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Major Article

Effect of intermittent deployment of an electronic monitoring system on hand hygiene behaviors in healthcare workers

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Background: Improving hand hygiene compliance among healthcare professionals is the most effective way to reduce healthcare–acquired infections. Electronic systems developed to increase hand hygiene performance show promise but might not maintain staff participation over time. In this study, we investigated an intermittent deployment strategy to overcome potentially declining participation levels.

Methods: An electronic monitoring system was deployed 3 times at 6-month intervals on a musculoskeletal rehabilitation nursing unit in Toronto. Each deployment lasted 4 consecutive weeks. Each wall-mounted soap and hand rub dispenser was outfitted with an activation counter to assess the impact of system deployments on overall handwashing activity.

Results: System deployments took place in October 2016, April 2017, and October 2017. A total of 76,130 opportunities were recorded, with an aggregate hand hygiene performance of 67.43%. A total of 515,156 dispenser activations were recorded. There was a significant increase in aggregate dispenser use with every deployment and a decrease over several weeks following each withdrawal. Participation was high at the beginning of each deployment and declined during each deployment but was restored to a high level with the start of the next deployment.

Conclusions: Intermittent deployment of an electronic monitoring intervention counteracts potential declines in participation rates sometimes seen with continuous system use. However, adoption of this strategy requires the acceptance of lower periods of performance between each deployment.

Improving hand hygiene (HH) compliance among healthcare professionals is considered the most effective way to reduce the occurrence of healthcare–acquired infections (HAIs).[1,2] Two major challenges of any intervention aimed at improving HH performance are the sustainability of increases it produces in the performance of staff and the sustainability of participation by the staff over the long term.[3] Methods of improving performance, such as poster campaigns, training sessions, and user feedback based on product use, have mixed results.[4-6]

The development of electronic monitoring systems (EMSs) to audit and increase HH performance shows promise but might not be sustainable in terms of staff participation over time. In previous work, we showed that with continuous deployment of an EMS over the course of a year in a quality improvement context, HH performance among participating staff is largely sustainable, but participation levels may decline.[7] These reductions in participation over time may be due to several factors, including use-fatigue, desensitization to the prompt, and the opinion that system rules do not apply to different professional roles.[8,9] In this study, we investigated the effect of intermittent deployment of an EMS on HH performance and staff participation over a 56-week period as a way to overcome declining participation levels.

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METHODS

The EMS used in this study was developed by the research team at Toronto Rehabilitation Institute. The system uses smart badges worn by staff to collect information about handwashing activity from electronic controllers installed in all soap and alcohol-based hand rub (ABHR) dispensers and on the ceiling, inside, and outside of all monitored zones including all patient rooms.[10,11] The controllers transmit unique identification codes to the badges via low-powered infrared light, with no potential adverse effects on the health of users or the operation of other electronic equipment. This information is used by the badges to produce real-time prompts to wash only when opportunities have been missed. A missed opportunity is defined as a patient room entry or exit without handwashing occurring within 60 seconds beforehand. The prompts are vibrations felt only by the badge wearer and are not audible to others, lasting 20 seconds. Green light-emitting diodes on the badge light up after washing at instrumented dispensers, remaining on while the wearer is considered to be clean (set at 1 minute for this study).

Each staff member working on the study unit was issued an electronic badge. Staff retrieve the badge from the docking station at the beginning of each shift and return it at the end of the shift. The dock provides automated badge recharging and transfer of collected data to a server. Daily aggregate HH performance results for the previous 7 days are displayed on a monitor attached to the system's docking station during system deployments. No results are provided between deployments. Before the initial deployment, staff were given live demonstrations and training sessions on the EMS. Written instructions were also posted beside the docking station along with researcher contact information. After the project launch, training was provided on an ad hoc basis in response to staff inquiries and when new staff arrived.

The EMS was installed on a musculoskeletal rehabilitation nursing unit at a teaching hospital in Toronto. A total of 111 wall-mounted soap and ABHR dispensers and 20 patient rooms were instrumented. The system was deployed 3 times at 6-month intervals. The first and third deployments occurred in the same month in consecutive years. Each deployment lasted 4 consecutive weeks. Each wall-mounted dispenser was also outfitted with an activation counter to assess the impact of EMS deployments on overall handwashing activity. Dispenser activation counters were installed before the first deployment and continued to collect data throughout the study. Staff were not aware of dispenser activation data collection.

Data collection was conducted as part of a quality improvement initiative. The University Health Network ethics board waived the requirement for consent based on the quality improvement focus of the project. The EMS is not yet commercially available; it is expected to be cost effective when it comes to market.

STATISTICAL ANALYSIS

The EMS calculates HH performance by dividing the number of times handwashing occurs within 1 minute before or 20 seconds after entering or exiting a monitored zone divided by the total number of zone entries and exits (opportunities).[12] Simple linear regression was used to evaluate the effect of time, measured weekly for 56 weeks, on HH performance and staff participation. HH performance was calculated at the aggregate unit level. Staff participation was calculated as the percentage of unique badges used compared with the number used in the first week of the initial deployment. The first week of the first deployment was used for training staff and was not included in HH trajectory analyses, but it was used as baseline for staff participation.[7]

Analysis of variance was used to detect group differences during the 3 deployments on HH performance and participation. Multiple comparisons of the 1-way analyses, with Bonferroni correction applied, were conducted to identify which deployments differed.

Activation counts from each dispenser were recorded continuously for 6 weeks before, 4 weeks during, and 16 weeks after each system deployment intervention. Data from the 2 weeks immediately preceding each deployment were not included in analyses, because the researchers' presence on the unit for system installation and maintenance may have influenced counts. The remaining data were divided into 4-week phases. The phase preceding each deployment was designated baseline, and the phase immediately following each deployment was designated return. Changes in dispenser activation counts between baseline, intervention, and return phases for each deployment were examined with a 1-way repeated-measures analysis of variance by ranks (Friedman test). These were followed by multiple comparisons between phases with Bonferroni correction applied to identify activation count differences before, during, and after each system deployment.

Statistical analyses for this study were conducted using R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The 3 EMS deployments took place October 3-30, 2016, April 3-30, 2017, and October 2-29, 2017. A total of 76,130 HH opportunities were recorded by 98 unique participants (housekeeping, n = 6; administration, n = 7; doctors, n = 8; allied health, n = 18; nurses, n = 59), with an aggregate HH performance of 67.43%.

Linear regression analyses show that HH performance had a trajectory of −0.08% per week over 55 weeks ($P = .56$; $R^2 = 0.04$). Similarly, participation levels had a trajectory of −0.10% per week over 55 weeks ($P = .58$; $R^2 = 0.03$). Figure 1 presents HH performance and participation results weekly by deployment. Participation rates were highest during the first week of each deployment and generally declined over the length of the deployment.

Separate univariate analyses of variance on the outcome variables revealed a significant group effect of deployment on HH performance ($F_{(2,9)} = 8.89$; $P < .01$), but not on participation ($F_{(2,9)} = 1.88$; $P = .20$). Multiple comparisons of HH performance results between deployment groups show that the first and second deployments differed significantly ($P < .01$; $d = 4.3$), whereas deployments 1 and 3 ($P = .66$; $d = 0.87$) and deployments 2 and 3 ($P = .06$; $d = -1.68$) did not.

Dispenser activation data were collected between August 22, 2016, and February 18, 2018. Six dispensers were damaged and unable to collect data continuously throughout the 78-week period. One dispenser was removed by the facility for renovations. There were a total of 515,156 dispenser activations from 104 soap and ABHR dispensers. There was a significant increase in aggregate dispenser activation counts with every deployment. Aggregate counts in return phases of deployments 1 and 3 remained significantly higher than their baseline counts, whereas the return phase count of deployment 2 reverted to its baseline level (Table 1). Figure 2 shows that change in activation counts of individual dispensers were concentrated in the ABHR dispensers located in hallways at patient room entrances.

DISCUSSION

The goal of this study was to determine whether intermittent deployment of an EMS in a quality improvement context would be able to maintain HH performance and staff participation levels over time. In our earlier study evaluating these trajectories for 4 different nursing units that used the EMS continuously for 1 year, 1 of the 4 units showed a significant negative trajectory of HH performance, and all 4 units had significant (albeit widely varying) negative trajectories in staff participation.[7] The results of this study show that a

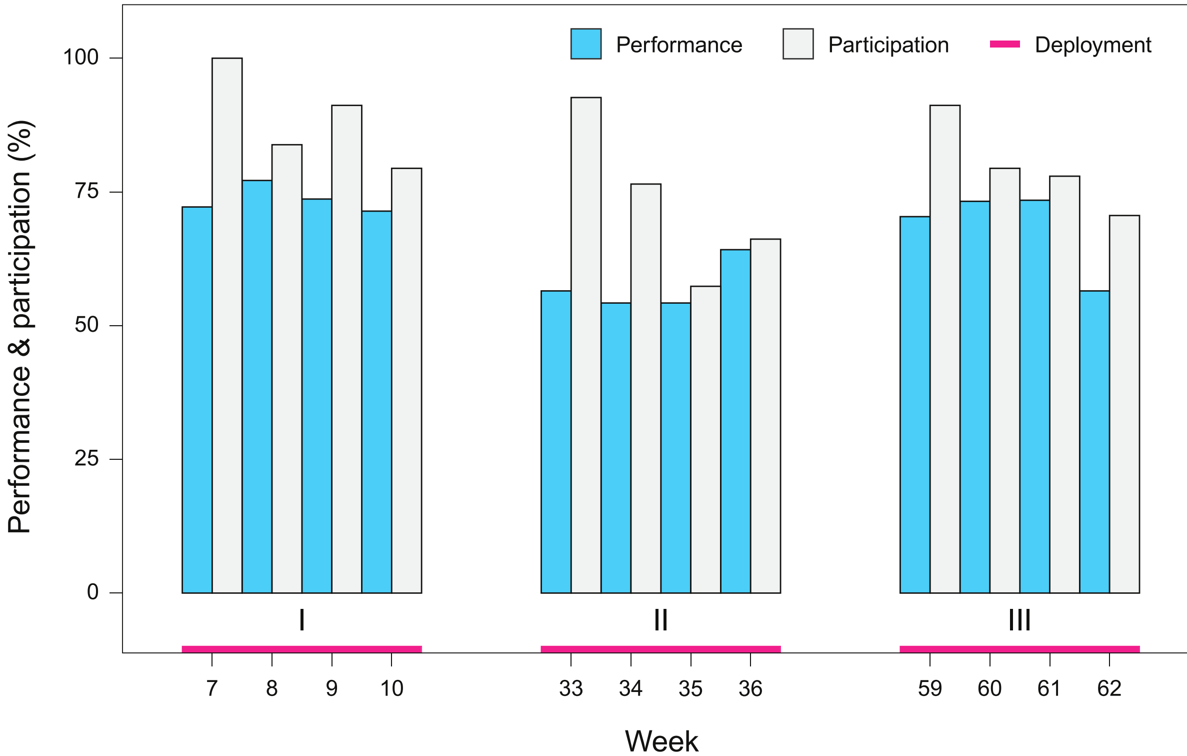

Fig 1. Hand hygiene performance and participation change over time. Weeks between deployments have been removed.

possible strategy to counter these negative trajectories might be to alternate periods when staff use and do not use the system (Fig 1). These phases of nonuse act to reduce the effects of use-fatigue and desensitization of staff to the real-time prompt feature of the system.

Despite the ability of the system to generate detailed reports of individual performance, this study used only the real-time prompts generated by the badge to provide feedback to the wearer to change behavior. No reports of performance were shared with staff, with the exception of a simple daily aggregate score that was automatically displayed on the docking station. Results of this and previous work examining the effect of prompts to wash and the impact of presenting staff with statistics lead us to conclude that it is the immediate intelligent prompt, not historical reports of performance, that changed staff behavior. This is an important observation, because this approach places no burden on management to circulate and discuss reports, although the opportunity is present if desired.

It has been reported that the additional burden of badge-based systems could lead to resistance to using such systems.[13] For this system, the only additional daily actions required by frontline staff are retrieving and returning their badges to the docking station. The electronic controllers that communicate with the badges are battery powered. The batteries are simple to change and only require annual replacement. Beyond these modest actions, no extra work was required of any hospital staff to keep the system functioning. In fact, such a system could be used to replace regular manual observations with more reliable electronically collected data and save labor.[14,15]

Non–badge-based monitoring systems, such as ones that track product use, require great amounts of effort to be effective. Dispenser count-based systems that rely on dynamic information, such as patient and staffing levels, require input from staff to ensure that variables predicting counts are as accurate as possible.[16] Such systems may be useful for examining the effects of interventions but do little on their own to change HH behavior. Improvements may be realized but at great cost to staff in time and effort by taking the generated reports and turning them into actionable targets and training initiatives that must be delivered repeatedly to be effective.[17] Because non–badge-based systems cannot track individuals' activity, goal setting and education can be presented only to a general audience.[18]

In addition to maintaining HH performance and participation levels, intermittent deployment of an EMS would reduce costs of

Table 1
Aggregate dispenser activation count results

Deployment	Phase (4 weeks each)	Total dispenser activations, n	Relative change, %*	Observed difference (*P* value, *r*)*,†
1	Baseline	19,932	—	—
	Intervention	39,347	97.41	106.50 (<.001, −0.478)
	Return	30,493	52.99	94.50 (<.001, −0.456)
2	Baseline	26,457	—	—
	Intervention	35,080	32.59	40.00 (<.001, −0.233)
	Return	34,735	31.29	7.00 (.677, −0.028)
3	Baseline	24,598	—	—
	Intervention	36,171	47.05	92.50 (<.001, −0.348)
	Return	31,215	26.90	62.00 (<.001, −0.292)

*From baseline phase.
†Critical difference = 35.02.

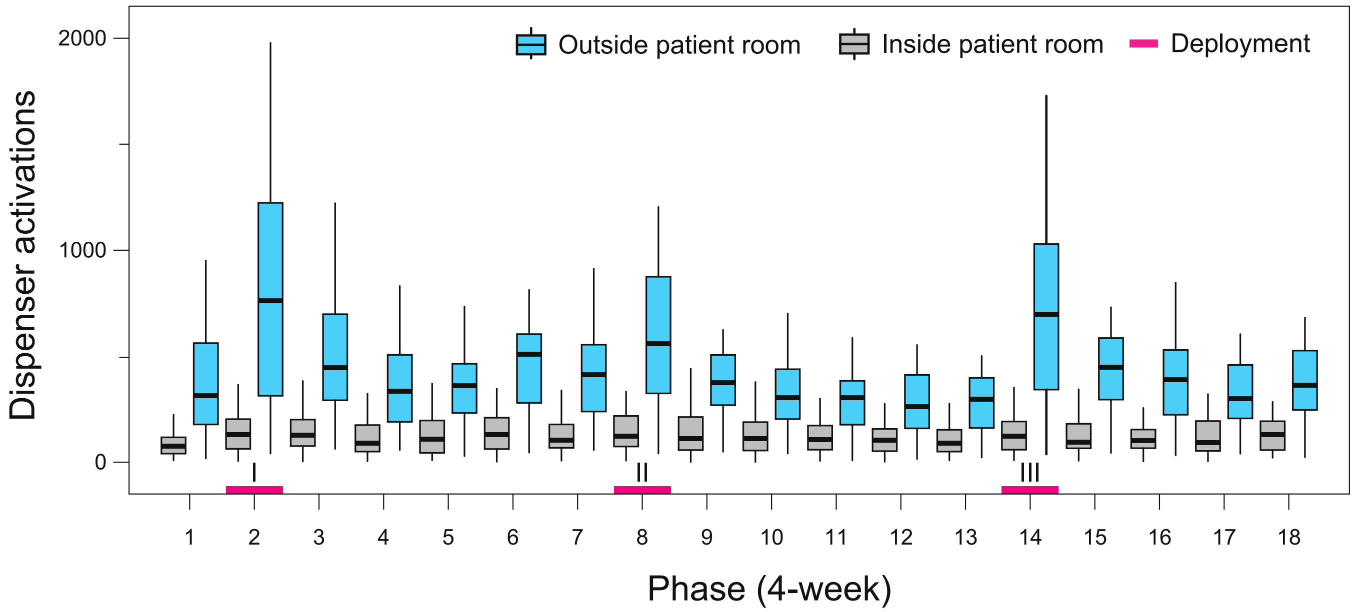

Fig 2. Activation counts of individual dispensers by location by 4-week phases. Most count changes occurred immediately outside patient rooms in alcohol-based hand rub dispensers.

implementation and allow more staff to participate. A multiunit facility would instrument the entire building with dispenser and patient room zone controllers, but the number of docking stations and badges would depend on the desired deployment length and frequency. For example, if a facility has 6 units and chooses to implement a 1-month deployment every 3 months, then each unit would use the system 4 times a year, and the facility would require only 2 docking stations and 2 sets of badges that would be rotated among the units.

Every time the EMS was removed from the study unit, dispenser activation counts dropped. We can see that the EMS affects HH behaviors and can reasonably conclude that the system-defined compliance rate also decreased when the system was removed. Can we in good conscience consider an implementation strategy that knowingly removes the tool that is helping staff perform better? However, participation rates with continuous deployment in a quality improvement context decline over time. Eventually, there may not be enough staff using the system to justify the cost of installation and maintenance. The intermittent-use strategy will help retain staff participants over time, leading to long-term HH practice improvements. A move from continuous to intermittent use shifts the purpose of the system away from augmenting practice to teaching. Perhaps the optimal strategy is to have “respite” periods when the system is removed, with reintroduction when dispenser use drops below a preset level. This strategy might be supplemented by management encouraging and rewarding staff to help maintain participation rates during each deployment.

An alternate strategy to maintain HH performance and participation rates is to retain the continuous-use model but make badge wearing mandatory for staff. To date, studies using the real-time prompting, badge-based system have largely been conducted in either a voluntary or quality improvement context. Future studies should investigate the impact of mandatory participation on HH performance and participation rates. Healthcare institutions interested in maintaining the highest possible HH compliance rates may be more interested in continuous deployment strategies.

Ultimately, activation counts after all interventions decline, but the rate of decline varies. Future studies will also investigate how different deployment and interval durations and management strategies affect HH behaviors, to determine the optimal balance between performance and participation trajectories during deployments and higher handwashing counts between deployments. The effectiveness of intermittent system deployment in different hospital environments will also be investigated.

CONCLUSIONS

Intermittent deployment of an EMS is a viable method of counteracting potential declines in HH performance and participation rates seen with continuous use in a quality improvement project context in which wearing of badges is voluntary. HH activity significantly increases with every EMS deployment and declines following removal. The ideal start dates and length of each deployment and the amount of time between them have yet to be determined and may be influenced by seasonal variables, such as staffing levels. We conclude that institutions might choose to deploy docking stations and badges on a rotating basis if they are willing to accept some performance declines between deployments or might choose to adopt management strategies that encourage and reward continuous uninterrupted participation.

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