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Major Article

Pitfalls and Unexpected Benefits of an Electronic Hand Hygiene Monitoring System

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Hawthorne effect

Background: No single strategy is more effective than proper hand hygiene (HH) in reducing the spread of nosocomial infections. Unfortunately, health care worker compliance with HH is imperfect. We sought to improve HH compliance using an electronic hand hygiene monitoring system (EHHMS) in 2 units to collect unbiased data and provide feedback.

Methods: In this prospective, quasi-experimental study, the Hyginex EHHMS was installed in 2 units at Tufts Medical Center. Ninety-one bracelets were assigned, and electronic data were collected over 8 months. Human observations continued. We compared HH compliance as measured by human observation before, during, and after EHHMS implementation. Pre- and post-implementation surveys were distributed to staff.

Results: The number of electronically captured HH compliance observations was small due to infrequent bracelet use after month 2 of the intervention. HH compliance, as determined by human observation, increased by an average of 1.3 percentage points per month ($P = .0005$). Survey responses revealed negative attitudes about the EHHMS before and after its implementation.

Conclusions: Despite poor EHHMS participation and negative attitudes toward its implementation, HH compliance, as measured by human observation, significantly improved. Hospitals considering implementing an EHHMS should look to refine the intervention to encourage health care worker participation.

BACKGROUND

Health care–associated infections are a major cause of unnecessary cost and patient morbidity and mortality worldwide.[1] Even though the association between poor hand hygiene (HH) and infection transmission is well established, health care facilities struggle to enforce adherence to this practice. The Centers for Disease Control and Prevention and World Health Organization have created guidelines and launched aggressive campaigns to encourage HH compliance in health care settings, including the Clean Hands Coalition, International Year of Sanitation, and Clean Care is Safer Care Program.[2-6] Within hospitals, improving HH compliance has been shown to reduce the spread of multidrug-resistant organisms, including methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE).[7] In the United States, improvement in HH has been one of the National Patient Safety Goals of the Joint Commission.[8]

At Tufts Medical Center in Boston, MA, HH compliance data are generated by discreet observations done by unit-based HH "champions." This strategy is commonly used to optimize resources and maximize accountability at the unit level; however, this type of reporting is susceptible to human error and bias, lacks person-specific data, and utilizes delayed feedback. Further, these "champions" have other responsibilities competing for their attention. To address the deficiencies in this HH data-gathering strategy and to improve HH compliance among health care workers (HCWs), we implemented an electronic hand hygiene monitoring system (EHHMS) in 2 units that were selected due to low baseline HH

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compliance and strong commitment by unit-based leadership to quality improvement.

The EHHMS was intended to electronically collect both quantitative and qualitative data on all HH interactions and produce real-time, individualized reports. Based on the experience of hospitals that had used the same system, we estimated that approximately 17,000 observations per 10-bed unit per month would be recorded by the EHHMS. The goal was to obtain more robust and valid data than what had been previously obtained through human observations, which averaged 441 observations per month in each of the 2 units over the prior year. Our objective was to explore the effect of an EHHMS on HH compliance rates. We have reported our findings in compliance with SQUIRE guidelines.

METHODS

In this prospective, quasi-experimental, before-and-after study, our team contracted with Hyginex (Los Angeles, CA), a company founded in 2008, to install the electronic system throughout the neurology critical care unit (NCCU) and adjacent neurology intermediate care unit (NIMC). Tufts Medical Center in Boston, MA, is a tertiary care, 415-bed, university-affiliated hospital with 5 adult and 2 pediatric intensive care units.

Hand hygiene compliance was measured electronically and through standard human observation for all HCWs who interacted with patients in the 2 units. For the purpose of this study, HCWs included physicians (attending physicians, fellows, and residents), medical students, physician assistants, nurses, nursing students, occupational therapists, physical therapists, respiratory therapists, speech pathologists, dietary technicians, nutritionists, social workers, case managers, critical care technicians, unit coordinators, and housekeepers.

Sensors in the soap and waterless hand sanitizer dispensers and above patient beds interacted via wireless connection with bracelets worn by HCWs to detect proper HH. The interaction between these sensors resulted in the following information being sent to a central server: whether hands were cleaned before entering the vicinity of a patient's bed, whether hands were cleaned after leaving the vicinity of a patient's bed, and the duration of cleaning. When a HCW entered the range of the sensor above a patient's bed, 3 things happened: (1) the bracelet vibrated if the HCW had not properly cleaned his/her hands within 30 seconds of entering the patient's bed space; (2) the patient was alerted via a green or red light on the HCW's bracelet that the HCW had or had not cleaned his/her hands; and (3) a signal was sent to a central server indicating whether that specific HCW, identified by bracelet number, appropriately cleaned his/her hands prior to and after that encounter and for how long. The compliance data were to be sent to managers via weekly e-mailed reports so they could provide feedback regarding HH performance to individual HCWs.

After HCWs on the 2 units underwent a series of training sessions conducted by investigators over a period of 2 months, EHHMS bracelets were distributed to HCWs to wear during their shifts for the time period spanning from October 2013 through early May 2014. Individuals who worked primarily in the NCCU or NIMC had specific bracelets assigned to them. If a role on the unit was shared by multiple people who also worked on other units, a bracelet was assigned to that role rather than to an individual. In the latter case, it was up to the manager to review the assignment schedule to interpret weekly compliance data reports.

To increase compliance with bracelet use, the person that used the bracelet most reliably each week received a $50 gift card. No other compensation was provided for participation. Bracelet use was encouraged but not mandatory. The Tufts Institutional Review Board approved the project protocol. Informed consent was waived, as the project was deemed to be of sufficient clinical importance for quality and patient safety, and it was determined that the study could not be effectively carried out if written consent was required.

Measurement of compliance

Before-care and after-care compliance as measured by the EHHMS was defined as washing with soap and water or using waterless hand sanitizer within 90 seconds before or after entering the vicinity of the patient's bed space, respectively. A HH episode was considered high quality if the individual washed for at least 15 seconds or rubbed hands with waterless hand sanitizer for at least 18 seconds. Shorter episodes of less than 2 seconds or less were documented as noncompliant.

Human observers continued to collect HH compliance data as had been the standard at our hospital. Before-care and after-care compliance as measured by a human observer was defined as washing with soap and water or using waterless hand sanitizer before entering the patient's room and immediately upon exiting the patient's room (and before touching anything else), respectively. The human observers also recorded job titles (but not names) of the staff that entered patient rooms to the best of their abilities. Bracelet usage rates were calculated based on the number of bracelets used (even once) in a given month as a proportion of the total number of bracelets (91) in operation.

Hospital-acquired infections

As part of regular infection prevention surveillance, rates of acquisition of MRSA, VRE, and *Clostridium difficile* infection (CDI) are monitored and reported according to the guidance and definitions of the National Health and Safety Network of the Centers for Disease Control and Prevention.[9] Epidemiologic curves for these markers of nosocomial infection transmission in the NCCU and NIMC were examined over the time period beginning 8 months prior to the intervention and ending 8 months following the intervention for trends that might be associated with concurrent changes in HH compliance rates.

Surveys

A 12-question anonymous survey was distributed to NIMC and NCCU HCWs pre- and post-intervention to gain their perspectives and feedback on the technology. Responses to most questions were solicited as ratings on a 5- or 6-point Likert scale with the option to provide free text comments.

Statistical analyses

Compliance rates were defined for both electronic and human observation data as the number of compliant HH events as a proportion of the number of opportunities. We compared compliance data generated by human observation in the pre-intervention phase (4 months prior to the intervention), intervention phase (8 months), and post-intervention phase (4 months following the intervention). We calculated HH compliance rates for the 2 study units combined and compared them to rates from the other intensive care units in the hospital during the same time period. Linear regression with percent compliance as the outcome and time as the independent variable was used to estimate the average change in compliance over time for the human observation HH data. Data were analyzed using SAS Enterprise Guide 7.15 (Cary, NC).

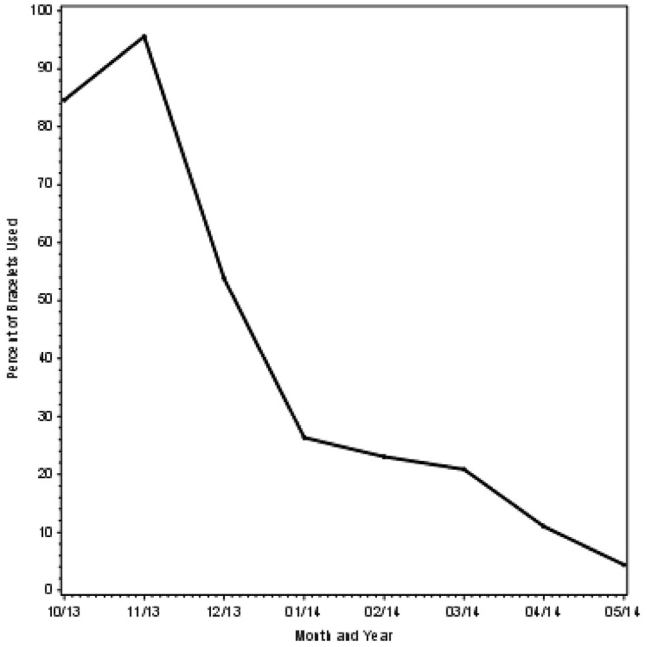

Fig 1. Bracelet usage by month since start of intervention.

RESULTS

Ninety-one EHHMS bracelets were assigned either to individuals or groups as described above.

Electronic measurement of compliance

The number of electronically captured HH compliance observations was small due to infrequent bracelet use after month 2 of the study. Figure 1 illustrates the rapid decline in the percentage of bracelets used per month over the course of the intervention period. The project was stopped 3 weeks early due to poor bracelet compliance and negative sentiment from HCWs. Figure 2 shows the compliance data obtained electronically. Compliance appears to have improved somewhat over time, but the data represent only the very small proportion of individuals who used the bracelet.

Compliance measured by human observation

Percent compliance as measured by human observation increased over time by an average of 1.3 percentage points per month ($P = .0005$). Compliance varied somewhat by job type but showed an upward trajectory for all job types (data not shown). Interestingly, compliance above 90% has been sustained through the time of this writing in these 2 units, and, although HH is generally improved throughout the hospital compared to 2013, these 2 units remain among the most consistent high performers. Figure 3 shows HH compliance before, during, and after the intervention in the study units in comparison to other intensive care units in the same hospital. Hand hygiene compliance was lower in the study units when compared to other intensive care units before EHHMS implementation. In the post-intervention period, the HH compliance rate in the study units had significantly improved and was comparable to that of other intensive care units. Besides the EHHMS, no other changes or interventions were introduced specifically in the study units. Hand hygiene educational campaigns, which are routinely carried out throughout the hospital, continued during the study period.

Hospital-acquired infections

Visual inspection of epidemiologic curves revealed no changes in rates of nosocomial acquisition of MRSA, VRE, or CDI over the course of the intervention (data not shown). Numbers of infections were extremely low in all periods.

Survey responses

Surveys regarding the perspectives of HCWs on EHHMS technology were sent by e-mail to the distribution lists of each category of HCWs known to work regularly in the NIMC and NCCU. The total

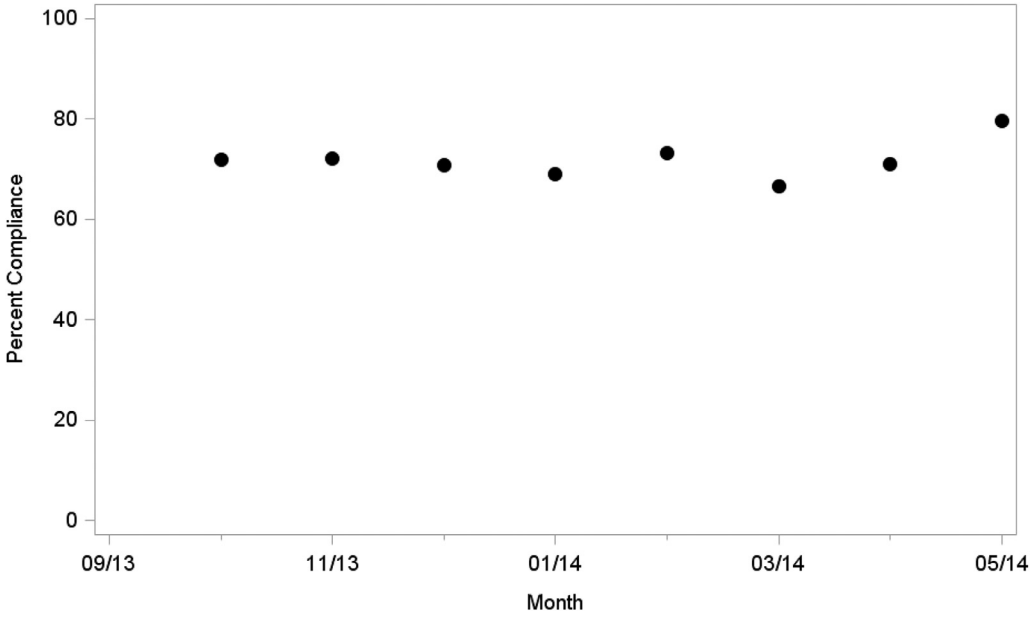

Fig. 2. Hand hygiene compliance (data obtained electronically).

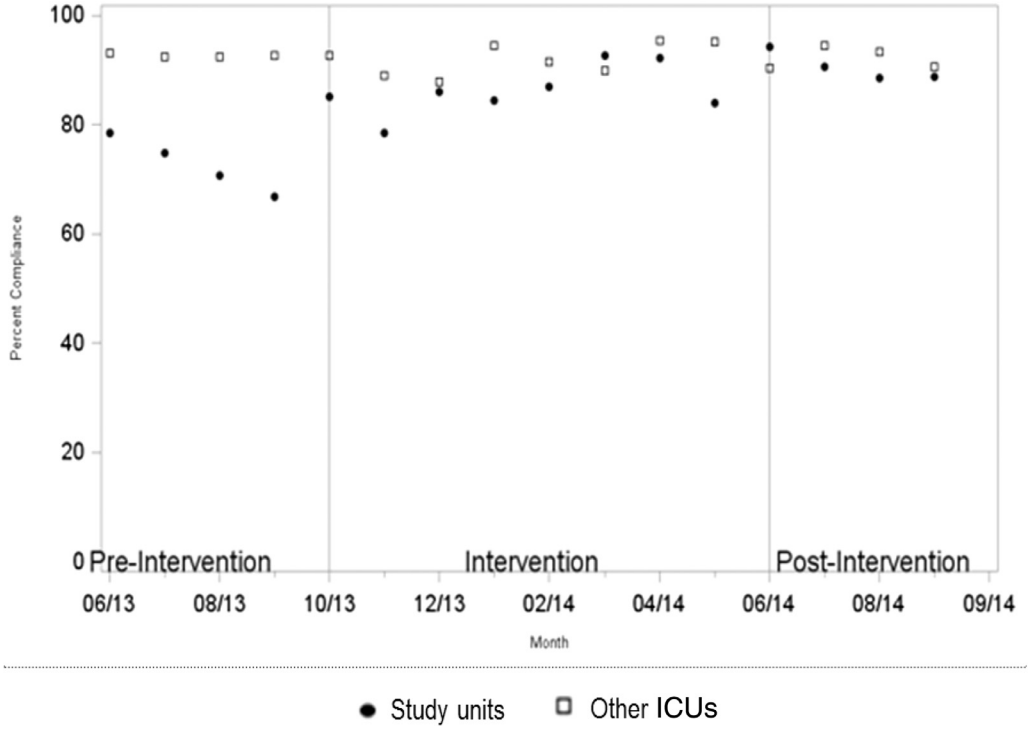

Fig. 3. Hand hygiene compliance by human observation before, during, and after the electronic hand hygiene monitoring system intervention in the study unit compared to other intensive care units (ICUs).

number of recipients is unknown. We received 55 pre-intervention and 12 post-intervention responses. The pre-intervention surveys reflected overall negative sentiment toward the technology. Although almost half of the survey respondents believed that the bracelets would be a helpful reminder and one-third felt comfortable with the idea of the bracelet, more than half believed that the technology would be a nuisance and would make them feel like "Big Brother" was watching. One-third felt they would be able to do their job without interference by the bracelet, but less than one-third felt that the technology would improve their work practice.

The post-intervention survey revealed even poorer acceptance of the EHHMS. A small minority felt comfortable using the bracelets, and the proportion that claimed the bracelet did not impact their ability to perform care had decreased to one-quarter. Three-quarters of respondents now believed that the technology was a nuisance. Only one-quarter believed that the bracelets improved the quality of care. Free text comments on the post-implementation survey indicated concerns about the accuracy and validity of the data. In one example, a HCW reported that the bracelet continued to vibrate during a family meeting inside the patient room. Another HCW commented that the device vibrated frequently upon approaching the head of the patient during rounds. Desensitization over time was also reported due to frequent false alarms. Some HCWs reported that the physical appearance and size of the device were barriers to its acceptance. The bracelets were described as bulky and uncomfortable. A smaller device or the use of a smart watch for a similar purpose was suggested.

DISCUSSION

This project was designed as a prospective, quasi-experimental quality improvement initiative to improve HH, with the ultimate goal being to reduce hospital-acquired infections. We hoped that the EHHMS would accurately measure HH quantity and quality without bias and allow for real-time feedback. Unfortunately, HCW reluctance to use the technology hindered our ability to fully fulfill our aims. Although some HCWs in our intervention units held negative preconceptions about EHHMS before the study, others became disenchanted with the idea of the system after trying the bracelet and perceived it to be a nuisance or its alerts to be inaccurate. This type of discontent with EHHMS systems has been previously reported.[10-12] In a study that looked at another EHHMS, focus groups with HCWs showed that accuracy was reported as the most common concern.[13] In another study, HCW interviews revealed improved compliance with HH but also expressed irritation and frustration with the system. Many reasons were stated including reluctance of HCWs to be monitored in this way. Issues with accuracy of the system were also reported in that study. HCWs felt the system lacked intelligence as it was based on sensors and would not allow them to use their own judgment. They offered valid examples of situations in which they would not engage in hand hygiene and expressed frustration at being held accountable by an electronic device. Concerns were also voiced regarding use of compliance data that could lead to criticism or unwanted consequences.[14]

Our survey responses suggested that some of the concerns expressed by the HCWs involved in our study regarding EHHMS technology can be addressed by making the devices more physically appealing, enhancing accuracy by reducing false alarms, and offering more autonomy to HCWs with regard to decision-making about instances in which HH is warranted. Concerns regarding data confidentiality and repercussions can be addressed by offering HCWs more control over access to and reporting of the results, empowering them rather than imposing punitive measures. Technology has continued to evolve rapidly, making it easier to collect and transmit data. Adding HH monitoring capabilities to smart watches, identification badges, and other devices already being used by HCWs might increase acceptance.

Hospitals considering implementing an EHHMS should consider its limitations and devise strategies to achieve successful implementation. Bracelet use was not made mandatory in our study because of considerations regarding the importance of staff autonomy. In the end, that decision resulted in such infrequent use that the electronic data were useless. Despite infrequent bracelet usage, compliance as measured by human observation significantly improved throughout the intervention period and beyond. Reasons for this success likely include factors such as the perception that investment in EHHMS demonstrates institutional prioritization of HH, the physical reminder to perform HH when the elements of the EHHMs (bracelet charging station, sensors) are seen on the unit, and perhaps a lingering effect from the individualized feedback given during the brief initial phase of the intervention during which more HCWs were engaged.

Research has shown mixed results when it comes to the sustained value of the "Hawthorne effect," the tendency of subjects to temporarily change their behavior when being observed, specifically as it related to HH. In studies by Bittner et al[15] and Harbarth et al[16] designed to capitalize on the Hawthorne effect as a tool to promote HH, compliance declined when the intervention ended. In contrast, other research groups, such as Kohli et al,[17] noted sustained HH compliance for 2 years after their intervention, suggesting that the Hawthorne effect can in fact persist. Sustained compliance with HH in the units in which we implemented EHHMS continues today and may indicate a successful culture shift. Future research should focus on best utilizing this psychological phenomenon as a tool to promote and sustain HH compliance.

Although other studies have seen decreased incidence of nosocomial infections coinciding with improved HH,[18,19] we did not see a decline in the acquisition of MRSA, VRE, or CDI. The already low baseline rate of transmission of these organisms in these units is the likely explanation for the lack of statistically significant effect seen in this analysis.

The strengths of our study included a long implementation period (8 months) as well as the comparison to control intensive care units in which the intervention was not carried out. Our findings are limited in several ways, however. First, HCW identities were not documented during the human observations, and we therefore could not adjust for a potential clustering effect in those data. As this is in essence a quasi-experimental, before-and-after study, one cannot exclude other influences, such as concomitant HH campaigns, as potential influencers of the rising HH compliance rate seen in these 2 units. One might be skeptical that an 8-month intervention associated with such negative sentiment could result in sustained HH rates lasting years; however, these 2 units remain consistent top HH performers, whereas most other units in the hospital have shown much more variability over time.

In conclusion, it is known that proper HH is critical to prevent hospital-acquired infection, but it is still unclear how to best promote the importance of HH to HCWs in order to achieve sustained high compliance. EHHMS technology might be a useful tool if either embraced willingly by HCWs or if mandated by hospital administration, although the latter approach could result in disgruntlement. In addition to improving the technology, future research should focus on HH improvement methods, electronic and otherwise, that are more appealing to HCWs.

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