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Residual moisture determines the level of touch-contact-associated bacterial transfer following hand washing

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SUMMARY

We report here a new and critical determinant of the effectiveness of hand hygiene procedures, namely the amount of residual moisture left on the hands after washing and drying. When samples of skin, food and utilities were touched with wet, undried hands, microbial numbers in the order of 68000, 31000 and 1900 respectively translocated to these representative surfaces. Bacterial numbers translocating on touch contact decreased progressively as drying with an air or cloth towel system removed residual moisture from the hands. A 10 s cloth towel–20 s air towel protocol reduced the bacterial numbers translocating to skin, food and utilities on touch contact to 140, 655 and 28 respectively and achieved a 99·8, 94 and 99% reduction in the level of bacterial translocation associated with wet hands. Careful hand drying is a critical factor determining the level of touch-contact-associated bacterial transfer after hand washing and its recognition could make a significant contribution towards improving handcare practices in clinical and public health sectors.

INTRODUCTION

An awareness that an individual's hands can be a source of cross infection and a vehicle for the transmission of infectious disease has remained undisputed since Semmelweiss in Europe [1] and Wendall Holmes in the United States [2] clearly demonstrated the efficacy of hand washing in the prevention of puerperal sepsis and its associated mortality. There is no shortage of scientific papers in the medical, nursing and surgical literature on the subject of hand hygiene and infection control but the emphasis has been on the effect of hand disinfection and washing on the indigenous or experimentally introduced skin microbial flora. As a result, hand hygiene has become synonymous with practices and products that reduce microbial numbers on the hands.

In the course of studying hand hygiene practices in relation to touch contamination induced peritonitis in patients undergoing peritoneal dialysis, we made the serendipitous discovery that the single most important determinant of the number of micro-organisms translocating from an individual's fingers to the dialysis bag exchange equipment was the residual moisture remaining on the hands after washing [3]. When a patient's hands were carefully dried, bacterial contamination of the plastic connecting devices was very low. Damp hands however facilitated the transfer of many thousands of micro-organisms to the connecting devices and ultimately, into the peritoneal cavity. These observations established a clear association between residual moisture on the hands and bacterial translocation with touch contact but the relationship was not determined in quantitative terms.

In the current investigation we set out to quantify the effect of hand drying on touch-contact-associated translocation of micro-organisms from fingers to surfaces representing skin, food and clinical utilities. With this information available, we were able to devise a practical hand drying procedure that reduced touch contact contamination to a minimum. The

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principles we established have considerable implications for infection control procedures in clinical practice, public health and nursing hygiene and, indeed, in any situation where it is important to limit touch-contact-associated dissemination of infectious agents.

MATERIALS AND METHODS

Subjects

Male and female volunteers from the administrative and technical staff of the Department of Medicine at Auckland Hospital participated in the bacterial translocation studies. Public rest rooms were monitored for studies involving 'use' hand drying practices.

Tap water microbiological quality

The tap water used for hand washing in all these experiments met Ministry of Health drinking water standards and, according to company records and our own regular analyses, it contained no demonstrable coliforms or other aerobic micro-organisms over the period of the study.

Hand drying methods

Reusable single serve cloth towels of the pull down roller type were supplied by New Zealand Towel Services (NZTS). Sections for drying were dispensed when pulled down by user. The towels were freshly laundered and autoclaved at 121 °C for 30 min before use. An automatic air towel, model Mk 9, supplied by NZTS was fitted with a timer which was designed to provide a 45 s uninterrupted flow of hot air.

Representative surfaces used in bacterial transfer analysis

Chamois cloth, representing skin, was cut into 2 cm squares and sterilized by autoclaving at 121 °C for 15 min. Food was represented by 2 cm squares of licorice straps which were sterilized by ethylene oxide gas. Plastic pipette tips (1 ml), cut in half laterally and sterilized by autoclaving, were representative of utility surfaces.

Quantitative bacteriology

After handling, the representative surface (chamois, licorice or plastic pipette tip) was placed into 9 ml of saline solution and vortexed for 15 s to remove adherent bacteria. A 1 ml aliquot was incorporated in a Columbia agar pour plate and incubated at 37 °C for 24 h, after which bacterial numbers were enumerated. Control plates, to check for sterility, were used for each experimental procedure but without the touch contact.

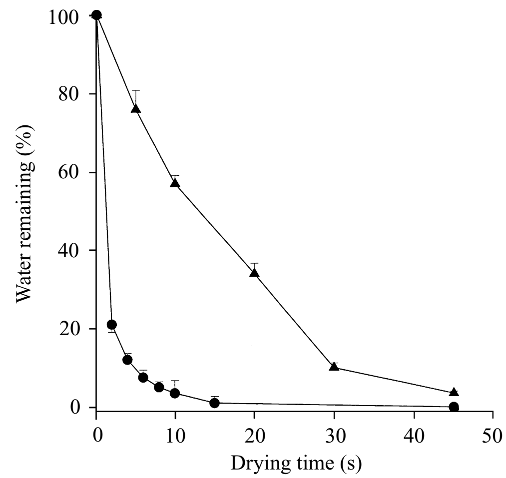

Fig. 1. Removal of residual water, after washing, by cloth (●) and air (▲) towel hand drying systems. Error bars represent the S.E.M., $n = 5$ for each time point.

Experimental protocols

Analysis of the drying efficacy of cloth and air towels

The subjects' hands were wet under running tap water for 5 s, flicked twice, and then dried for either 0, 2, 4, 6, 8, 10, 15 or 45 s for cloth and 0, 5, 10, 20, 30 or 45 s for the air towel. The amount of water left on the hands after each drying period was quantified by finishing the drying using a pre-weighed paper towel. This was then reweighed to determine the amount of water remaining on the hands and subsequently transferred to the pre-weighed paper towel, after the above drying times. Each point presented in the results is the mean of five samples.

Selection of hand drying times for cloth and air towel bacterial translocation experiments

Hand drying times used in the various experiments were based on the data from the above experiment and summarized in Figure 1. This shows that the drying efficiency of the cloth and air towel systems differed substantially. Bacterial translocation studies using the cloth towel were therefore carried out using drying times of 0, 2, 8, 15 and 45 s after hand washing. In the case of the air towel the hand drying intervals used were 0, 10, 20 and 45 s.

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Bacterial numbers transferring to representative surfaces after hand drying

Pretest sampling of hands was carried out, before any contact with water, by fingering a representative surface for 5 s using the fingers of both hands. The hands were then held under running water for 5 s and flicked twice to remove excess water, before fingering another piece of the representative surface (100% wet) for a further 5 s. The numbers of micro-organisms transferring to the surfaces were then quantified as described above. After an interval of 10 min normal activity, the hands were wet again. They were then dried, using one of the towel systems, for a period determined by the individual protocol and another portion of the surface under test was handled. Bacterial numbers transferred to each surface were estimated for the two towel types after drying for 0, 2, 8, 15 and 45 s for cloth towel and 0, 10, 20 and 45 s for the air towel. When using the air towel, emphasis was placed on drying the finger tips which were held vertically under the air flow. Seven volunteers were sampled six times for each type of material and each drying time.

Combination cloth towel and air towel

A dual drying protocol was developed to increase the efficiency of the previous drying procedures. Pretest and 100% wet samples were taken as above and after 10 min, the hands were wet again. The hands were then dried with a clean towel for 10 s and immediately placed under an air towel for a further 10 or 20 s, depending on the protocol. Bacterial transfer to chamois cloth ('skin'), food and utilities was then estimated as above. Six volunteers were sampled six times for each protocol.

Rest room observations

Male and female public rest rooms were monitored to ascertain the length of time that individuals dried their hands using cloth or air towels. A stop watch was used to time hand drying.

RESULTS

Comparative hand drying efficiency of air and cloth towels

Subjects' hands were wet under running tap water and dried for various times using either the air or cloth towel systems. The residual moisture on the hands was quantified by further drying on pre-weighed paper towels. Reweighing of these towels allowed the amount of water remaining on the hands after specific drying times to be determined. Residual water was effectively and efficiently removed from the hands by the cloth towel system. After 10 s drying with a cloth towel, 4% of the residual water remained on the hands and with 15 s drying this figure was reduced to 1%. The air towel took longer to achieve a similar endpoint and needed a drying time of 45 s to reduce residual water on the hands to 3% (Fig. 1).

Effect of hand drying using cloth and air towels, on microbial transfer following touch contact with 'skin', food and utilities

Cloth towel

When 'skin' was touch contaminated with dry fingers pretest, 200 micro-organisms translocated from the fingers to skin. Touch contact with wet hands led to an average of 60400 micro-organisms translocating. The number translocating on touch contact progressively declined as the time spent on hand drying increased. For example, after 8 s of drying 24200 micro-organisms translocated when 'skin' was touched (40% of the number transferred by wet, but undried hands, which were taken as 100%). After 15 s drying 6700 (11%) micro-organisms translocated and after 45 s 850 (1%) were transferred by touch contact. In the case of hand contact with food, a mean of 39300 micro-organisms translocated when licorice was handled with wet hands (drying time 0). Cloth drying of the hands had an immediate effect on microbial transfer. A drying interval as brief as 2 s reduced transferable numbers from 39300 to 7500. Further reductions in the number of micro-organisms transferred by touch contact were observed as more time was spent on hand drying and, after 8 and 45 s drying time, 3000 and 830 micro-organisms translocated respectively (8 and 2% of the potential transferrable number). Bacterial numbers translocating to the 'utility' representative surface were noticeably lower than the two previous surfaces (1800 translocating with wet hands). Hand drying with the cloth towel effectively reduced bacterial numbers translocating to this surface. After 2 s drying, 18% of the potentially transferable microbial flora had translocated but by 15 s this figure had fallen to 3% representing just 60 micro-organisms (Table 1, cloth towel).

Table 1. *Effect of hand drying with cloth or air towels on microbial transfer to representative surfaces following touch contact*

Drying time (s) after hand wetting…	Cloth towel 0	2	8	15	45	Pretest
Skin	60400* ± 7900† (100%)‡	27400 ± 5300 (45%)	24200 ± 6100 (40%)	6700 ± 950 (11%)	850 ± 130 (1%)	200 ± 50 (0·3%)
Food	39300 ± 5400 (100%)	7500 ± 2300 (19%)	3000 ± 400 (8%)	2800 ± 660 (7%)	830 ± 170 (2%)	490 ± 70 (1%)
Utilities	1800 ± 200 (100%)	320 ± 60 (18%)	160 ± 30 (9%)	60 ± 10 (3%)	40 ± 7 (2%)	15 ± 5 (0·8%)

Drying time (s) after hand wetting…	Air towel 0	10	20	45	Pretest
Skin	72300 ± 16400 (100%)	28000 ± 5000 (39%)	19000 ± 4200 (26%)	3700 ± 1000 (5%)	250 ± 40 (0·3%)
Food	41700 ± 6300 (100%)	26400 ± 3300 (63%)	9700 ± 1800 (23%)	690 ± 80 (2%)	500 ± 100 (1%)
Utilities	1600 ± 180 (100%)	1400 ± 180 (88%)	360 ± 100 (23%)	100 ± 50 (6%)	14 ± 4 (0·9%)

* $n = 42$ for each time point and representative surface.
† ± represents the standard error of the mean.
‡ Percent bacteria translocating after the specified drying time compared to the number translocating with wet, undried hands (time 0).

Air towel

Air towel hand drying took significantly longer than cloth towel use to affect microbial translocation levels. In the case of 'skin', bacterial translocation numbers were reduced to 26% after 20 s drying and 5% after 45 s drying (3700 translocating compared with 72300 with wet undried hands). Bacterial transfer levels to food were reduced with air towel drying but the subjects' hands needed protracted exposure. After 10 and 20 s drying, numbers translocating were 26400 and 9700 respectively representing 63 and 23% of the potentially transferable load (41700 at drying time 0). Drying for 45 s reduced transferable numbers to 690 (2% of potential). Air towel drying had a minimal effect on the bacterial transfer to utilities after 10 s drying (a mean of 1400 translocating *vs*. 1600 for wet hands), but by 20 s, bacterial numbers had decreased to 360 (23%). After 45 s air drying, the equivalent figures were 100 micro-organisms representing 6% of the number transferred at drying time 0 (Table 1, air towel).

Effect of a dual cloth and air towel hand drying protocol on bacterial translocation

The experiment involved hand washing followed by the use of a cloth towel for 10 s and an air towel for either 10 or 20 s – the so-called 10/10 or 10/20 protocols. Bacterial numbers in the order of 71500 which translocated to skin when the hands were wet

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Table 2. *Effect of a combined cloth and air towel hand drying protocol on bacterial translocation to representative surfaces*

Drying time (s)	Dual protocol 0	10/10*	10/20†	Pretest
Skin	71 500‡ ± 4900§ (100 %)¶	300 ± 50 (0·4 %)	140 ± 20 (0·2 %)	50 ± 10 (0·1 %)
Food	11 700 ± 5300 (100 %)	1600 ± 300 (14 %)	655 ± 120 (6 %)	420 ± 50 (4 %)
Utilities	2400 ± 400 (100 %)	90 ± 20 (4 %)	30 ± 10 (1 %)	30 ± 5 (1 %)

* Hand drying protocol using the cloth towel for 10 s followed by 10 s under the air towel.
† Similar procedure to above but using the air towel for 20 s.
‡ $n = 36$.
§ Standard error of the mean.
¶ Percentage of bacteria translocating compared to the number translocating with wet, undried hands (time 0).

Table 3. *Observations of hand drying practices in rest room areas*

Drying method	Male: Subject numbers	Male: Drying time (s)	Female: Subject numbers	Female: Drying time (s)
Air towel	100/74*	17·0 ± 10·3†	100/70	13·3 ± 6·4
Cloth towel	100/77	3·5 ± 2·3	100/97	5·2 ± 2·7

* Total number of subjects observed wetting hands/total number of subjects wetting and drying hands.
† ± 1 S.D.

were reduced to 300 when the 10/10 procedure was used. Extending the drying time with the air towel to 20 s (10/20) reduced the translocation process still further. Substantial reductions in bacterial translocation to food and utilities were also achieved with the 10/10 or 10/20 protocols (Table 2).

Hand drying practices under 'use' conditions

Observations were carried out in male and female rest rooms to ascertain the time individuals spent drying their hands using single serve cloth and air towels. Rest rooms used for the observations had either single serve cloth towel or hot air towels installed but not both. Male users spent an average of 3·5 s on cloth towel hand drying and 17 s under the air towel. The comparable figures for women were 5·2 and 13·3 s (Table 3).

Data obtained from Table 1 were used to construct curves (*a*) and (*b*), Figure 2, which defined the relationship between increments in hand drying times and a reduction in bacterial translocation. Hand drying times of male and female users of air towel (*a*) and cloth (*b*) systems (Table 3) were then related to these curves and the percentage reduction in bacterial translocation was estimated by reference to the vertical axis. Thus hand drying intervals of 15 s found in this study for female and male users of the air towel system (*c*) and (*d*) on curve (*a*) reduced bacterial translocation to skin to approximately 33 % of the translocation level associated with wet hand touch contact. Using data from Table 1, this would equate to 21 900 micro-organisms as compared with 66 300 (100 %). The average figure of 3–5 s of cloth towel drying for male and female users (positions (*e*) and (*f*) on curve (*b*)) achieved a slightly less favourable translocation figure of 40 % (26 500 micro-organisms).

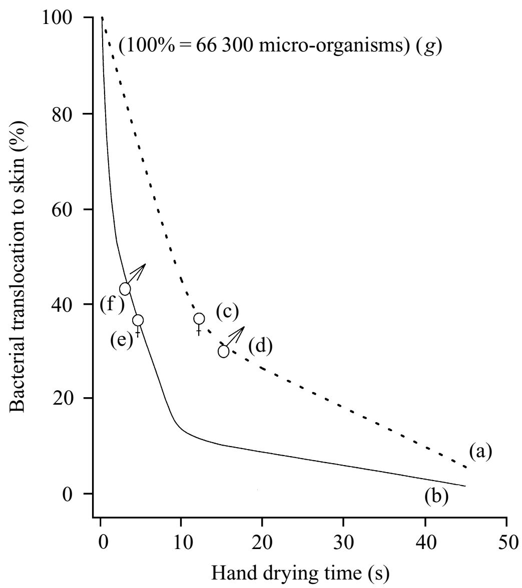

Fig. 2. Reduction in bacterial translocation achieved by cloth or air towel use in public rest rooms. (*a*), (*b*). Curves describing the relationship between bacterial translocation to skin, and hand drying time (data for cloth (——, curve (*b*)) and air (–––, curve (*a*)) towels derived from Table 1). (*c*), (*d*). Air towel drying times used by male and female rest room patrons (data derived from Table 3). (*e*), (*f*). Cloth towel hand drying times for male and female rest room patrons (data derived from Table 3). (*g*) 66 300 is the mean of the wet-hand bacterial translocation counts for cloth and air towel studies using 'skin' as the touch contact surface; $n = 84$ (see Table 1).

DISCUSSION

The contribution of poor hand hygiene to the spread of infectious diseases has been recognized for centuries and early civilizations incorporated hand washing procedures into rites and laws to ensure basic standards were met. Much of the research of the last 30 years on hand hygiene has focused on attempts to remove transient contaminants. Typically these protocols involved seeding a test subject's hands with a microbial contaminant and determining the effect of hand care agents and procedures on their numbers. While these procedures provided a valid answer to the questions being asked, they assessed a limited aspect of hand hygiene practice. A chance observation that the touch contamination level of peritoneal dialysis connector equipment increased after patients had washed their hands led us to the suggestion that a film of moisture left on the hands after washing acted as a conduit enhancing the transfer of skin microflora when touch contact was made. This led to the development of a test system capable of quantifying what we consider to be one of the principal objectives of hand hygiene procedures i.e. a reduction of the number of micro-organisms transferred by touch contamination.

In the current experiments, the drying efficiency of cloth and air towels was first compared. After 10 s drying, single serve cloth towels removed 96% of the water from a subject's hands, whereas air towel drying needed 45 s drying time to achieve the same endpoint. The experiments which followed were of considerable relevance to infection control measures in that they established hand drying as an essential component of hand hygiene procedures. When material representing skin, food and utilities was touched with wet hands, astonishingly high numbers of micro-organisms translocated from the subjects' fingers to the test material. Microbial numbers in the order of 68 000, 31 000 and 1900 were found on samples of skin, food and utilities respectively after touch contact. Equally surprising was the reduction in bacterial translocation achieved using a simple 10/20 post-wash hand drying procedure. A 10 s cloth towel–20 s air towel dry after washing reduced the translocation numbers to skin, food and utilities to 140, 655 and 30 respectively and achieved a 99·8, 94 and 99% reduction in bacterial translocation figures associated with wet hands. These results provide irrefutable support for our hypothesis that residual moisture left on the hands after washing provides an interface that allows the translocation of micro-organisms from fingers to solid surfaces during touch contact. Hand drying after washing is therefore a critical factor in determining the level of touch-contact-associated cross contamination, although its relevance to hand hygiene seems to have been overlooked. Indeed an extensive search of the literature has revealed only two studies which have recognized the relevance of the surface moisture to bacterial cross contamination [4, 5]. Questions have arisen as to why no soap or skin disinfectants were used in these studies. As our aim was to determine the relationship between residual moisture on the hands and bacterial translocation levels, the use of hand cleaning and disinfecting agents would have complicated the interpretation of the results. The effect of such agents on bacterial translocation levels is clearly relevant to hand hygiene and is a topic we will be pursuing.

Microbial translocation numbers following touch contact with wet hands and hands that have been carefully dried with appropriate equipment, represent the two extremes encountered in hand hygiene practice. We were able to show that the level of bacterial translocation following touch contact is related to the time spent on hand drying, i.e. bacterial numbers translocating progressively decrease, as moisture is removed with more conscientious drying (Table 1). The relationship between the theoretical extremes and hand drying, under use conditions, was examined by timing hand drying practices of male and female rest room patrons. This information was used to assess the effect of their hand drying practices on bacterial translocation following the use of restroom facilities. The results (Fig. 2) showed that, while users of cloth and air towel hand drying equipment were able to achieve a useful reduction in bacterial translocation (25000 micro-organisms translocating compared with a potential of 60–70000 with skin touch contact) the outcome fell well short of that achievable using an optimized protocol. Protocols such as the 10/20 procedure, which utilize both cloth and air towels, reduce translocatable bacteria to a few hundred micro-organisms and have clear implications for clinical areas where infection control is a high priority. Other areas likely to benefit from observing the principal findings of the study could be the food industry, home nursing situations and child care facilities where the spread of infection from person to person is a common event. The results in no way detract from the importance of adequate washing in reducing the transient contaminant numbers on the hands. Rather, they complement this basic aspect of hand hygiene by ensuring that touch-contact-associated cross contamination is reduced to a minimum. The introduction of this concept into hand hygiene practices will undoubtedly lead to improved hand care in a number of clinical and public health settings.

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