

Global implementation of WHO's multimodal strategy for improvement of hand hygiene: a quasi-experimental study



Benedetta Allegranzi, Angèle Gayet-Ageron, Nizam Damani, Loséni Bengaly, Mary-Louise McLaws, Maria-Luisa Moro, Ziad Memish, Orlando Urroz, Hervé Richet, Julie Storr, Liam Donaldson, Didier Pittet

Summary

Background Health-care-associated infections are a major threat to patient safety worldwide. Transmission is mainly via the hands of health-care workers, but compliance with recommendations is usually low and effective improvement strategies are needed. We assessed the effect of WHO's strategy for improvement of hand hygiene in five countries.

Methods We did a quasi-experimental study between December, 2006, and December, 2008, at six pilot sites (55 departments in 43 hospitals) in Costa Rica, Italy, Mali, Pakistan, and Saudi Arabia. A step-wise approach in four 3–6 month phases was used to implement WHO's strategy and we assessed the hand-hygiene compliance of health-care workers and their knowledge, by questionnaire, of microbial transmission and hand-hygiene principles. We expressed compliance as the proportion of predefined opportunities met by hand-hygiene actions (ie, handwashing or hand rubbing). We assessed long-term sustainability of core strategy activities in April, 2010.

Findings We noted 21884 hand-hygiene opportunities during 1423 sessions before the intervention and 23746 opportunities during 1784 sessions after. Overall compliance increased from 51·0% before the intervention (95% CI 45·1–56·9) to 67·2% after (61·8–72·2). Compliance was independently associated with gross national income per head, with a greater effect of the intervention in low-income and middle-income countries (odds ratio [OR] 4·67, 95% CI 3·16–6·89; $p < 0·0001$) than in high-income countries (2·19, 2·03–2·37; $p < 0·0001$). Implementation had a major effect on compliance of health-care workers across all sites after adjustment for main confounders (OR 2·15, 1·99–2·32). Health-care-workers' knowledge improved at all sites with an increase in the average score from 18·7 (95% CI 17·8–19·7) to 24·7 (23·7–25·6) after educational sessions. 2 years after the intervention, all sites reported ongoing hand-hygiene activities with sustained or further improvement, including national scale-up.

Interpretation Implementation of WHO's hand-hygiene strategy is feasible and sustainable across a range of settings in different countries and leads to significant compliance and knowledge improvement in health-care workers, supporting recommendation for use worldwide.

Funding WHO, University of Geneva Hospitals, the Swiss National Science Foundation, Swiss Society of Public Health Administration and Hospital Pharmacists.

Introduction

Health-care-associated infection is one of the most frequent issues of patient safety worldwide.¹ According to WHO estimates, hundreds of millions of patients are affected each year, leading to substantial morbidity, mortality, and financial losses for health systems.^{1,2} On average, health-care-associated infection affects at least 7% of patients admitted to hospital in high-income countries² and about 15% of those in low-income and middle-income countries.^{2,3} More than 4 million patients are affected every year in Europe, and 37000 deaths occur because of this infection.² According to the US Centers for Disease Control and Prevention, in 2002, at least 1·7 million episodes of health-care-associated infection arose in patients admitted to hospital in the USA, leading to almost 100000 deaths.² Annual costs were estimated to be as high as €7 billion in Europe and US\$6·8 billion in the USA.²

Hand hygiene is the most effective measure to prevent pathogen transmission during health-care delivery.^{4–6} Compliance of health-care workers with best practices varies between settings and countries, but is usually low

and insufficient to ensure patient safety.^{7,8} WHO issued draft guidelines in 2006 to provide evidence and recommendations for improvement of hand hygiene.⁷ These guidelines were based on successful experiences showing a consequent reduction in health-care-associated infection at institutional and regional levels.^{9,10} Because dissemination of guidelines alone is not enough to change practices,¹¹ WHO developed a multimodal implementation strategy and accompanying methods for hand hygiene,¹² which were pilot tested in hospitals worldwide. We assessed the effect of implementation of WHO's hand-hygiene strategy on a range of indicators, including strategy feasibility and adaptability to the local context and available resources.

Methods

Study design

We did a quasi-experimental study between December, 2006, and December, 2008, at six pilot sites (55 departments in 43 hospitals) in Costa Rica, Italy, Mali, Pakistan, and Saudi Arabia (table 1). We implemented WHO's strategy

Lancet Infect Dis 2013;
13: 843–51

Published Online
August 23, 2013
[http://dx.doi.org/10.1016/S1473-3099\(13\)70163-4](http://dx.doi.org/10.1016/S1473-3099(13)70163-4)

See [Comment](#) page 824

Copyright © 2013, World Health Organization. Published by Elsevier Ltd/Inc/BV. All rights reserved.

First Global Patient Safety Challenge, WHO Patient Safety Programme, WHO, Geneva, Switzerland (B Allegranzi MD); Infection Control Programme and WHO Collaborating Centre on Patient Safety, University of Geneva Hospitals and Faculty of Medicine, Geneva, Switzerland (A Gayet-Ageron MD, Prof D Pittet MD); Craigavon Area Hospital, Portadown, UK (N Damani MD); Hôpital Gabriel Touré, Bamako, Mali (L Bengaly PhD); University of New South Wales (UNSW), School of Public Health and Community Medicine, UNSW Medicine, Sydney, NSW, Australia

(Prof M-L McLaws PhD); Agenzia Sanitaria e Sociale Regionale, Bologna, Italy (M-L Moro MD); Public Health Directorate, Ministry of Health, Riyadh, Saudi Arabia (Z Memish MD); Hospital Nacional de Niños, San José, Costa Rica (O Urroz MD); Unité de Recherche sur les Maladies Infectieuses et Tropicales Emergentes, Faculté de Médecine, Université de la Méditerranée, Marseille, France (Prof H Richet MD); Institute of Global Health Innovation, Imperial College London, London, UK (J Storr MBA, L Donaldson MD)

Correspondence to: Prof Didier Pittet, Infection Control Programme and WHO Collaborating Centre on Patient Safety, University of Geneva Hospitals and Faculty of Medicine, 1211 Geneva 14, Switzerland didier.pittet@hcuge.ch

and assessed the hand-hygiene compliance of health-care workers and knowledge of microbial transmission and hand hygiene principles. WHO's hand-hygiene strategy consists of five main components:¹³ (1) ensuring of system change, particularly access of health-care workers to alcohol-based hand rub at the point of patient care to enable recourse to hand rubbing as the preferred method for hand hygiene; (2) training and education of health-care workers; (3) monitoring of practices and provision of feedback about performance; (4) visual reminders in the workplace; and (5) creation of a safety climate within the institution. Inclusion criteria for site selection were no previous hand-hygiene campaign; firm support by senior management and WHO regional and country offices;

agreement to implement WHO's strategy and techniques; and balanced country distribution in terms of geographical location, economy level, resources available, and culture. Five sites were single hospitals in which the strategy was implemented either hospital-wide or in specific wards. One site (Italy) comprised a network of 41 intensive-care units (ICUs) in 38 hospitals with a central coordination ensuring consistent implementation between all units.

All hospitals followed the study protocol and developed locally adapted techniques and initiatives (table 1).

Procedures

All sites received instructions about the WHO hand-hygiene strategy and associated methods and followed a

For more on the pilot sites see http://www.who.int/gpsc/country_work/pilot_sites/introduction/en/index.html

	City, country; WHO Region	Scope of study implementation	Implementation period	Features of the local intervention in addition to the standard implementation	Local method of preparation or adaptation in addition to WHO standard techniques
Hospital Nacional de Niños	San José, Costa Rica; Pan-American Region	Three departments (13 wards): medicine, surgery, paediatrics	March, 2007, to August, 2008	Local production of WHO-recommended ABHR by a private company Intervention launch event chaired by the Minister of Health Patient participation in hand-hygiene promotion	Training film, hand-hygiene song, posters
Network of 41 ICUs	18 cities in Italy*; European Region	38 intensive care departments selected according to the following criteria: participating in the national surveillance system for health-care-associated infection, no other major prevention project concurrent to the study implementation, and explicit consent to provide requested data by the agreed timeline	January, 2007, to December, 2008	Coordination and enquiries system through a web platform Increase of the number of ABHR dispensers at the point of care Fingertip method demonstrations for education of health-care workers Bedside feedback about recorded hand-hygiene compliance	Guide to implementation summary, posters, gadgets (badges, stickers)
Hôpital du Point G	Bamako, Mali; African Region	Five departments (nine wards): internal medicine, surgery, emergency, intensive care, and gynaecology and obstetrics	December, 2006, to June, 2008	Local production of WHO-recommended ABHR at the pilot hospital Intervention launch event chaired by the Minister of Health Separate educational sessions for doctors	Leaflet for launch of hand hygiene campaign, promotional t-shirts
Pakistan Institute of Medical Sciences	Islamabad, Pakistan; Eastern-Mediterranean Region	One intensive-care department (three medical, surgical, and neonatal ICUs)	October, 2007, to November, 2008	Local production of WHO-recommended ABHR at the pilot hospital Gender-specific educational sessions	Translation of posters into Urdu
King Saud Medical Complex	Riyadh, Saudi Arabia; Eastern-Mediterranean Region	Six departments (12 wards): surgery, emergency, intensive care, gynaecology and obstetrics, paediatrics, and others	September, 2007, to December, 2008	Local production of WHO-recommended ABHR at the pilot hospital Gender-specific educational sessions Demonstrations of the hand-hygiene technique Fingertip method demonstrations for education of health-care workers Patient participation in hand-hygiene promotion	Campaign original logo; posters and banners displayed outside the hospital; gadgets (cup and brooch with the campaign logo); screensaver; promotional video, educational brochures, and pocket leaflets for health-care workers, patients (adults and children), and visitors translated into four different languages (Arabic, English, Ragalog, and Urdu); drawing book for children with cartoons; national hand-hygiene guidelines; summary of hand-hygiene guidelines for health-care workers during the pilgrimage season
King Abdulaziz Medical City	Riyadh, Saudi Arabia; Eastern-Mediterranean Region	Two departments (nine intensive-care and surgical wards)	November, 2007, to August, 2008	Gender-specific educational sessions Separate educational sessions for doctors Stands for promotion of hand hygiene throughout the hospital Patient participation in hand-hygiene promotion	Banners and posters, brochures for health-care workers, brochures for patients, pocket leaflets for health-care workers, gadgets (badge)

ABHR=alcohol-based hand rub. ICUs= intensive care units. *Aosta, Bologna, Brescia, Cremona, Cuneo, Firenze, Imperia, Livorno, Lucca, Milano, Padova, Pisa, Torino, Trento, Treviso, Rimini, Ravenna, Vercelli.

Table 1: Characteristics of pilot sites

step-wise implementation approach divided into four 3–6 month phases: preparedness, baseline assessment, intervention, and follow-up assessment.¹³ During phase 1, actions were taken to ensure availability of alcohol-based hand rub at the point of care. At sites where no hand rub was available (Costa Rica and Mali), local production of the hand-rub formulation recommended by WHO was started (table 1).^{7,14,15} Two sites (Saudi Arabia King Saud Medical Complex [KSMC] and Pakistan) already used a commercially produced hand rub, but switched to local production because it was less expensive or regarded as better accepted by health-care workers (table 1).^{7,14,16} Local multidisciplinary committees appointed a study coordinator to deliver training for health-care workers and to ensure correct implementation of the study protocol.

Key intervention activities were started in phase 3 of the implementation approach (table 1). A formal launch was done at all sites with an official ceremony attended by health-care workers and health authorities, ranging from the minister of health to ministerial representatives and senior hospital managers. After the launch, alcohol-based hand rub was distributed at sites where it was not previously available and actions were taken where it was already in use to increase the number of dispensers and to optimise their location at the point of care. Hand-hygiene posters were displayed in all pilot wards. In the following weeks, all health-care workers on these wards attended intensive education sessions based on WHO methods,¹⁷ and hand rubbing was promoted as the gold standard for hand hygiene according to the so-called my five moments for hand hygiene concept.¹⁸ Survey results were presented to staff during educational and feedback sessions to motivate workers and administrators to understand the local situation, appreciate deficiencies, and secure support for sustainability.

In April, 2010, at least 2 years after the intervention, we assessed the status of implementation of core strategies of hand-hygiene activities with a qualitative assessment done through semi-structured telephone interviews with site coordinators using a pre-defined questionnaire.¹⁹

Outcomes

We assessed the main outcome of interest—health workers' hand-hygiene compliance—in phases 2–4 with a validated procedure using the WHO method^{20,21} for direct observation adapted from previous methods.⁹ In brief, two to three unobtrusive observers openly watched staff during 20 min sessions and recorded opportunities and actions for hand hygiene. We defined an opportunity as the occurrence of any indication during the observed care sequences.^{7,20,21} We recorded actions, either handwashing or hand rubbing, according to five indications: before patient contact, before an aseptic task, after risk of exposure to body fluid, after patient contact, and after contact with patient surroundings.^{7,18} All health professionals having direct contact with patients or their

surroundings were observed randomly at pre-defined times on weekdays. Health-care workers were not identified during observation sessions for confidentiality reasons. We expressed hand-hygiene compliance as the proportion of predefined opportunities met by hand-hygiene actions.^{9,18,20,21} As recommended,²¹ each site collected at least 200 opportunities per ward in phases 2 and 4. Because health-care workers contributed more than one hand hygiene opportunity, observations were not independent.

The secondary outcome was the knowledge of health-care workers about microbial transmission during health-care delivery, and key principles for best practices in hand hygiene. A questionnaire developed by WHO (available in several languages), which was partly based on a previously validated version,²² was administered anonymously to health-care workers before and after training sessions.^{15,23} We calculated knowledge questionnaire scores with methods described elsewhere.¹⁵ The maximum score was 37. All data were collected on paper forms and entered into pre-programmed templates with incorporated automated consistency and completeness checks (Epi Info, version 3.4.3).²⁴

We defined intervention feasibility as the capability of each site to implement all five main components of the WHO strategy for hand-hygiene improvement.¹³

	Number of opportunities	Overall compliance with hand hygiene (%)		Odds ratio (95% CI)*	p value
		Before	After		
Pilot site					
All sites†	44 334	51.0% (45.1–56.9)	67.2% (61.8–72.2)	2.15 (1.99–2.32)	<0.0001
Costa Rica‡	2100	39.7% (36.9–42.4)	66.4% (63.6–69.0)	5.82 (3.28–10.32)	<0.0001
Italy†	18 906	55.2% (54.2–56.2)	68.6% (67.6–69.5)	2.27 (2.00–2.57)	<0.0001
Mali‡	3546	8.0% (6.8–9.3)	21.9% (19.9–24.0)	2.40 (1.62–3.55)	<0.0001
Pakistan§	1332	38.2% (35.8–41.6)	58.6% (54.8–62.2)	2.48 (1.75–3.52)	<0.0001
Saudi Arabia KAMC‡	2829	41.7% (38.7–44.7)	61.3% (59.0–63.5)	2.54 (2.00–3.21)	<0.0001
Saudi Arabia KSMC‡	15 621	53.3% (52.1–54.5)	60.9% (59.9–61.9)	1.83 (1.60–2.09)	<0.0001
Patient population¶					
Intensive-care units	28 096	51.7 (46.2–57.2)	66.1 (64.1–68.1)	2.09 (1.90–2.30)	<0.0001
Surgery wards	7383	35.8 (33.0–38.6)	71.4 (68.1–74.4)	2.88 (2.34–3.54)	<0.0001
Emergency wards	2034	26.7 (7.7–61.4)	48.1 (41.3–55.0)	0.99 (0.72–1.36)	0.94
Internal medicine wards	1815	10.9 (1.7–46.7)	85.5 (77.8–90.8)	7.31 (4.10–13.02)	<0.0001
Paediatric wards	1664	49.8 (34.2–65.5)	79.4 (73.3–84.4)	3.99 (2.74–5.81)	<0.0001
Others	3342	71.5 (67.2–75.4)	47.9 (41.3–54.6)	0.71 (0.51–0.98)	0.04

Data in parentheses are 95% CI. Number of opportunities differ to those in the text because of missing data for some of the covariate-adjusted models. KAMC=King Abdulaziz Medical City. KSMC=King Saud Medical Complex. *Odds ratio for before the intervention was used as the reference. †Generalised linear mixed model with three nested clusters: session, inside intensive-care units, inside hospitals. ‡Generalised linear mixed model with two nested clusters: session inside departments. §Generalised linear mixed model with one cluster: session. ¶Generalised linear mixed model with two nested clusters: session, inside hospitals, except for others related to only one hospital where the cluster was the session only.

Table 2: Effect of the WHO intervention strategy on hand-hygiene compliance improvement by pilot site and patient population

irrespective of their level of resources and expertise. We assessed adaptability by considering the range of activities done to implement the strategy in the local context according to cultural and religious aspects and resources available, including the modification of WHO methods or creation of new methods.

Statistical analysis

We analysed hand-hygiene opportunities and actions, compliance by professional category and type of indication, and knowledge scores overall and separately for each pilot site. We estimated the 95% CI for the compliance rate with the exact binomial method. We assessed the global effect of the intervention on hand-hygiene compliance and on knowledge of health-care workers for all sites. For compliance, we used a generalised linear mixed-effects model with a logit link function. We used three nested levels of clustering (from the smallest to the largest) to take into account the correlation of data within three distinct levels: observation session, department, and hospital.

First, we applied the model for hand-hygiene compliance to all merged data from the six pilot sites, then used the model with two or three nested cluster levels (site dependent) for each site. We adjusted the effect of the main predictor for several confounders: professional category, hand-hygiene indications, country income level according to the 2008 World Bank classification,²⁵ availability of alcohol-based hand rub

before the study intervention, and day of the week (taking into account religious factors affecting the establishment of weekend days). In this first model, we assessed interactions between the study period (after vs before intervention) and the following variables: hand-hygiene indications, professional categories, country income level,²⁵ compliance rate (<60% or ≥60%) before the intervention, and percentage-point improvement in compliance after the intervention (<10%, 10–20%, and >20%). We presented the model with statistically significant interaction terms (ie, between study period and country income level and between study period and hand-hygiene indications). Finally, we calculated the compliance rate estimated by the generalised linear mixed-effects model and its 95% CI by study period alone, by study period and professional categories, and by study period and hand-hygiene indications.

We used a linear multilevel model with a two-nested clustering effect (department inside hospital level) to assess the intervention effect on the knowledge score of health-care workers and applied to merged data from the six pilot sites. We adjusted the model for respondents' sociodemographic variables (ie, sex, age group), professional category, and country income level. We tested the interaction between the study period and professional categories and hand-hygiene indications. We estimated the mean knowledge score and its 95% CI before and after the intervention in each pilot site with use of the coefficients obtained from the linear

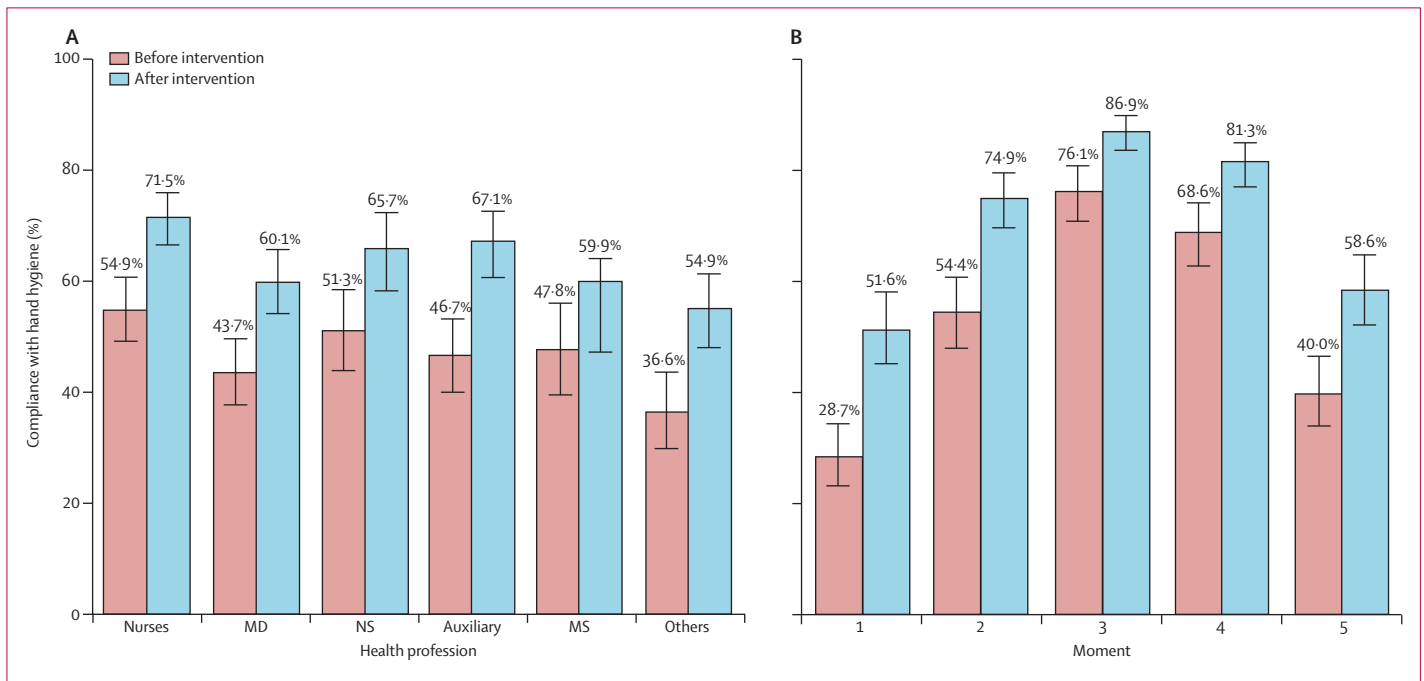


Figure 1: Overall hand-hygiene compliance in pilot sites worldwide before and after implementation of WHO's improvement strategy by category of health professional (A) and hand-hygiene indication (B)

Error bars show 95% CIs around the mean compliance. Observation periods before and after implementation lasted 3–4 months each. Moment 1 was before patient contact, 2 was before an aseptic task, 3 was after risk of exposure to body fluid, 4 was after patient contact, and 5 was after contact with patient surroundings. MD=medical doctor. NS=nursing student. MS=medical student.

multilevel model. *p* values were two-sided. We did statistical analyses with Stata (version IC 12).

Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

For all six pilot sites we recorded 21884 hand-hygiene opportunities during 1423 sessions before the intervention and 23746 opportunities during 1784 sessions after. Overall, we noted an increase in hand-hygiene compliance (table 2). This improvement was significant for each pilot site (table 2; appendix). Importantly, compliance improved significantly for all categories of health professional and for all hand-hygiene indications (all $p < 0.0001$; figure 1).

In high-income countries, compliance averaged 54.3% (95% CI 48.7–59.7) before intervention and 68.5% (63.5–73.1) after ($p < 0.0001$). In low-income and middle-income countries, compliance averaged 22.4% (12.2–37.3) before intervention and 46.1% (29.3–63.9) after ($p < 0.0001$). Hand-hygiene compliance was independently associated with gross national income per head and the effect of the intervention was greater in low-income and middle-income countries (odds ratio [OR] 4.67, 95% CI 3.16–6.89; $p < 0.0001$) than in high-income countries (2.19, 2.03–2.37; $p < 0.0001$) after adjustment for confounders. We recorded a significant increase in recourse to hand rubbing and this method became the preferred one for hand-hygiene action after intervention at all sites (figure 2), apart from one site in Saudi Arabia where handwashing with soap and water remained slightly more frequent (figure 2). Implementation of the WHO strategy had a major effect on measured compliance of health-care workers at all sites after adjustment for the main confounders (table 2). The effect of the intervention was significant in internal medicine, paediatric, and surgery wards, and in intensive-care units (table 2). The effect was also significant for compliance with all hand-hygiene indications ($p = 0.02$). The effect of the intervention on hand-hygiene compliance did not differ significantly among different categories of health professional ($p = 0.22$).

Health-care workers completed the knowledge survey before ($n = 1743$) and after ($n = 1282$) educational sessions at all sites. The average knowledge score improved substantially from 18.7 (95% CI 17.8–19.7) to 24.7 (23.7–25.6) after these sessions at all sites ($p < 0.0001$). We noted significant improvements in knowledge score at all sites, except Costa Rica (figure 3). After adjustment for main confounders, the mean knowledge score significantly increased by 6.1 percentage points (95% CI 5.8–6.5; $p < 0.0001$) after education. The score

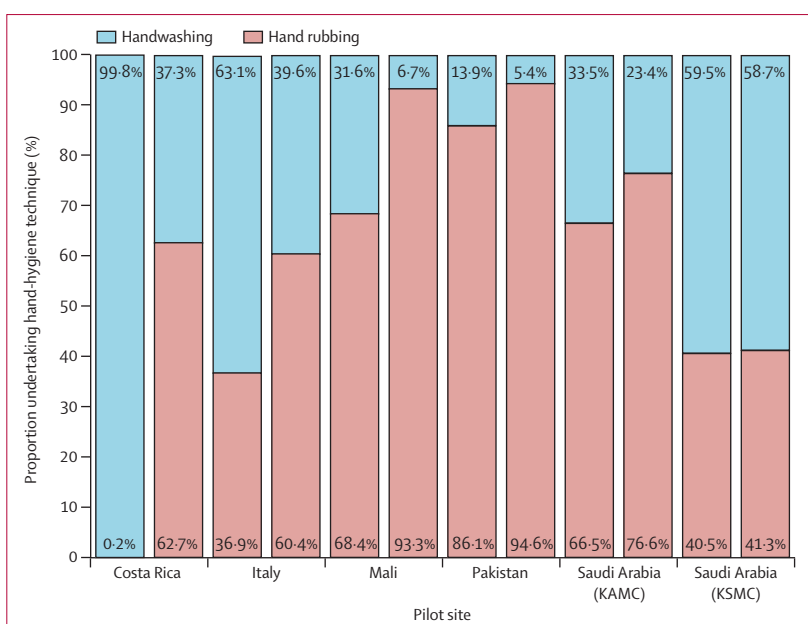


Figure 2: System change after implementation of WHO's hand-hygiene strategy

For each site, left bars show the proportion of health-care workers undertaking the hand-hygiene technique before strategy implementation, and right bars show the proportion after implementation. System change signifies access by health-care workers to alcohol-based hand rub at the point of patient care to enable their recourse to hand rubbing as the preferred method for hand hygiene. $p < 0.0001$ for all sites, except Saudi Arabia KSMC ($p = 0.44$). KAMC=King Abdulaziz Medical City. KSMC=King Saud Medical Complex.

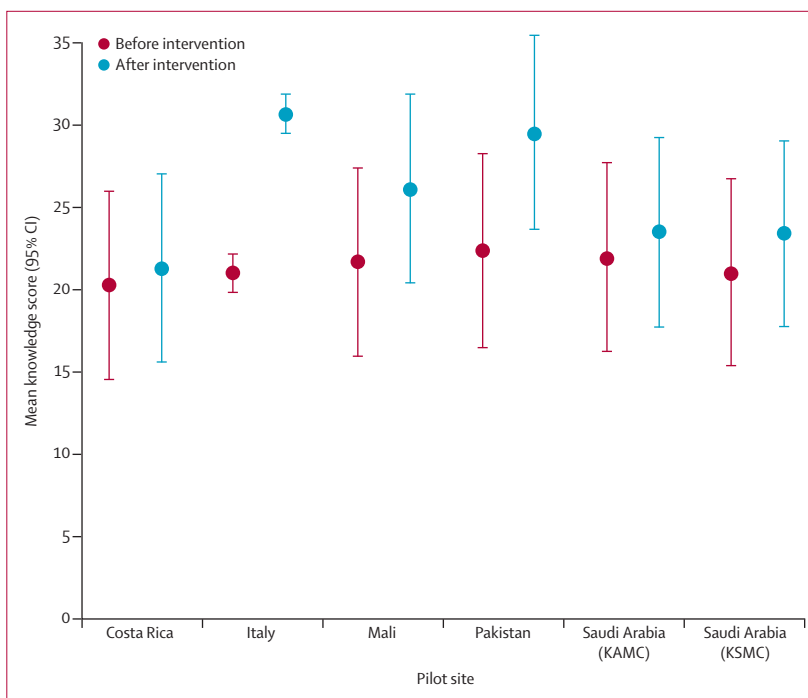


Figure 3: Knowledge of hand hygiene before and after training sessions

Data before and after training sessions were available for only a subgroup (26 [43%] of 41) intensive-care units in Italy. KAMC=King Abdulaziz Medical City. KSMC=King Saud Medical Complex.

was independently associated with age groups and professional categories (table 3). After the intervention, knowledge increased significantly in nurses, nursing

See Online for appendix

auxiliaries, and doctors (all $p < 0.001$) compared with other professions ($p = 0.35$). After adjustment for main confounders, score improvement was more important in nurses and nursing auxiliaries than in doctors (table 3). Neither gross national income nor sex significantly affected knowledge improvement (table 3).

In 2010, 2 years after the intervention, hand-hygiene promotion was ongoing at all sites (table 4) and had even extended to other wards (data not shown). Key activities were regularly repeated at most sites (table 4). Improvement in compliance of hand hygiene was sustained or had progressed even further where monitored (data not shown). Successful pilot test results stimulated strategy implementation in other hospitals or the launch or sustainment of nationwide hand-hygiene campaigns in all countries, apart from Pakistan (table 4).

Discussion

Our findings show that implementation of WHO's multimodal promotion strategy was associated with a significant increase in hand-hygiene compliance and knowledge for all health-care workers across facilities in a range of countries worldwide. Despite different cultural and educational backgrounds, levels of progress and resources, health-care system, and patient population, WHO's recommendations for hand hygiene in health care were successfully translated into practice, as shown by the significant improvement in the primary and secondary outcomes assessed (panel).⁷ Because these results were obtained mainly with use of local resources and expertise, and with support of WHO guidance documents and techniques, our study shows the feasibility of the WHO strategy in various health-care settings in different countries. The range of creative and successful activities and adaptation or development of instruments used during the strategy implementation shows its adaptability to the local context according to habits, culture, and resources available. These elements support the implementation of the strategy and techniques in more than 15 700 health-care settings in 168 countries worldwide between May, 2009, and April, 2013.²⁶

Our data show that health-care workers did not undertake hand-hygiene actions in roughly one of every two opportunities before the intervention, which supports previous evidence.^{7,8,27,28} Compliance levels varied greatly between hospitals and were lowest in low-income and middle-income countries. The highest rates were with the key indications that protect health-care workers from microbial contamination and infection⁴—ie, after exposure risk with body fluids and after patient contact. By contrast, compliance with indications specifically protecting the patient was significantly lower before the intervention—ie, before patient contact and before clean and aseptic tasks. This instinctive tendency towards privileging of oneself rather than towards patient protection has been identified repeatedly.^{7,27,29,30}

Compliance with the recommendation to undertake hand hygiene after contact with surfaces and objects in the patient surroundings was poorly understood by health-care workers and neglected before the intervention. Interventions to induce behavioural change should take into account these compliance aspects. This strategic approach was implemented at all sites through crucial evaluation of local performance data and interpretative feedback to health-care workers. The success of our intervention shows that real-life observations of practices are fundamental to confront health-care workers with their actual behaviour and responsibilities and to call for accountability with regard to patient safety.

Hand-hygiene promotion was associated with significant improvement across all specific indications and professional categories. Similar to other reports,^{7,8,31}

	Beta coefficient	95% CI	p value
Professional categories by study period*			
Nurses (vs nurses before the intervention)	6.77	6.31–7.22	<0.0001
Nursing auxiliaries (vs nursing auxiliaries before)	5.76	4.62–6.89	<0.0001
Doctors (vs doctors before)	5.06	4.42–5.70	<0.0001
Other categories (vs other categories before)	2.06	–1.39–5.51	0.24
Sex			
Male (vs female)	–0.17	–0.59–0.26	0.45
Gross national income per head			
High income (vs low income and middle income)	0.55	–3.30–4.40	0.78
Age (years)			
30–36 years (vs <30)	0.25	–0.29–0.78	0.37
36–44 years (vs <30)	0.53	–0.02–1.08	0.06
≥44 years (vs <30)	–0.16	–0.70–0.38	0.57

Generalised linear mixed model adjusted for main confounders and with interaction between study period and professional categories. Data included in the model: 2630 questionnaires from 45 departments in 33 hospitals. 2630 health-care workers participated and were distributed as follows: nurses (59.0%), nursing assistants (9.5%), doctors (30.5%), and health-care workers from other categories (1%). Italian data before and after the intervention were available only from 26 (63%) of 41 intensive-care units.

Table 3: Global effect of the WHO intervention strategy on the knowledge of health-care workers of pathogen cross-transmission and hand-hygiene across all pilot sites

	Number of sites (n/N)	Site
Strategy implementation continued	6/6	All
Alcohol-based hand rub continued to be available*	5/5	All
Educational sessions repeated at least once a year*	5/5	All
Regular monitoring and feedback of hand-hygiene compliance*	4/5	Costa Rica, Mali, Saudi KAMC and KSMC
Poster use continued and refreshed*	5/5	All
Implementation expanded to other hospitals in the country	5/6	Costa Rica, Italy, Mali, Saudi KAMC and KSMC
Launch or sustainment of a national campaign following pilot testing	4/6	Costa Rica, Italy, Saudi KAMC and KSMC

KAMC=King Abdulaziz Medical City. KSMC=King Saud Medical Complex. *Data not available for all hospitals participating in the Italian pilot site.

Table 4: Indicators of long-term sustainability of implementation of the WHO strategy in pilot sites

nurses had the highest compliance across all pilot sites before the intervention and doctors the lowest, apart from in Costa Rica and Mali. During the intervention, strong feedback was given to staff on the basis of local data, with an emphasis on differences between professional categories. After the intervention, compliance remained higher in nurses than in doctors across all test sites, apart from Mali. We attributed the initial better performance of doctors than nurses in Costa Rica and Mali to more appropriate education and a stronger perception of their professional role and responsibilities in the local social and cultural context.¹⁵

The effect of the intervention on hand-hygiene compliance was higher in low-income and middle-income countries than in high-income countries. Overall compliance before the intervention was significantly lower in low-income and middle-income countries than in high-income countries. As expected, achievement of a greater improvement in low-income and middle-income countries than in high-income countries might have been easier when starting from very low levels of compliance. In settings where basic knowledge and resources enabling hand hygiene are scarce, the contribution of innovation to bridge the gaps could lead to immediate and substantial progress. Such findings are very encouraging for settings with restricted resources and many other competing priorities in health care because they show a return on investment through application of a fairly simple multimodal intervention addressing real needs.

Knowledge of health-care workers significantly improved after the intervention in nurses, nursing auxiliaries, and doctors across all sites. Feedback of local data for defective behaviour, and the inappropriate perception of high hand-hygiene compliance (self-estimated at about 80% on average), were essential to evoke interest in acquisition of improved knowledge and to induce behavioural change. Clear explanations of the ultimate aims of specific hand-hygiene indications within the transmission dynamics, as emphasised in educational sessions and supported by scientific evidence, were also very influential.^{4,17,18} These findings suggest that improvement of the knowledge of health-care workers about health-care-associated infections and hand-hygiene principles contributes to achievement of best practices.

System change, represented by the preferred recourse to alcohol-based hand rubs after implementation of the WHO strategy, was a key determinant of practice improvement. Facilities can achieve system change either by commercial procurement of these hand rubs, according to key selection criteria,³² or by local production, according to WHO guidance instructions.¹⁴ In four sites (Costa Rica, Mali, Pakistan, and Saudi Arabia KSMC), WHO-recommended alcohol-based hand rubs were produced locally to either overcome serious infrastructure deficiencies or to replace previously available, but more

Panel: Research in context

Systematic review

We searched Medline for papers published between Jan 1, 2008, and Dec 31, 2012, with the terms "hand hygiene" [MeSH] OR "hand washing" OR "hand rubbing" OR "alcohol-based handrub" AND "intervention" OR "compliance improvement" OR "promotion" OR "implementation strategy" without language restriction. We used WHO's guidelines on hand hygiene in health care issued in 2009,⁷ which include systematic reviews on the topic, as a reference for the time before our search. We also searched the reference lists of identified articles for further relevant papers, and the personal libraries of authors (DP, BA). We selected potentially suitable papers according to the title, reviewed the abstracts, and read the full manuscript when pertinent to the topic. We identified several studies implementing strategies for hand-hygiene improvement and reporting data of compliance improvement. The most recently used multimodal interventions included some of the elements of the WHO strategy, but very few included all five elements. No multicentre, multicountry study, and no paper combining outcome assessment of both hand-hygiene compliance and health-care-workers' knowledge in more than one hospital were available.

Interpretation

To our knowledge, our study is the first to assess the implementation of WHO's multimodal strategy for improvement of hand hygiene in a large study population from sites in several countries in different continents. The intervention was associated with a significant improvement of hand-hygiene compliance in all sites, across all professional categories, and for all indications for hand hygiene. Furthermore, after adjustment for main confounders, the knowledge of health-care workers significantly increased after education. Our findings show the feasibility of implementation irrespective of the level of resources and expertise available at the facility. Further research, including assessment of effect on health-care-associated infection and cost-effectiveness aspects, would add value to the available evidence.

expensive, commercial products. A separate survey done at these sites and other settings worldwide⁷ showed that local production was easy to do, low cost, did not need specific expertise, and had good quality-control results.

The originality and uniqueness of our work are shown in the large study population and the participation of countries representing various regions with different cultural backgrounds, economic levels, health systems, and degrees of implementation of infection control. To take this diversity into account, we applied multilevel regression models, including nested clustering levels. This approach accounts for the complexity of datasets with some degree of intracorrelation and intercorrelation, and captures the variance between clusters, while estimating the global effect of WHO's programme in this heterogeneous study population.

Long-term sustainability of the hand-hygiene promotion strategy was shown by the continuation and reinforcement of core activities over time. The successful results from the test sites have encouraged the spread of the WHO strategy to other facilities, including the launch of nationwide initiatives and large-scale production of the WHO-recommended alcohol-based hand rub at the national level.³³ We considered potential unintended consequences of implementation of new strategies and new quality standards in various countries with different

systems, resources, and cultural backgrounds. Among these consequences are the risks of resistance to change, scarcity of continuous resources for sustainability, and cultural and religious barriers preventing the adoption, scale-up, and maintenance of the innovation. Findings from previous reports^{12,15,33,34} and results from this intervention, including sustained activities for promotion of hand hygiene with scale-up in most pilot sites after at least 2 years, strongly suggest the absence of unintended consequences.

Our study has limitations. First, the scope of the intervention varied across pilot sites and was based on local decisions, dependent on feasibility and available resources and expertise. For this reason, we were unable to uniformly include control wards. Second, because the identity of health-care workers was not recorded for confidentiality reasons, we could not include the participant level in the random part of our statistical models, and regarded all hand-hygiene observations and the knowledge score before and after the intervention as independent. Nonetheless, our mixed-effect regression models are conservative and therefore not considering the participant level should not change the direction of the observed effect. Third, we could not measure the effect of the intervention on rates of health-care-associated infection because surveillance was not in place in most pilot sites. Of note, the study was neither designed nor powered to monitor health-care-associated infection and we chose instead to invest available resources in support of the intervention. Finally, we did not include assessment of cost-effectiveness in the study objectives, although such data would have added value to our findings. Previous studies have shown that successful multimodal strategies for improvement of hand hygiene are cost-effective and that the financial investment for a campaign, including system change, is negligible compared with the cost of health-care-associated infection that can be prevented.^{7,35}

Our findings represent powerful support for decision and policy makers to enforce implementation of WHO's strategy, which is recommended by both the US Centers for Disease Control and Prevention and the European Centre for Disease Prevention and Control, Joint Commission International and accredited bodies, most professional organisations, and many governments worldwide, including 50 national hand-hygiene campaigns.^{33,36}

Contributors

BA and DP designed the study, supervised study implementation, contributed to data analysis, and wrote the paper. AG-A led the data analysis and contributed to the writing of the paper. BA, LB, ND, M-LM, ZM, OU, HR, and JS coordinated project implementation and data collection. MLM contributed to data analysis and interpretation. LB, ND, MLM, ZM, OU, HR, JS, and LD provided crucial revision of the manuscript for important intellectual content.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

Funding support for this research came from WHO, University of Geneva Hospitals, and the Swiss Society of Public Health Administration and Hospital Pharmacists. The authors acknowledge funding for partial financial support for activities in hand-hygiene research from the Swiss National Science Foundation (grant number 3200BO-122324/1). We thank Elias Tannous (King Abdulaziz Medical City, Riyadh, Saudi Arabia) and Saleem Abbasi (Pakistan Institute of Medical Sciences, Islamabad, Pakistan) for their support with data collection; Hugo Sax (University of Zurich Hospitals, Zurich, Switzerland) and Marie-Noelle Chraiti (University of Geneva Hospitals, Geneva, Switzerland) for their technical contribution to the development of WHO techniques; Rosemary Sudan (University of Geneva Hospitals and Faculty of Medicine, Geneva, Switzerland) for her substantial editing contribution; and Thomas Perneger and Christophe Combescure (University of Geneva Hospitals, Geneva, Switzerland) for their advice regarding statistical analyses and interpretation of the results. WHO takes no responsibility for the information provided or the views expressed in this paper.

References

- Burke JP. Infection control—a problem for patient safety. *N Engl J Med* 2003; **348**: 651–56.
- WHO. Report on the burden of endemic health care-associated infection worldwide. 2011. http://whqlibdoc.who.int/publications/2011/9789241501507_eng.pdf (accessed May 13, 2013).
- Allegranzi B, Nejad SB, Combescure C, et al. Burden of endemic health care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011; **377**: 228–41.
- 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.
- 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** (suppl 1): S18–27.
- Allegranzi B, Pittet D. The role of hand hygiene in healthcare-associated infection prevention. *J Hosp Infect* 2009; **73**: 305–15.
- WHO. WHO guidelines on hand hygiene in health care. 2009. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf (accessed May 13, 2013).
- 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.
- Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet* 2000; **356**: 1307–12.
- Grayson ML, Jarvie LJ, Martin R, et al. Significant reductions in methicillin-resistant *Staphylococcus aureus* bacteraemia and clinical isolates associated with a multisite, hand hygiene culture-change program and subsequent successful statewide roll-out. *Med J Aust* 2008; **188**: 633–40.
- Larson EL, Quiros D, Lin SX. Dissemination of the CDC's hand hygiene guideline and impact on infection rates. *Am J Infect Control* 2007; **35**: 666–75.
- Pittet D, Allegranzi B, Storr J. The WHO Clean care is Safer Care programme: field testing to enhance sustainability and spread of hand hygiene improvements. *J Infect Public Health* 2008; **1**: 4–10.
- WHO. Guide to implementation: a guide to the implementation of the WHO Multimodal Hand Hygiene Improvement Strategy. 2009. http://www.who.int/gpsc/5may/Guide_to_Implementation.pdf (accessed May 13, 2013).
- WHO. Guide to local production: WHO-recommended handrub formulations. 2010. http://www.who.int/gpsc/5may/Guide_to_Local_Production.pdf (accessed May 13, 2013).
- Allegranzi B, Sax H, Bengaly L, 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.
- Pittet D, Allegranzi B, Sax H, Chraiti 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.

- 17 WHO. Tools for training and education. 2009. http://www.who.int/gpsc/5may/tools/training_education/en/ (accessed May 13, 2013).
- 18 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.
- 19 Allegranzi B, S Bagheri Nejad, Dharan S, et al. Indicators of long-term sustainability of hand hygiene improvement and barriers in healthcare settings worldwide. *BMC Proc* 2011; **5** (suppl 6): P262.
- 20 Sax H, Allegranzi B, Chraiti MN, Boyce J, Larson E, Pittet D. The World Health Organization hand hygiene observation method. *Am J Infect Control* 2009; **37**: 827–34.
- 21 WHO. Hand hygiene technical reference manual. 2009. http://www.who.int/gpsc/5may/tools/evaluation_feedback/en/index.html (accessed May 13, 2013).
- 22 Sax H, Perneger T, Hugonnet S, Herrault P, Chraiti MN, Pittet D. Knowledge of standard and isolation precautions in a large teaching hospital. *Infect Control Hosp Epidemiol* 2005; **26**: 298–304.
- 23 WHO. Hand hygiene knowledge questionnaire for health-care workers. 2009. http://www.who.int/gpsc/5may/tools/evaluation_feedback/en/index.html (accessed May 13, 2013).
- 24 WHO. Data entry analysis tools. Tools for evaluation and feedback. 2009. http://www.who.int/gpsc/5may/tools/evaluation_feedback/en/index.html (accessed May 13, 2013).
- 25 World Bank. World Bank list of economies. July 18. 2011. <http://data.worldbank.org/news/2010-GNI-income-classifications> (accessed May 13, 2013).
- 26 WHO. Save lives: clean your hands—WHO's global annual campaign. 2012. http://www.who.int/gpsc/5may/registration_update/en/index.html (accessed May 13, 2013).
- 27 Lee A, Chalfine A, Daikos GL, et al. Hand hygiene practices and adherence determinants in surgical wards across Europe and Israel: a multicenter observational study. *Am J Infect Control* 2011; **39**: 517–20.
- 28 WHO. Hand hygiene moment 1—global observation survey. Summary report 2010. September, 2010. http://www.who.int/gpsc/5may/news/ps_moment1_results_2010_en.pdf (accessed May 18, 2013).
- 29 Cheng VC, Tai JW, Ho SK, et al. Introduction of an electronic monitoring system for monitoring compliance with moments 1 and 4 of the WHO "My 5 Moments for Hand Hygiene" methodology. *BMC Infect Dis* 2011; **11**: 151.
- 30 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.
- 31 Pittet D, Simon A, Hugonnet S, Pessoa-Silva CL, Sauvan V, Perneger TV. Hand hygiene among physicians: performance, beliefs, and perceptions. *Ann Intern Med* 2004; **141**: 1–8.
- 32 WHO. Alcohol-based handrub planning and costing tool. 2010. http://www.who.int/gpsc/5may/tools/system_change/en/ (accessed May 13, 2013).
- 33 Mathai E, Allegranzi B, Kilpatrick C, Bagheri Nejad S, Graafmans W, Pittet D. Promoting hand hygiene in healthcare through national/subnational campaigns. *J Hosp Infect* 2011; **77**: 294–98.
- 34 Ahmed QA, Memish ZA, Allegranzi B, Pittet D. Muslim health-care workers and alcohol-based handrubs. *Lancet* 2006; **367**: 1025–27.
- 35 Pittet D, Sax H, Hugonnet S, Harbarth S. Cost implications of successful hand hygiene promotion. *Infect Control Hosp Epidemiol* 2004; **25**: 264–66.
- 36 WHO. WHO clean hands net—a network of campaigning countries. 2012. http://www.who.int/gpsc/national_campaigns/en/ (accessed May 13, 2013).