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Effectiveness of an electronic hand hygiene monitoring system on healthcare workers' compliance to guidelines

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Summary Hand hygiene is a growing concern among populations and is a crucial element in ensuring patient safety in a healthcare environment. Numerous management efforts have been conducted in that regard, including education, awareness and observations. To better evaluate the possible impact of technology on a healthcare setting, we observed the impact of a particular niche technology developed as an answer to the growing hand hygiene concerns. A study was conducted at Salmaniya Medical Complex (SMC) in Bahrain on a total of 16 Coronary Care Unit (CCU) beds where the system was installed, and the hand hygiene activity of healthcare workers (HCWs) in this area was monitored for a total period of 28 days. Comments, remarks and suggestions were noted, and improvements were made to the technology during the course of the trial. While resistance to change was significant, overall results were satisfactory. Compliance with hand hygiene techniques went from 38—42% to 60% at the beginning of the trial and then increased to an average of 75% at the end of the 28-day trial. In some cases, compliance peaked at 85% or even at 100%. Our case study demonstrates that technology can be used effectively in promoting and improving hand hygiene compliance in hospitals, which is one way to prevent cross-infections, especially in critical care areas.

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Introduction

Hand contamination in a healthcare environment has been a subject of meticulous attention, and numerous studies have been performed to control this contamination. Healthcare-associated infections (HCAIs) at a healthcare institution jeopardize patient safety [1] and can sometimes lead to significant complications and even death [2]. Pathogens colonizing a patients' skin can easily spread to the surrounding environment and contaminate HCW hands while they perform routine activities [3]. As a result, and given that there is significant contact between HCWs and patients in some hospital areas (i.e., Intensive Care Units), there is a high risk of cross-transmission [4]. Ever since Dr. Semmelweis introduced the concept, hand hygiene has been emphasized as an important way to prevent the spread of infections among patients [5]. However, hand hygiene compliance levels are still considered to be under the acceptable thresholds, and adherence to hand hygiene procedures can sometimes be as low as 38% [6,7] despite the World Health Organization's (WHO) recommendations for proper hand hygiene practices [8].

Many reasons exist for the observed non-compliance to guidelines, some of which have been cited in previous literature, such as (i) skin irritation caused by hand hygiene agents [9], (ii) religious and cultural beliefs [10,11], (iii) high work load and prioritization [7], (iv) lack of administrative sanctions for non-compliers and lack of rewards for compliers [7], (v) lack of awareness [2], etc. Significant initiatives have been implemented to counter hand-hygiene-linked infections. Guidelines for proper hand hygiene have been initiated by international organizations, such as the ''Five Moments'' introduced by the WHO [12]. Hand hygiene is judged to be crucial in preventing the spread of infections, but it is also important to specify the ''when'' and ''how'' of hand sanitation [13] and to educate HCWs about those procedures. Leaflets representing the ''Five Moments'' of hand hygiene and guidelines for proper hand rubbing techniques have been released by the WHO (Figs. 1 and 2) with a recommendation for medical institutions to use those as a reference for HCW awareness [14].

Despite these efforts, HCW hand hygiene compliance is still insufficient and falls short of the recommended 30 hand rubs per hour [2]. Many different parameters appear to be necessary to increase compliance rates, including HCW education, reminders in the workplace, adoption of an institutional safety climate, monitoring of practices, and performance feedback [3,13].

Figure 1 How to hand rub, WHO Guidelines on hand hygiene in health care [8].

Unpublished data collected at the Salmaniya Medical Complex (SMC) in Bahrain showed a low rate of hand hygiene compliance among HCWs, especially in the CCU wing, obviously resulting in the need for improvements. Observation and monitoring of HCWs proved to be an effective tool in increasing hand hygiene compliance. However, its impact was low and is highly dependent on the presence of human observers, which is controversial and non-practical [4,15—17].

Given the importance of observation and monitoring in a healthcare setting [18], and given the effectiveness an electronic monitoring system can have [17] on improving hand hygiene, we will evaluate the impact of such a technology in a study performed on-site in cooperation with the SMC management. As with every new technology introduced in a specific setting, resistance to change might have a significant impact, thus limiting the use of the new system [19]. Technology acceptance is to be considered when planning the execution phase to minimize this resistance, and a specific approach has to be undergone to promote implementation and thus patient safety [20].

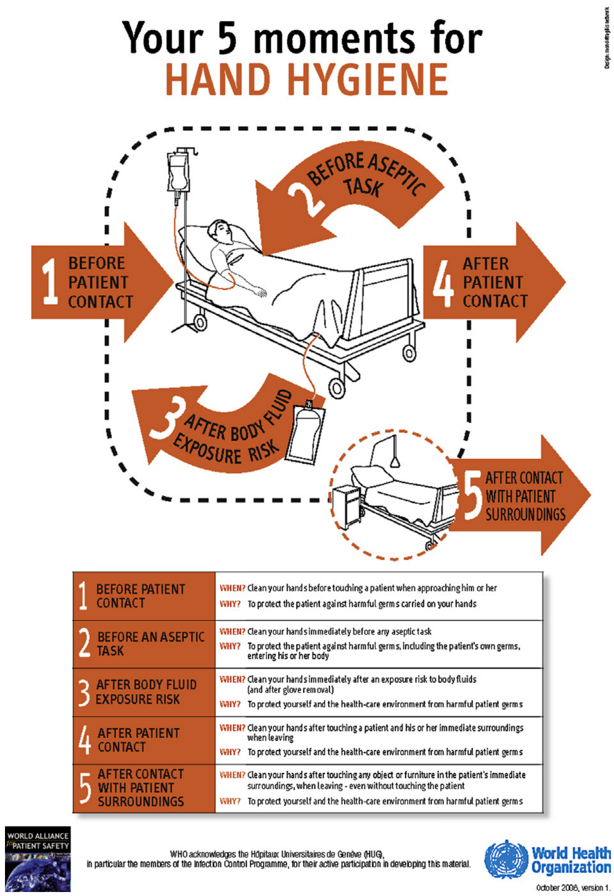

Figure 2 The 5 moments of hand hygiene [8].

We will first identify and describe the technology used and its implementation in the particular area within SMC. We will then evaluate its recordings and activity for the whole trial period of 28 days and record all signs of possible resistance to change as well as their impact. Subsequently, we will analyze these results to identify the acceptability and effectiveness of this specific technology in a healthcare environment. Our research project is simply exploratory in nature, and our objective is not to test the effectiveness of this particular technology in reducing infection rates, but rather to evaluate the potential impact technology can have in a healthcare setting and to identify the aspects of potential resistance to innovation.

Methods

Site and strategy

The Salmaniya Medical Complex (SMC) is a 1000-bed medical facility in the Kingdom of Bahrain, reputed for the quality of its healthcare services and for its highly educated staff, as well as for the proactive approach of its management to healthcare-quality related issues.

Many efforts, listed below, were implemented with the commitment of the highest management levels and the Infection Control Department to improve hand hygiene compliance:

- Adoption of skin-friendly and pleasant-smelling alcohol-based hand rubs in the dispensers to encourage their use.
- Adoption of skin-friendly and pleasant-smelling liquid soap next to the sinks.
- Training and education of HCWs regarding the importance of proper hand hygiene.
- Highly visible WHO posters and brochures were made available as reminders for the ''Five Moments'' of hand hygiene and the hand rubbing procedure.
- Official decision by the upper management to comply with the WHO guidelines.

Setting

The Hospital decided to begin with a trial in which a selected electronic hand hygiene monitoring system was used. The monitoring system ''MedSense'' from *General Sensing* was selected. The trial was conducted in Salmaniya, Bahrain, with the system's developer and manufacturer being present, two engineers educated at the Massachusetts Institute of Technology (MIT) in Boston, USA. To participate in this trial, we personally attended the installation and the 28-day trial.

Design

The electronic system for hand hygiene monitoring is a system designed to address the non-compliance of HCWs with hand washing and hand rubbing guidelines intended to reduce the number of nosocomial and other healthcare-associated infections (HCAIs). Following benchmarking methods, it was concluded that the electronic monitoring system is 88% accurate when compared to visual observations [21].

The system has different software and hardware components. The hardware is composed of the following (Fig. 3): a sensing beacon, dispenser monitors, badges, a base and a battery charger.

Sensing beacon

A sensing beacon is placed above each bed and will map out the patient environment; it will sense the activity of the HCW around the patient.

Figure 3 Electronic hand hygiene monitoring system (from left to right: dispenser monitor, badge, base + battery charger, beacon).

Dispenser monitor

A 500-mL bottle of hand lotion (alcohol hand rub or soap) is placed in a dispenser monitor. It will help identify usage when a HCW presses on the bottle's pump to dispense and, depending on which dispenser monitor is activated, record the type of liquid that is being used (i.e., sanitizer or soap). The dispenser monitor can identify a HCW badge in its immediate sensing range, which will exactly note when and where a HCW is using a hand rub.

Badge

Each HCW receives a personal badge, which he/she has to wear while performing his/her duties. When the badge gets into the range of a beacon, the system will know that the HCW is in the environment of the patient. When a HCW dispenses from a dispenser monitor, the badge will record information that the HCW has cleaned his/her hands. When he/she gets within the environment of a patient, the beacon will sense whether the badge has a positive record. If yes, then this is considered as a successful hand hygiene (HH) event; otherwise, it is recorded as an unsuccessful event and the badge will light red and vibrate to remind the HCW of the incident. Successful and unsuccessful opportunities are recorded in the base. The system monitors the HCW before entry into a patient's zone and after exiting the patient's environment, corresponding to specific moments 1 and 4 of hand hygiene, as defined by the WHO. These two moments are further recorded in this research as ''hand hygiene opportunities''.

Base and battery charger

Each badge contains a battery that can be charged by plugging it into a base that will locate signal activity from all badges and transfer the information to the ''cloud''.

Software

The software will gather all information via a Wi-Fi signal from the activity of all badges. It can be accessed from any computer browser using a registered user name and password. It helps to identify compliance trends for individuals, units and departments. Additionally, it helps to view compliance data in efficient and user-friendly ways, as well as set compliance goals and achievements.

Installation on site

On-site installation of the system was conducted in two identical wards, namely 207 (Unit 1) and 208 (Unit 2), of the Coronary Care Unit (CCU) at SMC. The installation was performed over a period of 2 days and covered physical installation, calibration and server configuration of the system.

Sixteen (16) beacons over 16 beds in one-patient rooms, eight in each of the two wards, were installed. Each beacon was properly calibrated, creating a wireless patient zone around each bed, depending on the size of the room, the height of the bed and the location of the bed inside the room.

We then installed 28 dispenser monitors, 14 in each ward: one dispenser monitor was installed on the wall in each patient room, three were installed on the walls in the nursing unit between the rooms, two next to the sinks in two patient rooms (the rooms that had sinks) and one next to the common sink in the nurse station. This setup was replicated in each of the two wards. A 500-mL bottle of Avaguard alcoholic sanitizer was placed in each dispenser monitor on the walls (a total of 14 in each ward), and 500-mL bottled soap was inserted in the dispenser monitors next to the sinks (3 in each ward). In addition to that, and after a request from the nursing staff, we installed two additional dispenser monitors outside of two rooms in Unit 1 and filled them with 500-mL bottles of Avaguard to raise the total of dispenser monitors to 16 in Unit 1.

To avoid any discrepancy and to monitor all existing activity, we emptied the fluids from all existing dispensers already fixed to the walls and stuck a red banner on each of them with the sign: DO NOT USE.

Software, base and server

The server was placed in the shared office room between the two wards. One base was installed in each ward on the nursing station and connected via Ethernet to the MedSense server. The badges were inserted and registered in the software.

Badge distribution

A total of 20 badges were distributed as follows: 10 badges to each unit, of which seven were labeled for nurses, and three for doctors. For the sake of this trial and given the limited number of badges, individual badges were not assigned to each person by his/her name; they were just distributed randomly among the HCWs and were passed among each other between shifts. The badges were registered on the software MedSense-HQ as follows: Nurse 1207, Nurse 2207, Nurse 3207, Nurse 4207, Nurse 5207, Nurse 6207, Nurse 7207 for the nurses in Unit 1; Doctor 1207, Doctor 2207, Doctor 3207 for the doctors in Unit 1; Nurse 1208, Nurse 2208, Nurse 3208, Nurse 4208, Nurse 5208, Nurse 6208, Nurse 7208 for the nurses in Unit 2; Doctor 1208, Doctor 2208, Doctor 3208 for the doctors in Unit 2.

Training and explanation

Each of the two wards had three shifts of nurses ranging from four to seven nurses, depending on the shift. Shifting times were everyday at 2 a.m., 10 a.m., and 6 p.m. Doctors were not always present in the wards, but frequent visits were usually made by the doctors. The number of doctors in one ward never exceeded three at the same time.

To train and better explain the usage and advantages of the system, and wanting to limit resistance to change [20] and enhance HCW cooperation, we were physically present during the whole duration of the trial at the shifting times to explain the use of the system to HCWs, to advise and assist them in the initiation of the monitoring system and to record their comments.

The trial period started on April 19, 2013, and spanned a total of 28 days until May 17, 2013.

Interviews

Throughout the entire trial process, several interviews were conducted with HCWs. Those included personnel from the Infection Control Department, management, nurses, doctors, IT personnel of the hospital or, in some cases, the patients and their families.

These interviews were performed to identify and evaluate the impact of resistance to change. We attended each shift change every day of the trial at 2 a.m., 10 a.m., and 6 p.m. and supervised the passing of the badges. At each shift, we checked the batteries of each badge and replaced them when necessary, as well as assisted the new shift members in clipping their badges onto their coats and making sure that that was done in an acceptable way (i.e., badge not covered by any clothing). We used this opportunity to interact with the personnel ending their shift and record their observations and comments. At the beginning of the trial, these interviews followed an ad-hoc questioning scenario. After the first week, we recorded the most significant and recurrent questions and developed a semi-structured interview system that we conducted for the rest of the trial (Table 1).

Table 1 Semi-structured interview questions.

a- Did you feel the system usage interfered negatively with your routine?
b- Are you in favor of using this system again at your next shift?
c- Did you, at any time during the shift, remove the badge in order to stop your hand hygiene monitoring? Why?
d- Are you motivated to use the system?
e- Do you feel that the system is important and that its positive impact is significant?
f- Do you understand the dangers of not using such a system?
g- Do you feel a patient's/family member's relief when they notice that this system is being used?
h- What do you think can be done to create a better environment where this system can be used?

HCWs were informed of the purpose of the study and were assured full confidentiality.

Results

All numbers, graphs and breakdowns were recorded and taken using the MedSense-HQ software. The system recorded, during the trial period, a total of 15,769 hand hygiene opportunities in the two units: Unit 1 and Unit 2.

The entire CCU average hand hygiene compliance started at approximately 60% on the first day of the trial and ended at an average of 82% on the last day of the trial, with an overall compliance rate of approximately 71% (Fig. 4). Average compliance in Unit 1 started with 60% on the first day and ended with 70% on the last day, with an overall average of 63%. Compliance was higher for Unit 2, where it started with 60% on the first day and ended with 85% on the last day, with an overall average of 75%. Averages were calculated automatically by the software based on the following ratio: positive opportunities/total number of opportunities. It is important to note, however, that HCWs in Unit 2 showed more motivation toward the system and less skepticism with regard to this solution. This was proven by less reluctance showed when HCWs were asked to wear the badges, by fewer remarks and less negative criticisms. Three of the HCWs in Unit 1 explicitly accused the system of being nothing but a way to monitor their activities and a pretext for constant surveillance (Fig. 5).

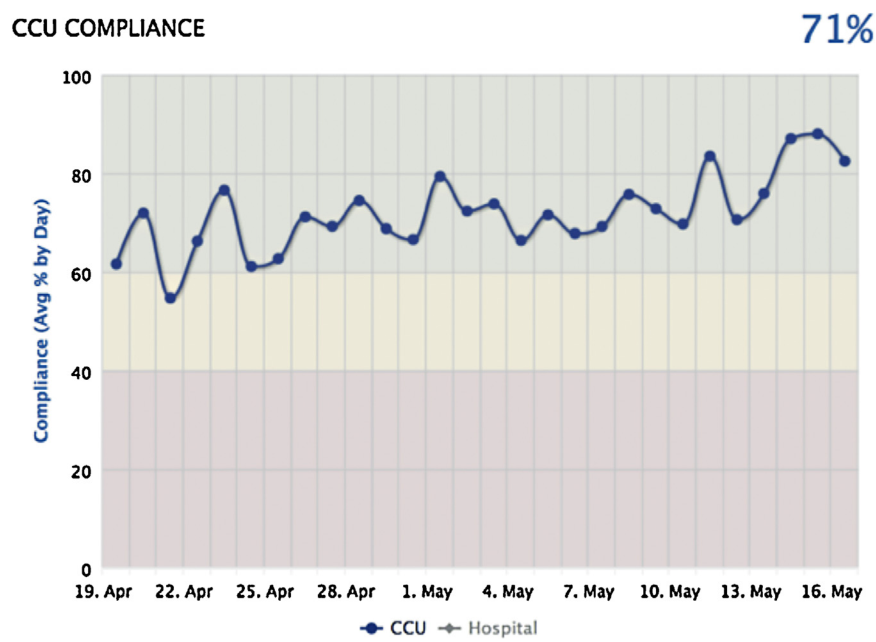

Figure 4 Overall hand hygiene compliance over the 28-day trial in both wards 207 and 208.

The system allowed us to observe compliance by shifts. The morning shift had the lowest compliance rate of 66%, followed by the evening shift with a rate of 70% and the night shift with a rate of 72%. The morning shift also showed 6022 opportunities or 38% of total number of opportunities recorded, the evening shift recorded 5633 opportunities or 35% of total number, and the night shift recorded 4144 opportunities or 26% of the total number of opportunities.

We have traced the breakdown of opportunities, relating them to the Hand Hygiene Moments 1 and 4. Moment 1 (before patient contact) had a 65% average compliance rate, while Moment 4 (after patient contact) showed a 74% average compliance rate. Of a total of 10,700 hand hygiene actions, 2247 or 21% were performed with soap and 8453 or 79% were performed with alcohol-based sanitizer. In recorded cases of exposure to bodily fluid, it was observed that both soap and water and an alcohol-based hand rub sanitizer were used by some HCWs.

To encourage HCWs to use this system and to motivate them by creating a friendly competitiveness between teammates, a leaderboard was

LEADERBOARD (AS AT 17 MAY)

POSITION	NAME	POINTS	TREND	TIME ON TOP
1	Nurse 7 208	2662	—	11 days
2	Nurse 1 207	2215	—	25 days
3	Nurse 2 208	2072	—	25 days
4	Nurse 4 208	1963	↓	11 days
5	Nurse 1 208	1855	↑	25 days
6	Nurse 5 207	1853	—	25 days
7	Nurse 4 207	1538	↓	25 days
8	Nurse 7 207	1484	↓	25 days
9	Nurse 3 208	1456	↑	25 days
10	Nurse 3 207	1399	↑	25 days

Figure 5 Leaderboard with most compliant HCWs.

created that would show HCW compliance all along the trial (Fig. 5).

Breaking down the results by user groups using the software showed that doctors had a 60% compliance rate over the entire period of the trial, while nurses showed a 69% compliance rate. It is important to note, however, that doctors would not often wear the badge adequately. Four cases were recorded where doctors explicitly stated that they were too busy to wear this badge and were just visiting the ward for a short time.

Many cases were recorded where HCWs actually stated that badge record control was not very precise, given that there was a badge exchange at the beginning of each shift, and that they would not want to be held accountable for others' compliance. Other cases were observed where HCWs mentioned that there would be an advantage in rewarding the best compliant worker; this was reported to the management of the hospital.

High skepticism of HCWs was observed during the first period of the trial, leading to difficult and reduced cooperation, which was subsequently increased for the rest of the study.

Discussion

In this paper, we are particularly looking at the impact of technology on professionals' behavior and its implementation in a medical unit. We are not trying to evaluate its impact on diminishing healthcare-associated infections, but rather its effect on raising compliance with hand washing procedure by healthcare workers and their attitude toward this type of technology.

Resistance to change is often a significant concern in a healthcare environment when introducing a new technology and is difficult to overcome [21]. The electronic hand hygiene monitoring system selected in this study has been proven to be easy to use [22], which made us believe, at first, that resistance to change would be minimal. Although welcomed at first, our initiative quickly clashed with skepticism from some of the HCWs who regarded this solution as a way and pretext used by management ''to monitor them'' and ''to spy on them'' and perceived it as an invasion of privacy. However, the installation went very smoothly and was well perceived by the HCWs and most importantly by the persons responsible for IT. The whole infrastructure was installed during normal working hours without any reported burden, inconvenience or disruption to the existing working habits. Our approach was more of a concerned approach, and we took the time to better explain, introduce and emphasize the advantages of the solution to the HCWs. The argument that the system was an important method to prevent infectious diseases from spreading and affecting HCWs and that it is a way to improve patient safety was of tremendous help in securing a positive reaction. In fact, given the growing concerns by the HCWs about their own safety, the idea that processes to improve their own environment were being adopted was received very smoothly [22,23], and positive responsiveness was perceived. Resistance, however, never ceased. In many cases (during the first week), while we were visiting the wards between shifts, we noticed that a number of nurses were not actually wearing the badges. When asked for the reason, some of them had constructive arguments:

a. The badge was vibrating and signaling at inappropriate times when there was neither a Moment 1 nor a Moment 4. We looked closer at this issue, and that led us to the recalibration of the beacon sensors above the beds, which would better define the patient environment in a more precise pattern.
b. Some HCWs complained about the effect of badge vibration on their cardiac state. We had to assure them that these vibrations had no secondary consequences whatsoever and that they were approximately 100 times less significant than the ones experienced by a cellular phone [24].
c. Some complaints concerned the strength of the vibrations and how those could cause some unpleasantness or even cause the badge to fall from its clip. We looked into that again and recalibrated the badge vibration.
d. We received two recommendations concerning the number of available dispensers around the area, which was low. Given the limited amount of dispenser monitors and given that the number of visible dispensers for the trial was greater than the initial number of dispensers before the trial, we decided to disregard this comment.

Concerning the effectiveness of the system, it is believed that the compliance rates of HCWs with hand hygiene procedures varies between 32%, 39% and 40.8% [6,16]. This new technology has increased the average of HCW hand hygiene compliance to 71% in 1 month, with an increasing trend showing that this technology helps change overall behavior and instills learning patterns. The rate started at 60% and went up to 85% at the end of the trial. There was even a recorded case of 100% compliance for 2 days in a row under badge tag: Nurse 6208. The significant increase in compliance rate from approximately 40% at the beginning of the trial [6,16] to 60% can be attributed to the bias of introducing the technology, but the subsequent increase from 60% to 85% is directly related to the impact of the system.

Overall, compliance with the system turned out to be higher in Unit 2 compared to Unit 1, which can be explained by the increased motivation that the teams from Unit 2 showed toward the system. As a matter of fact, most constructive remarks regarding the use of this system, recalibration and technology were made by HCWs in Unit 2. Furthermore, nurses from Unit 2 were constantly asking, during the course of the trial, if they could get access to their results on the software (we did not grant them access) and if they ''were doing well''. This excitement toward the use of the new technology might be a reason behind the better results observed. It is, however, important to note that Unit 1 recorded more opportunities than Unit 2, which might be one reason that explains the lower compliance.

Compliance also varied depending on the time of the day. It was highest during the night shift, followed by the evening shift and, lastly, the morning shift. Opportunities can be traced backwards, however, and this might be explained by how busy the wards are. Surgeries usually happen early in the morning, so new patients are introduced into the rooms and there is extensive activity of doctors and nurses. This is followed by the afternoon shift, where additional treatments and specific physician visits are made. Finally, the night shift is generally where only emergencies and special treatments occur, thus explaining the minimal activity.

Average compliance after patient contact was as high as 74%, while before patient contact, it was approximately 65%. This might be explained by the fact that motivation of the HCWs to comply with the system actually preserves their well-being as well and not only that of the patients, which is a growing concern in the medical community and one that has been the subject of recent research and activity [22,23,25].

Doctors showed a compliance rate of 60% in comparison with nurses at 69% over the duration of the trial. This can be explained by their lack of interest toward this technology and by their lack of time due to their extensive schedules. Very often, doctors did not wear the badges. Our team was present at every changing of shifts to assist in exchanging badges, batteries and proper wearing of the badges, but doctors often used to visit the units at unexpected times, making our activity unnoticed. It would be important that each doctor have his/her own badge registered under his/her name in the server and data. This should make them comply with hand hygiene techniques at any time and in any part of the hospital they are visiting (this system was installed in the CCU for a trial session but can be adapted to all departments of a medical facility) [24]. Upper management involvement might also be of important help when imposing the wearing of a badge by doctors [26]. A major issue faced in this study was the lack of individual badges, which could have created some discrepancy in our results. If individual badges had been present, HCWs would have been more concerned about the possibility that their individual results be reviewed by management and might have shown additional compliance and more significant improvement. It would be interesting, if this trial were to be redone, to ensure the presence of individual badges. In addition, and as per the recommendation of some of the HCWs, it would be a good idea to include incentives, where the best performing badge users would accumulate rewards, promotions, gifts, etc. This should lower resistance to change. It would also be wise to include a strict rule where non-compliers are reprimanded by management, given that their attitude and behavior compromises patient safety.

The observed increase in cooperation and responsiveness of the monitored HCWs after the first week of the trial can be attributed to different effects:

- Familiarity with the project team on a personal basis
- Better understanding of the research objectives
- Communication language with the project team: English was used during the first part of the trial which was then switched to the local language (Arabic)
- HCW feedback was taken into consideration by the project technical team, especially feedback concerning recalibrations and vibration effects

Given that compliance seemed to increase over the time of the trial, it would be interesting to perform the trial over a longer period of time, to check whether compliance still tends to increase, thus proving the educational capabilities of the technology.

Furthermore, it would be important to better manage the posters and reminders (Figs. 1 and 2) all over the CCU and to increase the number of dispensers to ensure the accuracy of our results and to prove the effectiveness of the electronic hand hygiene monitoring system.

Finally, when recording the opinion of the patients or of some family members, we felt their overall relief concerning their own safety or that of their family members.

On another note, usage of this system might be limited, especially in relation to budgeting and financing. Procurement and installation of such innovative technologies present with significant expenses related to the buying or leasing price of this technology. With the increase in competition in this particular field, overall prices of this technology are expected to drop, which will provide more opportunities for institutions to adopt this system.

Conclusion

It is clear that the use of this particular technology in this specific case seems promising and advantageous to the overall healthcare environment and that it is a step toward the establishment of a strong safety culture within the hospital organization. There were many errors and loops in this trial, but it seems that the installation of such a system, after taking care of the errors, should give positive results, especially if implemented for a period of longer than 1 month. Overall, the experience has proven that despite the strong resistance to change from some of the HCWs, the technology was well received by most HCWs, patients and even visitors.

Management's efforts are crucial in the implementation of a new technology, and additional efforts from that front would be important. However, a small dilemma remains: as observed in one emergency case, all HCWs directly or indirectly involved in interacting with this patient took off their badges. This makes us wonder whether the use of technology in this particular case should be a way to improve the quality of care or whether it should be imposed as a crucial method that is indispensable to proper healthcare techniques.

As a general finding, this study shows that resistance to technology, although significant at first, might be countered and thus reduced. Adaptation and customized methods have to be followed to ensure the best acceptability and reduced reluctance of professionals toward the use of an innovation.

Due to financial and site availability, our research was performed on a specific site and for a short period of time to preliminarily evaluate the responsiveness to the technology and its effectiveness. To better assess its impact on the spread of infections within a healthcare institution, further studies will have to be conducted on a larger scale and over longer durations.

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Competing interests

None.

Ethical approval

Obtained on-site.

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