

Infection Prevention Promotion Program Based on the PRECEDE Model: Improving Hand Hygiene Behaviors among Healthcare Personnel

Hanan Aboumatar, MD, MPH;^{1,2} Polly Ristaino, MS, CIC;^{3,4} Richard O. Davis, PhD;¹ Carol B. Thompson, MS, MBA;⁵ Lisa Maragakis, MD, MPH;^{3,4} Sara Cosgrove, MD, MS;^{3,4} Beryl Rosenstein, MD;⁶ Trish M. Perl, MD, MSc^{3,4}

BACKGROUND. Healthcare-associated infections (HAIs) result in significant morbidity and mortality. Hand hygiene remains a cornerstone intervention for preventing HAIs. Unfortunately, adherence to hand hygiene guidelines among healthcare personnel is poor.

OBJECTIVE. To assess short- and long-term effects of an infection prevention promotion program on healthcare personnel hand hygiene behaviors.

DESIGN. Time series design.

SETTING Our study was conducted at a tertiary care academic center.

PARTICIPANTS. Hospital healthcare personnel.

METHODS. We developed a multimodal program that included a multimedia communications campaign, education, leadership engagement, environment modification, team performance measurement, and feedback. Healthcare personnel hand hygiene practices were measured via direct observations over a 3-year period by "undercover" observers.

RESULTS. Overall hand hygiene compliance increased by 2-fold after full program implementation ($P < .001$), and this increase was sustained over a 20-month follow-up period ($P < .001$). The odds for compliance with hand hygiene increased by 3.8-fold in the 6 months after full program implementation (95% confidence interval, 3.53–4.23; $P < .001$), and this increase was sustained. There was even a modest increase at 20 months of follow up. Hand hygiene compliance increased among all disciplines and hospital units. Hand hygiene compliance increased from 35% in the first 6 months after program initiation to 77% in the last 6 months of the study period among nursing providers ($P < .001$), from 38% to 62% among medical providers ($P < .001$), and from 27% to 75% among environmental services staff ($P < .001$).

CONCLUSIONS. Implementation of the infection prevention promotion program was associated with a significant and sustained increase in hand hygiene practices among healthcare personnel of various disciplines.

Infect Control Hosp Epidemiol 2012;33(2):144-151

Healthcare-associated infections (HAIs) result in mortality, morbidity, and increased healthcare costs worldwide.¹ In the United States, approximately 90,000 patients die each year from HAIs, and many more experience the consequences of such infections.² HAIs result in increased hospital length of stay and increased healthcare costs, which are estimated at \$5.7 to \$6.8 billion annually.³ Multidrug-resistant organisms (MDROs) are increasingly reported to the National Healthcare Surveillance Network System as a cause of HAI.⁴ The prevalence of MDROs is increasing around the world, and there are increasing concerns about the emergence of drug-resistant organisms, such as methicillin-resistant or vancomycin-resistant *Staphylococcus aureus* and multidrug-

resistant gram-negative organisms.^{4,5} Transmission of MDROs from the hands of healthcare personnel (HCP) to patients is the primary method of transmission of these organisms in the healthcare environment.⁴ Other methods include contaminated environmental surfaces and equipment.⁶⁻⁸ Improved hand hygiene (HH) practices among HCP have been reported to reduce HAIs and transmission of MDROs; however, achieving and sustaining such improvement is challenging.⁹⁻¹¹ HCP adhere to HH guidelines in less than 50% of encounters.¹² Reported barriers to HH include lack of knowledge, poor role models, lack of time, skeptical attitudes, dermatologic problems, and poor placement of hand cleaning stations.¹² Hence, HH interventions have used a myriad of methods to address

Affiliations: 1. Center for Innovation in Quality Patient Care, Johns Hopkins Medicine, Baltimore, Maryland; 2. Division of General Internal Medicine, Department of Medicine, Johns Hopkins University, Baltimore, Maryland; 3. Division of Infectious Diseases, Department of Medicine, Johns Hopkins University, Baltimore, Maryland; 4. Department of Hospital Epidemiology and Infection Control, Johns Hopkins Hospital, Baltimore, Maryland; 5. Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland; 6. Department of Pediatrics, School of Medicine, Johns Hopkins University, Baltimore, Maryland.

Received July 5, 2011; accepted October 5, 2011; electronically published December 17, 2011.

© 2011 by The Society for Healthcare Epidemiology of America. All rights reserved. 0899-823X/2012/3302-0007\$15.00. DOI: 10.1086/663707

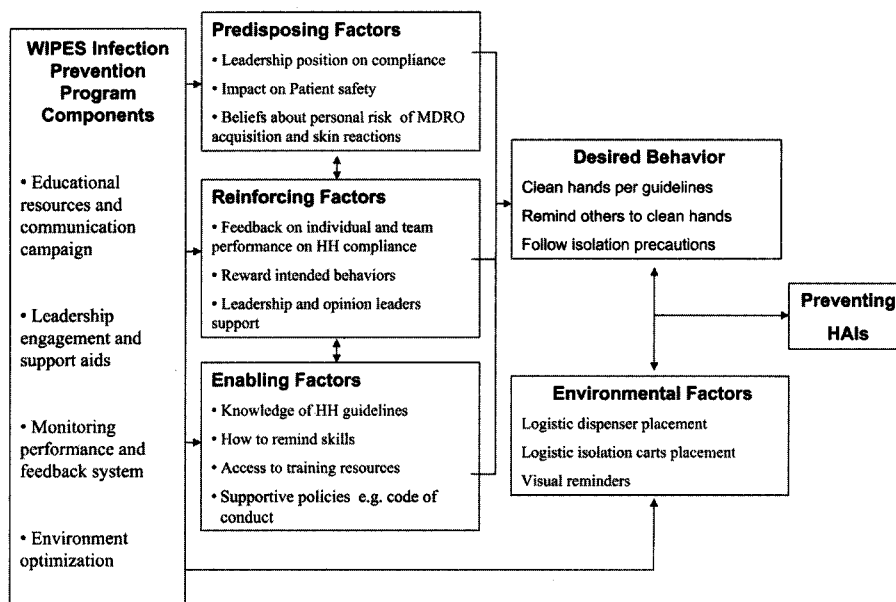


FIGURE 1. Predisposing, Reinforcing, and Enabling Constructs in Educational Diagnosis and Evaluation (PRECEDE) model for the WIPES Infection Prevention Program (see “Methods”). HAI, hospital-acquired infection; HH, hand hygiene; MDRO, multidrug-resistant organism.

those barriers. The success of interventions has varied among disciplines, with less success being achieved among physicians than among nurses.^{10,12}

Realizing that significant reductions in HAIs would require substantial and sustainable improvements in HH practices, we designed, implemented, and conducted a long-term evaluation of an infection prevention program that is grounded in behavior change theory. We involved all HCP disciplines, addressed multiple barriers, and targeted 2 key behaviors: cleaning hands in accordance with guidelines and reminding other colleagues to clean their hands. In this article, we describe our program and its impact on HH practices among HCP in the hospital setting.

METHODS

Study Setting

This study was conducted at The Johns Hopkins Hospital (JHH), which is located in Baltimore, Maryland. The Johns Hopkins Hospital is a 1,025-bed tertiary care academic center that includes 8 intensive care units (ICUs), a children’s center, and an oncology center.

Program Description

The WIPES Infection Prevention program (defined below) was developed and implemented in November 2007. The program development was initiated on the basis of the recommendation of the Stop Transmission of Multidrug-Resistant Organisms Permanently (STOMP) group, an institution-wide multidisciplinary group developed by the

Department of Hospital Epidemiology and Infection Control at JHH to engage frontline teams in improvement efforts with the goal of preventing MDRO transmission. The group identified the need for education and institution-wide promotion of HH and served as an advisory group during the WIPES Infection Prevention program’s development and implementation. We applied a Predisposing, Reinforcing, and Enabling Constructs in Educational Diagnosis and Evaluation (PRECEDE) framework for program design.¹³ This framework, which is based on multiple behavior change theories, departs from singular approaches to interventions and addresses both environmental factors and individual factors, such as knowledge, attitudes, and beliefs (Figure 1).^{13,14} With the aim of improving patient outcomes by preventing HAIs, we focused the program around the promotion of 2 target behaviors: cleaning hands in accordance with guidelines and reminding other colleagues to clean their hands. On the basis of a literature review and multiple focus groups, we identified environmental factors and predisposing, enabling, and reinforcing factors that are needed to improve HCP adoption of the selected target behaviors. Figure 1 depicts the identified factors. Accordingly, the WIPES Infection Prevention Program included the following components: a communications campaign, education, environment optimization, leadership engagement, performance monitoring, and a timely feedback system. Program components and their implementation dates are listed in Table 1. Below is a brief description of each component.

1. *Communications campaign.* Campaign development started with a situational analysis, educational needs assess-

TABLE 1. Program Components, Tools, and Implementation Dates

Program component, program materials and/or tools detail	Implementation date
Communication campaign	
Multimedia; multidisciplinary	November 2007
Posters, banners, stickers, screen savers	November 2008
Education	
Online course on "Healthcare-Associated Infection Prevention"	June 2007
Discipline-specific question-and-answer sets	November 2007
Fact sheets	November 2007
Environment optimization	
Hand sanitizer placement recommendations and survey	November 2007
Isolation signage	November 2007
Leadership engagement	
Leadership inclusion in communications campaign messages	November 2007
Leader guide to hand hygiene promotion and hand hygiene tool kit	October 2008
Tailored data reports	October 2008
Institutional leadership support letter (sequence of 2 letters)	November 2007 and October 2008
Performance measurement	
Hand hygiene monitoring system	November 2007
Feedback	
Online reporting tool (dashboard with goal setting)	October 2008
Public recognition and rewards for top-performing teams	January 2009
Attention to low-performing teams via leadership letters and/or calls	October 2008
Public recognition of individuals as hand hygiene superstars ^a	January 2009

^a Nomination by unit leaders for individuals demonstrating exemplary hand hygiene practices and reminding others to perform hand hygiene.

ment, and brainstorming of initial campaign ideas in a multidisciplinary group setting. Communication experts designed multiple communication messages that were shared in several informal focus group sessions for message selection and editing. The final campaign messages depicted photographs of 30 leaders and frontline providers on individual and group posters with a widely disseminated infection prevention message abbreviated by the acronym WIPES:

- W Wash/clean hands
- I Identify and isolate early
- P Precautions use (eg, use of gowns, gloves, and masks)
- E Environment kept clean
- S Share the commitment, raise your hand

2. *Education.* Standard educational methods, interactive games, and online learning were used. A 20-minute HAI prevention online course¹⁵ became part of the required learning for all HCP. The course incorporated the WIPES acronym, messages from hospital leaders, and instructions on how to follow standard and transmission-based precautions.

3. *Environment optimization.* Multidisciplinary meetings were held to explore factors contributing to poor HH practices in the hospital's physical environment and to recommend locations for placement of alcohol-based hand rub dispensers. A plan to strategically place HH dispensers at entrances to all patient rooms, between patient beds, and in designated public areas was developed. Subsequently, 2,500 dispensers were installed throughout the hospital. New isolation signs were also developed that showed the actual se-

quence and procedure for performing HH and using personal protective equipment.

4. *Leadership engagement.* In addition to depicting photographs of key multidisciplinary leaders on campaign messages, the overall campaign was initiated in November 2007 with a letter from high-level leadership announcing a new institutional focus on infection prevention. A follow-up letter was sent in November 2008 that set a HH compliance goal of 75% to be met by January 2009. An HH promotion guide and tool kit was sent to all unit managers and department chairs that included checklists on how to promote HH within their teams, how to discuss team performance data, and how to create additional self-monitoring and feedback for individual team members. A letter from institutional leaders encouraged tool kit use. HH compliance was regularly discussed at high-level leadership meetings throughout the institution. Department chairs and nursing directors discussed HH in their meetings and recognized units and teams that demonstrated significant improvements.

5. *Performance measurement and feedback.* Trained undercover observers conducted direct observations of HH behaviors throughout the institution, and a tailored feedback system on HH compliance was implemented. The latter included an online HH dashboard that all hospital staff could access, which provided compliance reports and graphs at a unit level and by various HCP types. HH compliance reports were also mailed electronically to institutional leaders and mid-level managers on a biweekly basis. High-performing

units were acknowledged and rewarded. "HH superstars" were nominated by team members and peers, and they were acknowledged by displaying their photographs in the hospital's public hallways and on screensavers. The "superstars" were individuals who demonstrated exemplary HH practices and reminded others to perform HH. Team leaders of units with persistently low HH compliance scores were encouraged to develop improvement plans in collaboration with the infection control team.

Implementation of the program began in November 2007 and was completed by January 2009. Table 1 includes a description of and release dates for each of the program components.

Definitions and Measurement

HH compliance was measured throughout the study period. The HH observers completed a standardized 60–90-minute online training and competency test that required them to record observations on 15 videotaped clinical scenarios. A HH episode was defined as any time that a healthcare provider used an alcohol-based hand rub or washed their hands with soap and water upon entry or exit from a patient environment. In a private or semiprivate room, the patient environment was defined by the walls of the patient room. In a multipatient room, the boundaries were defined by the walls on one side and the "curtain line" on the other. A HH compliance rate was calculated as the percentage of HH compliance episodes divided by the total number of observations. The observers aimed to collect 40 observations per unit per month. For each observation, the unit name, whether soap and water or an alcohol-based hand rub was used, and the HCP's role (eg, nurse or physician) were recorded. No HCP names were collected. As a second method to assess improvements in hand hygiene behaviors and to validate data from the direct observations measurement system, the monthly consumption of alcohol-based hand rubs in milliliters per 1,000 patient-days was measured during the first year of the study.

Data Analysis

Data were entered into an Access database and analyzed using Microsoft Excel, Minitab statistical software (Minitab), and Stata, version 11.1 (Stata). Interrater agreement among observers on online test video observations was analyzed, and a Fleiss kappa statistic was calculated. Overall hospital HH compliance was graphed by month during the full study period, and 95% confidence intervals (CIs) were calculated. Observations were categorized by HCP type as follows: a "medical provider" category comprising physicians, nurse practitioners, physician assistants, physicians in training, and medical students; a "nurse" category comprising registered nurses, practical nurses, and nurse students; an "environmental service" category; and an "other" category, which in-

cluded the remainder of HCP not accounted for by the other categories.

To allow for assessment of the short-term impact and sustainability of program results, data were aggregated for 3 time periods of 6 months each: October 2007–March 2008 (t0), which included the early months of preparation for program rollout and early implementation; January 2009–June 2009 (t1), which included the first 6 months after full program implementation; and March 2010–August 2010 (t2), which included months 14–20 after full program implementation. Overall HH compliance at the different time periods was compared with use of χ^2 tests and odds ratios. A generalized linear model (<http://www.gllamm.org>) was used to evaluate HH compliance rates while adjusting for within-unit correlation of observations and adjusting for unit bed size and nurse-to-patient ratio. To measure HH compliance increase at the unit level, the difference in percentage HH compliance for each hospital unit from t0 to t2 was used to calculate the average increase in HH compliance, and the statistical significance was tested using the 1-sample Wilcoxon test. Only units with observations from all 3 time periods were included in this analysis. A Spearman rank correlation coefficient was calculated to assess the correlation between HH compliance and consumption of alcohol-based hand rubs. All tests were 2-tailed, and P values $\leq .05$ were considered to be statistically significant. Although this work represents a large quality improvement effort at the institution, this retrospective analysis was approved by the Johns Hopkins University institutional review board.

RESULTS

A total of 74,746 observations were obtained over the study period. The number of observations and the number of observed hospital areas increased as the program implementation evolved. In the first 3 months of the study, a total of 971 observations were conducted. On average, we collected 2,093 observations each month. Interrater agreement among observers for reporting appropriately scored HH practices, determined using the training video, was 0.90 (standard error kappa = 0.01; $P < .001$).

Overall hospital HH compliance increased steadily as program implementation was underway, and this increase was sustained after full intervention implementation (after January 2009; Figure 2). Hospital-wide compliance increased from 34% during the first 6 months of the study (t0) to 72% during the last 6 months of the study (t2; $\chi^2 = 1,959.9$; $P < .001$).

Table 2 depicts HH compliance and 95% CIs at t0, t1, and t2. The adjusted odds ratio for HH compliance increased by 3.8-fold at t1, compared with baseline (95% CI, 3.53–4.23; $P < .001$). This improvement was sustained, and there was even a modest increase at 20 months of follow-up (t2). The number of beds per unit and the nurse-to-patient ratio did not impact HH compliance significantly.

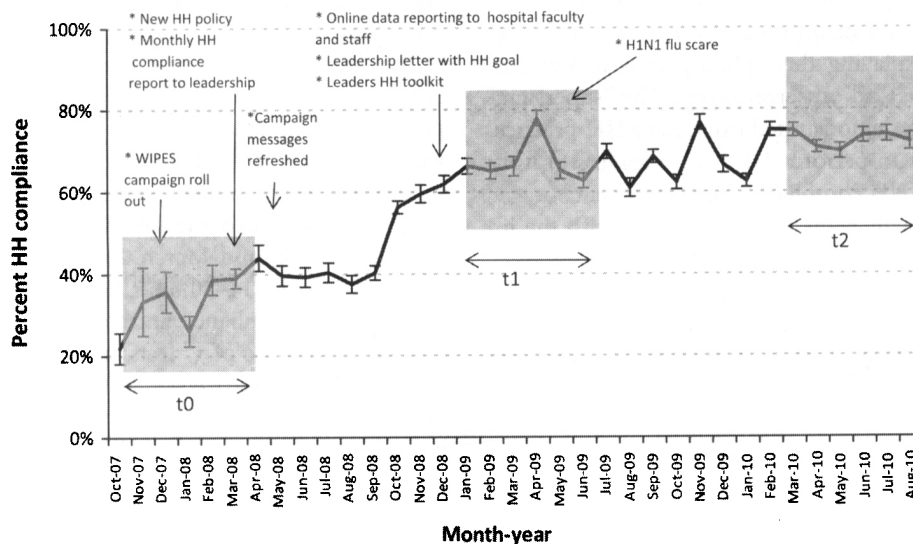


FIGURE 2. Monthly hand hygiene (HH) compliance (with 95% confidence intervals) for Johns Hopkins Hospital, October 2007–August 2010. An asterisk denotes institution-wide intervention.

Increases in HH compliance from t0 to t2 were demonstrated among all HCP categories, including an increase from 35% to 77% for nursing staff (χ^2 , 1,480.364; $P < .001$), an increase from 38% to 62% for medical providers (χ^2 , 175.548; $P < .001$), and an increase from 27% to 75% for environmental services staff (χ^2 , 184.503; $P < .001$; Figure 3). Furthermore, these increases were seen across all departments and clinical units between t0 and t2 (Figure 4). The median increase in HH compliance percentage at the unit level was 31% (95% CI, 28.39%–34.28%; $P < .001$).

Alcohol-based hand rub consumption increased from 15.6 L per 1,000 patient-days in October 2007 to 44.5 L per 1,000 patient-days in December 2008 ($P < .001$). The alcohol-based hand rub consumption positively correlated with HH compliance (Spearman rank correlation coefficient, 0.545; $P = .067$; calculation based on monthly hospital-wide HH compliance and alcohol-based hand rub consumption during 2008). The average ratio of soap and water use to alcohol-based hand rub use observed during the last 20 months of the study was 1 : 10.

DISCUSSION

HH is critical to prevent transmission of MDROs and the development of HAIs, yet compliance with recommendations is poor. In this study, we demonstrated a 4.9-fold increase in the odds for HH compliance over the study period, and improvements were seen across all HCP categories and various hospital units and departments. This improvement occurred over time as additional components of the program were released, modified, and disseminated and was sustained at 20 months after full program implementation. We suspect that all aspects of the program contributed to the improvement in HH compliance. However, we could not assess the importance or relative contribution of the individual components to the overall improvement in HH. Improvements among the nursing HCP category showed less variation over time, compared with other categories. This is likely related to the steady efforts that nurse managers made to promote HH within their teams and improve their unit's compliance data.

TABLE 2. Compliance with Hand Hygiene at Baseline (t0), after Full Program Implementation (t1), and during the Follow-up Period (t2), Johns Hopkins Hospital, Baltimore, Maryland, October 2007–August 2010

Variable	t0	t1	t2
Period	October 2007–March 2008	January 2009–June 2009	March 2010–August 2010
No. of observations	3,327	13,573	16,059
Overall compliance, % (95% CI)	34 (32.4–35.6)	67 (66.2–67.8)	72 (71.3–72.7)
Adjusted OR (95% CI) ^a	Reference	3.8 (3.53–4.23)	4.9 (4.45–5.34)

NOTE. CI, confidence interval; OR, odds ratio.

^a Adjusted for unit bed size, nurse-to-patient ratio, and within-unit correlation of observations.

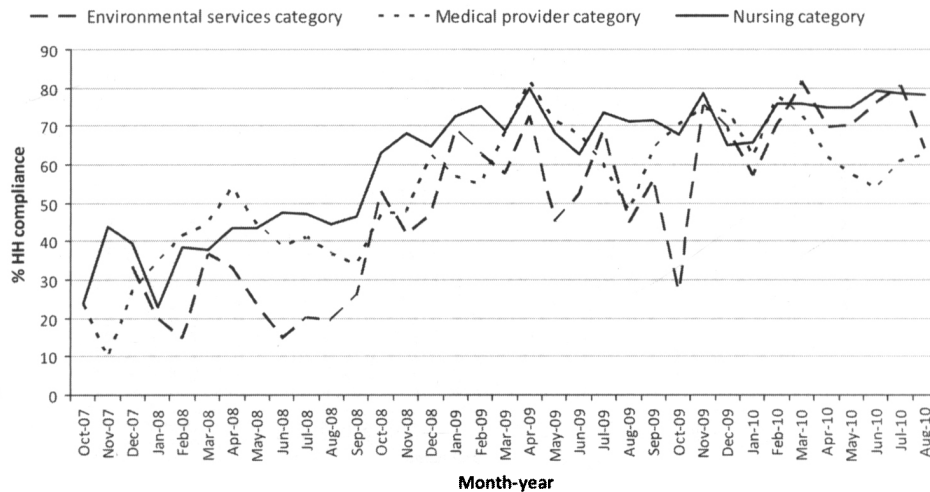


FIGURE 3. Hand hygiene (HH) compliance by healthcare personnel category at Johns Hopkins Hospital, October 2007–August 2010.

Providing ongoing monitoring and feedback to the teams on their HH compliance was a key component of our program. Frequent feedback to providers and combining group and individual feedback approaches has been linked to improvement in healthcare quality.¹⁶ However, establishing this ongoing feedback system was far from straightforward because of the paucity of reliable and valid methods for measuring HH compliance that are feasible to apply for ongoing monitoring.¹⁷ To protect patient privacy and minimize the Hawthorne effect, we aimed to create a measurement system that did not require observers to enter patient rooms but instead monitored healthcare providers' HH practices upon entry to and exit from a patient's environment. Similar approaches have been described in studies in which electronic monitoring was used.^{18,19} This measurement approach (coupled with concomitant education efforts, changes in HH policy, and placement of alcohol-based hand rub dispensers at room entrances) moved HH practice from inside patient rooms, where it is harder to monitor, to the room entrance areas, where it is more visible. In addition, HH practices became more visible to unit staff, who were able to provide reminders to each other regarding HH. Unlike earlier studies that showed a limited impact of HH improvement efforts on healthcare provider practices,¹⁰ we were able to demonstrate significant sustainable improvement in physician HH practices in our study. We attribute this improvement to the comprehensive nature of the intervention, which included an ongoing measurement and feedback component and a high level of physician leadership engagement in meeting the HH goals.

The program that we developed is comprehensive and has been deployed to other hospitals within our healthcare systems with similar results (data not shown). This suggests that this approach is generalizable to other settings, and other hospitals may benefit from implementing similar programs.

Program implementation was dually led by the infection

control and patient safety departments at the hospital, which helped in mobilizing resources, increasing support, and addressing implementation barriers in an expedited manner. Program costs included promotional materials (\$60,000), alcohol-based hand rubs (current expense, \$5,000 per month), and the equivalent of one full-time employee to conduct HH observations. The program is coordinated using existing human resources within the hospital.

Although our program was successful, we recognize limitations with our methods. First, a Hawthorne effect with direct observations may have occurred. To minimize this effect, temporary "undercover" observers were used. They were changed often and were instructed to spend no more than 20 minutes on any unit. Furthermore, increases in HH compliance based on direct observations correlated well with hospital-wide consumption of alcohol-based hand rubs. Second, the HH practices measured mainly included episodes of hand cleaning "between patients" and not within an individual episode of care. Although the program's educational materials included instruction on all opportunities for HH that may arise during a patient care episode (eg, before an invasive procedure or after exposure to bodily fluids), we cannot determine whether this program increased HH compliance for those opportunities. Additional program work is underway to assess HH practices in environments where monitoring of those opportunities is feasible, such as in intensive care units where rooms have glass partitions that make within-room activities visible from hallways.

This study is limited by its quasi-experimental design. We could not randomize units to receive the WIPES program, because by virtue of its design this program required hospital-wide implementation. Concomitant interventions might have resulted in the observed increases in HH compliance. The data analysis, however, revealed significant improvements in all units and services in the hospital that coincided with im-

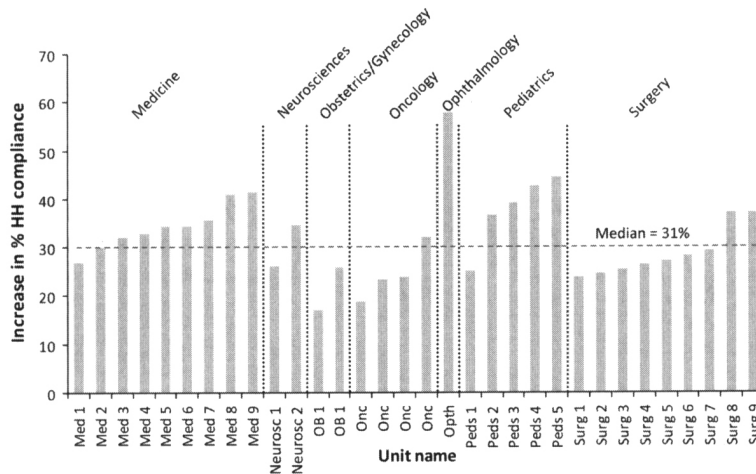


FIGURE 4. Increase in the percentage of hand hygiene (HH) compliance in major clinical services over the study period. Baseline values are compared with values for the last 6 months of the study, by unit.

plementation of the various program components. A significant transient increase in HH compliance did occur in April 2009, however, which was concomitant with an H1N1 influenza virus scare. This was likely attributable to the multiple educational activities conducted throughout the hospital to address the pandemic threat and HCP concerns about their personal risk from the H1N1 virus. To date, we have rarely seen units sustain compliance at levels greater than 80%, although several units have maintained compliance at 70%.

Finally, this study is limited by the lack of data on program impact on patient outcomes. We are currently conducting a study to assess the long-term impact of our program on HAIs and MDRO transmission.

CONCLUSION

We developed an infection prevention promotion program based on the PRECEDE model that incorporated a multimedia communications campaign, leadership engagement and support, ongoing monitoring, a Web-based dashboard, and a recognition program. Over the 3-year period during which we assessed this intervention, the program has successfully led to significant increases in HH compliance among all HCP and all hospital units. Additional research is needed to assess the impact of such improvements on the prevalence of HAIs and acquisition rates of MDROs in the acute health-care setting.

ACKNOWLEDGMENTS

We thank our institution, department, and unit leadership and our HH champions and advocates across all Johns Hopkins Hospital units and services for their support for this program and their relentless efforts to improve

hand hygiene and prevent hospital-acquired infections. We acknowledge Alex Shangraw and Eston Harden for setting the program database, members of the HH task force and STOMP committee, and the faculty and staff of the Center for Innovation in Quality Patient Care, Johns Hopkins Department of Epidemiology and Infection Control, Bloomberg School of Public Health Center for Communications Programs, and Desktop computing services.

Financial support. This program was funded by The Johns Hopkins Hospital and the Johns Hopkins University.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

Address correspondence to Hanan Aboumatar, MD, MPH, Division of General Internal Medicine, Department of Medicine, Johns Hopkins University, 601 North Caroline Street, Suite 2080, Baltimore, MD 21287 (haboumal@jhmi.edu).

REFERENCES

- Pittet D, Allegranzi B, Boyce J, World Health Organization World Alliance for Patient Safety First Global Patient Safety Challenge Core Group of Experts. The World Health Organization guidelines on hand hygiene in health care and their consensus recommendations. *Infect Control Hosp Epidemiol* 2009; 30:611–622.
- Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. *Public Health Rep* 2007;122:160–166.
- Stone PW. Economic burden of healthcare-associated infections: an American perspective. *Expert Rev Pharmacoecon Outcomes Res* 2009;9:417–422.
- Siegel JD, Rhinehart E, Jackson MP, Chiarello L; the Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in healthcare settings, 2006. <http://www.cdc.gov/ncidod/dhqp/pdf/ar/mdroGuideline2006.pdf>. Accessed October 12, 2009.
- Grundmann H, Aires-de-Sousa M, Boyce J, Tiemersma E. Emer-

- gence and resurgence of methicillin-resistant *Staphylococcus aureus* as a public-health threat. *Lancet* 2006;368:874–885.
6. Bhalla A, Pultz NJ, Gries DM, et al. Acquisition of nosocomial pathogens on hands after contact with environmental surfaces near hospitalized patients. *Infect Control Hosp Epidemiol* 2004; 25:164–167.
 7. Hardy KJ, Oppenheim BA, Gossain S, Gao F, Hawkey PM. A study of the relationship between environmental contamination with methicillin-resistant *Staphylococcus aureus* (MRSA) and patients' acquisition of MRSA. *Infect Control Hosp Epidemiol* 2006; 27:127–132.
 8. Maragakis LL, Cosgrove SE, Song X, et al. An outbreak of multidrug-resistant *Acinetobacter baumannii* associated with pulsatile lavage wound treatment. *JAMA* 2004;292:3006–3011.
 9. Doebbeling BN, Stanley GL, Sheetz CT, et al. Comparative efficacy of alternative hand-washing agents in reducing nosocomial infections in intensive care units. *N Engl J Med* 1992;327: 88–93.
 10. Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection control programme. *Lancet* 2000;356: 1307–1312.
 11. Barrera L, Zingg W, Mendez F, Pittet D. Effectiveness of a hand hygiene promotion strategy using alcohol-based handrub in 6 intensive care units in Colombia. *Am J Infect Control* 2011;39: 633–639.
 12. Boyce JM, Pittet D; Healthcare Infection Control Practices Advisory Committee (HICPAC)/Society for Healthcare Epidemiology of America (SHEA)/Association for Professionals in Infection Control (APIC)/Infectious Diseases Society of America (IDSA) Hand Hygiene Task Force. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA hand hygiene task force. *Infect Control Hosp Epidemiol* 2002;23:S3–S40.
 13. Green LW, Costagliola D, Chwalow AJ. Educational diagnosis and evaluation of educational strategies (PRECEDE model): practical methodology for inducing changes in behavior and health status. *J Annu Diabetol Hotel Dieu* 1991;227–240.
 14. Green LW, Kreuter MW. *Health Promotion Planning: An Educational and Ecological Approach*. Mountain View, CA: Mayfield, 1999.
 15. Center for Innovation in Quality Patient Care Web site, Johns Hopkins Medicine. http://www.hopkinsmedicine.org/innovation_quality_patient_care/areas_expertise/infections_complications/healthcarefiles/player.html. Accessed September 20, 2011.
 16. Hysong SJ. Meta-analysis: audit and feedback features impact effectiveness on care quality. *Med Care* 2009;47:356–363.
 17. McAteer J, Stone S, Fuller C, et al. Development of an observational measure of healthcare worker hand-hygiene behaviour: the hand-hygiene observation tool (HHOT). *J Hosp Infect* 2008; 68:222–229.
 18. Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA. Isolation status and voice prompts improve hand hygiene. *Am J Infect Control* 2007;35:470–476.
 19. Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA. Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit. *Crit Care Med* 2004;32:358–363.