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Covid-19 outbreak and health care worker behavioral change toward hand hygiene practices.

Running title: Covid-19 and hand hygiene practices.

Fanyu Huang¹, Marjorie Armando³, Stéphane Dufau³, Oleg Florea², Philippe Brouqui^{1,2}, Sophia Boudjema¹

¹ Aix Marseille Université, IRD, MEPHI, IHU-Méditerranée Infection, Marseille, France

² AP-HM, IHU-Méditerranée Infection, Marseille, France

³ Aix Marseille Université, Laboratory of Cognitive Psychology (UMR 7290), Marseille, France

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Corresponding author's contact:

HUANG F: fanyu.huang@etu.univ-amu.fr / vivifanyu@gmail.com

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Abstract

Background: The coronavirus disease (COVID-19) pandemic has affected healthcare workers (HCW) in their clinical practice. HCW were challenged with new guidelines and practices to protect themselves from occupational risks. We wished to observe if hand hygiene behavior by real-time measurement was related to the dynamic of the epidemic, and the type of patient being cared for in France.

Methods: This study used an automated hand hygiene recording system to measure HCW hand hygiene on entry to and exit from patient rooms throughout the COVID-19 pandemic. We analyzed the correlation between hand hygiene compliance and COVID-19 epidemiological data. Analysis of variance was performed to compare compliance rate during the different periods of the epidemic.

Findings: HCW hand hygiene rate on room entry decreased over time; on room exit, it increased by 13.73% during the first wave of COVID-19, decreased by 9.87% during the post-lockdown period, then rebounded by 2.82% during the second wave of the epidemic. Hand hygiene during patient care and hand hygiene on room exit had a positive relationship with the local COVID-19 epidemic; conversely, hand hygiene on room entry did not depend on the trend of the epidemic, nor on nursing of COVID-19 patients, and it decreased over time.

Conclusion: HCW modified their behaviors to face the risk propensity of the pandemic. However, to improve the poor compliance at room entry, reducing confusion between the hand hygiene recommendation and glove recommendation may be necessary; disinfection of gloving hands might solve this issue.

Introduction

Since the 2000's, coronaviruses (CoVs) have been associated with significant disease outbreaks in East Asia (Sars-CoV-1) and the Middle East (MERS-CoV). The spread of the novel coronavirus (SARS-CoV-2), initially identified in the Hubei province of China in December 2019, was declared by the World Health Organization (WHO) as the pandemic of coronavirus disease (COVID-19) in March 2020 [1]. At the time of writing there had been 91,938,218 cases and 1,967,655 deaths globally, including 2,806,590 cases and 68,802 deaths in France [2]. Healthcare workers worldwide, who have been regularly trained to avoid hospital-acquired infection by following guidelines, particularly hand hygiene, to reduce cross transmission and protect their patients are currently facing another objective: to protect themselves from SARS-CoV-2 infection using prevention protocols to which they are less commonly accustomed (self-protection). These new sanitary guidelines directed toward health care worker protection rather than toward patient protection is a new challenge for this community. With personal protection equipment (PPE), hand hygiene has been shown to be the cornerstone of protection from respiratory viruses [4,5], and hand hygiene remains a main way to limit cross-transmission, as recommended by the WHO [5].

Since 2012, we have developed an automated hand hygiene monitoring system and used it as a part of the management of healthcare-associated-infections at the University Hospital Institute Méditerranée Infection (IHU-MI) [6–9]. The changing paradigm of hand hygiene practice imposed by this new ongoing epidemic seemed interesting to monitor with our system, to evaluate if HCW had (or not) easily adjusted to this new approach of infection prevention and changed their behaviour. Since we have observed two epidemic waves, we were interested in monitoring HCW in between the two waves to evaluate if their hand hygiene behavior correlated with the outbreak amplitude and with the type of patient being cared for.

This study aims to observe if hand hygiene practices on entry and exit of the patient's room and during patient care were correlated with the dynamic of the epidemic, and the type of patient being cared for (COVID-19 cases or not) throughout the two waves of the COVID-19 pandemic.

Methods

Automated hand hygiene recording systems

Since the end of 2017, an automatic hand hygiene monitoring device (MediHandTrace©) has been in place in the infectious diseases unit, which contains 25 single bedrooms. This system measures HCW utilization of alcohol-based hand rubs (AHR) on entry and exit from patient rooms (hand hygiene opportunity). Thanks to voluntary HCW who gave their consent, a unique ID tag is inserted in their shoes and when entering or exiting the bedroom of each patient's room, this ID tag, a door sensor and a sensor on the hand sanitizer, communicate through a server and allow identification of who entered or exited the room, and if AHR was performed on entry and exit, with a very good accuracy in experimental settings [7–10]. However, in the real-life environment, the system does not tend to perform as well, especially when several HCW enter the room at the same time. Indeed, sensor events like “the door is opening” and “the door is closing” are not associated with an ID tag, and therefore cannot be directly linked to a particular HCW, leaving issues such as whether or not the person whose behavior is being evaluated truly exited the room.

To optimize the accuracy of interpretation of HCW activities, we developed an algorithm written in C++ programming language that identifies each activity by analysis of short sequences of consecutive events from raw sensor data. Sensor events were grouped in sequences defined as a serial of signals traducing an event (the door is opening, an identified

HCW puts their shoes on the carpet, he/she uses hydroalcoholic solution, etc.) associated with its corresponding time of occurrence.

Such event grouping enabled us to accurately pair entry and exit events with unique ID tags in the single bedroom / multiple HCW scenario. It was thus possible to follow the nursing staff's activities in a bedroom on an individual basis, for instance, for each HCW, to know whether they washed their hands when they entered and when they left the room. To assess the accuracy of the optimization algorithm, we compared its interpretation to a human-based video analysis from cameras set up in patients' rooms. Level of correspondence was excellent.

Piloting of the automated system

In order to assess accuracy of data capture, we examined 33 randomly selected HCW events occurring between 26th November to 29th November 2019 and compared video and interpretations from the algorithm. Eighteen room entries were correctly interpreted as such by the algorithm; for room exits, 13 were interpreted correctly but 2 interpretations were erroneous due to several HCW exiting at the same time. As a result, 93.9% of entries and exits were interpreted correctly by the algorithm and the kappa coefficient between the videos and interpretations from the algorithm was 0.88 (Supplementary material).

Infection control procedures

During the COVID-19 pandemic, HCW were trained and encouraged to adhere to the principles of WHO evidence-based guidelines for PPE use and hand hygiene practice [11,12]. HCW were asked to wear PPE (gown, FFP2 mask and gloves) before entering patient rooms. Hand sanitizers containing alcohol (75–85% v/v) effectively reduce the infectivity of coronaviruses *in vitro* [13]. Disinfection of gloved hands has been demonstrated as efficient and feasible during patient care for multiple activities, and a recent study shows that alcohol-based solution did not affect elongation at breakage of the nitrile gloves [14–16]. Thus, we

promoted the use of gloved AHR upon entry to the room, upon exit of the room and as often as necessary during patient care.

Definitions

Daily hand hygiene compliance rate on room entry and exit was computed by the daily number of AHR utilizations on entry and exit, divided by the total daily number of entries and exits. AHR during care were computed by the number of AHR recorded by our system after 18 seconds (grace delay period) from entering divided by the total daily number of room entries. AHR consumption was computed by the total volume (1 application of AHR=3ml) of AHR by each HCW each day.

The epidemiological COVID-19 data of our hospital was based on the monthly number of patients screened and the number of patients diagnosed positive for SARS-CoV-2, obtained from the hospital information system. To calculate nursing care of the COVID-19 patient, the bed-day total was calculated as the daily number of beds occupied by either a COVID-19 or a non-COVID-19 patient admitted as an inpatient each month. We then separated the study into four periods: (1) pre-COVID-19, from September 2019 to the end of February 2020; (2) the first wave of COVID-19, from March 2020 to the end of May 2020; (3) post-lockdown, from June 2020 to the end of August; (4) the second wave of COVID-19, from September 2020 to the end of November 2020.

Statistical analysis

Data analysis included descriptive analyses. The assumption of normality was assessed by analysis of skewness and kurtosis. First, to evaluate the relation between the local COVID-19 epidemic and hand hygiene behaviors, the Pearson correlation coefficient was used to evaluate the strength of the relationship between the compliance with AHR (on entry and exit), the number of patients screened, the number of patients diagnosed as positive for

SARS-CoV-2 and the total bed-day of care of each COVID-19 patient. Second, comparing any differences in compliance with AHR between the four COVID-19 periods, analysis of variance (ANOVA) was used to compare the mean of compliance with AHR (on entry, during care and on exit) and AHR consumption between these periods. Time series analysis using autoregressive integrated moving average (ARIMA) model was performed to analyze the trend of hand hygiene compliance over time. Results were considered statistically significant at p-values less than 0.05. All the collected data were entered into an Excel file and the statistical tests were performed with SPSS 25.

Ethics

The study protocol was approved by the Review Board of our institution and available under N° 2016-018; all participating HCW were informed about the automatic monitoring procedure and the guarantee of anonymity and confidentiality. Video was recorded and visualized for accuracy evaluation of the algorithm by two researchers not involved in patient care (MA and FH). Once the content was analyzed and anonymized, the recording video was destroyed. All HCW are protected by the French National Commission on Informatics and Liberty.

Results

Evolution of compliance with hand hygiene

From September 2019 to November 2020 (over 15 months of real-time observation), a total of 162 334 entries and exits were recorded by the automatic monitoring system. The mean of compliance with AHR use on entry to a patient's room within this period of observation was 21.02% (SD= 8.91) and on exit from a patient's room was 55.03% (SD= 11.9). During care, mean incidence of AHR use by HCW was 4.32% (SD=2.34). Mean AHR consumption was

61.63(SD= 22.45) mL/HCW/day. Figure 1 shows the evolution of compliance with AHR use on room entry, during patient care and on room exit.

Epidemiological data

From December 2019 to November 2020, 253547 new patients were screened at IHU-MI and 21938 patients were diagnosed as SARS-CoV-2 positive. A total of 1319 patients were admitted to our unit including 834 COVID-19 patients. Each month, the average number of patients screened was 16903 (SD= 18654) and the average number of COVID-19 patients was 1466 (SD= 2058) (Supplementary material). The average number of bed-days was 730 (SD=123) per month, including 313 (SD=265) bed-days for non-COVID-19 patients and 417 (SD= 330) bed-days for COVID-19 patients (Figure 2).

Compliance with AHR use on room exit had a positive correlation with the number of patients screened ($r=0.66$, $p=0.004$), the number of patients diagnosed ($r=0.53$, $p=0.021$) and the total number of bed-days of COVID-19 patients ($r=0.68$, $p=0.011$). Use of AHR during care had a strong positive correlation with the number of patients screened ($r=0.84$, $p<0.001$), the number of patients diagnosed ($r=0.77$, $p<0.001$), the number of bed-days of COVID-19 patients ($r=0.88$, $p<0.001$) and the moderate positive relation with total number of bed-days of care ($r=0.57$, $p=0.033$). AHR consumption had a positive correlation with the number of bed-days of COVID-19 patients ($r=0.63$, $p=0.019$) and total bed-days of care ($r=0.61$, $p=0.023$). Compliance with AHR use on room exit and AHR use during patient care increased as the epidemic of COVID-19 increased or the nursing of COVID-19 in the unit increased, and vice versa. AHR consumption increased when the total number of bed-days or the nursing of COVID-19 patients increased. However, compliance with AHR use on room entry was not associated with the COVID-19 epidemic or the nursing of COVID-19 in the unit (Table I).

The mean of compliance with AHR use on room entry was 23.88% (SD=7.56) during the pre-COVID-19 period. For the first wave of COVID-19 this was 27.31% (SD=6.45), for the post-lockdown period 17.3% (SD=6.77) and for the second wave was 13.3% (SD=6.27) ($F(3,435) = 77.93$, $p < 0.001$). This low compliance rate on room entry could be explained by the fact that HCW were gloved before entering the room and staff were not used to disinfecting gloved hands. The mean rate of AHR use during patient care was 3.21% (SD=1.43) at the pre-COVID-19 period; for the first wave of COVID-19 this was 5.37% (SD=2.11), for the post-lockdown period 4.41% (SD=2.15) and for the second wave 5.17% (SD=1.83) ($F(3,435) = 37.36$, $p < 0.001$). The mean of compliance with AHR use on room exit was 50.63% (SD=8.28) for the pre-COVID-19 period; for the first wave of COVID-19 this was 64.37% (SD=8.27), for the post-lockdown period 54.5% (SD=8.52) and for the second wave 57.32% (SD=9.93) ($F(3,435) = 51.57$, $p < .001$). Mean AHR consumption was 60.28 (SD=22.75) mL/HCW/day for the pre-COVID-19 period; for the first wave of COVID-19 this was 69.42 (SD=18.74) mL/HCW/day, for the post-lockdown period 54.94 (SD=15.97) mL/HCW/day and for the second wave, 66.98 (SD=21.83) mL/HCW/day ($F(3,435) = 9.578$, $p < .001$) (fig.3).

Mean rate of AHR use on room entry increased by 3.43% during the first wave of COVID-19 but got lower over time. Mean rate of AHR use during patient care increased by 2.15% during the first wave of COVID-19, decreased by 0.95% during the post-lockdown period, and then rebounded by 0.76% during the second wave of the epidemic. Mean rate of AHR use on room exit increased by 13.73% during the first wave of COVID-19, decreased by 9.87% during the post-lockdown period, then rebounded by 2.82% during the second wave of the epidemic. Concerning AHR consumption, this increased by 9.14 mL/HCW/day during the first wave of COVID-19, decreased by 14.48 mL/HCW/day post-lockdown and then rebounded by 12.05 mL/HCW/day during the second wave of the epidemic. Time series analysis confirmed that

there was a decrease of compliance with AHR use on room entry over time ($P<0.001$) and an increase of compliance with AHR use on room exit over time ($p=0.013$)

Discussion

This long-term hand hygiene observation using data from an automated monitoring system shows that HCW use of AHR during patient care and on room exit were positively correlated with the dynamics of the local COVID-19 epidemic and the nursing of COVID-19 patients. Total AHR consumption appeared to be related to the nursing of COVID-19 patients and the total number of bed-days of care. Conversely, AHR use on room entry did not depend on the trend of the epidemic nor nursing of COVID-19 patients. As a result, rates of AHR use on both room entry and room exit increased during the first wave of the epidemic and both decreased during the post-lockdown period, while AHR use on room exit and during care tended to follow the trend of the epidemic; AHR use on room entry decreased over time.

Four recent studies found that HCW hand hygiene compliance improved during the early pandemic (first quarter of 2020); however, three of these studies were observed by audit without comparing with any remarkable events in national COVID-19 control [17–20]. One study which was based on an automated monitoring system obtained a similar result to ours. The authors found decreased hand hygiene performance after school closures, and concluded that even during the global crisis, it seemed difficult to maintain improved hand hygiene performance [20].

Automated monitoring does afford some advantages during the pandemic, such as reducing the human cost for audit, continued measurement and reducing the Hawthorne effect [13]. Our finding shows the different evolution of four hand hygiene indicators: compliance with AHR use on room entry, AHR use during patient care, AHR use on room exit and total AHR consumption. AHR use on room entry and during patient care are mainly related to patient

protection whereas AHR use on room exit is related to self-protection of HCW. At the beginning of the epidemic, the improvement of both self-protection and patient-protection measures could be explained by HCW fear of the crisis, to avoid transmitting the virus to their family, to themselves or to their patients. A recent psychology study showed that fear of pandemic encouraged recommended public health behaviors due to the negative emotions that reduce motivation for risky behaviors [22]. It could be also explained by respect of the protocol. Among all required PPE within the COVID-19 protocol, our observations show a correlation between AHR use and the hospitalization of COVID-19 patients in the unit, with hand hygiene being performed frequently as recommended by the WHO [23].

The second observation was the different evolution of compliance with AHR use at room entry and room exit. It seems that the COVID-19 outbreak had more impact on compliance with AHR use on room exit and during care, and on total AHR consumption. HCW were asked to wear PPE before entering a patient's room and then to remove gloves and apply AHR before leaving a patient's room; this protocol was respected. Thus, even with the drop in compliance during the post-lockdown period, the AHR use on room exit and during patient care remained higher during the second wave of the epidemic than during the pre-COVID-19 period.

Under those circumstances, it seems that gloving hands cause the reduction of compliance at entry. After the first wave of the epidemic, HCWs disinfected their hands less and less on room entry. The low compliance rates on entry could be explained by the gloved hand which has been reported to reduce hand hygiene [24]. Moreover, one can imagine that HCW better perceived the risk to be exposed to the virus for themselves than to protect the patients. However, several recent studies showed the benefit of disinfection of gloved hands [25–27]; alcohol-based disinfectants may slightly affect the breaking load of nitrile gloves, but it does not affect its extensibility [15]. It seems our HCW were not aware on such evidence on room

entry. As noticed by Allegranzi et al. hand hygiene appears neglected when the emergent virus seems to disappear with compliance rates becoming lower, which ties in with our observations. The studies of Maltezou et al. shows there are gaps in infection control in non-COVID-19 referral hospitals; it is possible that adherence to recommendations could be even lower in non- COVID-19 hospitals [28].

Conclusion

In conclusion, HCW respected the protocol and modified their behaviors during the outbreak; however, improvements of compliance with AHR on both room entry and exit were not sustained throughout the epidemic especially for entry. This pandemic has led HCW to adapt their hand hygiene behavior to the visible risk (the epidemic's curve) to protect themselves; according to our finding, we enforce the importance of hand hygiene monitoring even during the pandemic, especially before patient contact. To reduce potential confusion between the hand hygiene recommendation and glove recommendation, disinfection of gloving hands might improve poor compliance at entry.

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Contributors

Conceived and designed the experiments: PB, FH, SB. Performed the experiments: FH, OF. Algorithm developed: SD and MA. Analysed the data: FH. Wrote the paper: FH, PB, SB, MA.

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Conflict of Interest

P Brouqui was a former advisor of the MediHandTrace® Company.

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374

Figure Legends:

Fig.1: The evolution of the compliance to AHR use on room entry, during patient care and on room exit; 95% confidence interval.

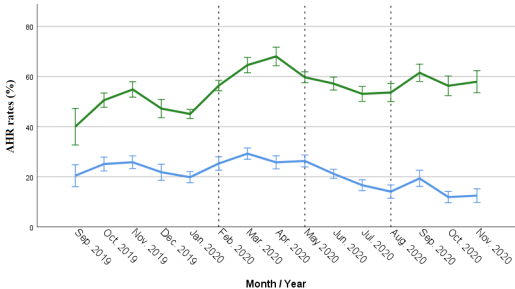
The green line represents AHR rates of use on room exit; the blue line represents AHR rates of use on room entry. The vertical dashed lines represent the different periods of the epidemic.

Fig.2: The evolution of bed-days of care

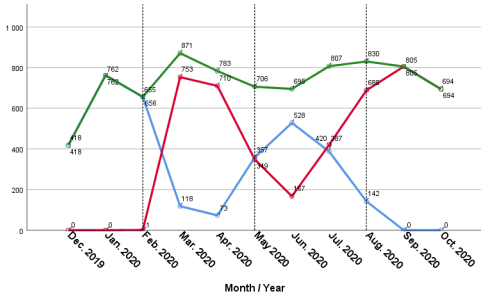
The green line represents the total number of bed-days of care, the red line represents the bed-days of care of COVID-19 patients and the blue line represents the bed-days of care of non-COVID-19 patients. The vertical dashed lines represent the different periods of the epidemic.

Fig.3: Boxplots and mean plots

(a.) AHR use on room entry (%), (b.) AHR use during patient care (%), (c.) AHR use on room exit and (%), (d.) AHR consumption (mL/HCW/day) in four periods of the COVID-19 epidemic.



Count



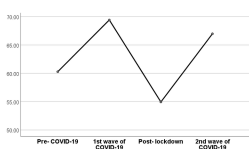
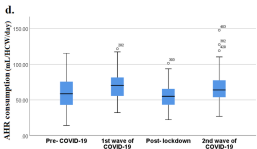
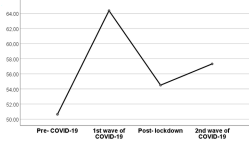
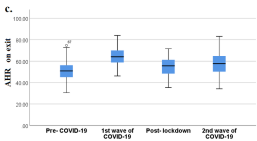
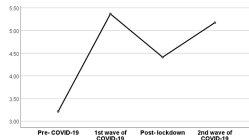
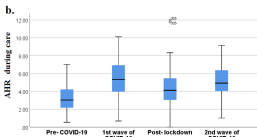
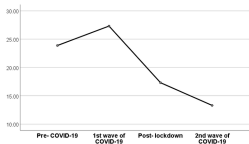
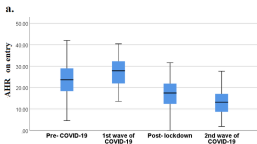


Table I.

Correlations between the monthly data of AHR use on room entry, AHR use during patient care, AHR use on room exit, number of patients screened, number of patients diagnosed, bed-days of COVID-19 patients and total bed-days of care.

		AHR on entry	AHR on exit	AHR during care	AHR consumption	Patients screened	Patients diagnosed	COVID patients
AHR on exit	Pearson Correlation	,211	1					
	(p values)	,226						
	N	15	15					
AHR during Care	Pearson Correlation	-,307	,782**	1				
	(p values)	,133	,000					
	N	15	15	15				
AHR consumption	Pearson Correlation	,203	,561*	,298	1			
	(p values)	,234	,015	,140				
	N	15	15	15	15			
Patients screened	Pearson Correlation	-,310	,656**	,842**	,290	1		
	(p values)	,131	,004	,000	,147			
	N	15	15	15	15	15		
Patients diagnosed	Pearson Correlation	-,360	,529*	,769**	,329	,915**	1	
	(p values)	,093	,021	,000	,116	,000		
	N	15	15	15	15	15	15	
COVID patients	Pearson Correlation	-,165	,676*	,882**	,628*	,932**	,848**	1
	(p values)	,314	,011	,000	,019	,000	,000	
	N	11	11	11	11	11	11	11
Bed-days of care	Pearson Correlation	-,022	,465	,573*	,612*	,493	,393	,659*
	(p values)	,475	,075	,033	,023	,062	,116	,014
	N	11	11	11	11	11	11	11