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Major Article

Current issues in hand hygiene

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Background: Multiple aspects of hand hygiene have changed in recent years.
Methods: A PubMed search was conducted to identify recent articles about hand hygiene.
Results: The COVID-19 pandemic caused temporary changes in hand hygiene compliance rates and shortages of alcohol-based hand sanitizers (ABHSs), and in marketing of some products that were ineffective or unsafe. Fortunately, ABHSs are effective against SARS-CoV-2 and other emerging pathogens including *Candida auris* and mpox. Proper placement, maintenance, and design of ABHS dispensers have gained additional attention. Current evidence suggests that if an adequate volume of ABHS has been applied to hands, personnel must rub their hands together for at least 15 seconds before hands feel dry (dry time), which is the primary driver of antimicrobial efficacy. Accordingly, practical methods of monitoring hand hygiene technique are needed. Direct observation of hand hygiene compliance remains a challenge in many healthcare facilities, generating increased interest in automated hand hygiene monitoring systems (AHHMSs). However, several barriers have hindered widespread adoption of AHHMSs. AHHMSs must be implemented as part of a multimodal improvement program to successfully improve hand hygiene performance rates.
Conclusions: Remaining gaps in our understanding of hand hygiene warrant continued research into factors impacting hand hygiene practices.

Hand hygiene continues to be considered 1 of the most important methods of preventing transmission of healthcare-associated pathogens and reducing the incidence of healthcare-associated infections (HAIs). Issues affecting hand hygiene practices in recent years include new recommendations from non-regulatory agencies, the COVID-19 pandemic, and continued challenges in achieving desired levels of hand hygiene compliance and appropriate hand hygiene technique. Many facilities still struggle with issues related to monitoring hand compliance and providing effective feedback to healthcare personnel (HCP). The purpose of this review is to provide a brief discussion of these issues.

CHANGES IN HAND HYGIENE RECOMMENDATIONS

In 2022, the Leapfrog group made a number of changes in sections of their hospital survey related to hand hygiene.[1] Facilities were given options regarding the number of hand hygiene opportunities that must be performed in order to meet the "Achieved the Standard" Performance Category. Conducting periodic audits of the volume of alcohol-based hand sanitizer (ABHS) delivered by dispensers is now recommended. Dispensers should deliver a minimum of 1.0 mL of ABHS with a single activation, OR a volume that is sufficient to cover all surfaces of the hands, and requires 15 seconds or more of rubbing before hands feel dry.

The Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA) and the Association of Professionals in Infection Control and Epidemiology (APIC) are in the process of revising the SHEA/IDSA/APIC Practice Recommendations on Hand Hygiene in Healthcare. The updated recommendations are scheduled to be published in late 2022 or early 2023. Readers are encouraged to review the revised recommendations upon their publication.

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IMPACT OF THE COVID-19 PANDEMIC ON HAND HYGIENE

Beginning in early 2020, the COVID-19 pandemic caused by the SARS-CoV-2 virus has impacted multiple aspects of hand hygiene in healthcare and community settings. Early in the pandemic, hand hygiene was promoted as 1 of the most important preventive measures because the prominent role of airborne and droplet transmission was not initially recognized. Although hand contact with fomites contaminated with SARS-CoV-2 may result in transmission, the risk is now considered to be low.[2] However, hand hygiene is still recommended because the virus can contaminate respirators/face masks and gowns and remain viable for hours or days.[3,4] And HCP and others frequently touch their faces or respirators/face masks from 9-15 times/h.[5-8] Errors in doffing personal protective equipment have been documented during the pandemic, and warrant hand hygiene following the doffing procedure.[9] Accordingly, frequent hand hygiene with either an ABHS or handwashing with soap and water is recommended. https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html.

ABHS safety

The pandemic created an unprecedented demand for ABHS products, both in healthcare settings and in the community at large. As a result, severe shortages of most, if not all, ABHSs manufactured in the United States occurred. Many healthcare facilities were forced to change product brands, and some even resorted to having pharmacists formulate alternative ABHSs. In the United States and in some other countries, companies with little or no experience in producing ABHSs marketed products that were ineffective (ie contained < 60% alcohol) or were toxic (eg multiple products were contaminated with either methanol, 1-propanol, or benzene.[10,11] As a result, multiple case of methanol toxicity due to ingestion of ABHS containing methanol occurred in the southwest U.S. and in other countries.[10,12,13] Some newly marketed products had labels with false, misleading or unproven claims, and 1 alcohol-free hand sanitizer was contaminated with *Burkholderia cepacia* complex and *Ralstonia pickettii*.[14] To assist healthcare facilities in avoiding such products, the Food and Drug Administration created an online list entitled “hand sanitizers consumers should not use”.[14]

Impact on hand hygiene compliance

Some infection preventionists and hospital epidemiologists assumed that increased attention to hand hygiene early in the pandemic might permanently change HCP attitudes regarding the importance of hand hygiene. However, it appears that this has not occurred. Several studies that employed automated hand hygiene monitoring systems documented that hand hygiene compliance rates increased significantly early during the pandemic, but subsequently decreased considerably, sometimes returning to baseline levels.[15-17] The findings are similar to trends that some facilities experienced during the 2009 H1N1 pandemic.[18,19]

ALCOHOL-BASED HAND SANITIZER EFFICACY

Both the HICPAC/SHEA/IDSA/APIC and World Health Organization guidelines on hand hygiene provided compelling evidence that alcohol-based hand rubs are more effective in reducing bacteria on hands than washing hands with soap and water.[20,21] Unfortunately in some healthcare facilities (primarily nursing homes), HCP most frequently wash hands with soap and water instead of using an ABHS as the preferred mode of hand hygiene.[22] Continued hand hygiene education, training and motivational strategies are warranted in such facilities.

Recent studies have confirmed that ABHSs with ≥ 60% ethanol are effective against a number of emerging pathogens, including *Candida auris*, SARS-CoV-2 and other coronaviruses, and monkeypox (mpox).[23-27] Some ABHS formulations with 70% to 95% ethanol plus certain excipients have reasonable activity against human norovirus and adenovirus.[28,29] In general, all formats (gel, foam, liquid) have similar antimicrobial efficacy.[30]

ABHS DISPENSER PLACEMENT AND FUNCTION

Making ABHS readily available to HCP is an important structural component of a successful multimodal hand hygiene improvement strategy, as outlined in the WHO Guidelines on Hand Hygiene in Health Care.[21] Dispensers should be near the point of care (eg near a patient’s bed or at the entrance to the room). In-room dispensers should be easily accessible and visible (preferably in the line-of sight) to HCP when entering and exiting the room.[31] Access to dispensers should not be hindered by placing portable equipment too close to (or in front of) wall-mounted dispensers. And placing dispensers solely at the back of a patient’s room should generally be avoided, as they are less likely to be used.[32] In addition, a number of studies have shown that when dispensers are also located in corridors near the doors to patient rooms, HCP use the dispensers in the corridor more often than those located in the room.[33,34] Standardizing the placement of dispensers in rooms and corridors may also promote ABHS usage.[31] Facilities should also consider conducting periodic audits of dispensers to check the volume of ABHS delivered and to determine if dispensers are functioning properly, as recently recommended in the 2022 Leapfrog Hospital Survey.[1,35]

Manual dispensers have the advantage of being less complex and not requiring batteries. However, dispensers can occasionally develop mechanical problems,[36] and they can allow HCP to obtain less than a full dose of ABHS by not pressing the lever to the full extent. Automated “touch-free” dispensers have the important advantage of providing a standardized volume of ABHS. Potential disadvantages of automated dispensers include pump dysfunction or frequent battery changes if not well-designed, and may raise environmental concerns regarding disposal of batteries.[37] In the future, it would be desirable if automated dispensers could dispense an amount individualized to the size of the healthcare worker’s hand.[38] Other innovative approaches to dispenser design would also be welcome. For example, a recent study evaluated a dispensing system that includes measurement of the volume of ABHS dispensed from a pocket bottle, and a wrist band that measures the duration of hand rubbing. The system can vibrate to give the user immediate and individualized positive feedback regarding the 2 measurements.[39]

HAND HYGIENE TECHNIQUE

Considerable efforts have been made in many healthcare facilities to improve HCP compliance with recommended hand hygiene indications, with compliance defined as the number of hand hygiene events performed/number of hand hygiene opportunities x 100. Less attention has been devoted to assessing and improving hand hygiene technique, and warrants critical analysis of the factors that impact hand hygiene technique effectiveness.[40] For the purposes of this review, technique refers to the method of applying ABHS to the hands, and is comprised of following elements: the duration of hand rubbing (amount of time hands are rubbed together before they feel dry [dry-time]), how the hands are rubbed together, the amount of ABHS applied to the hands, and the degree to which ABHS comes in contact with all surfaces of the hands (ie coverage).

Duration of rubbing with ABHS (dry time)

The WHO guideline recommends that performing hand hygiene with an ABHS should take 20-30 seconds.[21] However, several studies found that rubbing for 15 seconds is not inferior to rubbing for 30 seconds with respect to antimicrobial efficacy.[41-44] The shorter rubbing time may be beneficial, as nurses rubbing for 15 seconds may have higher compliance than those rubbing for 30 seconds.[42,44] Unfortunately, in clinical settings, HCP often rub their hands together for < 15 sec, with some individuals rubbing their hands for as little as 4 seconds.[45-49] Failure to rub hands together for an adequate amount of time is an important issue, since several studies have found that dry-time appears to be the primary factor affecting ABHS antimicrobial efficacy.[38,41] As a result, rubbing for an adequate amount of time (≥ 15 seconds) should be emphasized in hand hygiene education and training programs, and facilities should consider recording how long HCP rub their hands together with ABHS as part of protocols for monitoring hand hygiene technique.

How to rub with ABHS

The HICPAC/SHEA/IDSA/APIC Guideline recommended that ABHS be applied to the palm of 1 hand and hands should be rubbed together, covering all surfaces of hands and fingers until hands are dry. No detailed instructions were given regarding the pattern of rubbing or the order in which different parts of the hands should be rubbed. Based on earlier controlled laboratory-based studies, the WHO Guideline recommended a specific 6-step method for rubbing hands together.[21] The 6 steps include: (1) rubbing hands palm to palm, (2) right palm over left dorsum with interlaced fingers and vice versa, (3) palm to palm with fingers interlaced, (4) backs of fingers to opposing palms with fingers interlaced, (5) rotational rubbing of left thumb clasped in right palm and vice versa, and (6) rotational rubbing backwards and forwards with clasped fingers of right hand in left palm and vice versa. However, several subsequent clinical studies have found that HCP seldom complete all 6 steps recommended by the WHO.[50,51] In 1 study, all 6 WHO-recommended steps were performed in only 8.5% of hand hygiene opportunities.[50] In another study, 0/63 HCP performed all 6 steps of the WHO method.[51] After receiving training on the WHO method, 1/30 (3.3%) completed all 6 steps. A laboratory-based study found that a modified WHO method which involved rubbing the fingertips first resulted in greater antimicrobial efficacy when compared to the standard WHO 6-step method.[52]

To address this issue of poor compliance with the WHO 6-step method, Tschudin-Sutter et al.[53] have proposed a simplified 3-step method of rubbing hands, which included (1) cover all surfaces of the hands, (2) rotational rubbing of fingertips in the palm of the alternate hand, and (3) rotational rubbing of both thumbs. In a randomized controlled trial that compared the 6-step versus the 3-step method, the 6-step method reduced bacteria on hands to a significantly greater degree than the 3-step method.[54] However, the time taken to perform the 6-step method was 15% longer. Subsequently, a much larger cluster-randomized trial conducted on 12 hospital wards compared to 2 methods.[55] Compared to the 6-step method, the 3-step method yielded higher compliance with both hand hygiene indications and rubbing technique, and was not inferior to the 6-step method in reducing bacterial counts on hands. Accordingly, facilities may want to consider promoting the simplified 3-step method as an alternative to the 6-step method.

Volume of ABHS applied

The volume of ABHS delivered by dispensers is not standardized, and varies by facility policies, product manufacturer, type of dispenser, and may depend on the format (gel vs foam).[56] In several studies, the volume delivered with a single accession has varied from 0.6 to 1.8 mL, and may be greater in some facilities in Europe.[56-62] The volume delivered by manual dispensers can vary to some extent depending on the individual user. Several studies suggest that when HCP are given a choice of application volume, they often prefer to apply from 0.75 to 1.1 mL of ABHS.[49,60,63-65] Some studies have suggested that doses of 1.5-2.5 mL should be delivered, but such doses yield median dry-times of ~26 to 40 seconds, a range that many nurses consider to be unacceptable.[40,60] Nurses tend to favor small volumes to achieve short dry times.

As expected, the greater the volume of ABHS applied, the longer hands must be rubbed together before they feel dry.[38,66-68] Importantly, increasing the volume applied results in greater antimicrobial efficacy.[38,56,67] Small volumes (eg < 1 mL) of some ABHSs are likely to result in dry times that are less than what is recommended (ie 15-30 seconds), resulting in suboptimal $\log_{10}$ reductions of transient hand flora.[21,38,56]

A 2018 study by Suchomel M et al.[38] suggested that to achieve dry-times which yield adequate antimicrobial efficacy, the volume of ABHS applied should ideally be customized based on an individual's hand size. Current evidence suggests that facilities should ensure that dispensers deliver a minimum of 1 mL per accession,[1] with larger volumes being preferable. HCP with large hands may need to access a dispenser twice to receive an adequate amount of ABHS.

Hand size and coverage

There is considerable variation in HCP hand size (expressed by estimated hand surface area).[38,67-70] Therefore, when a fixed volume of ABHS is applied to hands, the volume of ABHS applied/cm^2 of hand surface area is significantly higher for small hands than for larger hands.[71] As a result, hand size and the ABHS volume applied/cm^2 hand surface area have a significant impact on dry-times.[38,68] Interestingly, while 1 study showed a significant negative association between hand size and $\log_{10}$ reductions achieved,[70] 2 other studies did not find a significant effect of hand size on bacterial $\log_{10}$ reductions achieved.[38,67]

Despite their best intentions, HCP often do not cover all surfaces of their hands and fingers as recommended when using an ABHS. Areas often missed include parts of the thumb and fingertips.[72-74] The degree of coverage increases as the volume of ABHS applied is increased.[60,68,69] Contrary to what 1 might expect, several studies failed to find a significant association between hand size bacterial $\log_{10}$ reductions achieved.[38,52,67]

Proposed approaches to monitoring technique

Currently, there is no widely adopted method for routine monitoring of hand hygiene technique. Perhaps 1 strategy would be to have auditors observe hand hygiene technique during sessions devoted to monitoring hand hygiene compliance. Covert observation would be preferable to avoid potential Hawthorne effects, but might prove difficult. Or separate observation sessions could be devoted solely to observing technique. One possible approach would be to have auditors observe HCP during an episode of ABHS use to determine if all surfaces of the hands and fingers have been covered with the sanitizer. However, since the duration of hand rubbing is often very brief, it may be difficult to make accurate assessments. Alternatively, it might be easier to observe only if the healthcare worker appeared to apply ABHS to fingertips and thumbs since these areas of often missed.

A simpler metric may be to record the duration of hand rubbing (dry-time), that is from the time rubbing begins until the individual stops rubbing their hands together. Since dry-time is a major factor

affecting antimicrobial efficacy, this may be the most practical and important metric. Based on current evidence, adequate duration of rubbing should be defined as 15 seconds or longer.

Methods used to assess hand hygiene technique in educational and training sessions include the use of ABHS containing an fluorescent dye combined with an ultraviolet light to determine areas of the hand to which the ABHS has been applied, and a system that utilizes a video camera to assess compliance with the WHO 6-step method.[51,68,75-79] However, these approaches do not appear to be practical for routine monitoring of HCP engaged in active patient care. A recent pilot study used a small infrared thermal camera attached to a smartphone to assess application of ABHS to the palmar surfaces of hands.[71] Additional studies involving a larger number of HCP under varying conditions, and using volumes typically delivered by wall-mounted ABHS dispensers are needed to establish if this would be practical for routinely monitoring hand hygiene technique.

MONITORING HAND HYGIENE COMPLIANCE

Direct observation method

Direct observation of HCP by trained observers is currently the "gold standard" method of estimating hand hygiene compliance rate, and is by far the most widely used method. Advantages and disadvantages of direct observation are listed in Table 1.

Factors that need to be considered in utilizing direct observations include the methods for training observers, periodic validation of observer accuracy, types of HCP responsible for making observations, use of covert versus overt observers, the proximity of other HCP to those being observed, criteria for defining adherence (room entry and exit, My 5 Moments [M5M],4 moments used in Canada), the length of observation sessions, shifts and days of the week on which observations are made, and whether or not observers provide immediate feedback to HCP being observed.[80-86] Having personnel make observations on their own unit leads to overestimated compliance rates due to unintentional observer bias.[87] Due to the relative ease and efficiency of making observations on room entry and exit, this approach to monitoring appears to be more common than observing M5M in the United States.[88] Direct observations can also be used to assess glove use and hand hygiene compliance during a sequence of care.[89] The latter is important because HCP tend to perform hand hygiene less frequently when moving from a dirty task to a cleaner task (a risk to the patient) than when moving from a clean task to a dirtier task.[90]

Obtaining a number of observations that provides a reasonable estimate of compliance rates is challenging due to the personnel time and resources needed.[91] In 1 study, facilities often obtained as few as 20-30 hand hygiene observations per unit per month.[81] In another study, 10-87 hand hygiene opportunities were directly observed per quarter on 1 nursing unit, while an automated monitoring system estimated that 468,452 opportunities had occurred on the same unit during the same quarter.[92] Depending on current compliance rates and degree of change detected, the number of opportunities that facilities should observe per surveillance area per time period has ranged from 79-723 in 1 publication,[91] or from 150-200 recommended by the WHO.[93] Recently, the Leapfrog Group recommended observing either 100 or 200 opportunities per nursing unit per month.[1]

The Hawthorne effect, wherein individuals improve their performance when they know they are being watched, results in falsely-high compliance rates that may in some instances be nearly 3-fold higher than actual compliance rates.[94-99] The effect can be minimized by using "secret shopper" observers and by limiting the duration of observation sessions spent on a unit. Some infection preventionists have argued that the Hawthorne effect has an overall beneficial effect on hand hygiene compliance rates, with the implicit assumption that it has a lasting effect on HCP after the observer leaves a unit. However, 2 careful studies have documented that the Hawthorne effect lasts only about 1 hour after observers leave a unit.[98,100] To optimize direct observation of compliance rates, facilities should consider strategies outlined in Table 2.

Automated hand hygiene monitoring

Due to the recognized limitations of monitoring hand hygiene compliance using direct observations, there is increasing interest in electronic systems that can address some of the shortcomings of direct observations. Such systems fall into the following categories: digital assistance apps used to record direct observation data, electronic counting devices placed inside dispensers, automated group monitoring systems, badge-based monitoring systems, and use of video cameras. Using digital apps on a smartphone or tablet can facilitate recording and analyzing direct observation data.[101-105] Sensors located in dispensers are useful for recording trends in the frequency of hand hygiene events (HHEs) and establishing which dispenser locations are accessed most frequently, but cannot determine if hand hygiene was performed when indicated.[33,34,62] Interest in automated

Table 1
Advantages and disadvantages of direct observation method

Advantages
• Ability to estimate adherence with all "My Five Moments for Hand Hygiene"
• Identify barriers to hand hygiene
• Evaluation of hand hygiene technique
• Most widely used method for monitoring adherence
• Applicable in virtually all facilities, regardless of the level of resources
Disadvantages
• Lack of standardized methods for training observers and conducting auditing sessions
• Periodic validation of observer accuracy is often not performed
• Inadequate sampling of hand hygiene opportunities
• Hawthorne effect results in exaggerated adherence rates
• Observing all indications for hand hygiene is difficult in some settings
• Conducting observations is time consuming
• Observers and front-line staff may have concerns regarding the accuracy of results

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Table 2
Tips for optimizing direct observations and analysis of hand hygiene opportunities

Provide observers with standardized training
• Include videos if possible
• Periodically validate observer reliability
Using "secret shoppers" is recommended by many experts
• Avoid having HCP perform observations on their own unit[87]
• Note: observations by Infection Preventionists may yield falsely-high compliance rates[160]
If possible, limit hand hygiene champion activities to: [86]
• Education, coaching staff, promoting compliance, and overcoming resistance
• Avoid having champions also monitor compliance, to reduce the Hawthorne effect
Consider monitoring hand hygiene during a sequence of care (eg when HCP move from a dirtier task to a cleaner task, and in the opposite direction.[90]
Limit observations sessions to ≤ 15 min to minimize the Hawthorne effect[80,91,102]
Consider using a digital application on a mobile handheld device (smartphone or tablet) to record results of observations[102,106,147]

Table 3
Advantages and limitations of automated group monitoring systems

Advantages
- Capture 100 to > 10,000 times as many hand hygiene opportunities as direct observations, on a 24/7 basis
- Require less personnel time than direct observations
- Not affected by observer bias and Hawthorne effect
- Near real-time feedback of performance rates by nursing unit
- Perceived by HCP as less intrusive than badge-based systems
- More acceptable in hospitals with HCP unions
- Less expensive than badge-based systems
- May identify nursing units at increased risk of outbreaks

Limitations
- Cannot differentiate visitors from HCP entering and exiting rooms
- Need complementary strategies to achieve meaningful increases in performance rates
- Limited evidence on their ability to sustain improved hand hygiene performance and reduce healthcare-associated infections
- Cost-effectiveness not yet established

Table 4
Advantages and limitations of automated badge-based monitoring systems

Advantages
- Have been shown to capture 5000 to 150,000 HHOs/unit/mo on a 24/7 basis
- Require less personnel time than direct observations
- Not affected by observer bias and Hawthorne effect
- Can provide real-time or near real-time feedback of individual performance rates
- Some systems provide immediate auditory, visual or vibratory feedback
- May yield higher performance rates than group-based monitoring systems

Limitations
- Some HCP are reluctant to wear badges for fear that data might be used in a punitive way by hospital administrators
- More expensive than group monitoring systems
- Frequent recharging of badges required by some systems may cause problems
- Need complementary strategies to achieve meaningful increases in performance rates
- Limited evidence on their ability to sustain improved hand hygiene performance and reduce healthcare-associated infections
- Cost-effectiveness not yet established

hand hygiene monitoring systems (AHHMSs) has increased recently because they provide large amounts of performance data on HCP groups or for individual healthcare workers.[106]

Group monitoring. Group monitoring systems are designed to estimate hand hygiene compliance of HCP, most commonly at the nursing unit level. Advantages and limitations of automated group monitoring systems are listed in Table 3.

One such system includes sensors which detect each time an ABHS or soap dispenser is accessed (hand hygiene event [HHE]), while other sensors placed near the doorway of patient rooms detect entry and exit of individuals, which are considered hand hygiene opportunities (HHOs).[15,16,92,98,107-109] Hand hygiene performance rates are expressed as the number of HHEs/Number of HHOs x 100. Although the system is unable to differentiate HCP from visitors entering the room (similar to other group monitoring systems), 1 study found that HCP accounted for approximately 84% of room entries and exits.[108] System accuracy may be affected when HCP stand in the doorway of patient rooms without entering. A validation study found that the above system had acceptable levels of sensitivity and positive predictive values.[107] By using nurse room assignment data combined with system room-specific entry and exit data, it may be possible to estimate individualized nurse performance rates.[109]

In several studies, installation of the system combined with additional complementary strategies resulted in significant increases in hand hygiene performance.[92,110] In 1 study in which HAI rates were measured, there was a trend toward reduction of non-*Clostridioides difficile*-related HAIs.[92] A different system with capabilities similar to the system described above also issued an audible reminder at the time of room entry and exit.[111]

Another group monitoring system uses electronic dispensers to record HHEs, and estimates HHOs by using a software algorithm that is based on direct observations of the number of HHOs on different nursing units, patient-to-nurse ratios, patient census, and several adjustments.[17,112-118] The system for estimating HHOs has been validated in a number of hospitals.[113,118] In a multicenter cluster randomized study, the system combined with several complementary strategies resulted in a significant increase in hand hygiene performance rates from 29% at baseline to 53% after 10 months of use.[116] The authors reported a trend toward reduced transmission of methicillin-resistant *Staphylococcus aureus*. Additional analyses revealed that nursing units with low performance rates were more likely to experience outbreaks of HAIs than units with higher performance rates.[117]

Two group monitoring systems have prospectively documented hand hygiene performance rates before and during the COVI-19 pandemic. Both systems found that substantial increases in hand hygiene performance rates that occurred early in the COVID-19 pandemic were followed by decreases to near-baseline levels as the pandemic evolved.[15-17]

Badge-based systems. Several AHHMSs use sensors that detect use of ABHS and soap dispensers and room entry and exit by HCP wearing badges or tags to estimate hand hygiene compliance at the individual healthcare worker level.[99,119-126] Advantages and limitations of badge-based systems are listed in Table 4.

Several systems can estimate hand hygiene performance rates for HCP who enter electronically-defined zones around patient beds.[99,120,123,126,127] A few systems have the capability of providing performance rates for both HCP groups (eg nurses, physicians) and for individual HCP.[124,128,129] In contrast, 1 badge-based system is designed to provide performance rates only for HCP groups.[123] Recently, Gould et al.[99] reported on a novel AHHMS that utilizes HCP badges plus room and dispenser sensors, but also tracks healthcare worker movements within patient rooms and their proximity to patient beds. Although the accuracy was somewhat affected by HCP standing in patient doorways without entering, the system agreed with direct observations 84% of the time. It would be interesting to evaluate how results obtained with this system compare with those generated by other systems that record proximity of a healthcare worker to an electronically-defined bed zone.

In addition to recording individual performance rates, 1 recently described system can record the duration of hand rubbing by the individual wearing a badge and provide a reminder if the duration is considered too short.[125] Another novel automated system comprised of an electronic wrist band and special wearable ABHS bottle equipped with a flow meter can monitor both the duration of hand rubbing and the volume of AHBS applied by the individual, but does not estimate hand hygiene compliance rates.[39,49]

Video camera-based monitoring. Few studies have investigated the use of video cameras for monitoring hand hygiene compliance.[46,130-135] For example, in 1 study, 21 video cameras were installed in hallways and patient rooms in a medical intensive care unit (ICU). Cameras were directed only toward hand-washing sinks and sanitizer dispensers to protect the privacy of patients.[130] Hand hygiene compliance increased from 10% to a range of 82% to 88% during 75 weeks of monitoring. When the same system was implemented in a surgical ICU, compliance improved to an average of 80% during a 64-week

period.[131] A recent study conducted in an isolation unit used 8 video cameras to observe compliance with WHO M5M during simulated healthcare worker-patient contacts. Compliance based on review of video footage was 88%, but was not compared to real-time direct observations. In a structured interview study of video monitoring by McKay et al.[134] HCP expressed concerns regarding privacy, security of video footage, medical-legal liability, system costs, and possible adverse effects on HCP-patient relationships. Other strategies have included use of a head-mounted video camera to study hand hygiene opportunities and compliance, or computer vision with depth sensing to assess hand hygiene opportunities.[46,136] Additional studies are needed to determine if video camera-based monitoring of hand hygiene practices will be practical, cost-effective, and acceptable with respect to HCP and patient privacy.

Combining an AHHMS with direct observations may provide the most complete picture of hand hygiene practices.[83] By combining the 2 approaches, concomitant direct observations can help evaluate AHHMS accuracy, and data from AHHMSs can define the magnitude of the Hawthorne effect.[95-99,126] Facilities might use an AHHMS to provide large amounts of quantitative data on estimated compliance rates, and devote direct observations to assessing compliance with Moments 2 and 3 and hand hygiene technique, and for identifying barriers to hand hygiene.[83]

AHHMS as part of a multidisciplinary program. AHHMSs should be implemented as part of a multidisciplinary hand hygiene improvement program that includes elements recommended in the WHO hand hygiene guideline.[21] Installing an AHHMS alone, without complementary strategies is unlikely to result in significant improvement in hand hygiene performance rates.[92,110] Examples of strategies used to complement AHHMSs include support by hospital leaders, giving unit managers and frontline staff frequent feedback using AHHMS data, setting reasonable goals, requiring nurse managers or champions to attend weekly "accountability meetings" or webinars, employing quality improvement initiatives, including patients in promotional activities, and involving AHHMS vendor personnel.[92,110,116,119,122,137,138]

Despite the advantages of AHHMSs, 1 survey suggests that automated systems have been adopted by only a small proportion of acute care hospitals.[139] And few studies have been conducted in long-term care settings.[140] Factors associated with the slow adoption of AHHMSs include:

- Suboptimal accuracy of some (mostly early) systems[141-143]
- Costs of system implementation and maintenance[139]
- HCP concerns regarding system accuracy and how data will be utilized[144,145]
- The need for complementary strategies to attain desired improvements in compliance [92,110,116,146]
- Relatively limited evidence demonstrating sustained improvements in hand hygiene performance and significant reductions in HAI rates[92,116,122,147-150]
- Inadequate data on cost-effectiveness[147,149,151]

Greater adoption of AHHMSs may require step wedged cluster randomized controlled trials that address issues related to the effectiveness and cost-effectiveness of these systems.[152,153] Furthermore, additional experience is needed on how to deal with unanticipated events (eg COVID-19 pandemic) that cause ABHS product shortages that may adversely affect the functioning and usefulness of AHHMSs.[126]

IMPACT OF HAND HYGIENE ON HAI RATES

There is considerable published evidence that hand hygiene can reduce transmission of healthcare-associated pathogens and/or HAIs.[21,154-158] Additional studies should ideally utilize a composite outcome that includes both reduction of pathogen transmission (newly-acquired colonization) plus HAIs since the direct effect of hand hygiene is on transmission of pathogens. To date, relatively few studies have shown that implementing an AHHMS has reduced HAIs,[122,149,150] or reduced transmission of healthcare-associated pathogens.[116]

RESEARCH GAPS

Although major advances have been made in improving hand hygiene practices in healthcare settings in the last 2 decades, many aspects of hand hygiene require additional research. For example, Lotfinejad et al.[159] have proposed a list of topics that warrant further research, including issues relating to hand hygiene products, hand hygiene technique, monitoring compliance, feedback mechanisms, promotional activities, and evaluating the cost-effectiveness of AHMMSs. Additional research is needed to better understand how to maintain optimal hand hygiene during and after public health emergencies such as the COVID-19 pandemic.

CONCLUSIONS

A welcome update of the SHEA/IDSA/APIC Practice Recommendations on Hand Hygiene is scheduled for publication in late 2022 or early 2023. The updated recommendations may be influenced by issues experienced during the COVID-19 pandemic, including transient increases in hand hygiene compliance rates and shortages in ABHSs, which resulted in marketing of unsafe products by inexperienced manufacturers. Several studies confirmed the efficacy of ABHSs against emerging pathogens such as *C. auris*, SARS-CoV-2, and monkeypox (mpox). The impact of ABHS dispenser placement on hand hygiene compliance rates and the potential benefit of dispensers that deliver individualized doses based on personnel hand size have received increased attention. A number of studies addressed the importance of duration of hand rubbing, ABHS volume applied, degree of coverage achieved, and dry time on ABHS efficacy. New evidence has emerged regarding the advantages and disadvantages of monitoring hand hygiene performance using direct observations versus AHHMSs. Additional studies are needed to assess the ability of automated systems to sustainably increase hand hygiene compliance rates and reduce HAIs.

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