American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Prospective cluster controlled crossover trial to compare the impact of an improved hydrogen peroxide disinfectant and a quaternary ammonium-based disinfectant on surface contamination and health care outcomes

John M. Boyce MD [a,*], Kerri A. Guercia MT [b], Linda Sullivan RN, CIC [a], Nancy L. Havill MT, MHA, CIC [c], Renee Fekieta PhD [a], Janet Kozakiewicz Pharm D [d], David Goffman Pharm D [d]

[a] *Quality Improvement Support Services, Yale New-Haven Hospital, New Haven, CT*
[b] *Department of Laboratory Medicine, Yale New-Haven Hospital, New Haven, CT*
[c] *Accreditation, Safety and Regulatory Affairs, Yale New-Haven Hospital, New Haven, CT*
[d] *Pharmacy Services, Yale-New Haven Hospital, New Haven, CT*

Key Words:
Disinfectants
Disinfection/*methods
Hydrogen peroxide
Quaternary ammonium
Controlled trial
Surface disinfection
Environmental microbiology
Prospective studies

Background: Quaternary ammonium–based (Quat) disinfectants are widely used, but they have disadvantages.

Methods: This was a 12-month prospective cluster controlled crossover trial. On 4 wards, housekeepers performed daily cleaning using a disinfectant containing either 0.5% improved hydrogen peroxide (IHP) or Quat. Each month, 5-8 high-touch surfaces in several patient rooms on each ward were tagged with a fluorescent marker and cultured before and after cleaning. Hand hygiene compliance rates and antimicrobial usage on study wards were obtained from hospital records. Outcomes included aerobic colony counts (ACCs), percent of wiped surfaces yielding no growth after cleaning, and a composite outcome of incidence densities of nosocomial acquisition and infection caused by vancomycin-resistant enterococci, methicillin-resistant *Staphylococcus aureus*, and *Clostridium difficile* infection. Statistical analysis was performed using χ^2 test, Fisher exact test, Welch test, and logistic regression methods.

Results: Mean ACCs per surface after cleaning were significantly lower with IHP (14.0) than with Quat (22.2) ($P = .003$). The proportion of surfaces yielding no growth after cleaning was significantly greater with IHP (240/500; 48%) than with Quat (182/517; 35.2%) ($P < .0001$). Composite incidence density of nosocomial colonization or infection with IHP (8.0) was lower than with Quat (10.3) (incidence rate ratio, 0.77; $P = .068$; 95% confidence interval, 0.579-1.029).

Conclusions: Compared with a Quat disinfectant, the IHP disinfectant significantly reduced surface contamination and reduced a composite colonization or infection outcome.

Quaternary ammonium–based (Quat) disinfectants are widely used in health care, but they have several disadvantages.[1,2] Recently marketed hydrogen peroxide–based disinfectants with greater antimicrobial potency, so-called improved hydrogen peroxide (IHP) disinfectants,[2,3] have been shown to reduce bacterial contamination of surfaces, and offer an alternative to Quat disinfectants.[3-6] One IHP product containing 0.5% hydrogen peroxide was found to have some activity against *Clostridium difficile* spores; however, it does not have an Environmental Protection Agency (EPA)–registered sporicidal claim.[7] Use of the same product, when combined with high rates of com-

* Address correspondence to John M. Boyce, MD, J.M. Boyce Consulting, LLC, 62 Sonoma Ln, Middletown, CT 06457.
E-mail address: jmboyce69@gmail.com (J.M. Boyce).
Funding/support: Supported by Diversey Care.
Conflicts of interest: JMB is a consultant to 3M Company, Clorox Company, and GOJO Industries, and became a consultant to Diversey Care, Sodexo and PDI, Inc. following completion of the study. He has received research support from GOJO Industries. All others have none to report.

http://dx.doi.org/10.1016/j.ajic.2017.03.010

pliance with recommended cleaning protocols, was associated with reductions in health care–associated infections caused by several multidrug-resistant pathogens.[8] Based on these earlier studies,[3-8] we conducted a quality improvement project to compare the effectiveness of IHP-containing wipes and a Quat disinfectant currently in use on reducing surface contamination and health care outcomes.

METHODS

Study design

A 12-month prospective cluster controlled crossover trial was conducted on 4 patient wards located on 2 campuses of a university-affiliated hospital. On each campus, 2 wards were randomized to have housekeepers continue performing daily and discharge cleaning using the Quat disinfectant (Hyperfect 256; Genesan, Gorham, ME) used in the rest of the hospital, or to perform daily and discharge cleaning using disinfectant wipes containing 0.5% IHP (Oxivir Tb; Diversey Care, Charlotte, NC). Both the IHP ready-to-use wipes and similar dry wipes used to apply the dilutable Quat disinfectant during the trial were made of melt blown polypropylene. During months when study wards were assigned to use the Quat disinfectant, rooms of patients with *C difficile* infection (CDI) were cleaned daily and at discharge with bleach wipes. When study wards were assigned to use the IHP disinfectant, all Quat-based wipes and bleach wipes were removed from the wards, bleach wipes were not used for daily or discharge cleaning of rooms occupied by patients with CDI, and the same IHP disinfectant in solution form was used to clean floors. The study was conducted in a medical intensive care unit (MICU) and its step-down unit on one campus, and on 2 general medical wards on the other campus. After 6 months, the ward assignments were reversed.

During the study, 5-8 high-touch surfaces in a convenience sample of several patient rooms on each of the 4 study wards were marked each month by fluorescent marker and cultured before cleaning, and were checked for the presence or absence of fluorescent marker and cultured again after daily cleaning by housekeepers. Rooms selected for tagging and culturing varied from month to month. High-touch surfaces were considered to have been wiped adequately if the fluorescent marker was removed. High-touch surfaces included bedside rails, remote control module, overbed tables, toilet seats, toilet grab bars, counters, supply cart keyboards, and work stations on wheels. Not all high-touch surfaces were present in all rooms. High-touch surfaces were cultured using 1 agar contact plate per surface on each occasion. All cultures of high-touch surfaces before and after cleaning were performed by a single microbiology laboratory technologist. Housekeepers, who were aware that the study was being conducted, received continued feedback during the study to increase the likelihood that high wipe rates would be maintained.[9]

Microbiologic methods

Cultures of high-touch surfaces were obtained by using Dey-Engley agar contact plates (Remel, Lenexa, KS), which were incubated at 36°C for 48-72 hours, followed by determination of aerobic colony counts (ACCs). ACCs were reported as the number of colony forming units (CFUs) per contact plate (ie, CFUs per high-touch surface). Plates with >200 CFUs per contact plate were classified as having 200 CFUs.

Outcome measures

Microbiologic outcome variables included the mean number of ACCs per high-touch surface and the percent of wiped surfaces yielding no growth after room cleaning. Because high-touch surfaces have sometimes been defined as clean if cultures yielded <2.5 CFUs/cm^2,[4] overall results were also expressed as the proportion of surfaces that yielded <2.5 CFUs/cm^2 (equivalent to <65 CFUs per contact plate).

A health care–related outcome measure represented a composite outcome of incidence densities (expressed as new, nosocomial cases per 1,000 patient days) of patients with a surveillance or clinical culture positive for vancomycin-resistant enterococci (VRE) or methicillin-resistant *Staphylococcus aureus* (MRSA), bloodstream infection caused by VRE or MRSA, and hospital-associated, hospital onset CDI. Surveillance or clinical culture results from patients with a history of colonization or infection by VRE or MRSA were excluded because such data would be unlikely to represent new acquisition (colonization) of these pathogens. Data on the occurrence of nosocomial cases of colonization or infection by target pathogens among patients on study wards were obtained from a TheraDoc database (TheraDoc, Salt Lake City, UT) maintained by the hospital epidemiology program.

Hand hygiene compliance rates on study wards, as determined by a single secret shopper throughout the study period, were obtained from a hospital database. Antimicrobial usage data for study wards (expressed as the number of defined daily doses [DDDs] per 1,000 patient days) were provided by the hospital pharmacy.[10] Antimicrobial agents were divided into 3 main categories: (1) anti–*C difficile* agents, including oral and intravenous metronidazole, oral vancomycin, and rifaximin; (2) agents with activity against MRSA or VRE; and (3) all other antibacterial agents.

Statistical analysis

ACCs after cleaning were excluded from further analysis if fluorescent markers revealed that surfaces had not been wiped or if cultures before cleaning revealed no growth because such surfaces cannot provide information regarding disinfectant efficacy and may overestimate the effectiveness of a disinfectant.[11,12] Our study protocol stipulated that only health care–related outcome data from months when fluorescent marker monitoring revealed that ≥80% of high-touch surfaces tested on a study ward had been wiped would be included in the data analysis, an approach used by others.[8] We assumed that a study in which disinfectants are not applied to a substantial proportion of high-touch surfaces in patient rooms would be unlikely to yield accurate estimates of the potential impact of the disinfectants on health care–related outcomes. Differences in proportions were tested by χ^2 or Fisher exact tests. Mean ACCs per high-touch surface obtained after cleaning on Quat and IHP wards were compared using Welch test. A multiple logistic regression model with a dependent variable of no growth versus ≥1 CFU on surfaces after cleaning included Quat ward vs IHP ward, high-touch surface cultured, and ACC before room cleaning as independent variables. The composite outcome measure of the incidence densities for VRE colonization or infection, MRSA colonization or infection, and CDI on Quat wards and IHP wards and antimicrobial usage data were compared as rates using univariate Poisson models (MedCalc, Ostend, Belgium).

RESULTS

Microbiologic findings

The total number of high-touch surfaces cultured before daily cleaning was 561 on IHP wards and 575 on Quat wards. On the IHP wards, 35 (6.2%) of the surfaces had not been wiped, and 25 (4.5%) yielded no growth before cleaning. On the Quat wards, 30 (5.2%) had not been wiped, and 28 (4.9%) yielded no growth before cleaning. The proportion of ACCs after cleaning that were excluded from further analysis of disinfectant efficacy was similar on IHP wards