

The Impact of Accelerated Drying on Alcohol-Based Antiseptic Efficacy: A Scoping Review

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Abstract

Background: Alcohol-based antiseptics are widely used in clinical settings for skin disinfection prior to procedures, with efficacy dependent on both concentration and adequate wet contact time. Despite recommendations to allow antiseptics to air dry naturally, practices such as fanning or blowing are commonly used to hasten drying. The impact of such practices on antiseptic efficacy and safety remains unclear.

Objectives: To systematically map the existing literature on the effects of accelerated drying, particularly through fanning, blowing, or forced evaporation, on the antimicrobial efficacy of alcohol-based antiseptics used for skin disinfection.

Methods: A scoping review was conducted following the Arksey and O'Malley framework and the PRISMA-ScR guidelines. Five databases (PubMed, Embase, Scopus, CINAHL, and Web of Science) and grey literature sources were searched from inception to July 2025. Eligible studies examined alcohol-based antiseptics and assessed drying methods or contact time in relation to antimicrobial efficacy. Data were synthesized thematically.

Results: Eighteen publications met inclusion criteria, comprising experimental studies, clinical guidelines, technical protocols, and reviews. Four key themes emerged: (1) Sufficient wet contact time is essential for antimicrobial efficacy; (2) Fanning or accelerated evaporation reduces microbial kill rates, particularly for *Staphylococcus aureus*; (3) Surgical and clinical guidelines emphasize complete natural drying due to infection and fire risk; and (4) There is a lack of clinical trials evaluating infection outcomes or real-world adherence to drying recommendations.

Conclusion: Accelerating the drying of alcohol-based antiseptics can compromise antimicrobial efficacy by shortening contact time and has no support in current guidelines. Despite its widespread use, fanning remains unvalidated and potentially harmful. There is a need for clinical research on the impact of drying practices and adherence to protocols in real-world settings.

Keywords: Alcohol-Based Hand Rubs, Disinfection, Anti-Infective Agents, Infection Control, Patient Safety, Health Personnel

1. Background

Alcohol-based antiseptics, primarily ethanol and isopropyl alcohol, are central to infection prevention strategies in healthcare settings due to their rapid, broad-spectrum antimicrobial activity against bacteria, fungi, and enveloped viruses.¹ Their effectiveness hinges on adequate concentration, typically between 60% and 90%, and sufficient contact time to allow for protein denaturation and membrane disruption.²⁻⁵ Optimal efficacy is usually achieved within 30 seconds of application, although certain pathogens or procedures may require longer exposure.^{2,4} Ethanol demonstrates stronger virucidal properties than isopropanol and is commonly used at concentrations of 70-85% for skin and surface disinfection.^{2,3}

Rapid evaporation of alcohol is both an advantage and a limitation: it allows for quick application and drying, but it may reduce contact time on large or uneven surfaces, potentially impairing antimicrobial effectiveness.¹ To compensate, antiseptics are often formulated with secondary agents such as chlorhexidine to provide

residual activity and sustained protection.^{4,6} However, when alcohol alone is used, it relies entirely on sufficient wet contact time to achieve microbial kill. As such, clinical protocols typically emphasize allowing alcohol-based antiseptics to air dry completely before proceeding with any invasive procedures.^{7,8}

Major health agencies, including the Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), and Infectious Diseases Society of America (IDSA), recommend alcohol-based solutions for hand hygiene, preoperative skin preparation, and surgical antisepsis, provided they are allowed to dry naturally.^{3,7-9} The CDC specifically advises that alcohol-based antiseptics should be visibly dry prior to any procedure, citing suboptimal disinfection when applied improperly.⁷ Despite these recommendations, in practice, clinicians and patients alike often expedite the drying process using fanning, blowing, or waving, particularly when pressed for time or working in high-throughput environments.

Evidence from adjacent domains, such as hand hygiene

and endoscope reprocessing, suggests that drying methods may affect disinfection outcomes and contamination risks. For example, the use of jet air dryers, compared to paper towels, has been shown to increase bacterial aerosolization and environmental contamination in hand hygiene studies.^{10,11} In endoscope sterilization, the American Society for Gastrointestinal Endoscopy emphasizes complete air drying after high-level disinfection but does not provide guidance on active versus passive drying methods, revealing a broader gap in standardization.¹² These findings raise important questions about whether similar issues exist for skin antiseptics with alcohol-based solutions.

Despite the ubiquity of fanning in clinical and public settings, there is a surprising lack of evidence directly addressing its impact on antiseptic efficacy. Neither major guidelines nor infection control literature provide definitive answers about whether hastening alcohol evaporation through fanning compromises antimicrobial performance or introduces risks such as uneven coverage, recontamination, or insufficient pathogen kill.¹² The theoretical concern is that premature drying may result in suboptimal disinfection, but empirical studies exploring this hypothesis are scarce or nonexistent.

2. Objectives

This scoping review was conducted to systematically map the existing literature on the impact of accelerated drying, particularly through fanning or blowing, on the efficacy of alcohol-based antiseptics. While fanning is a common practice across healthcare settings, its clinical implications remain poorly defined. Given the critical role of antiseptics in infection prevention and the emphasis on adherence to drying protocols in clinical guidelines, there is a clear need to understand whether deviations such as active drying may influence safety or

antimicrobial outcomes. This review aims to identify knowledge gaps, inform future research, and support evidence-based recommendations regarding antiseptic application techniques.

3. Methods

This scoping review was conducted using the methodological framework proposed by Arksey and O’Malley¹³ and further refined by Levac et al.,¹⁴ in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines.¹⁵ The primary objective was to map the available evidence on how drying methods, specifically fanning, blowing, or evaporation, impact the efficacy of alcohol-based antiseptics used for skin disinfection.

3.1. Search Strategy

A comprehensive search strategy was developed in consultation with a research librarian. We systematically searched five electronic databases: PubMed, Embase, Scopus, CINAHL, and Web of Science, from database inception to July 2025. Search terms included combinations of keywords and Medical Subject Headings (MeSH) related to antiseptic type (e.g., “alcohol-based antiseptic,” “rubbing alcohol,” “isopropyl alcohol”), drying methods (e.g., “fanning,” “blowing,” “drying,” “contact time,” “evaporation”), and disinfection outcomes (e.g., “skin disinfection,” “antimicrobial efficacy”).

In addition to peer-reviewed literature, we searched grey literature sources, including guidelines and publications from the CDC, WHO, United States Pharmacopeia (USP), and other national or international health agencies. Reference lists of all included studies were also screened to identify additional eligible sources.

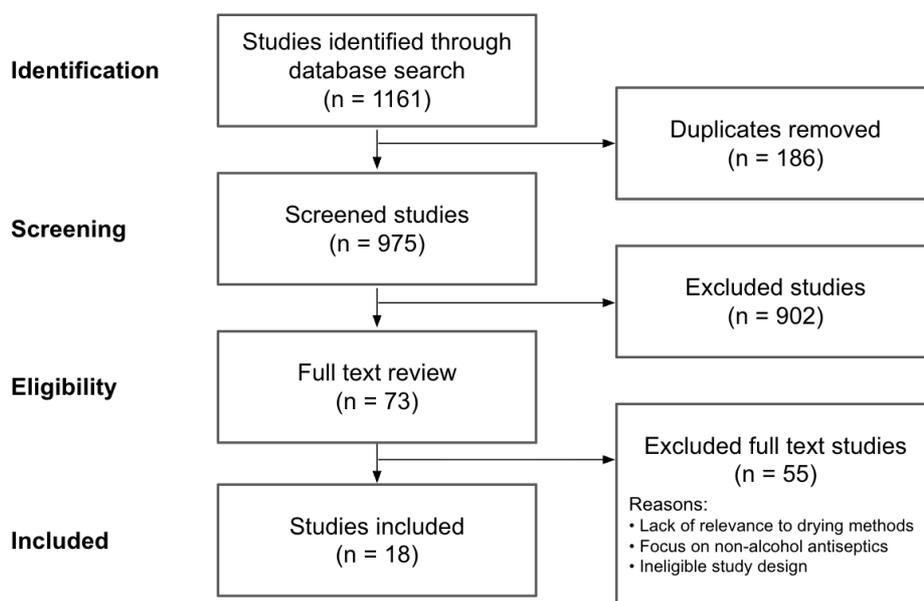


Figure 1. PRISMA-ScR Flow Diagram of Study Selection.

3.2. Eligibility Criteria

Studies were included if they examined any aspect of drying time or method in relation to the antimicrobial efficacy of alcohol-based antiseptics. Eligible study types included randomized controlled trials (RCTs), quasi-experimental studies, *in vitro* studies using human or simulated skin models, and clinical or procedural guidelines. Only studies published in English were included.

We excluded studies that evaluated non-alcohol-based antiseptics (e.g., iodine-only formulations) or those that did not address the drying method or contact time. Abstracts, commentaries, editorials, and non-original research were also excluded unless they provided guideline-level recommendations.

3.3. Study Selection

A total of 1,132 records were identified through database searching, and an additional 29 records were retrieved from grey literature sources and reference list screening, yielding a total of 1,161 records. After removing 186 duplicates, 975 unique records remained for title and abstract screening. Of these, 902 studies were excluded

for not meeting the inclusion criteria, resulting in 73 full-text articles assessed for eligibility. Following full-text review, 18 studies met all inclusion criteria and were included in the final synthesis. Reasons for full-text exclusion included lack of relevance to drying methods, focus on non-alcohol-based antiseptics, or ineligible study design (e.g., commentaries or unrelated interventions). A PRISMA diagram is presented in Figure 1.

4. Results

4.1. Overview

A total of 18 publications were included in this scoping review (Table 1). Four major themes emerged: (1) the importance of wet contact time for antiseptic efficacy, (2) the specific effects of fanning and evaporation on microbial kill rates, (3) clinical guideline recommendations on drying, and (4) the lack of clinical trials evaluating infection outcomes or adherence. Collectively, these studies suggest that accelerating the drying of alcohol-based antiseptics, such as through fanning, can impair their antimicrobial efficacy by reducing wet contact time and that no evidence supports the safety or equivalence of this practice.

Table 1. Summary of Included Studies

| Author (Year) | Study Type / Setting | Focus / Intervention | Main Findings | Theme(s) |
|--------------------------|--------------------------------------|--|---|----------|
| Boyce (2018) | Review / Healthcare settings | Alcohols as surface disinfectants | Alcohol efficacy depends on adequate wet contact time; rapid evaporation reduces activity | 1, 2 |
| Kampf (2018) | Experimental / <i>In vitro</i> | Ethanol activity vs viruses | Demonstrated need for sustained exposure; reduced contact weakens viral kill | 1 |
| Kampf & Kramer (2004) | Review | Hand hygiene agents | Contact time and concentration jointly determine antimicrobial activity | 1 |
| Reichel et al. (2009) | Experimental / Human skin | Alcohols for skin antiseptics | Friction aids penetration but cannot offset inadequate contact time | 1 |
| Suchomel et al. (2020) | Experimental / WHO formulations | Evaluation of WHO hand hygiene products | Shorter drying reduces microbial reduction; confirms importance of wet time | 1, 2 |
| Lim et al. (2023) | Experimental / Commercial sanitizers | Compare sanitizer formats | Drying time strongly influences antibacterial performance | 1, 2 |
| Calderwood et al. (2023) | Guideline / CDC–SHEA | Surgical site infection prevention | Recommends natural air-drying of alcohol-based antiseptics before procedures | 3 |
| Widmer et al. (2024) | Randomized Clinical Trial | Povidone-iodine vs chlorhexidine-alcohol | Supports alcohol-based antiseptics; no data on fanning or accelerated drying | 4 |
| Seidelman et al. (2023) | Narrative Review | SSI prevention | Emphasizes complete drying to prevent surgical site contamination | 3 |
| Best et al. (2014) | Experimental / Hand-drying | Air dryers vs paper towels | Forced air increases dispersion of microbes—parallels concerns with fanning | 2 |
| Best & Redway (2015) | Experimental / Airborne dispersal | Hand-drying methods | Demonstrated microbial spread with air movement; supports caution with fanning | 2 |
| Taunk et al. (2022) | Review / Guidelines | Endoscope reprocessing | Highlights need for complete drying to prevent contamination | 3 |
| Kampf et al. (2007) | Experimental / Human skin | Ethanol antiseptics at shorter times | Reduced microbial kill at < 20 s contact; supports minimum 30 s wet time | 1, 2 |
| Macinga et al. (2014) | Experimental / <i>In vitro</i> | Product volume & alcohol concentration | Shorter dry-time leads to lower efficacy; fanning accelerates evaporation | 1, 2 |

| | | | | |
|------------------------|---------------------------------------|---|---|------|
| Monstrey et al. (2022) | Randomized open-label / Surgical prep | 5% alcoholic povidone-iodine, 4 methods | Longer contact ($\geq 2-3$ min) gave best flora reduction; accelerated drying reduced efficacy | 1, 2 |
| Omidbakhsh 2010 | Experimental | Hard-surface alcohols | <1 min dry \rightarrow failed <i>S. aureus</i> bactericidal threshold | 2 |
| ASA Advisory 2013 | Practice advisory | OR fire risk with alcohol antiseptics | Must be fully dry before draping/electrocautery; wet = ignition risk | 3 |
| Wilkinson et al. 2018 | Experimental | Liquid/gel/foam ABHR | Format affects drying time; shorter dry \rightarrow reduced efficacy | 1,2 |

4.2. Theme 1: Wet Contact Time Is Critical for Antiseptic Efficacy

Alcohol-based antiseptics require a minimum duration of wet contact with the skin to exert their full antimicrobial effect.^{16,17} Both the CDC and WHO recommend that alcohol-based solutions remain wet on the skin for at least 20-30 seconds to achieve effective microbial kill.^{2,5} Experimental studies, including an *in vitro* evaluation of product volume, delivery format, and alcohol concentration affecting dry-time and efficacy, show that when drying is accelerated, either by reducing volume or by artificial means such as fanning, the actual contact time may fall below this threshold, significantly compromising antimicrobial activity.¹⁶⁻¹⁸ For surgical skin preparation or invasive procedures, longer durations of up to 2-3 minutes may be required for maximal flora reduction.^{17,18} While vigorous rubbing or friction during application can enhance penetration and efficacy, it does not compensate for inadequate wet contact time.^{4,16} In summary, wet contact time, rather than simply the alcohol concentration, is essential to ensure disinfection prior to procedures.^{2,5}

4.3. Theme 2: Fanning and Accelerated Drying Reduce Microbial Kill Rates

Several *in vitro* and *in vivo* studies confirm that fanning or forced evaporation accelerates alcohol drying and decreases the antiseptic's effectiveness by shortening contact time (e.g., an *in vitro* ABHR study manipulating volume/format/concentration and a laboratory hard-surface disinfection investigation evaluating alcohol dry-time and efficacy).^{17,19} Reduced kill rates have been observed, particularly for gram-positive cocci such as *Staphylococcus aureus*, which require adequate exposure to alcohol for optimal reduction.^{19,20} For example, an experimental study assessing syringe tip disinfection techniques against virulent *Staphylococcus* contamination found that shorter drying times (e.g., 10 seconds vs. 60 seconds) significantly reduced bacterial elimination.²⁰ Similar findings were reported for hard surface disinfection, where alcohol-based solutions that dried in less than 1 minute failed to achieve the required bactericidal activity against *S. aureus*.¹⁹ The antimicrobial effectiveness of alcohol-based formulations is therefore closely linked to their ability to remain wet on the skin for a sustained period, and accelerated evaporation compromises this action.^{1,17}

These results collectively suggest that fanning prior to complete natural evaporation reduces antiseptic efficacy.^{19,20}

4.4. Theme 3: Guidelines Emphasize Natural Drying and Fire Risk Mitigation

Surgical and clinical guidelines recommend that alcohol-based skin antiseptics be allowed to dry naturally and completely before invasive procedures or the use of electrocautery to prevent both infection and fire hazards.^{7,21,22} The American Society of Anesthesiologists specifically notes that flammable antiseptics must be completely dry before draping or electrosurgical use and identifies insufficient drying as a known cause of operating room fires.²¹ Experimental data confirm that ignition can only occur when alcohol is still wet or pooled, whereas completely dry surfaces are not flammable.^{23,24} While guidelines do not explicitly address fanning, they stress that drying must be complete, with no visible wetness, regardless of the method.^{7,22} The WHO and CDC echo these cautions, stating that alcohol use is contraindicated if pooling or incomplete drying is likely.^{7,8} As such, there is no regulatory or clinical support for fanning or other accelerated drying methods, especially when ignition sources will be used.^{21,23}

4.5. Theme 4: Lack of Clinical Trials and Real-World Adherence Data

There is a notable lack of randomized controlled trials directly evaluating whether fanning or accelerated drying of alcohol-based antiseptics affects clinical infection rates following injection procedures.^{8,23,25} Most existing studies focus on hand hygiene or surgical site antisepsis and are based on microbiological endpoints rather than clinical outcomes. No studies compare infection rates following natural versus accelerated drying of skin antiseptics at injection sites. Laboratory research shows that drying time affects antimicrobial efficacy,^{17,26} but these findings have not been extended to real-world settings or procedural outcomes. Moreover, no studies have investigated adherence to drying recommendations for injection site antisepsis in clinical practice. Most adherence literature focuses on surgical preparation or hand hygiene, leaving a gap in understanding how frequently fanning is used and whether this correlates with procedural infection risk.^{20,27} As a result, a critical evidence gap remains

regarding both the real-world impact of fanning and its consequences for infection prevention.

5. Discussion

This scoping review identified and synthesized the current literature on the impact of accelerated drying, particularly fanning or blowing, on the antimicrobial efficacy of alcohol-based antiseptics. Eighteen studies were included, covering experimental research, clinical guidelines, reviews, and infection control protocols. The findings collectively reinforce the critical role of wet contact time in the performance of alcohol-based antiseptics, with strong indications that accelerating the drying process may undermine antiseptic effectiveness. Despite the widespread use of fanning in clinical and public health settings, there is a striking lack of empirical evidence supporting this practice, and no guidelines recommend or endorse it.

One of the most consistent findings across included studies was the essential role of wet contact time in achieving effective microbial reduction. Alcohol-based antiseptics such as ethanol and isopropanol require sustained skin contact, typically at least 20-30 seconds, to denature microbial proteins and disrupt cell membranes.^{16,17} Studies also indicate that longer durations may be required for surgical or high-risk procedures, with some protocols recommending 2-3 minutes of contact for maximal flora reduction.¹⁸ The review findings align with longstanding recommendations from the CDC and WHO that emphasize both concentration and contact time as key to efficacy.^{2,5} While friction during application can enhance penetration, it does not compensate for inadequate drying time,⁴ underscoring the importance of natural drying over rushed techniques.

Experimental and *in vitro* studies have also shown that fanning and forced evaporation reduce antimicrobial efficacy by prematurely shortening contact time. This effect is especially pronounced for gram-positive cocci such as *Staphylococcus aureus*, which require adequate exposure to alcohol for effective kill rates.^{19,20} However, data on other key pathogens such as gram-negative bacteria, mycobacteria, and viruses remain limited, and few studies have directly compared efficacy across these groups. This highlights an important evidence gap in understanding whether accelerated drying differentially affects various pathogen types. Studies involving syringe tip disinfection and hard surface cleaning found that shorter drying times, whether from reduced volume or active fanning, led to significantly diminished microbial reduction.^{17,20} These findings are consistent with earlier work on hand and surface disinfection, which similarly demonstrated that rapid evaporation compromises effectiveness.¹ Taken together, this body of evidence raises serious concerns about the use of fanning in procedural contexts where antiseptic efficacy is paramount.

In terms of safety, the review highlighted a clear consensus in surgical and anesthesiology guidelines regarding the need for alcohol-based antiseptics to dry naturally and completely before the use of electrocautery or draping. Incomplete drying is a well-documented cause of operating room fires, as highlighted by the American Society of Anesthesiologists and corroborated by experimental ignition studies.^{21,23,24} While these guidelines do not explicitly address fanning, they emphasize complete dryness as the critical threshold for safety.^{7,22} The absence of guidance on fanning suggests that it is neither validated nor regulated, further reinforcing the need for caution and standardization in drying practices.

Despite these mechanistic and guideline-based insights, the clinical evidence base remains limited. Notably, no randomized controlled trials have directly examined whether fanning or accelerated drying influences infection rates at injection sites.^{8,23,25} Most available studies use microbiological endpoints rather than patient outcomes, and none evaluate real-world adherence to drying protocols in clinical settings. Although drying time has been shown to influence antiseptic performance *in vitro*,^{17,26} these findings cannot be directly extrapolated to clinical infection outcomes without further investigation. Moreover, there is a lack of data on how often fanning is used in practice and whether this correlates with increased infection risk or protocol deviations.^{20,27} Future studies should also explore the role of accelerated drying in the context of different microbial species and environmental conditions, as pathogen-specific resistance and surface characteristics may modify efficacy outcomes.

This review has several strengths, including a comprehensive and systematic search strategy across multiple databases and grey literature sources, adherence to the PRISMA-ScR framework, and thematic synthesis of both experimental and guideline-based data. However, key limitations include the small number of experimental studies addressing pathogen diversity, the lack of randomized control trials, the absence of patient-centered or clinical outcome data, and the inability to assess real-world compliance with drying protocols. The included studies were also heterogeneous in design, often using surrogate endpoints or simulated models. Future research should therefore prioritize controlled clinical trials comparing natural versus accelerated drying, expand investigation to include a broader range of pathogens, and incorporate observational audits of drying practices to better understand adherence and real-world implications.

6. Conclusion

This scoping review identified a consistent body of evidence indicating that fanning or otherwise accelerating the drying of alcohol-based antiseptics can impair antimicrobial efficacy by shortening critical wet contact time. Guidelines from major health organizations

recommend natural and complete drying, yet no studies support the safety or effectiveness of fanning. Despite its frequent use in clinical settings, fanning remains an unvalidated and potentially harmful deviation from evidence-based practice. There is a critical need for research that bridges the gap between microbiological mechanisms and clinical outcomes in order to inform safer, more standardized antiseptic protocols. Until such evidence emerges, adherence to natural air-drying as recommended by current guidelines should remain the standard of care.

Research Highlights

What Is Already Known?

Alcohol-based antiseptics are the standard for skin disinfection before clinical procedures, and their efficacy depends on sufficient wet contact time. Guidelines consistently recommend allowing antiseptics to air dry naturally to maximize antimicrobial activity and minimize risks such as infection or fire. However, in practice, healthcare providers often accelerate drying by fanning, blowing, or using forced air, despite limited evidence on how this affects efficacy.

What Does This Study Add?

This scoping review shows that accelerated drying techniques, such as fanning or forced evaporation, can reduce antimicrobial effectiveness by shortening wet contact time. These practices are not supported by clinical guidelines, and there is a lack of evidence on their impact on infection outcomes or adherence to drying protocols. The findings highlight the need for further research and reinforce the importance of allowing natural air drying to ensure optimal antiseptic performance.

Author Contributions

SQ conceptualized the study, led the literature search, data extraction, and analysis, and drafted the manuscript. JP contributed to data charting, synthesis of findings, and critical revisions of the manuscript. SW assisted with screening, data verification, and interpretation of results. KZ conceptualized the study, contributed to manuscript editing, reference management, and provided supervision. All authors reviewed and approved the final version of the manuscript.

Conflict of Interest Disclosures

All authors declared that they have no conflict of interest.

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