

✧ SCHOLARLY PAPER ✧

# *A systematic review on the effectiveness of alcohol-based solutions for hand hygiene*

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## **A systematic review on the effectiveness of alcohol-based solutions for hand hygiene**

The use of alcohol has been proposed as an option for hand hygiene. A systematic review was conducted to evaluate the clinical evidence supporting the use of alcohol-based solutions in hospitals as an option for hand hygiene. Studies published between January 1992 and April 2002 in English and Thai, related to the effectiveness of alcohol-based solutions, were reviewed. The databases searched included Medline, DARE, CINAHL and Dissertation Abstracts International. All studies were assessed as having adequate methodological quality. Results of this systematic review supported that alcohol-based hand rubbing removes microorganisms effectively, requires less time and irritates hands less often than does handwashing with soap or other antiseptic agents and water. Furthermore, the availability of bedside alcohol-based solutions increases compliance with hand hygiene among health care workers.

**Key words:** alcohol-based solution, hand hygiene, hospital personnel, systematic review.

## **INTRODUCTION**

Health care workers (HCWs) can acquire pathogens from patients and transmit them to susceptible patients. Microorganisms accumulate on the hands of HCWs during patient care.<sup>1</sup> Therefore, hand hygiene is considered one of the most important measures for preventing nosocomial infections. Several guidelines and recommendations on hand hygiene have been published.<sup>2,3</sup> Recommended methods include hand washing (washing hands with plain soap), hygienic hand washing (washing hands with medicated soap) and hygienic hand rubbing (use of antiseptic rubs). It is still unclear which method is the most effective. Studies consistently have shown that HCWs frequently do not wash their hands, and compliance rarely

exceeds 50%.<sup>4</sup> Several factors including time limitations might contribute to this unsatisfactory rate.<sup>5</sup> More rapid and effective hand disinfection procedures such as rubbing with alcohol have been proposed.<sup>6</sup> Three types of alcohol, ethyl (ethanol), normal-propyl (N-propanol), and isopropyl, have been shown to be the most appropriate for use on the skin. It has been shown that alcohol diluted with water provides maximal antimicrobial activity and preparations containing 60–90% alcohol are most effective.<sup>7</sup> Rub-in hand disinfectants with alcohol-based solutions were used for both hygienic and surgical hand disinfection.<sup>2</sup> Although most of the hospitals in Thailand still favour hand washing with soap or an antimicrobial detergent, recent studies have demonstrated that increased use of alcohol-based hand rubs can improve hand hygiene practices among HCWs. This systematic review evaluated the clinical evidence supporting the use of alcohol-based hand rubs in hospitals as an alternative for ensuring hand hygiene.

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## METHODS

The literature review was designed to assess both published and unpublished studies. The initial search terms included alcohol, alcohol-based, hand washing, hand hygiene and compliance. The time period of the search covered articles published between January 1992 and April 2002 in English and Thai. The databases which were searched for published studies included CINAHL, Medline and DARE. The search for unpublished studies was conducted through Dissertation Abstracts International. Studies identified from reference list searches were assessed for relevance based on the study title. The retrieved articles were assessed by two reviewers for their suitability for inclusion as evidence. Methodological quality of all eligible studies was assessed using a checklist, developed by three reviewers, based on the work of the Cochrane Collaboration and Centre for Reviews and Dissemination. Data extraction was performed using a form, developed and tested by the author, to extract key information from the eligible studies. The form contained such items as research design, description of intervention, outcome measures, results and author conclusions.

### Inclusion/exclusion criteria for studies

The study specifically searched for studies related to the effect of alcohol-based solutions in reducing microorganisms on the hands of HCWs or agar plates, compliance with hand hygiene among HCWs during introduction of alcohol-based solutions, skin problems on hands when using alcohol-based solutions and time involved in using alcohol hand rubs. Articles excluded consisted of expert opinion, literature reviews or those that lacked detailed results of the study.

### Data analysis

When possible, study results were pooled in statistical meta-analysis using Review Manager software from the Cochrane Collaboration.<sup>8</sup> Weighted mean differences (WMD) or odds ratio (OR) and 95% confidence intervals (CI) were calculated for each study. Heterogeneity between combined studies was tested using a standard chi-square test. Pooling of data from studies was initially based on comparable interventions. When statistical pooling was not appropriate or possible, the findings were summarized in narrative form. Data generated from observational and descriptive studies were summarized in narrative form, listing significant themes.

## RESULTS

A total of 58 citations were retrieved. Forty-one articles (70.69%) met the inclusion criteria. Of these, two studies testing alcohol-based solutions on the reduction of microorganisms on the hands of HCWs in Thailand were found. The majority of the studies (26/41) related to effectiveness in reducing microorganisms, seven to compliance with hand hygiene, 14 to skin problems and three to the time involved in using alcohol hand rubs.

### Effectiveness in reducing microorganisms

Twenty-six (63.41%) of the 41 studies were included in the review of effectiveness of alcohol-based solutions in reducing microorganisms. For the purpose of analysis, the range of interventions have been grouped by concentration, type of alcohol-based disinfectant, form of application modes and types of microorganisms. Analysis was conducted to determine the outcomes of log reduction factor (RF). As a variety of outcome measures were used in the studies, not all comparisons could be accomplished.

### Comparison of various concentrations, types and forms of alcohol-based solutions

Of the 26 studies, six (23.08%) studies examined the microbicidal efficacy of various concentrations, types and forms of alcohol-based solutions for hand hygiene. One study reported 99.9% reduction of bacterial colonies on hands after rubbing with alcohol-based solution.<sup>9</sup> The results of the study conducted by Dyer *et al.* showed that 70% ethanol reduced more bacteria than 62% ethanol.<sup>10</sup>

Rotter *et al.*<sup>11</sup> found that the immediate effect of hand rubbing with 90% isopropanol for 3 min was as effective as reference alcohol (RF =  $2.6 \pm 1.1$  vs.  $2.6 \pm 1.0$ ). But this pattern was not statistically significant for a sustained effect, even 3 h after disinfection and after gloves had been worn for this period of time (RF =  $1.4 \pm 0.8$  vs.  $1.6 \pm 0.9$ ). The effect of 70% isopropanol was found to be significantly smaller than the reference alcohol, both for immediate effect (RF =  $2.1 \pm 1.0$  vs.  $2.6 \pm 1.0$ ) and sustained effect (RF =  $1.1 \pm 0.9$  vs.  $1.6 \pm 0.9$ ).

After using sterillium (45% w/w of propan-2-ol, 30% w/w of propan-1-ol and 0.2% w/w of ethylhexadecyldimethyl ammonium ethylsulfate, skin care ingredients, colour and perfume) for 30 s, Pietsch found RF =  $4.26 \pm 0.45$  when compared with the reference alcohol (N-propanol 60% v/v;  $4.10 \pm 0.59$ ).<sup>6</sup> Therefore, sterillium appeared to have passed the requirement of the

norm of elimination of bacteria within 30 s. Pietsch also found that the pooled result for seven alcohol gels in comparison with the reference alcohol significantly favoured the reference alcohol with regard to the microbicidal efficacy on the hands of HCWs (WMD = 1.17, CI = 1.01–1.33).<sup>6</sup> None of the gels tested by Pietsch passed the European Norms (EN) 1500 requirement within 30 s. In addition, Kramer *et al.*, when comparing 10 alcohol-based hand gels with alcohol content of up to 70% (v/v) and four alcohol-based hand rinses with alcohol content of up to 75% (v/v) to the reference alcohol, also found that most alcohol-based hand rinses met the standard requirement within 30 s of application, whereas the tested gels did not fulfil this criterion.<sup>12</sup> Hobson *et al.* indicated that use of alcohol-based solutions without the use of a scrub brush produced results statistically similar to 3-min applications using either a brush or a sponge.<sup>13</sup> The alcohol-based formulation passed the Food and Drug Administration's current Tentative Final Monograph for Healthcare Antiseptic Products criteria for surgical scrubs in all three application modes tested.<sup>14</sup>

### Comparison of alcohol-based solutions with other solutions

Studies by Dyer *et al.*<sup>10</sup> Rotter *et al.*<sup>15</sup> Zaragoza *et al.*<sup>16</sup> and Herruzo-Cabrera *et al.*<sup>17,18</sup> demonstrated that hand rubbing with an alcohol-based solution significantly reduced bacteria more efficiently than did non-medicated soap.

Meta-analysis of the studies conducted by Pietsch<sup>6</sup> and Hobson *et al.*<sup>13</sup> demonstrated that the microbial reduction by alcohol-based solutions was significantly greater than that of 4% chlorhexidine gluconate (CHG) immediately after application (WMD = 1.10, CI = 1.01–1.19). In addition, Kampf *et al.* found that sterillium rub revealed a higher mean of  $\log_{10}$  reduction at all times.<sup>19</sup> Sterillium rub exceeded proposed performance criteria, whereas hibiclens (4% CHG) did not.

Larson *et al.* found that there was no significant difference at any time (middle of day 1, week 2 and week 4) in the number of  $\log_{10}$  colony-forming units between participants in the 2% CHG and 61% ethanol with emollients groups.<sup>20</sup> This result is consistent with findings of Bryce *et al.*, which showed that there was no statistical difference between microbial hand counts following presurgical hand disinfection with an alcohol-based product or 4% CHG/7.5% povidone iodine for cases of < 2 h duration (0.21 vs. 0.33).<sup>21</sup> Comparison of longer surgical cases (cases of > 3 h duration) also showed no significant differ-

ences in microbial counts (+ 1.19 vs. + 0.69). However, Hobson *et al.* demonstrated that surgical hand scrubbing with alcohol-based solutions significantly reduced microorganisms more efficiently than did 4% CHG during all five days of application.<sup>13</sup> On the contrary, Mulberry *et al.* found that the RF with 61% ethanol proved to be less than that of the 4% CHG product at all times on days one, two and five.<sup>22</sup>

Four studies evaluated the microbicidal efficacy of the combination of CHG and alcohol. The studies by Mulberry *et al.*,<sup>22</sup> Larson *et al.*<sup>23</sup> and Kjolen *et al.*<sup>24</sup> indicated that using the 1% CHG and 61% ethanol (CHG/ethanol) hand preparation proved to be significantly greater in bacterial RFs than that of 4% CHG products at all times ( $P < 0.05$ ). A study conducted by Sae Ung *et al.* found that the reduction of bacteria on HCWs' hands was 30–50% when washing with soap and > 90% when rubbing with solution of 0.5% CHG—70% alcohol and 1% glycerol, respectively.<sup>25</sup>

Hobson *et al.* demonstrated that the alcohol-based preparation led to significantly more microbial reduction than 7.5% povidone iodine ( $P < 0.05$ ).<sup>13</sup> Dyer *et al.* found that benzalkonium chloride and 62–70% ethanol were equally effective in reducing microorganisms after a single application (RF =  $2.8 \pm 0.2$ ).<sup>10</sup> The study performed by Moadab *et al.* showed that the antimicrobial activity of alcohol-based hand gel was significantly less effective than benzalkonium chloride (0.13% v/v) ( $P < 0.001$ ).<sup>26</sup>

### The effectiveness of alcohol-based solutions against multiple drug resistant microorganisms

The pooled results of the studies conducted by Guihermetti *et al.*<sup>27</sup> and Goroncy-Berme *et al.*<sup>28</sup> showed that hand rubbing with an alcohol-based solution significantly reduced methicillin-resistant staphylococcus aureus (MRSA) more efficiently than did non-medicated soap (WMD = 2.60, CI = 2.23–2.98) and 4% CHG (WMD = 4.13, CI = 3.55–4.71). In addition, Huang *et al.* found that the removing rate against MRSA was noted to be more for 80% ethyl alcohol than liquid soap and 4% CHG (99.1% vs. 96.1% and 99.1% vs. 97.2%).<sup>29</sup> Guihermetti *et al.* found that 10% povidone iodine detergent containing 1% iodine (PVP-1) had a higher removal rate against MRSA than 70% ethyl alcohol (RF = 4.39 vs. 3.27).<sup>27</sup> Huang *et al.* reported that 7.5% PVP-1 was less effective than 80% ethyl alcohol in eliminating MRSA contamination (RF = 3.13 vs. 3.22).<sup>29</sup>

Goroncy-Bermes *et al.* indicated that use of alcohol-based hand disinfectants was more effective against vancomycin-resistant enterococcus (VRE) than non-medicated handwash product (RF = 5.10 vs. 4.80) and the 4% CHG (RF = 5.10 vs. 3.22).<sup>28</sup> An *in vitro* study by Kampf *et al.* also found similar results that 1-propanol and three preparations based on propanol had highly effective reduction of VRE after 15 s (RF > 6.4), whereas CHG alone did not show sufficient RF against VRE even after 5 min (RF < 2.5).<sup>30</sup>

A study by Goroncy-Bermes *et al.* showed that the RFs of high-level gentamicin-resistant enterococcus obtained by using the alcohol-based hand disinfectant and the non-medicated cleanser were comparable (RF = 5.30 vs. 5.10). But the efficacy of the CHG was significantly lower (RF = 3.30).<sup>28</sup>

### The effectiveness of alcohol-based solutions against viruses and fungi

Studies by Sattar *et al.*<sup>31</sup> and Bellamy *et al.*<sup>32</sup> found that alcohol-based hand rubs reduced the infectivity titres of viruses including adeno-, rhino-, and rotaviruses by 3 to > 4 log<sub>10</sub> when compared to a reduction of ≤ 1 log<sub>10</sub> for the hard water rinse. An *in vitro* study by Fendler *et al.*<sup>33</sup> indicated that 62% ethanol and emollient (Purell) was highly effective in 15 s against all of the fungal species investigated (RF > 3.92) and was also effective against viruses in 30 s (RF > 1.24).

### The interactions of hand care products on the microbicidal efficacy of alcohol hand rubs

Heeg conducted two trials to investigate the impact of hand care products on the microbicidal efficacy of alcohol hand rubs.<sup>34</sup> The results indicated that the mean RF for three alcohol hand rubs varied between 4.03 and 4.22 compared with 3.76 and 4.43 for six possible combinations of alcohol hand rubs and alcohol hand gel products applied immediately prior to disinfection. The RFs achieved with alcohol hand rubs alone and in combination with hand care were not significant differences.

### Compliance with hand hygiene

The evidence that the introduction of hand rubbing with an alcohol-based solution in intensive care units (ICUs) and other wards improves compliance with hand hygiene among HCWs is strengthened by this review of studies. Six studies showed that compliance was significantly improved

from 23.4–62.2% to 48.4–66.5%.<sup>5,35–40</sup> Most of these studies involved the promotion of alcohol-based products together with an educational programme and other interventions, such as performance feedback and poster campaigns. However, all of these studies indicated that compliance improved mainly as a result of the increased use of alcohol-based hand rub solutions. The combined result significantly favoured the introduction of alcohol-based solutions (Peto OR = 1.96, CI = 1.56–2.46).

Four studies<sup>5,35,36,40</sup> indicated that nurses were more compliant than physicians and other HCWs in regards to hand hygiene. Furthermore, it was found in the study by Pittet *et al.* that average compliance differed between hospital locations, and that compliance improved significantly during the period of introduction of alcohol-based solutions in medical, surgical and ICUs ( $P < 0.001$ ).<sup>36</sup> Changes in compliance were not statistically significant in gynaecology/obstetrics ( $P = 0.17$ ) or paediatric wards ( $P = 0.12$ ).

### Skin problems

In comparing the effects of alcohol-based solution with soap or other antiseptic solutions in relation to skin problems, various skin assessments were used including dryness and irritation. Several studies used either subjective or objective methods and some studies used both methods to evaluate skin irritation and dryness due to using alcohol-based solutions for hand hygiene. Among the 14 studies designed to test the effect of alcohol-based solutions on skin condition, five tested before and after, one compared alcohol-based solutions and soap, and eight compared alcohol-based solutions and CHG.

Three studies conducted by Hobson<sup>13</sup> Conrad<sup>41</sup> and Kampf *et al.*<sup>42</sup> found no significant increase in skin problems due to the use of alcohol-based solutions. Most of the skin irritation problems could be controlled with more frequent skin care. Furthermore, after using an alcohol-based hand rub, Girard *et al.*<sup>5</sup> and Grove *et al.*<sup>43</sup> found that there was a significant decrease in hand dryness ( $P = 0.002$  and  $P = 0.02$ , respectively). Boyce *et al.* found that skin irritation and dryness increased significantly when nurses washed their hands with unmedicated soap products rather than disinfecting their hands with an alcohol-based gel.<sup>44</sup> Eight studies reported comparing the effects of alcohol-based solutions and CHG on skin condition. Five of them<sup>6,19,23,45,46</sup> found that alcohol-based solutions were less damaging to the skin than CHG and the other three studies<sup>21,22,47</sup> found no difference.

### Time involved in using alcohol hand rubs

There were three studies that reported on time consumption in using alcohol-based solutions. One was the study by Voss and Widmer which indicated that it took ICU nurses  $\approx 60$  s for hand washing whereas use of an alcohol-based solution available at each patient's bed required only 15 s.<sup>48</sup> In addition, given 100% compliance, hand washing with water and soap would consume 16 h of nursing time (17% of the total workforce), whereas bedside hand rubbing with an alcohol-based solution would require only 3 h ( $< 3\%$  of the workforce) ( $P = 0.01$ ). Larson *et al.* indicated similar results in two studies. The first study indicated a 41% decrease in application time in using alcohol-based solutions compared to CHG ( $P = 0.0001$ ).<sup>20</sup> The second study found that a significantly shorter time was required for a waterless hand rinse product containing an alcohol-based solution than for the traditional surgical hand scrub (CHG) (2 min vs. 6 min).<sup>23</sup>

### CONCLUSION

This systematic review appears to support the use of alcohol-based hand rubs for routine hand hygiene. Numerous studies have demonstrated that alcohol-based hand rubs remove microorganisms including bacteria, viruses, fungi and multiple drug resistance microorganisms from hands of personnel more effectively than hand washing with non-medicated soap or other antiseptic agents and water. At equal concentrations, N-propanol is the most effective alcohol of those commonly used and ethanol the least. Isopropanol 90% is as effective as N-propanol 60% in antimicrobial activity. Ethanol-based formulations should contain at least 70% ethanol (v/v). Most alcohol solutions used in hospitals meet the EN requirement with 3 mL and within 30 s. However, antimicrobial efficacy of alcohol-based hand gels did not pass the EN 1500 within 30 s whereas the rinses did. Brushless application of the alcohol-based surgical scrub formulation for a duration of 3 min yielded satisfactory results for use as an effective surgical hand scrub. The combination of 61% ethanol and 1% CHG was even more effective in reducing counts of microorganisms and produced residual antibacterial properties on the skin.

Data from recent studies consistently demonstrated that alcohol-based solutions for hand disinfection are less irritating on skin than washing hands with soap and water or any antiseptic detergents. Frequent use of alcohol can dry the skin, but the addition of suitable emollients into alcohol hand rinses greatly reduces this problem. There

was a study that showed the efficacy of alcohol-based hand rubs is not inevitably impaired when they are used in combination with selected, comparable hand care products.

Several studies showed that the availability of an alcoholic solution increased compliance with hand hygiene among HCWs. Nurses complied with hand hygiene more than physicians and others. In addition, the compliance improved significantly during the period of introduction of alcohol-based solutions in ICU more than other units.

Hand rubs with alcohol-based solutions required less time than hand washing with soap or disinfectants in certain clinical conditions. The shorter time required for use of the alcohol hand rub might explain the enhanced compliance. However, one clinical study did not favour use of alcoholic compounds because they found that infections in a surgical intensive care unit were significantly lowered by the use of a CHG soap compared with alcoholic compounds.<sup>49</sup> But one may question the results because this study did not control the confounding factors of compliance with hand hygiene and alcohol dosage.

These findings demonstrate a variety of benefits through the introduction of a well-tolerated hand disinfection programme using alcohol-based solutions. It is important to consider changes in hand hygiene practices in hospital settings, from traditional hand washing to the use of an alcohol-based product for hand hygiene.

### Recommendations

Hand hygiene is one of the most effective methods for preventing hospital-acquired infections. Based on the findings of this systematic review, hand rubbing with waterless, alcohol-based solutions has been proved to be effective in the reduction of microorganisms on hands, improvement of compliance with hand hygiene among HCWs, and less irritable for the skin. Therefore, these results confirmed the validity of the suggested benefits of promoting bedside, alcohol-based hand rubs as the main hand hygiene compliance tool in hospital settings. Another important advantage of alcohol-based solutions is that their use does not require sinks or plumbing. As a result, alcohol-based products can be placed in many locations on hospital wards. For optimal effectiveness for hand antiseptics, 3 mL of alcoholic solution is required to be rubbed over the surfaces of the hands and fingers. As a hand rub does not remove soiled and organic material, a hand rub is not an option if hands are visibly soiled or contaminated with proteins or organic matter.

Health care workers should use an alcohol-based hand rub between patients. In high demand situations, such as in most ICUs, hand rubs with alcohol-based solutions appear to be the only means of maintaining and, possibly, facilitating compliance with hand hygiene. Compliance can be improved with bedside alcoholic hand disinfection without increasing human resources or decreasing compliance.

However, strategies to improve compliance with hand hygiene practices should be multimodal and multidisciplinary, with easy-to-access alcohol-based solutions viewed as the main tool of the strategy. A training session for HCWs should be held with the introduction of the alcohol-based hand rub. Further research is needed to examine the association between use of alcohol-based solution for hand hygiene of HCWs and reduction in nosocomial infection rates among patients.

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