

# Overcoming Barriers to Hand Hygiene Compliance

Effects of hand hygiene on skin integrity

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## Premise

An important “barrier” to hand hygiene compliance is the damage caused to the skin “barrier,” the stratum corneum.

## Significance

### Patient Safety

Healthcare-acquired infections occur in two million people per year in the United States and result in 80,000 deaths.<sup>1</sup> The incidence of infection among intensive care patients is one in four in industrialized nations and estimated to be one in two in developing regions worldwide.<sup>2</sup> Reduction and prevention of hospital-acquired infections is a patient safety goal and a major focus of improvement efforts in healthcare institutions worldwide, particularly since about one-third may be preventable<sup>3-5</sup>. Nosocomial infections affect up to 26 percent of intensive care patients.<sup>6,7</sup> Those in the neonatal ICUs are at increased risk of complications due to immature host defense mechanisms and infection from exposure to invasive procedures.<sup>5,8</sup>

In 1947, postpartum maternal mortality was significantly reduced after hand disinfection

with a chlorine solution between patients, an intervention that was more effective than soap and water washing.<sup>9</sup> Beginning in 1961, formal guidelines for hand disinfection in healthcare institutions have been published by agencies including the U.S. Public Health Service, the Association for Professionals in Infection Control, the Healthcare Control Practices Advisory Committee, and the Centers for Disease Control and the World Health Organization (WHO).<sup>10</sup> The guidelines list the specific processes, frequencies, and types of products to be used for healthcare procedures, e.g., before direct patient contact, between patients, prior to catheter insertion, etc. They are based on data on the composition of skin microbial flora in normal and healthcare settings, the differentiation of transient and resident flora, the mechanisms of contamination and transfer of flora, and the specific organisms contributing to various infections. The colonization of normal hand skin is more than  $1 \times 10^6$  colony forming units (CFU/cm<sup>2</sup>) and range from  $3.9 \times 10^4$  to  $4.6 \times 10^6$  in healthcare workers.<sup>11-13</sup> Normal resident flora are on the skin surface and within the top layers. They typically include *Staphylococcus epidermidis*, *Staphylococcus hominis*, other coagulase-negative staphylococci, coryneform bacteria (*corynebacteria*, dermobacteria, *propionibacteria*, and micrococci), and sometimes fungi (*Pityrosporum* spp.)<sup>2</sup> Transient flora are on the outermost layers and can multiply on the surface. Increases in bacterial counts, including potential pathogens, were found with diaper changes, skin contact and respiratory care among neonates.<sup>14</sup>

### Hand Hygiene

*Consistent performance of hand hygiene procedures, e.g., soap and water washing, use of antimicrobial scrubs, use of hand sanitizers, is effective for preventing healthcare associated infections.*<sup>15</sup> Standard practice of hand hygiene is the most important measure for preventing healthcare-associated infections in critically ill neonates.<sup>5,7,8,16-21</sup> Hand hygiene is effective in reducing neonatal mortality.<sup>22,23</sup> Matters of compliance are very relevant in ICUs because the need for frequent hand hygiene coupled with the high workload create a significant barrier to good compliance.<sup>5-7,10,17,20,21</sup> The indications for hand hygiene from the most recent, comprehensive guideline to assemble the evidence and address the issues on a worldwide basis, i.e., the WHO Guidelines on Hand Hygiene in Health Care Advanced Draft of 2006 are listed in Table 1.<sup>2</sup>

### Healthcare Worker Safety

A goal of the U.S. Public Health Service for 2010 is to reduce occupational skin disorders to an incidence of 46 per 100,000 full-time workers.<sup>24</sup> Occupational dermatitis represents a significant health problem with chronic discomfort and lost work time.<sup>25</sup> Contact dermatitis is the most common disorder, accounting for 90 percent to 95 percent of cases and of those, 80 percent are the irritant type.<sup>26-28</sup>

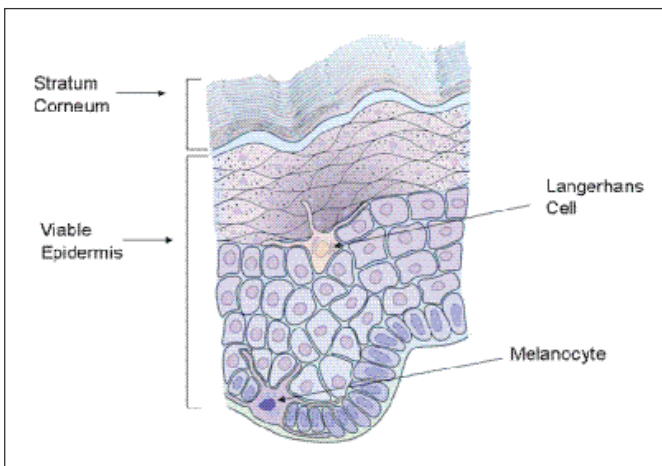
### The Skin in Infection Control

The skin serves multiple functions including barrier (to water loss, irritant exposure, light, etc.), immunosurveillance, infection control, sensation, structural support, and thermal regulation. The outermost layer, known as the stratum corneum (SC), provides a physical, mechanical and immunological barrier against environmental insults. The viable epidermis continuously builds and replenishes the barrier. The living cells release their contents to create lipid layers that assemble between the cells which have flattened in shape. In this process, the cells “move up” from the lower layers and are released or shed from the skin surface via desquamation. The sequence is carefully programmed and orchestrated through signaling mechanisms to form an incredibly thin and strong structure with that resembles a “brick and mortar” array. Extremely large forces are required to destroy its integrity. Langerhans cells (antigen presenting cells) are located in the viable layer (epidermis). They are part of the immune system and “defend” the organism if the SC barrier is breached. The SC barrier shields the Langerhans cells from direct environmental exposure thereby serving an essential function in infection control. Figure 1 shows the structural features of the stratum corneum and epidermis. *The maintenance of a normal, healthy intact skin barrier is essential for maximum protection of both patients and health care workers alike.*

**Table 1. Indications for Handwashing and Hand Antisepsis**

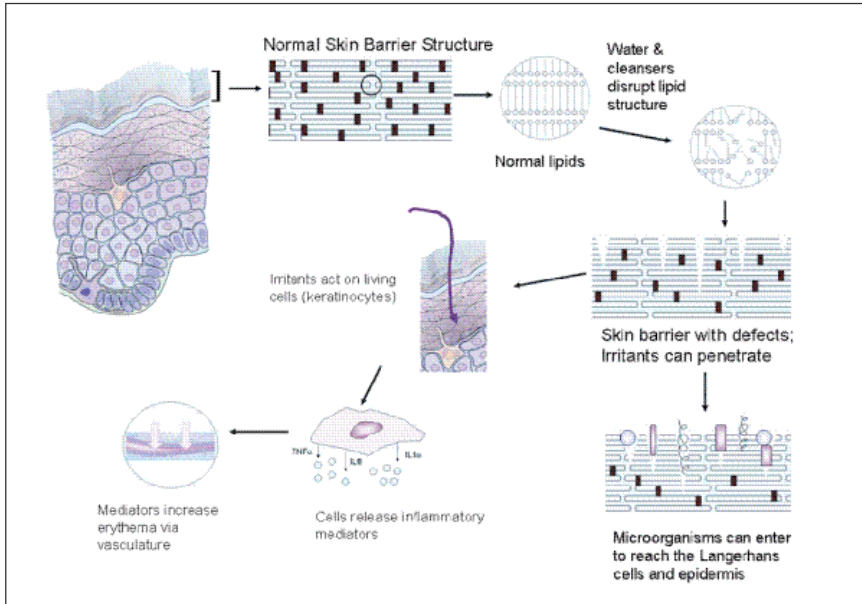
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| <p>A. Wash hands with soap and water when visibly dirty or contaminated with proteinaceous material, or visibly soiled with blood or other body fluids, or if exposure to potential spore-forming organisms is strongly suspected or proven (IB) or after using the restroom.</p> <p>B. Preferably use an alcohol-based handrub for routine hand antisepsis in all other clinical situations described in items C (1) to C (6) listed below, if hands are not visibly soiled. Alternatively, wash hands with soap and water.</p> <p>C. Perform hand hygiene:</p> <ol style="list-style-type: none"> <li>1. before and after having direct contact with patients;</li> <li>2. after removing gloves;</li> <li>3. before handling an invasive device for patient care, regardless of whether or not gloves are used;</li> <li>4. after contact with body fluids or excretions, mucous membranes, non-intact skin, or wound dressings;</li> <li>5. if moving from a contaminated body site to a clean body site during patient care;</li> <li>6. after contact with inanimate objects (including medical equipment) in the immediate vicinity of the patient.</li> </ol> <p>D. Wash hands with either plain or antimicrobial soap and water or rub hands with an alcohol-based formulation before handling medication or preparing food.</p> <p>E. When alcohol-based handrub is already used, do not use antimicrobial soap concomitantly.</p> |
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**Figure 1. Structure of the Epidermis**



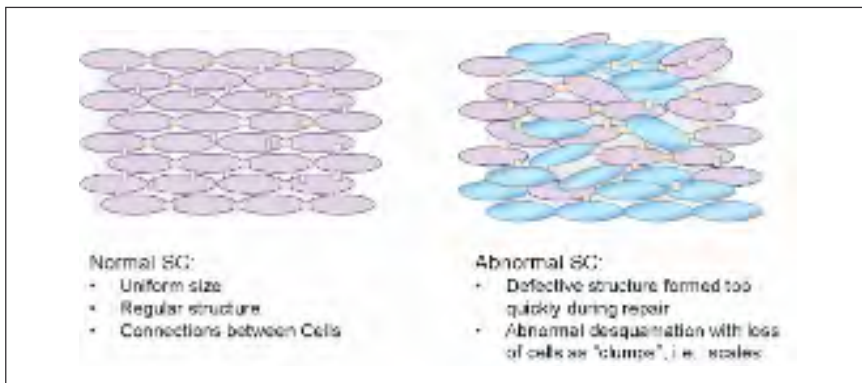
The structure of the epidermis is shown here. It consists of two parts. The outermost layer, known as the stratum corneum (SC), provides a physical, mechanical and immunological barrier against environmental insults. The viable epidermis continuously builds and replenishes the barrier. The living cells release their contents to create lipid layers that assemble between the cells which have flattened in shape. In this process, the cells “move up” from the lower layers and are released or shed from the skin surface via desquamation. The Langerhans cells (antigen presenting cells) are located in the viable layer (epidermis). They are part of the immune system and “defend” the organism. The melanocytes are in the lower epidermis and produce skin pigment known as melanin. When the skin is exposed to ultraviolet light, the melanocytes release pigment to shield the living cells of the epidermis and protect their DNA from damage. The production of pigment is responsible for the “tanning” response to sun exposure. The melanocytes work together with other cells in the epidermis to determine the skin coloration, e.g., Caucasian, African American.

**Figure 2. Skin Barrier Damage: Exposure to Water and Cleansers**



The effects of exposure to water and cleansers (e.g., bar soaps, liquid cleansers, surfactants) on the structure and function of the skin barrier, the stratum corneum (SC), are profound. They include disruption of the lipid bilayer architecture. This disruption creates defects or "holes" in the lipid layers. In turn, the barrier becomes more permeable, allowing irritants to penetrate into and through the uppermost layers. As a result, irritants can reach the living cells of the viable epidermis to cause inflammation. The cells respond by releasing mediators of inflammation which act on the capillaries and blood vessels of the dermis to produce visible erythema. In addition to chemical irritants, microorganisms on the skin surface or in the environment can also penetrate into the upper layers.

**Figure 3. Skin Barrier Following Damage**



Under normal conditions, the stratum corneum (SC) skin barrier is a regular arrangement of flattened cells with layers of lipid between them. The cells are connected together as shown. If the skin barrier is compromised, processes in the viable epidermis are up-regulated to repair the damage and generate "new" stratum corneum. As a result, the SC forms too quickly, resulting in an abnormal structure with defective architecture, compared to the SC that is formed during the normal course of SC replacement. This SC has poor water binding properties leading to insufficient skin moisture. Normally, the SC cells are lost from the surface as individual units but when the moisture is too low, they come off as clumps of cells observed as dry scales.

## Hand Hygiene and the Skin

Skin exposure to water and cleansers (e.g., bar soaps, liquid cleansers, surfactants) and water has profound effects on the SC structure and function, as shown in Figure 2. They include disruption of the lipid bilayer architecture to create defects or "holes" in the barrier. As a result, the barrier becomes more permeable, allowing irritants to penetrate into and through the uppermost layers (SC). The irritants can reach the living cells of the viable epidermis to cause inflammation. The cells release mediators of inflammation which act on the capillaries and blood vessels of the dermis to produce visible erythema. In cases of severe hand irritation, cracks or fissures (with or without bleeding) may develop indicating damage to the dermis. *In addition to chemical irritants, microorganisms on the skin surface or in the environment can also penetrate into the upper layers.*

The skin's response to these damaging effects is immediate since restoration of the barrier is critical for survival. Processes in the viable epidermis are up-regulated to repair the damage and generate "new" stratum corneum. As a result, the SC forms too quickly, i.e., hyperproliferates, resulting in a structure with defective architecture, compared to the SC that is formed during the normal course of SC replacement. This SC has poor water binding properties leading to insufficient skin moisture and inadequate desquamation<sup>29-42</sup> Normally, the SC cells are lost from the surface as individual units but when the moisture is too low, they come off as clumps of cells observed as dry scales, as shown in Figure 3. Under normal conditions, the cells move from the bottom of the SC to be released over 14 days.<sup>43</sup> However, the time is shorter when there is chronic exposure to irritants such as cleansers and surfactants.<sup>44</sup>

### Compliance and Healthcare Worker Skin

Despite the importance, compliance rates are only 30 percent to 57 percent<sup>10</sup> and some improvement programs have been unsuccessful.<sup>45-47</sup> *The primary reason for compliance failure is skin irritation and the deleterious effects of repeated exposure to products and procedures.*<sup>19</sup> Up to 85 percent of nurses described histories of skin problems and 25 percent reported symptoms of dermatitis.<sup>10</sup> Fifty-five percent of inpatient nurses and 65 percent in ICU had observable hand dermatitis.<sup>48</sup> ICD may predispose development of allergic contact dermatitis.<sup>49</sup> Overall, the rate of occupational dermatitis is unchanged from the 28 percent reported in 1980.<sup>50</sup>

Healthcare workers (HCWs) often work 12-hour shifts for two to three consecutive days followed by three to four days of time off. Others may work consecutive eight hour shifts. The number of hand hygiene procedures per shift depends upon the patient load, the severity of illness, the complexity of care-giving procedures, etc. In an ICU setting, the required hand hygiene can occur four to five times per hour or 50 per 12 hour shift, leading to 150 events over three consecutive shifts. These levels of exposure to water, cleansers, and alcohol-based hand rubs are substantially higher than those used in human studies to evaluate formulation effects on skin. Skin assessment methods often use repetitive exposure under an occlusive patch on the forearm, rather than the hand. Commonly, the studies are on people with healthy, undamaged skin, a context that is different from the actual HCW setting. It is difficult to conduct a clinically realistic study without disrupting normal practice in the clinical area. As a result, there are relatively few published accounts about various aspects of hand skin condition among HCWs under typical clinical conditions.<sup>17,51-58</sup>

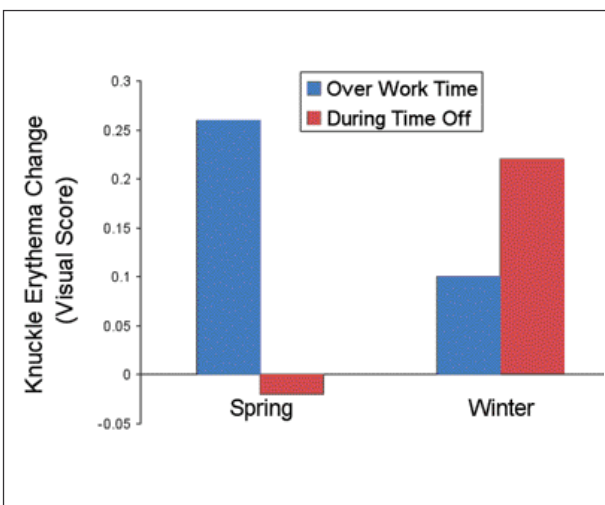
### Effects of Hand Hygiene Procedures on Skin Integrity in Healthcare Workers

The deleterious effects of repetitive hand cleansing/disinfection procedures on skin condition are well known.<sup>37,59-63</sup> We studied the effects of hand hygiene procedures on the hand skin condition of HCWs in an intensive care setting beginning in 2004.<sup>64,65</sup> To get a complete picture, we measured the skin dryness and erythema under several conditions: a) at the beginning and end of two to three consecutive work shifts to see the effects of high frequency exposure to products and procedures, b) at the end of the shifts and after three to four days off to see what happened after the high frequency of hand hygiene was stopped for a period, c) during spring time conditions (warmer temperatures, higher humidity), d) during winter conditions, e) with various hand hygiene products, and f) after treatment with skin lotion. Hand hygiene products included liquid products for soap and water washing and alcohol-based hand rubs. We compared HCWs to a similar age group of people who did not work in a wet environment. Here are the key findings:

1. Compared to a group of non-HCW control subjects, HCW hand skin was appreciably more compromised.
2. Skin dryness and erythema were higher for the knuckles than the back of the hands.
3. Dryness grades were significantly higher during the winter for the knuckles and dorsum regions, indicating greater skin barrier damage during winter. The HCWs themselves reported poorer condition during winter than in spring.
4. The changes in skin irritation during work were greater in winter than in spring.
5. Knuckle erythema increased over the cycle in both seasons (Figure 4).
6. Knuckle erythema decreased during time off in spring, but continued to increase during time away in winter.

*The skin was dry and erythematous at the start of a work cycle, after several days away from work. The apparent worsening of the skin condition during the time away from work most likely is due to continuing effects of exposure. Importantly, the skin barrier does not recover from the damage during the time off period. HCWs come back to work with a compromised skin barrier.*

**Figure 4. Effect of High Frequency Hand Hygiene Exposure**



This figure shows the average change in knuckle erythema score among HCWs who took part in the spring (54 subjects) and winter (60 subjects) trials. Knuckle erythema increased during the work cycle of two to three consecutive 12 hour shifts during both seasons (blue bars). During the time away from work, the erythema decreased slightly during spring, indicating improvement in skin condition. In winter, however, skin erythema increased (worsened) during the time off work (red bars).

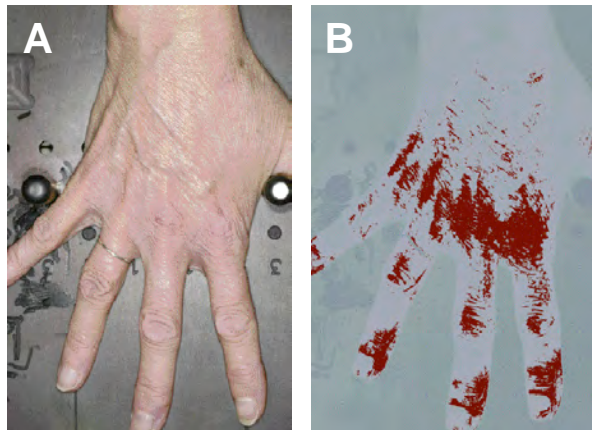
A striking feature of irritant hand dermatitis has been the high levels of erythema/inflammation, particularly at the knuckles. Visual scores were not different for spring and winter conditions. Clear determination of the extent (i.e., degrees of severity) is difficult. To quantify the erythema component of skin condition, we used high resolution digital photography with controlled lighting. Next, the image red channel is separated for analysis. The *excess erythema is the quantity of red that is above (or greater than) the value of the mean plus one standard deviation*. Figure 5 shows an example. The clinical image (digital photograph) is on the left (A) and the processed image showing excess erythema (in red) is on the right (B). In essence, excess erythema is the amount of the image that is much higher than normal. The process allows us to assign a number to this amount. The images in Figure 6 show additional examples to the locations of excess erythema on actual HCW hands. Excess erythema values were substantially higher in winter than in spring for the same HCWs.

*Regardless of season, high frequency hand hygiene lead to chronic, unresolved skin irritation in nearly all healthcare workers. Levels of inflammation are particularly high in winter conditions.*

**Figure 5. High Resolution Digital Photography and Image Analysis**

Subject 1 Normal image showing clinical condition

Subject 1 Processed image showing excess erythema



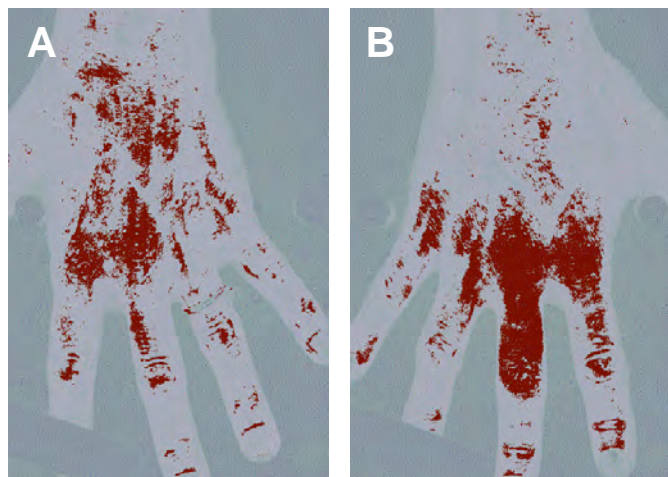
The figure shows a clinical digital photograph (A) of a subject. The regions of erythema and dryness are clearly visible in the original image. Figure B shows the processed red channel image with the areas of excess erythema in red. Excess erythema is anything greater than the mean plus one standard deviation of pixels in the red channel image. This provides a way to quantify the highest levels of hand erythema.

**Regardless of season, high frequency hand hygiene lead to chronic, unresolved skin irritation in nearly all healthcare workers.**

**Figure 6. Examples of Excess Erythema in Healthcare Workers**

Subject 2 Excess Erythema

Subject 3 Excess Erythema



Subject 4 Excess Erythema



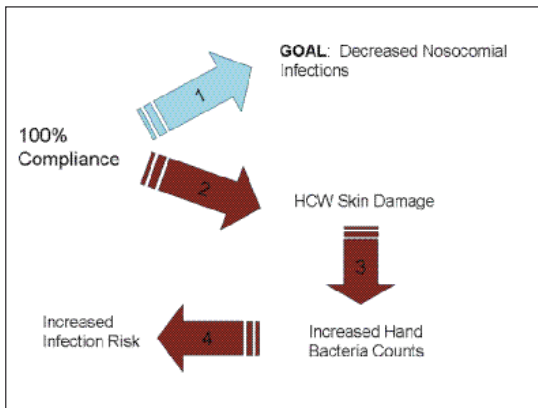
The figure shows three examples of the red channel from clinical digital photographs with the excess erythema shown in red. The locations of the excess erythema often involve the knuckle regions as shown in A, B and C. Figures A and B have involvement on the dorsal regions. Figures B and C show areas on the fingers.

**Implications for Infection Control**

Chronic hand skin compromise has significant implications for infection control. A damaged barrier is more susceptible to penetration by environmental insults, including microorganisms. As skin damage increased, the total bacteria counts on the hand were higher.<sup>66</sup> Irritated hands had significantly more colony forming units (CFUs) than non-irritated hands.<sup>67</sup> The frequency of colonization with *Staphylococcus hominis*, *Staphylococcus aureus*, gram-negative bacteria, enterococci, and *Candida* was higher on nurses with damaged hands.<sup>12</sup> Damaged hand skin in HCWs was associated with higher frequencies of *Staphylococcus aureus*, gram-negative bacteria and yeast.<sup>68</sup> Soap and water washing was ineffective for reducing microorganism contamination of damaged hands.<sup>67</sup> *The findings suggest that compliance with required procedures for hand hygiene results in damaged skin and an increased bacterial load* (Figure 7). What are the implications for the management of nosocomial infections?

**Figure 7. Effects of Hand Hygiene**

The goal of hand hygiene practice is to reduce the incidence

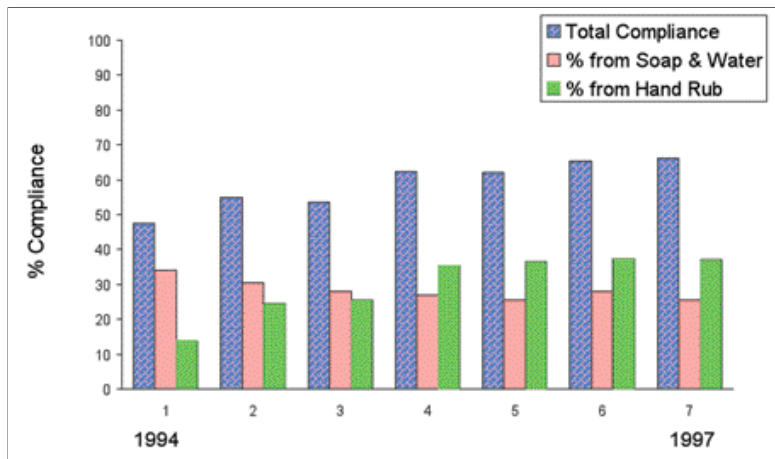


of nosocomial infections and strong evidence supports the efficacy. One of the effects of compliance is skin barrier compromise, e.g., inflammation, fissuring, dryness, etc. Damaged skin has higher levels of microflora which may increase the risk of infection for patients and healthcare workers.

**Impact of Alcohol Hand Rubs**

One of the most important interventions for nosocomial infections has been the addition of alcohol-based hand rubs. Their use leads to improved skin condition compared to soap and water washing<sup>17,52,56,60,62</sup> In a study among nurses, an alcohol hand rinse produced significantly better decontamination than

**Figure 8. Effect of Hand Rubs on Hand Hygiene Compliance**



soap and water, which caused an increase in skin dryness and erythema.<sup>66</sup> Protective effects have been reported.<sup>69,70</sup> Some HCWs report stinging or adverse reactions from alcohol rubs, perhaps indicating the presence of skin damage.<sup>53,71</sup> A change back to soap and water washing is likely to worsen skin condition. Inclusion of hydrating ingredients, e.g., emollients, improves the effects of hand rubs on skin.<sup>72-74</sup> Compliance improvement programs emphasize using alcohol rubs whenever indicated.<sup>5-7,10,75,76</sup> *The significant increase in hand hygiene compliance from 48 percent in 1994 to 66 percent in 1997 (teaching hospital, Geneva) was attributed to the use of hand rubs.*<sup>77</sup> Figure 8 shows the total percent compliance and the contributions from soap and water washing and use of hand rubs. The percent of hand hygiene events from hand rubs increased over the period while the proportion from soap and water was relatively constant. Net, the use of alcohol-based hand rubs has had a positive effect on compliance and on skin condition (i.e., improvements). *However, our HCW research was conducted after the implementation of alcohol-based hand rubs and clearly demonstrated significant, chronic skin barrier compromise.*

**Impact of Hand Lotions/Creams**

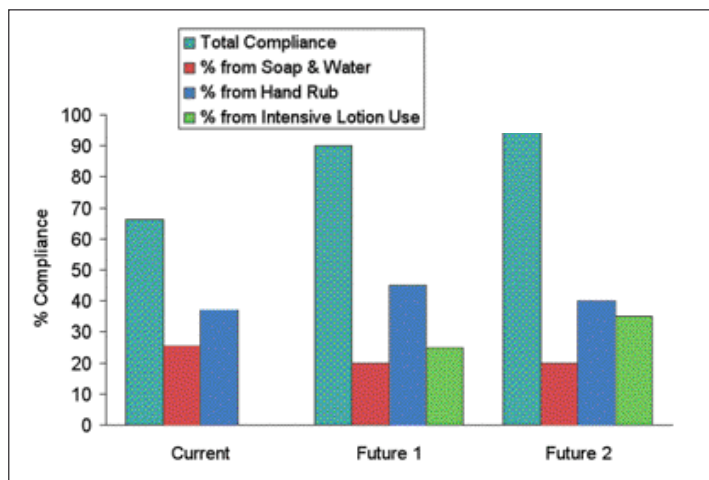
Healthcare institutions are to provide HCWs with lotions or creams to minimize the skin damage due to hand hygiene procedures. The positive effects of lotion on skin condition have been described.<sup>78</sup> Lotion application resulted in more rapid SC barrier repair following damage with surfactant compared to an untreated control.<sup>79</sup> An oil-based lotion (mineral oil, petrolatum, lanolin, etc) led to significantly better skin scores than one based on glycerin (glycerin, isopropyl myristate, stearic acid, etc.) over four weeks in workers with severe hand irritation.<sup>18</sup> A petrolatum-based lotion (Locobase: mineral oil, petrolatum, etc) reduced irritation versus the untreated control (crossover design).<sup>78</sup> Decreased dryness and increased hydration versus no treatment were seen for a cream (Baktolan: water, liquid paraffinum, petrolatum, liquid paraffin, wax, etc.) (4x daily, 2 weeks).<sup>80</sup> *However, lotions containing petrolatum and/or mineral oil are not compatible with gloves since their integrity*

can be compromised. Therefore, they are not a viable choice for use in healthcare institutions. At the present time, the literature on the effects of glove-compatible lotion/cream treatments for irritant hand dermatitis in the HCW clinical settings is limited.

**Table 2. Strategies to Manage Skin Barrier Compromise**

<ul style="list-style-type: none"> <li>▶ Use cleansers containing surfactants:                             <ul style="list-style-type: none"> <li>• With low irritation potential, i.e., “minimally damage”;</li> <li>• That are easily rinsed from the skin surface;</li> <li>• With low protein binding ability;</li> <li>• That are present in the “minimum” amounts for cleaning.</li> </ul> </li> <li>▶ Use alcohol hand rubs whenever possible:                             <ul style="list-style-type: none"> <li>• Reduce water and cleanser exposure.</li> </ul> </li> <li>▶ Use hand rubs containing emollients to help keep the skin hydrated.</li> <li>▶ Provide a skin lotion or cream that will:                             <ul style="list-style-type: none"> <li>• To hydrate the stratum corneum and provide moisture to help the skin recovery from damage (dryness, erythema);</li> <li>• Be compatible with gloves, i.e., free of petrolatum and mineral oil;</li> <li>• Have an acceptable feel on the skin;</li> <li>• Not interfere with HCW dexterity for bedside procedures, i.e., not slippery, greasy, tacky, etc., to avoid having to “wash it off.”</li> </ul> </li> <li>▶ Skin creams and lotions may:                             <ul style="list-style-type: none"> <li>• Create a “protective” layer on the surface;</li> <li>• Reduce water loss from the damaged skin;</li> <li>• Protect the skin during the next cleanser and water exposure.</li> </ul> </li> </ul>
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**Figure 9. Hand Hygiene Compliance: Future Potential**



Looking to the future, this figure portrays an increase in total hand hygiene compliance that is a step change above the current highest reported levels. It postulates that the addition of an intensive lotion treatment as part of the normal HCW regimen of hand skin care may be the way to achieve “clean hands without compromise.”

**Future Perspective**

Chronic exposure to irritants, e.g., repetitive hand hygiene procedures, has profound effects on the skin barrier, in some cases for weeks to months after treatment has stopped.<sup>81</sup> Recovery to the normal, healthy state depends on multiple factors including the inherent irritancy of the ingredients. In total, the research results emphasize the importance of providing hand hygiene products to minimize irritant dermatitis and maintain an effective skin barrier. Equally important are the use of protective skin care practices (mild cleansers, lotions, avoidance of harsh chemicals) both at work and during time away.

There is a substantial need for practices and products that disinfect the skin surface without compromising the integrity of the skin barrier. The current understanding of the causes of skin barrier damage among healthcare workers and the factors governing severity suggests strategies for minimizing the compromise and maximizing recovery when it occurs, as shown in Table 2.

Treatments can vary substantially in their effects on irritation and skin barrier integrity and, therefore, in the utility for chronic irritant dermatitis. An examination of long term moisturizer application and found differing effects on skin, some positive and some negative.<sup>82</sup> Specific moisturizers may not be effective against all irritants and formulations should be targeted at the causes of irritation and barrier compromise.<sup>83</sup>

Currently, there are few studies of the effects of intensive use of skin lotions or creams (glove compatible, CHG compatible) to protect the skin and to aid in the repair of barrier damage in HCWs. However, such a practice is expected to substantially impact and improve hand hygiene compliance. Looking to the future, the graph in Figure 9 portrays an increase in total hand hygiene compliance that is a step change above the current highest reported levels. It postulates that the addition of an intensive lotion treatment as part of the normal HCW regimen of hand skin care may be the way to achieve “clean hands without compromise.”

Finally, the research agenda outlined in the WHO guideline states the following as priorities pertaining to HCW skin condition:<sup>2</sup>

- ▶ Determine the most suitable hand hygiene agents;
- ▶ Study the systematic replacement of conventional handwashing by handrubbing;
- ▶ Develop hand hygiene agents with low skin irritancy potential;

- ▶ Study the possible advantages and eventual interaction of hand care lotions, creams, and other barriers to help minimize the potential irritation associated with hand hygiene agents.

Progress against this important agenda will require collaborations among people and institutions with expertise in infection control, public policy, healthcare quality and process improvement science, skin researchers, and representatives of the skin care industry. †

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