CONCISE COMMUNICATION

Feasibility of Routinely Using Hydrogen Peroxide Vapor to Decontaminate Rooms in a Busy United States Hospital

Jonathan A. Otter, BSc; Matthew Puchowicz, BS; David Ryan, BS; James A. G. Salkeld, BEng; Timothea A. Cooper, RN; Nancy L. Havill, MT; Kathy Tuozzo, MSN; John M. Boyce, MD

During a 22-month period at a 500-bed teaching hospital, 1,565 rooms that had housed patients infected with multidrug-resistant pathogens were decontaminated using hydrogen peroxide vapor. Hydrogen peroxide vapor decontamination required a mean time of 2 hours and 20 minutes, compared with 32 minutes for conventional cleaning. Despite the greater time required for decontamination, hydrogen peroxide vapor decontamination of selected patient rooms is feasible in a busy hospital with a mean occupancy rate of 94%.

Infect Control Hosp Epidemiol 2009; 30:000-000

Environmental contamination due to *Clostridium difficile* and other pathogens can contribute to their nosocomial transmission.[1,2] Hydrogen peroxide vapor is a sporicidal, vapor-phase decontamination method that has been shown to be effective in eradicating nosocomial pathogens in hospitals[3-5] and has been used to eliminate persistent contamination during outbreaks of infection.[6,7]

Although hydrogen peroxide vapor decontamination is more effective than bleach cleaning after patient discharge,[2,7] the vapor decontamination process requires that the room be vacated by patients and staff, cleaned of visible dirt and dust, and sealed during the hydrogen peroxide vapor cycle, which typically takes 90–120 minutes for a single-occupancy room. Therefore, the feasibility of using hydrogen peroxide vapor to decontaminate rooms in busy hospitals has been questioned because of the need to admit a new patient as soon as possible after the previous occupant of a room is discharged.[8] After completion of a 10-month trial that yielded promising results,[2] the Hospital of Saint Raphael (New Haven, Connecticut) introduced the routine use of hydrogen peroxide vapor to decontaminate selected rooms. We measured several parameters to assess the feasibility of routinely using hydrogen peroxide vapor for decontamination in a busy hospital.

METHODS

The Hospital of Saint Raphael is a 500-bed teaching hospital. In 2005, hydrogen peroxide vapor decontamination methods (Room Bio-Decontamination Service; BIOQUELL) were routinely used to decontaminate selected rooms.[2] From January 2006 through October 2007, we prospectively maintained a list of rooms targeted for hydrogen peroxide vapor decontamination after being vacated by patients infected with *C. difficile* or selected multidrug-resistant organisms, including methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci. Rooms vacated by patients with *C. difficile* infection (CDI) were given highest priority. Daily census data were obtained from the hospital's admissions department. To identify new nosocomial cases of CDI, an electronic medical record review was performed by infection control personnel for each patient who had a test result positive for *C. difficile* toxin, using methods described by Boyce et al.[2] Linear regression was used to assess the association between variables.

To compare the amount of time required to clean rooms by use of standard bleach cleaning and the amount of time required for hydrogen peroxide vapor decontamination, the duration of each stage of the process (bleach cleaning or hydrogen peroxide vapor decontamination) for each room was recorded from January through April 2007. The bleach cleaning process conducted by housekeeping staff after discharge of patients infected or colonized with multidrug-resistant organisms comprised wiping all hard surfaces in the room with bleach wipes (Clorox germicidal wipes; Clorox) and wet-mopping the floor. The hydrogen peroxide vapor decontamination process comprised an initial cleaning stage performed by housekeeping staff in which a detergent was used to clean surfaces of visible dirt, followed by the hydrogen peroxide vapor cycle, as described by French et al.[5] The vapor cycle was conducted by BIOQUELL personnel who worked full-time in the hospital. After the hydrogen peroxide vapor cycle, a second visit by housekeeping was necessary so that the bed could be made and the room prepared for the next occupant. The rooms that had been decontaminated with hydrogen peroxide vapor were matched with rooms that had undergone bleach cleaning; rooms were matched by ward, size, and the time of day and day of the week that disinfection was performed. Room cleaning times were extracted from a database (BedTracking, version 1.04.04; TeleTracking Technologies). The amount of time required for each stage of the hydrogen peroxide vapor decontamination process was recorded prospectively.

RESULTS

From January 2006 through October 2007, there were 1,565 rooms decontaminated with hydrogen peroxide vapor (Figure). The decontaminated rooms had been vacated by patients infected with *C. difficile* (1,095 rooms [70%]), norovirus (110 rooms [7%]), methicillin-resistant *Staphylococcus aureus* or vancomycin-resistant enterococci (78 rooms [5%]), *Aci-*

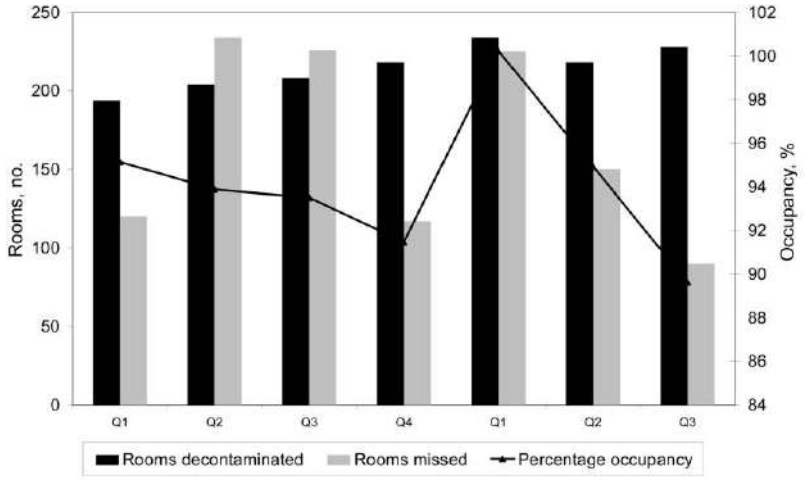

FIGURE. Number of rooms decontaminated with hydrogen peroxide vapor and the number of rooms that met the criteria for decontamination but could not be decontaminated (rooms missed; see Results for details), as well as percentage occupancy. Data are quarterly, from January 2006 through September 2007.

netobacter (63 rooms [4%]), or other multidrug-resistant organisms (219 rooms [14%]). During the same time period, we identified an additional 1,194 rooms that satisfied the criteria for decontamination but could not be decontaminated (hereafter, "missed rooms"). Most missed rooms (943 rooms [79%]) were missed because of discharges that occurred during time that BIOQUELL staff were not in the hospital (692 rooms [58%]) or lack of notification that the room was ready to be decontaminated (251 rooms [21%]), whereas only 251 rooms (21%) were missed because patients needed the rooms more quickly than they could be cleaned by this method (203 rooms [17%]) or because of lack of capacity (ie, insufficient hydrogen peroxide vapor equipment and/or decontamination staff; 48 rooms [4%]). A weak but statistically significant correlation was identified between the number of missed rooms and the percentage occupancy ($r^2 = 0.20$; $P = .048$) as well as between the number of missed rooms and the number of cases of nosocomial CDI ($r^2 = 0.35$; $P = .002$). The number of rooms decontaminated per week ranged from 8 to 29 (median, 17), and the

TABLE. Comparison of Hydrogen Peroxide Vapor Decontamination and Bleach Cleaning, According to the Time Required for Each Phase of Disinfection

	Hydrogen peroxide vapor decontamination, min		Bleach cleaning, min		
Phase of process	Mean	Median (range)	Mean	Median (range)	P[a]
Room vacant awaiting housekeeping	21	16 (0–180)	34	21 (0–242)	**.02**
First cleaning by housekeeping[b]	24	24 (0–48)	32	29 (8–73)	**<.001**
End of first cleaning to set up of hydrogen peroxide vapor system	19	0 (0–265)	NA	NA	
Hydrogen peroxide vapor cycle[c]	139	135 (102–225)	NA	NA	
Cumulative time from when room was vacated to end of hydrogen peroxide vapor cycle	206	179 (141–567)	NA	NA	
End of hydrogen peroxide vapor cycle to arrival of housekeeping	42	23 (0–272)	NA	NA	
Second cleaning by housekeeping[d]	23	24 (0–46)	NA	NA	
Cumulative time for all phases	270	234 (174–838)	67	55 (28–256)	**<.001**
End of disinfection process to occupation	198	119 (0–1025)	147	98 (15–1253)	.22

NOTE. There were 93 rooms decontaminated with hydrogen peroxide vapor and 64 matched rooms disinfected by use of bleach cleaning. Bold type indicates statistically significant P values ($P < .05$). The sum of means for the constituent phases may not equal the mean of the whole data set. Cumulative times were calculated using absolute times and are thus more accurate than the sum of the mean for the constituent phases. NA, not applicable.

[a] Calculated by use of a 2-tailed t test.

[b] Detergent-based cleaning to remove visible dirt prior to hydrogen peroxide vapor decontamination or bleach cleaning for rooms that were not decontaminated using hydrogen peroxide vapor.

[c] Time required to set up the decontamination equipment was included in the hydrogen peroxide vapor cycle time.

[d] In rooms decontaminated with hydrogen peroxide vapor, a second visit by housekeeping was necessary to make the bed and prepare the room for the subsequent occupant.

mean weekly occupancy rates ranged from 77% to 103% (median, 94%; the hospital records occupancy above 100% during very busy periods when all adult inpatient beds are full, and patients are held in the emergency department until rooms become available) (Figure).

Cycle times were recorded for 93 rooms that underwent hydrogen peroxide vapor decontamination; 64 matched rooms underwent bleach cleaning, and those data were used for comparison. Rooms that were to be cleaned prior to hydrogen peroxide vapor decontamination were prioritized by housekeeping; as a result, the time it took for housekeeping to arrive after the room was vacated was shorter for these rooms (mean time between vacancy and cleaning, 21 minutes for vapor-decontaminated rooms vs 34 minutes for bleach-cleaned rooms; $P = .02$) (Table). After precleaning with detergent, the mean time required for the hydrogen peroxide vapor cycle was 139 minutes, including set-up time. An additional 40–60 minutes was required after hydrogen peroxide vapor decontamination for housekeeping to arrive and prepare the room for the subsequent occupant. The total mean time from when a room was vacated until it was ready for a new patient was 270 minutes for hydrogen peroxide vapor decontamination, compared with 67 minutes for bleach cleaning ($P < .001$) (Table). Surprisingly, rooms decontaminated with hydrogen peroxide vapor and those cleaned with bleach remained empty for approximately 2–3 hours before they were occupied by other patients.

DISCUSSION

The hydrogen peroxide vapor decontamination method used in this study delivers the disinfectant vapor uniformly over all exposed surfaces in a room. In contrast to manual cleaning, it does not rely on the operator to ensure adequate distribution. However, the major drawback of hydrogen peroxide vapor decontamination is the cycle time of 2 hours and 20 minutes for a single room, which presents logistical challenges for the introduction of routine hydrogen peroxide vapor decontamination in healthcare settings.[2]

More than 1,500 rooms were decontaminated from January 2006 through October 2007, and 70% of these rooms had been vacated by patients with CDI, which reflects the targeted decontamination strategy focused on *C. difficile*.[2] At times of high occupancy, rooms could still be decontaminated using hydrogen peroxide vapor technology. However, as the hospital's occupancy rate increased, more of the rooms targeted for hydrogen peroxide vapor decontamination were missed (Figure). More cases of nosocomial CDI occurred during months when more rooms were missed; however, the colonization pressure created by a larger hospital population during these months is also likely to have affected transmission dynamics.[9]

The hydrogen peroxide vapor decontamination process, including the housekeeping cleaning phases, took 4–4.5 hours (or 3–3.5 hours, excluding the time spent waiting for housekeeping staff to arrive), which was more than 3 times longer than bleach cleaning. Although the hydrogen peroxide vapor process takes longer, we previously reported that 11 (26%) of 43 samples obtained before hydrogen peroxide vapor decontamination were positive for *C. difficile,* but none of the samples obtained after decontamination were *C. difficile* positive on culture; in addition, the routine use of hydrogen peroxide vapor resulted in a statistically significant reduction in the rate of CDI.[2] Other investigators have found that hydrogen peroxide vapor decontamination is more effective than conventional cleaning for removing or killing microbes on surfaces,[2,3,5,7] and it may be useful for outbreak control.[6,7] Therefore, the additional time that a room must remain vacant and other operational constraints associated with the routine use of hydrogen peroxide vapor may be offset by improved surface hygiene and consequent reductions in the acquisition of nosocomial pathogens.

Rooms that had been cleaned or decontaminated remained empty for approximately 2-3 hours prior to occupation, and the majority of missed rooms were missed because of off-shift discharges, rather than because patients were waiting to occupy the rooms. These facts suggest that the demand for beds, although high, was not acute in most instances.

Our study has several limitations. First, we relied on staff to enter accurate phase times into the database software, and information was not always entered correctly; for example, sometimes rooms that had been vacated were not marked as such in the system, or staff were not alerted when phases of the process were complete. Second, cleaning staff were blinded to the study and so may not have performed the cleaning process according to established protocols. Third, the weak linear correlation between missed rooms and the rate of nosocomial CDI may not be significant because of various confounding factors, including colonization pressure, hand hygiene compliance, and possible changes in antimicrobial prescribing practices.[2]

Future studies should investigate whether the routine use of hydrogen peroxide vapor decontamination is feasible in other institutions and whether hydrogen peroxide vapor could be useful for reducing the incidence of other nosocomial pathogens. The evaluation of hydrogen peroxide vapor is ongoing at this and other institutions.[10] In summary, despite the increased downtime associated with the use of hydrogen peroxide vapor, decontamination of selected rooms after patient discharge is feasible in a busy hospital with a high occupancy rate.

ACKNOWLEDGMENTS

Potential conflicts of interest. J.A.O., M.P., D.R., and J.A.G.S. are employed by BIOQUELL. J.M.B. is a consultant to Clorox Corporation and to BIOQUELL (since October 2008). T.A.C, N.L.H. and K.T. and have no potential conflicts of interest to declare. Hydrogen peroxide vapor decontamination was provided by BIOQUELL at discounted rates for this project.

From BIOQUELL (UK), Andover, Hampshire, United Kingdom (J.A.O.); BIOQUELL, Philadelphia, Pennsylvania (M.P., D.R., J.A.G.S.); and the Hospital of Saint Raphael (T.A.C., N.L.H., K.T., J.M.B.) and Yale University School of Medicine (J.M.B.), New Haven, Connecticut.

Address reprint requests to Jonathan A. Otter, BIOQUELL (UK), 52 Royce Close, West Portway, Andover, Hampshire, SP10 3TS United Kingdom (jon.otter@bioquell.com).

Presented in part: 18th Annual Scientific Meeting of the Society of Healthcare Epidemiology of America; April 5-8, 2008; Orlando, Florida.

Received September 15, 2008; accepted January 24, 2009; electronically published May 4, 2009.

 0899-823X/2009/3006-00XX$15.00. DOI: 10.1086/597544

REFERENCES

1. Mayfield JL, Leet T, Miller J, Mundy LM. Environmental control to reduce transmission of *Clostridium difficile. Clin Infect Dis* 2000; 31:995–1000.
2. Boyce JM, Havill NL, Otter JA, et al. Impact of hydrogen peroxide vapor room decontamination on *Clostridium difficile* environmental contamination and transmission in a healthcare setting. *Infect Control Hosp Epidemiol* 2008; 29:723–729.
3. Otter JA, Cummins M, Ahmad F, van Tonder C, Drabu YJ. Assessing the biological efficacy and rate of recontamination following hydrogen peroxide vapour decontamination. *J Hosp Infect* 2007; 67:182–188.
4. Johnston MD, Lawson S, Otter JA. Evaluation of hydrogen peroxide vapour as a method for the decontamination of surfaces contaminated with *Clostridium botulinum* spores. *J Microbiol Methods* 2005; 60:403–411.
5. French GL, Otter JA, Shannon KP, Adams NM, Watling D, Parks MJ. Tackling contamination of the hospital environment by methicillin-resistant *Staphylococcus aureus* (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. *J Hosp Infect* 2004; 57:31–37.
6. Bates CJ, Pearse R. Use of hydrogen peroxide vapour for environmental control during a *Serratia* outbreak in a neonatal intensive care unit. *J Hosp Infect* 2005; 61:364–366.
7. Jeanes A, Rao G, Osman M, Merrick P. Eradication of persistent environmental MRSA. *J Hosp Infect* 2005; 61:85–86.
8. Taneja N, Biswal M, Emmanuel R, Singh M, Sharma M. Hydrogen peroxide fogging in an overcrowded tertiary care referral centre: some practical queries. *J Hosp Infect* 2005; 60:85.
9. Lawrence SJ, Puzniak LA, Shadel BN, Gillespie KN, Kollef MH, Mundy LM. *Clostridium difficile* in the intensive care unit: epidemiology, costs, and colonization pressure. *Infect Control Hosp Epidemiol* 2007; 28:123–130.
10. Passaretti CL, Otter JA, Lipsett P, et al. Adherence to Hydrogen Peroxide Vapor (HPV) decontamination reduces VRE acquisition in high-risk units. Paper presented at: 48th Annual Meeting of the Interscience Conference on Antimicrobial Agents and Chemotherapy and the Infectious Diseases Society of America. October 10, 2008; Washington, DC (abstract K4124b).