Advantages and Disadvantages of Alcohol-Based Hand Sanitizers: A Systematic Review

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Abstract: Background: Hand hygiene is a very simple procedure to reduce hospital-acquired (nosocomial) infections, prevent the spread of antimicrobial resistance and increase patient safety. Hand disinfection involves the process of removing and decreasing skin resident flora through hand scrub. Therefore, the use of alcohol-based solutions for hand hygiene has been common nowadays. Despite many benefits of alcohol-based hand sanitizers, these compounds may suffer from some disadvantages too.

Objective: The present study aimed to determine the advantages and disadvantages of alcohol-based hand sanitizers.

Methods: This systematic review was conducted in three phases of literature searching, evaluating data, and analyzing data. All studies published during 2010-2020 were simultaneously searched in databases of MEDLINE, PubMed, Scopus, and Magiran using the keywords of hand hygiene, alcohol-based hand sanitizer, and healthcare-associated infections. Then, data of included studies were collected and analyzed.

Results: In the preliminary search, a number of 117 relevant studies were identified from which 22 were included in the study. After precise analysis of data extracted from the included studies, the advantages and disadvantages of alcohol-based hand sanitizers classified in 4 (having acceptable disinfectant effect, having better cleaning effect on microbial hand contamination compared to both conventional surgical scrub and soap and water, ease of use, and causing minor systemic complications) and 6 categories (incomplete activity against some microorganisms and inefficiency under some circumstances, leading to skin complications in case of long-term use, impairing the performance of latex and nitrile gloves, intolerance in some people, possibility of oral use, and flammability), respectively.

Conclusion: The present systematic review recommends alcohol-based hand sanitizers for daily use as these agents affect a broad spectrum of microorganisms and mainly have minor adverse effects.

Keywords: Alcohol-based Hand Sanitizer, Healthcare-associated Infections, Hand Hygiene.

1. Introduction

Healthcare-associated infections are one of the most common causes of mortality and disability in hospitalized patients in developing and developed countries. The World Health Organization (WHO) survey of 55 hospitals in 14 countries, including the countries of the Eastern Mediterranean Region, confirmed the prevalence of healthcare-associated infections in hospitals with an average rate of 8.7 (1).

Hospital-Acquired Infections (HAIs) are caused by many microorganisms among which Gram-positive cocci, including Staphylococcus aureus (coagulase positive) and Staphylococcus (coagulase-negative) and Gram-negative bacilli, including Klebsiella, Escherichia coli, Pseudomonas, Pseudomonas, Streptococcus and Enterobacter, are of considerable importance. Staphylococci are the major Gram-positive bacteria causing HAIs (2). Hands play an important role in transmission of infections, especially in health facilities. So that observation of hand hygiene is of great importance at health facilities (3).

WHO guidelines on hand hygiene are recommended and applied in almost all countries and are of vital importance in reducing HAIs prevalence (4, 5). Several methods for hand hygiene have been proposed, including: (a) hand washing (cleaning physical contamination of the skin using household soaps), (b) disinfecting the hands (removing skin transient flora and restraining skin resident flora using topical antimicrobial agents), (c) hand disinfecting gel (reducing the number of hand microbes without removing the visible skin contamination.

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using topical antimicrobial agents), and (d) surgical hand washing (removing transient flora and reducing resident flora using non-stimulant broad-spectrum antimicrobial agents with long-lasting effect.

Hand disinfection involves the process of removing skin transient flora and decreasing skin resident flora through hand scrub. To this end, two types of disinfectants are utilized, including Alcohol-Based Hand Sanitizers (ABHSs) and other antimicrobial agents such as betadine scrub, hexachlorophene and chlorhexidine gluconate (CHG) (5).

Nowadays, there is a widespread use of ABHSs, especially in European countries (6-8). In these formulations, it has been shown that ethanol, normal propanol, and isopropanol are the most suitable alcohols for the skin which have rapid and severe antimicrobial effect at appropriate concentration (60-90%), although they have no acceptable long-lasting effect. Therefore, non-volatile agents such as quaternary ammonium compounds, CHG and Betadine are added to alcohol. The combination of these agents creates products with high potency and efficacy, so that it has led to their widespread use in operating rooms (9).

Despite many advantages of ABHSs, these compounds have some disadvantages, including short-term effects (due to their volatility), dry skin and irritation (10, 11). Moreover, spore-forming bacteria tolerate these alcohol-based solutions (12). HAIs are of major problems in hospitals, and they are transmitted from one patient to another through the contaminated hand(s) of health professionals (13). Considering the above and given that there are limited and dispersed studies in this regard, we conducted this study to provide a general conclusion about these solutions. The present study aimed to answer this question that "what are the advantages and disadvantages of ABHSs?"

2. Methods

The present systematic review was conducted based on the Broome's method in the three phases of searching the literature, evaluating data, and analyzing data (14). All studies published during 2010-2020 were simultaneously searched in databases of MEDLINE, PubMed, Scopus, and Magiran using the keywords of hand hygiene, alcohol-based hand sanitizer, and healthcare-associated infections. In the preliminary search, a number of 117 relevant studies were identified from which 92 were excluded as they did not fulfilled the inclusion and pre-defined criteria. Inclusion criteria consisted of the followings: (a) similarity in the study objective, studies published in English and Persian, and studies published within the last 10 years, having access to the full-text article. Exclusion criteria consisted of the followings: lack of access to the full-text article, and studies published before 2010. Subsequently, the primary studies were evaluated based on CASP (Critical Appraisal Skills Program) checklists through which 3 studies were excluded due to the low quality of the evidence. Finally, a total of 22 studies were included in our study. (Fig.1).

To perform analyses, data extracted from the included studies were categorized and summarized in the aggregate. Similar studies were then compared with each other. Finally, the key concepts, including the advantages and disadvantages of ABHSs, were extracted and classified. The validity of data analysis was confirmed by the researchers of the present study. The results of data analysis were repeatedly reviewed and compared by the researchers in order to interpret the findings. Furthermore, in case of any problems, they discussed the issue and conclude an agreement through a re-evaluation.

This study was approved by the ethics committee of the Urmia University of Medical Sciences (#IR.UMSU.REC.1399.019). we attempted to adhere to all ethical considerations regarding the correct use of studies extracted and follow the publication rules.
3. Results

Based on the research question, the results of the data evaluation and analysis indicate that ABHSs enjoy several advantages. However, they suffer from some disadvantages. After precise analysis of data extracted from the included studies, the advantages and disadvantages of ABHSs classified in 4 (having acceptable disinfectant effect, having better cleaning effect on microbial hand contamination compared to both conventional surgical scrub and soap and water, ease of use, and causing minor systemic complications) and 6 categories (inability to eliminate all microorganisms, leading to skin complications in case of long-term use, impairing the performance of latex and nitrile gloves, intolerance in some people, possibility of oral use and flammability), respectively. Full details of each item are provided in Table 1, and Table 2.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Details</th>
<th>Author/Year</th>
</tr>
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<tbody>
<tr>
<td>Acceptable disinfectant effect</td>
<td>Complete activity against enveloped viruses (SARS-CoV, MERS-CoV, Influenza viruses, HIV, HBV, etc.)</td>
<td>Kampf G. 2017 (15)</td>
</tr>
<tr>
<td></td>
<td>Acceptable disinfectant effect</td>
<td>Nasution et al. 2019 (16), Saito et al. 2017 (17)</td>
</tr>
<tr>
<td>Better cleaning effect on microbial hand contamination compared to soap and water, and conventional surgical scrub</td>
<td>Better eradicating effect on contaminants and microorganisms of palm compared to soap and water</td>
<td>Mazloum Khorasani et al. 2013 (18)</td>
</tr>
<tr>
<td></td>
<td>More efficacious than conventional surgical scrub</td>
<td>Shen et al. 2015 (19)</td>
</tr>
<tr>
<td></td>
<td>Easy and fast application</td>
<td>O’Donoghue M. 2019 (20)</td>
</tr>
<tr>
<td></td>
<td>No need for water and sink</td>
<td>Nakhaee et al. 2015 (21)</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Well tolerated</td>
<td>Ahmed-Lecheheb et al. 2012 (22)</td>
</tr>
<tr>
<td></td>
<td>Applicable to use on nitrile and latex gloves</td>
<td>Gao et al. 2016 (23), Birnbach DJ. 2019 (24)</td>
</tr>
<tr>
<td></td>
<td>No dermal absorption</td>
<td>Ahmed-Lecheheb et al. 2012 (22)</td>
</tr>
<tr>
<td>Causing minor systemic complications</td>
<td>Low (not toxic) transpulmonary absorption and no detected absorption during care activities</td>
<td>Hautemanière A. 2013 (25), Ahmed-Lecheheb et al. 2012 (26)</td>
</tr>
<tr>
<td></td>
<td>Having no effect on skin barrier function</td>
<td>Ahmed-Lecheheb et al. 2012 (22)</td>
</tr>
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</table>
Table 2. Disadvantages of ABHSs based on analysis of data extracted from the included studies

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Details</th>
<th>Author/Year</th>
</tr>
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<tbody>
<tr>
<td>Incomplete activity against some microorganisms</td>
<td>Partial activity against non-enveloped viruses (Adenovirus, Rotavirus, Norovirus, etc.)</td>
<td>Iwasawa A et al. 2012 (27), Kampl G. 2017(15)</td>
</tr>
<tr>
<td>and inefficiency under some circumstances</td>
<td>Spore-forming bacteria resistance to these agents</td>
<td>Jasemizad et al. 2016 (12)</td>
</tr>
<tr>
<td></td>
<td>Not effective in reducing the number and viability of scabies present</td>
<td>Cinotti et al. 2015 (28)</td>
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<tr>
<td></td>
<td>on the hands skin surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inapplicable to obvious hand contamination</td>
<td></td>
</tr>
<tr>
<td>Leading to skin complications in case of long-</td>
<td>Skin dryness in case of long-term use</td>
<td>Mathur. 2011 (29)</td>
</tr>
<tr>
<td>term use</td>
<td></td>
<td>Birnbach DJ. 2019 (24), Hassani et al. 2017 (11)</td>
</tr>
<tr>
<td>Impairing the performance of latex and nitrile</td>
<td>Decreased skin pH</td>
<td>Ahmed-Lecheheb et al. /2012 (22)</td>
</tr>
<tr>
<td>gloves</td>
<td>Decreased superficial sebum values</td>
<td>Ahmed-Lecheheb et al. /2012 (22)</td>
</tr>
<tr>
<td></td>
<td>Causing irritant contact dermatitis in case of long-term use</td>
<td>Birnbach DJ. 2019 (10)</td>
</tr>
<tr>
<td>Intolerance in some people</td>
<td>Decreased tensile strength of latex and nitrile gloves</td>
<td>Gao et al. 2016 (23)</td>
</tr>
<tr>
<td>Possibility of oral use</td>
<td>Increased gloves' stickiness in case of long-term use</td>
<td>Birnbach DJ. 2019 (24).</td>
</tr>
<tr>
<td>Possibility of oral use</td>
<td>Likely to interfere with some of the person's functional tasks</td>
<td>Birnbach DJ. 2019 (24).</td>
</tr>
<tr>
<td></td>
<td>An unpleasant smell for some people</td>
<td>Forrester MB. 2015(30), Gormley et al. 2012 (31).</td>
</tr>
<tr>
<td></td>
<td>Intentional Ingestion in people with alcoholism, suicidal ideation and</td>
<td>Forrester MB. 2015 (30), Santos C et al. 2017 (32)</td>
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<td></td>
<td>high risk behaviors</td>
<td></td>
</tr>
<tr>
<td>Flammability</td>
<td>Unintentional ingestion in children</td>
<td>O'Leary &amp; Price. 2011 (33)</td>
</tr>
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</table>

4. Discussion

The results of data analysis indicated that the advantages of ABHSs include the followings: (a) having acceptable disinfectant effect, (b) having better cleaning effect on microbial hand contamination compared to both conventional surgical scrub and soap and water, (c) ease of use, and (d) causing minor systemic complications.

The antimicrobial activity of ABHSs has been proven, and results of this activity differ depending on the type of alcohol used (ethanol, normal propyl, and isopropanol) (27). ABHSs are mainly made up of ethanol as the U.S. Food and Drug Administration (FDA) considers ABHSs containing a concentration of 60% to 95% ethanol as perfectly safe and effective for hand rubbing (34). Saito et al. (2013) found that ABHSs are effective in reducing HAIs in surgical and pediatric wards (17).

The results of the included studies have shown that ABHSs do a complete antimicrobial activity against enveloped viruses (SARS-CoV, MERS-CoV, Influenza viruses, HIV, HBV, etc.). Moreover, murine norovirus (MNV) and adenovirus type 5 are usually inactivated by a concentration of 70% to 90% ethanol within 30 seconds (15, 27).

ABHSs are recommended for hand hygiene instead of hand washing with regular soap and water, and other hand sanitizers. Besides, ABHSs provide better skin tolerance. The type of hand disinfectant affects the amount of reduction in the microbial load of the hands, so that alcohol-based solutions (ethanol and propanol) have a faster and more lasting effect on hand decontamination compared to other sanitizers (19). Soap is simply a detergent but alcohol has a strong antiseptic effect. In procedure of hand washing, soap should be used with enough water. If not, soap cannot have a full cleansing action while alcohol does not require water and produces its bactericidal effect properly through reaching the hand surface (35). In a study by Mazloum Khorasani et al. (2013), it was found that there is a significant relationship between the use of ABHSs and the reduction in positive culture of hand microorganisms in healthcare staff. Moreover, they showed that ABHSs are more effective in removing germs (18). Shen et al. (2015) found that the culture positive rate of the alcohol-based hand rub was 6.2% before operations and 10.8% after operations. They were both lower than the conventional surgical scrub (47.6% before operations and 25.4% after operations). In their study, the major identified pathogens were Gram-positive with coagulate-negative staphylococci (19).
Alcohol-based hand rub is a quick and easy method of hand sanitizing, so that it is well accepted by health workers. ABHSs are very effective in eliminating pathogens because they require less time as well as no water and act quickly to kill microorganisms on hands (18, 19). On the other hand, they can also sanitize latex and nitrile gloves. Based on the results of a study by Gao et al. (2016), multiple EBHR (Ethanol-Based Hand Rub) applications on the latex and nitrile gloves should be safe (23). Birnbach et al. (2019) identified no microperforation among 50 new gloves that had been applied with alcohol-based hand rub 8 times (24).

Another advantage of ABHSs is that they cause minor systemic complications. In a study by Hassani et al. (2017), there was no significant change in overall skin integrity of the hand after one month of using ABHSs for hand rubbing. The results of their study demonstrated that ABHSs are compatible with the hand skin. However, the use of these compounds decreases both skin pH and superficial sebum values and have no effect on skin barrier function. The results of their study demonstrated that ABHSs are compatible with the hand skin. However, the use of these compounds decreases both skin pH and superficial sebum values. It also has no effect on skin barrier function. The results of their study demonstrated that ABHSs are compatible with the hand skin (11). However, the use of these compounds decreases both skin pH and superficial sebum values. It also has no effect on skin barrier function. Transpulmonary absorption of ethanol vapors may occur which has no toxicity (25, 26).

Based on the results of data analysis, the disadvantages of ABHSs consist of the followings: (a) incomplete activity against some microorganisms and inefficiency under some circumstances, (b) leading to skin complications in case of long-term use, (c) impairing the performance of latex and nitrile gloves, (d) intolerance in some people, (e) possibility of oral use and (f) flammability. ABHSs are not able to eliminate some microorganisms, although they are considerably effective in terms of microbial decontamination. The spore-forming bacteria tolerate these agents as poliovirus type 1 is often resistant to concentration of ethanol less than 95%. Furthermore, 80% ethanol is not sufficiently effective against poliovirus, feline calicivirus, hepatitis A virus, and foot-and-mouth disease virus. On the other hand, ABHSs containing ethanol and isopropanol are not effective against non-enveloped viruses. So they are not recommended in this regard and compounds containing povidone-iodine (betadine) are the only way to inactivate non-enveloped viruses (27).

ABHSs cannot be applied in any situation in which the hands are obviously contaminated or when they are contaminated with protein substances such as blood or other biofluids. In such cases, the hands should be washed thoroughly with soap and water (36).

Skin dryness, decreased skin pH, decreased superficial sebum values, and irritant contact dermatitis in case of long-term use are listed as skin complications caused by ABHSs. The way to prevent the skin complications is to add moisturizing ingredient like glycerin to these solutions (11, 22). However, in a study by Birnbach et al. (2019), it was found that adding moisturizer to ABHSs (every 15 minutes for five sequential days) caused no significant difference in prevention of skin complications compared to the same non-moisturizing sanitizers in anesthetists (10). Regarding the performance of latex and nitrile gloves, Gao et al. (2016) found that the use of ABHSs decreases the tensile strength of latex gloves. Moreover, Ethanol-Based Hand Rubs (EBHRs) resulted in lesser changes in tensile strength compared to isopropanol-based Hand Rubs (IBHRs). Therefore, in case of using ABHSs, it is recommended to use EBHRs to prevent a decrease in tensile strength of latex gloves (23).

There are some reports on intolerance to these agents. The reason for this goes back to the unpleasant smell of these agents for some people as well as their interference in performing functional tasks (24). There is also a possibility for intentional ingestion in adults and unintentional ingestion in children (30, 32). ABHSs should not contain methanol. Some people may produce and market ABHSs containing methanol because of profit motive. ABHSs containing methanol are extremely dangerous and toxic due to the presence of methanol and they can cause varying degrees of toxicity and threatening side effects if used orally (30).

ABHSs are flammable to some extent. So they should be installed in locations away from incendiary and heating devices. Healthcare worker should be aware of the flammability of these agents. They also have to provide required educations for patients in this regard as these agents are installed in passages where patients and their companions repeatedly pass back and forth, and any fire accident can cause irreparable consequences for patients, staff, and health care settings (33).

5. Conclusion

Applying ABHSs for hand hygiene is one of the most effective methods for controlling and preventing infections, especially HAIs. Based on the results of the present systematic review, the numerous advantages of
ABHSs outweigh the disadvantages and make them as the sanitizers of choice in health facilities. The use of these agents can be considerably effective in reducing HAIs and hospital readmissions due to HAIs. It can also improve patient safety and cut healthcare costs.

Acknowledgments

This study approved by Urmia University of Medical Sciences and is financially supported by this University. Hereby, the authors would like to sincerely thank all the authorities and everybody who helped us with this research.

Conflicts of interest

The authors declared no competing interests.

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