



Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Hand hygiene compliance among healthcare workers before and during the COVID-19 pandemic



Susanne Gundersborg Sandbøl MSc^{a,b,*}, Eva Natalia Glassou PhD^c, Svend Ellermann-Eriksen PhD, DMSc^{b,d}, Annette Haagerup DMSc^{a,b}

^a NIDO | Danmark, Gødstrup Hospital, Herning, Denmark

^b Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

^c Department of Quality, Gødstrup Hospital, Herning, Denmark

^d Department of Clinical Microbiology, Aarhus University Hospital, Aarhus, Denmark

Key Words:

Automated hand hygiene monitoring system
Hospital setting
Infection control

Background: Healthcare workers' (HCWs) adherence to hand hygiene is vital in combatting COVID-19 in hospitals. We aimed to investigate HCWs hand hygiene compliance before and during the COVID-19 pandemic and hypothesised that hand hygiene compliance would increase during the pandemic.

Methods: We conducted a prospective observational study in three medical departments at the Regional Hospital of West Jutland, Denmark from April 2019 to August 2020. A total of 150 HCWs participated before the COVID-19 pandemic and 136 during the pandemic. Hand hygiene observations were assessed using an automated hand hygiene monitoring system. Students unpaired t-test was used to assess differences in hand hygiene compliance rates in each department.

Results: Comparison analyses showed, that hand hygiene compliance in department A and B was significantly higher before the COVID-19 pandemic than during the pandemic; a 7% difference in department A and a 5% difference in department B. For department C, the total hand hygiene compliance was unchanged during the pandemic compared to before.

Conclusion: The COVID-19 pandemic did not raise hand hygiene compliance. Further studies are needed to verify these findings and further identify barriers to hand hygiene compliance among HCWs.

© 2022 The Author(s). Published by Elsevier Inc. on behalf of Association for Professionals in Infection Control and Epidemiology, Inc. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>)

Healthcare workers' (HCWs) adherence to hand hygiene guidelines is vital in combatting infectious diseases, especially hospital-acquired infections and COVID-19 in hospitals.^{1,2} HCWs are front-line personnel and therefore frequently exposed to infected patients and contaminated surfaces. This places them at risk of acquiring and transmitting pathogens. HCWs' adherence to hand hygiene before the COVID-19 pandemic has been reported to fall in the 5%–89% range, with an overall average of 38.7%.² Hand hygiene has been reported to differ by professional group, hand hygiene indication (before and after patient contact) and perceived severity of illness.^{2–4} Potential reasons explaining inadequate hand hygiene include

overcrowding, understaffing, shift type, unavailability of hand rub dispensers and the perception that hand hygiene is time-consuming.^{5–7}

Hand hygiene studies conducted in relation to previous pandemic influenzas have shown contradicting HCW adherence findings. Thus, Labarca et al reported that HCW hand hygiene adherence was considerably higher during the H1N1 influenza pandemic in 2009 (62%) than in the preceding years (48%), but that it declined to 35% in the following year.⁸ Fulcini et al recorded an increase in the use of alcohol-based hand rub during the H1N1 pandemic, although hand hygiene compliance did not increase significantly compared with the period leading up to the pandemic.⁹

Studies on the COVID-19 pandemic and HCW hand hygiene is sparse. According to two studies, HCWs hand hygiene compliance increased during the pandemic compared to before.^{10,11}

Hence, the purpose this study was to determine if the pandemic triggered changes in HCW hand hygiene compliance. We choose to conduct a pre-post study using hand hygiene data from a research

* Address correspondence to Susanne Gundersborg Sandbøl, MSc, NIDO | Danmark, Gødstrup Hospital, Hospitalsparken 15, 7400 Herning, Denmark.

E-mail address: susanne.gundersborg@vest.rm.dk (S.G. Sandbøl).

Funding: SGS received a grant from the Research Foundation, Gødstrup Hospital.

Conflicts of interest: SEE is on the Advisory Board on COVID-19 at the Danish Health Authority. The other authors declare that they have no competing interest. All authors have approved the final article.

project conducted in 2019. The research project investigated HCWs hand hygiene compliance in patient rooms using an electronic hand hygiene monitoring system in three medical departments at the Regional Hospital West Jutland (RHWJ). Data from this project has not previously been published. In 2020, the hand hygiene system was re-installed on the same departments and hand hygiene data from 2019 was used as baseline measurements. The departments remained general wards during the COVID-19 pandemic and treated only COVID-19 patients if the patients were diagnosed during admission. In line with the literature, we hypothesised that hand hygiene compliance would increase during the COVID-19 pandemic compared with before the pandemic.

METHODS

Study design and setting

This pre-post observational study was conducted in three medical departments at RHWJ, Denmark, from April 2019 to June 2019 (before COVID-19) and from May 2020 to August 2020 (during COVID-19). The three departments treat different patient type; Department A treat patients with cardiovascular diseases, Department B haematological disorders and Department C respiratory diseases. Data on hand hygiene compliance before the COVID-19 pandemic consisted of 12 weeks of observation from April 2019 to June 2019. Data on hand hygiene compliance during the COVID-19 pandemic consisted of 12 weeks of observation from May 2020 to August 2020. The two observation periods were separated by an 11-month interval.

Ethics

Permission to conduct the study was obtained from the hospital administration of the Regional Hospital of West Jutland and the managements of the three departments. The study was registered with the Central Jutland Research Register (no. 1-16-02-642-18). The Regional Committee on Health Research Ethics declared that its approval was not needed.

Study subjects and data collection

Hand hygiene observations included physicians and nurses. Participation in the study was voluntary. All participants were informed about the study purpose and the placement of the hand hygiene system prior to study initiation. To ensure anonymity, no information was obtained about the study subjects besides their healthcare profession. A total of 150 HCWs participated before the COVID-19 pandemic and 136 during the COVID-19 pandemic.

Automated hand hygiene monitoring system

Hand hygiene observations were collected using the automated hand hygiene monitoring system Sani Nudge.¹² The Sani Nudge system consists of sensors attached to the HCWs' name tags and to all alcohol-based hand rub dispensers and near patient beds. The sensors on the HCWs' name tags were profession coded and continuously registered the HCWs' hand hygiene opportunities and their visits to patient rooms. The sensors located on all alcohol-based sanitizers recorded HCWs' dispenser usage. Furthermore, sensors installed above patient beds created a patient zone around the bed and were used to register whether hand hygiene using alcohol-based hand rub had been performed before entering and after exiting the patient zone. The algorithm has previously been validated clinically.¹³ The system set-up allows it to be used as a proxy for monitoring the WHO's moments 1 "before touching a patient, 4 "after

touching a patient" and 5" after touching patient surroundings.² All data were anonymised. The Sani Nudge system was installed 2 weeks ahead and tested in all departments of each study period.

Outcomes

The primary outcome was to determine whether hand hygiene compliance differed before compared to during the COVID-19 pandemic. Hand hygiene compliance before and during the COVID-19 pandemic was subsequently compared for each department respectively. The secondary outcomes were to examine trends in hand hygiene compliance over time before and during the COVID-19 pandemic. This approach allowed us examine increasing or decreasing trends in the weekly hand hygiene compliance rates before and during the COVID-19 pandemic. In addition, we examined difference in hand hygiene compliance by profession and hand hygiene indication (before and after patient contact) before compared to during the pandemic.

Statistical analysis

Hand hygiene compliance was calculated by dividing number of compliant hand hygiene opportunities by the total number of patient contact opportunities and was stated as weekly mean hand hygiene compliance rates (0%-100%). Continuous variables were reported as means with standard error of the means. For the primary statistical analysis, the difference in the mean hand hygiene compliance before compared to during the COVID-19 pandemic was assessed using the Student's unpaired *t* test. For the secondary analyses, trend in weekly hand hygiene compliance rates over time before and during the COVID-19 pandemic were assessed by scatterplots and linear regression. From the linear regressions analyses report the slope of the regression lines for before and during the COVID-19 pandemic and subsequently test for difference in slopes. Additionally, difference in hand hygiene compliance by profession and hand hygiene indication (before and after patient contact) was assessed using the Student's unpaired *t* test. *P*-values < .05 were considered statistically significant. All statistical analyses were conducted using STATA version 16.

RESULTS

Each department's patient beds remained the same throughout the study periods. Likewise, admission numbers, average durations of stay and number of employees and participation in the study were similar in the period leading up to and during COVID-19 (Table 1). The total participation rate was 76.5% in the before COVID-19 study period and 77.3% in the COVID-19 study period. Participation varied by department and by profession (Table 1). Data on hand hygiene compliance were based on a total of 23,507 compliant hand hygiene opportunities and 84,485 patient contact opportunities and varied by department, study period and profession (Table 1).

Hand hygiene compliance before compared to during the COVID-19 pandemic stratified by departments

For department A, the total hand hygiene compliance rate before and during the pandemic was 29% and 22% respectively, with a difference of 7% (95% CI, 5%-9%), *P* = <.001 (Table 2). For Department B, the total hand hygiene compliance rate before and during the pandemic was 34% and 29% respectively, with a difference of 5% (95% CI, 2%-7%), *P* = <.001 (Table 2). For Department C, hand hygiene compliance rate before and during was 31% and 29%, with a difference of 2% (95% CI 2%-6%), *P* = .24 (Table 2).

Table 1

Tabular summary of each department's patient beds, admission numbers, average duration of stay, employees, participation and number of compliant hand hygiene opportunities and patient contact opportunities in the before and during COVID-19 study periods. Values are stated as numbers unless otherwise specified

	Before COVID-19	During COVID-19
<i>Department A, Cardiology</i>		
Patient beds, n*	48	48
Admissions, n	863	827
Average duration of stay (days)	2.9	3.2
Nurses, n	55	49
Participating nurses, n (%)	47 (85.5)	41 (85.4)
Physicians, n	27	22
Participating physicians, n (%)	21 (77.8)	15 (68.2)
Compliant hand hygiene opportunities, n	7,006	6,122
Patient contact opportunities, n	23,642	27,280
<i>Department B, Hematology</i>		
Patient beds, n	16	16
Admissions, n	303	335
Average duration of stay (days)	1.6	1.1
Nurses, n	30	27
Participating nurses, n (%)	21 (70)	15 (55.6)
Physicians	15	13
Participating physicians, n (%)	12 (80)	13 (100)
Compliant hand hygiene opportunities, n	1,438	2,419
Patient contact opportunities, n	4,201	8,139
<i>Department C, Respiratory diseases</i>		
Patient beds, n	32	32
Admission, n	605	575
Average duration of stay (days)	2.0	1.9
Nurses, n	58	50
Participating nurses, n (%)	42 (72.4)	40 (80)
Physicians, n	11	15
Participating physicians, n (%)	7 (63.6)	12 (80)
Compliant hand hygiene opportunities, n	3,562	2,960
Patient contact opportunities, n	11,159	10,064

*number.

Weekly mean hand hygiene compliance rates over time – scatterplots and linear regression

For department A and B, the weekly mean hand hygiene compliance rates followed a slightly decreasing trend over time both before and during the COVID-19 pandemic (Fig 1). For department A and B, regression analyses revealed, that the decreasing trend in weekly hand hygiene compliance before the COVID-19 pandemic compared to during the pandemic was non-significantly (Table 3). For department A, difference in slopes before and during the COVID-19 pandemic was 0.001(95% CI -0.002, 0.004), $P = .56$. For department B, difference in slopes before and during the COVID-19 pandemic was -0.002 (95% CI -0.010, 0.005), $P = .47$.

In department C, during the first 8 weeks, the weekly hand hygiene compliance rates before the COVID-19 pandemic decreased, while the weekly hand hygiene compliance rates during the COVID-19 pandemic was more scattered (Fig 1). At week 9 and week 10, the hand hygiene compliance during the COVID-19 pandemic were above the levels recorded before the COVID-19 pandemic (Fig 1). For Department C, regression analyses showed a significantly difference in the slope before the COVID-19 pandemic to during the pandemic (Table 3); the difference in slopes before and during the COVID-19 pandemic was -0.013 (95% CI -0.021, -0.005), $P = .004$.

Hand hygiene compliance by profession and hand hygiene indication

The mean hand hygiene compliance among nurses and hand hygiene indication (before and after patient contact) differed significantly in favour of the before COVID-19 pandemic study period in departments A and B (Table 2) For department C, the mean hand

hygiene compliance by profession and hand hygiene indication also differed, but non-significantly so (Table 2).

DISCUSSION

To summarise, hand hygiene compliance levels differed with overall compliance being higher in favour of the period initiated before the COVID-19 pandemic, indicating that the COVID-19 pandemic did not have a beneficial effect on HCW hand hygiene as we expected.

The study showed, that department A and Bs total hand hygiene compliance levels was higher before the COVID-19 pandemic than during the pandemic. However, a 5%-7% difference in hand hygiene compliance with narrow confidence intervals does not seem to signal a major clinical difference. Furthermore, for department A and B, the trend in hand hygiene over time did not vary between the two study periods.

Department C was the only department, in which the hand hygiene compliance was unchanged during the pandemic compared to before. Furthermore, trend in hand hygiene compliance over time during the COVID-19 pandemic did not decrease throughout the 12 weeks. We consulted with the hospital preventionists to seek information about the sudden increase in hand hygiene compliance in week 9 and 10 during the COVID-19 study period. A week prior to these weeks, department C experienced cases of COVID-19 patients, and the Danish Working Environment Authority effected a working environment inspection. The sudden increase in hand hygiene compliance during the COVID-19 pandemic may have affected the overall hand hygiene compliance during the COVID-19 study period. However, the findings in department C support previous research indicating that adherence to hand hygiene increases with a fear of acquiring infection (self-protection) and with risk to take the infection home to one's family.^{14,15}

This study's findings are in line with another Danish study comparing hand hygiene compliance before and during COVID-19. Stangerup et al, using the same electronic hand hygiene monitoring system, showed that hand hygiene compliance was lower during the COVID-19 pandemic (from October 2020 to December 2020) than during a before-COVID-19 study period (from January 2019 to April 2019); 34% vs 58%.¹⁶ However, the before-COVID-19 study period was a nudging intervention, which might have affected the results.

Other studies published in the context of the COVID-19 pandemic and focusing on HCW adherence to hand hygiene have presented contradictory results. Israel et al showed that average hand hygiene compliance rates before the COVID-19 pandemic ranged from 35% to 71% and increased to 46% to 89% during the pandemic.¹⁰ Roshan et al reported that hand hygiene compliance rates from November 2019 to February 2020 ranged from 41% to 62% which increased in the period from March 2020 to April 2020 to 97%.¹¹ Both studies used direct observations based on the WHO's five moments of hand hygiene guidelines. Direct observation of hand hygiene is well-known to be subject to the Hawthorne effect.¹⁷

In our study, the electronic hand hygiene system was installed 2 weeks before each study period in an attempt to minimise the risk of confounding due to the Hawthorne effect. However, based on the slightly decreasing trend in hand hygiene in both study periods in department A and B, and for department C in the before study period, we cannot exclude that our study may have been affected by a residual Hawthorne effect. However, comparison of the declines in hand hygiene between the two study periods in department A and B was non-significantly different, indicating that the potential Hawthorne effect may be considered similar in the two study periods.

In this study, department A and Cs number of hand hygiene opportunities decreased in the COVID-19 study period compared to

Table 2
Mean values – standard error of the mean (SEM) and 95% confidence intervals of healthcare workers' hand hygiene compliance stratified by department, profession and hand hygiene indication. Mean values, SEM and 95% confidence intervals are listed as percentages

Departments	Before COVID-19 [†]	During COVID-19 [‡]	P value [*]
	Mean percentages (SEM) (95% CI)	Mean percentages (SEM) (95% CI)	
Department A, Cardiology			
Total hand hygiene compliance	29.44 (0.47) (28.41,30.47)	22.5 (0.59) (21.2, 23.79)	<.001
Profession			
Nurses	30.4 (0.49) (29.32, 31.48)	22.87 (0.63) (21.49, 24.25)	<.001
Doctors	19.69 (0.88) (17.75, 21.63)	14.62 (1.24) (11.88, 17.35)	.003
Hand hygiene by indication			
Before patient contact	21.04 (0.43) (20.01, 21.99)	16.33 (0.4) (15.51, 17.14)	<.001
After patient contact	37.84 (0.63) (36.44, 39.23)	28.66 (0.87) (26.75, 35.51)	<.001
Department B, Hematology			
Total hand hygiene compliance	33.86 (0.78) (32.14, 35.58)	29.33 (0.88) (27.40,31.28)	<.001
Profession			
Nurses	34.19 (0.8) (32.42, 35.96)	29.53 (0.9) (27.49, 31.56)	.001
Doctors	28.1 (21.35) (23.38, 32.78)	24.05 (2.56) (18.4, 29.69)	.24
Hand hygiene by indication			
Before patient contact	24.67 (0.6) (23.35, 25.99)	20.31 (0.9) (18.34, 22.28)	<.001
After patient contact	43.1 (1.08) (40.67, 45.44)	35.19 (2.32) (30.1, 40.31)	.01
Department C, Respiratory Diseases			
Total hand hygiene compliance	31.42 (1.33) (28.5, 34.35)	29.35 (1.1) (26.94, 31.77)	.24
Profession			
Nurses	31.52 (1.38) (28.48, 34.56)	29.42 (1.11) (26.99, 31.85)	.25
Doctors	28.1 (1.37) (25.08, 31.12)	28.00 (3.03) (21.33, 34.67)	.98
Hand hygiene by indication			
Before patient contact	24.13 (1.08) (21.76, 26.51)	22.51 (1.03) (20.24, 24.78)	.29
After patient contact	38.71 (1.63) (35.13, 42.3)	36.2 (1.07) (33.2, 39.2)	.25

*P-values compare hand hygiene compliance before and during the COVID-19 pandemic. Students unpaired t-tests were used for comparison.

[†]For before COVID-19, boldface indicates the period April 2019 to June 2019.

[‡]For during COVID-19, boldface indicates the period May 2020 to August 2020.

the before study period. While department Bs number of hand hygiene opportunities increased. Based on these data, bundling of nursing activities might not be the reason for why hand hygiene compliance did not increase during the COVID-19 study period. If bundling of nursing activities had been the case, department A and Bs

number of hand hygiene opportunities should have decreased, while department Cs increased.

However, potential contributing factors that might explain why hand hygiene compliance did not increase during the pandemic might include increase workload and the use of medical gloves in

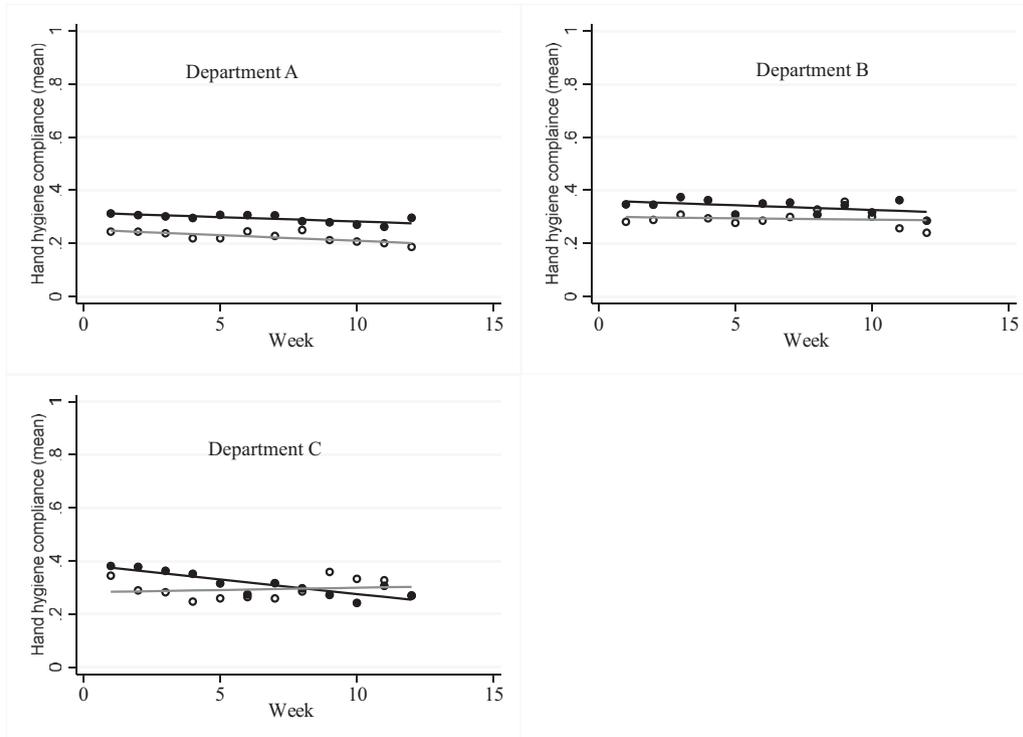


Fig 1. Mean weekly hand hygiene compliance rates in department A, B and C, 12 weeks before and 12 weeks during the COVID-19 pandemic. Black line and dots reflects before COVID-19 study period and grey line and hollow dots reflects the during COVID-19 study period.

Table 3
Linear regression analyses of trend (slope) in the weekly mean hygiene compliance rates over time before and during study period, and the comparison of difference in trends in weekly hand hygiene compliance before compare to during the COVID-19 pandemic

	Before COVID-19 slope (95% CI) [§]	During COVID-19 slope (95% CI) [§]	Difference in slopes (95% CI)	P-value*
Department A	-0.003 [-0.006, -0.001]	-0.004 [-0.006, -0.002]	0.001 [-0.002, 0.004]	.56
Department B	-0.004 [-0.009, 0.001]	-0.001 [-0.006, 0.004]	-0.002 [-0.010, 0.005]	.47
Department C	-0.011 [-0.017, -0.005]	0.002 [-0.004, 0.007]	-0.013 [-0.021, -0.005]	.004

*P-values compare the slope of hand hygiene compliance before and during the COVID-19 pandemic. Linear regression was used for comparison.

[§]Before COVID-19, boldface indicates the period April 2019 to June 2019. Linear regression was used to report the slope.

[§]During the COVID-19, boldface indicates the period May 2020 to August 2020. Linear regression was used to report the slope.

lieu of hand disinfection. In this study, Department A and B had a considerable increase in the number of patient contact opportunities in the COVID-19 study period compared to the before study period. If we consider the number of patient contact opportunities to be an expression for HCWs workload, this might be a reason for why hand hygiene compliance did not increase during the pandemic. More studies on factors that may influence hand hygiene compliance during the COVID-19 pandemic are needed.

During the COVID-19 study period, each of the three departments remained general wards and only treated COVID-19 patients if the patients was diagnosed during their admission. The hand hygiene compliance rates may therefore be considered an unequivocal expression of the HCW hand hygiene behavior. As we lack data on hand hygiene behavior in COVID-19 departments, it is possible that HCWs in these critical units may have shown a different hand hygiene behavior.

Limitations

This was a single-centre study, which may affect generalisability. In addition, this study did not include all professions and may thus not be representative for other healthcare professions. Furthermore, the hand hygiene system used probability-based algorithms based on time and distance measurements in the patient zone to calculate if a contact between the HCW and patient had occurred. This proxy measure for physical patient contact may have produced an over- or underestimation of hand hygiene compliance. However, the hand hygiene system is validated and was used in other studies.^{13,18} Furthermore, during installation (pre and post), the system was tested and validated in all departments and rooms to ensure correct data collection.

Other limitations to this study was that the study period during the COVID-19 pandemic missed the beginning of the pandemic (January 2020–April 2020). We do not know if hand hygiene behavior during this critical period might have changed as the pandemic initially moved forward. Also of importance, by the time we measured hand hygiene during the COVID-19 pandemic, more information was known about the transmissibility SARS-CoV-2, which could have had an impact on HCWs hand hygiene behavior.

CONCLUSION

This study demonstrates that the COVID-19 pandemic did not lead to increase in HCWs hand hygiene compliance. Management focus and ongoing improvement initiatives seem to be crucial in ensuring that HCWs adhere to hand hygiene measures. Further studies are

warranted to evaluate HCW hand hygiene after the COVID-19 pandemic, and to curb the challenges limiting HCW hand hygiene compliance.

Acknowledgments

We thank all HCWs who participated in the study.

References

1. WHO. Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected. Interim Guidance. 2020. Accessed April 22, 2022. <https://www.who.int/publications/i/item/10665-331495>.
2. WHO. WHO Guidelines on Hand Hygiene in Health Care. First global patient safety challenge clean care is safer care. 2009. Accessed April 22, 2022. <https://www.who.int/publications/i/item/9789241597906>.
3. Allegranzi B, Pittet D. Role of hand hygiene in healthcare-associated infection prevention. *J Hosp Infect.* 2009;73:305–315.
4. Randle J, Arthur A, Vaughan N. Twenty-four-hour observational study of hospital hand hygiene compliance. *J Hosp Infect.* 2010;76:252–255.
5. Salmon S, Pittet D, Sax H, et al. The “My five moments for hand hygiene” concept for the overcrowded setting in resource-limited healthcare systems. *J Hosp Infect.* 2015;91:95–99.
6. Sadule-Rios N, Aguilera G. Nurses' perceptions of reasons for persistent low rates in hand hygiene compliance. *Intensive Crit Care Nurs.* 2017;42:17–21.
7. Cure L, Van Enk R. Effect of hand sanitizer location on hand hygiene compliance. *Am J Infect Control.* 2015;43:917–921.
8. Labarca J, Zambrano A, Niklitschek S, et al. H1N1 pandemic influenza impact on hand hygiene and specific precautions compliance among healthcare workers. *J Hosp Infect.* 2011;79:177–179.
9. Fulchini R, Kohler P, Kahlert CR, et al. Hand hygiene adherence in relation to influenza season during 6 consecutive years. *Am J Infect Control.* 2018;46:1311–1314.
10. Israel S, Harpaz K, Radvugin E, et al. Dramatically improved hand hygiene performance rates at time of coronavirus pandemic. *Clin Microbiol Infect.* 2020;26:1566–1568.
11. Roshan R, Feroz AS, Rafique Z, et al. Rigorous hand hygiene practices among health care workers reduce hospital-associated infections during the COVID-19 pandemic. *J Prim Care Community Health.* 2020;11:1–4.
12. Nudge S. Accessed April 22, 2022. <https://saninudge.com/>.
13. Hansen MB, Wismath N, Fritz E, et al. Assessing the clinical accuracy of a hand hygiene system: learnings from a validation study. *Am J Infect Control.* 2021;49:963–965.
14. Smiddy MP, O'Connell R, Creedon SA. Systematic qualitative literature review of health care workers' compliance with hand hygiene guidelines. *Am J Infect Control.* 2015;43:269–274.
15. Borg MA, Benbachir M, Cookson BD, et al. Self-protection as a driver for hand hygiene among healthcare workers. *Infect Control Hosp Epidemiol.* 2009;30:578–580.
16. Stangerup M, Hansen MD, Hansen R, et al. Hand hygiene compliance of healthcare workers before and during the COVID-19 pandemic: a long-term follow-up study. *Am J Infect Control.* 2021;49:1118–1122.
17. Chen LF, Weg MWV, Hofmann DA, et al. The Hawthorne effect in infection prevention and epidemiology. *Infect Control Hosp Epidemiol.* 2015;36:1444–1450.
18. Iversen AM, Kvavalaris CP, Hansen R, et al. Clinical experiences with a new system for automated hand hygiene monitoring: a prospective observational study. *Am J Infect Control.* 2020;48:527–533.