



REVIEW

# 'My five moments for hand hygiene': a user-centred design approach to understand, train, monitor and report hand hygiene

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**Summary** Hand hygiene is a core element of patient safety for the prevention of healthcare-associated infections and the spread of antimicrobial resistance. Its promotion represents a challenge that requires a multi-modal strategy using a clear, robust and simple conceptual framework. The World Health Organization First Global Patient Safety Challenge 'Clean Care is Safer Care' has expanded educational and promotional tools developed initially for the Swiss national hand hygiene campaign for worldwide use. Development methodology involved a user-centred design approach incorporating strategies of human factors engineering, cognitive behaviour science and elements of social marketing, followed by an iterative prototype test phase within the target population. This research resulted in a concept called 'My five moments for hand hygiene'. It describes the fundamental reference points for healthcare workers (HCWs) in a time–space framework and designates the moments when hand hygiene is required to effectively interrupt microbial transmission during the care sequence. The concept applies to a wide range of patient care activities and healthcare settings. It proposes a unified vision for trainers, observers and HCWs that should facilitate education, minimize inter-individual variation and resource use, and increase adherence. 'My five moments for hand hygiene'

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bridges the gap between scientific evidence and daily health practice and provides a solid basis to understand, teach, monitor and report hand hygiene practices.

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## Introduction

Healthcare-associated infections (HCAs) represent a major risk to patient safety and contribute towards suffering, prolongation of hospital stay, cost and mortality.<sup>1,2</sup> Hand hygiene is the core element to protect patients against HCAs and colonisation with multi-resistant micro-organisms.<sup>3</sup> Cleansing hands with alcohol-based hand rub is a simple and undemanding procedure that requires only a few seconds.<sup>4,5</sup> If hand rub is easily available at each point of care, hand hygiene can also easily be integrated in the natural workflow – even in high-density care settings.<sup>6–8</sup> However, most healthcare workers (HCWs) practice hand hygiene less than half as often as they should.<sup>9,10</sup>

Reasons for neglecting hand hygiene have been investigated and include forgetfulness, fear of skin damage, lack of time due to other patient care priorities, and scarce or inconvenient access to hand rub and sinks.<sup>11,12</sup> However, one essential element is frequently overlooked: the quality of the information and training dispensed to HCWs to explain why, when and how to apply hand hygiene during routine care activity. Yet, there is accumulating evidence that failure to comply with good practice is often due to poor design, whether it be device-related, human–machine interfaces or, importantly, process design.<sup>13–15</sup> This includes misleading language, complicated descriptions, or poor definition of target outcomes.<sup>16</sup>

Several disciplines such as human factors engineering and ergonomics, social marketing, pedagogy, and communication science have been found to be helpful in bridging the gap between scientific literature and user-centred, error-proof products and processes.<sup>17–20</sup> When measured against these standards, the concept of hand hygiene has been poorly assessed from these perspectives until now. Even infection control experts have difficulties in reaching a consensus on the relative risk levels of different care activities and how to best define key moments for hand hygiene action.

Building on the longstanding experience at the University of Geneva Hospitals and work on tool development in the framework of the Swiss national hand hygiene campaign and the WHO Global

Patient Safety Challenge ‘Clean Care is Safer Care’, we developed a user-centred concept for recognising when hand hygiene should be done, as well as training, performance assessment and reporting.<sup>6–8,11,21–32</sup> We describe here the design process of the concept, the rationale for elements included, and its potential practical use.

## Requirements and development

### Requirement specifications for a user-centred hand hygiene concept

The main specifications for the concept are given in [Table I](#). Importantly, it must result in a minimal complexity and density of hand hygiene actions, integrate well into a natural workflow, but still attain a maximum preventive effect. For applicability across a wide range of care settings and healthcare professions, it must also create a unified approach without losing the necessary detail to produce meaningful data for risk analysis and feedback.

The concept should be absolutely congruent in design and meaning to trainers, observers and the observed HCWs. This has the dual purpose of avoiding any lack of clarity by an expert–lay person gap and to cut down on training time requirement and expenditure. Moreover, the sharing of a unified vision should lead to a strong sense of ownership.<sup>33</sup> Additionally, concept robustness is equally instrumental both to avoid inter-observer variation and to guarantee intra-hospital,

**Table I** Requirement specifications for a user-centred hand hygiene application concept

Consistent with evidence-based risk assessment of healthcare-associated infections and spread of multi-resistant micro-organisms
Stealth integration into a natural care workflow
Easy to learn
Logical clarity of the concept
Applicable in a wide range of healthcare settings
Minimising the density of the need for hand hygiene
Maximal concept congruence between trainers, observers, and healthcare workers

inter-hospital and international comparisons and communication.

Finally, characteristics known to neuroscience to increase learning and facilitate uptake such as limited number of items, clustering of items, symmetry, rhythm, plain and meaningful terminology, colour codes, clarity and logic, high signal-to-noise ratio, and correspondence to pre-existing concepts in the concerned population were applied during the design process whenever possible.<sup>34–36</sup>

### Healthcare-associated colonisation and infection: the negative outcome targets

For conceptual clarity, it is useful to revisit two distinct outcomes of transmission pathways. Colonisation denotes the presence of micro-organisms on body sites without invading the tissue and without triggering a symptomatic host defence reaction; infection denotes tissue invasion of micro-organisms triggering an inflammatory host response.<sup>37</sup>

Transmission of micro-organisms from the healthcare environment (e.g. furniture, equipment, walls, doors, documents, neighbouring patients, etc.) to a patient most often results in cross-colonisation and not in infection.<sup>38,39</sup> Cross-colonisation with multi-resistant micro-organisms represents an important target for prevention because it contributes to increasing antimicrobial resistance and the reservoir of potential pathogens.<sup>40,41</sup>

With respect to cross-colonisation, it is important to recognise three facts: first, colonised or infected patients represent the main reservoir for healthcare-associated micro-organisms; second, the environment in the healthcare facility contains a wide variety of different healthcare-associated micro-organisms and represents a secondary source for transmission; and third, the immediate patient environment becomes colonised by the patient flora.<sup>42–47</sup> Cross-transmission can result in exogenous HCAI, in particular if the patient's defence against the implicated micro-organism is low or if it is directly introduced into a vulnerable body site, or mucous membrane.<sup>48</sup>

Most HCAIs, however, are of an endogenous nature, and due to micro-organisms already colonising the patient before the onset of infection.<sup>39,49</sup> This implies that hands may play a role in this process by transferring micro-organisms from a colonised body site to a 'clean' one in the same patient, e.g. from the perineum to a tracheal tube, or from the leg skin to a catheter hub.<sup>3</sup> Care-induced breaks of physical and biological defence mechanisms by invasive procedures and devices represent risk factors for infection.

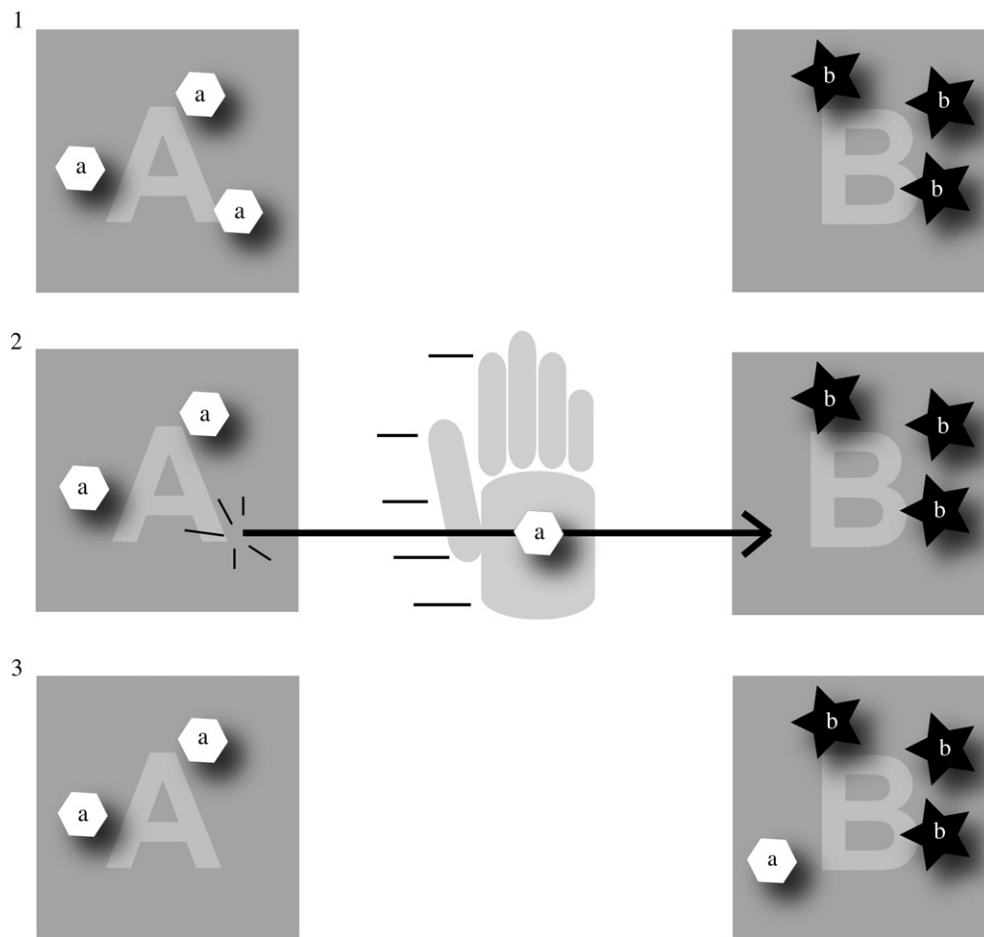
In addition to patient colonisation and/or infection, two additional negative outcomes are targeted by hand hygiene: infection in HCWs with pathogens contained in body fluids and cross-colonisation of inanimate objects in the healthcare environment and colonisation of HCWs by patient flora.

In summary, four negative outcomes constitute the prevention target for hand hygiene: (i) cross-colonisation of patients; (ii) endogenous and exogenous infection in patients; (iii) infection in HCWs; and (iv) cross-colonisation of the healthcare environment including HCWs.

### The core element of hand transmission

During daily practice, HCWs' hands typically touch a continuous sequence of surfaces and substances including inanimate objects, patients' intact or non-intact skin, mucous membranes, food, waste, body fluids and the HCW's own body. The total number of hand exposures in a healthcare facility might reach as many as several tens of thousands per day. With each hand-to-surface exposure a bidirectional exchange of micro-organisms between hands and the touched object occurs and the transient hand-carried flora is thus continuously changing. In this way, micro-organisms can spread throughout a healthcare environment within a few hours.<sup>50,51</sup>

An evidence-based hand transmission model has been described elsewhere.<sup>3,27</sup> In brief, we illustrate the core elements stripped down to their simplest level in Figure 1. Effective hand cleansing can prevent transmission of micro-organisms from surface A to surface B if applied at any moment during hand transition between the two surfaces. Typically, surface A could be a door handle colonised by meticillin-resistant *Staphylococcus aureus* (MRSA) and surface B the skin of a patient. If transmission of micro-organisms between A and B would result in one of the four negative outcomes detailed above, the corresponding hand transition time between the surfaces is usually called a 'hand hygiene opportunity'. If avoidable, not touching A or B or both would be another very effective way of preventing cross-contamination and infection. Touching twice in a row surface B would equally not generate a need for hand hygiene. Hence, it follows clearly that the necessity for hand hygiene is defined by a core element of hand transmission consisting in a donor surface, a receptor surface and hand transition from the first to the second. Merely describing a hand hygiene opportunity as a moment before executing a certain care task is an oversimplification and will be discussed in a further section.



**Figure 1** Core element of hand transmission. (1) Donor surface 'A' contains micro-organisms 'a'; receptor surface 'B' micro-organisms 'b'. (2) A hand picks up a micro-organism 'a' from donor surface 'A' and carries it over to receptor surface 'B', no hand hygiene action performed. (3) Receptor surface 'B' is now cross-contaminated with micro-organism 'a' in addition to original flora 'b'. The arrow marks the opportunity for hand hygiene, e.g. the time period and geographical dislocation within which hand hygiene will prevent cross-transmission; the indications for hand hygiene are determined by the need to protect surface 'B' against colonisation with 'a' – the preventable negative outcome in this example.

### Conceptualisation of the risk: two zones, two critical sites

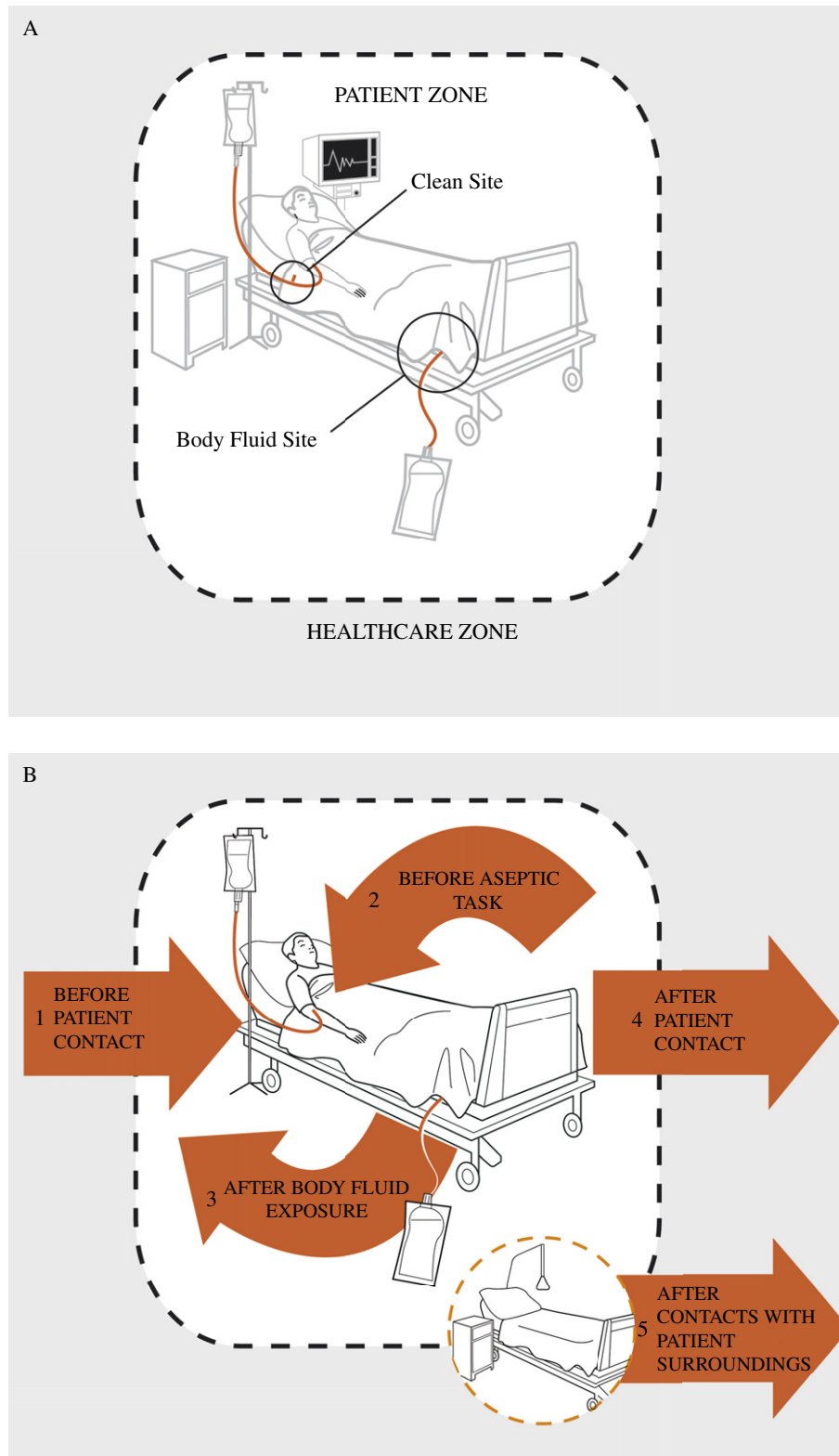
To achieve the objective of creating a user-centred concept, we opted for a direct translation of the evidence-based hand transmission model described above to a practical description of hand hygiene indications. The terms 'zone' and 'critical sites' were introduced to allow a 'geographical' visualisation of key moments for hand hygiene (Figure 2A).

Focusing on a single patient, the healthcare setting is divided into two virtual geographical areas, the patient zone and the healthcare zone (Figure 2A and B).

The patient zone contains the patient X and his/her immediate surroundings. This typically includes the intact skin of the patient and all inanimate surfaces that are touched by or in direct

physical contact with the patient such as the bed rails, bedside table, bed linen and infusion tubing and other medical equipment. It further contains surfaces frequently touched by HCWs while caring for the patient such as monitors, knobs and buttons, and other 'high frequency' touch surfaces within the patient zone. The model assumes that the patient flora rapidly contaminates the entire patient zone, but that it is being cleaned between patient admissions.

The healthcare zone contains all surfaces outside the patient zone of patient X, i.e. all other patients and their patient zones and the healthcare facility environment. Conceptually, the healthcare zone is contaminated with micro-organisms that might be foreign and potentially harmful to patient X, either because they are multi-resistant or because their transmission might result in exogenous infection.



**Figure 2** Unified visuals for 'My five moments for hand hygiene'. Patient zone defined as the patient's intact skin and his/her immediate surroundings colonised by the patient flora and healthcare zone containing all other surfaces. (A) Symbols for clean site and body fluid site, two critical sites for hand hygiene within the patient zone. (B) Zones and sites with inserted time-space representation of 'My five moments for hand hygiene'.

Within the patient zone, two critical sites should be distinguished (Figure 2A): clean sites corresponding to body sites or medical devices that have to be protected against micro-organisms potentially leading to HCAs, and body fluid sites leading to hand exposure to body fluids and blood-borne pathogens. Critical sites may co-exist: drawing blood for example would result in a clean site and a body fluid site at the same time at the site of needle perforation of the skin. The added value of critical sites lies in their potential use in visual material and training: risk-prone tasks become geographically located and hence more palpable.

## The concept and its practical application

### 'My five moments for hand hygiene' explained

The geographical representation of the two zones and the two critical sites (Figure 2A) is useful to introduce the five moments for hand hygiene. The correlation between these five moments and the indications for hand hygiene according to WHO *Guidelines on Hand Hygiene in Healthcare*<sup>27</sup> is given in Table II. To further facilitate ease of recall and expand the ergonomic dimension, the five moments for hand hygiene are numbered according to the habitual care workflow (Figure 2B).

#### Moment 1: Before patient contact

From the two-zone concept, a major moment for hand hygiene is naturally deduced. It occurs between the last hand-to-surface contact with an object belonging to the healthcare zone and the first within the patient zone – best visualised by crossing the virtual line between the two zones. Hand hygiene at this moment will mainly prevent cross-colonisation of the patient and, occasionally, exogenous infection. A concrete example would be the temporal period between touching the door handle and shaking the patient's hand: the door handle belongs to the healthcare zone and the patient's hand to the patient zone.

#### Moment 2: Before an aseptic task

Once within the patient zone, usually after a hand exposure to the patient's intact skin, clothes or any other object, the HCW might engage in an aseptic task on a clean site such as opening a venous access line, giving an injection, or performing wound care.

Importantly, hand hygiene required at this moment aims at preventing colonisation and HCAI. In line with the predominantly endogenous aetiology of these infections, hand hygiene is taking place between the last exposure to a surface, even within the patient zone and immediately before access to a clean site. This is important because HCWs customarily touch another surface within the patient zone before contact with a clean site.

For some tasks on clean sites, e.g. lumbar puncture, surgical procedures, tracheal suctioning, etc., the use of gloves is standard procedure. In this case, hand hygiene is required before donning gloves because gloves alone may not prevent contamination entirely.<sup>25,52–54</sup>

#### Moment 3: After body fluid exposure risk

After a care task associated with a risk to expose hands to body fluids, e.g. after accessing a body fluid site, hand hygiene is required instantly and must take place before any hand-to-surface exposure, even within the same patient zone. This has a double objective. First and most importantly, it reduces the risk of colonisation or infection of HCWs with infectious agents which can occur even in the absence of visible soiling. Second, it reduces the risk of a transmission of micro-organisms from a 'colonised' to a 'clean' body site within the same patient.<sup>3,27</sup> This routine moment for hand hygiene concerns all care actions associated with a risk of body fluid exposure and is not identical to the hopefully very rare case of accidental visible soiling calling for immediate handwashing.<sup>27</sup> Often, clean sites coincide with body fluid sites (Table II).

Disposable gloves are meant to be used as a 'second skin' to prevent exposure of hands to body fluids. However, hands are not sufficiently protected by gloves and hand hygiene is strongly recommended after glove removal.<sup>27</sup> Even if glove removal represents a strong cue to hand hygiene action, the concept chooses to identify this moment for hand hygiene with the associated risk (e.g. exposure to body fluids) rather than with the additional protective action (e.g. glove use). This has the double advantage of being more consistent with the risk-driven logic of the overall concept and to cover all times when gloves are not worn.<sup>55</sup>

#### Moment 4: After patient contact

After a care sequence, when leaving the patient zone and before touching an object in the healthcare zone, hand hygiene action substantially reduces contamination of HCWs' hands with the flora

**Table II** ‘My five moments for hand hygiene’: explanations and link to evidence-based recommendations

Moment	Endpoints of hand transmission	Prevented negative outcome	Examples	Link to WHO <i>Guidelines for Hand Hygiene in Health Care</i> <sup>27</sup>	
				WHO recommendation (ranking for scientific evidence <sup>a</sup> )	Comments
1 Before patient contact	Donor surface: any surface in the healthcare zone. Receptor surface: any surface in the patient zone	Patient cross-colonisation; rarely exogenous infection	Shaking hands, helping a patient to move around, getting washed, taking pulse, blood pressure, chest auscultation, abdominal palpation	Before and after touching patients (IB)	The two moments before and after touching a patient were separated because of their specific sequential occurrence in routine care and unequal negative outcome in case of failure to adhere, and usual adherence level.
2 Before aseptic task	Donor surface: any other surface Receptor surface: clean site	Patient endogenous infection; rarely exogenous infection	Oral/dental care, secretion aspiration, skin lesion care, wound dressing, subcutaneous injection; catheter insertion, opening a vascular access system; preparation of food, medication, dressing sets	Before handling an invasive device for patient care, regardless of whether or not gloves are used (IB)  If moving from a contaminated body site to a clean body site during patient care (IB)	This concept was enlarged to cover all transfer of micro-organisms to vulnerable body sites potentially resulting in infection.  Since it is not possible to determine these body sites objectively, this indication was not retained as a separate item, but covered by within-patient-zone moments.
3 After body fluid exposure risk	Donor surface: body fluid site Receptor surface: any other surface	Healthcare worker infection	Oral/dental care, secretion aspiration; skin lesion care, wound dressing, subcutaneous injection; drawing and manipulating any fluid sample, opening draining system, endotracheal tube insertion and removal; clearing up urines, faeces, vomit, handling waste (bandages, napkin, incontinence pads), cleaning of contaminated and visibly soiled material or areas (lavatories, medical instruments)	After removing gloves (IB)  After contact with body fluids or excretions, mucous membranes, non-intact skin, or wound dressings (IA)  If moving from a contaminated body site to a clean body site during patient care (IB)	‘After body fluid exposure risk’ covers this recommendation; see text for further comments.  This risk was generalised to include all tasks that can potentially result in hand exposure to body fluids. A paradox of body fluid exposure was resolved by including the notion of exposure risk instead of actual exposure.  See comment (2) ‘Before aseptic task’

(continued on next page)

Table II (continued)

Moment	Endpoints of hand transmission	Prevented negative outcome	Examples	Link to WHO <i>Guidelines for Hand Hygiene in Health Care</i> <sup>27</sup>	
				WHO recommendation (ranking for scientific evidence <sup>a</sup> )	Comments
4 After patient contact	Donor surface: any surface in the patient zone with touching a patient. Receptor surface: any surface in the healthcare zone	Healthcare worker cross-colonisation; environment contamination	Shaking hands, helping a patient to move around, getting washed, taking pulse, blood pressure, chest auscultation, abdominal palpation	Before and after touching patients (IB)	See comment (1) 'Before patient contact'
5 After contact with patient surroundings	Donor surface: any surface in the patient zone <i>without</i> touching the patient. Receptor surface: any surface in the healthcare zone	Healthcare worker cross-colonisation; environment contamination	Changing bed linen, perfusion speed adjustment, monitoring alarm, holding a bed rail, clearing the bedside table	After contact with inanimate objects (including medical equipment) in the immediate vicinity of the patient (IB)	Retained to cover all situations where the patient's immediate and potentially contaminated environment is touched but not the patient

<sup>a</sup> Ranking system for evidence according to WHO guidelines<sup>27</sup>: category IA, strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiological studies; category IB, strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and a strong theoretical rationale.



from patient X, minimises the risk of dissemination to the healthcare environment, and protects the HCWs themselves. It is noteworthy that HCWs usually touch an object within the patient zone and not the patient before leaving. Hence, the term 'after patient contact' is somewhat misleading and should be understood as 'after contact with the patient or his/her immediate surroundings'.

### **Moment 5: After contact with patient surroundings**

The fifth moment for hand hygiene is a variant of moment 4. It occurs after hand exposure to any surface in the patient zone but without touching the patient. This typically extends to objects contaminated by the patient flora that are extracted from the patient zone to be decontaminated or discarded. Because hand exposure to patient objects without physical contact with the patients is associated with hand contamination, hand hygiene is required.

### **Coincidence of two moments for hand hygiene**

Two moments for hand hygiene may sometimes fall together. Typically this occurs when going from one patient to another without touching any surface outside the corresponding patient zones. Naturally, a single hand hygiene action will cover the two moments for hand hygiene.

### **Practical applications of the model**

A multi-modal approach to hand hygiene promotion has been found to be the most efficient technique to increase patient safety in a sustained way.<sup>8,21,27,56,57</sup> A robust description of the critical moments for hand hygiene is important for the various elements of a multi-modal strategy including training, workplace reminders, ergonomic localisation of hand rub at the point of care, performance assessment by direct observations, and reporting.

### **Understanding and visuals**

A critical feature to facilitate the understanding and communication of 'My five moments for hand hygiene' lies in its strong visual message (Figure 2). The objective was to represent the ever-changing situations of care into pictograms that could serve a wide array of purposes and healthcare settings. The model depicts a single patient in the centre

of a unified visual to represent the point of care of any type of patient. The zones, critical sites and moments for hand hygiene action are arranged around this patient to depict the infectious risks and the corresponding moments for hand hygiene action in time and space.

### **Training**

There are important interpersonal differences in the most effective learning styles. Some individuals respond better to conceptual grouping and will respond well to the risk-based construct of zones and critical sites and the five moments for hand hygiene. For most, however, the rational background of a concept is a strong motivator. It is thus helpful to make very clear the reason for each of the five moments for hand hygiene (Table II). Others respond better to circumstantial cues and it is useful to list the most frequent examples occurring in the specific care setting. The approach also offers many possibilities for the development of training tools, including on-site accompanied learning kits, computer-assisted learning, and off-site simulators.

### **Monitoring**

Direct observation is the gold standard to monitor compliance with optimal hand hygiene practice.<sup>27</sup> The five-moments model can be instrumental in several ways. Many care activities do not follow a standard operating procedure. Thus, it is difficult to define the crucial moment for hand hygiene. The concept lays a reference grid over these activities and minimises inter-observer variation. Once HCWs are proficient in the concept, they are able to become observers with minimal additional effort, thus cutting down on training costs.<sup>58</sup> Furthermore, the concept solves the typical problems of clearly defining the denominator as an opportunity and the numerator as a hand hygiene action.

### **Reporting**

Reporting results of hand hygiene observation to HCWs is an essential element of multi-modal strategies to improve hand hygiene practices.<sup>21,27,59</sup> Therefore, reporting details on risk-specific hand hygiene performance may increase the impact of any feedback and make it possible to monitor progress in a meaningful way that fully corresponds to training and promotional material.

## Discussion

Hand hygiene as it is understood today requires three to 30 applications of hand rub per hour during patient care which translates to one hand rub application up to every 2 min during intensive care activities.<sup>3,4,6–8,11,21,27,59</sup> The reality, however, is that unobserved HCWs only perform very few hand hygiene actions during their work day. The magnitude of the task of fixing this substandard quality of care has challenged infection control professionals worldwide for many years.<sup>60,61</sup>

Various indications for hand hygiene during care have been described in the scientific literature but, to date, there are few studies which focus in detail on practical issues within the framework of observation.<sup>62,63</sup> We describe a new model for hand hygiene that is intended to meet the needs for training, observation, and performance reporting across all healthcare settings worldwide. The model 'My five moments for hand hygiene' was created to bridge the gap between the results of scientific studies and evidence-based guidelines and the necessity to provide user-centred, practical tools. It is based on available evidence in the fields of microbiology and infectious diseases, a long-standing practical experience in hand hygiene research and promotion,<sup>21</sup> and several years of a trial-and-error process.<sup>21</sup> Principles and recent insight in the three overlapping domains of human factors engineering, behaviour science and social marketing were used to craft the concept for optimal performance at minimal cost.

The importance of human factors design and ergonomics for patient safety is increasingly being recognized.<sup>64–66</sup> What has led to a 100-fold decrease in aeroplane crashes is now being progressively implemented in healthcare: a deliberate design process to avoid human error by streamlining processes and work environment to intuitive human understanding, behaviour and limitations. Building on this understanding, we provide a concept that applies to the complex and unpredictable task of healthcare delivery and serves as a solid basis for the engineering of the necessary implementation tools.

Behavioural science is used in human factors engineering. According to cognitive behaviour models, intention to perform any action is motivated by positive outcome evaluation, social pressure, and the perception of being in control.<sup>23,32,67–70</sup> The concept of 'My five moments of hand hygiene' tries: (i) to foster positive outcome evaluation by linking specific hand hygiene to specific infectious outcomes in patients and HCWs (positive outcome

beliefs); and (ii) to increase the sense of being in control by giving HCWs clear advice on how to integrate hand hygiene in the complex task of care (positive control beliefs).

Successful examples of powerful commercial marketing strategies transferred to the realities of healthcare exist.<sup>19,71</sup> It has been suggested that science-based work and guidelines regularly fail to translate into daily practice because of lack of appeal to the targeted user.<sup>17,72</sup> We used the concept of branding, term coining, simple wording and visuals to facilitate the 'marketing' of hand hygiene to HCWs as 'users'. While developing this concept, we faced some fundamental difficulties which were mainly rooted in the lack of detailed scientific evidence on hand transmission and its implication in the aetiology of specific infectious outcomes. If the relative risk level of specific care tasks remains unknown, a 'safe system' has to treat them on an equal level. This prohibited further concept simplification, which would have been possible had we been able to eliminate the 'less important' moments for hand hygiene. It is possible that accumulating evidence might make future adaptations of the concept necessary. We believe, however, that gaps in detailed evidence should not prevent the construction of an applicable holistic approach.<sup>61</sup> In this respect, 'My five moments for hand hygiene' can be compared to wearing a safety belt while driving. Although the risk through neglecting a single preventive gesture may be very low, cumulative negligence results in a high total number of fatal outcomes due to the sheer frequency of the risk situation. Furthermore, some assumptions made in this model might not be fulfilled at all facilities. A high standard of cleaning of the healthcare environment and all objects brought in close contact with patients is required if the proposed hand hygiene concept is to make sense.

Standardisation is essential to the robustness of the concept, i.e. its applicability to a large range of healthcare settings. For this, however, we had to omit certain potentially useful concept features. For example, powerful cues for action such as glove use, catheter insertion, or other frequently described moments in care were discarded. Furthermore, we opted against educating HCWs to recognize the transmission risk themselves and to use hand hygiene whenever they considered that micro-organisms on their hands could be harmful to patients.

In conclusion, efforts to improve hand hygiene practices of HCWs have already travelled far over the past few years by the application of human

factors engineering: handwashing at the sink has been replaced by alcohol-based hand rubbing as the quicker and more effective method, and hand rub location at the point of care has been advocated to make it even more convenient. In this work, we revisited the main negative outcomes and their causal mechanisms to design a user-centred, out-of-the-box concept to make understanding, training, and monitoring of hand hygiene in health-care a 'top seller' among HCWs worldwide.

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### Conflict of interest statement

None.

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