

In the setting of the coronavirus disease 2019 pandemic, efficient methods are needed to decontaminate shared portable devices and large open areas such as waiting rooms. We found that wheelchairs, portable equipment, and waiting room chairs were frequently contaminated with potential pathogens. After minimal manual precleaning of areas with visible soiling, application of a dilute sodium hypochlorite disinfectant using an electrostatic sprayer provided rapid and effective decontamination and eliminated the benign virus bacteriophage MS2 from inoculated surfaces.

**Key Words:** *Clostridioides difficile*, Wheelchairs, Viruses, Surfaces

Contaminated surfaces are a potential source for dissemination of many bacterial and fungal pathogens.<sup>1</sup> There is also increasing concern that the environment may be an underappreciated source for spread of respiratory viruses, including severe acute respiratory syndrome coronavirus 2.<sup>2, 3, 4</sup> Many respiratory viruses survive for hours to days on surfaces,<sup>2, 3, 4</sup> and respiratory virus nucleic acid has been recovered from surfaces in health care and community settings, including households, day care centers, airports, and schools.<sup>4, 5, 6, 2</sup> Enhanced environmental cleaning and disinfection is therefore recommended as one component of control measures for severe acute respiratory syndrome coronavirus 2 in health care and community settings.<sup>4</sup>

Most cleaning and disinfection of surfaces is performed through manual application of liquid disinfectants. Cleaning prior to or concordant with application of disinfectants is generally considered important to reduce bioburden that might decrease the action of the disinfectant.<sup>1</sup> However, in one study, organic and inorganic material recovered from hospital surfaces did not affect efficacy of sodium hypochlorite and only modestly affected efficacy of ultraviolet-C (UV-C) light.<sup>2</sup> Moreover, thoroughness of manual cleaning is often inadequate, and application can be challenging and time-consuming particularly when surfaces are irregular or large open areas are being cleaned.<sup>1</sup> One potential strategy to improve cleaning and disinfection under these conditions might be to apply disinfectant as a spray with only minimal precleaning to remove visible soil. However, relatively little information is available on this approach to cleaning and disinfection. Here, we tested the effectiveness of a novel spray disinfectant technology that uses an electrostatic sprayer to apply a sporicidal disinfectant to surfaces after minimal precleaning. We focused on items or areas that are challenging to manually clean and disinfect, including wheelchairs, portable equipment, and patient waiting areas.

Setting

The Louis Stokes Cleveland Veterans Affairs Medical Center is a 215-bed acute care facility. Shared-use wheelchairs are present throughout the facility, and hospital transport staff are available to assist patients. The facility policy states that wheelchairs should be wiped daily with a disinfectant wipe and as needed if they become soiled and portable equipment is to be wiped by personnel after each use. Waiting areas are to be cleaned daily by environmental services personnel, but cleaning of these areas is not monitored.

Test organisms

Test organisms included the nonenveloped single-stranded bacteriophage MS2 (American Type Culture Collection [ATCC] 15597-B1) and *Clostridioides difficile* spores (ATCC strain 43598). Bacteriophage MS2 was propagated in *Escherichia coli*.<sup>10</sup> *C difficile* spores were prepared as previously described.<sup>9</sup>

Electrostatic sprayer device and disinfectant

[Figure 1](#) shows the electrostatic sprayer device (Clorox Total 360 System-Electrostatic Sprayer, Clorox, Oakland, CA). The device is 1 m tall and is moved from room to room on wheels. It is plugged into a standard electrical outlet and a hand-held nozzle is used to direct a fine mist onto surfaces. The sprayer delivers electrostatically charged droplets with an average size of 40–80 μm that are actively attracted to surfaces to improve thoroughness of surface coverage. The device is intended to be used with a variety of different disinfectants and sanitizers. For the current study, the disinfectant used was Spore Defense Cleaner Disinfectant (Clorox) which contains 0.25% sodium hypochlorite. Per the manufacturer, this relatively dilute sodium hypochlorite solution leaves only minimal residual when sprayed and is noncorrosive to common materials in health care settings. No protective equipment is required, but the manufacturer recommends that users wear goggles.

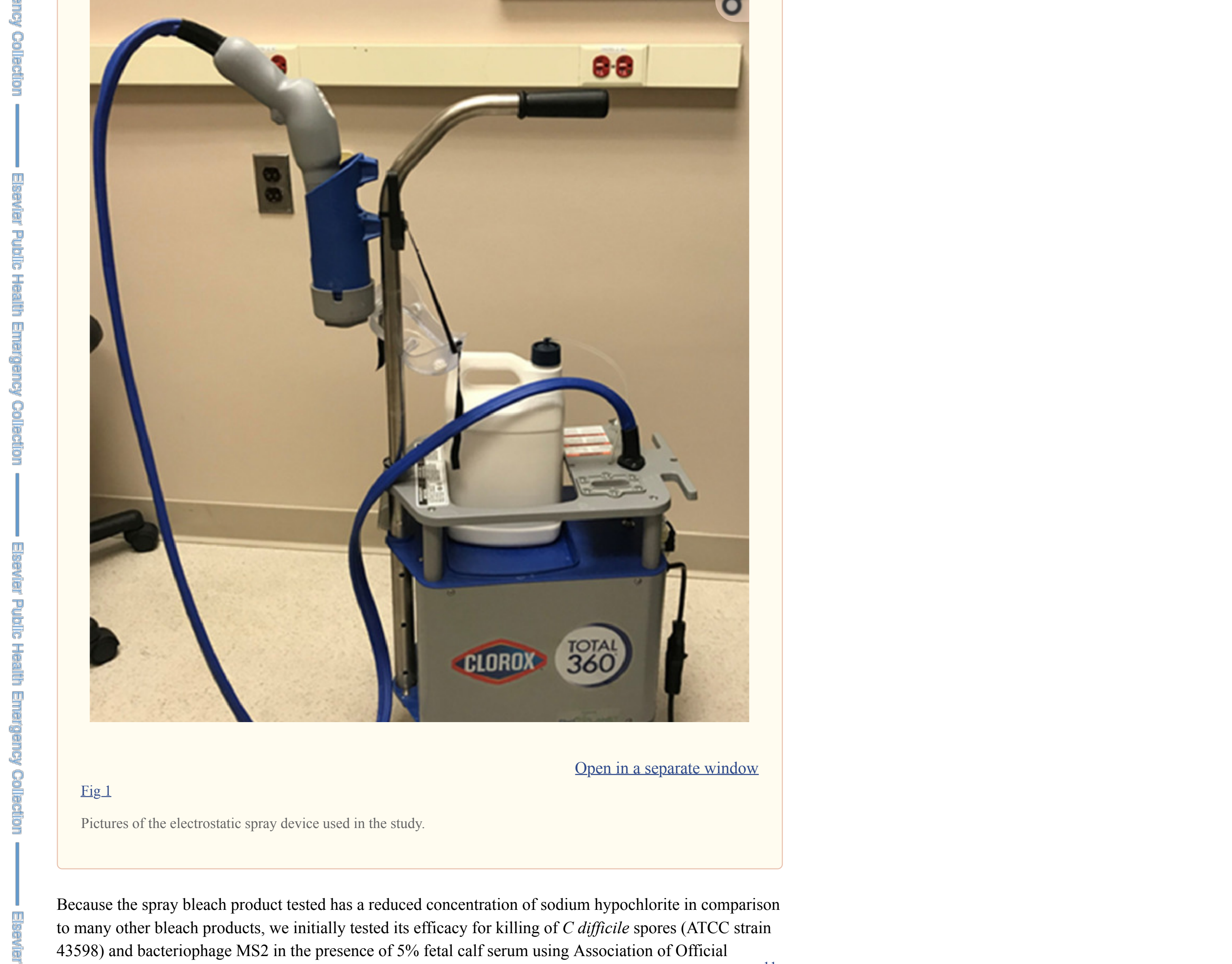


Fig 1. Pictures of the electrostatic spray device used in the study.

Because the spray bleach product tested has a reduced concentration of sodium hypochlorite in comparison to many other bleach products, we initially tested its efficacy for killing of *C difficile* spores (ATCC strain 43598) and bacteriophage MS2 in the presence of 5% fetal calf serum using Association of Official Agricultural Chemists International Official Method 961.02 Germicidal Spray Products as Disinfectants.<sup>11</sup> Based on the manufacturer's recommendations, a 5-minute exposure time was used for *C difficile* spores and a 2-minute exposure time was used for MS2; the product has a 1-minute claim against vegetative bacterial pathogens and many viruses. The product was sprayed once at 6 inches from stainless steel carriers applying sufficient disinfectant to thoroughly wet the inoculated surface of the carrier for the specified exposure time. The carriers were neutralized with Dey-Engley neutralizer (Remel Products, Lenexa, KS). Serial dilutions were plated on selective media and cultured as previously described.<sup>2</sup> Log<sub>10</sub> reductions were calculated by subtracting viable organisms recovered after exposure to the disinfectants versus deionized water controls. Experiments were performed in triplicate.

Effectiveness in reducing bacterial pathogens and inoculated bacteriophages on surfaces

We examined the effectiveness of the spray application of disinfectant on wheelchairs (N=30), portable medical equipment (N=40 devices), and patient waiting area chairs (N=30). The wheelchairs and chairs in waiting areas included soft and hard surfaces. Portable equipment included bladder scanners, electrocardiogram machines, pulse oximeters, workstations on wheels, and Doppler ultrasounds. A commercial improved hydrogen peroxide wipe was used to clean and disinfect areas with obvious visible soiling. The spray disinfectant was then applied once to the surfaces in accordance with the manufacturer's instructions and allowed to air dry. After spraying, all surfaces remained visibly wet for 2 minutes or longer. Horizontal surfaces typically remained wet for at least 5 minutes but areas at the periphery began to appear visually dry within 2 minutes, and surfaces that were curved or vertically oriented also became dry within 2 minutes.

Cultures were collected before spraying and after spraying and air drying. CultureSwabs (Becton Dickinson) premoistened with Dey-Engley neutralizer were used to collect samples from the wheelchairs (composite of arm rest, seat, seat back rest, and hand grips for pushing the wheelchairs), portable equipment (composite including the controls and handles commonly touched during use), and waiting area chairs (composite of chair arm rests, seat, and seat back rest); 10 cm<sup>2</sup> areas were sampled using a template or one-half of the entire surface of small items such as hand grips were sampled. For *C difficile* cultures, sterile gloves were donned and sterile 2×2 cm gauze pads premoistened with Dey-Engley neutralizer were used to sample the same sites. After spraying, adjacent 10 cm<sup>2</sup> areas were sampled or alternate halves of small items were sampled. Cultures were processed for *C difficile*, methicillin-resistant *Staphylococcus aureus*, enterococci, and gram-negative bacilli as previously described.<sup>9</sup>

For the wheelchair evaluation, additional work was performed to assess ability to eradicate inoculated viruses and to assess the time required for the spray application versus manual cleaning. For 3 of the wheelchairs, 10<sup>6</sup> plaque-forming units (PFU) of bacteriophage MS2 was inoculated and spread to cover 1 cm<sup>2</sup> areas of the seat, seat back rest, arm rest, and hand grip and allowed to air dry before the spray disinfectant was applied; 3 control wheelchairs were inoculated concurrently but not treated with disinfectant application. The personnel spraying the disinfectant was blinded to the location where the MS2 was applied. Cultures of swabs and gauze pads for bacteriophage MS2 were processed as previously described.<sup>11</sup> The time required to apply the spray disinfectant was measured in comparison to the time required for research personnel to manually apply the same disinfectant to thoroughly cover the surfaces on the body of the wheelchair.

Data analysis

Fisher exact test was used to compare the percentages of contamination of the wheelchairs, portable equipment, and waiting area chairs with a composite of any of the pathogens cultured. All analyses were performed using R version 3.5.1 statistical software (The R Foundation for Statistical Computing, Vienna, Austria).

Results

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On steel disks, the sodium hypochlorite spray reduced *C difficile* spores by ≥6.0 log<sub>10</sub> colony-forming units with a 5-minute contact time and bacteriophage MS2 by ≥6.0 log<sub>10</sub> PFU with a 2-minute contact time. As shown in [Figure 2](#), contamination with 1 or more of the potential pathogens was present on 30% or more of surfaces cultured in waiting rooms and on portable equipment and wheelchairs. However, areas of visible soiling requiring precleaning were uncommon (3 of 30, 10% wheelchairs; 2 of 40, 5% portable devices; 0 of 30 waiting room chairs). There was a significant reduction in contamination for each site after application of the spray disinfectant (*P* ≤ 0.1 for each comparison). *C difficile* contamination was reduced but not eliminated for each of the sites, whereas the other bacteria were eliminated except for 1 isolate of gram-negative bacilli recovered after spraying a wheelchair. Approximately 5 minutes were required to complete spraying of a waiting room area with 15–20 chairs.

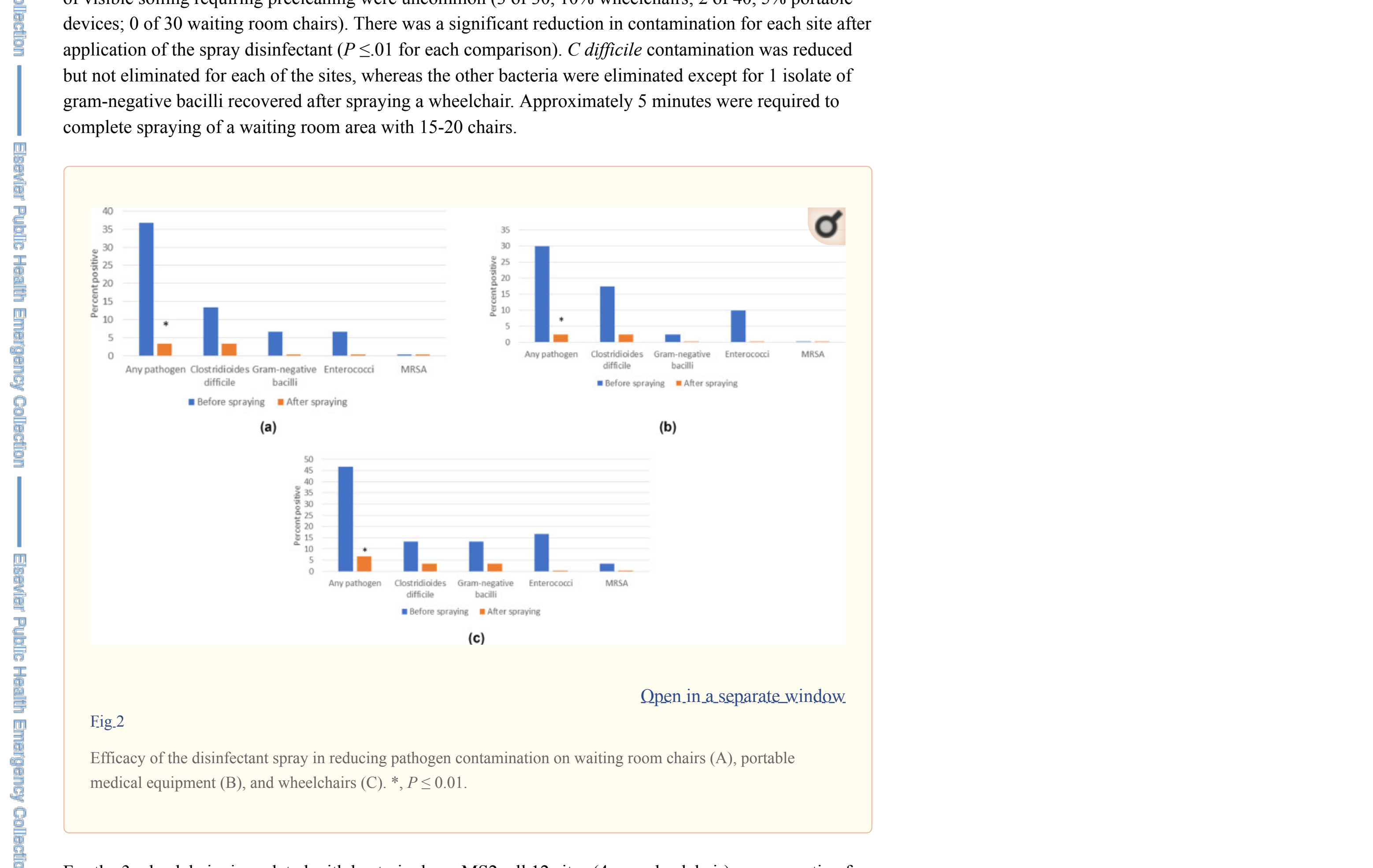


Fig 2. Efficacy of the disinfectant spray in reducing pathogen contamination on waiting room chairs (A), portable medical equipment (B), and wheelchairs (C). \*, *P* ≤ 0.01.

For the 3 wheelchairs inoculated with bacteriophage MS2, all 12 sites (4 per wheelchair) were negative for MS2 after application of the spray disinfectant whereas 4 log<sub>10</sub> PFU was recovered from inoculated but untreated wheelchairs. The amount of time required to apply the spray disinfectant to a wheelchair was 20 seconds, whereas manual disinfection required 84 seconds. There was minimal to no visible residue after spraying the product. Eight environmental services personnel trialed the device and all expressed positive opinions regarding its use for devices such as wheelchairs and waiting areas.

Discussion

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In the setting of the coronavirus disease 2019 pandemic, there has been increasing attention to the need for improved decontamination of portable devices and large open areas such as waiting rooms. Television and online reports suggest that spray disinfectants are commonly being used despite limited information on their efficacy. In the current study, we found that wheelchairs, portable equipment, and waiting room chairs were frequently contaminated with potential pathogens including *C difficile* spores. Application of a dilute sodium hypochlorite disinfectant using an electrostatic sprayer provided a rapid and effective means to reduce bacterial contamination on these surfaces and to eliminate an inoculated bacteriophage.

As noted previously, the electrostatic sprayer can be used with a variety of different disinfectant and sanitizers. The dilute sodium hypochlorite solution applied in the current study has several advantages. There is no requirement that protective equipment be worn, but the manufacturer does recommend use of goggles during operation. The product left minimal to no residue, whereas disinfectants with higher sodium hypochlorite concentrations often leave a residue. The disinfectant has a 1-minute contact time for killing of many vegetative bacteria and respiratory viruses.

One limitation of the dilute sodium hypochlorite product used in this study is that a 5-minute contact time is required for *C difficile* spores. On real-world surfaces, *C difficile* spores were reduced but not eliminated completely after a single spray application of the disinfectant. It is likely that failure to eliminate *C difficile* spores was in part related to the fact that curved or vertical surfaces typically had drying times of approximately 2 minutes. Thus, in settings where *C difficile* is a concern, repeated application of the dilute sodium hypochlorite product may be required to maintain 5 minutes of wet contact time.

Our study has some limitations. First, we assessed efficacy of the spray disinfectant against the benign bacteriophage MS2 rather than against viral pathogens. However, there is evidence that bacteriophage MS2 may have increased resistance to liquid disinfectants in comparison to enveloped respiratory viruses.<sup>12</sup> Second, we only studied one type of disinfectant with the spray technology. Third, we did not compare the efficacy and efficiency of the spray technology with alternatives such as UV-C light. However, UV-C light is not well-suited for irregular devices with multiple angles (eg, wheelchairs) that might result in shadowing or large open areas such as waiting rooms.<sup>1</sup> Fourth, we did not collect information on the number of colonies of the pathogens recovered from the surfaces. Finally, we did not compare the efficacy of the spray technology with manual application of disinfectant. However, we do not anticipate that the spray technology will replace manual cleaning of items and surfaces that can easily be wiped. Rather, the technology will be most useful for items and areas that are not amenable to standard cleaning and disinfection.

In summary, our results suggest that application of a dilute sodium hypochlorite disinfectant using an electrostatic sprayer could provide rapid and effective decontamination of portable equipment and large open areas. Additional studies are needed to evaluate the utility of the spray technology in community settings. For example, the technology could be useful for decontamination of areas such as airport waiting areas, classrooms, and gyms during situations such as the coronavirus disease pandemic.

Footnotes

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