The Effects of Surgical Hand Scrubbing Protocols on Skin Integrity and Surgical Site Infection Rates: A Systematic Review

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ABSTRACT

This systematic review aimed to critically appraise and synthesize updated evidence regarding the effect of surgical-scrub techniques on skin integrity and the incidence of surgical site infections. Databases searched include the Cumulative Index to Nursing and Allied Health Literature, MEDLINE, Embase, and Cochrane Central. Our review was limited to eight peer-reviewed, randomized controlled trials and two nonrandomized controlled trials published in English from 1990 to 2015. Comparison models included traditional hand scrubbing with chlorhexidine gluconate or povidone-iodine against alcohol-based hand rubbing, scrubbing with a brush versus without a brush, and detergent-based antiseptics alone versus antiseptics incorporating alcohol solutions. Evidence showed that hand rubbing techniques are as effective as traditional scrubbing and seem to be better tolerated. Hand rubbing appears to cause less skin damage than traditional scrub protocols, and scrub personnel tolerated brushless techniques better than scrubbing using a brush. *AORN J* 103 *(May 2016) 468-482. © AORN, Inc, 2016. http://dx.doi.org/10.1016/j.aorn.2016.03.003*

Key words: *surgical hand scrubbing, hand rubbing, skin, irritation, surgical site infection.*

Surgical site infections (SSIs) are a major issue in health care worldwide, accounting for approximately 16% of all health care–associated infections in England[1] and an estimated 24% in the United States.[2] Patients who have SSIs are subject to longer hospital stays, delayed incision site healing, and the use of antibiotics, which add additional psychological and financial burdens. Additionally, a severe SSI can be fatal.[3,4] The treatment of SSIs represents a significant cost burden to health care services. In the United Kingdom, the annual cost of SSIs to the National Health Service is approximately £700 million (approximately $1 billion).[5] In the United States, the estimated annual cost of SSIs is even higher—approximately $3.3 billion.[6] Although many factors lead to SSI occurrences, hygiene of the surgical-team members' hands has been documented as one of the important factors.[7,8]

Hand hygiene has been associated with reducing infections since the nineteenth century.[9,10] In 1847, Dr Ignaz Semmelweis observed that postdelivery mortality in women whose babies were delivered by physicians and medical students was much higher (13% to 18%) than in women whose

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babies were delivered by midwives (2%). Semmelweis believed that this was because the physicians performed autopsies on cadavers before performing clinical procedures. He asked his medical staff members to wash their hands with a chlorinated lime solution before performing clinical procedures, and found that patients' mortality was reduced to approximately 2%.[9] Two decades later, a Scottish surgeon named Joseph Lister began using carbolic acid as an antiseptic in his clinical work, a compound used by engineers to treat sewage. He reported that dressings containing carbolic acid dramatically reduced patients' mortality caused by incision site infection.[10] Since the twentieth century, a number of antiseptic formulas have been introduced for routine hand scrubbing before surgery; as a result, to prevent SSIs, surgical hand hygiene has been part of the standard care provided before any surgical procedure. To limit the risk of SSIs, several national and international organizations, such as the World Health Organization (WHO), AORN, and the National Institute for Health and Care Excellence (NICE) recommend protocols for surgical scrubbing in ORs.[1,11,12] Despite the implementation of guidelines, the length of time taken to scrub and the type of scrub solution used varies across health care settings, hospitals, and countries.

Traditionally, 7.5% povidone-iodine or 4% chlorhexidine gluconate solutions have been used in the United States and worldwide; the use of 4% chlorhexidine, 1% triclosan, or some alcohol preparations has been more common in Europe.[8,13] Some studies suggest that adherence to guidelines is generally poor.[14,15] Skin irritation is considered to contribute to poor adherence to the required guidelines. Asensio and de Gregorio[16] conducted a survey of 70 surgeons and perioperative nurses in Spain to evaluate the performance of surgical hand scrubbing and perceptions concerning the use of alcohol hand rubbing or antiseptic hand scrubbing. They found that 85% of survey participants agreed that alcohol hand rubbing improved hand hygiene compliance. Participants who used alcohol-rubbing methods reported better skin outcomes more frequently than those who used antiseptic scrubbing.[16]

Hand washing has been shown to remove dermal fatty acids and may result in dry skin.[17] Excessive scrubbing can also cause dermatologic problems such as skin irritation and skin dryness.[18] More importantly, skin damage can lead to disruptions in the normal bacterial hand flora and may cause more organisms to be shed, which could increase the risk of staff members transferring infections to patients.[19] A study conducted by Boyce et al[14] compared the effect of two hand hygiene regimens on the epidermal water content of the dorsal surface of nurses' hands. They found that the epidermal water content was significantly lower in nurses who washed their hands with soap and water than in those who used an alcohol hand rub. The target population in this study was nurses who worked in hospital wards rather than ORs. Understanding the available evidence on the effect of hand scrubbing on surgical-team members' skin is necessary to appropriately inform hand hygiene practices.

PURPOSE OF THE LITERATURE REVIEW

We conducted this systematic review to critically appraise and synthesize the evidence regarding the effects of various surgical-scrub protocols on skin integrity and their effectiveness in preventing SSIs. This review sought to address three specific questions.

- What is the effect of various scrub protocols on skin integrity?
- How has skin damage associated with scrubbing been measured, and which measurement tools were used?
- How has the effectiveness of surgical scrubbing protocols on preventing SSIs been measured, and what differences exist between scrubbing protocols?

RESEARCH METHODS

We developed a systematic review protocol for the identification, retrieval, and appraisal of the evidence. We registered our review in the PROSPERO database[20] in November 2014. We searched all relevant literature published from 1990 through January 2015 in four databases, without any language restrictions. We used free-text, key word, and Medical Subject Headings (MeSH) terms for each of the following databases: MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, and the Cochrane Central Register of Controlled Trials. We entered subject subheadings and word truncations according to database requirements to map all possible key word terms. Search terms included

- hand, hands, or hand wash;
- hand disinfection;
- surgical scrub;
- surgical NEAR infection;
- surgical NEAR wound;
- post-operative or postoperative;
- NEAR (wound NEXT infection);
- perioperative care;
- preoperative or pre-operative;
- skin integrity, skin damage, and skin irritation;
- dermal tolerant; and
- skin redness, skin roughness, and skin condition.

We also searched the NICE, AORN, Scottish Intercollegiate Guidelines Network, and WHO for relevant published guidelines. In addition, we checked the reference lists of included studies and other relevant review papers for other eligible studies.

Inclusion Criteria

For the primary analysis, eligible studies included randomized controlled trials (RCTs) and non-RCTs that compared any type of surgical-scrub protocol as a procedure for preventing SSIs. Other study criteria included

- primary studies,
- studies with a target population that included any personnel on the scrub team who work in the OR in any hospital or community surgical service,
- studies with interventions that included any surgical hand scrubbing protocols used for preventing SSIs, and
- studies with outcome parameters that included SSI rates resulting from surgical procedures and skin integrity assessments.

We excluded studies if they were laboratory studies only, were animal studies, were presented in conference proceedings, consisted of participants who were not OR personnel, or did not report on skin reactions related to surgical scrubbing.

Data Extraction

We used tables to organize data extracted from eligible articles. The data extracted into tables included the year of publication, country of affiliated author, type of study design, sample size, participants' role (eg, surgeon, nurse), type of surgical-scrub protocols (eg, disinfecting agent, scrub equipment, duration of first scrub, duration of subsequent scrubs), SSI rate, and skin integrity outcome measures. All data were verified by a second reviewer to ensure accuracy.

Quality Assessment

Two reviewers independently assessed the methodological quality of each study, discussing and resolving any disparities. We used the Effective Public Health Practice Project (EPHPP) quality assessment tool[21] to determine the methodological quality of each study. The EPHPP tool is an established quality-assessment tool for use in systematic reviews.[22,23] Other previous studies have evaluated the validity of the tool in terms of its content and construction.[22,24] The tool assesses six domains—selection bias, study design, confounders, blinding, data collection method, and withdrawals/dropouts. Guidelines for the tool suggest that each domain be rated as high quality (1 point), moderate quality (2 points), or low quality (3 points).[22] We determined that the quality of evidence for each paper was high if there were no low ratings across six domains, moderate if there was one low rating, and low if there were two or more low ratings.

Data Analysis

We used Microsoft Excel 2007 to perform the analyses of all descriptive statistics. We performed a quantitative pooled analysis to estimate the pooled effect of surgical-scrubbing protocols on SSIs if the studies reported a common intervention type, shared outcome measures, and homogenous populations. For trials with more than two arms, we compared the outcomes separately with the control arm (eg, scrub versus rub, brush versus no brush). To combine the data from different trials for a pooled analysis, if the data were continuous, we calculated weighted mean differences with 95% confidence intervals (CIs). If the data were categorical or binary, we calculated relative risks with 95% CIs. We used Review Manager (RevMan version 5.3)[25] to pool the incidence of SSIs. The estimated effect was considered significant if $P < .05$. We used the standard random-effects model to complete the pooled analysis, depending on the heterogeneity among trials. We tested the heterogeneity between studies using a χ^2 test (significant if $P < .1$) alongside an I^2 test (with substantial heterogeneity defined as values >50%). When studies showed significant heterogeneity ($I^2 > 50\%$), we used a random-effects model to calculate the mean differences. If studies did not show heterogeneity ($I^2 < 50\%$), we used a fixed-effects model to calculate the effect sizes. A formal pooled analysis of the effect of surgical scrubbing on skin integrity was not possible, because of the absence of a uniform outcome measure. We descriptively synthesized and tabulated data related to the effect on skin integrity.

FINDINGS

The literature search identified a total of 1,078 references from four databases (473 from MEDLINE, 186 from CINAHL, 313 from Embase, and 106 from Cochrane Central), and we identified two additional articles from the reference list of reviewed articles. We exported all 1,080 hits to Endnote version X7 for eligibility assessment. A total of 10 studies met the inclusion criteria, which we subjected to full data extraction. Figure 1 provides a flow chart of the process and results.

Sample Characteristics

All 10 articles identified the study target population as the surgical-scrub team or surgical personnel. Although our

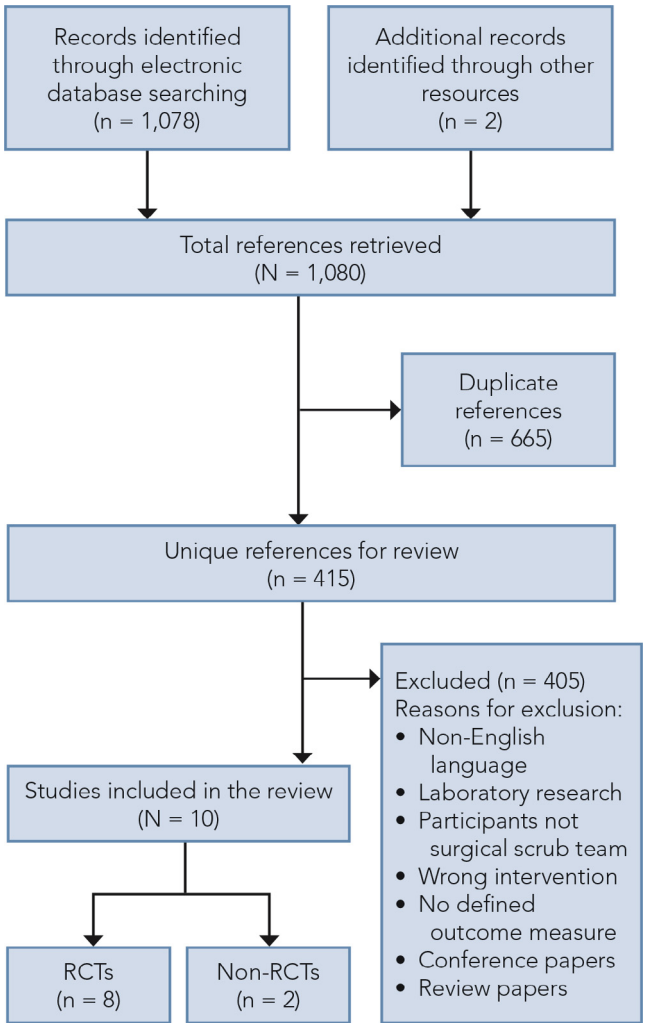

Figure 1. A flow chart detailing the selection process for articles. RCT = randomized controlled trial.

search date extended to January 2015, no trials that met the inclusion criteria were published after 2009. The studies were conducted across eight countries. Of the 10 trials, eight trials were RCTs and two trials were non-RCTs. Five trials compared traditional scrub protocols using either chlorhexidine gluconate or povidone-iodine with hand rub protocols with alcohol-based solutions, regardless of the solution concentration or the duration of the scrub.[8,26-29] Of these five trials, the traditional scrub protocols in two[26,28] involved scrubbing with a combination sponge/brush tool, but it is not clear whether the sponge or brush side was used. Four trials compared surgical-scrub protocols with brushes versus those without brushes,[18,30-32] and the remaining trial compared five different scrub protocols, all of which involved scrubbing with a sponge.[33] If a brush was used to scrub nails only (but was not used on hands or arms), the trial was not included in the brush versus brushless group.

The form of scrub or rub solution, the concentration of the agent, scrubbing techniques, and durations were often different across studies. The use of different scrubbing protocols introduces significant heterogeneity among studies, thus limiting the comparability of some results from the interventions across different samples. All 10 trials assessed the skin integrity of participants using a variety of assessment tools. The details of the sample characteristics, scrubbing solutions, and outcome measures of each study are displayed in Table 1.

Quality of Methodology

We used the EPHPP tool to assess the quality of each study included in this review. Although eight RCTs reported that participants were randomized into different intervention groups, only two trials described an appropriate method of randomization (ie, randomization was completed using a random number table or Latin square design).[28,33] The nature of complex interventions (eg, disinfecting agent used, scrubbing technique used, duration) meant that none of the 10 trials was double-blind. Two studies reported that the outcome assessor was blinded to the allocation of participants to groups.[8,31] Three trials reported numbers and reasons for withdrawals and dropouts per group, along with an indication of the percentage of participants who completed the study.[18,28,31] Using the EPHPP tool, we classified more than half of the studies as low methodological quality,[26,27,29-32] three studies as moderate quality,[18,28,33] and only one study as high methodological quality.[8]

Effect of Scrubbing on Skin

Of the five trials that compared traditional scrubbing with rubbing using an alcohol-based solution, four trials reported better skin condition in the rubbing group,[8,27-29] although only one of these trials[28] reported a statistically significant difference. One trial reported no difference in skin damage between scrubbing and rubbing groups.[26] Scrub personnel in three of the studies reported a preference for a hand rubbing protocol.[8,26,27]

Of the four trials that compared scrubbing using disinfecting agents and a brush with scrubbing using no brush,[18,30-32] two of these trials showed that skin condition was significantly better (eg, less skin dryness, lower incidence of erythema) in the nonbrushing group through the use of a self-assessment tool or through dermatologic evaluation.[18,31] In one of these studies, skin irritation was reported in two of 55 participants

Table 1. Summary of Studies Included in the Systematic Review

Study, Year, Country	Evidence Type	Sample Size, Setting, and Sample Interventions	Study Findings	Limitations	Quality and Evidence Level
Al-Naami et al,[1] 2009, Saudi Arabia	RCT	• 500 patients/surgeons at a university hospital • I: Traditional three- to five-minute hand scrub with 7.5% povidone-iodine or 4% chlorhexidine and water • II: Traditional scrub to remove dirt for the first procedure, followed by alcohol-based hand rub for subsequent procedures during the day	• A total of 40 skin reactions occurred in the surgical scrub group and 31 reactions in the alcohol-rub group ($P = .07$). • Most surgeons (64%) preferred alcohol rubbing over traditional scrubbing. • SSIs were reported in 12 (5.3%) patients in the scrubbing group and in 8 (2.94%) patients in hand rubbing group ($P > .05$).	• The dermatologic outcome was self-reported; there were no measurement tools or scales used.	EPHPP score = 1, high-level evidence
Bryce et al,[2] 2001, Canada	Non-RCT	• 41 surgical nurses and physicians in hospital ORs • I: Traditional surgical scrub with sponge/brush and 4% chlorhexidine or 7.5% povidone-iodine • II: Alcohol-based antiseptic rinse	• Skin integrity measures revealed no difference between the alcohol rinse and the traditional scrub. • There was a trend toward preference for the alcohol rinse among surgeons and nurses who performed longer procedures.	• The interventions were not randomly allocated; there was no outcome measurement of SSI, only measured CFU.	EPHPP score = 3, low-level evidence
Carro et al,[3] 2007, France	Non-RCT	• 54 surgical-team members at a university hospital • I: Hand scrubbing with chlorhexidine gluconate (4%) or povidone-iodine • II: Hand rubbing with propanol-2 (45%), propanol-1 (30%), and ethylhexadecyldimethyl ammonium ethylsulfate (0.2%)	• Skin tolerance: 10 of 16 participants reported skin condition improved with hand rubbing, five of 16 reported unchanged, and one participant reported worse with hand rubbing compared with hand scrubbing. • Acceptability: 12 participants preferred hand rubbing, three preferred hand scrubbing, and one had no opinion.	• Intervention allocations were not randomized nor blinded to outcome assessors. • There was no outcome measurement of SSI, only measured CFU. • The dermatologic outcome was descriptive, not measured.	EPHPP score = 3, low-level evidence
Gupta et al,[4] 2007, United States	RCT	• 18 OR staff members working in ophthalmic, pediatric, and general surgery at a community hospital • I: Brush application of 7.5% povidone-iodine aqueous scrub • II: 1% chlorhexidine gluconate in 61% ethyl alcohol applied in three	• The alcohol-based waterless product was significantly preferred ($P < .001$) over the other surgical-scrub solutions, and was considered to be the easiest to use ($P = .007$) with the best-resulting hand skin condition ($P < .001$).	• The sample size was relatively small. • The report provided no description on how the randomization was performed.	EPHPP score = 3, low-level evidence

(continued)

Table 1. *(continued)*

Study, Year, Country	Evidence Type	Sample Size, Setting, and Sample Interventions	Study Findings	Limitations	Quality and Evidence Level
		2-mL applications without the use of water • III: 70% ethyl alcohol and zinc pyrithione applied over three minutes and required rinsing with water		• The report gave no outcome measurement of SSI, only measured CFU.	
Herruzo-Cabrera et al,[5] 2000, Spain	RCT	• 154 surgical-team members in plastics or trauma surgery • I: Scrubbing with 4% chlorhexidine brushes for a minimum of three minutes • II: Scrubbing with 7.5% povidone-iodine brushes for a minimum of three minutes • III: Application of an alcohol solution of 2.3% N-duopropenide for three minutes without scrubbing	• Two of 55 participants with previous sensitivity to chlorhexidine and iodophors used the alcohol solution and reported skin irritation. • Three participants considered allergic to iodophors reported no reaction in the N-duopropenide group.	• The report supplied no description of how the randomization was performed. • There was no outcome measurement of SSI, only measured CFU. • The dermatologic outcome was self-reported; there were no measurement tools used.	EPHPP score = 3, low-level evidence
Kikuchi-Numagami et al,[6] 1999, Japan	RCT	• 55 female perioperative nurses at a university hospital • I: Scrubbed hands using povidone-iodine with a brush (brush-washing group) • II: Washed hands without a brush followed by sterilized water rinse (simple hand-washing group)	• Five of 35 participants showed mild dryness of the skin on days four and 11 in the early summer, but they were equally distributed between the brush-scrubbing and simple hand-washing groups. • In the autumn study, at day 11, skin dryness score increased in five of 10 participants in the brush-washing group and six of 10 in the simple hand-washing group. • Only one of 10 participants in the simple hand-washing group reported erythema on day 11, and three of 10 participants in the brush-washing group showed erythema on both days four and 11. No significant	• The report gave no description of how the randomization was performed. • There was no outcome measurement of SSI, only measured CFU. • Participants included female nurses only.	EPHPP score = 3, low-level evidence

(continued)

Table 1. *(continued)*

Study, Year, Country	Evidence Type	Sample Size, Setting, and Sample Interventions	Study Findings	Limitations	Quality and Evidence Level
			difference in TEWL, high-frequency conductance, or pH values was observed between the two groups.		
Larson et al,[7] 2001, United States	RCT	• 27 surgical staff members at an academic health center • I: Traditional hand scrubbing with brush using 4% chlorhexidine • II: Waterless hand rub containing 61% ethyl alcohol with 1% chlorhexidine gluconate	• Hand preparation without scrubbing was associated with less skin damage than traditional surgical scrubbing ($P = .002$). • Erythema rating was better in the alcohol group (mean = 3.8) than in the traditional group (mean = 3.5). • Self-assessed skin condition was better in the alcohol group (mean = 21.2) than in the traditional group (mean = 23.4). • More participants preferred the hand preparation without scrubbing ($P = .001$).	• The intervention allocation was not blinded to participants, nor to the outcome assessors. • The report gave no outcome measurement of SSI, only measured CFU.	EPHPP score = 2, moderate-level evidence
Parienti et al,[8] 2002, France	RCT	• 77 surgical staff members at a teaching hospital, surgical services, and general hospital • I: Five-minute scrub with sponge/brush using either 4% povidone-iodine or 4% chlorhexidine gluconate • II: Five-minute hand rub with alcohol solution containing 75% propanol-1 and propanol-2 with mecetronium ethylsulfate	• Skin dryness score decreased by 0.9 cm (95% CI, 0.5-1.2) after hand rubbing, but increased 0.4 cm (95% CI, −0.1 to 1.2) after hand scrubbing, $P = .046$. • Skin irritation score decreased by 1.5 cm (95% CI, 1.1-1.9) after hand rubbing, but increased 0.4 cm (95% CI, 0.2-0.6) after hand scrubbing, $P = .03$. • SSIs were reported in 55 (2.44%) in the hand-rubbing group and 53 (2.48%) in the hand-scrubbing group.	• The intervention allocation was not blinded to participants, nor to the outcome assessors.	EPHPP score = 2, moderate-level evidence

(continued)

Table 1. *(continued)*

Study, Year, Country	Evidence Type	Sample Size, Setting, and Sample Interventions	Study Findings	Limitations	Quality and Evidence Level
Pereira et al,[9] 1997, Australia	RCT	• 23 perioperative nurses at a large metropolitan hospital • I: Five-minute initial and 3.5-minute consecutive scrubs with sponge and 4% chlorhexidine gluconate (CHG-5) • II: Three-minute initial and 2.5-minute consecutive scrubs with sponge and 4% chlorhexidine gluconate (CHG-3) • III: Three-minute initial and 2.5-minute consecutive scrubs with sponge and 5% povidone-iodine and 1% triclosan (PI-3) • IV: Two-minute initial scrub with sponge and 4% chlorhexidine gluconate followed by a 30-second application of 70% isopropanol and 0.5% chlorhexidine gluconate only • V: Two-minute initial scrub with sponge and 4% chlorhexidine gluconate followed by a 30-second application of 70% EA and 0.5% chlorhexidine gluconate; consecutive scrubs using a 30-second application of ethanol 70% and 0.5% chlorhexidine gluconate	• Improvement of skin condition was reported in two alcohol-based antiseptic protocols, no changes were reported for the CHG-5 protocol, and scores were worse in the CHG-3 and PI-3 protocols at the end of the study. • Independent rating scores, skin squama ratings, and ratings of the photographs revealed no significant differences among the groups. • The EA protocol was most frequently associated with an improvement in skin integrity, and the isopropanol protocol scores showed very little improvement or deterioration. • Participants favored the alcohol-based antiseptic protocols because of better skin condition.	• The report gave no description of how the randomization was performed. • There was no outcome measurement of SSI, only measured CFU.	EPHPP score = 2, moderate-level evidence
Pietsch et al,[10] 2001, Germany	RCT	• 75 surgeons and 60 volunteers at a university hospital • I: Hand scrubbing with 4% chlorhexidine gluconate as active agent, with surfactants • II: Hand rubbing with 45% propanol-2, 30% propanol-1, and 0.2% ethylhexadecyldimethyl ammonium ethylsulfate	• Skin roughness was "poor" in the scrub group and scored "very good" in the rub group. • D-squamas scored "very poor" in the scrub group and scored "poor" in the rub group. • Electrical capacity scored "very poor" in the scrub group but scored "good" in the rub group.	• The report gave no description of how the randomization was performed. • There was no outcome measurement of SSI, only measured CFU.	EPHPP score = 3, low-level evidence

(continued)

Table 1. *(continued)*

Study, Year, Country	Evidence Type	Sample Size, Setting, and Sample Interventions	Study Findings	Limitations	Quality and Evidence Level
			• TEWL scored "poor" in the scrub group but scored "good" in the rub group. • 15 participants dropped out because of skin adverse reaction in the scrub group; only one participant dropped out of the rub group.		

EPHPP = Effective Public Health Practice Project assessment tool; CFU = colony-forming unit; RCT = randomized controlled trial; SSI = surgical site infection; TEWL = transepidermal water loss; CI = confidence interval; EA = ethyl alcohol.

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Table 2. Skin Outcome Measurement Tools in 10 Studies Included in the Systematic Review

Author, Year, Country	Comparison	Skin Integrity Parameters	Measurement Tools
Al-Naami et al,[1] 2009, Saudi Arabia	Scrub versus rub	Incidence of surgeon's skin reactions: itching, redness, urticaria, dryness within 30 days, surgeon's preference	• None; participants self-reported skin condition.
Bryce et al,[2] 2001, Canada	Scrub versus rub	Dermal irritation of both hands, as evaluated immediately before and after surgical antisepsis	• Dermal irritation was assessed using a scale in which 0 = negative; 1 = erythema only; 2 = erythema and induration or broken skin; 3 = erythema, induration or broken skin, and vesicles; 4 = erythema, induration or broken skin, and bullae. • Skin integrity, appearance, moisture content, sensation, and general acceptability were evaluated using a seven-point rating scale.
Carro et al,[3] 2007, France	Scrub versus rub	Skin tolerance and product acceptability, as evaluated at the end of each trial	• A four-question survey assessed the difficulty of implementing hand rubbing, modification of scrubbing technique, skin condition, and preferred technique between scrubbing and rubbing.
Gupta et al,[4] 2007, United States	Scrub with brush versus brushless alcohol water-based solution versus brushless alcohol waterless solution	Skin condition, ease of use, and overall preference	• A questionnaire using a scale of 1-5 (1 = strongly disagree and 5 = strongly agree) asked participants to grade the product's ease of use, satisfaction with their hand skin condition, and preference to use one product over other products.
Herruzo-Cabrera et al,[5] 2000, Spain	Scrub with povidone-iodine brush versus scrub with chlorhexidine gluconate brush versus alcohol-solution rub	Incidence of skin irritation	• None; participants self-reported skin condition.
Kikuchi-Numagami et al,[6] 1999, Japan	Scrub using povidone-iodine with a brush versus brushless simple hand wash	Skin condition assessed by clinical evaluation and objective measurement	• Dryness and erythema were evaluated by a trained dermatologist on a scale from 0-3 (0 = none, 1 = mild, 2 = moderate, and 3 = severe). • Noninvasive measurement of the stratum corneum: TEWL, high-frequency conductance, and skin-surface pH were measured with an evaporimeter, moisture evaluator, and skin-pH meter.
Larson et al,[7] 2001, United States	Traditional hand scrub with brush versus brushless waterless hand rinse containing 61% EA	Skin damage and erythema examined by objective measurement and self-assessment, and participant's preference	• A visual scoring scale of skin from 1-6 using 3× magnifying glass was used; scoring was performed by an expert. • An erythema scale from 0-4 was used; scoring was performed by an expert. • A scale from 1-7 measuring the condition of both sides of the dominant hand was used; scoring was completed by participants.

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Table 2. *(continued)*

Author, Year, Country	Comparison	Skin Integrity Parameters	Measurement Tools
Parienti et al,[8] 2002, France	Scrub versus rub	Skin tolerance	• A 10-cm VAS of skin dryness and irritation, in which 0 represented absence of a problem and 10 represented maximum dryness (chapped hands, desquamation) or maximum irritation (erythema, burning sensation, abrasion) was used.
Pereira et al,[9] 1997, Australia	Comparison of five different scrub solutions (EA, isopropanol, chlorhexidine gluconate [three minutes versus five minutes], and povidone-iodine)	Skin damage measured as appearance, integrity, moisture, sensation, erythema, cracking, and scaling	• Participants used a skin self-assessment scale to rate hand appearance, integrity, moisture, and sensation. • Macrophotography measured erythema, cracking, and scaling.
Pietsch et al,[10] 2001, Germany	Scrub versus rub	Dermal tolerance including skin roughness, peeling, skin hydration, and TEWL	A dermatologist assessed and observed the hands and forearms of participants, and measured • skin roughness with automatic profilometric measurements on silicone impressions of the volar surface of the forearms, • peeling with image analysis of scales removed by adhesive disks (D-squamas), • skin hydration by electric capacity measurement, and • TEWL by means of an evaporimeter.

EA = ethyl alcohol; TEWL = transepidermal water loss; VAS = visual analog scale.

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in the alcohol-rub group, but the incidence of skin irritation in the scrub groups was not reported for comparison.[30] The last of these studies included an objective dermatology measurement and reported no significant difference in transepidermal water loss, high-frequency conductance (a measure of skin hydration), or pH values between the brush-scrubbing and brushless-scrubbing groups.[32]

The remaining study, conducted by Pereira et al,[33] compared five different scrub protocols for skin reaction. The five protocols were three detergent-based (ie, chlorhexidine gluconate or povidone-iodine) antiseptic-only protocols and two alcohol-based antiseptic protocols after traditional scrubbing with chlorhexidine gluconate. The authors reported no significant difference in participants' skin

condition according to skin squama ratings (ie, a measure of skin irritation) and ratings of photographs of participants' skin among five protocols. The participants preferred to use the two alcohol-based antiseptic protocols, however. Researchers measured skin reaction outcomes very differently across all trials, using seven self-reported assessment tools and eight objective dermatologic measurement tools. The details of the measurement parameters and instrument tools for all studies are listed in Table 2.

Effectiveness of Scrub Protocols in Preventing SSIs

Two out of 10 trials measured SSI rates within 30 days of surgery.[8,28] The remaining eight trials measured the numbers of colony-forming units (CFUs) to assess the effectiveness of scrubbing protocols. Al-Naami et al[8] compared the use of a traditional hand scrub using 7.5% povidone-iodine or 4% chlorhexidine gluconate and water for three to five minutes with a traditional hand scrub for the first procedure of the day and an alcohol hand rub for subsequent procedures. Parienti et al[28] conducted a trial in which the authors compared a five-minute hand scrub using either 4% povidone-iodine or 4% chlorhexidine gluconate with a five-minute hand rub using an alcohol-based solution containing 75% propanol-1 or propanol-2 with mecetronium ethylsulfate. We performed a pooled analysis of these two trials, and the SSI rate did not differ significantly between a traditional scrub containing either 4% povidone-iodine or 4% chlorhexidine gluconate and a hand rub with alcohol solution (risk ratio 1.17, 95% CI, 0.72-1.88, $P = .53$), as shown in Table 3. The heterogeneity was small ($I^2 = 26\%$).

DISCUSSION

Although not all studies found statistically significant differences in skin integrity, most did report less skin damage in alcohol-rubbing groups. Our findings are consistent with those of laboratory studies and studies conducted outside ORs that were not included in this review. For example, other studies demonstrated that surgical scrub protocols can cause various skin reactions, such as skin itching, dryness, or even allergic responses,[34,35] and less skin damage has been associated with alcohol-based hand rubbing.[36,37]

Our review found that using brushes for surgical hand scrubbing may cause skin damage. Scrubbing with a brush can result in excessive shedding of the superficial skin layers and microscopic cuts on the skin surface.[38] In addition, some studies have demonstrated relatively poor compliance for optimal scrubbing time and techniques by personnel using a brush.[31,37] More participants across studies also preferred using alcohol-based hand rubbing techniques, suggesting that non—brush-based scrubbing protocols may have the potential to increase compliance.

Our findings related to skin damage should be interpreted with caution. Despite the fact that researchers reported less skin damage in hand rubbing groups in most of the trials in our review, not all studies used statistical methods. Only three studies[18,28,31] reported a statistically significant reduction in skin damage. Several studies reported outcomes only

Table 3. Pooled Analysis of Two Trials that Reported 30-day SSIs

Study	SSIs Developed in Scrub Group (Number of SSIs / Total Participants)	SSIs Developed in Alcohol-Rub Group (Number of SSIs / Total Participants)	Weight	Risk Ratio (M-H, Random, [95% CI])
Al-Naami et al,[1] 2009	12 / 228	8 / 272	24.3%	1.79 [0.74-4.30]
Parienti et al,[2] 2002	53 / 2,135	55 / 2,252	75.7%	1.02 [0.70-1.48]
Total SSI events	65 / 2,363	63 / 2,524	100%	1.17 [0.72-1.88]
Heterogeneity: $Tau^2 = 0.04$, $\chi^2 = 1.35$, $df = 1$ ($P = .24$), $I^2 = 26\%$				
Test for overall effect: $z = 0.63$ ($P = .53$)				

SSI = surgical site infection; M-H = Mantel-Haenszel test; CI = confidence interval.

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descriptively.[26,27,29,30] Also, various intrinsic and extrinsic factors can contribute to an individual's skin damage, such as the nature of the individual's skin condition and different seasons of the year. To confirm the beneficial effect of hand rubbing protocols, better-designed clinical trials using large sample populations and standard dermatologic outcome measures are necessary.

The applicability of our results to SSI prevention is somewhat limited because most studies included in this review examined CFUs instead of SSI rates. No significant difference was found between traditional scrubbing protocols and alcohol-based hand rubbing protocols in preventing SSIs. Therefore, we can only suggest that hand rubbing protocols can be as effective as traditional scrubbing protocols at preventing SSIs.

Measuring Skin Damage

With respect to dermatologic measurement, nearly every trial reported skin reaction outcomes differently. Some studies reported the numbers of skin reactions, whereas others used a self-assessment scale or other objective dermatologic tools to determine skin integrity. Skin reactions were generally described as a burning sensation, cracking, scaling, itching, irritation, dryness, roughness, or erythema. In appraising the tools used, we recognize the challenges of selecting standard dermatologic measurement in perioperative care. Researchers should advocate for the use of well-established or commonly reported tools to permit comparison across studies. Additional work is needed to establish tools that reflect skin damage in surgical teams and validate the need for additional skin outcome research and clinical practice.

LIMITATIONS

Although systematic reviews have their own merit for increasing the statistical power of the existing small sample size of individual studies, they often present a number of limitations. These include publication bias (particularly against negative findings), language restrictions, heterogeneity across studies, and coding of key words. The studies were limited as well by the lack of double blinding. In addition, the substantial heterogeneity in dermatologic outcomes prevents us from performing a pooled analysis on some trials, which made it difficult to interpret some findings and draw firm conclusions.

Another limitation was the inclusion of two trials published in the 1990s. It may be argued that infection and hand hygiene practices have changed during the last 25 years. Both trials were RCTs and assessed skin condition related to surgical scrubbing, which met our inclusion criteria. From a clinical point of view, in the future we should include only more recent trials.

An additional limitation of our review was excluding non—English-language literature. The language restriction could not be avoided, because we lacked interpretation resources. Nevertheless, we worked with a clinical librarian to create an appropriate search strategy and to structure our search in a way that minimized potential bias.

CONCLUSION

We appraised the most effective surgical-scrub protocol (eg, scrubbing solutions, length of scrubbing time, dermatologic outcome measures) in reducing the risk of SSIs and minimizing the incidence of skin damage to the surgical team. Challenges in selecting protocols arise because of the lack of standardized interventions and findings across studies. Based on the studies we reviewed, current available evidence shows that hand rubbing techniques are as effective as traditional scrubbing in preventing SSIs, whether the solutions used contain chlorhexidine gluconate or povidone-iodine, regardless of concentration and length of time. Hand rubbing techniques also appear to be better tolerated by scrub personnel, causing less skin damage than traditional scrub protocols. Brushless techniques appear to be better for participants' skin than scrubbing with a brush. Better-designed clinical trials using standardized dermatologic outcome measurements, optimized scrubbing solutions, and length of time for scrubbing are warranted to confirm our findings.

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