



## Surgical hand hygiene: scrub or rub?

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### SUMMARY

Surgical hand hygiene is standard care prior to any surgical procedure. Per-operative glove punctures are observed in almost 30% of all interventions, and a risk factor for postoperative infections. In the past, washing hands with antimicrobial soap and water (surgical scrub) was the norm, mainly with chlorhexidine or iodine. More recently, alcohol-based hand rub has been successfully introduced, showing greater effectiveness, less irritation to the hands, and requiring less time than washing hands. All products should have a remnant effect that delays microbial growth under the gloved hand. Some of the alcohol-based compounds are effective (as determined by the European Norm EN 12791) within 90 s whereas others require 3–5 min, similar to the scrub. The short procedure relies heavily on proper technique and timing, since lowering the exposure time to <90 s leads to significantly lower effectiveness of bacterial killing. Today, surgical hand hygiene should meet EN 12791 in Europe, or other standards, such as the US Food and Drug Administration tentative final monograph norm in the USA. It is best performed by using an alcohol-based hand rub, but a scrub with chlorhexidine-containing soap also meets these standards.

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### Evidence for surgical hand preparation

Surgical site infections (SSIs) belong to the most important nosocomial infections in surgical departments, leading to increased morbidity, mortality and additional cost.<sup>1</sup> Bundles of different tools are required to optimize prevention of SSI. The bacterial load at the incision site should be below the minimum infectious dose to prevent SSIs. The goal of routine antimicrobial surgical prophylaxis is to prevent the onset of infection from residual bacteria at the insertion site.<sup>1</sup> Today, disinfection of the incision site is recommended based on randomized controlled clinical trials.<sup>2</sup> Joseph Lister (1827–1912) was among the first to demonstrate the effect of skin disinfection on the reduction of SSIs.<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 antiseptics by the surgeon even more imperative. 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. In the early twentieth century, three steps were suggested: (i) wash hands with

hot water, medicated soap using a brush for five minutes; (ii) apply 90% ethanol for 3–5 minutes with a brush; and (iii) rinse the hands with an 'aseptic liquid'. In 1939, Price suggested a seven-minute hand wash with soap, water and a brush, followed by 70% ethanol for three minutes after drying the hands with a towel.<sup>4</sup> In the second half of the twentieth century, the recommended time for surgical hand preparation decreased from >10 minutes to 5 minutes. Even today, five-minute protocols are common, and still suggested for surgical hand hygiene with the World Health Organization (WHO) recipe for an alcohol-based compound.<sup>5</sup> A comparison of different countries showed almost as many protocols as countries listed.<sup>6</sup>

The introduction of sterile gloves did not render surgical hand preparation unnecessary. Our own studies have shown that pinholes in the gloves increase the risk for SSIs by more than fourfold, if routine surgical antimicrobial prophylaxis is not correctly administered.<sup>7</sup> However, using a high-quality glove or even double-gloving for exposure-prone procedures still makes sense to reduce the risk of infection by contaminated hands.

Sterile gloves contribute to preventing surgical site contamination and reduce the risk of blood-borne pathogen transmission from patients to the surgical team. However, 18%

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(range: 5–82%) of gloves have tiny punctures after surgery, and more than 80% of cases go unnoticed by the surgeon after two hours of surgery. In one study, even 35% of all gloves demonstrated puncture, thus allowing water as well as body fluids to penetrate the gloves without using pressure.<sup>8</sup> Double-gloving decreases the risk of puncture during surgery, but punctures are still observed in 4% of cases after the procedure.<sup>9</sup> In addition to protecting the patient, gloves reduce the risk of healthcare workers (HCWs) being exposed to blood-borne pathogens. The risk for HCWs is much lower than in the past, since most human immunodeficiency virus-positive patients have undetectable viral load in blood, and HCWs are protected lifelong from hepatitis B after successful vaccination. 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>10</sup>

Several reports of healthcare-associated infection outbreaks have been traced to the contaminated hands of the surgical team despite wearing sterile gloves. An early study by Koiwai and Nahas 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>11</sup> More recently, Boyce *et al.* reported a similar outbreak with CoNS and endocarditis with strain identity confirmed by molecular methods.<sup>12</sup> Mermel *et al.* 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>13</sup> One outbreak of surgical site infections even occurred when surgeons who normally used an antiseptic surgical scrub preparation switched to a non-antimicrobial product.<sup>14</sup>

## Surgical hand antisepsis using medicated soap

The products most commonly used 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. Triclosan is mainly bacteriostatic, is inactive against *Pseudomonas aeruginosa*, and has been associated with water pollution in lakes.<sup>15</sup> Application of chlorhexidine or povidone-iodine results in similar initial reductions of bacterial counts (70–80%) increasing to 99% after repeated applications. Rapid regrowth occurs after the application of povidone-iodine, but not after the use of chlorhexidine.<sup>16,17</sup>

Hexachlorophene and triclosan detergents are rarely used in European operating theatres because other products such as chlorhexidine or povidone-iodine have similar or better efficacy at lower levels of toxicity, faster mode of action, or broader spectrum of activity. Povidone-iodine is still commonly used 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>18,19</sup> At the end of a surgical procedure, iodophor-treated hands can have even more microorganisms than before surgical scrubbing.<sup>20</sup> The application technique is probably less prone to errors compared with hand rubbing, as all parts of the hands and forearms become

wet under the tap. By contrast, all parts of the hands and forearms must come into direct contact with the alcohol-based compound during hand rubbing.

Hingst *et al.* compared hand bacterial counts after three-minute and five-minute scrubs with seven different formulations. The three-minute scrub was shown to be as effective as the five-minute scrub, depending on the scrub agent formula.<sup>21</sup> Immediate and postoperative hand bacterial counts after five-minute and ten-minute scrubs with 4% chlorhexidine gluconate were compared by O'Farrell *et al.* before total hip arthroplasty procedures.<sup>22</sup> The ten-minute scrub reduced the immediate colony count more than the five-minute scrub. Although the postoperative mean Log<sub>10</sub> cfu count was slightly higher for the five-minute than for the ten-minute scrub, the difference between the post-scrub and postoperative mean cfu counts was higher for the ten-minute scrub than for the five-minute scrub in longer (>90 min) procedures. This study recommended a five-minute scrub before total hip arthroplasty.<sup>22</sup> A study by O'Shaughnessy *et al.* using 4% chlorhexidine gluconate in two-, four- and six-minute scrubs observed a reduction in post-scrub bacterial counts in all groups. Scrubbing for longer than two minutes did not confer any advantage. This study recommended a four-minute scrub for the surgical team's first procedure and a two-minute scrub for subsequent procedures.<sup>23</sup> Poon *et al.* applied different scrub techniques with a 10% povidone-iodine formulation. They found that a 30-second hand wash can be as effective as a 20-minute contact with an antiseptic in reducing bacterial flora, and that vigorous friction scrub is not necessarily advantageous.<sup>24</sup>

## Side-effects of surgical hand scrub

Hand washing removes fatty acids from the skin and can lead to dry skin, especially in areas with cold winters. 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. 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 capacitance of the skin following two hand-hygiene regimens. The water content decreased significantly during the hand-wash phase with soap and water compared with the alcohol-based hand-rub phase.<sup>25</sup> Most data have been generated outside the operating theatre, but these results may apply also to surgical hand antisepsis.

## 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. Faucets are common sources of *P. aeruginosa* and other Gram-negative bacteria and have been linked to infections in a variety of clinical settings, including intensive care units.<sup>26</sup> It is therefore prudent to remove tap aerators from sinks designated for surgical hand antisepsis, since they allow growth of water-borne bacteria.<sup>27,28</sup> Recontamination may occur when the

soap is rinsed off, and droplets may spill over the hands. Even automated sensor-operated taps have been linked to *P. aeruginosa* contamination.<sup>29</sup> However, outbreaks or cases clearly linked to contaminated hands of surgeons after proper surgical hand scrub have not yet been documented. Importantly, in countries lacking continuous monitoring of drinking water, or with improper tap maintenance, recontamination may be a real risk even after correct surgical hand scrub.<sup>30</sup> Even in European countries, drinking water may contain up to 300 cfu/mL of mesophilic bacteria, and though it should not contain detectable amounts of *E. coli* or enterococci in a sample of at least 100 mL, low-level contamination with *P. aeruginosa* is within the European limits for drinking water.<sup>31</sup> One surgical hand preparation episode with traditional agents uses ~20 L of water and represents >60 L for the entire surgical team. This is a critical issue worldwide, particularly in countries with a limited safe water supply.

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

Alcohol-based hand rubs have been shown in *in vitro* and *in vivo* studies to be superior to currently available surgical hand scrubs.<sup>32</sup> 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>6</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, are more effective than other agents in lowering bacterial counts on the skin immediately post scrub. Skin emollients may be beneficial for the skin, and do not impede activity of the alcoholic hand rub.<sup>33</sup>

The hands of the surgical team should be clean upon entering the operating theatre by washing with 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. 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. To eliminate bacterial spores, non-medicated soaps are sufficient. 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 for hand rub has not been standardized worldwide. The WHO approach for surgical hand preparation requires the same six basic steps as for hygienic hand antisepsis, but requires an additional step for rubbing the forearms.<sup>34</sup> The sequence of the WHO proposal on how to apply the hand rub is not crucial, but rubbing specifically

thumb and fingertips is beneficial. Kampf *et al.* challenged this method, and suggested a 'responsible application', or one of the other new techniques.<sup>35</sup> However, several studies provide evidence that training in properly applying the WHO technique significantly improves bacterial killing.<sup>36–38</sup> During the whole procedure, the hands should remain wet from the alcohol-based rub, thus requiring ~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 required to keep the skin area wet during the entire time of the hand rub.

#### Time required for the procedure

For many years, surgical staff frequently scrubbed their hands for ten minutes preoperatively, which frequently led to skin damage. Several studies have demonstrated that scrubbing for 5 minutes reduces bacterial counts as effectively as a ten-minute scrub.<sup>22,23</sup> Following the reference method outlined in EN 12791, surgical hand antisepsis using an alcohol-based hand rub required three minutes.<sup>39,40</sup> In a recent study with healthy volunteers in an *in vivo* experiment, even a 90-second rub was shown to be equivalent to a three-minute rub with a product containing a mixture of iso- and n-propanol and mecetronium ethylsulphate.<sup>41</sup> However, the WHO formulation failed to meet this requirement.<sup>42</sup> These results were corroborated in a similar study performed under clinical conditions with 32 surgeons.<sup>43</sup> However, further studies need to be conducted with other alcohol-based hand rubs to compare the usual 2–3-minute hand preparation with shorter times before such a recommendation could be generalized to other products.

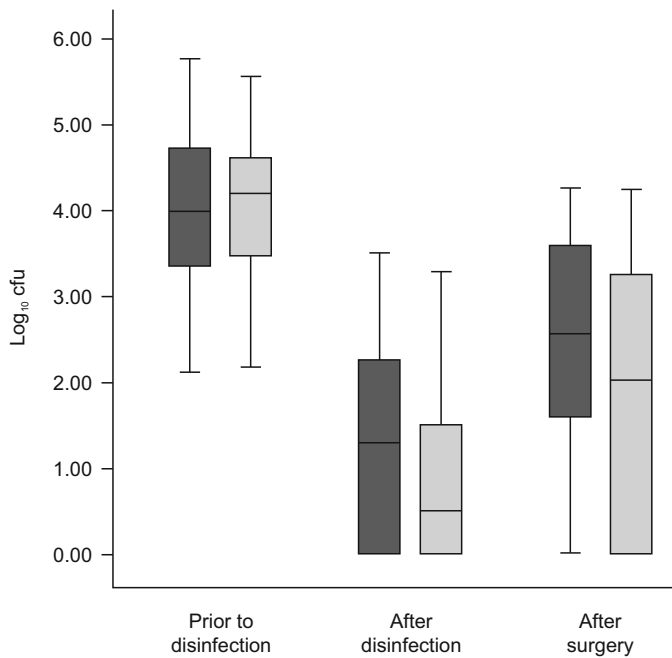
Alcohol-based hand gels should not yet be used unless they pass the test EN 12791 or an equivalent standard required for hand-rub formulations. Many of the currently available gels for hygienic hand rub do not meet EN 1500. The technique to apply the alcohol-based hand rub defined by EN 1500 matches the one defined by EN 12791. The latter requires an additional rub of the forearms that is not required for the hygienic hand rub.<sup>5</sup>

However, one has to keep in mind that 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, a three-minute exposure is recommended for most commercially available products, but it can be shortened to 1.5 minute for a few formulations (Figure 1).<sup>5</sup> The manufacturer must provide recommendations as to how long the product must be applied for. Manufacturers' recommendations should be based on *in vivo* evidence at least, considering that clinical effectiveness testing is unrealistic.

#### Side-effects of alcohol-based hand rub

Overall, the alcohol-based hand rub is well tolerated, better than the surgical scrub with medicated soap.<sup>44</sup> In fact, reported allergies to alcohols have not yet been confirmed independently.<sup>45</sup> However, the application technique is more prone to errors for hand rubs than for scrubs. A simple training session may be sufficient to prevent such errors.



**Figure 1.** Comparison of Sterillium® 1.5 min (dark grey bars) vs 3 min (light grey bars) application with surgeons ( $N = 32$ ); error bars indicate 95% confidence intervals. (Reprinted with permission from Weber *et al.* <sup>43</sup>).

Especially in the USA, storing flammable fluids is of concern, because US regulations regarding the storage of alcohol in hallways are very strict. However, fires are extremely rare in the operating room and almost never related to hand rubs. <sup>46,47</sup>

## Conclusion

The surgical scrub or the surgical hand rub – both are suitable today for preparation of the hands prior to surgery. Several factors favour the use of hand rub, including rapid action, time savings, fewer side-effects, and no risk of recontamination by rinsing hands with water. Hand rub does not depend on high-quality drinking water, an issue particularly important in countries with limited resources.

### Conflict of interest statement

The author has no conflict of interest to report.

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