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Major article

# Fomite-fingerpad transfer efficiency (pick-up and deposit) of *Acinetobacter baumannii*—with and without a latex glove

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***Background:*** *Acinetobacter baumannii* is a significant health care–associated pathogen because it is easily transmitted via fomites, extremely difficult to eradicate from the environment, and highly drug resistant. Understanding the environmentally mediated transmission dynamics of *A baumannii* is critical for more effective infection control. However, transfer efficiency of pathogen pick-up and deposit remains poorly understood. Our study estimates the transfer efficiency of *A baumannii* with and without latex glove use from the fingerpad to a fomite and from a fomite to the fingerpad.

***Methods:*** Fomite-fingerpad transfer efficiencies were determined for 6 materials (glass, stainless steel, porcelain, polypropylene, polycarbonate, and rubber).

***Results:*** For *A baumannii*, the fomite-to-fingerpad transfer efficiency was 24.1%, and the fingerpad-to-fomite transfer efficiency was 5.6%. When latex gloves were worn, the fomite-to-fingerpad transfer efficiency was reduced by 55.9% (to 10.6%) and the fingerpad-to-fomite transfer efficiency was reduced by 47.1% (to 3.0%). The average transfer efficiency between 2 skin surfaces was 32.5%.

***Conclusions:*** The fomite-to-fingerpad transfer efficiency of *A baumannii* was statistically significantly higher than the fingerpad-to-fomite transfer efficiency, regardless of glove use. There was no significant difference in transfer efficiency by material type, except for rubber, which resulted in marginally higher transfer efficiencies. Our results underscore the importance of frequently changing gloves during patient care and frequent handwashing-hand hygiene during bare-handed care for the reduction of pathogen transmission.



*Acinetobacter baumannii* transmission within hospitals is a significant problem.[1,2] This gram-negative, frequently multidrug-resistant bacterium produces a variety of health care–associated infections, including pneumonia, bacteremia, wound infections, and urinary tract infections, primarily among those who are already very ill, making it particularly a problem within intensive care units.[3] Effective control is challenging because *A baumannii* can survive long periods of desiccation, persisting in the environment for 1-4 months,[4-6] and typical disinfection practices are often inadequate.[7,8] Therefore, understanding the environmentally mediated transmission dynamics of *A baumannii* is critical for identifying a more targeted approach to effective infection control. Previous studies have determined the pick-up transfer efficiencies (fomite-to-fingerpad or hand) for a variety of gram-positive and gram-negative bacteria,[9,10] but to our knowledge, transfer efficiencies in the direction of fingerpad and hand to fomite have not been previously reported. Because these studies have already shown that transfer efficiency is dependent on organism and material type, we have chosen 6 nonporous surface materials that are commonly found in the hospital environment to evaluate the variation in transfer efficiencies.

Most fate and transport mathematical models assume the same transfer efficiency value for calculating both the fomite-to-fingerpad rate of pathogens and the fingerpad-to-fomite rate of pathogens.[11-13] This assumption may be appropriate when the 2 contacting surfaces are composed of the same material of similar physical characteristics (ie, dry skin-skin contact). However, when

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the 2 contacting surfaces are not composed of the same material (ie, contact between the skin and an environmental surface), this assumption may not hold. Moreover, transfer efficiencies of *A baumannii* have never been quantified. Therefore, the first aim of this study is to compare the transfer efficiencies of *A baumannii* in 2 directions: fomite to fingerpad and fingerpad to fomite, with and without the use of latex gloves. For comparative purposes, we also determined the transfer efficiency of *A baumannii* between 2 skin surfaces: fingerpad to fingerpad. Specific pathogen transmission parameters, such as pathogen transfer efficiencies in both directions of transfer, are needed to fill current knowledge gaps of environmental infection transmission systems. These data will enable more robust use of quantitative microbial risk assessment models for exposure assessment and evaluation of pathogen fate and transmission in the hospital environment.

## MATERIALS AND METHODS

Ten volunteer subjects participated. The study protocol was reviewed and approved by the University of Michigan Institutional Review Board (HUM00075484).

### *Preparation of initial inoculum*

All transfer experiments were performed using *A baumannii* ATCC 17978 (American Type Culture Collection, Manassas, VA). The initial inoculum was prepared fresh for each experiment by transferring a frozen aliquot of the ATCC 17978 into 2.5 mL of BBL Mueller Hinton II Broth (BD Diagnostics, Sparks, MD) and incubating at 37°C for 18 ± 2 hours on a rotating shaker table (150-180 rpm). The culture was streaked onto BBL Mueller Hinton II Agar (BD Diagnostics, Sparks, MD) and grown at 37°C. An isolated colony was transferred to Mueller Hinton II Broth and incubated at 37°C with shaking at 150-180 rpm for 15-18 hours. From this, a starting culture with an OD600 of 0.200 ± 0.01, which approximates $10^8$ colony forming units (CFU)/mL, was used (Synergy HT Multi-Mode Microplate Reader; BioTek Instruments, Winooski, VT).

### *Preparation of fomite material coupons*

All material coupons were round disks that are 1 cm in diameter and approximately 3 mm thick. The following nonporous material coupons were used to determine *A baumannii* transfer efficiencies: medical grade stainless steel (RD128-304), white high grade BUNA-N Rubber (RD128-BUNA), porcelain (RD128-PL), polycarbonate plastic (RD128-PC), polypropylene plastic (RD128-PP), and borosilicate glass (RD128-GL) (all material coupons from BioSurface Technologies, MO). Before and after each use, all material coupons were washed with soap and water, followed by a 70% ethanol bath, and then autoclaved for sterilization.[10]

### *Method for determining the direct recovery rate of bacteria*

The direct recovery rate was determined to estimate the total amount of bacteria that can theoretically be recovered from each surface after drying. The direct recovery rate was used to help validate study results by demonstrating that differences seen between the fomite-to-finger and fingerpad-to-fomite transfer efficiencies were not caused by possible biases in recovery methods from the various surface types. For this determination, a transfer of bacteria between the 2 surfaces was not performed. In triplicate, each material used in these experiments (6 material coupons, glove fingertips, and fingerpads of a hand) was prepared as described for each material type, inoculated with 20 μL (or $1.4 \times 10^9$ CFU) of *A baumannii*, and allowed to dry. Once dry (with no transfer event), the bacteria was recovered exactly as subsequently described for that surface type, and the percentage of CFU recovered was calculated by $(CFU_{Recovered}/CFU_{Applied}) \times 100$.

### *Preparation of volunteer hands*

Before and after each transfer event, volunteer hands were prepared using the following control wash procedure regardless of glove use[10]: hands were squirted with 70% ethanol for 10 seconds, alcohol was rubbed thoroughly over hands (concentrating on the finger tips) for 15 seconds, and hands were then rinsed with tap water for 15 seconds. Hands were then scrubbed for 1 minute with 2 mL of Huntington Brand Medi-Scrub liquid soap containing the active ingredient 0.6% chloroxylenol (Ecolab, Hanover, MN) and warm water. Hands were rinsed in warm water for 15 seconds and air dried until thoroughly dry.

### *Recovering bacteria from the fingerpad*

Immediately after each transfer event, bacteria on the finger were recovered using a sterile, individually wrapped CultureSwab (BD Diagnostics, Sparks, MD) swab, moistened in 3 mL of 1 × phosphate-buffered saline (PBS) solution. Excess buffer was first pressed out of the swab by pressing the tip of the swab against the inside of the tube. The fingerpad was swabbed in both a forward-back motion and a side-to-side motion while rotating the tip of the swab.[10] The swab was then returned to the 1× PBS buffer and homogenized in the buffer using Omni Tips disposable rotor stator generator probes (OMNI International, Kennesaw, GA) for 45 seconds to remove all cells from the swab. Samples were then serial diluted to $10^{-3}$, spread plated onto Mueller Hinton II Agar, and incubated overnight at 37°C for colony enumeration. All samples were kept on ice during sampling. This swab method was used to avoid an additional step of bacterial transfer (eg, from fingerpad to the inside wall of the centrifuge tube containing the PBS buffer).

### *Recovering bacteria from fomite coupons and latex gloves*

Bacteria on the coupons and gloves were recovered by vortexing the sample in a sterile, 50-mL conical centrifuge tube (Falcon; Corning Life Sciences, Corning, NY) containing 6 mL of 1× PBS buffer for 1 minute. Samples were then serial diluted to $10^{-3}$, spread plated onto Mueller Hinton II Agar, and incubated overnight at 37°C for colony enumeration. All samples were kept on ice during processing.

### *Simulation of fingerpad-to-fomite transfer event by the fingerpad (n = 10)*

A cleaned, randomly chosen fingerpad was inoculated with 20 μL of *A baumannii* ATCC 17978 and allowed to air dry for 10-15 minutes in a laminar hood. Once dry, the inoculated fingerpad was placed onto a coupon, applying an average constant pressure of 25 kPa (range, 16-38 kPa) for 30 seconds.[14] This was performed using a top-loading balance (XP-150; Denver Instrument, Bohemia, NY) to monitor the amount of pressure applied in grams per centimeter squared. After the transfer event was complete, the coupon was placed in a centrifuge tube containing 1× PBS buffer, and the finger was swabbed (Fig 1A). All samples were stored on ice.

### *Simulation of fingerpad-to-fomite transfer event by the latex glove (n = 10)*

Powder-free, single-use, latex examination gloves (19-058-801C; Thermo Fisher Scientific, Pittsburgh, PA) were placed on a clean hand (cleaned as previously described). The fingerpads of the