



## Review

## Hand hygiene in low- and middle-income countries

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## ABSTRACT

A panel of experts was convened by the International Society for Infectious Diseases (ISID) to overview evidence based strategies to reduce the transmission of pathogens via the hands of healthcare workers and the subsequent incidence of hospital acquired infections with a focus on implementing these strategies in low- and middle-income countries. Existing data suggests that hospital patients in low- and middle-income countries are exposed to rates of healthcare associated infections at least 2-fold higher than in high income countries. In addition to the universal challenges to the implementation of effective hand hygiene strategies, hospitals in low- and middle-income countries face a range of unique barriers, including overcrowding and securing a reliable and sustainable supply of alcohol-based handrub. The WHO Multimodal Hand Hygiene Improvement Strategy and its associated resources represent an evidence-based framework for developing a locally-adapted implementation plan for hand hygiene promotion.

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## Key issues

- The burden of healthcare-associated infections (HAIs) is greater in low- and middle-income countries (LMICs) than in high-income countries.
- Hand hygiene is one of the most effective strategies to reduce HAIs and the transmission of antimicrobial resistant pathogens.
- Several studies have demonstrated effective implementation of hand hygiene interventions in LMICs.
- LMICs face unique challenges related to hand hygiene, such as procurement of and local production of alcohol-based handrub (ABHR) and application of 'My 5 Moments' to overcrowded settings.
- World Health Organization's 'Guidelines on Hand Hygiene in Health Care' (World Health Organization, 2009b) and the accompanying suite of implementation tools are key resources for practitioners in LMICs.

## Known facts

### Introduction

Healthcare-associated infections (HAIs) represent a significant threat to patient safety, affecting hundreds of millions of individuals worldwide (Allegranzi et al., 2011). HAIs result in increased mortality and morbidity, greater length of stay, and higher healthcare costs (Marchetti and Rossiter, 2013). Hand hygiene among healthcare workers (HCWs) is considered one of the most critical strategies to reduce the frequency of HAIs. While most evidence is from high-income countries (HICs), now there is sufficient data from LMICs to suggest that hand hygiene is also a key and effective strategy in this context.

### Burden of healthcare-associated infections in low- and middle-income countries

The incidence of HAIs is significantly higher in LMICs compared to HICs. However, a detailed description of HAIs in LMICs is restricted by a relative lack of data and the small number of high-quality studies (Damani et al., 2017). A WHO survey demonstrated that only 23/147 (15.6%) LMICs reported a functioning national surveillance system for HAIs (World Health Organization, 2010a). Barriers to effective surveillance include insufficient financial resources, scarcity of training in infection prevention and control (IPC) and hospital epidemiology, limited microbiological and radiological services, and other important competing healthcare priorities. Sustained investments to tackle any of these barriers – such as improving the capacity of microbiology laboratories – can also have flow-on benefits in other related areas, such as improving the detection and surveillance of antimicrobial resistant pathogens.

A small number of studies have quantified the burden of HAIs in LMICs, which is estimated to be 2–20 times greater than in HICs (Allegranzi et al., 2011; World Health Organization, 2009b). In a large systematic review of HAIs in LMICs the overall pooled prevalence was 15.5 per 100 bed days, with the highest density of infections among intensive care unit (ICU) patients – pooled

density of 47.9 per 1000 patient-days (Allegranzi et al., 2011). A systematic review focusing on HAIs in Africa highlighted the paucity of high-quality data, yet reported a hospital-wide cumulative incidence of 2.5%–14.8%, which was as high as 45.8% in some surgical wards (Bagheri Nejad et al., 2011). The discrepancy between LMICs and HICs was also found among neonatal settings, with HAIs being 3–20 times higher in resource-limited settings (Zaidi et al., 2005).

### Transmission of pathogens via healthcare workers' hands

The hands of healthcare workers play a central role in transferring microorganisms throughout the clinical environment and, more importantly, to patients (Allegranzi and Pittet, 2009; Pittet et al., 1999). Hands have the potential to exchange microorganisms at each hand-to-surface contact, and HCWs' hands transiently contaminated with nosocomial pathogens are considered to be the primary route of transmission (Pittet et al., 2006). Performing hand hygiene, most commonly through the use of ABHR, leads to a significant reduction in the bacterial counts present on hands and therefore reducing the likelihood of cross-transmission (Bellissimo-Rodrigues et al., 2017; Salmon et al., 2014).

### Hand hygiene reduces healthcare-associated infections

Over the last few decades there has been an increasing body of evidence to show that improved hand hygiene, with a particular focus on the use of ABHR, can reduce HAI rates (Allegranzi and Pittet, 2009; Kingston et al., 2016); in particular bloodstream and surgical site infections (Stewardson et al., 2011). LMICs are under-represented in these studies, with a systematic review on hand hygiene compliance finding that only 2 of 16 high-quality studies were performed within a LMIC context (Kingston et al., 2016).

There are, however, encouraging examples of hospitals in LMICs implementing strategies to significantly improve hand hygiene compliance, often associated with reductions in HAIs. Most of these studies report implementation of the WHO's multimodal improvement strategy (World Health Organization, 2009b) – see Suggested Practice, below. In a university teaching hospital in Mali, hand hygiene compliance increased from 8% at baseline to 21.8% (Allegranzi et al., 2010); similarly large increases from 34.1% to 68.9% were achieved in a rural, non-referral hospital in Rwanda (Holmen et al., 2016). In Columbian ICUs, the implementation of hand hygiene resulted in a reduction in central line-associated bloodstream infections and the cessation of an *Acinetobacter* outbreak (Barrera et al., 2011). In a Vietnamese tertiary hospital, hand hygiene compliance increased from 25.7% to 57.5%, associated with a significant reduction in HAIs from 31.7% to 20.3% (Thi Anh Thu et al., 2015). Importantly, the cost-effectiveness of multimodal hand hygiene interventions in such settings has been demonstrated from both modelling (Luangsanatip et al., 2018) and clinical trial data (Thi Anh Thu et al., 2015).

Despite limited resources, organizations such as the Infection Control Africa Network (ICAN) made significant progress by supporting countries in their efforts of putting IPC policies and specifically hand hygiene policies into place. There are currently

several countries in Africa (South Africa, Mozambique, Namibia, Guinea and others) with specific hand hygiene policies. Tanzania and Ethiopia are examples of countries that have hand hygiene policies embedded in their IPC policies. Policies on local production of ABHR are now used in South Africa, Cameroon, Mali, Sierra Leone, Uganda and Mozambique with other LMICs implementing these policies in the near future.

In summary, while less research is available from LMICs than HICs, there is sufficient data to indicate high rates of HAIs, and that effective interventions such as hand hygiene and other IPC measures are critical to patient safety and the overall better delivery of care.

## Controversial issues

### Hand hygiene in overcrowded settings

A key component of the WHO's 'My 5 Moments for Hand Hygiene' strategy (see below) is the division of the healthcare environment into two zones: the patient zone and the healthcare zone. The **patient zone** contains the patient him/herself and his or her immediate surrounding inanimate objects, which is assumed to be "contaminated" by that patient's microbiota. The **healthcare zone** includes all other surfaces (including other patients) and is considered to be "contaminated" by microorganisms that are foreign to, and potentially harmful to, the patient in question. This has subsequent implications for when hand hygiene is indicated to prevent cross-contamination and HAIs (Sax et al., 2009; Sax et al., 2007).

However, in resource-limited settings, overcrowding may challenge this conceptual model e.g. two or more patients sharing the same bed or having insufficient spacing between individual patient beds. The resulting loss of distinct patient zones complicates application of the 'My 5 Moments' approach (Salmon et al., 2015). Efforts have been made within the WHO Guidelines on Hand Hygiene in Health Care (World Health Organization, 2009b) and subsequent publications (Salmon et al., 2015) to adapt the 'My 5 Moments' strategy specifically for overcrowded settings. This has been done to provide clarity on the indications for hand hygiene in this context and ensure generalisability of the 'My 5 Moments' strategy.

Overcrowding is often accompanied by a relative shortage of nursing staff. In such healthcare facilities, family caregivers may be relied on to provide a large proportion of patient care. These caregivers may be responsible for more hand hygiene opportunities than HCWs (Hornig et al., 2016), and represent another key target for hand hygiene and IPC education (Islam et al., 2014).

### Hand hygiene technique

The WHO guidelines currently promote a six-step technique for applying ABHR to ensure complete coverage of the hands (World Health Organization, 2009b). However, full compliance with this technique appears to be as low as 0%–8.5% (Stewardson et al., 2014; Tschudin-Sutter et al., 2015), even in the context of good compliance with hand hygiene indications. A number of recent studies suggest that a shorter and simpler hand hygiene technique be as effective while maintaining antibacterial efficacy. Recommended modifications include 'fingertips-first' (Pires et al., 2017a), shortening the duration of rubbing hands (15 s instead of 20–30 s) (Kramer et al., 2017; Pires et al., 2017b), or performing 'three-steps' instead of 'six-steps' (Tschudin-Sutter et al., 2017; Tschudin-Sutter et al., 2018). It is important to recall however that the latter technique also requires complete coverage of the hands. The majority of the studies were performed in laboratory conditions and further clinical research is needed.

## Cultural and religious factors

Many cultures and religions acknowledge the importance of handwashing and personal hygiene, with washing activities embedded in their religious practice or cultural norms (World Health Organization, 2009b). As efforts are made to promote hand hygiene globally, it is important to recognise the influence of different cultural and religious factors on HCWs' attitudes towards hand hygiene and their subsequent hand hygiene adherence (World Health Organization, 2009b). Such issues, including the use of alcohol, need to be carefully and respectfully considered in dialogue with appropriate stakeholders. For example when asked to address the question of ABHR, the Muslim Scholars' Board of the Muslim World League clarified that "alcohol may be used as an external wound cleanser, to kill germs and in external creams and ointments" (Ahmed et al., 2006; World Health Organization, 2009b). A recent cohort study demonstrated that religion-relevant, culturally-specific interventions could significantly improve compliance with and beliefs about ABHR in the United Arab Emirates (Ng et al., 2019).

## Suggested practice

### My 5 moments for hand hygiene

The WHO 'My 5 Moments for Hand Hygiene' defines when healthcare workers should perform hand hygiene during clinical care (Sax et al., 2007). It is based on the conceptual model of microorganism cross-transmission and is designed to be used to teach, audit, and report hand hygiene behaviour. The **patient zone** is the central element of the 'My 5 Moments for Hand Hygiene.' The '5 Moments' are (Figure 1):

- 1) Before touching a patient
- 2) Before clean/aseptic procedures
- 3) After body fluid exposure/risk
- 4) After touching a patient
- 5) After touching patient surroundings

The preferred method for hand hygiene is rubbing with ABHR including after removal of gloves. However, hand washing with soap and water is recommended when hands are visibly dirty, soiled with blood or body fluids, or potentially contaminated with spore-forming organisms (e.g. *Clostridium difficile*).

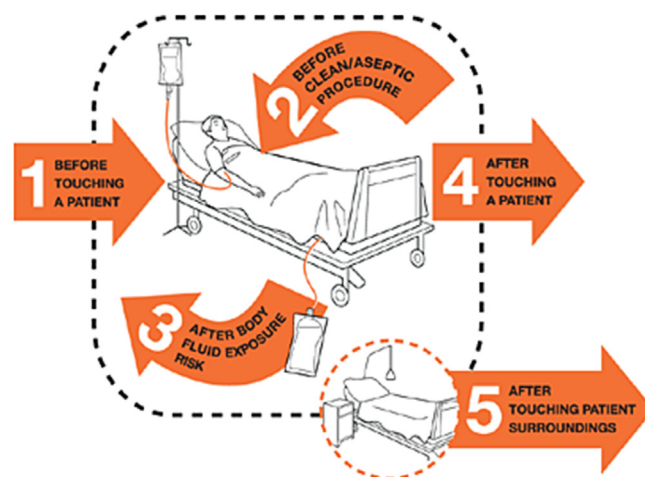


Figure 1. The My 5 Moments of Hand Hygiene.

### WHO multimodal hand hygiene improvement strategy

In addition to outlining the evidence base for focusing on hand hygiene improvement as part of efforts to reduce HAIs, the WHO 'Guidelines on Hand Hygiene in Health Care' (World Health Organization, 2009b) introduced the Multimodal Strategy for Hand Hygiene Improvement as a means to achieve and sustain optimal hand hygiene behaviour.

In brief, the five components of this multimodal strategy are (World Health Organization, 2009a):

- 1) **System change:** ensuring that healthcare facilities have the necessary infrastructure to allow HCWs to perform hand hygiene. This includes not only the reliable and uninterrupted provision of ABHR at the point of care, but also a continuous supply of safe water, soap, towels, and disposable non-powdered gloves. To help ensure optimal adherence to hand hygiene recommendations, products such as ABHR and gloves should be proven to be tolerable and acceptable to HCWs (Meneguetti et al., 2019; World Health Organization, 2009a).
- 2) **Staff education and training:** HCWs should be educated about the impact of HAIs and the role of hand hygiene in safe patient care, and trained about implementation of the 'My 5 Moments for Hand Hygiene' and correct hand hygiene technique. Staff in healthcare facilities can change often; it is therefore important to repeat this training intermittently, to ensure that newly arrived staff are educated, and that the knowledge of others remains up to date. Emphasising hand hygiene (as part of a larger IPC training programme) in the undergraduate curriculum for both clinical and non clinical staff is recommended. Additional education sessions should also be conducted exclusively for hand hygiene observers – allowing them to learn and practice the proposed methods of observation.
- 3) **Evaluation and feedback:** regular evaluation of hand hygiene compliance is a crucial behaviour change strategy when coupled with performance feedback; it ensures that progress can be monitored over time. Hand hygiene observations can be used to demonstrate improvements following interventions and help sustain motivation for good practice. Alternatively, it may highlight certain professional categories or indications for hand hygiene that have poor compliance and need improvement. The Hand Hygiene Self-Assessment Framework (World Health Organization, 2010c) (see below) is a structured and consistent method of collecting such data and supports "blame-free" evaluation and regular feedback.
- 4) **Reminders in the workplace:** most commonly taking the form of a poster, these can continually prompt HCWs regarding the importance of – and the indications for – hand hygiene. Additionally, they inform patients and their visitors of the level of care they should expect from HCWs with regards to hand hygiene. To increase their efficacy, these posters can be adapted to the local context, and evaluated and updated on a regular basis.
- 5) **Institutional safety climate:** creating an environment that prioritises patient safety and high compliance with hand hygiene. This can occur at an institutional level – with clear messages of public support for hand hygiene from leaders within the institution, setting benchmarks or targets, and having hand hygiene champions. Equally this can occur at an individual level, with HCWs identifying hand hygiene as a priority that reflects their commitment to do no harm to patients. Partnering with patients and patient organizations to promote hand hygiene may also foster a climate of patient safety, but should be undertaken sensitively and in close consultation with key stakeholders including healthcare workers and patient representatives (Butenko et al., 2017; Longtin et al., 2010).

This strategy was created following a review of published literature and expert consensus. These components were subsequently validated in a range of healthcare settings around the world, including LMICs, to ensure that they could be implemented in a variety of contexts regardless of the resources available (Allegranzi et al., 2013). To facilitate broad uptake and effective execution of these hand hygiene guidelines, the WHO have published an accompanying Guide to Implementation of the WHO Multimodal Hand Hygiene Improvement Strategy (World Health Organization, 2009a).

### WHO hand hygiene self-assessment framework

The Hand Hygiene Self-Assessment Framework (HHSAF) is a self-administered validated questionnaire designed to provide a systematic situation analysis of hand hygiene structures, resources, promotion and practices within a healthcare facility (Stewardson et al., 2013; World Health Organization, 2010c). Structured around the five components of the WHO Multimodal Hand Hygiene Improvement Strategy, the HHSAF assesses interventions being implemented by healthcare facilities to ensure adherence to hand hygiene action as per WHO recommendations (World Health Organization, 2009b). The HHSAF directs users to different tools developed by the WHO depending on the specific area warranting attention, and can therefore be used to develop an action plan for local hand hygiene promotion (Stewardson et al., 2013). The WHO has conducted two global surveys using the HHSAF in 2011 and 2015 (Kilpatrick et al., 2018). Overall, HHSAF scores increased significantly ( $p < 0.001$ ) in facilities that participated in both surveys. When compared to other WHO regions, the Africa region scored lowest, which could be indicative of poorer IPC infrastructure, resources and basic knowledge in hand hygiene implementation and sustainability.

### Local production of alcohol-based handrub

ABHRs are the preferred method for hand hygiene, as they offer a broad antimicrobial spectrum, are highly effective, are well tolerated by the skin and can be made available at the point of care. However, the availability of these products in LMIC countries is still limited. To overcome such constraints, in 2005, the WHO developed and tested two ABHR formulations according to European norms for hand antisepsis (World Health Organization, 2009b, 2010b). In a randomized cross-over trial, both formulations showed excellent skin tolerability and acceptability among HCWs (Pittet et al., 2007). Their active component is either ethanol (80% v/v) or isopropanol (75% v/v). These formulations also contain glycerol as emollient to protect hands, and hydrogen peroxide to eliminate spores from components or reused bottles (World Health Organization, 2010b). Since 2009, these formulations are recommended for use by the WHO guidelines on Hand Hygiene in Health Care (World Health Organization, 2009b) together with a specific methodology adapted for their local production, and tested in pilot sites mostly located in LMICs (World Health Organization, 2010b). Since 2014, these formulations are listed in the WHO essential medicines list (World Health Organization, 2017).

Commercially-available ABHRs are produced mainly in the USA, in Europe and in Japan; they meet international standards required for market introduction of ABHRs and for antimicrobial efficacy (ASTM 1174 or EN 1500 standards), and exist reliably in health care in most high-income countries. However, ABHRs are not available in all regions of the world (World Health Organization, 2017). When commercially-produced ABHRs are not available or affordable, local production according to the methodology proposed by WHO, could be an alternative (Allegranzi et al., 2013; Allegranzi et al., 2010; World Health Organization, 2010b). Over the past

decade, there have been several examples of local production of ABHR as part of multimodal approaches to improve hand hygiene, from single hospital pharmacy to national level (Allegranzi et al., 2013; Allegranzi et al., 2010; Bauer-Savage et al., 2013; Hopitaux Universitaires de Genève, 2015; World Health Organization, 2010b). Local production provides a low-cost alternative to commercially-produced ABHRs, in particular in LMICs. However, several challenging issues have been reported, including the lack of expertise, the lack of basic equipment and material needed to assure quality control, as well as difficulties in the procurement of raw materials and dispensers (Bauer-Savage et al., 2013; World Health Organization, 2013). In most instances, alcohol and glycerol can be easily procured from local suppliers. Ethanol could be derived from sugar cane, wheat, rice, bananas or manioc, easily available in most of LMICs (World Health Organization, 2010b). However, local sourcing dispensers and hydrogen peroxide can prove problematic and importation might be the only solution in some instances, thus increasing the overall cost of production (Bauer-Savage et al., 2013; World Health Organization, 2010b). Possible additional advantages of local ABHR production include sustainability, economic empowerment and job creation, particularly in countries with severe economic constraints (Kama-Kieghe, 2016; SARAYA Co. LTD, 2019).

One emerging solution for the development of country-based capacity in ABHR production has been promoted through South-North partnership mechanisms. In 2006, a partnership between European and African countries was developed and organized practical ABHR production workshops with quality control (World Health Organization, 2013); tools are available online for wide replication in the African region (Bengaly et al., 2013; Pharm-Ed, 2015), as well as in LMIC. Based on such North-South partnership model, a project of local ABHR production during the 2014–2016 Ebola Outbreak in twenty facilities in West Africa (Guinea and Liberia), demonstrated the feasibility to develop local capacity in ABHR production during an emergency situation and in limited-resource settings, when materials and training are provided. In this case, the implementation program was a success but factors of sustainability remain to be identified (Hopitaux Universitaires de Genève, 2015; Jacquieroz Bausch et al., 2018).

There are many examples of ABHR local production occurring in hospital pharmacies (Olivier et al., 2015). In some cases, particularly when larger volumes of ABHR are required, a national production company could be an interesting alternative to production in a hospital pharmacy, improving availability. Demonstration of successful models based on national ABHR production that integrate hand hygiene improvement efforts into regular local and national budget plans to ensure long-term sustainability would be highly beneficial since literature remains scarce.

#### “Turn Africa Orange”

The WHO global campaign SAVE HANDS: Clean Your Hands with the primary objective “to promote best hand hygiene practices globally, at all levels of health care, as a first step in ensuring high standards of infection control and patient safety”, has been very successful with countries worldwide pledging their support to implement hand hygiene and reduce HAI. African countries participation in the campaign remains low. The Turn Africa Orange programme, an initiative of the Infection Control Africa Network (ICAN), aimed to encourage as many African countries as possible to participate in the global campaign of enlisting healthcare facilities in support of hand hygiene improvement. The phrase was coined to encourage African countries to move from pale yellow to deep orange on the map, reflecting the number of healthcare facilities registered on the WHO website

(WHO Collaborating Centre on Patient Safety, 2017). Between 2014 and 2018 an annual sustained campaign by ICAN saw an increase in the number of registered institutions from 757 to 1272 (World Health Organization, 2019).

#### Summary

Existing data suggests that hospital patients in LMICs are exposed to rates of HAIs at least 2-fold higher than in HICs. Hand hygiene is an evidence-based strategy to reduce both the transmission of pathogens via the hands of HCWs and the subsequent incidence of HAIs. In addition to the universal challenges to the implementation of effective hand hygiene strategies, hospitals in LMICs face a range of unique barriers, including overcrowding and securing a reliable and sustainable supply of ABHR. The WHO Multimodal Hand Hygiene Improvement Strategy and its associated resources represent an evidence-based framework for developing a locally-adapted implementation plan for hand hygiene promotion.

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None.

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Not required.

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#### References

- Ahmed QA, Memish ZA, Allegranzi B, Pittet D. Muslim health-care workers and alcohol-based handrubs. *Lancet* 2006;367:1025–7.
- Allegranzi B, Bagheri Nejad S, Combescur C, Graafmans W, Attar H, Donaldson L, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011;377:228–41.
- Allegranzi B, Gayet-Ageron A, Damani N, Bengaly L, McLaws ML, Moro ML, 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.
- Allegranzi B, Pittet D. Role of hand hygiene in healthcare-associated infection prevention. *J Hosp Infect* 2009;73:305–15.
- Allegranzi B, Sax H, Bengaly L, Richet H, Minta DK, Chraïti MN, et al. Successful implementation of the World Health Organization hand hygiene improvement strategy in a referral hospital in Mali, Africa. *Infect Control Hosp Epidemiol* 2010;31:133–41.
- Bagheri Nejad S, Allegranzi B, Syed SB, Ellis B, Pittet D. Health-care-associated infection in Africa: a systematic review. *Bull World Health Organ* 2011;89:757–65.
- Barrera L, Zingg W, Mendez F, Pittet D. Effectiveness of a hand hygiene promotion strategy using alcohol-based handrub in 6 intensive care units in Colombia. *Am J Infect Control* 2011;39:633–9.
- Bauer-Savage J, Pittet D, Kim E, Allegranzi B. Local production of WHO-recommended alcohol-based handrubs: feasibility, advantages, barriers and costs. *Bull World Health Organ* 2013;91:963–9.
- Bellissimo-Rodrigues F, Pires D, Soule H, Gayet-Ageron A, Pittet D. Assessing the likelihood of hand-to-hand cross-transmission of bacteria: an experimental study. *Infect Control Hosp Epidemiol* 2017;38(5):553–8.
- Bengaly L, Hightower J, Bonnabry P, Syed SJAR, Control I. P334: Catalysing local production of alcohol based handrub in african hospitals: the power of south-north-south partnership 2013;2: P334.

- Butenko S, Lockwood C, McArthur A. Patient experiences of partnering with healthcare professionals for hand hygiene compliance: a systematic review. *JBI Database System Rev Implement Rep* 2017;15(6):1645–70.
- Damani N, Mehtar S, Allegranzi B. Hand hygiene in resource-poor settings. In: Pittet D, Boyce J, Allegranzi B, editors. *Hand hygiene: a handbook for medical professionals*. Chichester, West Sussex: John Wiley & Sons; 2017. p. 357–66.
- Holmen IC, Seneca C, Nyiranzayisaba B, Nyiringabo V, Bienfait M, Safdar N. Improving hand hygiene practices in a rural hospital in Sub-Saharan Africa. *Infect Control Hosp Epidemiol* 2016;37:834–9.
- Hopitaux Universitaires de Genève. Local production of WHO handrub during and after the Ebola crisis in West-Africa. 2015. . . [Accessed 9 January 2019] [https://www.youtube.com/watch?v=ss\\_0TZJUuQU8&feature=youtu.be](https://www.youtube.com/watch?v=ss_0TZJUuQU8&feature=youtu.be).
- Hornig LM, Unicomb L, Alam MU, Halder AK, Shoab AK, Ghosh PK, et al. Healthcare worker and family caregiver hand hygiene in Bangladeshi healthcare facilities: results from the Bangladesh National Hygiene Baseline Survey. *J Hosp Infect* 2016;94(3):286–94.
- Islam MS, Luby SP, Sultana R, Rimi NA, Zaman RU, Uddin M, et al. Family caregivers in public tertiary care hospitals in Bangladesh: risks and opportunities for infection control. *Am J Infect Control* 2014;42(3):305–10.
- Jacquerioz Bausch FA, Heller O, Bengaly L, Matthey-Khouity B, Bonnabry P, Toure Y, et al. Building local capacity in hand-rub solution production during the 2014–2016 ebola outbreak disaster: the case of Liberia and Guinea. *Prehosp Disaster Med* 2018;33:660–7.
- Kama-Kieghe S. Local production of alcohol based hand rubs (ABHR) in Nigeria – the way of the future? *InfectionControltips*. 2016. . . [Accessed 9 January 2019] <https://infectioncontrol.tips/2016/03/05/abhr/>.
- Kilpatrick C, Tartari E, Gayet-Ageron A, Storr J, Tomczyk S, Allegranzi B, et al. Global hand hygiene improvement progress: two surveys using the WHO Hand Hygiene Self-Assessment Framework. *J Hosp Infect* 2018;100:202–6.
- Kingston L, O'Connell NH, Dunne CP. Hand hygiene-related clinical trials reported since 2010: a systematic review. *J Hosp Infect* 2016;92:309–20.
- Kramer A, Pittet D, Klasinc R, Krebs S, Koburger T, Fusch C, et al. Shortening the application time of alcohol-based hand rubs to 15 seconds may improve the frequency of hand antiseptics actions in a neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2017;38:1430–4.
- Longtin Y, Sax H, Leape LL, Sheridan SE, Donaldson L, Pittet D. Patient participation: current knowledge and applicability to patient safety. *Mayo Clinic Proc* 2010;85(1):53–62.
- Luangsanatip N, Hongsuwan M, Lubell Y, Limmathurotsakul D, Srisamang P, Day NPJ, et al. Cost-effectiveness of interventions to improve hand hygiene in healthcare workers in middle-income hospital settings: a model-based analysis. *J Hosp Infect* 2018;100:165–75.
- Marchetti A, Rossiter R. Economic burden of healthcare-associated infection in US acute care hospitals: societal perspective. *J Med Econ* 2013;16:1399–404.
- Meneguetti MG, Ciol MA, Araújo TR, Bellissimo-Rodrigues F, Auxiliadora-Martins M, Basile-Filho A, et al. The impact of replacing powdered gloves with powder-free gloves on hand hygiene compliance among healthcare workers from an intensive care unit: a quasi-experimental study. *Amsterdam: European Congress of Clinical Microbiology & Infectious Diseases*; 2019.
- Ng WK, Shaban RZ, van de Mortel T. The effect of a hand hygiene program featuring tailored religion-relevant interventions on healthcare workers' hand rubbing compliance and beliefs in the United Arab Emirates: a cohort study. *Infect Dis Health* 2019;. doi:<http://dx.doi.org/10.1016/j.idh.2019.01.002> [Epub ahead of print].
- Olivier H, Tye TT, Mulbah J, Massaquoi M, Dahn B, Bengaly L, et al. Local production of alcohol based handrub solution (ABHS) in Liberia during the Ebola outbreak. *Antimicrob Resist Infect Control* 2015;4(Suppl. 1):P8.
- Pharm-Ed. Tutoriels pour la production locale de solution hydro-alcoolique en ligne!. 2015 Available from: <http://pharmacie.g2hp.net/tutoriel-pour-la-production-locale-de-solution-hydro-alcoolique/>. [Accessed 8 January 2019].
- 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* 2017a;38:230–3.
- 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* 2017b;38:547–52.
- Pittet D, Allegranzi B, Sax H, Chraïti MN, Griffiths W, Richet H. Double-blind, randomized, crossover trial of 3 hand rub formulations: fast-track evaluation of tolerability and acceptability. *Infect Control Hosp Epidemiol* 2007;28:1344–51.
- Pittet D, Allegranzi B, Sax H, Dharan S, Pessoa-Silva CL, Donaldson L, et al. Evidence-based model for hand transmission during patient care and the role of improved practices. *Lancet Infect Dis* 2006;6:641–52.
- Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger TV. Bacterial contamination of the hands of hospital staff during routine patient care. *Arch Intern Med* 1999;159:821–6.
- Salmon S, Pittet D, Sax H, McLaws ML. The 'My five moments for hand hygiene' concept for the overcrowded setting in resource-limited healthcare systems. *J Hosp Infect* 2015;91:95–9.
- Salmon S, Truong AT, Nguyen VH, Pittet D, McLaws ML. Health care workers' hand contamination levels and antibacterial efficacy of different hand hygiene methods used in a Vietnamese hospital. *Am J Infect Control* 2014;42(2):178–81.
- SARAYA Co. LTD. 100% hospital hand hygiene project <https://hospital-en.tearai.jp/> [Accessed 8 January 2019].
- Sax H, Allegranzi B, Chraïti MN, Boyce J, Larson E, Pittet D. The World Health Organization hand hygiene observation method. *Am J Infect Control* 2009;37:827–34.
- Sax H, Allegranzi B, Uckay 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.
- Stewardson A, Allegranzi B, Sax H, Kilpatrick C, Pittet D. Back to the future: rising to the Semmelweis challenge in hand hygiene. *Future Microbiol* 2011;6:855–76.
- Stewardson AJ, Allegranzi B, Perneger TV, Attar H, Pittet D. Testing the WHO Hand Hygiene Self-Assessment Framework for usability and reliability. *J Hosp Infect* 2013;83:30–5.
- Stewardson AJ, Iten A, Camus V, Gayet-Ageron A, Caulfield D, Lacey G, 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.
- Thi Anh Thu L, Thi Hong Thoa V, Thi Van Trang D, Phuc Tien N, Thuy Van D, Thi Kim Anh L, et al. Cost-effectiveness of a hand hygiene program on health care-associated infections in intensive care patients at a tertiary care hospital in Vietnam. *Am J Infect Control* 2015;43:e93–9.
- Tschudin-Sutter S, Rotter ML, Frei R, Nogarth D, Hausermann P, Strandén A, 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.e1–e4.
- 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;36:482–3.
- Tschudin-Sutter S, Sepulcri D, Dangel M, Ulrich A, Frei R, Widmer AF. Simplifying the WHO protocol: three steps versus six steps for performance of hand hygiene – a cluster-randomized trial. *Clin Infect Dis* 2018; [in press].
- World Health Organization Collaborating Centre on Patient Safety. Turn Africa Orange. 2017. . . [Accessed 26 March 2019] <http://tinyurl.com/AfricaOrange>.
- World Health Organization. Gui the WHO multimodal hand hygiene improvement strategy. Geneva: World Health Organization; 2009.
- World Health Organization. WHO guidelines on hand hygiene in health care: first global patient safety challenge clean care is safer care. Geneva: World Health Organization; 2009.
- World Health Organization. The burden of health care-associated infection worldwide: a summary. Geneva: World Health Organization; 2010.
- World Health Organization. Guide to local production: WHO-recommended handrub formulations. Geneva: World Health Organization; 2010.
- World Health Organization. Hand hygiene self-assessment framework. 2010. . . [Accessed 22 December 2018] [https://www.who.int/gpsc/country\\_work/hhsa\\_framework\\_October\\_2010.pdf?ua=1](https://www.who.int/gpsc/country_work/hhsa_framework_October_2010.pdf?ua=1).
- World Health Organization. Local production of alcohol based hand rub training workshop report – african partnerships for patient safety. 2013. . . [Accessed 9 January 2019] <https://www.who.int/patientsafety/implementation/apps/events/ABHR-workshop-report.pdf>.
- World Health Organization. WHO model list of essential medicines. 20th ed. 2017 Geneva.
- World Health Organization. Infection prevention and control: registration update – countries or areas. 2019. . . [Accessed 26 April 2019] [https://www.who.int/infection-prevention/campaigns/clean-hands/registration\\_update/](https://www.who.int/infection-prevention/campaigns/clean-hands/registration_update/).
- Zaidi AK, Huskins WC, Thaver D, Bhutta ZA, Abbas Z, Goldmann DA. Hospital-acquired neonatal infections in developing countries. *Lancet* 2005;365:1175–88. raphy>