Journal of Hospital Infection (2003) **54**, 109–114

Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

www.elsevier.health.com/journals/jhin

Comparison of the effect of detergent versus hypochlorite cleaning on environmental contamination and incidence of *Clostridium difficile* infection

M.H. Wilcox*, W.N. Fawley, N. Wigglesworth, P. Parnell, P. Verity, J. Freeman

Department of Microbiology, General Infirmary at Leeds and University of Leeds, Leeds LS1 3EX, UK

Received 22 November 2002; accepted 4 December 2002

KEYWORDS
Clostridium difficile; Environmental contamination; Hypochloryte; Cleaning agents

Summary To determine how best to decontaminate the hospital environment of *Clostridium difficile*, we carried out a cross-over study on two elderly medicine wards to determine whether cleaning with a hypochlorite disinfectant was better than using neutral detergent in reducing the incidence of *C. difficile* infection (CDI). We examined 1128 environmental samples in two years, 35% of which grew *C. difficile*. There was a significant decrease of CDI incidence on ward X, from 8.9 to 5.3 cases per 100 admissions ($P < 0.05$) using hypochlorite, but there was no significant effect on ward Y. On ward X the incidence of CDI was significantly associated with the proportion of culture-positive environmental sites ($P < 0.05$). On ward Y the only significant correlation between CDI and *C. difficile* culture-positive environmental sites was in patient side-rooms ($r = 0.41$, $P < 0.05$). The total daily defined doses of cefotaxime, cephradine and aminopenicillins were similar throughout the trial. These results provide some evidence that use of hypochlorite for environmental cleaning may significantly reduce incidence of CDI, but emphasize the potential for confounding factors.

Introduction

Clostridium difficile is the major infective cause of hospital-acquired diarrhoea. Despite increasing awareness of the need to avoid high-risk antibiotics in susceptible elderly patients, reports of *C. difficile* infection (CDI) continue to increase in England and Wales.[1] In addition to hands, environmental contamination is considered an important factor in hospital-acquired infections.[2,3] However, there is little evidence of how best to decontaminate the hospital environment.[4]

Spores may persist in the hospital environment for months, and are resistant to many commonly used cleaning agents.[5] We reported widespread environmental contamination of elderly medicine wards, which tends to increase when detergent-based cleaners are used.[6] Daily detergent-based cleaning of side-rooms used for isolation of patients with CDI still led to 25% of all environmental samples taken over four-week periods being contaminated

*Tel.: +44-113-392-6818; fax: +44-113-343-5649.
E-mail address: markwi@pathology.leeds.ac.uk

0195-6701/03/$ - see front matter
doi:10.1016/S0195-6701(02)00400-0

with *C. difficile*, down from 35% at the start of the study.[7] Cleaning agents also show marked differences in their ability to promote sporulation of *C. difficile*, which can be enhanced when cultured in faeces exposed to chlorine-free cleaners.[8]

It is unclear, however, whether these laboratory findings have relevance in vivo. We, therefore, carried out this study to determine whether environmental cleaning with a hypochlorite disinfectant as compared with a neutral detergent could reduce the incidence of CDI.

Methods

We carried out a two-year (March 1999–February 2001) ward-based cross-over study to compare the effect of environmental cleaning with either hypochlorite (Saniclor, Henkel Ecolab Professional Hygiene Ltd, Wiltshire, UK; 1000 ppm available chlorine) or neutral liquid detergent (Hospec, Youngs Detergents Lancare Ltd, Cheshire, UK; 1/1000 dilution) on CDI incidence in an endemic setting, on hand carriage by healthcare workers and environmental prevalence of *C. difficile*. Two elderly medicine wards (X and Y) with similar patient mix, design, and layout (ward X has five four-bedded bays with two single-bedded and one two-bedded side-rooms; ward Y is the same but without the two-bedded side-room) were cleaned with one or other regimen for six to 12 month periods, chosen to take account of possible seasonal variation of CDI incidence. Hence, hypochorite-based cleaning was used on ward X between September 1999 and August 2000, while detergent was used for the remainder of the study period. Appropriate training was given to domestic staff on how to undertake each type of cleaning. This included the need to use detergent before hypochlorite if surfaces were visibly dirty. Hypochorite residue was not removed. Ward side-rooms, usually single occupancy, were cleaned with the same agent as the rest of the ward. Antibiotic policy and infection control awareness by nursing and medical staff was not altered during the study.

Surveillance for environmental and hand contamination by *C. difficile* was performed monthly. Sites were sampled in a systematic manner (10×10 cm^2 areas) with sterile cotton wool swabs moistened with 0.25% Ringer's solution (Oxoid, Basingstoke, UK), and cultured immediately for *C. difficile*. *C. difficile* isolates were recovered from environmental samples by culture on cycloserine cefoxitin supplemented agar without egg yolk (CCA; Lab M Bury, UK), but containing 5 mg/L lysozyme (Mast Laboratories, Merseyside, UK), for 48 h in an anaerobic cabinet at 37°C.[9] After direct inoculation on to lysozyme CCA, enrichment for *C. difficile* was performed by placing environmental swabs in Robertsons cooked meat broth and incubating anaerobically for 48 h at 37°C. Resultant broth cultures were then inoculated on to lysozyme CCA as before. All *C. difficile* isolates were recognized by their characteristic colonial morphology and odour, and in cases of doubt, RapID ANA II System (Innovative Diagnostic Systems, GA, USA) was used. Hands of ten healthcare workers (nurses, doctors and paramedical staff) were sampled at one time each month using a standard hand impression plate technique on to lysozyme CCA medium.

CDI was diagnosed on request by laboratory detection of cytotoxin, neutralized by (*Clostridium sordellii* antitoxin) in diarrhoeal faecal samples. The hospital pharmacy database was used to quantify utilization of antibiotics (defined daily doses) on the study wards. Correlation coefficients and associated standard errors were used to determine significant differences. Where applicable, standard errors of the differences between percentages were also used.

Results

We examined 1128 environmental samples, of which 35% were *C. difficile* positive. A comparison of the two cleaning regimens indicated a significant decrease in CDI on ward X, from 8.9 to 5.3 cases per 100 admissions ($P < 0.05$), associated with the use of hypochlorite. This represented 17 fewer cases of *C. difficile* cytotoxin-positive diarrhoea during hypochlorite cleaning ($N = 38$) compared with detergent cleaning ($N = 21$) (Figure 1). On ward Y, however, there was no similar significant effect; CDI incidence increased from 3.5 to 4.7 per 100 admissions ($P < 0.05$). On ward X there was a significant correlation between incidence of CDI and the proportion of *C. difficile* culture positive environmental sites ($r = 0.36$, $P < 0.05$) (Figure 2). On ward Y, there was a significant correlation between CDI and *C. difficile* culture positive sites in patient side-rooms only ($r = 0.41$, $P < 0.05$). On ward X there was a significant correlation between the percentage of *C. difficile* culture positive environmental sites and the prevalence of *C. difficile* culture positive healthcare workers' hands ($r = 0.36$ $P < 0.05$). This relationship was strengthened when rarely cleaned environmental sites (radiators, bed frames, the floor of the domestics' room, and high dust sites in side-rooms,

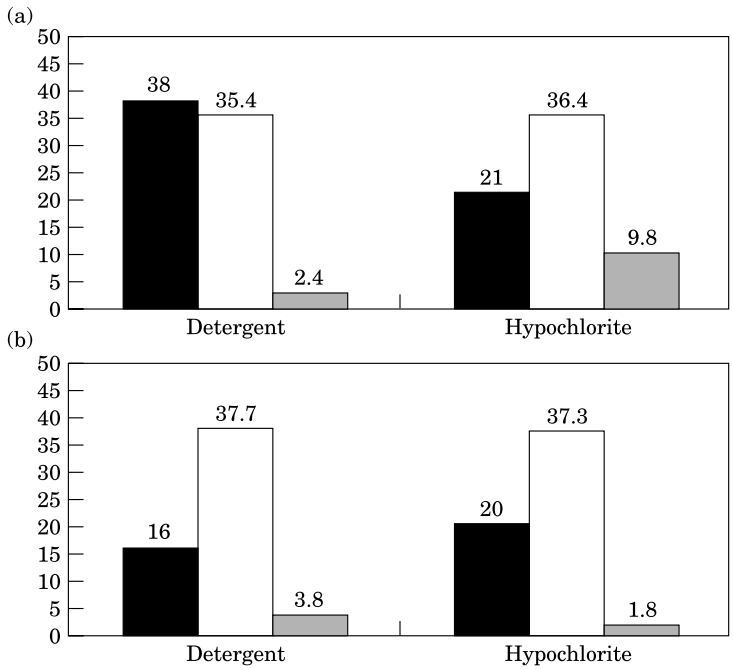

Figure 1 Summary of *C. difficile* infections, ward contamination, and positive hand-impression plates (HIPs) on wards (a) X and (b) Y. (■) Number of toxin-positive patients; (□) average percentage of culture positive environmental sites; (▣) average percentage of positive HIPs.

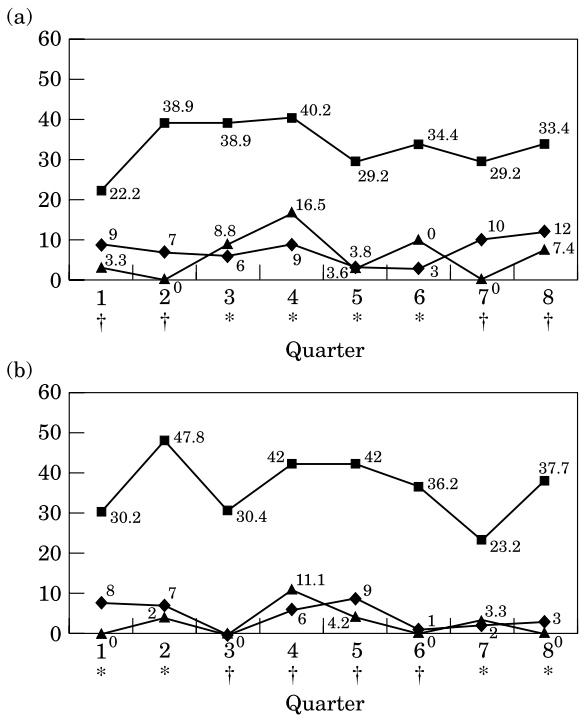

Figure 2 Quarterly incidence of *C. difficile* infections, ward contamination, and positive hand-impression plates (HIPs) on wards (a) X and (b) Y during detergent- (†) and chlorine-based (*) cleaning. (◆) Toxin-positive patients; (■) percentage of culture-positive environmental sites; (▲) percentage of positive HIPs.

i.e. curtain rails and window frames) were removed from the analyses ($r = 0.47$, $P < 0.01$). On ward Y there was no significant correlation between the prevalence of *C. difficile* culture positive environmental sites and the percentage of *C. difficile* culture positive healthcare workers' hands.

There was a marked similarity between the two study wards in the overall prevalence of environmental *C. difficile* in terms of which sites were contaminated (Figure 3). Contamination in some environmental sites was significantly more persistent. Commodes, toilet floors and bed frames were found to be *C. difficile* positive on approximately $\geq 50\%$ of occasions. Conversely, radiators, non-toilet floors and curtain rails were relatively infrequently ($\leq 30\%$) contaminated with *C. difficile*.

Pharmacy antibiotic utilization data in terms of total defined daily doses were similar on the two wards during the study. Also, these did not differ significantly in respect of cefotaxime, cephradine and aminopenicillins during periods of detergent-based as compared with chlorine-based cleaning (Figure 4). Data concerning individual durations of prescribed antibiotics and antimicrobial polypharmacy were not collected.

Discussion

In general evidence for an important role for

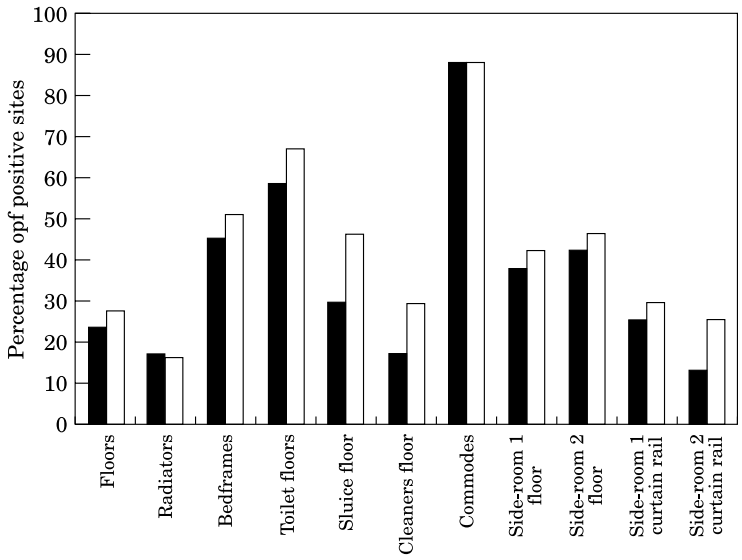

Figure 3 Frequency of *C. difficile* culture positive sites on study wards. (■) Ward X; (□) ward Y.

environmental contamination in the aetiology of hospital-acquired infection is poor, and several attempts to reduce infection rates by enhancing environmental cleaning have proved unsuccessful.[10–12] Not surprisingly, floor cleaning with either detergent or disinfectant did not affect nosocomial infection rates.[10] Recently Pittet *et al.*[12] also found that the incidence of nosocomial infections did not change during a four month trial of different cleaning agents. They observed that a quaternary ammonium compound was inadequate for disinfecting bathrooms and toilets but an active oxygen-based compound was satisfactory. Interestingly, unknown to the investigators, the detergent being examined was contaminated so that environmental surface count actually increases post-cleaning. However, given the long environmental persistence of spores,[5] support for enhanced endemicity and virulence of particular strains,[6–8,13,14] and evidence that the prevalence of *C. difficile* can still increase in elderly medicine wards with the use of conventional detergent-based environmental cleaning,[6,7,15] we believe that it is at least plausible that reducing the environmental burden may lessen the risk of cross-infection.

We therefore, completed a two-year in situ study to determine whether cleaning with a chlorine-based disinfectant was more effective than using a neutral detergent at reducing environmental *C. difficile* contamination, hand carriage by health-care workers and symptomatic disease. The environmental prevalence of *C. difficile* was similar during the two different cleaning regimens. However, there was a significant decrease in CDI

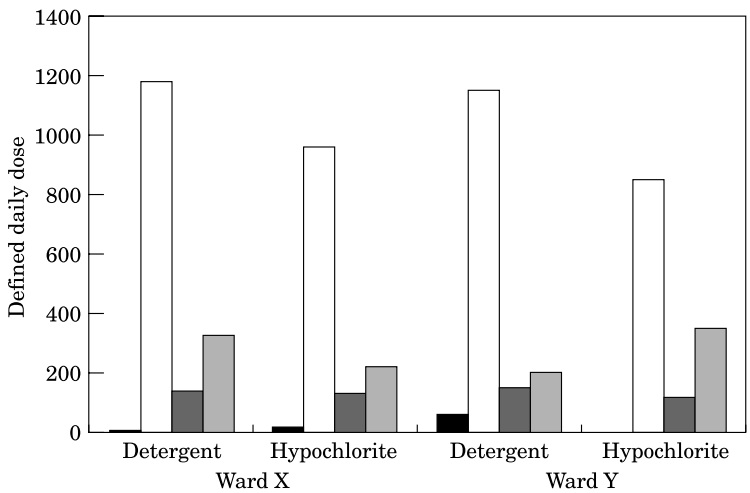

Figure 4 Antibiotic usage (defined daily dose) for study wards X and Y during periods of detergent and hypochlorite cleaning (12 months each). (■) Amoxycillin; (□) ampicillin; (▩) cefotaxime; (▣) cephradine.

incidence during hypochlorite cleaning on one of the two study wards, with 17 fewer cases of cytotoxin-positive diarrhoea than during detergent-based cleaning. A significant correlation also existed between the percentage prevalence *C. difficile* positive environmental sites and CDI incidence on this (but not the other) study ward. Although several studies have documented a high prevalence of *C. difficile* spores in areas occupied by infected patients,[3,6,7,15] bacterial acquisition from the environment has been difficult to prove. Additionally, we found a significant correlation between CDI and culture positive sites in patient side-rooms on the same ward. This was not unexpected and emphasizes that environmental contamination may indirectly affect the risk of cross-infection (presumably via healthcare workers' hands).[3,6] Samore and colleagues[3] found that the frequency of positive personnel hand culture was strongly correlated with intensity of environmental contamination. Our results for ward X support this. Clearly, good hand hygiene practice could mask a correlation between hand carriage and environmental burden of a pathogen, although we have no evidence that this explains the lack of such an association on ward Y.

Why did the results differ so markedly between wards X and Y which ostensibly are very similar? We are unaware of major confounding factors (such as changes in antibiotic policy), but variations in prescribing, patient type or cleaning efficiency, may have influenced either incidence of CDI or environmental contamination. Antibiotic use data indicated approximately equivalent use of the antibacterial agents implicated in CDI for each cleaning period on the study wards (Figure 4). In an earlier study where we intensively studied the environment of two wards from when they opened, we found that environmental contamination with *C. difficile*, not present immediately before opening, rose markedly during the first six months.[6] In this study the CDI incidence data correlated significantly with the prevalence of environmental *C. difficile* on one ward but not on the other.[6] These observations emphasize the need to examine more than one clinical area to determine the epidemiology of *C. difficile*, and indeed to assess the potential effectiveness of interventions such as environmental cleaning. *C. difficile* environmental contamination of some items/ward areas, such as sites frequently touched by patients or healthcare workers, may be far more likely to result in cross-infection than, for example toilet floors. Aggregated, point-prevalence environmental surveillance data may thus hide true correlations between the *C. difficile* burden and infection risk. We did not feed back to clinicians data on antibiotic use or CDI incidence as there is evidence that this process alone may affect such rates.[16]

In an outbreak setting, Kaatz *et al.*[17] isolated *C. difficile* from 31% of ward environmental samples. The outbreak ended after the introduction of disinfection with unbuffered hypochlorite (500 ppm available chlorine), and surface contamination decreased to 21% of initial levels. Phosphate-buffered hypochlorite (1600 ppm available chlorine, pH 7.6) was found to be more effective at reducing environmental *C. difficile* levels (98% reduction in surface contamination). As Kaatz and colleagues reported[17] we found that contamination with *C. difficile* may persist after environmental cleaning with hypochorite. Indeed, it is clear that once a hospital environment becomes contaminated, it is very difficult to render it *C. difficile* free.[6,16,18] While hypochlorite-based cleaning may be more effective at reducing levels of environmental spores, it is uncertain, whether such long-term use, particularly at high concentrations, is sustainable given its corrosive nature. Another potential drawback of hypochlorite-based disinfection is a reduced effectiveness to clean surfaces. Instructions given to cleaning staff included use of detergent first if surfaces were visibly dirty. In reality, it is doubtful that such extra steps were often taken. However, products are commercially available that combine detergent and hypochlorite components, and we have adopted use of one of these (in side-rooms housing CDI cases and during outbreaks) following the results of our studies.[6–8]

There is a divergence of opinion on whether detergents or disinfectants should be used for routine hospital cleaning.[19–21] A consensus conference highlighted the difference in approach to routine environmental decontamination in the US (disinfectant-based) and UK (detergent-based) hospitals.[19] UK guidelines produced in 1994 recommended, in the absence of evidence to the contrary, that detergent-based hospital cleaning should be used to remove environmental *C. difficile*.[4] However, the choice of cleaning agent could affect persistence of *C. difficile* spore in the hospital environment.[8] In vitro sporulation of the UK epidemic *C. difficile* strain (ribotype 1),[13] which already produces significantly more spores than non-prevalent strains, was further increased when cultured in faeces exposed to non-chlorine based hospital cleaning agents.[8] Conversely, the two chlorine-releasing agents tested did not increase *C. difficile* sporulation. In a recent before-and-after intervention study, Mayfield *et al.*[22] found that incidence of *C. difficile* diarrhoea in patients on a bone marrow transplant

unit, where there was a high endemicity of cases, decreased significantly after substitution of a quaternary ammonium solution by hypochlorite for environmental disinfection. When cleaning with the quaternary ammonium solution was reintroduced, the incidence of *C. difficile* diarrhoea increased almost to baseline level. Unfortunately, however, environmental *C. difficile* prevalence was not measured, and antibiotic use altered during the study period. Also, the results were not reproducible for patients on other units.

Our results provide some evidence that hypochlorite environmental cleaning may significantly reduce CDI incidence, but also emphasize the potential for confounding factors. It has been estimated that each CDI case costs more than £4000, primarily because of hotel costs associated with prolonged length of stay.[23] This high figure can be used to justify expenditure on improved standards of hospital cleanliness. Indeed, the increased cost of using hypochlorite-based products rather than detergents for environmental cleaning is very modest compared with the healthcare-associated costs of avoidable cases of CDI.

Acknowledgements

We thank the Hospital Infection Society and the Trustees of The General Infirmary at Leeds for research grants that made this study possible. The invaluable support of nursing and domestic staff on the elderly medicine wards is also gratefully acknowledged.

References

1. Communicable Disease Surveillance Centre, *Clostridium difficile* in England and Wales: 1999. *Commun Dis Rep CDR Weekly* 2000;**10**:135.
2. Samore MH, Venkataraman L, DeGirolami PC, Arbeit RD, Karchmer AW. Clinical and molecular epidemiology of sporadic and clustered cases of nosocomial *Clostridium difficile* diarrhoea. *Am J Med* 1996;**100**:32—40.
3. McFarland LV, Mulligan ME, Kwok RY, Stamm WE. Nosocomial acquisition of *Clostridium difficile* infection. *N Engl J Med* 1989;**320**:204—210.
4. Department of Health and Public Health Laboratory Service Joint Working Group, *Clostridium difficile* infection: prevention and management. *BAPS* 1994.
5. Kim KH, Fekety R, Batts DH, et al. Isolation of *Clostridium difficile* from the environment and contacts of patients with anitbiotic-associated colitis. *J Infect Dis* 1981;**143**:42—50.
6. Fawely WN, Wilcox MH. Molecular epidemiology of endemic *Clostridium difficile* infection. *Epidemiol Infect* 2001;**126**: 343—350.
7. Verity P, Wilcox MH, Fawley WN, Parnell P. Prospective evaluation of environmental contamination by *Clostridium difficile* in isolation side-rooms. *J Hosp Infect* 2001;**49**: 204—209.
8. Wilcox MH, Fawley WN. Hospital disinfectants and spore formation by *Clostridium difficile*. *Lancet* 2000;**356**:1324.
9. Wilcox MH, Fawley WN, Parnell P. Value of lysozyme agar incorporation and alkaline thioglycollate exposure for the environmental recovery of *Clostridium difficile*. *J Hosp Infect* 2000;**44**:65—69.
10. Danforth D, Nicolle LE, Hume K, Alfieri N, Sims H. Nosocomial infections on nursing units with floors cleaned with a disinfectant compared with detergent. *J Hosp Infect* 1987;**10**:229—235.
11. Dancer SJ. Mopping up hospital infection. *J Hosp Infect* 1999; **43**:85—100.
12. Dharan S, Mourouga P, Copin P, Bessmer G, Tschanz B, Pittet D. Routine disinfection of patients' environmental surface. Myth or reality? *J Hosp Infect* 1999;**42**:113—117.
13. Stubbs SLJ, Brazier JS, O'Neill GL, Duerden BI. PCR targeted to the 16 S—23 S rRNA gene intergenic spacer region of *Clostridium difficile* and construction of a library consisting of 116 different PCR ribotypes. *J Clin Microbiol* 1999;**37**: 461—463.
14. Johnson S, Samore MH, Farrow KA, et al. Epidemics of diarrhoea caused by a clindamycin-resistant strain of *Clostridium difficile* in four hospitals. *N Engl J Med* 1999; **341**:1645—1651.
15. Bender BS, Bennett R, Laughon BE, et al. Is *Clostridium difficile* endemic in chronic-care facilities? *Lancet* 1986;**ii**: 11—13.
16. Stone S, Kibbler C, How A, Balestrini A. Feedback is necessary in strategies to reduce hospital acquired infection. *BMJ* 2000;**321**:321.
17. Kaatz GW, Gitlin SD, Schaberg DR, Wilson KH, Kauffman CA, Seo SM. Acquisition of *Clostridium difficile* from the hospital environment. *Am J Epidemiol* 1988;**127**:1289—1293.
18. Wilcox MH, Settle CD, Fawley W, et al. Isolation of patients with *Clostridium difficile* infection. *J Hosp Infect* 1997;**37**: 331—334.
19. Anonymous Global consensus conference: final recommendations, *Am J Infect Control* 1999;**27**:503—513.
20. Rüden H, Daschner F. Should we routinely disinfect floors? *J Hosp Infect* 2002;**51**:309.
21. Rutala WA, Weber DJ. Should we routinely disinfect floors? Reply to Professor F. Daschner. *J Hosp Infect* 2002;**51**: 309—310.
22. Mayfield JL, Leet T, Miller J, Mundy LM. Environmental control to reduce transmission of *Clostridium difficile*. *Clin Infect Dis* 2000;**31**:995—1000.
23. Wilcox MH, Cunnliffe JG, Trundle C, Redpath C. Financial burden of hospital acquired *Clostridium difficile* infection. *J Hosp Infect* 1996;**34**:23—30.