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The neglected element of hand hygiene - significance of hand drying, efficiency of different methods and clinical implication: A review

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Abstract

Hand hygiene is a fundamental strategy for controlling the spread of infection. Careful hand drying is integral to the process of hand hygiene, which aims to optimise the removal of potentially pathogenic microorganisms. Ineffective hand drying results in wet hands that are an infection risk increasing the potential for cross-infection, occupational contact dermatitis for healthcare practitioners, harm to patients and environmental contamination.

Evidence indicates that there has been limited research regarding the significance of hand drying and the efficacy and clinical impact of different drying methods. The purpose of this review paper was to scope and evaluate the existing literature pertaining to hand drying; to examine the clinical consequences associated with wet hands for patients, healthcare practitioners and the clinical environment; to assess the efficacy of different drying methods; to consider the impact on patient safety; and to progress the research, debate and practice relating to hand drying. The methodological framework applied in this review was that of Arksey and O'Malley (2007). Twenty-one papers identified from 112 abstracts screened were included in the review. Analysis identified three primary themes emerging from the literature: (1) efficacy of hand drying methods; (2) drying method and microbial translocation, dispersion and environmental contamination; and (3) drying methods and environmental sustainability. This review highlights the equal importance of hand drying in the process of hand hygiene and suggests that the efficacy of hand drying is a critical factor in the prevention of the transfer of microorganisms to the environment, and from person to person following hand washing. In conclusion, this paper argues that greater attention needs to be given to hand drying in terms of practice, policy and research and its importance in clinical settings given greater focus.

Keywords

Hand hygiene, hand drying, wet hands, translocation, review

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Introduction

Hand hygiene is universally accepted as the single most important strategy for preventing and reducing healthcare-associated infections (HCAIs), as well as being critical for patient and practitioner safety. It is our hands that we use to care, our hands to impart comfort and reassure our patients; and yet the same hands can act as vehicles to transmit microorganisms which can impact on patient safety, causing harm and even killing. Promotion of improved hand hygiene is thus recognised as being a crucial measure in public health and is considered to be an integral component of the practice of infection prevention (Bloomfield et al, 2007). As such, the notion of the most effective method for performing hand hygiene has been a particularly active area

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of research (Magiorakos et al, 2010) and the importance of thorough cleansing of the hands with soap and water or a sanitiser to reduce the burden of HCAIs is well documented, having been heavily researched and publicised for a number of years by campaigns and initiatives such as the NHS CleanYourHandsCampaign (Gould et al, 2007; Stone et al, 2012).

Hand drying is integral to effective hand hygiene processes. Correct drying of hands after washing is vital for best infection prevention and should be an essential component of hand hygiene procedures and practices (Boyce and Pittet, 2002; Centres for Disease Control and Prevention, 2002; National Health Service Professionals, 2013; World Health Organization, 2009). The significance of hand drying encompasses not only the removal of moisture from the hands but involves mechanical friction which further reduces the bacterial load and thus transfer of microorganisms (Taylor et al., 2000; Yamamoto et al., 2005). Nonetheless hand drying is a much-neglected aspect of hand hygiene, with limited evidence relating to the options for hand drying, the efficacy of different methods of hand drying in reducing contamination, the amount of consequential microbial dispersion into the clinical environment, the efficacy, frequency and compliance of drying by healthcare practitioners and the consequences of wet hands for the healthcare practitioner.

The purpose of this paper is to offer a critical review of research examining the clinical importance of hand drying and the implications of wet hands for patients, healthcare practitioners and the clinical environment, to assess the efficacy of different drying methods, to consider the impact on patient safety, and to progress the research, debate and practice relating to hand drying.

Methods of review

This review drew on the five-stage methodological framework suggested by Arksey and O'Malley (2007). These five stages are: identification of research questions; identification of relevant studies; study selection; charting the data; and collating, summarising and evaluating the results of the scoping review. The research questions identified were:

- What is the research supporting and evidencing contemporary hand drying practice and procedures?
- To what extent does ineffective hand drying, and consequently wet hands, impact on infection prevention and control (IPC)?
- What is the impact and efficacy of contemporary hand drying methods?

Utilising Arksey and O'Malley's (2007) framework enabled an examination of the extent, range and nature of research activity relating to hand drying, the identification of gaps in the existing literature, and provided rigour and transparency in terms of the methods adopted, allowing replication and validity of the review findings. The credibility and reflexive nature of this framework, together with its wider recognition, were the reasons for its application. The framework used to critically appraise the quality of included studies was that of Greenhalgh (2010).

Electronic searches were undertaken of ASSIA, Medline and PubMed databases for research that had collected data about some aspect of hand drying. The review was limited primarily to English language studies in the health arena but not to any particular nation state. The search terms used were hand drying, hand hygiene, wet hands, drying methods and environmental contamination. The abstracts of potentially relevant citations were examined to determine the relevance of the original research. Full texts of all relevant articles were then obtained. In addition, bibliographies and secondary references of obtained articles were examined for additional studies. Policy documentation and reports were further searched for online.

Eligibility criteria for inclusion of articles in this review were English language papers reporting empirical research and published between 1985 and 2018, that related to aspects of hand drying, most specifically papers that focused on our identified research questions. We define an empirical paper as one that contains evidence of data collection and analysis, and included any studies that utilised any method of empirical investigation: quantitative, qualitative or mixed methods. All relevant papers were included. Papers published in languages other than English were excluded. Of the 319 papers identified on screening, 279 did not meet the inclusion criteria and 40 full articles were retrieved. Twenty-one original papers were identified as addressing the identified research questions and are included in this review.

Identified themes

Following the identification of the review research questions and relevant studies, the selected studies were charted, analysed and synthesised, and emerging themes identified and discussed. From this analysis, three primary themes emerged:

- Efficacy of hand drying methods;
- Drying method and microbial translocation, dispersion and environmental contamination;
- Drying methods and environmental sustainability.

Further themes of note emerging from our review were:

- Hand drying and occupational dermatitis;
- Policy and practice;
- Financial considerations.

However, these themes are not discussed at length in this paper.

Summary Table: *Included Studies*

For a more comprehensive overview of studies, see Table 1: Characteristics of included studies (see web appendices).

Publication details	Theme
Ali Alharbi et al., 2016; Saudi Arabia.	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Ansari et al., 1991; Canada.	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Berkowitz, 2015; USA	Theme 3: Drying methods and environmental sustainability
Best et al., 2014; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Best and Redway, 2015; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Budisulistiorini, 2007; Australia	Theme 3: Drying methods and environmental sustainability
Gregory et al., 2013; USA	Theme 3: Drying methods and environmental sustainability
Gustafson et al., 2000; USA	Theme 1: Efficacy of hand drying methods Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Hanna et al., 1996; Australia	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Huesca-Espitia et al., 2018; USA	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Jensen et al., 2015; USA	Theme 1: Efficacy of hand drying methods
Joseph et al., 2015; Canada	Theme 3: Drying methods and environmental sustainability
Kimmitt and Redway, 2015; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Margas et al., 2013; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Matthews and Newsom, 1987; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Ngeow et al., 1989; Malaysia	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Patrick et al., 1997; New Zealand	Theme 1: Efficacy of hand drying methods
Redway and Fawdar, 2008; UK	Theme 1: Efficacy of hand drying methods Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Snelling et al., 2010; UK	Theme 1: Efficacy of hand drying methods
Taylor et al., 2000; UK	Theme 2: Drying method and microbial translocation, dispersion and environmental contamination
Yamamoto et al., 2005; Japan	Theme 1: Efficacy of hand drying methods

Theme 1: Efficacy of hand drying methods

Efficiency of different drying methods and their suitability within clinical settings was one of the main themes in the research evidence. Efficacy can be measured in terms of extent of moisture removal and bacterial reduction. However, there is limited evidence to inform clinical practice. Table 2 (see web appendices) summarises the existing knowledge. Of the seven studies identified, the majority

acknowledge paper towels to be the most effective means of hand drying. This has been the consistent finding since the early research of Redway and Knights (1998), who argued that effective drying of hands reduces the number of bacteria on hands and the risk of transfer, and that paper towels, in terms of speed, drying efficiency, hygiene and microbial environmental contamination, perform better than warm air dryers or jet blade dryers.

For Patrick et al. (1997), residual water was most efficiently removed from the hands by cloth towels, rather than by warm air dryers. Their study found that it took around 45 s for an air dryer to achieve the equivalent results in 20 s using a cloth. Given that many healthcare practitioners do not use the devices for this length of time, they are not gaining the hygiene benefit of completely dry hands.

Gustafson et al. (2000) examined the hygiene performance of four hand drying methods: paper towel; cloth towel; warm air dryers; and evaporation. Their study compared the amounts of bacteria on the hands following drying by the four methods. All bacteria counts were determined using a modified glove-juice sampling procedure. Gustafson et al.'s (2000) study demonstrated no statistically significant differences in the efficiency of the four hand drying methods for removing wetness or bacteria from hands that had been washed.

Snelling et al. (2010) compared an ultra-rapid hand dryer against warm air dryers and their effect on bacterial transfer following drying, and the impact on bacterial numbers of rubbing hands during dryer use. Snelling et al. quantified the effects of hand drying by measuring the number of bacteria on different parts of the hands before and after drying by the different methods. The authors suggest that where hands are dried for at least 30 s using conventional warm air dryers, it is likely that hygiene benefits will be similar to that achieved with 10 s of use of an ultra-rapid hand dryer. However, if the drying time is significantly $<$ 30 s, the ultra-rapid hand dryer is hygienically superior for reducing transfer of microbes to other surfaces. Their study further found that rubbing the hands together while using warm air dryers potentially counteracts the reduction in bacterial numbers accrued during handwashing. In this, paper towels consistently outperformed all other drying techniques, especially with regard to bacteria left on the palms and fingertips. This, the authors note, suggests that bacteria repopulating the surface of the skin during the rubbing process were being physically removed by the paper towels along with the moisture. In so doing, paper towels appear to remove bacteria in a way in which conventional warm air dryers are incapable of replicating. This is further confirmed in the work of Jensen et al. (2015). Nonetheless, it should be noted that towels can become contaminated (Jensen et al., 2015; Taylor et al., 2000), which, in itself, could pose a hygiene hazard. In situations where demand for hand hygiene is high and stocks of clean towels can become exhausted, washed hands remain damp and the risk of bacterial transfer increases.

Redway and Fawdar's (2008) study suggests that while the drying efficiency of paper towels and jet air dryers are equal, the hygiene performance of jet air dryers and warm air dryers compared to paper towels is significantly worse 'in all respects' including drying efficiency, bacterial numbers on the hands, bacterial contamination of the air flow and surfaces of the devices, and transmission of bacteria. This may be as a result of friction. According to Redway and Fawdar (2008), paper towels are more effective as bacteria are physically removed from the hands in a way that is not possible with jet air dryers and warm air dryers. In many ways, rubbing hands vigorously when using warm air dryers increases bacteria numbers on the skin and airborne dissemination (Yamamoto et al., 2005). It may be that rubbing hands causes the migration of bacteria from the hair follicles to the skin surface (Snelling et al., 2010).

Theme 2: Drying method and microbial translocation, dispersion and environmental contamination

In deciding the most suitable method of hand drying for healthcare settings, the extent of moisture removal needs to be considered alongside the potential of microbial translocation, dispersion and environmental contamination. This review identified 13 studies assessing the capacity of different drying methods to translocate and disperse microorganisms into the immediate environment and to other persons. Nine studies identified note that jet dryers and warm air dryers result in greater microbial dispersion compared to paper towels. A number of studies noted greatest microbial dispersal to be associated with the jet dryer while other studies noted no significant difference.

Ngeow et al. (1989) investigated the potential risk of warm air dryers contributing to airborne infection in a hospital setting. Their study compared bacterial dispersal caused by warm air dryers with that of paper towels. Ngeow et al. (1989) demonstrated the dispersal of marker bacteria within a radius of 3 ft from hot air dryers. Conversely, when paper towels were used for hand drying, no bacteria were found. The authors thus affirmed warm air dryers to be unsuitable for use in critical care environments for risk of contributing to cross-infection either via airborne dissemination or by way of contaminated personnel. Similarly, Redway and Fawdar's (2008) study suggests that paper towels are likely to cause considerably less contamination of other users and of the washroom environment than jet air dryers, which were found to disperse artificial hand contamination to a distance of at least 2 m. Paper towels and warm air dryers produced more positive results than jet air dryers regarding contamination of the washroom environment. Paper towels created less contamination at 0 m (directly below the device) than warm air dryers, although there was no significant difference at greater distances. Hanna et al. (1996) further reported that warm air dryers

resulted in significant numbers of airborne bacteria in the environment surrounding the user, while paper and cloth towels produced negligible contamination of the vicinity.

Margas et al. (2013) compared the potential for cross-contamination of the surrounding environment resulting from paper towels and the use of a jet air dryer. Their study showed that the two hand drying methods produced different patterns of ballistic droplets and levels of microbial contamination, under heavy use conditions: the jet air dryer producing a greater number of droplets dispersed over a larger area and more microbial contamination of the immediate environment than paper towels. Similarly, Best et al. (2014) used a paint and *Lactobacillus* bacterial model to compare aerosolisation and dispersal following hand drying with paper towels, a warm air or jet air dryer. They demonstrated that paper towels produced less dispersal from the hands into the surrounding environment than jet air dryers. Utilising an acid-indicator model and artificial contamination of the hands with yeast, research by Best and Redway (2015) showed that the use of a jet air dryer to dry the hands dispersed liquid and consequently, potential microbial contamination on the hands, to greater distances (up to 1.5 m) than paper towels, roller towels or warm air dryers (up to 0.75 m). In Best and Redway's (2015) study, jet air dryers were further shown to disperse more liquid from the hands to a range of different heights compared to the other hand drying methods.

Ali Alharbi et al. (2016) sought to evaluate the performance of warm air dryers in relation to microbial contamination of the washroom environment at an academic institution in the Kingdom of Saudi Arabia. Their study found bacteria to be numerous in the air flows. Bacterially contaminated air was found to be emitted whenever the warm air dryer was running, even at times when not being used for hand drying. Their research asserts that that *Staphylococcus haemolyticus, Micriciccus luteus, Pseudomonas alcaligenes, Bacillus cereus* and *Brevundimonad diminuta vesicularis* were emitted from all warm air dryers sampled, with 95% showing evidence of the potential pathogen *Staphylococcus*. The presence of these bacteria in the air flow of high numbers of warm air dryers and increase in the numbers of these bacteria on the hands of users suggests the potential for the spread of food poisoning organisms following this method of hand drying. Ali Alharbi et al. further isolated bacteria from the contaminated air of the washroom, with *Staphylococci* and *Micrococci* being blown out of 95% of the air; 56% showing evidence of the potential pathogen *S. aureus*, thus substantiating the findings of Yamamoto et al. (2005). Ali Alharbi et al. (2016) conclude that warm air dryers produce more ballistic droplets which are potentially carrying bacteria across extensive areas spread further and have the potential for depositing pathogenic bacteria onto the hands and body of users. Bacteria can further be inhaled and distributed into the wider environment at times when the dryer is running.

As noted previously, a number of studies identified in this review noted no significant difference regarding microbial translocation and dispersal, and method of hand drying. Matthews and Newsom (1987) compared the bacteria aerosols released into the air when drying hands using paper towels and warm air dryers. The authors conclude that there was no significant difference between warm air dryers and paper towels in terms of aerosol liberation and that the former could be considered safe. Likewise, Taylor et al. (2000) assessed whether warm air dryers alter the levels of airborne microorganisms in the washroom environment. Their study determined that air emitted from the dryer outlet contained fewer microorganisms than air entering the dryers and further, that levels of microorganisms on the external surfaces of warm air dryers were not different from those on other washroom surfaces. According to Taylor et al., warm air dryers are appropriate for use in both healthcare and food industry settings. The studies of Matthews and Newsom (1987) and Taylor et al. (2000) are further confirmed in the work of Ansari et al. (1991) and Gustafson et al. (2000).

To date, there have been a few studies (Kimmitt and Redway, 2015) evaluating the aerosolisation and dispersal of virus particles during hand drying. Viral pathogens, such as Norovirus, are thought to have a low infectious dose and can be shed in large numbers of faeces (Gerhardts et al., 2012). Kampf and Kramer (2004) note that viruses can survive on the hands for varying times: influenza and CMV (10–15 min); HSV (up to 2 h); adenovirus (for a number of hours); rhinovirus (seven days); and rotavirus and HAV (up to 60 days). Thus, within the washroom environment, virus dispersal has the potential to contaminate persons and surfaces, including surfaces of hand drying devices. Recent research by Huesca-Espitia et al. (2018) determined that sporeformers, including a laboratory strain of *B. subtillis*, were found on plates exposed to hand dryer air or air moved by small fans at multiple locations at the University of Connecticut School of Medicine, including areas far away from where these spores were produced. Their work indicates that since spores in washroom air can be deposited on surfaces from the air by hand dryers, this suggests a further means of *Clostridium difficile* transmission and one that may not be interrupted by either hand washing or traditional methods of surface decontamination methods.

Kimmitt and Redway (2015) used a MS2 bacteriophage model to compare paper towels, warm air dryer and jet air dryer, for their potential to disperse viruses and contaminate the immediate environment during times of use. When the three hand drying devices were compared in this study, there were clear differences in the extent of virus dispersal from the hands. The jet air dryer produced significantly greater virus dispersal compared to the warm air dryer and paper towel devices: $>$ 60 times more viral plaques than the warm air dryer and $>$ 1300 times more than paper towels. The authors suggest the differences in results between the three

hand drying devices can largely be explained by their mode of drying of hands: paper towels remove water by absorption; warm air dryers of the type tested in this study remove water primarily by evaporation; and jet air dryers remove water by shearing forces and dispersal in to the air.

Theme 3: Drying methods and environmental sustainability

It is imperative to give consideration to the environmental sustainability of different drying methods. Nevertheless, rather surprisingly, this review found limited research regarding the relative environmental impact of different methods of hand drying. In total, six studies are included in this review. While a number of descriptive articles noted differing positions on this subject, they were not included in this review as these papers very much presented the opinions of individuals and/or commercial corporations.

The most widely used tool to assess the environmental impact of products and services appears to be the Life Cycle Analysis or Life Cycle Assessment (LCA) (Budisulistiorini, 2007; Gregory et al., 2013; Joseph et al., 2015; Montalbo et al., 2011). The LCA approach involves the identification of all material demand, energy requirement and environmental emissions associated with the manufacture, use, transport and disposal phases of a product through its life cycle, thus ascertaining the life cycle impacts that occur during the life cycle stages of the product systems.

Budisulistiorini (2007) compared the environmental performance of two methods of hand drying: paper towels and electric hand dryer. According to Budisulistiorini (2007), the electric hand dryer by means of hand drying method surpasses paper towels towards environmental sustainability performers. Paper towels emit relatively higher greenhouse gases than the electric dryer method. Regarding environmental sustainability, the electric dryer method surpasses paper towels with more positive scores for six indicators (respiratory organics, respiratory inorganics, ozone layer, ecotoxicity, acidification/eutrophication and fossil fuels), with five indicators for paper towels (carcinogens, climate change, radiation, land use and minerals).

In a more recent study, researchers at the Massachusetts Institute of Technology conducted a LCA of the environmental impact (with a particular focus on global warming potential) of five hand drying systems (Gregory et al., 2013)[1]. The authors conclude that high speed dryers have a lower environmental impact and global warming potential than paper towels and cotton roll towels. Gregory et al. (2013) were unable to differentiate between the hands under dryer, cotton roll towels and paper towels.

Drawing on the above studies, Joseph et al. (2015) carried out a comparative LCA case study of two hand drying methods at a university campus setting in Canada: conventional hand dryer and roll paper towel. Their study concluded that the use of a conventional hand dryer (rated at 1800 W and under a 30-s use intensity) has a lesser environmental impact than the use of two paper towels (100% recycled content, unbleached and weighing 4 g) issued from a roll dispenser.

Jet air dryers are particularly noisy compared to all other methods of hand drying, including warm air dryers. Redway and Fawdar (2008) ascertain the mean decibel level of jet air dryers at 0.5 m is 94.1 dB, which is in excess of that of a passing heavy lorry 3 m away. The mean decibel levels at 1.0 m and 2.0 me are in excess of a typical busy street at 87.4 dB and 86.3 dB, respectively. When two jet air dryers were used concurrently, the decibel level at a distance of 2 m was 92dB. Thus, in environments with jet air dryers such as public washrooms, the noise levels could constitute a potential risk to those people exposed to it for long periods. Likewise, Berkowitz (2015) found that electric dryers produced more intense sound than predicted by manufacturers.

Discussion

This review found there to be little agreement regarding the most hygienic method of hand drying and the published evidence regarding whether hand drying methods vary in their efficacy or tendency to aerosolise and thus transmit microorganisms is inconsistent. A number of studies affirm that paper towels are the most efficient method of hand drying and that warm air dryers (including jet air dryers) are associated with amplified aerosolisation of microorganisms (Redway, 1994; Redway and Fawdar, 2008; Redway and Knight, 1998) compared to paper towels, while others suggest there is no difference (Ansari et al., 1991; Gustafson et al., 2000; Mathews and Newsom, 1987; Taylor et al., 2000).

Methodological issues may explain these inconsistencies, in part (Huang et al., 2012). Nevertheless, the degree of wetness appears to be an important factor in determining numbers of bacteria detected. Taylor et al. (2000) and Mathews and Newsom (1987) investigated the residual bacteria on the hands following drying with warm air dryers and paper towels using contact plates. These studies suggest little differentiation regarding the removal of bacteria for the different drying methods. In their study, Taylor et al. (2000) claim that the contact plate results appeared to be a reflection of the degree of wetness following drying, rather than the actual number of bacteria on the hands. In other reviewed studies, a number of authors used longer drying times of hot air dryers than others. Matthews and Newsom (1987) used warm air dryers until the hands of study participants were completely dry – ordinarily around 1 min. Redway and Fawdar (2008) sought to reproduce as closely as possible the hand drying practices people use. In their study, the mean hand drying times were 10 s for paper towels and 20 s using warm air dryers. Thus, the significantly poorer hygiene performance of warm air dryers may be a reflection of their low efficiency and thus the greater

amount of water remaining on participants' hands. Drying times will consequently have practice implications and impact on compliance.

Transmission of bacteria is most likely to occur from hands that are wet than dry hands. There is a clear correlation between the extent of wetness and the transfer of organisms, which consequently will impact on infection prevention within the healthcare settings (Merry et al., 2001; Patrick et al., 1997) and thus consequently patient safety. Bacterial numbers translocating on touch contact decrease progressively as efficacy of drying removes residual moisture from the hands. Patrick et al. (1997) note the single most important determinant of the number of microorganisms translocated from hands was the extent of residual moisture remaining on hands after washing. The work of Merry et al. (2001) further confirms the role of residual water on the hands in the level of touch- or contact-associated contamination. Therefore, careful hand drying is a critical factor determining the level of touch- or contact-associated bacterial transfer following hand washing; its recognition consequently could make a significant contribution towards improving hand hygiene care practices in clinical and public healthcare sectors.

Bacterial dispersal and transmission can be encouraged by the movement of air, thus increasing the likelihood of cross-contamination. Redway and Fawdar's (2008) research suggests that air dryers in washrooms are often contaminated and emit bacteria in their airflow. Thus, there is a potential risk of those persons standing at warm air or jet air dryers acquiring pathogenic bacteria being potentially dispersed: either through inhalation; being deposited onto the hands and body of users; and from being further distributed into the wider environment (Ali Alharbi et al., 2016; Ngeow et al., 1989; Taylor et al., 2000; Yamamoto et al., 2005).

The nature of clinical practice means that the hands of healthcare practitioners are frequently exposed to wetness. The literature refers to this as wet work. Healthcare practitioners are at high risk for developing occupational hand dermatitis as a consequence of frequent exposure to 'wet work' (Behroozy and Keegel, 2014) due to the nature of mandatory hygiene procedures, coupled to ineffective hand drying and/or the use of hand gloves. Among healthcare practitioners, nurses are particularly at high risk of hand dermatitis. It is estimated that around one thousand nurses develop work-related irritant contact dermatitis each year in the UK (Behroozy and Keegel, 2014).

Hand hygiene and the efficacy of the hand drying method involves not only the percentage of dryness of the hands but also the removal of bacteria from washed hands and the prevention of cross-contamination (Huang et al., 2012). In healthcare settings, the appropriate cleansing of the hands of staff or visitors before, or after, certain procedures and practices is of particular importance and a number of guidelines on handwashing and hand cleansing have been issued by the Centres for Disease Control and Prevention (CDC), the National Health Service (NHS) and the World Health Organization (WHO) (Boyce and Pittet, 2002; Centres for Disease Control and Prevention, 2002; National Health Service Professionals, 2013; World Health Organization, 2009). Warm air and jet air dryers are not recommended for use in healthcare settings as a result of their hygiene and environmental performance (Kimmitt and Redway, 2015; Redway and Fawdar, 2008). Continuous cloth roller towels are not recommended as they become common use towels at the end of the roll and can be a source of pathogen transfer to clean hands. Thus, disposable paper towels offer the most hygienic method of hand drying in healthcare settings (Kimmitt and Redway, 2015; Redway and Fawdar, 2008). As part of our review, we studied national and local UK government policy regarding hand drying. Contained within wider NHS infection prevention and hand hygiene policy and procedure, disposable paper towels are advocated in all clinical settings as the 'quickest and most effective' means of removing residual moisture that may facilitate transmission of microorganisms (Loveday et al., 2014). This review found this directive adopted at localised levels by NHS Trusts and NHS Health Boards throughout the UK.

The review found warm air dryers to have a lower environmental impact (Budisulistiorini, 2007; Gregory et al., 2013; Joseph et al., 2015) and to be less of an economic burden (Budisulistiorini, 2007) than paper towels. Nonetheless, Redway and Fawdar (2008) found the noise levels of jet air dryers to constitute a potential risk and disturbance for patients within the clinical environment, and to those people exposed to it for extended periods in environments such as public washrooms. Paper towels are considered to be more of an economic burden than the use of electric hand dryers (Budisulistiorini, 2007), in that it is necessary to frequently replace paper towels, while following initial instillation, electric air dryers require little maintenance. These tensions between IPC objectives and environmental impact beyond infection prevention, merits future research that explores the interrelation between infection prevention, environmental sustainability, and the design and structure of hand drying machines and products.

Limitations

Scoping reviews are most typically concerned with reporting the results of collective studies. This review has focused on the clinical importance of hand drying and the implications of wet hands for patients, healthcare practitioners and the clinical environment. Like all scoping reviews, it is subject to a number of important limitations.

This review is limited by the phrases used for searching, the databases accessed, the frame and method of searching for literature and by time constraints. Searching additional databases or using additional search phases may have identified more publications. The criteria that the article be written or available in the English language may further

have led to omissions of studies published in other languages, particularly since studies that were screened and included were international.

Scoping reviews are one step removed from the primary data, and therefore we rely on the authors' reporting of results. A number of studies included in our review did not report sample sizes (Table 1; see web appendices). No attempts were made to contact authors for this additional information. In other studies, sample sizes were small (Table 1; see web appendices). Nevertheless, this review offers insight into efficacy of different hand drying methods and the consequences of different hand drying methods in terms of microbial translocation and dispersal, occupational dermatitis and environmental sustainability.

This review did not identify research that specifically measured the extent of drying (or residual moisture) by healthcare practitioners irrespective of the methods used. Research to measure wetness on the hands and hand drying compliance by healthcare practitioners is an area of research that needs to be considered.

Conclusion

Good hand hygiene is recognised as a critical factor in controlling the spread of infectious diseases and delivering effective IPC practice. Effective hand hygiene which includes sound hand drying has the potential to control and reduce the spread of HCAIs, prevent environmental contamination, protect patients and minimise contact dermatitis for healthcare practitioners.

This scoping review suggests that greater attention needs to be given to effective hand drying and its importance when considering hand hygiene in the clinical context and that patient safety is put at risk when healthcare practitioners fail to dry their hands or inappropriate methods are used. More high-quality studies regarding the significance of hand drying to hand hygiene and the hand hygiene debate are needed.

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Note

1 See also: Montalbo et al. (2011).

Supplemental material

Supplemental material for this article is available online.

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