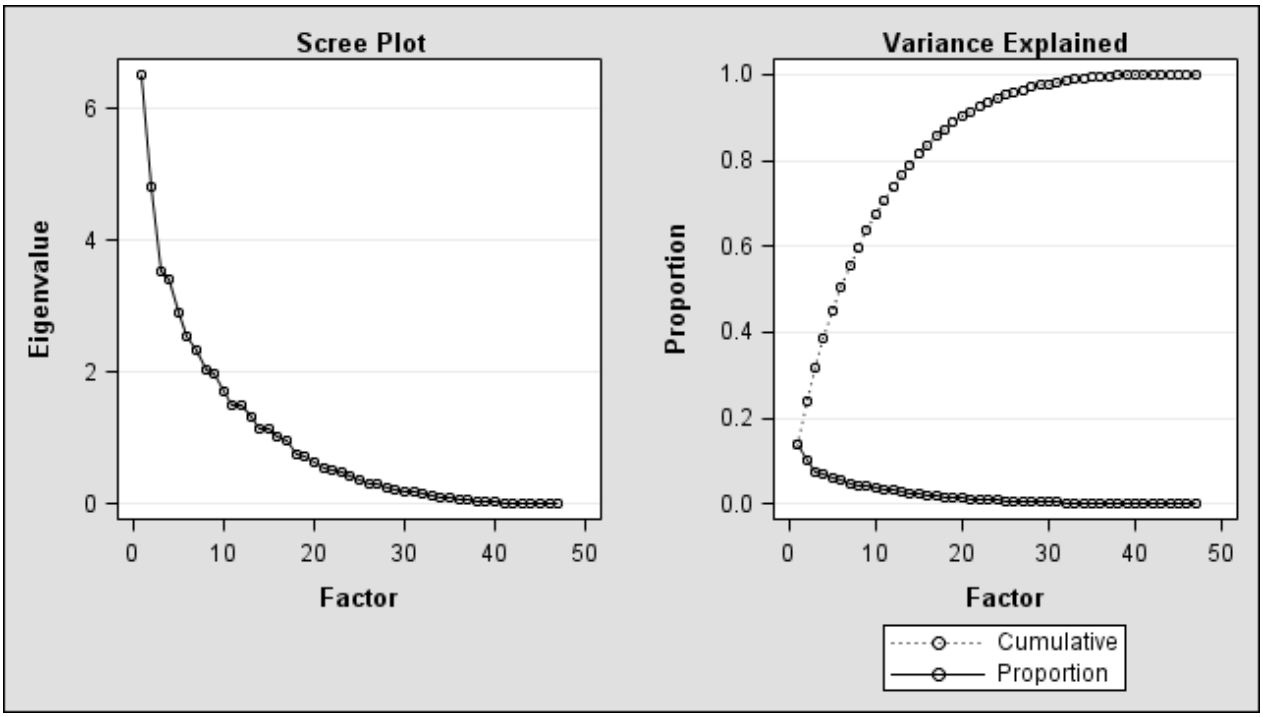

Figure 4: Scree plot and plots of variance explained for the factor analysis performed on 47 variables describing state health department capacity for healthcare-associated infection prevention abstracted from baseline grant application materials submitted prior to ARRA funding.

National Healthcare Safety Network (NHSN) Denominators

Table 15: A comparison of the number of intensive care units expected to report central line associated bloodstream infection (CLABSI) data to NHSN by January 1, 2011, as required by Centers for Medicare and Medicaid Services for states with ARRA Surveillance funding and states without.

Surveillance (Activity B)	States (n)	Min	25%	Median	75%	Max	Wilcoxon Two-Sample Test Statistic	p-value
Funded	31	15	87	170	254	1049	388	0.0029
Non-funded	21	13	31	71	115	301		

Table 16: Mean Percent of ICUs reporting CLABSs in Surveillance (Activity B) funded states at three time points: baseline (January 2008), start of ARRA (September 2009), and end of year one (December 2010).

	Overall			Only states without mandates		
	Act B	No Act B	p-value*	Act B	No Act B	p-value*
Number of states (n)	31	21		14	17	
Median Denominator	170	71		181	81	
Mean (SD) Percent Reporting in Jan 2008 (baseline)	26.7% (28.40)	12.0% (20.85)	t = 2.04 p=0.0467	10.6% (11.10)	7.3% (8.72)	t = 0.90 p=0.3743
Mean (SD) Percent Reporting in Sep 2009 (start of ARRA)	50.0% (34.15)	15.5% (21.68)	t= 4.04 p=0.0002	17.3% (11.19)	9.2% (10.34)	t= 2.09 p=0.0451
Mean (SD) Percent Reporting in Dec 2010 (end of year one)	64.4% (28.02)	34.0% (27.11)	t= 3.89 p=0.0003	40.1% (19.12)	23.9% (16.83)	t = -2.51 p = 0.0178

**P-value was calculated using two sample t-test for difference in means.*

Table 17: Estimates from Model 1, $Y_i = \beta_0 + \beta_1 mon0_i + \beta_2 mon1_i + \varepsilon_i$, (for each state i=1 to 52) where β_1 is the rate of participation before ARRA, and β_2 is the rate of participation after ARRA, and $\beta_2 - \beta_1$, the change in rates of participation. A significant test statistic (t) represents a significant change in the rate of participation before and after ARRA.

i	β_0	β_1	β_2	$\beta_2 - \beta_1$	t - statistic	p-value	Significant Change
1	0.156	-0.002	0.009	0.012	9.81	<.0001	Increase
2	-0.004	0	0.003	0.004	8.97	<.0001	Increase
3	0.032	0.002	0.012	0.01	8.93	<.0001	Increase
4	0.029	-0.005	0.036	0.041	8.39	<.0001	Increase
5	0.026	0.001	0.018	0.017	8.11	<.0001	Increase
6	0.218	0.003	0.017	0.014	7.52	<.0001	Increase
7	0.27	0.009	0.054	0.045	7.49	<.0001	Increase
8	0.203	0.002	0.014	0.012	7.3	<.0001	Increase
9	0.397	-0.002	0.012	0.014	6.65	<.0001	Increase
10	0.045	0	0.013	0.013	6.18	<.0001	Increase
11	0.073	0	0.005	0.006	6.11	<.0001	Increase
12	0.759	0.004	0.012	0.008	6.07	<.0001	Increase
13	0.051	0.003	0.022	0.019	5.99	<.0001	Increase
14	-0.019	-0.011	0.047	0.058	5.7	<.0001	Increase
15	0.141	-0.001	0.009	0.01	5.35	<.0001	Increase
16	0.235	0	0.023	0.023	5.26	<.0001	Increase
17	0.1	0.001	0.019	0.018	5.12	<.0001	Increase
18	0.028	0.001	0.014	0.013	4.75	<.0001	Increase
19	0.041	0.001	0.009	0.009	4.6	<.0001	Increase
20	0.017	-0.001	0.003	0.004	4.33	0.0001	Increase
21	0.191	0	0.007	0.007	3.9	0.0005	Increase
22	0.169	0.004	0.009	0.004	3.44	0.0016	Increase
23	0.166	0	0.008	0.008	3.3	0.0024	Increase
24	0.061	-0.001	0.007	0.008	2.93	0.0061	Increase
25	0.015	0	0.002	0.002	2.54	0.0161	Increase
26	0.139	0.003	0.005	0.003	2.5	0.0175	Increase
27	-0.001	0	0.001	0.001	2.18	0.0365	Increase
28	0.133	0.007	0.013	0.006	2.16	0.0381	Increase
29	0.685	0.003	0.006	0.003	1.74	0.0919	No
30	0.341	0.016	0.024	0.008	1.58	0.1242	No

i	β_0	β_1	β_2	$\beta_2 - \beta_1$	t - statistic	p-value	Significant Change
31	0.958	0.002	0.002	0.001	1.46	0.1535	No
32	-0.001	0	0.001	0.001	1.13	0.2682	No
33	0.362	0.008	0.01	0.002	0.99	0.331	No
34	0.17	0.001	0.002	0.001	0.98	0.3338	No
35	0.834	0.001	0.005	0.004	0.75	0.4606	No
36	0.204	0.01	0.009	-0.001	-0.38	0.71	No
37	0.498	0	0	0	-0.72	0.4796	No
38	0.335	0.007	0.003	-0.005	-1.82	0.0782	No
39	0.886	0.004	0.001	-0.003	-2.02	0.0515	No
40	0.648	0.018	0.006	-0.012	-2.37	0.024	No
41	0.562	0.032	0.012	-0.02	-3.5	0.0014	No
42	0.95	0.012	0.001	-0.011	-3.95	0.0004	No
43	1.014	0.033	-0.008	-0.041	-3.96	0.0004	No
44	0.681	0.021	-0.002	-0.022	-4.36	0.0001	No
45	1.147	0.046	-0.015	-0.061	-4.86	<.0001	Decrease
46	0.694	0.041	0	-0.041	-4.88	<.0001	Decrease
47	0.963	-0.003	-0.028	-0.025	-5.28	<.0001	Decrease
48	0.825	0.042	0.012	-0.029	-5.84	<.0001	Decrease
49	0.7	0.031	-0.002	-0.033	-5.98	<.0001	Decrease
50	1.02	0.049	-0.006	-0.055	-6.2	<.0001	Decrease
51	1.05	0.035	-0.007	-0.042	-7.11	<.0001	Decrease
52	0	0	0	0			No

Table 18: A summary of the changes in rates of enrollment for states with and without Surveillance funding (funded vs funded) from pre-ARRA to post ARRA, stratified by states with and without mandates for reporting.

	Change in Estimates	**Activity B funded**	**Non Activity B funded**	**Total**
***No** Mandate for reporting*	*Increase*	9	15	***24***
	No change	5	2	***7***
	Decrease	0	0	***0***
	Total	**14**	**17**	**31**
Mandate for reporting	*Increase*	2	2	***4***
	No change	3	1	***4***
	Decrease	12	1	***12***
	Total	**17**	**4**	**21**

Table 19: Parameter Estimates for Model 2, $Y_i = \beta_0 + \beta_1 mon0_i + \beta_2 mon0_i + b_{0i} + \varepsilon_i$, a mixed effects model with random intercepts for each of the 14 states without a mandate and with ARRA Surveillance (Activity B) funding.

Variable	**Parameter**	**Effect Estimate**	**Standard Error**	**Degrees of Freedom**	**T-statistic**	**p-value**
Intercept	β_0	0.1677	0.02843	13	5.90	<.0001
Slope before ARRA	β_1	0.002653	0.000579	488	4.58	<.0001
Slope after ARRA	β_2	0.01240	0.000810	488	15.30	<.0001

Table 20: Fixed effect parameter estimates for Model 3 $Y_{ij} = (\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB) + b_{0i} + \varepsilon_{ij}$, a mixed effects model with random intercepts for each of the 31 states without a mandate, and controlling for the effect of ARRA Surveillance (Activity B) funding.

Effect	**Parameter**	**Effect Estimate**	**Standard Error**	**Degrees of Freedom**	**T-statistic**	**p-value**
Intercept	β_0	0.09535	0.02699	29	3.53	0.0014
Slope before ARRA	β_1	0.001059	0.000433	1081	2.45	0.0146
Slope after ARRA	β_2	0.008696	0.000606	1081	14.36	<.0001
Effect for Surveillance funding	β_3	0.07234	0.04017	1081	1.80	0.0720
Change in slope before ARRA for states with Surveillance funding	β_4	0.001594	0.000644	1081	2.48	0.0134
Change in slope after ARRA for states with Surveillance funding	β_5	0.003702	0.000901	1081	4.11	<.0001

Table 21: Fixed effect parameter estimates for Model 4, $Y_{ij} = (\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB) + (b_{0i} + b_{1i} mon0_{ij} + b_{2i} mon1_{ij}) + \varepsilon_{ij}$, a mixed effects model with random intercepts and slopes for each of the 31 states without a mandate, and controlling for the effect of ARRA Surveillance (Activity B) funding.

Effect	**Parameter**	**Effect Estimate**	**Standard Error**	**Degrees of Freedom**	**T-statistic**	**p-value**
Intercept	β_0	0.09535	0.02759	29	3.46	0.0017
Slope before ARRA	β_1	0.001059	0.000985	29	1.08	0.2911
Slope after ARRA	β_2	0.008696	0.001941	29	4.48	0.0001
Effect for Surveillance funding	β_3	0.07234	0.04106	1023	1.76	0.0784
Change in slope before ARRA for states with Surveillance funding	β_4	0.001594	0.001465	1023	1.09	0.2768
Change in slope after ARRA for states with Surveillance funding	β_5	0.003702	0.002888	1023	1.28	0.2002

Table 22: Changes in pre-ARRA and post-ARRA participation rates for states without Surveillance (Activity B) funding, for both model 3 (random effect for states, intercept only) and model 4 (random effects for states, intercept and slope).

	Difference in participation rates	**Standard Error**	**Degrees of freedom**	**Test-statistic**	**p-value**
Model 3*	0.007638	0.000931	1081	8.21	<.0001
Model 4**	0.007638	0.002131	1023	3.58	0.0004

* Model 3: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + b_{0i} + \varepsilon_{ij}$

**Model 4: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + (b_{0i} + b_{1i} mon0_{ij} + b_{2i} mon1_{ij}) + \varepsilon_{ij}$

Table 23: Changes in pre-ARRA and post-ARRA participation rates for states with Surveillance (Activity B) funding, for model 2(only states funded for Surveillance, and random effect or states, intercept only), model 3 (random effect for states, intercept only) and model 4 (random effects for states, intercept and slope).

	Difference in participation rates	**Standard Error**	**Degrees of freedom**	**Test-statistic**	**p-value**
Model 2***	0.009745	0.001245	488	7.83	<.0001
Model 3*	0.08209	0.04007	1081	2.05	0.0407
Model 4**	0.08209	0.04089	1023	2.01	0.0450

***Model 2: $Y_i = \beta_0 + \beta_1 mon0 + \beta_2 mon0 + b_{0i} + \varepsilon,$

* Model 3: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + b_{0i} + \varepsilon_{ij}$

**Model 4: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + (b_{0i} + b_{1i} mon0_{ij} + b_{2i} mon1_{ij}) + \varepsilon_{ij}$

Table 24: Changes in the effect of Surveillance funding on the effect of ARRA funding (i.e., testing for significant differences between the two interaction terms to determine if states who received Surveillance funding have a different effect on participation rates during the ARRA funding period).

	Difference in participation rates	**Standard Error**	**Degrees of freedom**	**Test-statistic**	**p-value**
Model 3*	0.002107	0.001385	1081	1.52	0.1283
Model 4**	0.002107	0.003171	1023	0.66	0.5064

* Model 3: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + b_{0i} + \varepsilon_{ij}$

**Model 4: $Y_{ij} = \left(\beta_0 + \beta_1 mon0_{ij} + \beta_2 mon1_{ij} + \beta_3 ActB + \beta_4 mon0_{ij} ActB + \beta_5 mon1_{ij} ActB\right) + (b_{0i} + b_{1i} mon0_{ij} + b_{2i} mon1_{ij}) + \varepsilon_{ij}$

Appendix

Appendix 1: Factor analyses completed on the 47 variables collected from grant application materials for the 51 states at baseline.

Description of each variable	Factor 1 "Collaboratives"	Factor 2 "Campaigns/ Trainings"	Factor 3 "Human Capital/ Expertise"
External Collaboratives	0.88601		
Number of Collaboratives (0,1,2,3+)	0.86423		
CLABSI or CLABSI/CUSP Collaboratives	0.76305		
Hospital Association Collaborator Score	0.56378		
Other Collaboratives	0.55537		
NHSN Training	0.47270		
MRSA or MRSA/9SOW Collaboratives	0.45123		
HAI Advisory Group	0.44466		
HAI as a priority	0.42560		
NHSN enrollment categorized by quartiles	0.40130		
QIO Collaborator Score	0.38440		
Academic Collaborator Score	0.35348		
Training External	0.35259		
MRSA 9th Scope of Work Training	0.19886		
State HAI Plan	0.14353		
Number of campaign topics (0,1,2,3)		0.74826	
Hand Hygiene Campaign		0.67822	
Campaign Internal		0.64932	
Campaign External		0.58974	
General Infection Control Campaign		0.57282	
Antimicrobial Stewardship Campaign		0.54859	
Training Internal		0.49058	

General Infection Prevention Training		0.46385	
Number of Training Topics Covered		0.45764	
Lab: 0-No Mention 1- Exists 2-		0.32215	
Other Training		0.31669	
Contextual Factors: Outbreaks		0.30424	
Infection Specific Campaign		0.24457	
Other Surveillance System: 0- No mention		0.22074	
APIC Collaborator Score		0.21114	
Number of Staff: (None, 1-2, >2 Staff)			0.73272
PhD or MD Level Staff			0.71036
Infection Preventionist Staff			0.60329
NHSN in proposal: 0-None 1-Enrolled 2-			0.59938
Formal_Number			0.59719
Community Coalitions for Healthcare			0.54543
Number of Collaborators by quartile			0.53225
Addtl State-Other or Local Health Depts			0.52281
Contracts: 0-None 1-Exists 2-Actively			0.48368
Masters or Nurse Level Staff			0.45873
Addtl Stakeholders (Insurers, Consumers,			0.43409
HAI Website			0.36612
Additional Experts (CDC and Professional			0.34885
Contextual Factors: Electronic Health Data			0.29156
Additional staff available (Y/N)			0.28126
Contextual Factors: EIP			0.27784
Internal Collaboratives			0.00754

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