New technologies to monitor healthcare worker hand hygiene

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Abstract

Compliance with hand hygiene is a good quality indicator for hospital patient safety programmes. Hand hygiene is a major infection control prevention intervention, but in many medical centres compliance rates are only c. 50%. Given the enormous number of hand hygiene opportunities in hospitals, direct observation to monitor compliance is very inefficient. However, technologies are emerging to obviate the need for direct observation. These new technologies for monitoring hand hygiene compliance are discussed in this article.

Keywords: Compliance, electronic devices, electronic handwash counters, feedback loop, hand hygiene, innovation, positive deviance, wireless technology, Zigbee

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Introduction

One hundred and sixty-five years after the publication of Ignaz Semmelweis’ study demonstrating the impact of hand hygiene (HH) in the inpatient setting, hospitals continue to struggle with suboptimal rates of compliance with this basic infection prevention activity, despite widespread agreement that HH is the most important intervention for the prevention of infection [1,2]. The most common reasons given by healthcare workers (HCWs) for non-compliance include insufficient time, work overload, lack of knowledge, scepticism about HH as a prevention method, inconvenient locations of sinks and soap dispensers, and lack of incentives for HH compliance [3]. Studies have confirmed that HH compliance can be affected by the accessibility of products [4] and by the formulations of these products (liquids, gels, and foams) [1,5]. If hands are not visibly soiled, the WHO recommends the use of an alcohol-based hand rub for routine decontamination of hands in all clinical situations [1]. We also know that alcohol-based HH requires less time than washing with soap (plain or medicated) and water, but is as effective for most pathogens [1,5].

Implementation Science

Implementation science entails the development of strategies and tools that promote the adoption of effective interventions to improve the quality of healthcare. There is often a considerable gap between experimental results for an intervention and its transformation into practice, and implementation science aims to fill this gap [6]. The WHO ‘My Five Moments for Hand Hygiene’ is a very nice example of implementation science. Although the Five Moments can add value to any HH improvement programme [5,7], in many medical centres where alcohol gel has been made available, HH compliance rates continue to be only approximately 50% [3,8].

Measuring Compliance

Observers. Complicating the problem of suboptimal compliance with HH is our difficulty in measuring compliance. Direct observation is considered to be the reference standard method for evaluating HH compliance [3]. However, it is
generally able to capture only a very small fraction of HH opportunities [9]. There are also issues with validity, including inter-rater reliability, the Hawthorne effect, and concerns regarding patient privacy [10]. Observers can be workers who are primarily assigned to this function, personnel embedded in their own units, or workers from other units who make surreptitious observations (i.e. secret shoppers). Technology can be used to assist direct observation. For example, hand-held personal digital assistants (iPod, Apple) using a free application (iScrub) have been successfully used to record observations and analyze compliance [11,12].

**Electronic counters.** Another option for HH compliance measurement is the use of electronic handwash counters on dispensers of alcohol-based hand rub [9,13]. Generally, studies using observers have employed relatively short observation periods [3,9]; however, electronic counters record continuously for 24 h per day. There is ongoing discussion about the usefulness of electronic HH counters in HH compliance measurement [14]. They can be very useful in counting dispenser activities, but lack utility for determining the appropriateness of HH episodes by the user, and they cannot determine the quality of HH episodes. These are disadvantages as compared with direct observation. It is questionable whether this electronic HH counter can be used as a baseline assessment for HH compliance, given the potential for under-reporting or over-reporting [10]. However, these devices can deliver rapid results without requiring the expenditure of many hours to obtain a small sample of observations. These results can be assessed at short intervals to further encourage the practice of HH among HCWs.

Another interesting study [15] assessed HH compliance through a quasi-experimental design with a duration of 30 weeks, using automated count technology and direct observation by a secret shopper with a feedback intervention. Electronic HH dispenser counts increased significantly in the post-intervention period relative to the pre-intervention period, with the average count per patient-day being increased by 22.7 in the neurological intensive-care unit (ICU) and by 7.3 in the cardiac care ICU (both p <0.001). However, direct observation of HH compliance did not change significantly (percentage compliance increased by 2.9% in the neurological ICU and decreased by 6.7% in the cardiac care ICU (p 0.47 and p 0.07, respectively)). The investigators concluded that passive electronic monitoring of HH dispenser counts does not correlate with direct human observation, and is more responsive than observation to a feedback intervention [15].

**Product utilization measurement.** Handwash product utilization has been used as a proxy for direct observation for determining HH compliance [9]. Typically, the total volume of product used (alcohol gel or chlorhexidine) is expressed in litres per 1000 patient-days. Although data collection is relatively simple, and trends may be useful over time, this method provides less detail about HH compliance than direct observation. Although measuring product use is less resource-intensive and less expensive than direct observation, it can be inaccurate and produce misleading results [14,16].

One reason for not finding a strict correlation between three HH compliance measurement methods (direct observation, electronic handwash counters, and product volume measurement) was that patients and their families inside the rooms also use alcohol gel for HH [17]. As the patient is taught about the importance of using alcohol gel for HH to prevent infections, but not taught about the quality of hand disinfection, or the way to use the electronic handwash device, it is possible that patients and family members, and even HCWs, pushed the dispenser multiple times in a short time period (although the product will be dispensed on demand, only one episode of HH is recorded for every 2-s time period), or pushed the dispenser once suboptimally, resulting in a small dispensed volume [13,17].

**New Electronic Systems for Monitoring HH**

More recently, electronic HH systems have emerged to not only record compliance but also promote it. These systems are designed to ensure that HCWs perform HH before approaching the patient’s bedside, and issue an alert to do so. They can use sensors that detect alcohol vapours [18], or radiofrequency identification to determine whether HH has occurred [13]. In one study, each nurse wore a credit card-sized badge containing a solid-state metal oxide semiconductor that detects alcohol vapours [18]. The alcohol sensor in the badge is activated at the doorway to the patient room by a sensor on the doorframe. Following the performance of HH with an alcohol-based product, the HCW places their hand near the badge sensor. If alcohol is detected within 8 s of room entry or exit, the badge light turns green, and it emits a ‘ping’ sound. If alcohol is not detected, the badge light turns red, and the badge beeps. The HH compliance data for each badge are instantaneously transmitted via wireless telemetry to a centralized database, where individual compliance data can be monitored. In this trial of alcohol vapour sensor badges, HH compliance for all HCWs before the intervention was 66%. During the intervention, HH compliance was driven to a median compliance of 92%, which is a likely underestimate of the potential impact of the device, given that no feedback was given to HCWs on their individual compli-
ance rates, and nor were unit managers informed of compliance rates [18]. One of the limitations is that HH compliance could only be assessed when the nurse performed HH with an alcohol product. A solution to this problem would be to add a marker to liquid soaps used with water.

Other studies [18,19], have evaluated new options for identification technologies (Granado-Villar and Simmonds, 21st Scientific Meeting of the Society for Healthcare Epidemiology of America, 2011, Abstract 63). Among those that are more widespread, including for use in medical equipment, there are WiFi (wireless system based on IEEE 802.11 standards) and Zigbee (wireless communication protocols based on IEEE 802.15.3 standards) [20].

Both receivers are inexpensive, are easy to maintain, and can be portable. Many medical device manufacturers are already using this technology to exchange information [13]. This technology, in addition to identification, allows the exchange of information in both directions at high speed (even in remote-monitoring systems). In addition, mobile devices, such as mobile phones, smartphones, and tablets, have communication via WiFi, raising the possibility of new applications (e.g. the use of mobile phones for identification). The major inconvenience of this technology is the need to use batteries in the badge that is attached to the clothing of the HCW [13]. Moreover, they are able to transmit data on compliance wirelessly to a centralized tracking station, which can display personal compliance rates for every HCW. This can also allow the use of a feedback loop in real time to improve HH compliance. Feedback loops are profoundly effective tools for changing human behaviour on the basis of a simple premise—give people information about their actions in near real time, and then show them how to change those actions into better behaviours [21].

A recent study placed video cameras with views of every sink and hand sanitizer dispenser in an ICU to record the HH of HCWs. Sensors in doorways identified when an individual entered or exited. When remote video auditors observed an HCW performing HH upon entering or exiting, they assigned a pass; if not, a fail was assigned. Performance feedback was continuously displayed on electronic boards mounted in hallways, and summary reports were delivered to supervisors by email. The remote video monitoring of HH with real-time feedback to HCWs was responsible for a significant increase in HH compliance [22]. Recently, another study demonstrated the utility and validity of ultrasound transmitters to measure HH compliance [23].

In Hospital Israelita Albert Einstein, São Paulo, Brazil, a controlled trial of radiofrequency badges (Zigbee) is underway in a step-down unit. These badges detect HCWs inside the room, and determine whether they have performed HH through a wireless communication system with a 2.4-GHz frequency (Zigbee). If the HCW triggers the alcohol gel dispenser, it detects the radio signal emitted by the badge (Fig. 1), and, after detection of the HCW badge, the dispenser sensor forwards a signal to the bedside sensor (i-HealthSys, São Carlos, Brazil) [24]. The bedside sensor monitors the radio signal emitted by the HCW badge. If the HCW performed HH inside the room, the bedside sensor light turns green (a positive message). If HH was not performed, a red light appears, signalling that HH needs to be performed. The disadvantage of Zigbee is that is an accurate location may require multiple beacons in an area, or combination with another technology; some systems may credit two HCWs with a HH event if the HCWs are in very close proximity [14].

Despite the advantages of newer technologies, at this time they are unable to differentiate the Five Moments for Hand

**FIG. 1.** A hand hygiene (HH) system working through a feedback loop with a wireless communication system (Zigbee). (a) A healthcare worker (HCW) performs HH, and the radio signal emitted by the badge is detected by the product dispenser. (b) After detection of the HCW badge, the dispenser wirelessly sends the data (data, hour, and badge identification) to the bedside sensor. (c) The bedside sensor monitors the signal of the radio emitted by the badge. If the HCW is inside the room, the bedside sensor light turns green if the HCW performed HH, or red if the HCW did not perform HH.
Hygiene. It is also important to note that these technologies have remained limited in use, as they are expensive and generate high maintenance costs, although it is likely that the cost will decrease over time. However, having different technologies for measuring compliance available allows hospitals to choose among tools with different advantages and disadvantages, and to combine them with standard approaches.

**Changing Behaviour**

Positive deviance is a non-technological approach that can improve HH compliance. In traditional leadership models, HCWs execute decisions, and are rarely engaged in decisions about how the work should be done. Alternatively, in positive deviance, HCWs decide how the work should be done, and promote discovery among their peers [10]. Positive deviants are those workers who, given the same resources as their peers, are able to find solutions to problems that seem to be intractable. Leaders and managers provide support, filter ideas, and remove barriers to implementation of best practices identified by positive deviants for improving HH compliance. In this model, the first step is to decrease the distance between the infection control unit personnel and the HCWs [10]. Positive deviance promotes ownership of problems by frontline workers, and empowers the positive deviants to develop and implement changes to improve HH compliance [10,12].

Recently, in a Brazilian hospital, the number of nurse visits to patient rooms was measured by a nurse-call system in two step-down units [10]. Positive deviants suggested the additional metric of compliance with the use of alcohol-based hand rubs by the nursing staff. This allowed calculation of the number of alcohol rub aliquots dispensed per number of nurse visits to patient rooms [12], and ultimately improved HH compliance.

Recent evidence from social network analysis confirms that we are influenced not only by people close to us (parents, siblings, or friends), but also by friends of friends [25]. In a similar vein, HCWs can be influenced by patients and visitors. A recent study demonstrated that most patients (93%) prefer electronic reminders, i.e. a button or light on HCWs indicating they did not clean their hands, rather than printed information (7%) as an intervention to encourage patients to discuss HH practices with their physicians [26]. Another study demonstrated a measurable improvement in visitor’s HH compliance after an audiovisual reminder of infection control procedures on entry to a neonatal ICU [27]. Incorporating a training programme for HCWs with an automated gaming technology training and audit tool to educate staff on HH techniques in an acute healthcare setting led to an improvement in HH compliance among HCWs [28].

Displaying posters with gain-framed messages, i.e. messages promoting HH, emphasizing the positive consequences of adherence, is theoretically effective in improving HCWs’ HH behaviour [29], and may promote HH in daily practice. An interrupted time-series analysis conducted in a neonatal ICU tested the impact of gain-framed messages on the frequency of HH events and compliance, using electronic devices on hand alcohol dispensers. They noticed a negative trend in HH events per patient-day before the intervention (decreased by 2.3 (standard error, 0.5) per week), which changed to a significant positive trend (increased by 1.5 (0.5) per week) after the intervention (p <0.01) [30].

**Conclusions**

Although HH is considered to be a simple intervention, and new technologies for measuring and improving compliance are very welcome, multidisciplinary teams are generally necessary to plan and implement interventions across hospital units. With regard to new technologies, much more analysis needs to be performed, and hospitals should carefully evaluate the technology prior to making a significant investment. In addition, the feedback loop must be better explored and, after that, the other steps for the ‘My Five Moments for Hygiene’ will need to be incorporated in the electronic process to assist HCWs in improving HH compliance and result in an innovative advance for patient safety in hospital settings.

**Transparency Declaration**

The authors declare no conflicts of interest.

**References**


