

Hand hygiene in health care: 20 years of ongoing advances and perspectives



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Health-care-associated infections are the most prevalent adverse events of hospital care, posing a substantial threat to patient safety and burden on society. Hand hygiene with alcohol-based hand rub is the most effective preventive strategy to reduce health-care-associated infections. Over the past two decades, various interventions have been introduced and studied to improve hand hygiene compliance among health-care workers. The global implementation of the WHO multimodal hand hygiene improvement strategy and constant efforts to replace the use of soap and water with alcohol-based hand rub have led to a faster and more efficient hand cleaning method. These strategies have strongly contributed to the success of behaviour change and a subsequent decrease in health-care-associated infections and cross-transmission of multidrug-resistant organisms worldwide. The WHO multimodal behaviour change strategy requires a series of elements including system change as a prerequisite for behaviour change, education, monitoring and performance feedback, reminders in the workplace, and an institutional safety climate. Successful adoption of the promotion strategy requires adaptation to available resources and sociocultural contexts. This Review focuses on the major advances and challenges in hand hygiene research and practices in the past 20 years and sets out various ways forward for improving this lifesaving action.

Introduction

Health-care-associated infections (HAIs) are preventable events associated with considerable morbidity and mortality among hospitalised patients and a heavy burden for society.^{1,2} According to WHO, the prevalence of HAIs at any given time is estimated to be in the range of 3·5–12% in high-income countries and 5·7–19·1% in low-income and middle-income countries, although this estimation might be only a small proportion of the true prevalence, considering the under-reporting of HAIs from many countries.^{3,4} HAIs are mainly transmitted through the contaminated hands of health-care workers and therefore strategies to keep hands clean have always been of utmost importance in health care.^{5,6} A systematic review of data from 1980 to 2013 reported that improvements in hand hygiene compliance are associated with a reduction of HAIs in general and multidrug-resistant organisms, such as health-care-associated methicillin-resistant *Staphylococcus aureus* infections in particular.⁷ Hand hygiene with alcohol-based hand rub is the global standard of care since the late 1990s and the most effective measure available to reduce HAIs.^{5,6,8,9} The importance of hand hygiene extends into the community as well, especially during outbreaks of infectious diseases, as exemplified in the COVID-19 pandemic.^{10,11}

Although hand hygiene might seem simple, compliance in health-care settings has always been far from ideal worldwide.^{12,13} The average hand hygiene compliance rate has been reported as 40% in high-income countries and less than 20% in low-income countries.^{3,14} In the preview issue of *The Lancet Infectious Diseases* in 2001, we explained the potential barriers to compliance and examined the necessary factors for shaping a multimodal approach to improve hand hygiene behaviour.¹⁵ In celebrating the journal's 20th anniversary, we aimed to review the progresses made in the past two decades, explain the remaining barriers to achieve optimal

compliance, and propose a research agenda based on the remaining gaps that still need to be bridged.

The modern era of hand hygiene

Ignaz Philipp Semmelweis (1818–65) is known as the pioneer of the modern era of hand hygiene with antiseptics in health care, whose suggested regimen of hand scrubbing with chlorinated lime was shown to be effective in decreasing maternal mortality at the Vienna General Hospital (Vienna, Austria) in 1847.¹⁶ Semmelweis observed that between the two existing obstetric wards, there was a higher rate of maternal mortality due to puerperal fever in the ward staffed by doctors and medical students than in the other ward staffed by midwives. At that time, autopsy was a new scientific field practiced only by doctors, and Semmelweis was convinced that the increased mortality was due to contamination of doctors' and medical students' hands with so-called cadaverous particles, which they could subsequently pass on to the women in labour.¹⁷ Although using hand antiseptics reduced maternal mortality, Semmelweis' intervention was not accepted by his colleagues, mainly as a result of skin irritation caused by chlorinated lime, his inability to provide scientific explanations, and his erratic behaviour.¹⁷

After a century of stagnation in the field of infection prevention and control, the US Centers for Disease Control and Prevention (CDC) published a review highlighting the major role of handwashing in preventing HAIs in 1975, and by the mid-1980s, handwashing with plain soap and water appeared in CDC guidelines as the method of choice.^{6,18,19} At the time, antimicrobial substances were only recommended before and after invasive procedures or when caring for high-risk patients, and the use of alcohol-based hand rub was limited to environments in which handwashing facilities were inaccessible.^{20,21} The University of Geneva Hospitals (Geneva, Switzerland) attempted to implement the first

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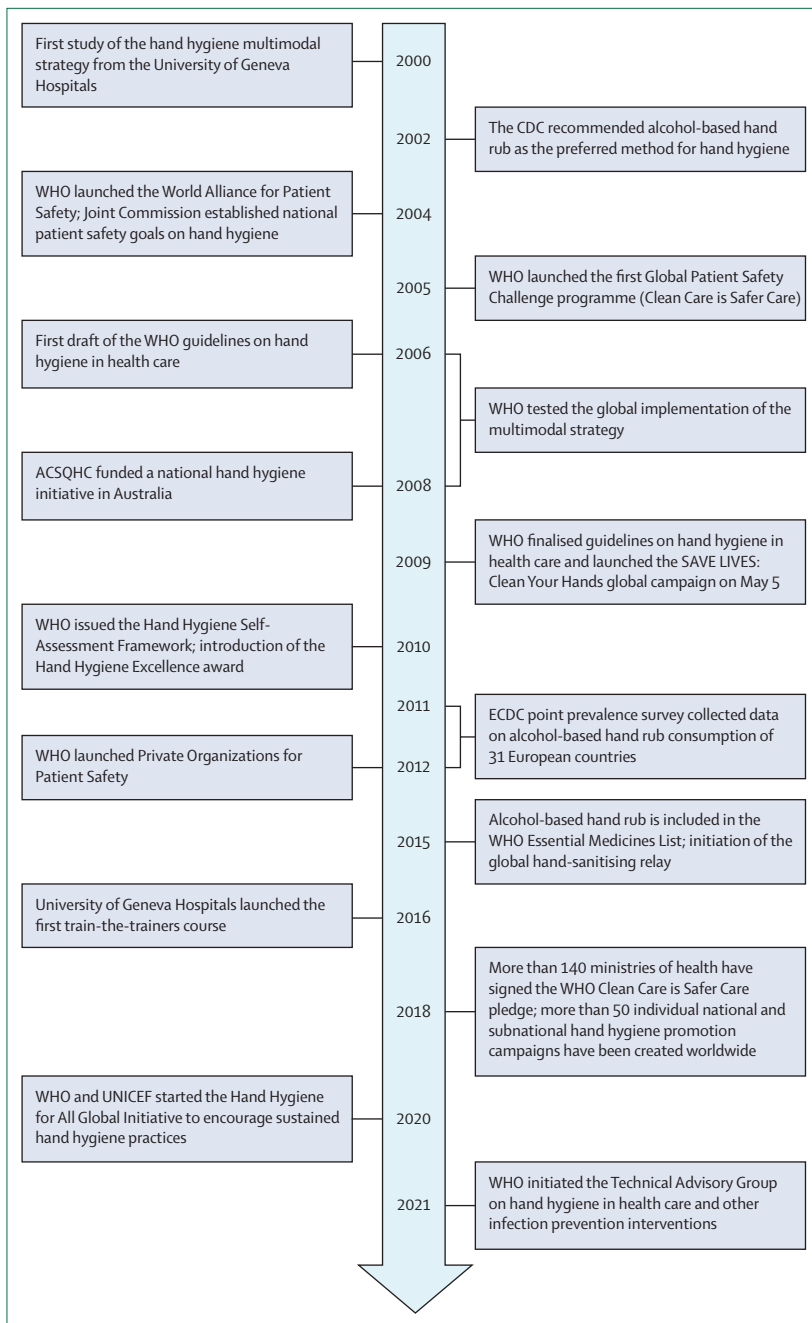


Figure 1: Timeline of hand hygiene landmarks in the past two decades

ACSQHC=Australian Commission on Safety and Quality in Healthcare. CDC=US Centers for Disease Control and Prevention. ECDC=European Centre for Disease Prevention and Control.

hand hygiene promotion campaign using a multimodal strategy by replacing soap and water with alcohol-based hand rub between 1995 and 1998.²² This campaign greatly improved hand hygiene compliance among health-care workers, subsequently reducing HAI rates by 50% and cross-transmission of methicillin-resistant *S aureus* bacteraemia by 70%; it rapidly became the global model for hand hygiene implementation.

In 2002, the CDC published a guideline to support the use of alcohol-based hand rub as the preferred hand hygiene method and recommended the use of soap and water only for visibly soiled hands or when spore-forming organisms are present.²³ WHO committed to promote hand hygiene in health care in 2005, which led to the development of the WHO Guidelines on Hand Hygiene in Health Care in 2006 as a draft, which was finalised in 2009.²⁴ Indications for routine hand hygiene are mainly identical between the CDC and WHO guidelines, although they provide different details in implementation sections.²⁵ Figure 1 depicts major hand hygiene landmarks in the past two decades, following the successful results of using alcohol-based hand rubs to clean hands in health care.

Two decades of alcohol-based hand rub

Selecting alcohol-based hand rub as the gold standard of care was a turning point in hand hygiene practices that prompted further research to determine the most effective ingredients and formulations against HAIs. Alcohol is the major active component used in alcohol-based hand rubs as it is germicidal considering its ability to denature proteins; it is mostly potent at concentrations between 60% and 80%.²⁴ Alcohol significantly reduces the bacterial counts on skin and inactivates all enveloped and most non-enveloped viruses, but it cannot eliminate most spores.²⁶ There are still ongoing debates regarding the preference of alcohol-based hand rubs over soap and water for specific microbes, among which are noroviruses, and further studies are required to compare the effectiveness of both methods.^{24,27} However, regardless of their efficacy, alcohol-based hand rubs should always be present at the point of care, even during outbreaks of pathogens such as *Clostridioides difficile* for which handwashing with soap and water is mainly preferred, as alcohol is still effective against a range of pathogens and directly effects patient safety.²⁴

Alcohol efficacy is associated with the type of alcohol, concentration, contact time, used volume, and whether it is used on wet skin, which decreases its efficacy.²⁸ The formulation of alcohol-based hand rubs can be complex and expensive, such as some of those produced by commercial manufacturers or simple and inexpensive rubs, such as the WHO formulations containing 80% volume per volume (v/v) ethanol or 75% v/v isopropanol with 1.45% v/v glycerol and 0.125% v/v hydrogen peroxide.²⁴ Alcohol-based hand rubs with lower emollient concentrations, such as those containing 0.5% glycerol, have also shown higher skin tolerability with lower negative effects on alcohol efficacy than the original WHO formulation.^{29,30} Overall, it is important to emphasise that the alcohols used in alcohol-based hand rubs are safe for use on skin, that these formulations are effective in killing all but some very specific organisms, and, because of the mechanism by which alcohol destroys microorganisms, there is no resistance of pathogens to alcohol-based hand rubs.³¹

Panel 1: Hand hygiene research agenda: 2021 and beyond—55 proposals³⁴**Hand hygiene substances and laboratory research**

- 1 Assessing the possible effect of emollients and gelling agents on the efficacy of alcohol-based hand rubs and formulating new products using in-vitro followed by in-use studies
- 2 Assessing and validating alcohol-based hand rubs produced in low-resource countries
- 3 Assessing the efficacy of alcohol-based hand rubs on emergent microorganisms
- 4 Identifying the best methods to recover microbial pathogens from hands and doing comparative studies close to clinical contexts
- 5 Developing new innovative methods to measure microbial pathogens on hands, either directly or indirectly, that could be used at the point of care during care delivery and ideally allow immediate feedback to health-care workers
- 6 Producing evidence-based, high-quality data comparing different formulations of alcohol-based hand rubs (ie, rinse, gel, spray, and foam) from the laboratory (eg, antimicrobial efficacy) to the point of care (eg, acceptability, tolerability, frequency of use, and compliance)
- 7 Monitoring the effect of alcohol-based hand rubs on skin using realistic, pragmatic clinical trials and further clarifying their effect on the human microbiome among high-frequency and low-frequency users in different populations
- 8 Assessing the minimal level of reduction of microbial pathogens on hands needed to be reached by alcohol-based hand rub use to ensure patient safety
- 9 Studying interactions between alcohol-based hand rub and glove use according to acceptability, tolerability, frequency of use, and observed compliance
- 10 Evaluating the added value of antiseptics, such as chlorhexidine, to alcohol-based hand rubs in real-life conditions using randomised controlled studies
- 11 Developing new norms for the validation and accreditation of alcohol-based hand rubs, closer to clinical practices requirements and recommendations

Simplification of the hand hygiene concept

- 12 Identifying the contribution of each of the WHO My Five Moments for Hand Hygiene to specific infectious outcomes and causes
- 13 Understanding whether a simplification of the My Five Moments concept would be appropriate and safe
- 14 Proposing alternative hand hygiene concepts to improve the overall effectiveness on patient outcomes
- 15 Studying the best technique to clean hands compared with the current standard WHO six-step How to handrub technique, using validated microbiological and clinical performance indicators
- 16 Testing alternative simplified steps to improve both hand hygiene techniques and compliance

Compliance with hand hygiene

- 17 Identifying the determinants of health-care workers' compliance in different socio-economic and cultural backgrounds and suggesting strategies to improve compliance
- 18 Assessing the effect of measuring hand hygiene compliance on improvement in action
- 19 Identifying the specific determinants of physicians' hand hygiene behaviour and the best approaches to improve it
- 20 Identifying the most effective educational strategies in the short-term and long-term through clinical trials and studying variations among different settings and health-care professional categories
- 21 Determining whether education during training is more effective or sustainable and what would be the ideal repeated frequency among health-care workers
- 22 Developing games and studying the effect of innovative approaches to teach and ensure sustainability of hand hygiene knowledge and best practices among health-care workers
- 23 Determining the effect of glove use on hand hygiene practices, HAIs, and antimicrobial resistance cross-transmission
- 24 Determining whether the benefit of appropriate hand hygiene behaviour could be better than using gloves when contact precautions are indicated
- 25 Comparing glove changing with glove disinfection using alcohol-based hand rubs in randomised controlled studies
- 26 Assessing the potential added value and risks of gloves containing antimicrobial materials
- 27 Identifying the minimum or ideal target for hand hygiene compliance percentage improvement to have an impact on outcomes

Hand hygiene promotion strategies

- 28 Assessing the effect of hand hygiene promotion on different types of HAIs
- 29 Evaluating the importance of specific components of the multimodal strategy to induce health-care workers' sustained behavioural change and reduce HAIs and antimicrobial resistance cross-transmission
- 30 Evaluating the effectiveness of hand hygiene improvement in reducing HAIs and antimicrobial resistance cross-transmission using randomised and controlled studies, interrupted time series analyses, and cluster-randomised, and stepped wedge studies
- 31 Determining how institutions succeed at implementing complex multimodal improvement strategies and barriers and facilitators to implementation, using qualitative studies
- 32 Assessing the cost-effectiveness of hand hygiene promotion strategies in different settings

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- 33 Determining the correlation between different monitoring techniques with infectious outcomes to assess the best prediction fit
- 34 Determining the relationship between different levels of hand hygiene performance and their preventive effect
- 35 Identifying the best strategies to implement hand hygiene in non-hospital settings
- Implementation of hand hygiene improvement strategies**
- 36 Identifying the best mechanisms to achieve widespread access to alcohol-based hand rubs worldwide, including at time of crises in which demand increases resulting in shortage
- 37 Determining the best approaches to facilitate system change implementation and long-term maintenance at institutional, regional, national, and worldwide levels
- 38 Determining the cost-effectiveness of alcohol-based hand rub introduction in different settings
- 39 Evaluating the benefits and possible consequences of using alcohol-based hand rubs among patients and their families
- 40 Producing individual health-care worker-level hand hygiene performance data to investigate the effect of individual performance feedback on infectious outcomes
- 41 Performing effectiveness studies on the preventive effect of performance feedback and developing an overall system for monitoring and feedback
- 42 Determining best strategies and parameters to apply performance feedback and their cost-effectiveness
- 43 Evaluating the incorporation and cost-effectiveness of automated systems into hand hygiene feedback approaches
- 44 Evaluating the effect of message framing, language, and digital communication technologies within social marketing strategies across different culture and contexts
- 45 Conducting controlled studies on improving patient participation by proposing best methods of providing information, the benefit of including user feedback during the design, and implementation stages of initiatives
- 46 Describing the perceptions of service users and patients about a given safety climate, in both high-income and low-income and middle-income countries
- 47 Identifying and explaining factors associated with successful local adaptations of the multimodal hand hygiene improvement strategy
- 48 Identifying the best approaches to ensure the sustainability of the multimodal hand hygiene improvement strategy and its positive results
- 49 Determining the best methodological approaches for comparing the WHO Hand Hygiene Self-Assessment Framework results from health-care facilities in different countries
- 50 Developing semi-automated and electronic tools to facilitate regular and easy completion of the WHO Hand Hygiene Self-Assessment Framework
- 51 Determining the time span between the implementation of the hand hygiene improvement intervention and the detection of a demonstrable effect on HAI reduction using time series analyses, in high-income and low-income countries
- Hand hygiene campaigning**
- 52 Conducting outcome research on national campaigning, preferably versus local action
- 53 Evaluating the effect of hand hygiene campaign integration versus promotion in isolation
- 54 Determining the optimum approach and outcome measure for a global health-care campaign focused on hand hygiene, and its cost-effectiveness
- 55 Evaluating the effects of engaging consumers and the public in global campaigning

HAI=health-care-associated infection.

Choosing the right type of alcohol-based hand rub can be just as important as choosing the right formulation. High-quality rinses and gels have been studied the most and have been shown to have a high efficacy.²⁴ Foams and sprays also have a lot of potential, but they are newer products, thus the body of literature on them is still sparse.^{24,28,32} Since there is no one product that fits all needs, facilities are recommended to provide at least two different rubs, considering their target populations.³³ Panel 1 presents the research priorities in hand hygiene with alcohol-based hand rub that still need to be clarified and further studied.³⁴

COVID-19 serving as a wake-up call

Looking back at the past 20 years, advances in the hand hygiene literature have been impressive from the early 2000s^{35,36} and particularly important during the COVID-19 pandemic. Studying the frequency and trends of the most

commonly used hand hygiene-related keywords from Jan 1, 1920 to Dec 30, 2020, we identified major changes over time with a considerable peak of studies during the pandemic (figure 2). As the use of alcohol-based hand rub was proved effective against the SARS-CoV-2 virus, a growing number of studies were undertaken to improve hand hygiene both in health-care settings and in the community.^{37,38} Caution should always be exercised when dealing with immense amounts of information during crises, because there is a trend to favour quantity over quality in decision making.^{39,40}

The COVID-19 pandemic revealed shortcomings in the field of hand hygiene, and the continued need for behaviour improvement. Amid the pandemic, alcohol-based hand rub, primarily developed for health-care settings, was extensively used in the community, leading to an abrupt shortage of supplies.¹¹ Although industrial manufacturing is the most preferable option for producing

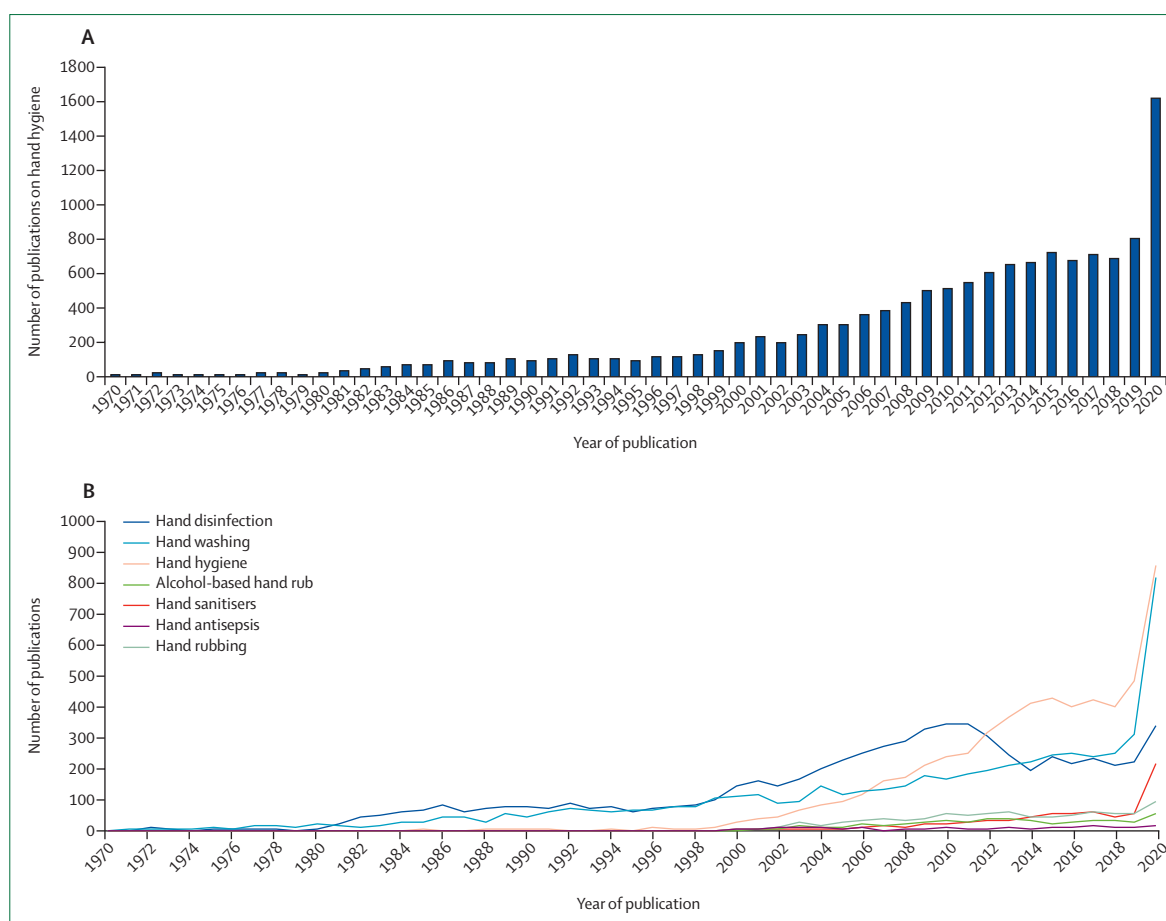


Figure 2: Number of publications on hand hygiene retrieved from MEDLINE by year, using Medical Subject Headings search terms and keywords from Jan 1, 1920, until Dec 31, 2020

Considering the scarcity of publications from the earlier years, we only presented data from 1970. (A) Number of publications on hand hygiene by year. The search detail retrieved for all keywords was: ("Hand Hygiene"[MeSH] OR "hand hygiene" OR "hand disinfection"[MeSH] OR "hand disinfect*" OR "hand sanitizers"[MeSH] OR "hand sanit*" OR "hand washing" OR "handwashing" OR "hand wash" OR "hand rub*" OR "handrubbing" OR "hand cleans*" OR "hand deconta*" OR "hand cleaning" OR "alcohol-based hand rub*" OR "hand-antisept*" OR "surgical scrub*") AND (("1920/01/01"[Date - Publication] : "2020/12/31"[Date - Publication])). (B) Trends in hand hygiene-related keywords used in medical literature. Search terms used were: "hand hygiene"; "hand disinfect*"; "hand sanit*"; "hand washing" OR "handwashing" OR "hand wash"; "hand rub*" OR "handrubbing"; "alcohol-based hand rub*"; "hand-antisept*".

large amounts of high-quality alcohol-based hand rub, local production of the WHO alcohol-based hand rub formulations following guidelines and e-learning tools has been life-saving during the pandemic, even in high-income countries.^{24,41,42} However, it is common to find low-quality alcohol-based hand rub for sale, especially owing to a global shortage due to skyrocketed demands.⁴³ During public health emergencies including infectious disease outbreaks, local governments should reinforce the already existing alcohol-based hand rub production and distribution networks and, if not sufficient, develop new networks by asking well equipped companies such as perfume, cosmetics, and alcohol manufacturers to produce alcohol-based hand rub solutions at large scale.

Barriers to compliance

Historically, one of the major barriers to hand hygiene compliance has been time constraint, especially when

using soap and water, which requires at least 1 min to reach a sink, wash hands, dry them, and return to patient care.⁴⁴ Changing from washing with soap and water to rubbing with alcohol-based hand rub reduces the time needed for action to only 20–30 s.^{24,45,46} By decreasing the duration of the hand hygiene procedure, system change to alcohol-based hand rub has led to increased and sustained compliance rates even in intensive care units (ICUs) where health-care workers are often facing time pressure.^{45,46}

Studies done in the past two decades have identified multiple additional factors associated with low hand hygiene adherence. Understaffing and overcrowding are major obstacles for achieving appropriate compliance levels, which worsen during infectious disease outbreaks.^{47,48} Similarly, workload can also be a barrier; health-care workers in settings with a high number of hand hygiene opportunities per hour of patient care, such as ICUs, are at risk for lower compliance.⁴⁹ Different

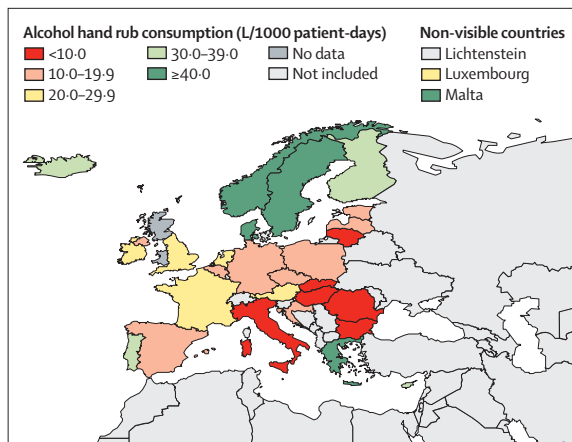


Figure 3: Median alcohol hand rub consumption (L per 1000 patient-days), European Centre for Disease Prevention and Control point prevalence survey, 2011–12

Point prevalence survey data representativeness was poor in Austria, Croatia, Czech Republic, Estonia, Norway, and Romania and was very poor in Denmark and Sweden (indicated by asterisks). Reproduced from the European Centre for Disease Prevention and Control.⁶⁴

studies have concluded that doctors tend to be less compliant than nurses.^{15,50,51} Wearing gloves is also considered as a predictor for non-compliance as it is often wrongly perceived as a substitute for hand hygiene, and misusing gloves could give a false sense of protection and facilitate pathogen cross-transmission.^{24,52} Although reusing gloves has been strictly discouraged in health-care settings and there is currently no standardised glove reprocessing method, the increased rate of reuse is alarming, especially in resource-limited settings or during health crises.^{24,53,54}

It is well documented that health-care workers have a higher incidence of irritant contact dermatitis than the general population due to frequent hand hygiene practices.⁵⁵ Using alcohol-based hand rub has been shown to be much less damaging to skin than handwashing with soap and water.^{56,57} Still, alcohol is a solvent that can destroy the lipids surrounding the corneocytes in the stratum corneum.⁵⁸ Conceivably, it is essential for institutions to choose alcohol-based hand rubs with high acceptability and tolerability, such as those that contain emollients and humectants to avoid skin irritation.⁵⁹ Other barriers include nurses' perceptions that patient needs should take priority over hand hygiene and that this action interferes with their relationship with patients.²⁴ Some health-care workers can be reluctant to encourage patients to ask them if they have cleaned their hands as they believe that this is not considered to be a patient's responsibility, and both health-care workers and patients could feel uncomfortable in this situation.^{60–62}

The global implementation of the WHO multimodal hand hygiene improvement strategy with five major components vanquished many previous barriers to compliance to a large extent. System change from soap and water to using alcohol-based hand rubs addressed the

issue of time constraint, standardised educational programmes and guidelines have become available worldwide in different languages to ensure appropriate knowledge among health-care workers, evaluation and performance feedback strategies were prioritised and new validated monitoring tools were developed, reminders in the workplace have prevented forgetfulness, and institutional safety climate supported the active participation of leaders, awareness of individuals to improve their practice, and the contribution of patients to their care.⁶³ However, despite the success of the multimodal hand hygiene improvement strategy and continuous improvement, barriers still exist, and new effective means to improve hand hygiene compliance are yet to be identified. In 2011–12, the European Centre for Disease Prevention and Control point prevalence survey gathered alcohol-based hand rub consumption data from 31 European countries (figure 3), highlighting the need for further progress in hand hygiene practices.⁶⁴

Towards simplification of the hand hygiene concept

The My 5 Moments for Hand Hygiene approach was designed by WHO to highlight hand hygiene indications to facilitate understanding, training, and monitoring in a broad range of health-care settings worldwide (appendix).^{5,24,65–67} This concept has been universally adopted and it forms the core of the WHO multimodal hand hygiene improvement strategy. The ubiquitously used My 5 Moments for Hand Hygiene poster has also been adapted to different settings, such as the Your Moments for Hand Hygiene Vaccination Campaign, Your Moments for Hand Hygiene Pediatric Consultation, and Your 5 Moments for Hand Hygiene Haemodialysis in ambulatory care.⁶⁷ Although globally accepted, some countries recommend alternative concepts to describe the hand hygiene indications, such as the Your 4 Moments for Hand Hygiene campaign that is used in Canada. More studies should be done to identify alternative and simplified concepts that could eventually improve overall effectiveness on patient outcomes.

Another important mainstay of the multimodal hand hygiene improvement strategy is the WHO guidance on how to perform hand hygiene, the How to Handrub approach, which is a six-step technique using a palmful of alcohol-based hand rub for 20–30 s (appendix).²⁴ Regarding volume, 2–3 mL of alcohol-based hand rub has been shown to be adequate, but the size of the hands should also be considered for whole hand coverage.⁶⁸ Regarding duration, an experimental study reported that hand rubbing for 15 s was not inferior to 30 s in terms of bacterial reduction on hands.⁴⁵ Despite the continuous efforts to provide a user-friendly technique, only a few health-care workers complete the six-step technique, which has prompted researchers to evaluate modified and simplified alternatives.^{69,70} The Fingertips First technique is an example of a modified sequence of the standard

See Online for appendix

WHO technique that suggests rubbing fingertips to be the first step instead of the sixth.⁷¹ This approach has shown greater bacterial reductions compared with the standard WHO technique, as fingertips are heavily colonised and strongly implicated in cross-transmission.⁷² A cluster-randomised trial has also been done to compare the WHO six-step technique with a simplified three-step technique consisting of covering all surfaces of the hands, rotational fingertip rubbing in the palm of the other hand, and rotational rubbing of both thumbs.^{73,74} According to the results of this study, the simpler three-step technique was associated with increased compliance with hand hygiene indications (51.7% vs 12.7%) and technique (75.9% vs 65.0%), and the reduction of bacterial colony counts was similar in both techniques. Because of the paucity of evidence for the most effective alternative technique, the WHO six-step technique is still recommended as the standard approach, and future research is necessary to evaluate other methods.

Adoption of a multimodal strategy

The accumulated evidence has suggested that multimodal promotion strategies are more effective than single interventions in changing health-care workers' behaviour, considering the complex and multifactorial determinants of hand hygiene compliance.^{75,76} In subsequent years, multimodal strategies became paramount in managing different HAIs including surgical site infections, ventilator-associated pneumonia, and central venous catheter-associated bloodstream infection.⁷⁷⁻⁷⁹ WHO developed the multimodal hand hygiene improvement strategy in 2005 on the basis of the successful results and cost-effectiveness of the Geneva hand hygiene improvement multimodal strategy.^{22,80} Different studies have reported improved compliance and reduced HAIs following the implementation of the multimodal hand hygiene improvement strategy in many countries with different income levels.^{13,76}

System change, as one of the five major components of the multimodal strategy, represents necessary actions to ensure the availability of hand hygiene supplies at the point of care, especially alcohol-based hand rubs, and running water, soap, and single-use towels.⁸¹ WHO has introduced various tools to support health-care administrators and governments to preferably provide high-quality alcohol-based hand rubs for health-care workers.²⁴ Alcohol-based hand rubs are increasingly being used instead of soap and water for hand hygiene in health-care settings; for instance, more than 99% of hand hygiene actions are with alcohol-based hand rubs at University of Geneva Hospitals with progressive consumption rates, in particular during the COVID-19 pandemic (figure 4). Global access to alcohol-based hand rubs will make hand hygiene best practices feasible in settings with lower levels of resources for infection control.

Education of health-care workers is the next key component of the multimodal hand hygiene improvement strategy that should mainly focus on the importance

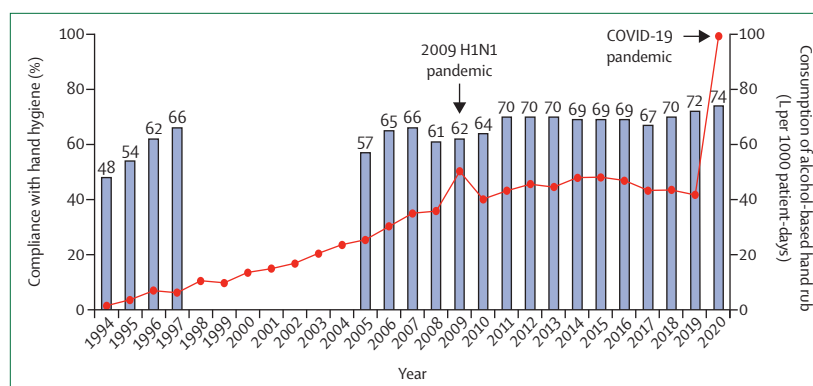


Figure 4: Compliance with hand hygiene and use of alcohol-based hand rub at the University of Geneva Hospitals, 1994-2020

Purple bars represent compliance with hand hygiene and the red line indicates consumption of alcohol-based hand rub. Compliance with hand hygiene practices has been monitored throughout the University of Geneva Hospitals (Geneva, Switzerland) as indicated in the study by Pittet and colleagues,²² from 1994 to 1997; subsequently, the method was adapted to the My 5 Moments for Hand Hygiene concept according to Sax and colleagues,⁶⁵ to monitor practices from 2005 to 2020. Between 1998 and 2004, compliance was recorded using a different approach in specific wards; therefore, compliance levels of this period have not been shown in the figure.

of hand hygiene, and when and how to clean hands using the recommended techniques.⁸² It has been shown that single-element implementation of techniques and traditional education are less effective than multifaceted institution-wide strategies with strong and positive leaders in improving behaviour, including the education of administrators and cleaning personnel in addition to health-care workers.^{83,84} A systematic review published in 2019 emphasised that hand hygiene adherence results were higher among nurses when audiovisual media was used than when traditional teaching methods were used.⁸⁵ WHO has developed various educational tools in the form of PowerPoint presentations, training videos, brochures, and leaflets available in many languages.⁶³ To support countries with capacity building for training infection prevention and control professionals, the Infection Prevention and Control programme and WHO Collaborating Centre on Patient Safety at the University of Geneva Hospitals launched and piloted so-called train-the-trainer courses in hand hygiene.⁸⁶ This educational model has been successful in many countries. Infection prevention and control experts can use this training method to train and disseminate knowledge and best practices to other health-care workers.

Evaluation and feedback are known as key performance indicators and an integral part of the multimodal hand hygiene improvement strategy.⁸⁷ Hand hygiene monitoring and feedback should be promoted continuously to ensure maintenance of acceptable compliance levels.^{66,88,89} There is no perfect indicator for hand hygiene performance, but it is usually calculated as the number of hand hygiene actions done within opportunities divided by the total number of opportunities.²⁴ Direct observation by a validated observer is the gold standard for monitoring compliance that allows detection of opportunities even in complex situations, and provides additional data on glove

use and hand hygiene technique.⁹⁰ On the downside, this method is time consuming and demands a specific trained workforce who are susceptible to error. The Hawthorne effect is another major drawback, which occurs when individuals change their behaviour in response to an observation and assessment of their activities, resulting in an inflated estimation of compliance.⁹¹ Some approaches used to diminish this occurrence are doing observations by the same observer, doing covert or discrete observations, and decreasing the duration of the observation session.^{92–95} Self-assessment by health-care workers is another monitoring method that could lead to substantially over-estimated compliance.²⁴ Electronic monitoring enables precise and continuous evaluation without being affected by the Hawthorne effect while saving human resources.⁹⁶ Although monitoring all five moments for hand hygiene has not yet been fully achievable using technical systems, innovations in this field could result in major improvements in hand hygiene behaviour.⁹⁷ Alcohol-based hand rub consumption is often monitored as an inexpensive surrogate marker that could correlate with hand hygiene compliance, but it does not reflect whether hand hygiene actions were done at the right moment or with the appropriate technique and duration.⁹⁸

Performance feedback enhances behaviour by magnifying discrepancies between perceived and actual behaviour. It is most effective when it is immediate, individualised, and followed by goal setting, and it is best achieved by direct observation.^{99,100} However, setting high and unachievable hand hygiene targets (eg, 90–100% compliance), which are used in some health-care settings, are less likely to improve compliance and encourage behaviour change.¹⁰¹ Considering that few health-care workers might benefit from resource-intensive personalised feedback that only covers a small number of opportunities, alternative methods have been proposed. Group feedback is another approach that includes an increased number of observations with more accurate compliance estimates.^{100,102} The main feedback content is hand hygiene compliance that could be provided in verbal format during direct observation sessions, or written format such as letters, emails, posters, and cards that could illustrate hand hygiene compliance trends over time.¹⁰²

Reminders in workplaces, as one of the five major components of the multimodal strategy, are necessary tools that should be present at the point of care to help health-care workers keep hand hygiene at the forefront of their mind. Reminders must be noticed to be effective, thus it is important to design them to stand out from the visual information overload often found in hospitals.¹⁰³ Posters are the most frequently used reminders as they are inexpensive and usually able to convey hand hygiene best practices to patients and visitors.¹⁰⁴ The WHO My 5 Moments for Hand Hygiene image has been internationally recognised as the visual branding of hand hygiene for health-care workers (appendix). However, it should be kept in mind that continuous exposure even to

the most appropriate signs could induce habituation over time, reducing the occurrence of the anticipated actions.¹⁰⁵ Different nudging approaches have been suggested in the past few years to attract attention and influence mindless choosing rather than conscious thought, such as using olfactory (eg, citrus smell), visual (eg, emojis and various posters), and auditory cues, but, as of yet, there is no specific design of these reminders to maximise their efficacy.^{106–110} According to a cluster-randomised clinical trial by Vander Weg and colleagues¹⁰⁶ it is also essential to consider that frequent change of reminders can lead to lower compliance.

The institutional safety climate is the overarching component of the multimodal hand hygiene improvement strategy that emphasises the social burden of HAIs and antimicrobial resistance, known as major patient safety issues.⁶³ This component recommends developing an environment and attitude focusing on patient safety to motivate health-care workers, senior managers, and patients to optimise hand hygiene performance. One of the major elements of a successful institutional safety climate is the active participation of leaders as role models in hand hygiene who set an example for other team members in a positive manner.²⁴ Education of staff members and raising awareness about hand hygiene and its effect on reducing HAIs are helpful means to improve attitudes and behaviour.²⁴ Patient participation has gained traction with the aim of educating and empowering patients and asking them to remind health-care workers to perform hand hygiene.^{111–116} Obtaining satisfactory patient participation requires the implementation of a multimodal strategy to engage and educate all stakeholders, including patients and their relatives, health-care workers, and decision makers, as single strategies using only posters usually lead to failure.²⁴

The WHO Hand Hygiene Self-Assessment Framework tracks the level of progress with hand hygiene according to the WHO multimodal hand hygiene improvement strategy and evaluates improvement over time.¹⁷ This tool helps health-care facilities to develop an action plan and an ongoing review to ensure long-term sustainability of improved hand hygiene compliance and infection prevention and control practices. The most recent WHO global survey from 2019 using the WHO Hand Hygiene Self-Assessment Framework reported data from 3206 health-care facilities in 90 countries worldwide (abstract submitted to the 6th International Conference on Prevention & Infection Control, Sept 14–17, 2021).¹¹⁸ Most health-care facilities reported an intermediate or high level of hand hygiene implementation, and additional key elements for improvement included availability of resources, leadership, and organisational support. Further improvement is needed particularly in low-income settings and publicly funded health-care facilities, if health systems worldwide are to provide safe care, with the ability to prevent and control outbreaks.

Despite the proved effectiveness of the multimodal hand hygiene improvement strategy design, widespread adoption of this approach is challenging because of its complexity.²⁴ Therefore, considerable research efforts should be directed at disentangling the components of this strategy, deciphering the most effective combination of multifaceted interventions to guide infection prevention and control teams in their daily practice while reducing the burden of complex approaches with potentially ineffective components (panel 1). Bundled interventions using some of the approaches recommended by the multimodal hand hygiene improvement strategy or even adding further interventions such as goal setting, reward incentives, and accountability have shown favourable results in improving compliance.¹³

Worldwide and national hand hygiene campaigns

Hand hygiene campaigning has been a very successful approach, first launched by WHO as the global SAVE LIVES: Clean Your Hands campaign in 2009.¹¹⁹ Since then, May 5 has been designated as World Hand Hygiene Day and is celebrated globally with different themes each year (panel 2). Participating countries and health-care facilities can use available resources and toolkits developed by WHO to celebrate World Hand Hygiene Day with the aim of improving hand hygiene. Many innovative approaches were developed following the SAVE LIVES: Clean Your Hands campaign.

Accordingly, the Hand Hygiene Excellence Award was introduced in 2010 in Asia-Pacific as a platform to recognise and honour the multimodal hand hygiene improvement strategy success stories of health-care facilities,¹²⁰ and was later expanded as a global award. In another effort, the WHO Service Delivery and Safety Department launched Private Organizations for Patient Safety in 2012 to gain support from private industry companies and improve the WHO hand hygiene recommendations worldwide.¹²¹ The global hand-sanitising relay is among other new ideas to fight campaign fatigue and motivate health-care workers in improving hand hygiene. In 2014, a hospital in Hong Kong organised a human chain to perform hand hygiene that awarded a Guinness World Record; this activity led to compliance improvements, and eventually became a worldwide programme in 2015.^{122–124} Social media platforms have been key in distributing campaign materials, including hand hygiene songs and dances, all over the world.^{125,126} As of May 5, 2021, health-care settings from 192 countries have registered to join the campaign and more than 140 ministries of health signed the First Global Patient Safety Challenge Clean Care is Safer Care pledge to show their commitment to reduce HAIs.^{6,127}

National hand hygiene promotion campaigns have been done in many countries. The campaigns have provided an immense opportunity to gain new skills and some have inspired action in other health-care facilities

Panel 2: Themes and calls to action of the WHO SAVE LIVES: Clean Your Hands May 5 World Hand Hygiene annual campaign, 2009–21¹¹⁹

- 2009: Global launch of the 1st annual campaign SAVE LIVES: Clean Your Hands on May 5
- 2010: Participation of health-care facilities in a Hand Hygiene Moment 1 Global Observation Survey
- 2011: “Track your progress, plan actions, and aim for hand hygiene sustainability”; participation of health-care facilities in the first WHO Hand Hygiene Self-Assessment Framework global survey
- 2012: “Create your action plan based on your facility’s results using the WHO Hand Hygiene Self-Assessment Framework”
- 2013: Focusing on hand hygiene monitoring and feedback, and reminding health-care facilities that patients have a voice too
- 2014: “It’s in your hands, prevent sepsis in health care”; participation of health-care facilities in the second WHO Hand Hygiene Self-Assessment Framework global survey
- 2015: “Safety starts here”
- 2016: “See your hands, hand hygiene supports safe surgical care”
- 2017: “Fight antibiotic resistance—it’s in your hands”
- 2018: “No action today; no cure tomorrow—make the WHO 5 Moments for Hand Hygiene part of protecting your patients from resistant germs”
- 2019: “Clean care for all—it’s in your hands”; participation of health-care facilities in the third WHO Hand Hygiene Self-Assessment Framework global survey
- 2020: “Nurses and Midwives, clean care is in your hands”
- 2021: “Seconds save lives—clean your hands”

around the world.¹²⁸ The Australian National Hand Hygiene Initiative was established in 2008 to implement a uniform culture-change programme targeting Australian hospitals with the aims of improving compliance levels and alcohol-based hand rub consumption, introducing a local compliance auditing system, and reducing HAIs.¹²⁹ According to the preliminary results of this intervention published in 2011 and further analysed in detail 8 years later, sustained improvement was observed in hand hygiene compliance and HAIs were decreased, showing successful model applicable to other health-care facilities.^{130,131} This initiative highlights the impact that national and state health organisations have on implementing any national hand hygiene improvement strategy. Similarly, the Joint Commission in the USA supported hand hygiene improvements by establishing a National Patient Safety Goal based on guidelines from CDC and WHO in 2004.¹³² Experiences obtained from the Joint Commission suggested that achieving best practices demands a well structured and auditable measurement system and that this goal might not be fulfilled without specific programmes for each individual organisation as they differ in needs. Another intervention is the US Veterans Healthcare System Affairs initiative that provides guidance for establishing the basic requirements for hand hygiene practice in a wide variety of health-care settings.¹³³ The Asia Pacific Society of Infection Control, Infection Control Africa Network, and the International Federation of Infection

Search strategy and selection criteria

References for this Review were identified through a search of MEDLINE from Jan 1, 2000, to June 10, 2021. The search terms included “healthcare-associated infection”, “hand hygiene”, “alcohol-based hand rubs”, “disinfectant”, “handrubbing”, and “handwashing”. Other relevant references were identified from key online sources (eg, WHO) and authors’ personal files. Only articles published in English were included.

Control are among other launched campaigns led by regional and global organisations.

Conclusion

Since the first hand hygiene Review published in *The Lancet Infectious Diseases* in 2001, there have been a growing number of studies addressing the proposed research questions of that time.¹⁵ Today, more than half of the issues surrounding hand hygiene education, the preferred hand hygiene solution, and laboratory-based research that were discussed in 2001 have been solved or better understood. Importantly, however, new aspects and challenges are discovered continuously (panel 1). WHO is actively continuing to promote hand hygiene best practices, and organising the Technical Advisory Group has been its latest effort to evaluate the scientific aspects of hand hygiene in health care and define a research agenda for the next 5 years.¹⁴ The attitude towards alcohol-based hand rubs and adoption of behaviours that lead to increased compliance are unfortunately not only affected by scientific evidence. There is an enormous amount of misinformation around alcohol-based hand rubs, which negatively affects their use in health-care and community settings.¹³⁵ Thus, in addition to the need for more resources to pursue the proposed research agenda, clinicians and researchers should be aware of the infodemic.¹³⁶

Hand hygiene with alcohol-based hand rub is the cornerstone of infection prevention and control and possibly the single most effective measure to reduce HAIs and the spread of antimicrobial resistance, both responsible for silent global pandemics.²⁴ Hand hygiene was among the very first measures recommended with the emergence of the COVID-19 pandemic that quickly became the centre of attention among health-care workers and the general population. Hence, the time is ripe to harness this unprecedented opportunity to arm everyone against potential infectious diseases and be better prepared to face similar health crises. Good preparation cannot be achieved without providing equitable and global access to high-quality alcohol-based hand rubs, continuing the implementation of the multimodal hand hygiene improvement strategy to reach worldwide acceptable levels, and doing scientific studies to overcome the existing barriers to achieve optimal hand hygiene compliance in health care.

Contributors

NL, AP, ET, CF-R, and DaP did the literature search. NL, AP, ET, and CF-R wrote the manuscript. NL and DiP created the figures and tables. DiP supervised and edited the manuscript. All authors reviewed the publication.

Declaration of interests

We declare no competing interests.

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References

- WHO. Report on the burden of endemic health care-associated infection worldwide. 2011. https://apps.who.int/iris/bitstream/handle/10665/80135/9789241501507_eng.pdf?sequence=1 (accessed July 6, 2021).
- Monegro AF, Muppidi V, Regunath H. Hospital acquired infections. StatPearls. Treasure Island, FL: StatPearls Publishing, 2021.
- Allegranzi B, Bagheri Nejad S, Combescurie C, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011; **377**: 228–41.
- WHO. Health care-associated infections. Fact sheet. https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf (accessed May 3, 2021).
- Pittet D, Allegranzi B, Sax H, et al. Evidence-based model for hand transmission during patient care and the role of improved practices. *Lancet Infect Dis* 2006; **6**: 641–52.
- Vermeil T, Peters A, Kilpatrick C, Pires D, Allegranzi B, Pittet D. Hand hygiene in hospitals: anatomy of a revolution. *J Hosp Infect* 2019; **101**: 383–92.
- WHO. Evidence of hand hygiene to reduce transmission and infections by multi-drug resistant organisms in health-care settings. 2014. https://www.who.int/gpsc/5may/MDRO_literature-review.pdf?ua=1 (accessed May 8, 2021).
- Pincock T, Bernstein P, Warthman S, Holst E. Bundling hand hygiene interventions and measurement to decrease health care-associated infections. *Am J Infect Control* 2012; **40**: S18–27.
- Pittet D. Hand hygiene: from research to action. *J Infect Prev* 2017; **18**: 100–02.
- WHO. Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected. 2020. <https://www.who.int/publications-detail-redirect/10665-331495> (accessed April 29, 2021).
- Berardi A, Perinelli DR, Merchant HA, et al. Hand sanitisers amid CoViD-19: a critical review of alcohol-based products on the market and formulation approaches to respond to increasing demand. *Int J Pharm* 2020; **584**: 119431.
- Gould DJ, Moralejo D, Drey N, Chudleigh JH, Taljaard M. Interventions to improve hand hygiene compliance in patient care. *Cochrane Database Syst Rev* 2017; **9**: CD005186.
- Luangasanatip N, Hongsuwan M, Limmathurotsakul D, et al. Comparative efficacy of interventions to promote hand hygiene in hospital: systematic review and network meta-analysis. *BMJ* 2015; **351**: h3728.
- 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**: 283–94.

- 15 Pittet D, Boyce JM. Hand hygiene and patient care: pursuing the Semmelweis legacy. *Lancet Infect Dis* 2001; **s1**: 9–20.
- 16 Semmelweis IP. Die aetiologie, der begriff und die prophylaxis des kindbettfiebers. 1. Auflage. Pest; Wien; Leipzig: Hartleben: 1861.
- 17 Stewardson A, Pittet D. Ignác Semmelweis—celebrating a flawed pioneer of patient safety. *Lancet* 2011; **378**: 22–23.
- 18 Simmons BP. CDC guidelines for the prevention and control of nosocomial infections. Guideline for hospital environmental control. *Am J Infect Control* 1983; **11**: 97–120.
- 19 Garner JS, Favero MS. CDC Guideline for handwashing and hospital environmental control, 1985. *Infect Control* 1986; **7**: 231–43.
- 20 Mathur P. Hand hygiene: back to the basics of infection control. *Indian J Med Res* 2011; **134**: 611–20.
- 21 Steere AC, Mallison GF. Handwashing practices for the prevention of nosocomial infections. *Ann Intern Med* 1975; **83**: 683–90.
- 22 Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection Control Programme. *Lancet* 2000; **356**: 1307–12.
- 23 Boyce JM, Pittet D. Guideline for hand hygiene in health-care settings. Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR Recomm Rep* 2002; **51**: 1–45.
- 24 WHO. WHO guidelines on hand hygiene in health care. 2009. <https://www.who.int/publications/i/item/9789241597906> (accessed Oct 3, 2020).
- 25 Ellingson K. Hand hygiene promotion from the US perspective: putting WHO and CDC guidelines into practice. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 221–29.
- 26 Bonnabry P, Voss A. Hand hygiene agents. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 51–57.
- 27 Barclay L, Park GW, Vega E, et al. Infection control for norovirus. *Clin Microbiol Infect* 2014; **20**: 731–40.
- 28 Jing JL, Pei Yi T, Bose RJC, McCarthy JR, Tharmalingam N, Madheswaran T. Hand sanitizers: a review on formulation aspects, adverse effects, and regulations. *Int J Environ Res Public Health* 2020; **17**: E3326.
- 29 Menegueti MG, Laus AM, Ciol MA, et al. Glycerol content within the WHO ethanol-based handrub formulation: balancing tolerability with antimicrobial efficacy. *Antimicrob Resist Infect Control* 2019; **8**: 109.
- 30 Suchomel M, Eggers M, Maier S, Kramer A, Dancer SJ, Pittet D. Evaluation of World Health Organization–recommended hand hygiene formulations. *Emerg Infect Dis* 2020; **26**: 2064–68.
- 31 Tinajero CG, Bobadilla-Del Valle M, Alvarez JA, Mosqueda JL, Ponce De Leon A, Macias AE. Vancomycin-resistant *Enterococcus faecium* sensitivity to isopropyl alcohol before and after implementing alcohol hand rubbing in a hospital. *Am J Infect Control* 2019; **47**: e27–29.
- 32 Macinga DR, Shumaker DJ, Werner H-P, et al. The relative influences of product volume, delivery format and alcohol concentration on dry-time and efficacy of alcohol-based hand rubs. *BMC Infect Dis* 2014; **14**: 511.
- 33 Voss A. Rinse, gel, foam, soap ... selecting an agent. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 109–14.
- 34 Pittet D, Boyce JM, Allegranzi B. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017.
- 35 Pires D, Tartari E, Bellissimo-Rodrigues F, Pittet D. Why language matters: a tour through hand hygiene literature. *Antimicrob Resist Infect Control* 2017; **6**: 65.
- 36 Pires D, Bellissimo-Rodrigues F, Pittet D. Conducting a literature review on hand hygiene. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 391–99.
- 37 Kratzel A, Todt D, V'kovski P, et al. Inactivation of severe acute respiratory syndrome coronavirus 2 by WHO-recommended hand rub formulations and alcohols. *Emerg Infect Dis* 2020; **26**: 1592–95.
- 38 Leslie RA, Zhou SS, Macinga DR. Inactivation of SARS-CoV-2 by commercially available alcohol-based hand sanitizers. *Am J Infect Control* 2021; **49**: 401–02.
- 39 Raynaud M, Zhang H, Louis K, et al. COVID-19-related medical research: a meta-research and critical appraisal. *BMC Med Res Methodol* 2021; **21**: 1.
- 40 Kang M, Gurbani SS, Kempker JA. The published scientific literature on COVID-19: an analysis of pubmed abstracts. *J Med Syst* 2020; **45**: 3.
- 41 YouTube. Tutorial of local production of alcohol-based solution (WHO formulation). 2016. <https://www.youtube.com/watch?v=lu18ULyJxVA> (accessed May 7, 2021).
- 42 WHO. Local production of WHO-recommended alcohol-based handrubs: feasibility, advantages, barriers and costs. 2013. <https://www.who.int/publications/i/item/local-production-of-who-recommended-alcohol-based-handrubs-feasibility-advantages-barriers-and-costs> (accessed May 9, 2021).
- 43 US Food & Drug Administration. FDA updates on hand sanitizers consumers should not use. 2021. <https://www.fda.gov/drugs/drug-safety-and-availability/fda-updates-hand-sanitizers-consumers-should-not-use> (accessed April 29, 2021).
- 44 Voss A, Widmer AF. No time for handwashing!? Handwashing versus alcoholic rub: can we afford 100% compliance? *Infect Control Hosp Epidemiol* 1997; **18**: 205–08.
- 45 Pires D, Soule H, Bellissimo-Rodrigues F, Gayet-Ageron A, Pittet D. Hand hygiene with alcohol-based hand rub: how long is long enough? *Infect Control Hosp Epidemiol* 2017; **38**: 547–52.
- 46 Hugonnet S, Perneger TV, Pittet D. Alcohol-based handrub improves compliance with hand hygiene in intensive care units. *Arch Intern Med* 2002; **162**: 1037–43.
- 47 Clements A, Halton K, Graves N, et al. Overcrowding and understaffing in modern health-care systems: key determinants in methicillin-resistant *Staphylococcus aureus* transmission. *Lancet Infect Dis* 2008; **8**: 427–34.
- 48 Harbarth S, Sudre P, Dharan S, Cadenas M, Pittet D. Outbreak of *Enterobacter cloacae* related to understaffing, overcrowding, and poor hygiene practices. *Infect Control Hosp Epidemiol* 1999; **20**: 598–603.
- 49 Pittet D, Mourouga P, Perneger TV. Compliance with handwashing in a teaching hospital. Infection Control Program. *Ann Intern Med* 1999; **130**: 126–30.
- 50 Le CD, Lehman EB, Nguyen TH, Craig TJ. Hand hygiene compliance study at a large central hospital in Vietnam. *Int J Environ Res Public Health* 2019; **16**: E607.
- 51 Karaaslan A, Kepenekli Kadayifci E, Atci S, et al. Compliance of healthcare workers with hand hygiene practices in neonatal and pediatric intensive care units: overt observation. *Interdiscip Perspect Infect Dis* 2014; **2014**: 306478.
- 52 Fuller C, Savage J, Besser S, et al. “The dirty hand in the latex glove”: a study of hand hygiene compliance when gloves are worn. *Infect Control Hosp Epidemiol* 2011; **32**: 1194–99.
- 53 Kampf G, Lemmen S. Disinfection of gloved hands for multiple activities with indicated glove use on the same patient. *J Hosp Infect* 2017; **97**: 3–10.
- 54 Cohen J, Rodgers YVM. Contributing factors to personal protective equipment shortages during the COVID-19 pandemic. *Prev Med* 2020; **141**: 106263.
- 55 Larson E, Girard R, Pessoa-Silva CL, Boyce J, Donaldson L, Pittet D. Skin reactions related to hand hygiene and selection of hand hygiene products. *Am J Infect Control* 2006; **34**: 627–35.
- 56 Pedersen LK, Held E, Johansen JD, Agner T. Less skin irritation from alcohol-based disinfectant than from detergent used for hand disinfection. *Br J Dermatol* 2005; **153**: 1142–46.
- 57 Slotsch CM, Kampf G, Löffler H. Effects of disinfectants and detergents on skin irritation. *Contact Dermat* 2007; **57**: 235–41.
- 58 Hatta I, Nakazawa H, Obata Y, Ohta N, Inoue K, Yagi N. Novel method to observe subtle structural modulation of stratum corneum on applying chemical agents. *Chem Phys Lipids* 2010; **163**: 381–89.
- 59 Moncrieff G, Cork M, Lawton S, Kokiet S, Daly C, Clark C. Use of emollients in dry-skin conditions: consensus statement. *Clin Exp Dermatol* 2013; **38**: 231–38.
- 60 Longtin Y, Farquet N, Gayet-Ageron A, Sax H, Pittet D. Caregivers' perceptions of patients as reminders to improve hand hygiene. *Arch Intern Med* 2012; **172**: 1516–17.
- 61 Longtin Y, Sax H, Allegranzi B, Hugonnet S, Pittet D. Patients' beliefs and perceptions of their participation to increase healthcare worker compliance with hand hygiene. *Infect Control Hosp Epidemiol* 2009; **30**: 830–39.

- 62 Michaelsen K, Sanders JL, Zimmer SM, Bump GM. Overcoming patient barriers to discussing physician hand hygiene: do patients prefer electronic reminders to other methods? *Infect Control Hosp Epidemiol* 2013; **34**: 929–34.
- 63 WHO. A guide to the implementation of the WHO multimodal hand hygiene improvement strategy. 2009. <https://apps.who.int/iris/handle/10665/70030> (accessed Oct 3, 2020).
- 64 European Centre for Disease Prevention and Control. Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals 2011–2012. 2013. <https://www.ecdc.europa.eu/en/publications-data/point-prevalence-survey-healthcare-associated-infections-and-antimicrobial-use-0> (May 10, 2021).
- 65 Sax H, Allegranzi B, Uçkay I, Larson E, Boyce J, Pittet D. ‘My five moments for hand hygiene’: a user-centred design approach to understand, train, monitor and report hand hygiene. *J Hosp Infect* 2007; **67**: 9–21.
- 66 Sax H, Allegranzi B, Chraïti M-N, Boyce J, Larson E, Pittet D. The World Health Organization hand hygiene observation method. *Am J Infect Control* 2009; **37**: 827–34.
- 67 WHO. Hand hygiene in outpatient care and home-based care and long-term care facilities: a guide to the application of the WHO multimodal hand hygiene improvement strategy and the “My Five Moments for Hand Hygiene” approach. 2012. https://www.who.int/gpsc/5may/lh_guide.pdf (accessed April 29, 2021).
- 68 Bellissimo-Rodrigues F, Soule H, Gayet-Ageron A, Martin Y, Pittet D. Should alcohol-based handrub use be customized to healthcare workers’ hand size? *Infect Control Hosp Epidemiol* 2016; **37**: 219–21.
- 69 Tschudin-Sutter S, Sepulcri D, Dangel M, Schuhmacher H, Widmer AF. Compliance with the World Health Organization hand hygiene technique: a prospective observational study. *Infect Control Hosp Epidemiol* 2015; **36**: 482–83.
- 70 Stewardson AJ, Iten A, Camus V, et al. Efficacy of a new educational tool to improve handrubbing technique amongst healthcare workers: a controlled, before-after study. *PLoS One* 2014; **9**: e105866.
- 71 Pires D, Bellissimo-Rodrigues F, Soule H, Gayet-Ageron A, Pittet D. Revisiting the WHO “How to Handrub” hand hygiene technique: fingertips first? *Infect Control Hosp Epidemiol* 2017; **38**: 230–33.
- 72 Longtin Y, Schneider A, Tschopp C, et al. Contamination of stethoscopes and physicians’ hands after a physical examination. *Mayo Clin Proc* 2014; **89**: 291–99.
- 73 Tschudin-Sutter S, Rotter ML, Frei R, et al. Simplifying the WHO ‘how to hand rub’ technique: three steps are as effective as six—results from an experimental randomized crossover trial. *Clin Microbiol Infect* 2017; **23**: 409.
- 74 Tschudin-Sutter S, Sepulcri D, Dangel M, Ulrich A, Frei R, Widmer AF. Simplifying the World Health Organization protocol: 3 steps versus 6 steps for performance of hand hygiene in a cluster-randomized trial. *Clin Infect Dis* 2019; **69**: 614–20.
- 75 Zingg W, Holmes A, Dettenkofer M, et al. Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. *Lancet Infect Dis* 2015; **15**: 212–24.
- 76 Allegranzi B, Gayet-Ageron A, Damani N, et al. Global implementation of WHO’s multimodal strategy for improvement of hand hygiene: a quasi-experimental study. *Lancet Infect Dis* 2013; **13**: 843–51.
- 77 Koopa M, Slowik R, Wałaszek M, Wolak Z, Różańska A, Wójkowska-Mach J. Multimodal strategy in surgical site infections control and prevention in orthopaedic patients—a 10-year retrospective observational study at a Polish hospital. *Antimicrob Resist Infect Control* 2020; **9**: 20.
- 78 Álvarez-Lerma F, Sánchez García M. “The multimodal approach for ventilator-associated pneumonia prevention”—requirements for nationwide implementation. *Ann Transl Med* 2018; **6**: 420.
- 79 Zingg W, Cartier V, Inan C, et al. Hospital-wide multidisciplinary, multimodal intervention programme to reduce central venous catheter-associated bloodstream infection. *PLoS One* 2014; **9**: e93898.
- 80 Pittet D, Sax H, Hugonnet S, Harbarth S. Cost implications of successful hand hygiene promotion. *Infect Control Hosp Epidemiol* 2004; **25**: 264–66.
- 81 Allegranzi B, Sax H, Pittet D. Hand hygiene and healthcare system change within multi-modal promotion: a narrative review. *J Hosp Infect* 2013; **83**: S3–10.
- 82 Mathai E, Allegranzi B, Seto WH, et al. Educating healthcare workers to optimal hand hygiene practices: addressing the need. *Infection* 2010; **38**: 349–56.
- 83 Cherry MG, Brown JM, Bethell GS, Neal T, Shaw NJ. Features of educational interventions that lead to compliance with hand hygiene in healthcare professionals within a hospital care setting. A BEME systematic review: BEME Guide No. 22. *Med Teach* 2012; **34**: e406–20.
- 84 Huis A, Schoonhoven L, Grol R, Donders R, Hulscher M, van Achterberg T. Impact of a team and leaders-directed strategy to improve nurses’ adherence to hand hygiene guidelines: a cluster randomised trial. *Int J Nurs Stud* 2013; **50**: 464–74.
- 85 Martos-Cabrera MB, Mota-Romero E, Martos-García R, et al. Hand hygiene teaching strategies among nursing staff: a systematic review. *Int J Environ Res Public Health* 2019; **16**: e3039.
- 86 Tartari E, Fankhauser C, Masson-Roy S, et al. Train-the-trainers in hand hygiene: a standardized approach to guide education in infection prevention and control. *Antimicrob Resist Infect Control* 2019; **8**: 206.
- 87 WHO. Guidelines on core components of infection prevention and control programmes at the national and acute health care facility level. 2016. <https://www.who.int/gpsc/core-components.pdf> (accessed April 29, 2021).
- 88 Stewardson A, Pittet D. Quicker, easier, and cheaper? The promise of automated hand hygiene monitoring. *Infect Control Hosp Epidemiol* 2011; **32**: 1029–31.
- 89 Stewardson A, Sax H, Longet-Di Pietro S, Pittet D. Impact of observation and analysis methodology when reporting hand hygiene data. *J Hosp Infect* 2011; **77**: 358–59.
- 90 Ellingson K, Haas JP, Aiello AE, et al. Strategies to prevent healthcare-associated infections through hand hygiene. *Infect Control Hosp Epidemiol* 2014; **35**: 937–60.
- 91 Sedgwick P, Greenwood N. Understanding the Hawthorne effect. *BMJ* 2015; **351**: h4672.
- 92 Boyce JM. Current issues in hand hygiene. *Am J Infect Control* 2019; **47S**: A46–52.
- 93 Hagel S, Reischke J, Kesselmeier M, et al. Quantifying the Hawthorne effect in hand hygiene compliance through comparing direct observation with automated hand hygiene monitoring. *Infect Control Hosp Epidemiol* 2015; **36**: 957–62.
- 94 Gould DJ, Creedon S, Jeanes A, Drey NS, Chudleigh J, Moralejo D. Impact of observing hand hygiene in practice and research: a methodological reconsideration. *J Hosp Infect* 2017; **95**: 169–74.
- 95 Wu K-S, Lee SS-J, Chen J-K, et al. Identifying heterogeneity in the Hawthorne effect on hand hygiene observation: a cohort study of overtly and covertly observed results. *BMC Infect Dis* 2018; **18**: 369.
- 96 Boyce JM. Electronic monitoring in combination with direct observation as a means to significantly improve hand hygiene compliance. *Am J Infect Control* 2017; **45**: 528–35.
- 97 Pires D, Pittet D. Hand hygiene electronic monitoring: are we there yet? *Am J Infect Control* 2017; **45**: 464–65.
- 98 Boyce JM. Measuring healthcare worker hand hygiene activity: current practices and emerging technologies. *Infect Control Hosp Epidemiol* 2011; **32**: 1016–28.
- 99 Loveday HP, Wilson JA, Pratt RJ, et al. epic3: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect* 2014; **86**: S1–70.
- 100 Stewardson AJ, Sax H, Gayet-Ageron A, et al. Enhanced performance feedback and patient participation to improve hand hygiene compliance of health-care workers in the setting of established multimodal promotion: a single-centre, cluster randomised controlled trial. *Lancet Infect Dis* 2016; **16**: 1345–55.
- 101 Stewardson AJ, Sax H. Performance feedback. In: Pittet D, Boyce JM, Allegranzi B, eds. *Hand hygiene: a handbook for medical professionals*. USA: John Wiley & Sons, 2017: 172–79.
- 102 Naikoba S, Hayward A. The effectiveness of interventions aimed at increasing handwashing in healthcare workers—a systematic review. *J Hosp Infect* 2001; **47**: 173–80.
- 103 Wogalter MS, Conzola VC, Smith-Jackson TL. Research-based guidelines for warning design and evaluation. *Appl Ergon* 2002; **33**: 219–30.
- 104 Caris MG, Labuschagne HA, Dekker M, Kramer MHH, van Agtmael MA, Vandenbroucke-Grauls CMJE. Nudging to improve hand hygiene. *J Hosp Infect* 2018; **98**: 352–58.

- 105 Grill-Spector K, Henson R, Martin A. Repetition and the brain: neural models of stimulus-specific effects. *Trends Cogn Sci* 2006; **10**: 14–23.
- 106 Vander Weg MW, Perencevich EN, O'Shea AMJ, et al. Effect of frequency of changing point-of-use reminder signs on health care worker hand hygiene adherence: a cluster randomized clinical trial. *JAMA Netw Open* 2019; **2**: e1913823.
- 107 Gaube S, Tsvirikos D, Dollinger D, Lermer E. How a smiley protects health: a pilot intervention to improve hand hygiene in hospitals by activating injunctive norms through emoticons. *PLoS One* 2018; **13**: e0197465.
- 108 Birnbach DJ, King D, Vlaev I, Rosen LF, Harvey PD. Impact of environmental olfactory cues on hand hygiene behaviour in a simulated hospital environment: a randomized study. *J Hosp Infect* 2013; **85**: 79–81.
- 109 Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA. Isolation status and voice prompts improve hand hygiene. *Am J Infect Control* 2007; **35**: 470–76.
- 110 Lotfinejad N, Assadi R, Aelami MH, Pittet D. Emojis in public health and how they might be used for hand hygiene and infection prevention and control. *Antimicrob Resist Infect Control* 2020; **9**: 27.
- 111 Davis R, Parand A, Pinto A, Buetow S. Systematic review of the effectiveness of strategies to encourage patients to remind healthcare professionals about their hand hygiene. *J Hosp Infect* 2015; **89**: 141–62.
- 112 McGuckin M, Govednik J. Patient empowerment and hand hygiene, 1997–2012. *J Hosp Infect* 2013; **84**: 191–99.
- 113 Longtin Y, Sax H, Leape LL, Sheridan SE, Donaldson L, Pittet D. Patient participation: current knowledge and applicability to patient safety. *Mayo Clin Proc* 2010; **85**: 53–62.
- 114 Doherty C, Stavropoulou C. Patients' willingness and ability to participate actively in the reduction of clinical errors: a systematic literature review. *Soc Sci Med* 2012; **75**: 257–63.
- 115 Agency for Healthcare Research and Quality. Guide to patient and family engagement. <http://www.ahrq.gov/research/findings/final-reports/ptfamilyscan/index.html> (accessed April 30, 2021).
- 116 Davis RE, Koutantji M, Vincent CA. How willing are patients to question healthcare staff on issues related to the quality and safety of their healthcare? An exploratory study. *Qual Saf Health Care* 2008; **17**: 90–96.
- 117 WHO. Hand hygiene self-assessment framework 2010. 2010. https://www.who.int/gpsc/country_work/hhsa_framework_October_2010.pdf (accessed April 30, 2021).
- 118 International Conference on Prevention & Infection Control. Antimicrobial resistance and infection control. 6th International Conference on Prevention & Infection Control; Geneva; Sept 14–17, 2021 (ICPIC21-1119).
- 119 WHO. Sign up for SAVE LIVES: clean your hands. Annual global campaign. 2021. <https://www.who.int/campaigns/world-hand-hygiene-day> (accessed July 6, 2021).
- 120 Hand Hygiene Excellence Award. Proof your excellence with your hand hygiene programme. <https://www.hhea.info/en/about-hhea.html> (accessed May 8, 2021).
- 121 WHO. POPS for hand hygiene. 2021. <https://www.who.int/initiatives/private-organizations-for-patient-safety/pops-for-hand-hygiene> (accessed May 10, 2021).
- 122 Seto WH, Cowling BJ, Cheung CWY, et al. Impact of the first hand sanitizing relay world record on compliance with hand hygiene in a hospital. *Am J Infect Control* 2015; **43**: 295–97.
- 123 Seto WH, Li K-H, Cheung CWY, Ching PTY, Cowling BJ. Breaking a Guinness World Record on hand sanitizing relay, initiating a call for vital research in overcoming campaign fatigue for hand hygiene. *F1000 Res* 2014; **3**: 234.
- 124 Tartari E, Pires D, Bellissimo-Rodrigues F, et al. The global hand-sanitizing relay: promoting hand hygiene through innovation. *J Hosp Infect* 2017; **95**: 189–93.
- 125 Thampi N, Longtin Y, Peters A, Pittet D, Overy K. It's in our hands: a rapid, international initiative to translate a hand hygiene song during the COVID-19 pandemic. *J Hosp Infect* 2020; **105**: 574–76.
- 126 Pires D, Pittet D. Hand hygiene mantra: teach, monitor, improve, and celebrate. *J Hosp Infect* 2017; **95**: 335–37.
- 127 WHO. SAVE LIVES: Clean your hands—registration update. 2021. <https://www.who.int/registration-update> (accessed July 6, 2021).
- 128 Kilpatrick C, Storr J. National hand hygiene campaigns. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 249–55.
- 129 Grayson ML, Russo PL. The national hand hygiene initiative. *Med J Aust* 2009; **191**: 420–21.
- 130 Grayson ML, Russo PL, Cruickshank M, et al. Outcomes from the first 2 years of the Australian National Hand Hygiene Initiative. *Med J Aust* 2011; **195**: 615–19.
- 131 Grayson ML, Stewardson AJ, Russo PL, et al. Effects of the Australian National Hand Hygiene Initiative after 8 years on infection control practices, health-care worker education, and clinical outcomes: a longitudinal study. *Lancet Infect Dis* 2018; **18**: 1269–77.
- 132 Chassin MR, Braun BI, Benedicto AM. Improving hand hygiene through Joint Commission Accreditation and the Joint Commission Center for Transforming Healthcare. In: Pittet D, Boyce JM, Allegranzi B, eds. Hand hygiene: a handbook for medical professionals. USA: John Wiley & Sons, 2017: 263–74.
- 133 Reisinger HS, Yin J, Radonovich L, et al. Comprehensive survey of hand hygiene measurement and improvement practices in the Veterans Health Administration. *Am J Infect Control* 2013; **41**: 989–93.
- 134 WHO. Call for experts—Technical Advisory Group on hand hygiene in health care and other infection prevention interventions research and guidance. 2021. <https://www.who.int/news-room/articles-detail/call-for-experts---technical-advisory-group-on-hand-hygiene-in-health-care-and-other-infection-prevention-interventions-research-and-guidance> (accessed April 30, 2021).
- 135 Peters A, Tartari E, Lotfinejad N, Parneix P, Pittet D. Fighting the good fight: the fallout of fake news in infection prevention and why context matters. *J Hosp Infect* 2018; **100**: 365–70.
- 136 WHO. Fighting misinformation in the time of COVID-19, one click at a time. 2021. <https://www.who.int/news-room/feature-stories/detail/fighting-misinformation-in-the-time-of-covid-19-one-click-at-a-time> (accessed May 9, 2021).

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