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Major Article

Microbial transmission in an outpatient clinic and impact of an intervention with an ethanol-based disinfectant

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Background: Halting the spread of harmful microbes requires an understanding of their transmission via hands and fomites. Previous studies explored acute and long-term care environments but not outpatient clinics. Objectives of this study were to track microbial movement throughout an outpatient clinic and evaluate the impact of a disinfectant spray intervention targeting high-touch point surfaces.

Methods: At the start of the clinic day, a harmless viral tracer was placed onto 2 fomites: a patient room door handle and front desk pen. Patient care, cleaning, and hand hygiene practices continued as usual. Facility fomites (n = 19), staff hands (n = 4), and patient hands (n = 3-4) were sampled after 2, 3.5, and 6 hours. Tracer concentrations at baseline (before intervention) were evaluated 6 hours after seeding. For the intervention trials, high-touch surfaces were cleaned 4 hours after seeding with an ethanol-based disinfectant and sampled 2 hours after cleaning.

Results: At 2, 3.5, and 6 hours after seeding, virus was detected on all surfaces and hands sampled, with examination room door handles and nurses' station chair arms yielding the highest concentrations. Virus concentrations decreased by 94.1% after the disinfectant spray intervention (P = .001).

Conclusions: Microbes spread quickly in an outpatient clinic, reaching maximum contamination levels 2 hours after inoculation, with the highest contamination on examination room door handles and nurses' station chairs. This study emphasizes the importance of targeted disinfection of high-touch surfaces.

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BACKGROUND

Health care-associated infections are a significant threat to the safety of patients seeking medical care. The United States Centers for Disease Control and Prevention (CDC) estimates that 721,800 health care-acquired infections occurred in the United States in 2011, equating to about 1 hospital-acquired infection in every 25 inpatients.[1] Organisms that are common causes of health care-associated infections are known to survive on surfaces for days to months.[2] Environmental contamination has also been demonstrated to play a role in the transmission of pathogens, including viruses such as norovirus,[3,4] coronaviruses, and influenza,[5] as well as bacteria such as methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci.[6,7] Evidence indicates that contamination of environmental surfaces is linked with contamination of health care personnel hands and that improved terminal cleaning and disinfection practices lead to decreased infection rates.[8,9] Improving environmental cleaning and disinfection in health care settings therefore is a critical practice in reducing the incidence of health care-associated infections.

Outpatient health care has been steadily increasing in recent decades, shifting care from the inpatient to outpatient setting. Between 1997 and 2007, outpatient office visits increased by 25%.[10] Between 1996 and 2013, outpatient care spending increased by \$324.9 billion, whereas inpatient care spending increased by \$259.2 billion,[11] and in 2016, hospital care spending increased 4.7%, whereas outpatient services spending increased 5.4%.[12] As more care is provided in outpatient facilities, it is increasingly important to understand the potential for disease transmission and study the practices that ensure infection prevention in this setting. Although disinfection interventions have

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been quantitatively evaluated in hospitals[13,14] and workplaces,[15,16] studies have not been published measuring their effect in health care facilities beyond hospitals, despite evidence of environmental contamination in outpatient care sites.[17,18] Understanding the dynamics of transmission and reservoirs of contamination in an outpatient setting can help inform effective infection control guidelines and practices. Previous studies in home and office environments demonstrated that human viruses and virus surrogates spread rapidly throughout a facility and may contaminate more than half of the surfaces within 4 hours.[16,19] Ethanol-based products, particularly those targeting hand hygiene, play a strong role in infection control because of rapid, broad-spectrum efficacy and ease of use. For surface disinfection, however, ethanol-based disinfectants have required high levels of alcohol (≥50%) for antimicrobial efficacy, which led to concerns with fast dry times and material compatibility.[9] The aim of this study was to quantify pathogen contamination potential and assess the impact of a high-touch point cleaning intervention with a 29.4% ethanol spray disinfectant on reducing the spread of a virus tracer in an outpatient clinic.

METHODS

Study design

This study site was an outpatient, urgent care clinic with approximately 3,000 square feet of total treatment area. Patients entering the facility signed in at a common front desk before evaluation by a triage nurse. After initial evaluation for care needs, patients typically waited in a common area in the front of the facility before moving through a common door to private examination rooms in the back of the facility.

To track transmission of microbes, a harmless virus tracer, bacteriophage MS2, was used. MS2 only infects specific strains of *Escherichia coli*, can be grown to high concentrations, and has been extensively used as a surrogate for human viruses and bacteria in a variety of transmission studies.[20-22] The MS2 bacteriophage has been shown to be an appropriate surrogate for both transmission of pathogenic viruses and susceptibility of more resistant viruses to disinfectants.[23-25] The outpatient clinic tracer study was reviewed and approved by the University of Arizona institutional review board.

This study was divided into 3 distinct phases (Table 1). Phase 1 was a pilot time series study evaluating the movement of the tracer virus through the facility over the course of the day. Patient care, surface cleaning practices, and hand hygiene practices continued as usual. Tracer virus (1×10^9 plaque-forming units [PFUs] of MS2) was inoculated onto 2 fomites in the clinic: the door handle exiting the patient care area and the sign-in pen at the front desk. Fomites throughout the facility (n = 19), hands of clinic staff (n = 4), and hands of patients (n = 3-4) were sampled at 2, 3.5, and 6 hours. Phase 2 was a baseline study during which fomite and hand samples were collected 6 hours after seeding while hygiene practices continued as usual by clinic staff, including use of the facility's current disinfectant wipe product. Phase 3 was an intervention study during which select surfaces (Table 2) were cleaned by study personnel 4 hours after seeding using an Environmental Protection Agency (EPA)−registered ethanol-based spray disinfectant (Purell Surface Disinfectant, 29.4% Ethanol; GOJO Industries, Akron, OH) with efficacy claims against bacteria, nonenveloped viruses and influenza, and fungi. As per manufacturer instructions for surface disinfection, product was sprayed 6-8 inches from surfaces until thoroughly wet. Treated surfaces remained wet for a minimum of 30 seconds and were then wiped with disposable dry paper towels. Samples were collected 2 hours after the targeted cleaning (6 hours after seeding). Phase 3 intervention was repeated twice, 3 days apart.

Table 1
Summary of study design and intervention

Study phase	Study design
1	Pilot time series study: Current cleaning practices and products used by clinic staff; hand/fomite sampling at 2, 3.5, and 6 hours after seeding
2	Baseline: Current cleaning practices and products used by clinic staff; hand/fomite sampling at 6 hours after seeding
3	Intervention: Clinic staff using disinfectant spray for typical use scenarios, plus targeted use of intervention disinfectant, by study staff, on high-touch surfaces at 4 hours after seeding; hand/fomite sampling at 6 hours after seeding

Table 2
Sample sites and surface areas

Sample sites	Area sampled (cm^2)
Bathroom inner and outer door handles (2)	100
Bathroom faucet (2)	100
Waiting room nurses' mouse	100
Waiting room counter	100
Waiting room survey computer mouse	100
Patient triage seat arms	30
Treatment area nurses' station mouse	100
Treatment area nurses' station chair arms	100
Patient room countertop storage canister lids (3)	100
Patient room exposed edge of examination table (3)	100
Patient room inner door handle (3)	50
Staff hands (4)	100
Patient hands (4)	100

Sample collection and processing

Before the clinic opening, targeted surfaces (Table 2) were disinfected with a 70% ethanol solution to eliminate any potential background contamination. Upon opening, 2 surfaces (front desk sign-in pen and door handle exiting patient care area) were seeded with 100 μL of 1×10^9 PFUs/mL of bacteriophage MS2. Clinic personnel continued their typical work practices throughout the day. Targeted cleaning and sample collection occurred 4 and 6 hours after seeding, respectively.

Samples were collected using a sponge-stick (3M, Maplewood, MN) containing 10 mL of neutralizing Letheen broth. Samples were transported on ice to the laboratory for immediate processing. Samples were assayed in duplicate using the top agar overlay technique and incubated at 37°C for 24 hours. After incubation, plaques were counted and total concentrations were calculated. If the number of PFUs was too numerous to count, within 24 hours the subsamples were diluted by a factor of 10 until a countable number was obtained.

Statistical analysis

This study used a within-subjects design to compare the effect of a disinfection intervention on the spread of a virus throughout an urgent care facility. In the analysis of phase 1 pilot time series, the percent of sites positive, represented by detection of a single PFU per volume assayed, compared with total sites sampled were calculated for total sites and also for segments of the facility, including nurses' station fomites, patient area fomites, and hands of nurses and patients. Average log virus concentrations (PFUs/surface) at each time point were compared using pairwise t tests and R software.[26] In addition, a linear mixed effects model with a random intersect for fomites was used to calculate the reduction coefficient.

PFUs were averaged across both subsample replicates, for each sample from each surface from each phase, and then divided by the area of the surface. These PFUs per unit area were averaged across both repeats of each phase (yielding the log of the geometric mean).

Table 3
Time series analysis of virus spread

	2 hours	3.5 hours	6 hours	Total (all time points)
Sample type (% positive over time)				
Nurses station fomites	50% (3/6)	67% (4/6)	50% (3/6)	56% (10/18)
Patient area fomites	77% (10/13)	31% (4/13)	46% (6/13)	51% (20/39)
Staff hands	75% (3/4)	75% (3/4)	100% (4/4)	83% (10/12)
Patient hands	100% (3/3)	75% (3/4)	33%(1/3)	70% (7/10)
All sample types	73% (19/26)	52% (14/27)	54% (14/26)	59% (47/79)
PFU concentration data type (PFUs/surface)				
PFU range	$<$1 to 1.8×10^4	$<$1 to 7.3×10^4	$<$1 to 3.4×10^3	$<$1 to 7.3×10^4
PFU mean of all sites	1.0×10^3	370	141*	496
PFU mean of contaminated sites only	1.4×10^3	634	261	824

PFU, plaque-forming unit.
*Estimated PFU reduction of 38% per hour over 4-hour sampling period.

Comparisons of the average log PFUs/cm^2 were made between phases 2 and 3 using pairwise t tests and R software.

RESULTS

In phase 1, a comparison of virus percent positive and PFU results was found to not differ significantly across various time points throughout the day, although there was a decrease of 38% every hour (reduction coefficient of −0.381) (Table 3). Maximum contamination levels were reached after only 2 hours. Throughout the day, staff and patient hands were frequently contaminated with the tracer, at times reaching 100%, although the sample size was low (n = 3-4). More than half (59%; 47 of 79) of all fomites and samples tested were positive for the tracer when averaged over all time points, showing that the tracer survived well and readily spread in the environment.

Specific sites, in phase 1, that showed the highest levels of contamination were typically from patient hands or patient surfaces. The top 5 most heavily contaminated sites in the time series experiment (phase 1) included patient door handles, patient hands, staff hands, nurses' station chair arms, and the waiting room survey computer mouse. Concentrations on these surfaces ranged from 1.04 PFUs/cm^2-4.40 PFUs/cm^2.

In phases 2 and 3, samples were collected at the 6-hour time point after contamination. This timing was designed to allow the tracer to spread throughout the facility for at least 2 hours before and after the high-touch point disinfection intervention. MS2 PFU/cm^2 concentrations under each intervention (boxplots) and geometric means across replicates of interventions (diamonds) are shown in Figure 1. Observations in each condition greater than 1.5 times the interquartile range are presented as separate points in the plot. The new intervention product's geometric mean viral count was 94.1% (95% CI, −71.4 to −98.8; P = .001) lower than that of the baseline.

In both the baseline (phase 2) and intervention (phase 3), the patient waiting room and the nurses' station were the most contaminated areas. Specific surfaces included the nurses' station chair arms (70.0 PFUs/cm^2; 8.24 ± 18.8 PFUs/cm^2), the waiting room counter (31.0 PFUs/cm^2; 3.12 ± 0.18 PFUs/cm^2), and the patient triage seat arms (63.0 PFUs/cm^2; 2.14 ± 10.1 PFUs/cm^2) for phases 2 and 3, respectively. Virus concentrations decreased on all surfaces after intervention, with the exception of the bathroom door handle and the bathroom faucet. Values for the bathroom door handle and the bathroom faucet before intervention ranged 0.03-21 PFUs/cm^2 and 0.065-0.17 PFUs/cm^2, respectively, whereas postintervention values ranged from 0.48-8.3×10^3 PFUs/cm^2 and 0.056-3.0 PFUs/cm^2, respectively.

DISCUSSION

Guidelines for cleaning and disinfection in outpatient facilities are not specific regarding how often to clean and disinfect or what

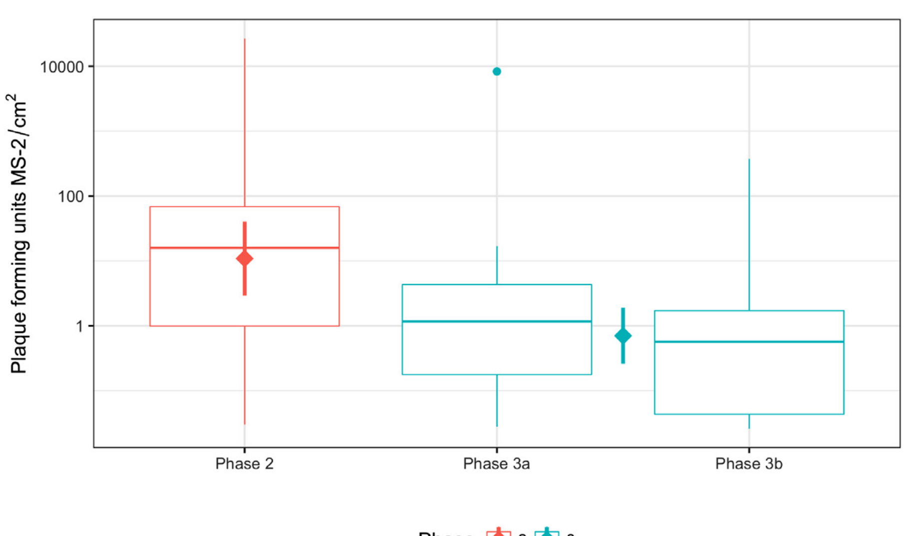

Fig 1. Outpatient clinic tracer concentration before and after disinfectant spray intervention.
Vertical lines represent 95% confidence intervals for the geometric means. Phase 2 refers to the baseline current cleaning practices by site staff, phase 3a refers to the first replicate of the spray disinfectant intervention. Phase 3b refers to the second replicate of the same intervention. Outliers are represented by a single point on the chart.

methods should be used to ensure adequate cleaning.[27] Rather, such facilities typically develop their own policies and procedures for routine cleaning and disinfecting of environmental surfaces. Tracer studies help to identify pathogen-spread potentials and demonstrate the involvement of both close patient contact surfaces and other environmental surfaces in infection transmission to support development of evidence-based disinfection guidelines.

The results from phase 1 of this tracer study showed that more than half of surfaces and hands were contaminated in less than 2 hours in an outpatient, urgent care clinic environment. Initial contamination of only 2 high-touch point surfaces (patient sign-in pen and common examination area exit door handle) resulted in spread to hands and fomites in both patient and restricted staff areas. Frequently touched surfaces, such as bathroom faucets, and patient room examination table sides and door handles had higher levels of contamination compared with less frequently touched items, such as canisters storing cotton swabs and other medical supplies in patient rooms. Contamination levels did decrease on sampled fomites and hands over the course of the day. Possible explanations for the decrease are that the tracer continues to be transferred to fomites not included in sampling and is transported out of the facility on the hands of exiting patients, reducing the numbers on the sampled areas. Additionally, the sampling itself at each time point reduces the available virus for transfer. In reality, it is likely that as patients who are ill or colonized with a pathogen visit the facility throughout the day, they will continually shed pathogens and contaminate surfaces.

High-touch point cleaning has been recommended in acute care settings to help prevent the spread of pathogens.[28,29] This approach also can be beneficial in other settings, particularly in outpatient clinics where a high volume of patients is treated. Based on comparisons of tracer PFU concentrations between phase 2 baseline and phase 3 intervention, a 94.1% reduction with a single cleaning event demonstrates the value of high-touch point cleaning in this environment. This single cleaning event was performed with a low ethanol−based disinfectant. Pure ethanol and water solutions require ethanol concentrations between 60% and 90% to be antimicrobial[30] but are fast drying, lack detergent properties, and have reduced material compatibility.[9] The data from this study demonstrate that products formulated with lower ethanol (ie, $\leq$30%) can be efficacious and used to reduce the spread of microorganisms in outpatient care facilities.

Although reduction of pathogen concentrations in the environment is expected to reduce exposures and risk of infection, information is not currently available to determine whether a 94.1% ($<$2-log) reduction would have a significant impact on health outcomes in the outpatient clinic environment. Currently, there are no standards for disinfection claims on surfaces in practice. Thus more research is needed to define contamination levels in real-world scenarios and appropriate disinfection targets to achieve specific health goals. Despite this data gap, longer contact times and more frequent use of disinfectants may be beneficial to further reduce pathogen concentrations on environmental surfaces.

This study demonstrated that 4 out of 5 of sites with the highest levels of contamination occurred on entry to the facility during phases 2 and 3 (waiting room mouse and counter; triage chair arms) or immediately after interaction with the patient (nurses' station chair arms). This result warrants a more active approach in disinfection of these areas throughout the day. The increase in contamination of the bathroom surfaces between phases 2 and 3 could be a result of increased hand hygiene and use of the sink influenced by the presence of the study staff during the intervention.

According to the CDC recommendations, patient care areas should be cleaned on a regular basis, after spills, and when surfaces are visibly soiled.[31] In this study, health care staff reported cleaning examination tables and other close-contact patient area surfaces after each patient contact using an EPA-registered disinfectant wipe or spray. Other surfaces were cleaned by environmental service personnel each evening after clinic hours. Although site staff reported frequent cleaning with disinfecting products throughout the day, product weight analysis showed little or no change at the end of the day compared with the beginning of the day, indicating limited product use. Based on the spread of contamination observed in the facility, including high levels in the patient care area, proper disinfection of the patient room between patients should be emphasized.

Many health care interventions and research studies focus on health care personnel hand hygiene compliance and the desire to achieve a target of 90%-100%.[32] In reality, despite extensive education and intervention, a maximum compliance rate of 57%, after interventions, and a mean of 34%, as a routine, are documented.[33] Given the deficiencies in hand hygiene compliance, the known relationship between surface and hand cross-contamination, and the demonstrated link between contaminated surfaces and disease contraction, a more holistic approach to hygiene that includes improvements in surface disinfection is needed to prevent health care-associated infections.[34,35] Further concerns related to the lack of hygiene compliance include the potential presence of the more resilient spore-forming bacteria. CDC guidelines for prevention of *Clostridium difficile*, for example, include the supplemental use of specific EPA-approved, spore-killing disinfectants where patients with *C difficile* are treated. Questions remain regarding the relationship between hygiene compliance and the impact on health care-associated infection rates. Data from this study can be used to inform risk assessment models designed to predict health outcomes and quantitatively assess disinfection targets for meeting infection control goals.

This study emphasizes the importance of a comprehensive approach to hygiene that includes not only frequent hand hygiene but also targeted disinfection of high-touch surfaces and patient care areas to reduce microbial cross-contamination and exposure risks. A single disinfection of targeted surfaces by study staff, 4 hours after clinic opening, was shown to significantly reduce the overall microbial load on hands and environmental surfaces. Thus we recommend that site staff be more intentional about surface disinfection practices throughout the workday. In addition, patient hands were contaminated as often as clinic staff but at higher concentration levels. Therefore promotion of routine hand hygiene among patients should be encouraged, as well as among health care staff, to prevent disease transmission from infected patients to fomites and other staff, patients, and visitors.

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