MediHandTrace*: a tool for measuring and understanding hand hygiene adherence

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**Abstract:** Proper performance of hand hygiene at key moments during patient care is the most important means of preventing health-care associated infection. Despite many programs aiming to enhance hand hygiene, HCW compliance stays incredibly low. One limiting point is the lack of standardized measure and reporting of hand hygiene opportunity. Direct observational audit have reported their weakness. We report here a RFID-based real-time automated continuous recording system (MedihandTrace®) that allow following hand hygiene opportunity and disinfection compliance of HCW that we evaluated against video recording as very accurate (99.02%) sensitive (95.65%) and specific (100%). The system can also provide information useful to understand noncompliance of HCW and will allows evaluation of future intervention studies.
Introduction:

Hand hygiene is a core element of patient safety for the prevention of health care–associated infections. Alcohol-based hand rub has become a gold standard of care for hand hygiene practice in health care settings. The observed compliance rates among health care worker (HWC) have been regarded by public health authorities as unacceptably poor. In a recently published systematic review of 96 studies, unadjusted compliance rates were 30-40% in intensive care units, and never pass 60% in other setting. Interestingly the compliance rate was lower among physician (32%) than nurses (48%) and before (21%) rather than after (47%) patient contact. In this context, measuring health care worker hand hygiene has become a challenge. Several methods for monitoring hand hygiene were proposed; among them direct observational survey of “My five moments” that becomes the gold standard recommended by the WHO. However, direct observational surveys have several limitations. They are time consuming, costly, they do not allow a continuous monitoring and they provide information about a very low percentage of all hand hygiene opportunities. Moreover, direct observation of HCWs may affect their behavior. When compared with product usage and electronic counting devices some authors consider that direct observation should not be considered anymore as gold standard. Product consumption, because requiring fewer resources than observational survey, is one of the most used method to evaluate hand hygiene but study results are discrepant on the correlation between product consumption and observed compliance rates, the use of electronic counting devices being more relevant. New technologies are currently developed to monitor hand hygiene (See AR Marrac et al. in this section). Electronic monitoring systems such as dedicated hand hygiene monitoring system, real time locating system and video monitoring of hand hygiene appear promising. More accurate than the first two methods they allow real time and continuous follow-up of hand hygiene opportunities. However, most devices do not allow distinguishing whom from staff members or visitors enter or exit the patients’ room and if which of the “five moments” to consider. Although new technologies allow completing a set for hand hygiene improvement, the information allowing understanding the non-adherence to hand washing is scarce. The lack of compliance to hand hygiene is likely multifaceted and is expected to be due to different factors such as HCW behavior, bedroom design and alcohol dispenser location, patient comorbidity and workload, day and week period... that merit being studied. In this paper we evaluate in a pilot phase, the accuracy of a new patented radio frequency identification/location based device coupled with an alcohol dispenser sensor (Medihandtrace®) and compared with video recording of hand hygiene practice in 2 equipped rooms of an infectious disease ward and present the capacity of the device.
Material and Methods

This study was conducted from November 2012 to April 2013 in 2 equipped rooms of a 17 bed infectious disease ward in France. **Material:** The system is based on the "iCode RFID 15693" tags technology (ex NXP) that uses the frequency band of 13.56 MHz. Each room was equipped with four soil antennas that were used to read tags inserted in the HCW's shoes (*Figure 1 and 2*). One antenna is located before the room door under the alcohol dispenser, the second antenna is located at the door entrance, the third within the room under another alcohol dispenser, and the last antenna is located around the bed and define a secure zone (zone in which alcohol disinfection should have been done before entering). A sensor was placed on both alcohol dispenser and measure the use of hydro-alcoholic solution inside and outside the room by indicating the number of spray and the volume distributed. One reader that coordinates the antennas reads the HCW's shoes-inserted tags and the dispenser sensors and transfers the information to the main server by Ethernet connection. The intelligence of the system lies in the server, which manages, interprets, and provides results in real time. Contact delay between the tag and the antenna can be adjusted allowing variation in sensitivity and specificity. In the first stage 0 and 1, they were set up at 5s and then reduced to 4s and finally 3s. It is important to notice that only one antenna is active at a given point in time, although the extremely short time of reading makes those antennas alternate almost simultaneously. At stage 0 and 1 only one antenna was installed near the bed (the side in front of the door) and at stage 2 the antenna was extended by adding a second antenna coupling with the first one in order to detect HCW presence in both sides of the bed (*figure 1*). For the study, rooms were equipped with video camera connected via Ethernet on the main server. Video camera was oriented in a way that only HCWs were recorded. Data collected from antennas and tags, video camera and alcohol dispenser sensors were send to the main server. To implicate HCW in this project, real-time data were given back on a dedicated screen in the nurse office indicating by personnel category the hand washing compliance (*Figure 3*). **Ethics:** Data were capture anonymously as required by the National Commission for Data protection (CNIL). A fact sheet was given to the participant informing HCWs about the project, the functioning of the system as well as about the presence of a video camera in the room recording the HCW activities during the test phase. The HCW are also informed about the fact that the video camera will be removed out the room once the well-functioning of the device will be validated. In order to validate the participation a HCW, he/she had to sign a consent letter that will be filed as a proof. All HCW (19) agreed in participating in the project. **Methods:** The three events to be detected within the HCW path are: the entrance-exit to the patients' room; the use of the hydro-alcoholic solution (inside-outside the room); and the contact with the patient within a risk zone defined as the area around the patient's bed. These events define 7 steps to be recorded...
by the system in the following order: 1) hands disinfection before entrance in the room, 2) entrance into the room, 3) hands disinfection before either being in the risk zone (around the bed) or in contact with the patient, 4) being in the risk zone or in contact with the patient for a given time, 5) hands disinfection before leaving the room, 6) leaving the room, and 7) hands disinfection after leaving the room (Figure 1). A complete path is the one where the 7 steps were performed by the HCW and identified by the system. According to risk assessment for microbe transmission and in order to give a comprehensive feedback to HCWs, paths were noted 100 points (pts), 75pts, 50pts, and 0pts to define a perfect protective path (no risk of contamination for patient, HCW and door handle is 100pts) to one unacceptable one (risk of patient contamination is 0pt) (Figure 4).

Study sequences: We performed three consecutive stages (0, 1 and 2). At the stage 0, 2 experimenters made 310 pre-identified paths with the purpose of verifying whether the RFID system was recording the information properly or not. During the stage 0, the gold standard was the pre-identified pathways meticulous performed by the experimenters. Stage 1 and 2 were performed in “real life” by recording HCW activities. Statistical Analysis: Our RFID system can be regarded as a “RFID test” which can be positive or negative depending on the detection of the path steps. Evaluation of our “RFID test” is based on general principles of comparison with a reference gold standard using calculation of sensitivity, specificity and accuracy².

Results

The main results of stage 0 showed that the system recorded correctly 93.5% of the path (n= 290): the remaining 6.5% (n=20) were discrepant results mostly explained by presence of urine drainage bag on the antenna near the patient’s bed or misplacement of the bed inducing a misplacement of the HCW onto the bed-surrounding antenna. Moreover, the antenna detecting the use of the hydro-alcoholic solution was too close to the wall (10cm) and HCW were not detected when they were placed more than 10 cm away the dispenser. The identified problems were fixed before processing to the next stage. Among the 152 videos read in stage 1, 56.6% (86 paths) were usable for analysis (Table 1). AsFor step 3 (Disinfection before the contact with the patient), the accuracy, sensitivity and specificity were respectively 99.34% [96.39; 99.98], 97.06% [84.67 ; 99.93] and 100% [96.92 ; 100]. There was only 1 false negative which according to the corresponding video was due to the fact that the HCW took the hydro-alcoholic solution extremely fast and without touching the antenna on the floor. As for step 4 (Contact with the patient), the accuracy, sensitivity and specificity were respectively of 63.82% [55.64 ; 71.44], 45.54% [35.60 ; 55.76] and 100% [96.41 ; 100]. There were 55 false negatives according to the following reasons: detection problem of the antenna near the bed (5 cases); the system did not detected the contact with the patient for 12 cases due to the fact that the
HCW stayed less than 5 seconds; for 22 out of the 55 false negatives, the reason of non-recording was that the contact with the patient was done in the left side of the bed (i.e. where there is no antenna at this stage); finally, 16 contacts with the patients were undetectable due to the misplacement of the bed (i.e. the HCW was out of the range of the antenna and in contact with the patient). As for Step 5 (Disinfection after the contact with the patient) for this step the computation of the accuracy, sensitivity and specificity were respectively 97.37% [93.40 ; 99.28], 73.33% [44.90 ; 92.21] and 100% [97.34 ; 100]. There were only 4 false negatives, 2 non detections due to the fact that the HCW took the hydro-alcoholic solution extremely fast; and 2 non detections due to the presence of obstacles near the antenna that avoided the HCW to establish the contact. The analysis of the three steps yields in 456 events (152 videos and 3 events per video). In doing so, we found that accuracy, sensitivity and specificity were respectively 86.84% [83.39 ; 89.81], 60% [51.69 ; 67.90] and 100% [98.80 ; 100] with 60 false negatives (among the 456 events). The analysis in stage 1 highlighted that bad records are principally due either to obstacles on the antennas or the misplacing of the bed. It is important to notice that the presence of more than one HCW (detectable for the system) in the room did not disturb the system. The main problems emerging from stage 1 were principally the missing antenna on the left side of the bed and the long contact delay (5 seconds) needed to detect an HCW when it is near the bed (in the area considered as being in contact with the patient). These problems were fixed before processing to the stage 2; one antenna (missing in the stage 1) was installed in the other side; to avoid misplacement of the bed, the good place was marked on the floor; finally the contact delay for the bed surrounding antenna was first reduced to 4 seconds and then to 3 seconds. In the first Part A of Stage 2, we analyzed 106 new videos (Table 1). For Step 3 and 5 accuracy, sensitivity and specificity were equal to 100% (see Table 1 for confidence intervals) and were 94.34% [88.09 ; 97.89], 86.96% [73.74 ; 95.06] and 100% [94.04 ; 100] for step 4. In this step, there were 6 false negatives due mainly to a problem of detection by the antenna near the bed (1 case without explanation); and due to contact delay of less than 4 seconds (5 cases). Overall, the analysis of steps 3, 4 and 5 together yields an accuracy of 98.11% [95.94 ; 99.30], a sensitivity of 90.63% [80.70 ; 96.48] and a specificity of 100% [98.56 ; 100]. Finally before proceeding to Part B of stage 2 we reduced the detection time of the antenna near to the bed to 3 seconds. This impacted only the step 4. We analyzed 102 new videos (paths). As for previous stage, no error was committed by the RFID system for steps 3 and 5: accuracy, sensitivity and specificity were maintained to 100% (see Table 1 for confidence intervals). As for Step 4, the accuracy was 97.06% [91.64 ; 99.39], the sensitivity was 93.62% [82.46 ; 98.66] and the specificity equal to 100% [93.51 ; 100]. In this step, there were only 3 false negatives (1 not detected by the antenna near the bed, and 2 contacts with duration of less than 3 seconds). The overall analysis of steps 3, 4 and 5 together yields in an accuracy
of 99.02% [97.16 ; 99.80], a sensitivity of 95.65% [87.82 ; 99.09], and a specificity of 100% [98.46 ; 100] (table 1).

**Discussion**

To our knowledge it is the first study that use video recording as gold standard. This has the advantage of avoiding observer bias as HCW rapidly forgot that they are video recorded. In case of discrepant interpretation, video recording also allow to reread some sequences to reach consensus. But video recording need human interpretation which is costly. In our study we concentrated onto step 3,4 and 5. These step are the most important as they represent moment 1,2 and 3, 4 of my five moment \(^{10}\). Step 4 was the most critical in term of adjustment. The risk zone was defining by the bed surrounding and was considered as a zone where the HCW was in situation to touch the patient or his nearby environment. This zone is surrounded by very large antennas which explain the technical difficulties. Hand hygiene compliance is a complex phenomenon likely multifactorial, implicating HCW behavior but also work overload, inconvenient location of dispensers.... Many technologies such as electronic alerts \(^{12}\), or voice prompt\(^{11}\)report to be efficient on compliance at least during study time but real-time continuous automatic hand hygiene compliance recorder is a very important step toward understanding non-compliance and the evaluation of innovative techniques or behavioral changes to enhance hand hygiene. Medihandtrace\(^{\circ}\) by its ability to continuously record many variables is capable of studying compliance during time (day/week/night...) , it can calculate the alcohol consumption (by room by HCW..), the HCW compliance by patient (type /disease), the HCW compliance and the work flow (nb of HCW in the room, mean duration of stay in the room...) and many other variable opening mind on factors that may intervene in compliance. In their recent review Erasmus claimed that “there is a great need for a standardized measuring instrument and standardized reporting” \(^{7}\). Medihandtrace \(^{\circ}\) is a tool that would allow replacing direct observational monitoring.
Figure 1: Room’s antennas and steps in HCW paths as in stage 2 analysis. In stage 1, the antenna on the windows side was not placed.

Figure 2: HCW’s tagged shoes. The passive tag was inserted in the heel cap.
Figure 3: Nurse’s office back screen. From left to right; medical staff, nurses, assistant nurses, housekeeping and whole staff. Data were recorded continuously. Large number indicates the evaluation of each group as a number of points during the 8 hours shift and small numbers are cumulated evaluation since the beginning of the experiment.
Figure 4: The number of points is attributed depending on the path done and the risk assessment for microbe transmission.


