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Three-Year Hand Hygiene Monitoring and impact of real-time reminders on compliance

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Conflict of interest

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SUMMARY

Introduction Hand hygiene remains both the major strategy and an ongoing challenge for infection control. The main issues in the sustainability of hand hygiene automatic monitoring are healthcare worker (HCW) turnover rates and declining participation. In this study we had the opportunity to observe hand hygiene compliance over three years, with the intervention of a real-time reminder system. We aimed to assess hand hygiene compliance and the impact of real-time reminders.

Methods We observed HCWs and room compliance with using alcohol-based hand rubs (AHR) on room entry and exit. Linear multilevel mixed models with time autocorrelations were performed to analyse the repeated measurements of daily room compliance and the effect of reminders over eight quarters (24 months).

Results 111 HCWs were observed and 525,576 activities were identified in the database. We observed an improvement in compliance both on room entry and exit over two years, and the rooms which had activated reminders had better performance than the rooms which did not have activated reminders.

Conclusions This study showed the benefit of using real-time reminders. In this study even 20% of rooms with an activated reminder improved overall hand hygiene compliance. A randomized real-time reminder setting may be a potential solution in reducing user fatigue and enhancing HCW self-awareness.

Key words: hand hygiene compliance, real-time reminder, real-time monitoring, infection control, carry-over effect

Introduction

Hand hygiene is a cost-effective way to prevent healthcare-associated infections (HAIs). More than 70% of HAIs are caused by poor hand hygiene; however, hand hygiene compliance by healthcare workers (HCW) is still inadequate [1,2]. In the European Union, the number of HAIs is estimated at 8.9 million cases annually [3]. Regarding the 2017 data in France, the prevalence of HAIs was 5.8%, while in the European Union the prevalence was 5.5% [4]. Thus, hand hygiene monitoring and its promotion remain an ongoing challenge for infection control programs.

Direct observation, recommended by the WHO, is considered the gold standard in monitoring hand hygiene compliance [5]. However, this approach is time-consuming and biased due to the Hawthorne effect [6]. To overcome these limitations, automated hand hygiene monitoring systems have been developed. A recent study showed the reduction of HAIs with an electronic monitoring system [7]. This approach provides observations of hand hygiene compliance in real-time without human intervention as well as continued data over time. However, HCW turnover rates and declining participation are still the main issues for the sustainability of hand hygiene over the long-term [8,9].

In this study which took place from 2018 to 2020, we had an opportunity to observe hand hygiene compliance over a long period with the intervention of a real-time reminder system. As the COVID-19 pandemic is a remarkable event that has influenced HCW behaviour, we treated the monitoring of 2020 hand hygiene compliance in a dedicated study [10]. To the authors' knowledge, no studies show carryover effects from real-time reminders on increasing self-awareness about HCW hand hygiene compliance or sustainability in long-term observations. This study aimed to assess hand hygiene compliance and the impact of real-time reminders throughout the two years (2018-2019) of real-time monitoring.

Methods

Starting in 2018, we observed compliance with using an alcohol-based hand rub (AHR) upon entering and exiting patient rooms with an automatic hand hygiene monitoring system (MediHandTrace©). It was performed by HCWs who provided their consent in an infection unit with 25 private rooms at Marseille University Hospital in France. This monitoring system relies on passive Radio-Frequency Identification (RFID) technology. Each volunteer HCW was assigned a unique ID tag inserted in their shoes; this ID tag, a door sensor, and a sensor on the hand sanitizer communicated through a cloud server. More details on this automated hand hygiene monitoring system can be found in our previous papers [11–14].

This system aims to improve hand hygiene guideline compliance by continuously and automatically measuring HCWs hand hygiene behaviour and signalling with immediate feedback (real-time reminder) when non-compliance occurred. A 70-80 dB sound alarm (buzzer) was configured so that it activates when AHR utilization was absent upon entering and exiting patient rooms from 6 am to 9 pm. An identified HCW could stop the buzzer if they returned to the antenna area and use AHRs (correcting behaviour). In this study, we established three intervention periods to evaluate the impact of a real-time reminder. In the first period (January 2018 to October 2018), reminders which were configured with a 45-second buzzer were activated in five randomly selected rooms. In the second period, only one reminder in these rooms (and a 15-second buzzer) was kept activated until the end of June 2019. In the last period (July 2019 to October 2019), another five randomly selected rooms had activated reminders with 15-second buzzers.

The hand hygiene-related activities were interpreted by the algorithm written in C++ programming language. This program grouped sensor events (the door opening, an identified HCW shoes onto the carpet, using the AHR, etc.) into sequences defined as a series of signals that transmit an activity [10]. HCWs compliance with AHR upon entering and exiting a

patient's room was computed by the percentage of daily AHR utilization in the total daily number of entries and exits of each HCW in each room.

Generalized linear mixed-effect models were performed to analyse the repeated measures of daily HCWs compliance and the effect of reminders over eight quarters (24 months) [8].

Compliance rates were treated as a binary outcome with logistic regression. For fixed effects, we applied time (quarters), HCW profession, and a reminder type (activated or deactivated buzzer) into the model. For random effects, we had intercepts for individual HCW and room. P-values were obtained by likelihood ratio tests (F-Test) of the full model with the effect compared to the model without the effect. R 4.0.1 was used for data management, and statistical tests were performed with SPSS 25.

Ethics

All procedures for this study were approved by the Institutional Review Board of the IHU (No. 2020-008) and are in line with the Declaration of Helsinki and the French Commission Nationale de l'Informatique et des Libertés. The investigators informed the HCWs that anonymity and confidentiality were guaranteed.

Results

Three-year automated monitoring observed 111 HCWs, including 38 physicians, 13 interns, 37 nurses, 18 nursing assistants, and five housekeeping personnel. According to the registered ID tags in our database, the average working period was 8.2 months per HCW. The total annual HCW turnover rates were high, ranging from 22.85% to 40%. We collected 7,780,313 rows of signals observations (door events, shoe events, and AHR events), of which 525,576 activities were identified in the database, including 224,472 entries and 224,472 exits and 76,632 link-up entries and exits within 20 seconds. Figure 1 shows the evolution of daily compliance with using AHR and the three periods of real-time reminder interventions.

Between 2018 and 2019, average daily compliance was 25.81% (SD=39.57, med=18.18) on room entry and 49.31% (SD=43.86, med=50) on room exit. Compliance varied among the professions on entry: physicians (66.39%, SD=29.27), interns (67.23%, SD=29.04), nurses (28.25%, SD=30.97), nursing assistants (10.86%, SD= 16.67) and housekeeping personnel (10.23%, SD=13.66); on exit: physicians (79.59%, SD=23.96), interns (86.39%, SD=18.34), nurses (56.69%, SD=26.77), nursing assistants (37.91%, SD= 24.89) and housekeeping personnel (30.39%, SD=21.11).

The mixed models showed that both time (quarters) and reminders had a significant effect on compliance with using AHR upon entering and exiting. There was a significant improvement in compliance on both room entry and exit over the eight quarters ($F_{7, 57139} = 27.87, p < 0.001$; $F_{7, 50015} = 22.75, p < 0.001$). Moreover, there was a significantly different improvement between the rooms with activated reminder and those without activated reminder on both room entry and exit ($F_{1, 57139} = 98.07, p < 0.001$; $F_{1, 50015} = 40.61, p < 0.001$).

Table 1 shows the estimates of fixed effects on compliance with using AHR. The rooms with an activated reminder demonstrated better compliance improvement than the rooms without activated reminder; on room entry (OR= 1.58, CI [1.44, 1.73]), and room exit (OR=1.24, CI [1.16, 1.33]). Physicians and interns showed significant improvement (OR=28.8, CI [8.21, 101.06]; OR=26.65, CI [6.20, 114.57] on entry. For exit, physicians, interns, and nurses showed significant improvement. Compliance with using AHR upon entering and exiting improved significantly over time, from the second quarter to the eighth quarter (OR >1, $p < 0.001$) (Table1 and Fig.2).

To better illustrate the impact of a reminder, we grouped rooms as: 1) the first five rooms which had a 45-second buzzer activated reminder over ten months; 2) the room which had a 15-second buzzer activated reminder over 18 months; 3) the second five rooms which had a 15-second buzzer activated reminder over four months and 4) the rooms that never had an

activated reminder (Fig.3). Figure 3 shows the proportion of monthly compliance in these grouped rooms. As an illustration, the density of good compliance occurred while a reminder was activated.

Discussion

We observed an improvement in compliance over two years in both room entering and exiting. Moreover, the rooms which had activated reminders had better performance than the rooms which never had activated reminders. Most of the data showed improvement in hand hygiene compliance using automatic monitoring systems with real-time feedback or reminders (visual or audio). In addition, the improvement returned to baseline or had short-term sustainability after removal of the reminders and interventions [15–18]. It reinforces the necessity of continuously monitoring and promoting hand hygiene.

Most importantly, in this study we observed improvement even in the rooms that never had activated reminders. To the best of our knowledge, no study has discussed the carryover effect of hand hygiene reminders. Desensitization to the reminders (alarm fatigue) is a widely known phenomenon that impacts patient safety in hospital settings, especially when HCWs experience a large number of alarms [19]. To avoid alarm fatigue and improve compliance with minimum reminders, we activated reminders in five randomly selected rooms and switched to a different five rooms over two years. Given the high HCW turnover rates and different types of work shifts, HCWs were never sure: “Maybe an alert buzzer will ring in this room”. Under those circumstances, it seems HCWs carried over their experience from the rooms which had activated reminders to other “silent” rooms. Afterwards, they anticipated and modified their behaviour [20]. As a result, reminders had an immediate impact on hand hygiene compliance upon both entering and exiting rooms, especially in the first three quarters. Then the improvement slowed. HCWs learned and modified hand hygiene compliance rapidly, and reminders not only engaged HCWs in hand hygiene practice but also

increased their awareness and brought about a carryover effect to the rooms without an activated reminder. According to our previous study, HCWs have good knowledge of hand hygiene (Huang et al., submitted manuscript); thus, the neglect of performance is more likely attributable to unconscious omission, information overload and work overload [21]. Different than a visual reminder, a real-time reminder buzzer appears more effortless in reminding HCWs to perform hand hygiene at the right moment and raising their self-awareness [18,22]. A recent study using a visual reminder showed that changing the visual reminder frequently had no effect on hand hygiene compliance; on the contrary, it most frequently demonstrated worsening compliance [23].

In the present study, the improvement on room entry was slightly better than on room exit, because compliance on room exit was already twice as high as entry; thus, the range of improvement for room exit was much smaller. Differently than most studies published on direct monitoring of hand hygiene, in our unit, physicians and medical interns systematically demonstrated higher compliance than nurses and other HCWs. This may be explained by medical leadership in this study, the hand hygiene culture, or the fact that physicians were less susceptible to the Hawthorne effect [11].

The original idea of this study was to assess how far reminders could impact compliance and its sustainability. The frequency and number of the reminders still needs further evaluation.

We designed a further experiment to begin at the start of 2020; each month an additional five randomized rooms would have an activated reminder until the entire unit was involved.

Unfortunately, during the COVID-19 pandemic due to the change in clinical practice protocols and the use of personal protective equipment, we suspended our experiment at the end of 2019. However, our preliminary results on real-time reminders still showed the import of our hypothesis.

The compliance we studied showed the global compliance of HCWs without considering individual factors. The main limitation of this study was accessing HCWs individual improvement over the long term due to the high turnover rates. Our previous study concluded that hand hygiene seemed an individual-dependent behaviour [11]. We recognized a different evolution among the HCW professions (see supplementary data). Thus, further research should focus on individual factors, to evaluate whether individual improvement exists and if it truly prevents cross-transmission.

During COVID-19 outbreaks, without any interventions, we observed a different evolution in compliance. There was increased daily compliance upon room exiting because of the increased awareness of self-protection; conversely, decreased daily compliance changed upon room entering due to the protocol, glove use and less patient-protection motivation [10]. As two studies have reported, negative emotions play an important role on the intention-behaviour gap associated with modifying behaviour in hand hygiene [24,25]. In our case, glove use seemed to reinforce the feeling of being protected and contributed to non-compliance.

Conclusion

This study showed the benefit of using real-time reminders and reinforces the importance of continuous hand hygiene monitoring over time. In this study, we showed that even 20% of rooms with an activated reminder could improve hand hygiene compliance. Randomized real-time reminders could be a potential solution for enhancing HCWs self-awareness and reducing alarm fatigue.

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Conflict of interest

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Founding source

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<https://doi.org/10.1007/s11469-020-00281-5>.

Figure Legends

Figure 1: Evolution of daily compliance with using AHR and the three periods of real-time reminder interventions.

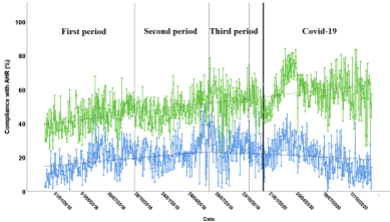
The green line represents compliance upon exiting the room and the blue line represents compliance upon entering the room. The first period shows five randomly selected rooms with activated reminders (45-second buzzer). In the second period, one of the first five rooms had a 15-second buzzer. In the third period, there were five randomly- selected rooms with activated reminders (15-second buzzer).

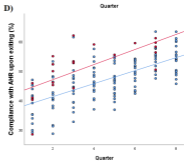
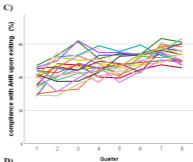
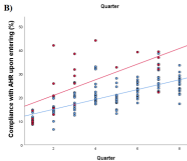
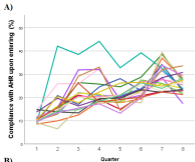
Figure 2: Evolution of compliance with using AHR in each patient room.

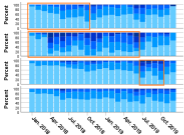
A) shows the evolution of compliance on room entry over eight quarters. B) the red line shows the linear regression of rooms with activated reminder and quarters; the blue line shows the linear regression of rooms without activated reminder and quarters. C) shows the evolution in compliance on room exit over eight quarters. D) the red line shows the linear regression of rooms with activated reminder and quarters; the blue line shows the linear regression of rooms without activated reminder and quarters.

Figure 3: The percentage of monthly compliance on room entry and exit over two years.

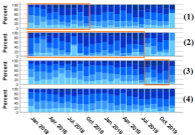
(1) shows the first five rooms which had a 45-second buzzer activated reminder: (2) shows the one room which had a 15-second buzzer activated reminder. (3) shows another five rooms which had 15-second buzzer activated reminders. (4) shows the rooms which never had an activated reminder. The orange line indicates the activated reminder period.







Month / Year
On room entry



Month / Year
On room entry

Compliance



Table 1: Estimates of fixed effects on AHR compliance on room entry and exit.

Model Term	Coefficient	t	Sig.	95% Confidence Interval		OR	95% Confidence Interval for OR	
				Lower Limit	Upper Limit		Lower Limit	Upper Limit
On room entry								
Buzzer								
Activated	0.458	9.903	0.000	0.367	0.549	1.581	1.444	1.731
Deactivated	0*							
Profession								
Physician	3.361	5.250	0.000	2.106	4.616	28.817	8.216	101.064
Intern	3.283	4.412	0.000	1.825	4.741	26.653	6.200	114.570
Nurse	0.633	0.987	0.324	-0.624	1.890	1.883	0.536	6.618
Nursing assistant	-0.004	-0.006	0.995	-1.328	1.320	0.996	0.265	3.742
Housekeeping	0*							
Time								
1 st Quarter	0*							
2 nd Quarter	0.446	7.425	0.000	0.329	0.564	1.563	1.389	1.758
3 rd Quarter	0.361	5.905	0.000	0.241	0.480	1.434	1.272	1.617
4 th Quarter	0.669	11.559	0.000	0.556	0.783	1.953	1.744	2.188
5 th Quarter	0.617	10.417	0.000	0.501	0.733	1.853	1.650	2.081
6 th Quarter	0.752	12.439	0.000	0.634	0.871	2.122	1.885	2.389
7 th Quarter	0.657	10.385	0.000	0.533	0.781	1.930	1.705	2.185
8 th Quarter	0.637	9.913	0.000	0.511	0.763	1.891	1.667	2.145
On room exit								
Buzzer								
Activated	0.218	6.372	0.000	0.151	0.285	1.243	1.163	1.330
Deactivated	0*							
Profession								
Physician	2.545	6.132	0.000	1.732	3.359	12.746	5.650	28.755
Intern	2.723	5.415	0.000	1.738	3.709	15.230	5.684	40.811
Nurse	0.917	2.219	0.027	0.107	1.727	2.501	1.113	5.622
Nursing assistant	0.374	0.859	0.390	-0.479	1.228	1.454	0.619	3.413
Housekeeping	0*							
Time								
1 st Quarter	0*							
2 nd Quarter	0.244	6.261	0.000	0.167	0.320	1.276	1.182	1.377
3 rd Quarter	0.213	5.269	0.000	0.134	0.293	1.238	1.143	1.340
4 th Quarter	0.335	8.799	0.000	0.260	0.409	1.398	1.297	1.506
5 th Quarter	0.304	7.804	0.000	0.228	0.381	1.356	1.256	1.463
6 th Quarter	0.490	12.211	0.000	0.412	0.569	1.633	1.509	1.766
7 th Quarter	0.301	7.036	0.000	0.217	0.385	1.351	1.243	1.469
8 th Quarter	0.388	8.930	0.000	0.303	0.474	1.475	1.354	1.606

* This coefficient is set to zero because it is redundant.