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Bacterial transfer and cross-contamination potential associated with paper-towel dispensing

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Background: The role of hands in disease transmission is well established, and the importance of handwashing is recognized. However, the exits of paper-towel dispensers used in hand drying may be contaminated, and the functionality of handwashing equipment increasingly is being questioned.

Objectives: We sought to study the transfer and cross-contamination potential between hands, towels, and dispenser exits if one or more is contaminated using bacteria representative of the skin's flora.

Materials and Method: A generic wall-mounted paper-towel dispenser and a range of different paper towels were used. Volunteers with either clean or contaminated hands were asked to remove, using a range of protocols, towels from dispensers which themselves were either clean or contaminated. Previously clean surfaces were then microbiologically tested.

Results: Recoverable bacterial transfer rates from a contaminated hand to clean dispenser exits ranged from 0.01% to 0.64% depending on the bacteria used with an even higher transfer rate for clean towels. The reverse transfer (ie, from contaminated exits to clean hands) was between 12.4% and 13.1%.

Conclusions: The results indicate that zig-zag transfer of bacteria between paper-towel dispensers and hands can take place if either one is contaminated. This potential should be considered in the design, construction, and use of paper-towel dispensers. (Am J Infect Control 2003;31:387-91.)

The role of the hands in disease transmission and the importance of hand hygiene in controlling infection in both hospitals and the food industry is well established.[1-4] Handwashing has been identified as the single most important means of preventing the spread of infection[5,6] and if poorly or improperly implemented, can lead to foodborne illness outbreaks[3,7,8] and hand-transmitted nosocomial infections.[1,2,5,6,9]

Hand drying is the critical last stage of the handwashing process and needs to be implemented in a way that reduces, rather than increases, the risk of cross-contamination.[3,4] This requires that the drying is effective and that contamination of hands does not take place. However, concerns are now starting to be expressed about the dispensing of handwashing materials and the functionality of dispensing systems.[9,10] The 3 methods frequently used for hand drying are hot air dryers, cloth towels, and paper towels.[3,11,12,13] Whereas paper towels are recognized as the most hygienic method of hand drying,[3,9,12,13] paper towels, exits,[3,14] and dispensing mechanisms[3,15,16] (levers and mount location), have been identified as potential sources of contamination, especially for paper towels hanging in sink splash zones.[16]

Paper towels require dispensing or delivery to individual users from storage cabinets. The towels should dispense cleanly without hand or paper-towel contact with other surfaces. The jamming of towels as a result of dispensing malfunctions can result in users reaching into the dispenser cabinet with wet, contaminated hands; and touching the paper slot or other paper towels could increase the risk of other people contaminating their hands. The frequency of dispenser

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malfunction is dependent upon the compatibility of paper towel and dispenser.

The aim of the present study was to quantify the cross-contamination potential associated with paper-towel dispensing using bacteria representative of the skin's resident and transient flora. The study utilized a generic folded paper-towel dispenser in conjunction with different brands of paper towels; however, the methodology developed can be used for any combination of towel and dispenser.

METHODS

Paper towels tested and paper-towel dispenser used

All paper products were received in good condition and considered equivalent to those seen in everyday commerce in the United States and United Kingdom. Five brands of paper towels were obtained from major suppliers and were coded X, YW, YN, ZW, and ZN, and all were used in the donor studies. Towels X and YN only were used in the recipient studies.

Four identical stainless steel front-loading generic paper-towel dispensers were used to dispense all makes of towel. The type is a popular off-the-shelf dispenser often listed in building specifications for hospitals, clinics, dental offices, and class A office buildings in the United States.

Micrococcus luteus (ATCC 14452) and a strain of *Serratia marcescens* were grown on plate count agar-coated slides (PCA, Oxoid Basingstoke, United Kingdom). The *S marcescens* was a human isolate and represents a common opportunistic pathogen in hospitalized patients.[17,18] These organisms were used to represent the skin's resident and transient flora.[19] Contamination of volunteer's hands during this study resulted in approximately 1×10^8 cfu being transferred to the hands and was determined using controls counted by the glove juice method.[19] This involved the addition of phosphate-buffered saline to the finger of a surgical glove followed by hand insertion and rubbing. Bacteria transferred to the saline were then counted.

Before all experiments, hands were cleaned using a standardized 5-stage protocol starting with soap and rinsing, followed by antibacterial soap and rinsing, and finally drying using paper towels. All dispenser exits were cleaned using a 3-stage protocol using a hypochlorite-based sanitizer, sterile water rinse, and finishing with a 70%-alcohol wipe. Hands and surfaces were microbiologically checked after cleaning/washing to be free of Serratia and Micrococcus organisms. The dispenser exit counts were <2.5 cfu/cm^2 and are indicative of a well-cleaned surface.[14] At the end of the experiments, the surfaces were swabbed and transfer rates calculated using the method of Chen et al[20] (cfu on the hand/cfu on the exit surface) $\times$ 100 = transfer rate %). After inoculation with the marker organisms, experiments were carried out immediately while relevant hands and surfaces were still moist. This simulated real life conditions associated with hand-washing and drying. It is considered unlikely that there was a loss of bacterial viability, and the numbers present were assumed to be the numbers of bacteria added. It could not be guaranteed the organisms would behave in an identical manner to the skin's normal flora, and sampling errors were recognized.[21]

Cross-contamination donor studies

Bacterial transfer from hands to dispenser exit surfaces and paper towels (donor study) was assessed using *M luteus* and *S marcescens*; both have a distinctive colonial morphology on the plate count agar used.

Three male and 3 female volunteers were employed in the *M luteus* study, whereas 2 male and 2 female volunteers were used for the *S marcescens* study. All experiments were performed 5 times. Volunteers were instructed to pull all paper-towel types, with the towel tail not readily available from the dispensers (ie, jammed) using a hand contaminated with known levels of marker bacteria. Testing was performed from 2 different reach (towel pulling) perspectives: (1) a straight approach, directly facing the dispenser (shoulders parallel with the long axis of the paper towel), with no obstructions or objects between it and the user; and (2) a side approach, in which the shoulders were perpendicular to the long axis of the paper towel, and the user was standing away from (not in front of) the dispenser, with no obstructions or objects between it and the user. In all, 600 paper towels were pulled using *M luteus* and 400 using *S marcescens*.

Once the paper towels had been removed, bacterial samples were obtained from the front and back of the dispenser exits using premoistened TS6A cotton tip swabs (Technical Service Consultants Ltd, Lancashire, United Kindgom). The entire dispenser exit was sampled and was consistent across all experiments. Contaminated regions of towels (those pulled and those remaining in the dispenser) were stomached (Laboratory Blender *Stomacher* 400, Seward, London, United Kingdom) in 20 mL Maximum Recovery Dilutent (MRD, Oxoid, Basingstoke, United Kingdom).

Contaminated swabs were directly spread onto PCA spread plates, and 0.1-mL samples (at an appropriate dilution) of the contaminated diluents from paper-towel samples were spread onto PCA spread plates. *M luteus* spread plates were incubated overnight at 30°C and *S marcescens* spread plates were incubated overnight at 37°C.

Table 1. Bacteria isolated and average transfer rates from dispenser exits during the freeing of jammed towels with a contaminated hand

Organism used for contamination	Dispenser exit surface	Average no. bacteria isolated (cfu)	Average bacterial transfer rate % (SD)
Micrococcus luteus	Front	8.72×10^3	0.03 (0.001)
	Back	6.14×10^3	0.02 (0.002)
			overall transfer rate, 0.03 (0.002)*
Serratia marcescens	Front	4.5×10^3	0.05 (0.004)
	Back	1.61×10^3	0.02 (0.001)
			overall transfer rate, 0.04 (0.003)*

There was no statistically siginificant differece between transfer rates for Serratia and Micrococus where n was 600 and 400, respectively.
*The overall bacterial transfer rate (%) was obtained by combining the bacterial results from the front and back of dispenser exits.

Cross-contamination recipient studies

Bacterial transfer from contaminated dispenser exit surfaces to a person's hands (recipient study) used *M luteus* and *S marcescens* grown on agar-coated slides. The slides enabled bacteria on the agar to come into contact with regions of the dispenser exits shown to be a particular problem from the donor experiments. This resulted in contamination with approximately 10^8 cfu which was determined by swabbing. Subjects then reached into contaminated dispenser exits to obtain jammed towels. Hand contamination with the marker organisms then was assessed using the glove juice method.[19] Only 2 towel types, those found to jam more frequently (X and YN), were used in this study. In addition, the experiments with towel YN were repeated with towels loaded and jammed upside down. This mimicked incorrect insertion of the towels which is known to take place.

Bacterial transfer to a recipient's clean hand from a contaminated jammed paper towel was performed using *S marcescens*, using the same methods described for contaminated exits. This experiment was performed to replicate the real life situation of contaminated, jammed towels in the dispenser.

A paired *t* test or one-way analysis of variance was performed (using Mircosoft Excel, Redmond, Wash) to determine the significance of differences in bacterial transfer because of incorrect insertion of towels, organism type, and different towel types.

RESULTS

Donor cross-contamination

The transfer rates and the average number of bacteria isolated from dispenser exits (front and back) during the freeing of jammed towels with a *M luteus* and *S marcescens* contaminated hand are shown in Table 1. The average total number of bacteria isolated (cfu) from the dispenser exit surfaces after freeing a jammed towel with a *M luteus* contaminated hand was 8.72×10^3 (front surface) and 6.14×10^3 (back surface). The average bacterial transfer rate was 0.03%. The results obtained using a *S marcescens*–contaminated hand resulted in an average 4.5×10^3 cfu (front) and 1.61×10^3 cfu (back) bacteria being isolated with an overall 0.04% average bacterial transfer rate.

There was a greater transfer of both types of bacteria to the towels (pulled or remaining within the dispenser). In some cases the total numbers of *M luteus* on towels pulled was 1×10^6 cfu and 2×10^4 cfu on towels remaining in the dispenser. The numbers of *S marcescens* on towels pulled and remaining in the dispenser were 3.4×10^5 and 4.5×10^3 cfu, respectively.

Recipient cross-contamination

The bacterial transfer rates (%) from contaminated dispenser-exit surfaces to users' hands using *M luteus* and *S marcescens* as marker organisms are shown in Table 2. Data for both *M luteus* and *S marcescens* transfer rates were similar for each towel. Overall, a statistically significantly greater bacterial transfer rate ($P < .05$) from dispenser exits to recipients' hands was obtained when freeing jammed X towels compared with YN towels. The results showed 13.1% and 12.4% transfer rates for towel X using *M luteus* and *S marcescens*, respectively. Transfer rates were 6.0% and 6.7% for towel YN. A statistically significantly higher ($P < .05$) bacterial transfer to recipients' hands was noted when the YN towels were jammed in the incorrect (upside down) orientation.

Similar bacterial transfer rates (not statistically significantly different) ($P > .05$) from contaminated towels to recipients' hands were noted for each towel type (0.6%–1.9%) with an average of 1.3% for all 3 towels.

DISCUSSION

Hand drying and its importance as the critical last stage in the handwashing process has been somewhat overlooked.[22] The choice of equipment for handwashing

Table 2. Average bacterial transfer rates obtained during freeing of jammed towels from contaminated dispenser exit surfaces to users' hands

Organism used for contamination	Towel position and pull	Average bacterial transfer rate % (SD)	
		X towels	YN towels
Micrococcus luteus	Correct front	16.0 (0.64)	6.6 (0.22)
	Correct side	10.1 (0.40)	4.2 (0.10)
	Incorrect front	—	8.2 (0.45)
	Incorrect side	—	4.9 (0.12)
		overall transfer rate, 13.1 (0.39)	overall transfer rate, 6.0 (0.22)
Serratia marcescens	Correct front	13.9 (0.39)	5.4 (0.14)
	Correct side	10.8 (0.42)	5.6 (0.16)
	Incorrect front	—	9.2 (0.58)
	Incorrect side	—	6.4 (0.11)
		overall transfer rate, 12.4 (0.41)	overall transfer rate, 6.7 (0.25)

Correct, Insertion of towels according to manufacturer instructions; *incorrect*, insertion of towels upside down; *front*, towels pulled from the front; *side*, towels pulled from the side.

and drying is an important economic and infection control decision and this includes the choice of hand towels and their dispensers. Topical zig-zag transmission from one person's hand to surfaces, then from surfaces to another individual's hand, and then to other parts of the body or food, is an established fact with numerous bacterial, viral, parasitic, and mycotic diseases.[23,24]

Hattula and Stevens[16] indicated problems of cross-contamination associated with paper-towel dispenser levers and dispenser placement above sinks and in splash zones. Paper-towel exits from folded paper-towel dispensers located at handwash stations in food processing facilities have been found contaminated with *Eshcerichia coli*.[15] More recently, studies[14] have indicated towel dispenser exits in hospitals are often not included in routine cleaning and are contaminated.

This study has shown that even "manual pull" disposable folded towels and towel dispensers that are considered "hands free" or touchless can become contaminated if the surfaces at the dispenser exit are touched. This usually occurs when the paper towel is not cleanly delivered to a user, and this varies considerably depending on the compatibility of paper towel and dispenser combination.[25]

The total numbers of bacteria isolated from the dispenser exits after freeing a jammed towel with a contaminated hand was relatively low but should be viewed within the context of the number of times per day this activity may need to be carried out. It is also important to note that the swabbing method used could provide only an estimate of bacterial transfer rates. Limitations associated with the pick up and release of microorganisms from swab samples[21] imply that the actual bacterial transfer rates may be greater than those recorded. The same swabbing protocol as used in this study may only yield 3% of the numbers of bacteria actually present and this is typical of the swabbing process.[21] This could mean the number of bacteria being transferred between hands and exits was, in reality, much higher. Similar variations and values have been noted in the results obtained by other workers, with bacterial transfer rates of organisms from hands to contact surfaces within hospital and food service settings varying from 0.001% to nearly 100% depending on circumstances.[20,24]

It is also important to note that in some cases, although the minimum infective dose can be variable, only small numbers of pathogens, especially for intestinal disease, may be required to cause illness. A number of these pathogens are known to cause outbreaks in hospitals.[26] Therefore, even the low estimates obtained in the present study still allowed for sufficient bacteria to be transferred for them to exceed the minimum infective dose for a number of human pathogens.[3,23] This was particularly true of the numbers transferred from wet, contaminated hands to dry towels remaining in the dispenser. The type of contamination demonstrated in this study, coupled with the survival potential of some pathogens causing hospital acquired infections,[26] could also assist in the spread of organisms within the hospital environment.

The results indicated that a greater number of bacteria were transferred to the front surface of the dispenser exits, especially when the experiments were conducted using the surrogate transient organisms. The front of dispenser exits has previously been identified as a prime area for undesirable contamination[14,15] and this study highlights the need for their inclusion in routine cleaning.[15]

Higher transfer rates were noted from contaminated dispenser exits to hands when freeing jammed towels. A possible reason for the difference noted may have been because of the different sampling technique used. The glove juice method was used for sampling hands,

which may have been more sensitive than the swabbing technique. The recovery of organisms from surfaces is influenced by numerous factors such as transfer medium, surface type and characteristics, temperature, relative humidity, degree of drying, light, the presence of chemical disinfectants, and/or competing microorganisms.[23]

There was an even greater transfer of both the resident and transient bacteria to the towels pulled or remaining within the dispenser. Paper towels with damp patches or spots may, in addition to being aesthetically unappealing, present an infection risk. Emphasis on decreasing accidental contact by educating and training healthcare and food workers may reduce the spread of pathogens and lower the risk of nosocomial infections. In addition, this work further highlights the need for careful selection of paper-towel types and their dispensers on the basis of functionality.

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