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Major Article

The impact of COVID-19 pandemic on hand hygiene performance in hospitals

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Key Words:
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Background: Achieving high levels of hand hygiene compliance of health care personnel has been an ongoing challenge. The objective of this study was to examine the impact of the COVID-19 pandemic on hand hygiene performance (HHP) rates in acute care hospitals.

Methods: HHP rates were estimated using an automated hand hygiene monitoring system installed in 74 adult inpatient units in 7 hospitals and 10 pediatric inpatient units in 2 children's hospitals. A segmented regression model was used to estimate the trajectory of HHP rates in the 10 weeks leading up to a COVID-19-related milestone event (eg, school closures) and for 10 weeks after.

Results: Three effects emerged, all of which were significant at $P < .01$. Average HHP rates increased from 46% to 56% in the months preceding pandemic-related school closures. This was followed by a 6% upward shift at the time school closures occurred. HHP rates remained over 60% for 4 weeks before declining to 54% at the end of the study period.

Conclusions: Data from an automated hand hygiene monitoring system indicated that HHP shifted in multiple directions during the early stages of the pandemic. We discuss possible reasons why HHP first increased as the pandemic began and then decreased as it progressed.

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Hand hygiene is considered an important measure to prevent the transmission of pathogens in health care facilities,[1] and it is proven that improving hand hygiene compliance significantly reduces health care-acquired infections.[2-4] Accordingly, hand hygiene has been recommended as an important strategy to help prevent the spread of COVID-19 in hospitals.[5]

Monitoring hand hygiene compliance is considered a critical aspect of an effective hand hygiene program.[1,6] Data obtained can be used to provide health care workers with feedback, to identify areas within the hospital with poor hand hygiene compliance, and to evaluate the impact of targeted interventions.[7] Gathering infection prevention data in the current environment may be challenging for most health care facilities with resources being diverted to COVID-19 outbreak management. Process measures such as the direct observation of hand hygiene compliance may also be compromised.[8] Hospitals with automated hand hygiene monitoring systems have an advantage during this pandemic with the ability to quickly gather robust hand hygiene data with minimal investment of personnel time.

Effects of this pandemic in the United States are unprecedented with declarations of states of emergency, school closures, postponement of elective surgeries and procedures, visitor restrictions, restaurant closings, and stay-at-home quarantine orders. School closures have attracted much attention, and it has been estimated that those working in health care settings are among those with the highest childcare obligations in the United States with 28.5% of the health care workforce needing to provide care for children aged 3-12 years.[9]

Little is known about the effects of national public health quarantine practices on hand hygiene compliance in hospitals. A literature search did not reveal any studies reporting on hand hygiene compliance of health care workers in hospitals during the first pandemic of the 21st century (influenza A/H1N1) or the current COVID-19 pandemic. A recent study of 2 pediatric hospital units during this pandemic did find that 100% hand hygiene compliance is achievable (n = 72 health care workers),[10] an encouraging finding.

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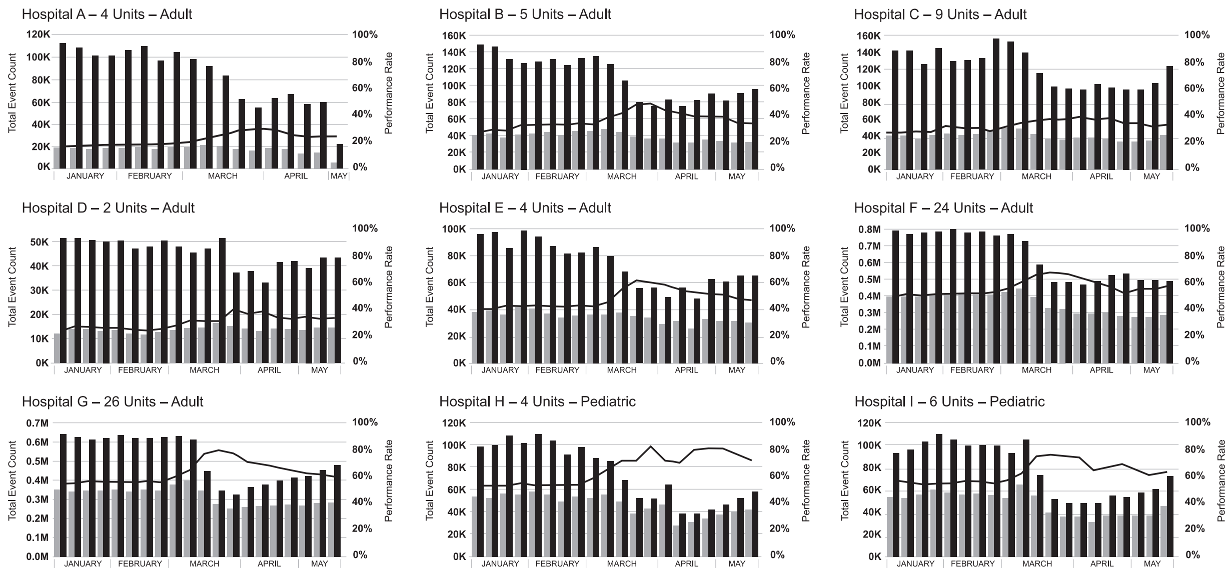

Fig 1. Weekly opportunities (black bars), events (gray bars), and average performance rates (solid lines), for each hospital (2020).

The purpose of this study was to examine hand hygiene performance of health care workers in hospitals during a pandemic. To determine if this pandemic would lead to changes in hand hygiene behaviors, we needed to pick a point in time that might have been related to behavioral changes. For this analysis, we chose school closures because they occurred during the same week for all hospitals in the study.

METHODS

Data analyzed in this study were captured from January 5 to May 23, 2020, utilizing data from the PURELL SMARTLINK Activity Monitoring System installed in 9 US hospitals. Elements of this system, including the validation process, have previously been described.[11,12] Outpatient units, including 2 emergency departments, were excluded from the study. Final analysis included data from 74 adult inpatient units in 7 hospitals (2 Academic, 4 Federal Veterans Administration, and 1 Community) and 10 pediatric inpatient units in 2 children's hospitals (Academic); see data by hospital in Figure 1. Alcohol-based hand rub and soap dispensers recorded each actuation as a hand hygiene event. Activity monitors placed near each patient room doorway detected each entry into and exit from the room as a hand hygiene opportunity. Data captured by dispensers and activity monitors were sent to a secure cloud-based server that stored the information at the device level. Unit level hand hygiene performance rates (a proxy or estimate of compliance) were calculated by dividing events by opportunities.

Statistical analyses were conducted to determine whether hand hygiene performance differed before and after the time schools were closed due to the pandemic. First, we computed mean values of opportunities, dispense events, and performance rates for the periods before and after school closures and used t tests to determine whether these values differed significantly. In addition, we performed a segmented regression analysis[13] to examine changes in hand hygiene performance rates longitudinally, week by week. This approach allowed us to test for significant increasing or decreasing trends in hand hygiene performance in the weeks prior to the school closures, at the time the school closures occurred, and in the weeks following the school closures. For each of these 3 periods, we report the rate of change in hand hygiene performance rate (ie, the slope of the regression line for each segment, represented by $ß$) and an estimate of the variability of the data around the slope (standard error, SE), which are used to calculate the t statistic ($t = ß/SE$) used to test for statistical significance.

RESULTS

Data from the 9 hospitals were aggregated, resulting in a dataset containing 18,457,669 dispense events and 35,362,136 hand hygiene opportunities. We computed weekly mean values for both dispense events and hand hygiene opportunities. Analyses compared data from the 10 weeks before the time of the school closures (the week beginning January 5 through the week beginning March 8) with the 10-week period after school closures (the week beginning March 15 through the week beginning May 17). The week of March 15 is when schools closed in the states where the 9 hospitals are located. Events, opportunities, and average performance rates by week for all 9 hospitals combined are shown in Table 1.

The 2 time periods we examined (before school closures and after school closures) did show significant differences. The weekly mean number of hand hygiene opportunities decreased dramatically from 2,153,702 (standard deviation [SD] = 45,407) prior to the school closures to 1,382,512 (SD = 107,999) after the school closures, $t(12.09) = 20.82$, $P < .001$. Weekly dispense events also decreased from 1,044,060 (SD = 42,102) prior to the school closures to 801,707 (SD = 79,922) after the school closures, $t(13.64) = 8.48$, $P < .001$. Although both opportunities and dispenses decreased, hand hygiene performance rates increased from 48.52% (SD = 0.03) before the school closures to 58.05% (SD = 0.04) after the school closures, $t(15.83) = -5.92$, $P < .001$. Mean weekly opportunities, events, and performance rates before and after school closures for all 9 hospitals combined are shown in Table 2.

The pre- and post- t test analyses clearly demonstrated a difference in hand hygiene behavior before versus after the time when school closures occurred. In addition, our rich data set enabled us to dig deeper and better understand how and when hand hygiene behavior changed over time. Specifically, we were able to examine when the changes began and how long they lasted (whether improvements in hand hygiene performance were fleeting or sustained). We used segmented regression analysis to track the trajectory of weekly performance rates over time providing an important complement to the pre- and post- t test analyses. Segmented

Table 1
Summary of events, opportunities, and average performance rates by week, all 9 hospitals combined (2020)

Week	Events	Opportunities	Performance rate
Jan 5	1,017,778	2,218,295	45.88%
Jan 12	1,011,360	2,177,610	46.44%
Jan 19	1,007,001	2,140,575	47.04%
Jan 26	1,036,834	2,182,270	47.51%
Feb 2	1,049,858	2,194,350	47.84%
Feb 9	1,032,560	2,149,565	48.04%
Feb 16	1,024,031	2,121,889	48.26%
Feb 23	1,031,279	2,157,718	47.79%
Mar 1	1,083,439	2,140,848	50.61%
Mar 8	1,146,462	2,053,898	55.82%
Mar 15	1,015,528	1,633,575	62.17%
Mar 22	835,286	1,306,496	63.93%
Mar 29	804,211	1,257,569	63.95%
Apr 5	784,709	1,301,234	60.30%
Apr 12	758,830	1,316,023	57.66%
Apr 19	772,837	1,375,098	56.20%
Apr 26	761,382	1,425,334	53.42%
May 3	740,776	1,350,726	54.84%
May 10	755,317	1,396,337	54.09%
May 17	788,191	1,462,726	53.89%
Total	18,457,669	35,362,136	

Shaded area denotes the weeks after school closures.

regression has been recommended as a powerful tool to measure change in an outcome before and after an event of interest.[14-16]

Our regression model analyzed 3 segments of our longitudinal data set. First, we tested for changes in performance rates within the pre-test section of the data (the 10 weeks before the week when school closures occurred). As can be seen in Figure 2, this first segment of the model was characterized by a statistically significant increasing slope, $ß = 0.008$, $SE = 0.002$, $t = 3.85$, $P < .01$. Performance rates were fairly consistent from week 1 to week 8 and then began to increase in weeks 9 and 10. This shows that performance rates were beginning to increase before the event of interest (school closures).

The second segment of the model shows a significant upward shift in the level of performance rates between our pre- and post-test data, $ß = 0.13$, $SE = 0.02$, $t = 8.18$, $P < .001$. This is depicted in Figure 2 as the large spike in performance rates that occurred between week 10 and week 11 (the week of school closures).

Finally, the third segment in the model, which tested for changes in performance rates within the post-test section of the data (Fig 2, weeks 11-20), showed a significant decrease in performance rates over time, $ß = -0.02$, $SE = 0.003$, $t = -7.33$, $P < .001$. Performance rates remained higher than 60% during the first 4 weeks of the post-school closure period before declining significantly. By week 20, performance rates were still higher than the rates during weeks 1-8 of the study but were lower than the peak performance rate which occurred 2 weeks after the week of school closures.

DISCUSSION

To our knowledge, examination of hand hygiene performance in hospitals during a pandemic utilizing an automated hand hygiene monitoring system has not been previously reported. In this study, over 35 million hand hygiene opportunities were captured over the 20-week period. Hand hygiene performance rates seen in weeks 1-8 represent typical performance in 2020. Performance reached higher than typical levels during the initial period of pandemic-related hospital and public health prevention measures (including school closures), however, began to decline. Even during pandemic conditions, it appears to be difficult to sustain improvements in hand hygiene performance.

Table 2
Mean weekly opportunities, events, and performance rates before and after school closures, all 9 hospitals combined

	Before school closures	After school closures	*P* value
Opportunities	2,153,702	1,382,512	<.001
Events	1,044,060	801,707	<.001
Performance rates	48.52%	58.05%	<.001

School closures occurred the week of March 15, 2020.

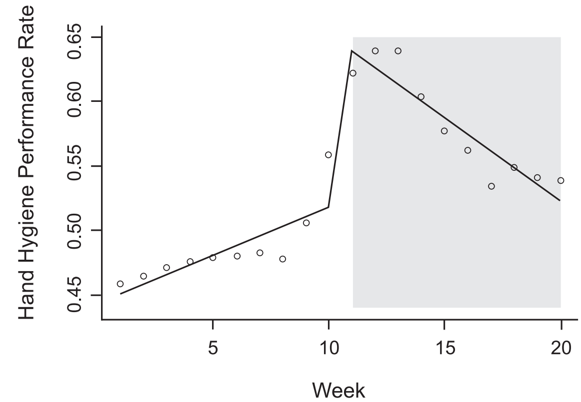

Fig 2. Segmented regression analysis of performance rates over time, all 9 hospitals combined.
Shaded area denotes the weeks after school closures.

A significant increase in hand hygiene performance was associated with the timing of school closures for all 9 hospitals (the week of March 15). Possible factors for the spike in performance include: 1) increased emphasis on the importance of hand hygiene, 2) significant decrease in opportunities (workload) making higher performance more achievable, 3) decrease in the room entries and exits from visitors and patients (non-health care workers), and 4) heightened perception of risk to health care workers themselves and their families. Perception of risk is of particular interest. COVID-19 has received significant media attention which can amplify perceptions of personal risk.[17] Health care workers may have improved their hand hygiene behaviors, in part, to protect themselves and their family members. Previous studies have reported self-protection as a major driver of hand hygiene among health care workers.[18-22]

The finding of decreased hand hygiene opportunities (patient room entries and exits) was not unexpected. It is likely due to visitor restrictions and decreased patient census (eg, a result of postponement of elective surgeries and procedures). Additionally, bundling of nursing activities to decrease unnecessary patient room entries and exits and conservation of hand hygiene products and personal protective equipment may also have played a role.

Several hypotheses are possible for the most recent decrease in performance rates (weeks 14-20 as compared to weeks 11-13). Possible contributing factors include increase in workload as opportunities for hand hygiene increased,[23] concerns over limited supplies of hand hygiene products,[20,24] use of gloves in lieu of hand hygiene,[24,25] and less frequent direct observation/reminders[8] from nurse managers and infection prevention leaders due to competing pandemic-related priorities.

Further study can include analysis of data over an extended period of time to determine if increased hand hygiene will become the new normal or resemble a campaign that drives an increase but is not sustained due to lack of a multimodal, long-term program.[6] Comparison of hand hygiene performance rates between hospitals with comparison of the various unit types and COVID-patient census may also provide insight into the impact of this pandemic on hand hygiene in hospitals. Consideration can also be given to examining the impact of visitor restrictions and reintroduction of visitors on opportunities and performance rates by hospital.

CONCLUSIONS

We are currently in uncharted territory with much to be learned. Hand hygiene is a key factor in reducing germs that can potentially cause disease. Monitoring hand hygiene performance with direct observation may continue to present challenges for many hospitals throughout this pandemic. As we move forward, hospitals may benefit from implementing technology to gather hand hygiene data and evaluate behaviors.

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References

1. Boyce JM, Pittet D, HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Guideline for hand hygiene in health-care settings. *MMWR Morb Mortal Wkly Rep*. 2002;51 (RR-16):1–45.
2. Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet*. 2000;356:1307–1312.
3. Larson EL, Early E, Cloonan P, Sugrue S, Parides M. An organizational climate intervention associated with increased handwashing and decreased nosocomial infections. *Behav Med*. 2000;26:14–22.
4. Sickbert-Bennett EE, DiBiase LM, Willis TM, Wolak ES, Weber DJ, Rutala WA. Reduction of healthcare-associated infections by exceeding high compliance with hand hygiene practices. *Emerg Infect Dis*. 2016;22:1628–1630.
5. Lotfinejad N, Peters A, Pittet D. Hand hygiene and the novel coronavirus pandemic: the role of healthcare workers. *J Hosp Infect*. 2020;105:776–777.
6. World Health Organization. *WHO Guidelines for Hand Hygiene in Health Care*. Geneva, Switzerland: World Health Organization; 2009.
7. Boyce JM. Measuring healthcare worker hand hygiene activity: current practices and emerging technologies. *Infect Control Hosp Epidemiol*. 2011;32:1016–1028.
8. Stevens MP, Doll M, Pryor R, Godbout E, Cooper K, Bearman G. Impact of COVID-19 on traditional healthcare-associated infection prevention efforts. *Infect Control Hosp Epidemiol*. 2020;41:946–947.
9. Bayham J, Fenichel EP. Impact of school closures for COVID-19 on the US healthcare workforce and net mortality: a modelling study. *Lancet Public Health*. 2020;5:e271–e278.
10. Wong SC, AuYeung CH, Lam GK, et al. Is it possible to achieve 100 percent hand hygiene compliance during the COVID-19 pandemic? *J Hosp Infect* 2020;105:779–781.
11. Limper HM, Slawsky L, Garcia-Houchins S, Mehta S, Hershow RC, Landon E. Assessment of an aggregate-level hand hygiene monitoring technology for measuring hand hygiene performance among healthcare personnel. *Infect Control Hosp Epidemiol*. 2016;38:348–352.
12. Boyce JM, Laughman JA, Ader MH, Wagner PT, Parker AE, Arbogast JW. Impact of an automated hand hygiene monitoring system and additional promotional activities on hand hygiene performance rates and healthcare-associated infections. *Infect Control Hosp Epidemiol*. 2019;40:741–747.
13. Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther*. 2002;27:299–309.
14. Taljaard M, McKenzie JE, Ramsay CR, Grimshaw JM. The use of segmented regression in analyzing interrupted time series studies: an example in pre-hospital ambulance care. *Implement Sci*. 2014;9:77.
15. Penfold RB, Zang F. Use of interrupted time series analysis in evaluating health care quality improvements. *Acad Pediatr*. 2013;13(6 Suppl):S38–S44.
16. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol*. 2017;46:348–355.
17. Chakraborty S. How risk perceptions, not evidence, have driven harmful policies on COVID-19. *Eur J Risk Regul*. 2020:236–239.
18. Whitby M, McLaws ML, Ross MW. Why healthcare workers don't wash their hands: a behavioral explanation. *Infect Control Hosp Epidemiol*. 2006;27:484–492.
19. 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.
20. Erasmus V, Brouwer W, van Beeck EF, et al. A qualitative exploration of reasons for poor hand hygiene among hospital workers: lack of positive role models and of convincing evidence that hand hygiene prevents cross-infection. *Infect Control Hosp Epidemiol*. 2009;30:415–419.
21. Korniewicz DM, El-Masri M. Exploring the factors associated with hand hygiene compliance of nurses during routine clinical practice. *Appl Nurs Res*. 2010;23:86–90.
22. Smiddy M, O'Connell R, Creedon S. Systematic qualitative literature review of health care workers' compliance with hand hygiene guidelines. *Am J Infect Control*. 2015;43:269–274.
23. Erasmus V, Daha TJ, Brug H, et al. Systematic review of studies on compliance with hand hygiene guidelines in hospital care. *Infect Control Hosp Epidemiol*. 2010;31:283–294.
24. 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.
25. Acquarulo BA, Sullivan L, Gentile AL, Boyce JM, Martinello RA. Mixed-methods analysis of glove use as a barrier to hand hygiene. *Infect Control Hosp Epidemiol*. 2019;40:103–105.