



REVIEW

## Surgical hand preparation: state-of-the-art

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**Summary** Surgical hand preparation has been recommended since the nineteenth century as a measure to reduce infection resulting from surgery. We review the evidence and major objectives of surgical hand preparation, as well as the criteria for the choice of products currently in use. Test and validation procedures for selecting products for surgical hand preparation in North America and Europe are compared. Surgical hand antisepsis using medicated soap and alcohol-based hand-rub formulations is discussed, including the technical aspects, time required for the procedure, drying time, potential for side-effects, and the parameters for the selection of the most appropriate formulations. Brushes are not recommended for surgical hand preparation. Rapid antimicrobial action, wider spectrum of activity, lower side-effects, and the absence of the risk of hand contamination by the rinsing water, clearly favour the use of alcohol-based hand rubs for surgical hand preparation, even in countries with limited resources where the provision of water is scarce or of doubtful quality. © 2009 The Hospital Infection Society. Published by Elsevier Ltd. All rights reserved.

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## Introduction

Surgical site infection (SSI) is a leading cause of healthcare-acquired infection. It is associated with significant morbidity and impacts on patient safety and the use of healthcare resources. Surgical hand preparation is among the oldest strategies to reduce SSI and also represents one of the most important ritual acts in medicine. Within the framework of the newly developed World Health Organization (WHO) *Guidelines on hand hygiene in health care*, the main output of the WHO Patient Safety First Global Patient Safety Challenge initiative, a task force of international experts reviewed the evidence for surgical hand preparation.<sup>1,2</sup> This state-of-the-art review aims to summarise current knowledge and to highlight areas requiring further research.

## Evidence for surgical hand preparation

Historically, Joseph Lister (1827–1912) demonstrated the effect of skin disinfection on the reduction of SSI.<sup>3</sup> At that time, surgical gloves were not yet available, making the appropriate disinfection of the surgical site of the patient and hand antisepsis by the surgeon even more imperative.<sup>4</sup> During the nineteenth century, surgical hand preparation consisted of washing the hands with antimicrobial soap and warm water, frequently with the use of a brush.<sup>5</sup> In 1894, three steps were suggested: (1) wash hands with hot water and medicated soap using a brush for 5 min; (2) apply 90% ethanol for 3–5 min with a brush; and (3) rinse the hands with an 'aseptic liquid'.<sup>5</sup> In 1939, Price suggested a 7 min hand wash with soap, water and a brush, followed by 70% ethanol for 3 min after drying the hands with a towel.<sup>6</sup> In the second half of the twentieth century, the recommended time for surgical hand preparation decreased from >10 min to 5 min.<sup>7,8</sup> Even today, 5 min protocols are common.<sup>9</sup> A comparison of different countries showed almost as many protocols as listed countries.<sup>10</sup>

The introduction of sterile gloves does not render surgical hand preparation unnecessary.

Sterile gloves contribute to preventing surgical site contamination and reduce the risk of blood-borne pathogen transmission from patients to the surgical team.<sup>11,12</sup> However, 18% (range: 5–82%) of gloves have tiny punctures after surgery, and more than 80% of cases go unnoticed by the surgeon. After 2 h of surgery, 35% of all gloves demonstrate puncture, thus allowing water and also body fluids to penetrate the gloves without using pressure.<sup>13</sup> A

recent trial demonstrated that punctured gloves double the risk of SSI.<sup>14</sup> Double-gloving decreases the risk of puncture during surgery, but punctures are still observed in 4% of cases after the procedure.<sup>15,16</sup> Of note, even unused gloves do not fully prevent bacterial contamination of hands.<sup>17</sup> In addition to protecting the patient, gloves reduce the risk for the healthcare worker of being exposed to bloodborne pathogens. In orthopaedic surgery, double-gloving is a common practice that significantly reduces, but does not eliminate, the risk of cross-transmission after punctures during surgery.<sup>18</sup>

Several reports of healthcare-associated infection outbreaks have been traced to the contaminated hands of the surgical team despite wearing sterile gloves.<sup>19,20</sup> Koiwai *et al.* demonstrated that a matching strain of coagulase-negative staphylococci (CoNS) was recovered from the bare fingers of a cardiac surgeon and a patient with postoperative endocarditis.<sup>21</sup> More recently, Boyce *et al.* reported a similar outbreak with CoNS and endocarditis with strain identity confirmed by molecular methods.<sup>22</sup> Mermel documented the case of a cardiac surgeon with onychomycosis identified as the source of an outbreak of SSI with *Pseudomonas aeruginosa*, possibly facilitated by not routinely using double-gloving.<sup>23</sup> One outbreak of SSI even occurred when surgeons who normally used an antiseptic surgical scrub preparation switched to a non-antimicrobial product.<sup>24</sup>

Despite this indirect evidence for the need for surgical hand antisepsis, its requirement before surgical procedures has never been proven by a randomised, controlled clinical trial.<sup>25</sup> Most likely, such a study will never be performed, nor be acceptable to an ethics committee. A randomised clinical trial comparing an alcohol-based hand rub versus a chlorhexidine hand scrub failed to demonstrate a reduction of SSI, despite the considerably better in-vitro activity of the alcohol-based hand-rub formulation.<sup>9</sup> Therefore, even considerable improvements in the antimicrobial activity in surgical hand preparations are unlikely to lead to significant reductions of SSI. These infections are the result of multiple risk factors related to the patient, the surgeon, and the healthcare environment and the reduction of only one single risk factor will have a limited influence on the overall outcome.

## Objective of surgical hand preparation

Surgical hand preparation should reduce the release of skin bacteria from the hands of the surgical team for the duration of the procedure in the case of an

unnoticed puncture of the surgical glove releasing bacteria to the open wound.<sup>26</sup> The virulence of the micro-organisms, the extent of microbial exposure, and host defence mechanisms are key factors in the pathogenesis of postoperative infection, risk factors that are largely beyond the influence of the surgical team. In contrast to hygienic hand wash or hand rub, products for surgical hand preparation must eliminate the transient flora and significantly reduce the resident flora at the beginning of a procedure, and maintain the microbial release from the hands below baseline until the end.<sup>27–29</sup> They should also inhibit growth of bacteria on the gloved hand. Rapid multiplication of skin bacteria occurs under surgical gloves if hands are washed with a non-antimicrobial soap, whereas it occurs more slowly following preoperative scrubbing with a medicated soap. The skin flora, mainly CoNS, *Propionibacterium* spp., and *Corynebacteria* spp., are rarely responsible for SSI, but even inocula as low as 100 colony-forming units (cfu) can trigger such an infection in the presence of a foreign body or necrotic tissue.<sup>30</sup> The spectrum of antimicrobial activity for surgical hand preparation should be as broad as possible against bacteria and fungi.<sup>29,31</sup> Viruses are rarely involved in SSI and are not part of test procedures for licensing in any country. Similarly, activity against spore-producing bacteria is not part of international testing procedures.

### Product testing for surgical hand preparation

The lack of appropriate, conclusive clinical trials precludes uniformly acceptable criteria. In-vitro and in-vivo trials conducted outside the operating theatre with healthy volunteers are the best evidence currently available.

In the USA, antiseptic preparations intended for use as surgical hand preparation, based on the Food and Drug Administration (FDA) Tentative Final Monograph, 17 June 1994, are evaluated for their ability to reduce the number of bacteria released from hands immediately after scrubbing, after wearing surgical gloves for 6 h (persistent activity), and after multiple applications over five days (cumulative activity).<sup>32</sup> The most important criteria are immediate and persistent activity. US guidelines recommend that agents for surgical hand preparation should significantly reduce micro-organisms on intact skin, contain a non-irritating antimicrobial preparation, have broad-spectrum activity, and be fast-acting and persistent.<sup>33</sup>

In Europe, all products must be at least as efficacious as a reference surgical rub with

*n*-propanol as outlined in the European Norm (EN) 12791. By contrast to the USA, only the immediate effect after the hand hygiene procedure and the level of regrowth after 3 h under the gloved hands are measured. The cumulative effect over five days is not a requirement of EN 12791, nor needed.

### Surgical hand antisepsis using medicated soap

The steps before starting surgical hand preparation are given in Table I. Most guidelines prohibit any jewellery or watches on the wrists/hands of the surgical team (Table I).<sup>29,34,35</sup> Artificial fingernails are associated with changes of the normal flora and impede proper hand hygiene.<sup>29,36</sup> They should be prohibited for the surgical team or in the operating theatre.<sup>29,36,37</sup> The most commonly used products for surgical hand antisepsis are chlorhexidine or povidone-iodine-containing soaps. The most active agents (in order of decreasing activity) are chlorhexidine gluconate, iodophors, triclosan, and plain soap.<sup>29,38–43</sup> Triclosan-containing products have also been tested for surgical hand antisepsis, but triclosan is mainly bacteriostatic, inactive against *Pseudomonas aeruginosa*, and has been associated with water pollution in lakes.<sup>44,45</sup> Hexachlorophene has been banned worldwide because of its high rate of dermal absorption and subsequent toxic effects.<sup>46,47</sup> Application of chlorhexidine or povidone-iodine results in similar initial reductions of bacterial counts (70–80%) that increase to 99% after repeated applications. Rapid regrowth occurs after the

**Table I** Steps before starting surgical hand preparation

- Keep nails short and pay attention to them when washing your hands as most microbes on hands come from beneath the fingernails.
- Do not wear artificial nails or nail polish.
- Remove all jewellery (rings, watches, bracelets) before entering the operating theatre.
- Wash hands and arms with a non-medicated soap before entering the operating theatre area or if hands are visibly soiled.
- Clean subungual areas with a nail file. Nailbrushes should not be used as they may damage the skin and encourage shedding of cells. If used, these should be single-use sterile nailbrushes. Re-usable autoclavable nail brushes are commercially available.

application of povidone-iodine, but not after the use of chlorhexidine.<sup>48</sup>

Hexachlorophene and triclosan detergents show a lower immediate reduction, but a good residual effect. These agents are no longer commonly used in operating theatres because other products such as chlorhexidine or povidone-iodine provide similar efficacy at lower levels of toxicity, faster mode of action, or broader spectrum of activity. Povidone-iodine remains one of the most widely used products for surgical hand antisepsis, despite both in-vitro and in-vivo studies demonstrating that it is less efficacious than chlorhexidine, induces more allergic reactions, and does not show similar residual effects.<sup>49,50</sup> At the end of a surgical procedure, iodophor-treated hands can have even more micro-organisms than before surgical scrubbing.

Some chloroxylenol-containing products are available on the market as surgical hand-scrub preparations. However, available studies showed contradictory results about immediate and persistent bacterial count reduction.<sup>32,38,51–53</sup> Therefore, these products do not seem to be suitable for surgical hand preparation, as more effective agents are available.

Warm water makes antiseptics and soap work more effectively, whereas very hot water removes more of the protective fatty acids from the skin and should be avoided. The application technique is probably less prone to errors compared to hand rubbing (Table II) considering that all parts of the hands and forearms get wet under the tap. By contrast, all parts of the hands and forearms must actively come into contact with the alcohol-based compound during hand rubbing.

### Required time for the procedure

Hingst *et al.* compared hand bacterial counts after 3 min and 5 min scrubs with seven different formulations.<sup>42</sup> Results showed that the 3 min scrub could be as effective as the 5 min scrub, depending on the scrub agent formula. Immediate and postoperative hand bacterial counts after 5 min and 10 min scrubs with 4% chlorhexidine gluconate were compared by O'Farrell *et al.* before total hip arthroplasty procedures.<sup>54</sup> The 10 min scrub reduced the immediate colony count more than the 5 min scrub. Although the postoperative cfu mean log count was slightly higher for the 5 min than the 10 min scrub, the difference between the post-scrub and postoperative mean cfu counts was higher for the 10 min scrub than the 5 min scrub in longer (>90 min) procedures. This study recommended a 5 min scrub before total hip arthroplasty. A study by O'Shaughnessy *et al.* using

**Table II** Protocol for surgical scrub with a medicated soap

- Start timing. Scrub each side of each finger, between the fingers, and the back and front of the hand for 2 min.
- Proceed to scrub the arms, keeping the hand higher than the arm at all times. This helps to avoid re-contamination of the hands by water from the elbows and prevents bacteria-laden soap and water from contaminating the hands.
- Wash each side of the arm from the wrist to the elbow for 1 min.
- Repeat the process on the other hand and arm, keeping hands above elbows at all times. If the hand touches anything except the brush at any time, the scrub must be lengthened by 1 min for the area that has been contaminated.
- Rinse hands and arms by passing them through the water in one direction only, from fingertips to elbow. Do not move the arm back and forth through the water.
- Proceed to the operating theatre holding hands above elbows.
- At all times during the scrub procedure, care should be taken not to splash water on to surgical attire.
- Once in the operating theatre, hands and arms should be dried using a sterile towel and aseptic technique before donning gown and gloves.

4% chlorhexidine gluconate in 2, 4, and 6 min scrubs observed a reduction in post-scrub bacterial counts in all groups. Scrubbing for longer than 2 min did not confer any advantage. This study recommended a 4 min scrub for the surgical team's first procedure and a 2 min scrub for subsequent procedures.<sup>55</sup> Wheelock and Lookinland compared bacterial counts on hands after 2 and 3 min scrubs with 4% chlorhexidine gluconate.<sup>56</sup> A statistically significant difference in mean cfu counts was found between groups with the higher mean log reduction in the 2 min group and the investigators recommended a 2 min procedure. Poon *et al.* applied different scrub techniques with a 10% povidone-iodine formulation.<sup>57</sup> They found that a 30 s hand wash can be as effective as a 20 min contact with an antiseptic in reducing bacterial flora and that vigorous friction scrub is not necessarily advantageous.

### Use of brushes

Almost all studies discourage the use of brushes. Early in the 1980s, Mitchell *et al.* suggested a brushless surgical hand scrub.<sup>58</sup> Scrubbing with a disposable sponge or the combination sponge-brush has

been shown to reduce bacterial counts on the hands as effectively as scrubbing with a brush.<sup>59–61</sup> Furthermore, a recent randomised controlled clinical trial failed to demonstrate an additional antimicrobial effect by using a brush.<sup>62</sup> If hands are visibly soiled, wash hands with plain soap before surgical hand preparation. Remove debris from underneath fingernails using a nail cleaner, preferably under running water. Brushes are not recommended for surgical hand preparation. Members of the surgical team who have contaminated their hands before entering the hospital may wish to use a sponge or brush to render their hands visibly clean before entering the operating theatre area.

### Drying of hands

Sterile cloth towels are most frequently used in operating theatres to dry wet hands after surgical hand antisepsis. Several methods of drying have been tested without significant differences between techniques.<sup>63</sup>

### Side-effects of surgical hand scrub

Skin irritation and dermatitis are more frequently observed after surgical hand scrub with chlorhexidine than after the use of surgical hand antisepsis with an alcohol-based hand-rub formulation.<sup>9,64</sup> Overall, skin dermatitis is more frequently associated with hand antisepsis using a medicated soap than with an alcohol-based hand rub. Boyce *et al.* quantified the epidermal water content of the dorsal surface of nurses' hands by measuring the electrical capacitance of the skin following two hand-hygiene regimens. The water content decreased significantly during the hand-wash phase with soap and water compared to the alcohol-based hand-rub phase.<sup>65</sup> Most data have been generated outside the operating theatre, but these results may apply also to surgical hand antisepsis.<sup>66</sup>

### Potential for recontamination

Surgical hand antisepsis with medicated soap requires clean water to rinse the hands after application of the medicated soap. However, *Pseudomonas* spp., specifically *P. aeruginosa*, are frequently isolated from taps in hospitals.<sup>67</sup> Taps are common sources of *P. aeruginosa* and other Gram-negative bacteria and have been linked to infections in multiple settings, including intensive care units.<sup>68</sup> It is therefore prudent to remove tap aerators from sinks designated for surgical hand antisepsis.<sup>68–70</sup> Of note, even automated

sensor-operated taps have been linked to *P. aeruginosa* contamination.<sup>71</sup> Outbreaks or cases clearly linked to contaminated hands of surgeons after proper surgical hand scrub have not yet been documented. However, outbreaks with *P. aeruginosa* were reported as traced to members of the surgical team suffering from onychomycosis, but a link to contaminated tap water has never been established.<sup>23,36</sup> Importantly, in countries lacking continuous monitoring of drinking water and proper tap maintenance, recontamination may be a real risk even after correct surgical hand scrub. One surgical hand preparation episode with traditional agents uses about 20 L of water and represents more than 60 L for the entire surgical team.<sup>72</sup> This is a crucial issue worldwide, particularly in countries with a limited safe water supply.

### Surgical hand preparation with alcohol-based hand rubs

The antimicrobial efficacy of alcohol-based formulations is superior to that of all other currently available products for preoperative surgical hand preparation. Several alcohol-based hand rubs have been licensed for the commercial market, frequently with additional, long-acting compounds (e.g. chlorhexidine gluconate or quaternary ammonium compounds) limiting regrowth of bacteria on gloved hands.<sup>29,31,73–79</sup> Studies have demonstrated that formulations containing 60%–95% alcohol alone, or 50%–95% when combined with small amounts of a quaternary ammonium compound, hexachlorophene or chlorhexidine gluconate, reduce bacterial counts on the skin immediately post scrub more effectively than other agents. Hand-care products should not decrease the antimicrobial activity of the hand rub. A study by Heeg *et al.* failed to demonstrate such an interaction, but hand-rub manufacturers should provide good evidence for the absence of interaction.<sup>80,81</sup>

It is not necessary to wash hands before hand rub unless hands are visibly soiled or dirty.<sup>80,82</sup> The hands of the surgical team should be cleaned upon entering the operating theatre by washing with a non-medicated soap. While this hand wash may eliminate any risk of contamination with bacterial spores, experimental and epidemiological data failed to demonstrate an additional effect of washing hands before applying hand rub in the overall reduction of the resident skin flora.<sup>31</sup> The activity of the hand-rub formulation may even be impaired if hands are not completely dried before applying the hand rub or by the hand-washing phase itself.<sup>80,82,83</sup> To eliminate bacterial spores, non-

medicated soaps are sufficient.<sup>84,85</sup> However, this procedure is necessary only upon entering the operating theatre; repeating hand rubbing without prior hand wash or scrub is recommended before switching to the next procedure.

### Technique for the application of surgical hand preparation using alcohol-based hand rub

The application technique has not been standardised worldwide. The WHO approach for surgical hand preparation requires the same six basic steps as for hygienic hand antisepsis, with an additional step for rubbing the forearms (Table II and Figure 1). This simple procedure appears not to require training. However, two studies provide evidence that training significantly improves bacterial killing.<sup>31,86</sup> During the whole procedure, the hands should remain wet from the alcohol-based rub, thus requiring about 9–15 mL, depending on the size of the hands. One study demonstrated that keeping the hands wet with the rub is more important than the volume used, but the size of the hands and forearms ultimately determines the volume to keep the skin area wet during the entire time of the hand rub.<sup>87</sup>

### Time required for the procedure

For many years, surgical staff frequently scrubbed their hands for 10 min preoperatively, which frequently led to skin damage. Several studies have demonstrated that scrubbing for 5 min reduces bacterial counts as effectively as a 10 min scrub.<sup>54,60,88</sup> In other studies, scrubbing for 2 or 3 min reduced bacterial counts to acceptable levels.<sup>28,42,55,56,89,90</sup> Following the reference method outlined in EN 12791, surgical hand antisepsis using an alcohol-based hand rub required 3 min. In a recent study with healthy volunteers in an in-vivo experiment, even a 90 s rub was shown to be equivalent to a 3 min rub with a product containing a mixture of iso- and *n*-propanol and mecetronium etilsulfat.<sup>74</sup> These results were corroborated in a similar study performed under clinical conditions with 32 surgeons.<sup>91</sup> However, further studies need to be conducted with other alcohol-based hand rubs to compare the usual 2–3 min hand preparation with shorter times before such a recommendation could be generalised to other products.

Alcohol-based hand gels should not yet be used unless they pass the test EN 12791 or an equivalent standard required for hand-rub formulations.<sup>35</sup> Many of the currently available gels for hygienic

hand rub do not meet the European standard EN 1500.<sup>92</sup> The technique to apply the alcohol-based hand rub defined by EN 1500 matches the one defined by EN 12791 (Figure 1). The latter requires an additional rub of the forearms that is not required for the hygienic hand rub. However, at least one commercially available gel that meets the EN 12791 has been tested and introduced in a hospital for hygienic hand antisepsis and surgical hand preparation, and several gels meet the US FDA Tentative Final Monograph norm.<sup>93,94</sup> As mentioned above, the minimal bacterial killing is not defined and, therefore, the interpretation of the effectiveness remains elusive.

In summary, the time required for surgical alcohol-based hand rubbing depends on the compound used. Although the application time may be longer for some formulations, most commercially available products recommend a 3 min exposure, but it can be shortened to 1.5 min for a few formulations. The product manufacturer must provide recommendations as to how long the product must be applied. These recommendations should be based on in-vivo evidence at least, considering that clinical effectiveness testing is unrealistic.

### Surgical hand scrub with medicated soap or surgical hand preparation with alcohol-based formulations?

Both methods are suitable for the prevention of SSI. However, although medicated soaps have been and are still used by many surgical teams worldwide for presurgical hand preparation, it is important to note that the antibacterial efficacy of products containing high concentrations of alcohol by far surpasses that of any medicated soap presently available.<sup>95</sup> In addition, the initial reduction of the resident skin flora is so rapid and effective that bacterial regrowth to baseline on the gloved hand takes more than 6 h.<sup>96</sup> This makes the demand for a sustained effect of a product superfluous. For this reason, preference should be given to alcohol-based products. Furthermore, several factors including rapid action, time savings, fewer side-effects, and no risk of recontamination by rinsing hands with water, clearly favour the use of presurgical hand rubbing. Nevertheless, some surgeons consider the time taken for surgical hand scrub as a ritual for the preparation of the intervention, and a switch from hand scrub to hand rub must be prepared with caution.<sup>97</sup> In countries with limited resources, particularly when the availability, quantity or quality of water is

The hand-rubbing technique for surgical hand preparation must be performed on perfectly clean, dry hands.

On arrival in the operating theatre and after having donned theatre clothing (cap/hat/bonnet and mask), hands must be washed with soap and water.

After the operation when removing gloves, hands must be rubbed with an alcohol-based formulation or washed with soap and water if any residual talc or biological fluids are present (e.g. the glove is punctured).

Surgical procedures may be carried out one after the other without the need for hand washing, provided that the hand-rubbing technique for surgical hand preparation is followed (Images 1-17).



1 Put approximately 5 mL (3 doses) of alcohol-based hand rub in the palm of your left hand, using the elbow of your other arm to operate the dispenser



2 Dip the fingertips of your right hand in the hand rub to decontaminate under the nails (5 s)



Images 3-7: Smear the hand rub on the right forearm up to the elbow. Ensure that the whole skin area is covered by using circular movements around the forearm until the hand rub has fully evaporated (10-15 s)



4 See legend for Image 3



5 See legend for Image 3



6 See legend for Image 3



7 See legend for Image 3



8 Put approximately 5 mL (3 doses) of alcohol-based hand rub in the palm of your right hand, using the elbow of your other arm to operate the dispenser



9 Dip the fingertips of your left hand in the hand rub to decontaminate under the nails (5 s)

**Figure 1** Surgical hand preparation technique with an alcohol-based hand-rub formulation.<sup>1</sup> (Reproduced with permission by the World Health Organization. © World Health Organization, 2009).



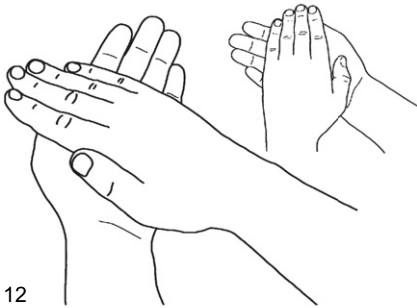
10

Smear the hand rub on the left forearm up to the elbow. Ensure that the whole skin area is covered by using circular movements around the forearm until the hand rub has fully evaporated (10-15 s)



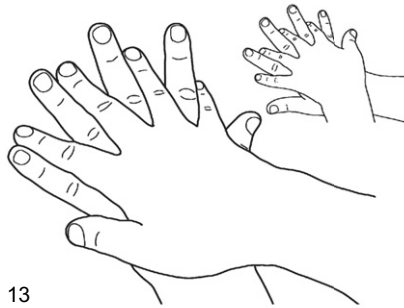
11

Put approximately 5 mL (3 doses) of alcohol-based hand rub in the palm of your left hand, using the elbow of your other arm to operate the distributor. Rub both hands at the same time up to the wrists, and ensure that all the steps represented in Images 12-17 are followed (20-30 s)



12

Cover the whole surface of the hands up to the wrist with alcohol-based hand rub, rubbing palm against palm with a rotating movement



13

Rub the back of the left hand, including the wrist, moving the right palm back and forth, and vice versa



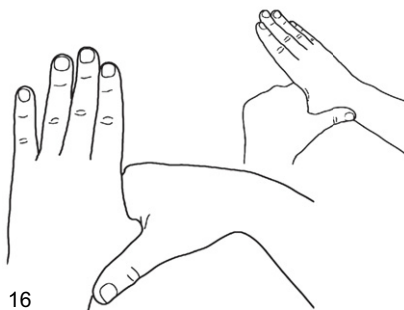
14

Rub palm against palm back and forth with fingers interlinked



15

Rub the back of the fingers by holding them in the palm of the other hand with a sideways back-and-forth movement



16

Rub the thumb of the left hand by rotating it in the clasped palm of the right hand and vice versa



17

When the hands are dry, sterile surgical clothing and gloves can be donned

Repeat the above-illustrated sequence (average duration 60 s) according to the number of times corresponding to the total duration recommended by the manufacturer for surgical hand preparation with an alcohol-based hand rub.

Figure 1 (continued).



doubtful, the current panel of experts clearly favours the use of alcohol-based hand rub for presurgical hand preparation also for this reason.

### Perspectives and research directions

A large, preferably randomised, controlled clinical trial is necessary to answer the key question: which compound should be used and how long should it be applied to reduce SSI? In addition, the in-vitro advantage of the alcohol-based hand rub should be corroborated by a clinical study, again with SSI as the outcome variable. Finally, the optimal duration of surgical hand preparation should be determined. Differences in clinical practice around the globe can be explained in part by the fact that until such results become available, recommendations are primarily based on observational studies and regulatory requirements to market the proposed compounds.

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