



Health
Protection
Scotland



**Transmission Based Precautions Literature Review:
Management of Care Equipment and
Environmental Decontamination**

Version: 1.0
Owner/Author: Infection Control Team
Review Date: Financial Year 2020/21

DOCUMENT CONTROL SHEET

Key Information:		
Title:	Transmission Based Precautions Literature Review: Management of Care Equipment and Environmental Decontamination	
Date Published/Issued:	November 2017	
Date Effective From:	November 2017	
Version/Issue Number:	1.0	
Document Type:	Literature Review	
Document status:	Final	
Author:	Name:	David Scott
	Role:	Healthcare Scientist
	Division:	HPS
Owner:	Infection Control	
Approver:	Lisa Ritchie	
Approved by and Date:		
Contact	Name:	Infection Control Team
	Tel:	0141 300 1175
	Email:	nss.hpsinfectioncontrol@nhs.net

Version History:			
This literature review will be updated in real time if any significant changes are found in the professional literature or from national guidance/policy.			
Version	Date	Summary of changes	Changes marked
1.0	November 2017	<p>This new literature review combines the previous 2015 TBP literature reviews on 'Management of patient care equipment' and Environmental decontamination and terminal cleaning'.</p> <p>How should an isolation room/cohort area be decontaminated? Inclusion of 'or at 15 minutes intervals' regarding changing of cleaning solution.</p> <p>New recommendation added (p. 7): "Hydrogen peroxide vapour may be considered as an additional measure following disinfection of vacated isolation rooms for patients colonised or infected with multidrug-resistant organisms (e.g. carbapenemase-producing organisms) or high consequence pathogens (e.g. Ebola virus), or where environmental contamination is contributing to an outbreak with ongoing transmission. Hydrogen peroxide vapour is not recommended for routine use. (AGREE rating: Recommend)"</p>	

Approvals – this document requires the following approvals (in cases where signatures are required add an additional 'Signatures' column to this table)::				
Version	Date Approved	Name	Job Title	Division
1.0	October 2017	NPGO Steering and Consensus Groups		

HPS ICT Document Information Grid	
Title:	Transmission Based Precautions Literature Review: Management of Care Equipment and Environmental Decontamination.
Purpose:	To inform the Transmission Based Precautions section of the National Infection Prevention and Control Manual in order to facilitate the prevention and control of Healthcare Associated Infection in NHSScotland hospital settings.
Target audience:	All NHS Scotland staff involved in the prevention and control of infection in the hospital setting.
Description:	This literature review examines the available professional literature on the management of care equipment and environmental decontamination in hospital settings.
Update/review schedule:	Updated as new evidence emerges, with changes made to recommendations as required.
Cross reference:	<p>Standard Infection Control Precautions (SICP) Literature Reviews: Routine cleaning of the care environment http://www.nipcm.hps.scot.nhs.uk/documents/sicp-routine-cleaning-of-the-environment-in-the-hospital-setting/</p> <p>Management of blood and body fluid spillages in health and social care settings http://www.nipcm.hps.scot.nhs.uk/documents/sicp-management-of-blood-and-body-fluid-spillages-in-the-hospital-setting/</p> <p>Management of patient care equipment http://www.nipcm.hps.scot.nhs.uk/documents/sicp-management-of-patient-care-equipment-in-the-hospital-setting/</p>
Update level:	<p>Practice – <i>Initial review therefore currently not applicable</i></p> <p>Research – <i>Initial review therefore currently not applicable</i></p>

Contents:

1. Objectives	5
2. Recommendations	6
3. Discussion	9
3.1 Implications for practice.....	9
3.2 Implications for research	13
Reference List.....	15

1. Objectives

The aim is to review the extant scientific literature regarding management of care equipment and environmental decontamination in isolation rooms/cohort areas to form evidence based recommendations for practice. The specific objectives of the review are to determine:

- What measures are required for the management of patient care equipment when applying TBPs in addition to those outlined in SICPs?
- How should an isolation room/cohort area be decontaminated?
- When should an isolation room/cohort area be decontaminated?
- What is a terminal clean and why is it required?
- When should terminal cleaning be carried out?
- What additional steps are required for a terminal clean?

Note:

Transmission Based Precautions (TBPs) are measures that may be required in addition to Standard Infection Control Precautions (SICPs). It is assumed, for the purpose of this literature review, that all SICPs are adhered to, and therefore are not the focus of this literature review and the associated recommendations.

2. Recommendations

This review makes the following recommendations based on an assessment of the extant scientific literature on management of care equipment and environmental decontamination in isolation rooms/cohort areas:

What measures are required for the management of patient care equipment when applying TBPs in addition to SICPs?

Single-use disposable care equipment should be used for patients known or suspected to be infected with microorganisms spread by airborne (aerosol), droplet, or contact routes.

(Good Practice Point (GPP))

Where the use of single-use disposable equipment is not practical, dedicated care equipment should be used for patients suspected or known to be infected with microorganisms spread by airborne (aerosol), droplet or contact routes. This equipment must be disinfected prior to use on another patient.

(AGREE rating: Recommend)

How should an isolation room/cohort area be decontaminated?

The NHSScotland National Cleaning Services Specification should be followed with respect to the decontamination of isolation rooms/cohort areas.

(Mandatory)

Isolation rooms/cohort areas should be decontaminated by starting from the highest to the lowest point, and from the least contaminated to the most contaminated, changing cleaning equipment/solutions when they become dirty or at 15 minutes intervals or when moving to new task or location.

(Good Practice Point (GPP))

Neutral detergent followed by a disinfectant containing 1000 parts per million (ppm) available chlorine (av cl) (or a combined detergent/disinfectant (1000 ppm av cl)) should be used for decontamination of isolation rooms/cohort areas, including sanitary fittings (e.g. sinks).

(AGREE rating: Recommend)

Manufacturer instructions should be followed with regard to the preparation of disinfectants and contact time required for effective disinfection.

(Mandatory)

Only cleaning products supplied by employers should be used. Cleaning products should be used in accordance with Control of Substances Hazardous to Health (COSHH) Regulations and manufacturer instructions.

(Mandatory)

Environmental decontamination should be thorough and include all frequently touched surfaces.

(AGREE rating: Recommend)

Any new products/technologies for decontamination of isolation rooms/cohort areas should be formally assessed (including cost, benefit, potential hazards and user safety) before they are adopted for application in NHSScotland (e.g. via the Health Innovation Procurement Portal or HAI Commodities Group).

(Good Practice Point (GPP))

Hydrogen peroxide vapour may be considered as an additional measure following disinfection of vacated isolation rooms for patients colonised or infected with multidrug-resistant organisms (e.g. carbapenemase-producing organisms) or high consequence pathogens (e.g. Ebola virus), or where environmental contamination is contributing to an outbreak with ongoing transmission. Hydrogen peroxide vapour is not recommended for routine use.

(AGREE rating: Recommend)

When should an isolation room/cohort area be decontaminated?

The NHSScotland National Cleaning Services Specification should be followed with regard to cleaning frequency of isolation rooms within NHSScotland, i.e. at least once a day.

(Mandatory)

Cleaning frequency should be increased at times of potentially high environmental and equipment contamination, and should be particularly targeted at frequently touched surfaces.

(AGREE rating: Recommend)

What is a terminal clean and why is it required?

A terminal clean is defined as: “a procedure required to ensure that an area has been cleaned/decontaminated following discharge of a patient with an infection (i.e. alert organism or communicable disease) in order to ensure a safe environment for the next patient.”

(Mandatory)

When should terminal cleaning be carried out?

Terminal cleaning should be carried out after a patient with an alert organism or communicable disease has been discharged (or transferred), in order to ensure a safe environment for the next patient.

(Mandatory)

What additional steps are required for a terminal clean?

The NHSScotland National Cleaning Services Specification should be followed with respect to terminal cleaning.

(Mandatory)

Bed screens, curtains and bedding should be removed prior to the room/area being decontaminated.

(Mandatory)

3. Discussion

3.1 Implications for practice

What measures are required for the management of patient care equipment when applying TBPs in addition to those outlined in SICPs?

Single-use disposable care equipment should be used for patients known or suspected to be infected with microorganisms spread by airborne (aerosol), droplet, or contact routes.¹

(Good Practice Point (GPP))

The use of dedicated non-critical care equipment (e.g. stethoscopes, blood pressure cuffs, electronic thermometer) for patients infected with microorganisms spread by the airborne (aerosol), droplet, or contact routes has been shown to be effective in preventing cross-transmission of infection.² Where the use of single-use disposable equipment is not practical, dedicated care equipment should be used for patients suspected or known to be infected with microorganisms spread by airborne (aerosol), droplet or contact routes.² This equipment must be disinfected prior to use on another patient.^{1;2}

(AGREE rating: Recommend)

How should an isolation room/cohort area be decontaminated?

The NHSScotland National Cleaning Services Specification (NCSS) outlines the tasks required for decontamination of an isolation room/cohort area and should be followed.³

(Mandatory)

The room should be decontaminated from the highest to the lowest point (e.g. curtain rails to floors) and from the least contaminated to the most contaminated (i.e. from infrequently touched surfaces to surfaces such as shower and toilet areas), changing cleaning equipment/solutions when they become dirty or at 15 minutes intervals or when moving to new task or location.⁴

(Good Practice Point (GPP))

When the environment is potentially contaminated with transmissible pathogens, disinfectants such as chlorine-releasing agents should be used.¹⁻⁸ For disinfectants to work effectively, the surface being decontaminated must be free from organic soil; a neutral detergent solution

should be used to clean the environment prior to disinfection or a combined detergent/disinfectant may be used.⁹⁻¹²

There is substantial evidence to support the effectiveness of hypochlorite solutions (1000ppm) and sodium dichloroisocyanurate (NaDCC) for the disinfection of surfaces contaminated with norovirus or *C. difficile*.^{8;10;11;13-16} It is recommended by epic3 guidelines⁵ and the Centers for Disease Control and Prevention² (CDC) that chlorine-based disinfectants, such as sodium hypochlorite solution or sodium dichloroisocyanurate (NaDCC) solution at the manufacturer's recommended concentration of 1000 parts per million (ppm) available chlorine (av cl), are used for the disinfection of surfaces contaminated with norovirus or *C. difficile*.

Therefore, neutral detergent followed by a disinfectant containing 1000 ppm av cl (or a combined detergent/disinfectant (1000 ppm av cl)) should be used for decontamination of isolation rooms/cohort areas, including sanitary fittings (e.g. sinks).

(AGREE rating: Recommend)

Only cleaning products supplied by employers should be used and the solution should be prepared in accordance to manufacturer instructions and local policy.³ Manufacturer instructions should be followed with regard to the preparation of disinfectants and contact time required for effective disinfection. Cleaning products are covered by Control of Substances Hazardous to Health (COSHH) Regulations and are subject to risk assessment before use.¹⁷

(Mandatory)

Several studies indicate that cleaners may miss or fail to adequately clean certain frequently touched objects in the patient environment such as door handles, toilet handles and light switches.¹⁸⁻²² This is thought to reflect a ritualistic rather than a risk based approach to cleaning.²³ The risks of HAI resulting from inadequate cleaning have been widely discussed.^{12;13;24-37} It is important to ensure that environmental decontamination is thorough and includes all frequently touched surfaces to reduce the risk of acquiring infections from the environment.²

(AGREE rating: Recommend)

There is an emerging body of evidence to support novel technologies as a supplement to the use of a chlorine-based disinfectant (e.g. hydrogen peroxide vapour³⁸⁻⁴³ and ultraviolet light⁴⁴⁻⁵¹) or new disinfectant formulations to replace the use of a standard chlorine-based disinfectant

(e.g. chlorine dioxide solution^{52;53} and peracetic acid^{54;55}). However, several practical and safety concerns are relevant to the use of novel disinfection methods, such as: the additional time required; a requirement for rooms to be cleaned with detergent prior to use of the novel technology; and, in the case of hazardous cleaning solutions, the necessity for rooms to be vacated before the decontamination process. While some novel technologies are already widely in use within NHSScotland (e.g. microfibre and steam cleaning), further research is required to adequately assess these in terms of efficacy, cost, potential hazards, and user safety. In addition, a range of studies demonstrate that audit and feedback programmes using either fluorescent marker or ATP bioluminescence may be used to improve the effectiveness of terminal cleaning.⁵⁶⁻⁶¹ Any new products/technologies should be formally assessed (e.g. cost, benefit, potential hazards and user safety) before they are adopted for application in NHSScotland (e.g. via the Health Innovation Procurement Portal or HAI Commodities Group).

(Good Practice Point (GPP))

Hydrogen peroxide vapour may be considered as an additional measure following disinfection of vacated isolation rooms for patients colonised or infected with multidrug-resistant organisms (e.g. carbapenemase-producing organisms) or high consequence pathogens (e.g. Ebola virus), or where environmental contamination is contributing to an outbreak with ongoing transmission. Hydrogen peroxide vapour is not recommended for routine use.³⁸⁻⁴³

(AGREE rating: Recommend)

When should isolation room/cohort areas be decontaminated?

The NHSScotland NCSS outlines the frequency required for decontamination of isolation rooms in NHSScotland hospitals.³ It mandates that decontamination should take place regularly (at least once per day) and following patient discharge.

(Mandatory)

Cleaning frequency should be increased at times of potentially high environmental and equipment contamination, and should be particularly targeted at frequently touched surfaces, e.g. bed rails, door handles, toilets used by patients with gastrointestinal symptoms.⁵

(AGREE rating: Recommend)

What is a terminal clean and why is it required?

Terminal cleaning is defined in the NHSScotland NCSS, which is applicable throughout Scotland wherever healthcare is delivered (i.e. NHS as well as private independent and voluntary sectors).³

A terminal clean is defined as: “a procedure required to ensure that an area has been cleaned/decontaminated following discharge of a patient with an infection (i.e. alert organism or communicable disease) in order to ensure a safe environment for the next patient.”³

(Mandatory)

When should terminal cleaning be carried out?

The NHSScotland NCSS states that a terminal clean is required “following discharge of a patient with an infection (i.e. alert organism or communicable disease), in order to ensure a safe environment for the next patient”.³

(Mandatory)

What additional steps are required for a terminal clean?

The NHSScotland NCSS states that items such as bed screens, curtains and bedding should be removed prior to the room being decontaminated.³

(Mandatory)

3.2 Implications for research

The volume of evidence on technical procedures for decontamination and terminal cleaning remains limited, particularly with regard to frequency and protocols, although there is a growing body of evidence on novel technologies for terminal cleaning and alternative sporicidal (i.e. high-level) disinfectants. These included hydrogen peroxide vapour, ultraviolet light, peracetic acid and chlorine dioxide solution; however, the most common research designs were interrupted time series or before-and-after studies, indicating that the quality of existing evidence is low. There is a need for more high-quality randomised controlled trials that assess hydrogen peroxide vapour and ultraviolet light as an additional measure following decontamination with a chlorine-based disinfectant at 1000 ppm available chlorine, as currently recommended for NHSScotland. There was also an expansion in the published literature on evaluating audit and feedback programmes for improving the quality of terminal cleaning, using fluorescent markers and ATP bioluminescence for educational purposes. Yet, most of the guidance on this subject is still provided by the NHSScotland National Cleaning Services Specification, which mandates the standards required for cleaning in healthcare settings.

Few of the studies were conducted in the UK, and none of the studies were performed in Scotland. In particular, most of the research activity on ultraviolet light disinfection was based within the USA. Since chlorine-releasing agents are typically only used for the disinfection of rooms contaminated with *C. difficile* in the USA, whereas quaternary ammonium disinfectants are preferred for most other transmissible pathogens, the only evidence relevant to NHSScotland concerned the efficacy of ultraviolet light against *C. difficile*. In addition, only those studies where hydrogen peroxide vapour or ultraviolet light were used as an adjunct to a chlorine-releasing agent were included in this review, since the practical difficulties of these technologies precludes their use as an alternative to a chlorine-based disinfectant. Especially in the USA, even when studies did combine novel technologies with chlorine-based disinfectants, they often used concentrations of available chlorine different from that recommended for use in NHSScotland.

There is a risk of significant bias posed by the role of industry funding bodies in supporting research on new technologies for equipment and environmental decontamination. This is most clearly the case for ultraviolet light disinfection devices, for which manufacturers are concerned

with promoting this technology as a more efficient alternative to hydrogen peroxide vapour. Chlorine dioxide solution has likewise been promoted by manufacturers as an alternative to sodium hypochlorite solution, citing improved safety for users, a less corrosive effect on surfaces, and appropriateness for use in cleaning up urine spills. It can therefore be seen that comparable effectiveness of sodium hypochlorite and chlorine dioxide in reducing the incidence of healthcare-associated infections may tend towards placing the latter in a more favourable light.

Reference List

- (1) Department of Health. Isolating patients with healthcare associated infection: a summary of best practice. 2010
http://webarchive.nationalarchives.gov.uk/20120118171850/http://hcai.dh.gov.uk/files/2011/03/Document_Isolation_Best_Practice_FINAL_100917.pdf
- (2) Siegel, J. D., Rhinehart, E., Jackson, M., Chiarello, L., and the Healthcare Infection Control Practices Advisory Committee. Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. 2007
<https://www.cdc.gov/niosh/docket/archive/pdfs/NIOSH-219/0219-010107-siegel.pdf>
- (3) Health Facilities Scotland. NHSScotland National Cleaning Services Specification. 2016
<http://www.hfs.scot.nhs.uk/publications/1479818599-The%20NHSScotland%20National%20Cleaning%20Services%20Specification%20%20-%20June%202016.pdf>
- (4) Association of Healthcare Cleaning Professionals. Revised Healthcare Cleaning Manual. 2013
<http://www.ahcp.co.uk/downloads/revised-healthcare-cleaning-manual-2009-06-v2.pdf>
- (5) Loveday HP, Wilson JA, Pratt RJ, Golsorkhi M, Tingle A, Bak A, et al. epic3: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. J HOSP INFECT 2014;86S1:S1-S70.
- (6) Sehulster LM, Chinn RYW, Arduino MJ, Carpenter J, Donlan R, Ashford D, et al. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR 2003;52:1-42.
- (7) Mitchell BG, Digney W, Locket P, Dancer SJ. Controlling methicillin-resistant Staphylococcus aureus (MRSA) in a hospital and the role of hydrogen peroxide decontamination: An interrupted time series analysis. BMJ Open 2014;4(4):e004522.
- (8) Vonberg RP, Kuijper EJ, Wilcox MH, Barbut F, Tull P, Gastmeier P, et al. Infection control measures to limit the spread of Clostridium difficile. [Review] [178 refs]. Clinical Microbiology & Infection 2008 May;14:Suppl-20.
- (9) Fraise A. Currently available sporicides for use in healthcare, and their limitations. Journal of Hospital Infection 77 (3) (pp 210-212), 2011 Date of Publication: March 2011 2011;(3):March.
- (10) Wheeldon LJ, Worthington T, Hilton AC, Lambert PA, Elliott TS. Sporicidal activity of two disinfectants against Clostridium difficile spores. Br J Nurs 2008 Mar 13;17(5):316-20.
- (11) Ungurs M, Wand M, Vasse M, Brien S, Dixon D, Walker J, et al. The effectiveness of sodium dichloroisocyanurate treatments against Clostridium difficile spores contaminating stainless steel. AM J INFECT CONTROL 2011 Apr;39(3):199-205.
- (12) Otter JA, Yezli S, French GL. The role played by contaminated surfaces in the transmission of nosocomial pathogens. Infection Control and Hospital Epidemiology 2011 Jul;32(7):687-99.
- (13) Weber DJ, Rutala WA, Miller MB, Huslage K, Sickbert-Bennett E. Role of hospital surfaces in the transmission of emerging health care-associated pathogens: norovirus, Clostridium difficile, and

Acinetobacter species. [Review] [60 refs]. American Journal of Infection Control 2010 Jun;38(5:Suppl 1):Suppl-33.

- (14) Sehulster L, Chinn RY. Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR Recommendations and Reports 2003 Jun 6;52(RR-10):1-42.
- (15) Omidbakhsh N. Evaluation of sporicidal activities of selected environmental surface disinfectants: Carrier tests with the spores of *Clostridium difficile* and its surrogates. Am J Infect Control 2010 Nov;38(9):718-22.
- (16) Whitehead K, McCue KA. Virucidal efficacy of disinfectant actives against feline calicivirus, a surrogate for norovirus, in a short contact time. Am J Infect Control 2010 Feb;38(1):26-30.
- (17) Health and Safety Executive. Control of Substances Hazardous to Health Regulations. 2002
- (18) Carling PC, Von BS, Kim P, Woods C, Healthcare Environmental Hygiene Study Group. Intensive care unit environmental cleaning: an evaluation in sixteen hospitals using a novel assessment tool. Journal of Hospital Infection 2008 Jan;68(1):39-44.
- (19) Carling PC, Parry MF, Von Beheren SM, Healthcare Environmental Hygiene Study Group. Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals. Infection Control & Hospital Epidemiology 2008 Jan;29(1):1-7.
- (20) Alfa MJ, Dueck C, Olson N, DeGagne P, Papetti S, Wald A, et al. UV-visible marker confirms that environmental persistence of *Clostridium difficile* spores in toilets of patients with *C. difficile*-associated diarrhea is associated with lack of compliance with cleaning protocol. BMC Infectious Diseases 2008;8:64.
- (21) Blue J, O'Neill C, Speziale P, Revill J, Ramage L, Ballantyne L. Use of a fluorescent chemical as a quality indicator for a hospital cleaning program. Canadian Journal of Infection Control 2008;23(4):216-9.
- (22) Goodman ER, Platt R, Bass R, Onderdonk AB, Yokoe DS, Huang SS. Impact of an environmental cleaning intervention on the presence of methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci on surfaces in intensive care unit rooms. Infection Control & Hospital Epidemiology 2008 Jul;29(7):593-9.
- (23) Boyce JM, Havill NL, Lipka A, Havill H, Rizvani R. Variations in hospital daily cleaning practices. Infection Control & Hospital Epidemiology 2010 Jan;31(1):99-101.
- (24) Weber DJ, Rutala WA. The role of the environment in transmission of *Clostridium difficile* infection in healthcare facilities. Infect Control Hosp Epidemiol 2011 Mar;32(3):207-9.
- (25) Morter S, Bennet G, Fish J, Richards J, Allen DJ, Nawaz S, et al. Norovirus in the hospital setting: virus introduction and spread within the hospital environment. Journal of Hospital Infection 2011 Feb;77(2):106-12.
- (26) Langer AJ, Lafaro P, Genese CA, McDonough P, Nahass R, Robertson C. Using active microbiologic surveillance and enhanced infection control measures to control an outbreak of health care-associated extended-spectrum beta-lactamase-producing *Klebsiella pneumoniae* infections-New Jersey, 2007. Am J Infect Control 2009;37(1):73-5.

- (27) Giannini MA, Nance D, McCullers JA. Are toilet seats a vector for transmission of methicillin-resistant *Staphylococcus aureus*? *American Journal of Infection Control* 2009 Aug;37(6):505-6.
- (28) Carling PC, Bartley JM. Evaluating hygienic cleaning in health care settings: what you do not know can harm your patients. [Review] [76 refs]. *American Journal of Infection Control* 2010 Jun;38(5:Suppl 1):Suppl-50.
- (29) Markogiannakis A, Fildis G, Tsiplakou S, Ikonomidis A, Koutsoukou A, Pournaras S, et al. Cross-transmission of multidrug-resistant *Acinetobacter baumannii* clonal strains causing episodes of sepsis in a trauma intensive care unit. *Infection Control and Hospital Epidemiology* 29 (5) (pp 410-417), 2008 Date of Publication: May 2008 2008;(5):May.
- (30) Dancer SJ. Hospital cleaning in the 21st century. *European Journal of Clinical Microbiology and Infectious Disease* 2011 Dec;30(12):1473-81.
- (31) Datta R, Platt R, Yokoe DS, Huang SS. Environmental cleaning intervention and risk of acquiring multidrug-resistant organisms from prior room occupants. *Archives of Internal Medicine* 171 (6) (pp 491-494), 2011 Date of Publication: 28 Mar 2011 2011;(6):28.
- (32) Stiefel U, Cadnum JL, Eckstein BC, Guerrero DM, Tima MA, Donskey CJ. Contamination of hands with methicillin-resistant *Staphylococcus aureus* after contact with environmental surfaces and after contact with the skin of colonized patients. *Infection Control and Hospital Epidemiology* 2011 Feb;32(2):185-7.
- (33) Dancer SJ, White LF, Lamb J, Girvan EK, Robertson C. Measuring the effect of enhanced cleaning in a UK hospital: a prospective cross-over study. *BMC Med* 2009;7:28.
- (34) Hota B, Blom DW, Lyle EA, Weinstein RA, Hayden MK. Interventional evaluation of environmental contamination by vancomycin-resistant enterococci: failure of personnel, product, or procedure? *Journal of Hospital Infection* 2009 Feb;71(2):123-31.
- (35) Masterton RG, Galloway A, French G, Street M, Armstrong J, Brown E, et al. Guidelines for the management of hospital-acquired pneumonia in the UK: Report of the working party on hospital-acquired pneumonia of the british society for antimicrobial chemotherapy. *Journal of Antimicrobial Chemotherapy* 62 (1) (pp 5-34), 2008 Date of Publication: Jul 2008 2008;(1):Jul.
- (36) Shaughnessy MK, Micielli RL, DePestel DD, Arndt J, Strachan CL, Welch KB, et al. Evaluation of hospital room assignment and acquisition of *Clostridium difficile* infection. *Infection Control and Hospital Epidemiology* 2011 Mar;32(3):201-6.
- (37) Wilson APR, Smyth D, Moore G, Singleton J, Jackson R, Gant V, et al. The impact of enhanced cleaning within the intensive care unit on contamination of the near-patient environment with hospital pathogens: A randomized crossover study in critical care units in two hospitals. *Critical Care Medicine* 39 (4) (pp 651-658), 2011 Date of Publication: April 2011 2011;(4):April.
- (38) Blazejewski C, Wallet F, Rouze A, Le GR, Ponthieux S, Salleron J, et al. Efficiency of hydrogen peroxide in improving disinfection of ICU rooms. *CRIT CARE* 2015;19:30.
- (39) Otter JA, Yezli S, Schouten MA, van Zanten ARH, Houmes-Zielman G, Nohlmans-Paulssen MKE. Hydrogen peroxide vapour decontamination of an intensive care unit to remove environmental reservoirs of multidrug-resistant gram-negative rods during an outbreak. *AM J INFECT CONTROL* 2010;38:754-6.

- (40) Best EL, Parnell P, Thirkell G, Verity P, Copland M, Else P, et al. Effectiveness of deep cleaning followed by hydrogen peroxide decontamination during high *Clostridium difficile* infection incidence. J HOSP INFECT 2014;87:25-33.
- (41) Manian FA, Griesnauer S, Bryant A. Implementation of hospital-wide enhanced terminal cleaning of targeted patient rooms and its impact on endemic *Clostridium difficile* infection rates. AM J INFECT CONTROL 2013;41:537-41.
- (42) Wilson APR, Livermore DM, Otter JA, Warren RE, Jenks P, Enoch DA. Prevention and control of multi-drug-resistant Gram-negative bacteria: recommendations from a Joint Working Party. J HOSP INFECT 2016;92:S1-S44.
- (43) Advisory Committee on Dangerous Pathogens. Management of Hazard Group 4 viral haemorrhagic fevers and similar human infectious diseases of high consequence. 2015 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/534002/Management_of_VHF_A.pdf
- (44) Miller R, Simmons S, Dale C, Stachowiak J, Stibich M. Utilization and impact of a pulsed-xenon ultraviolet room disinfection system and multidisciplinary care team on *Clostridium difficile* in a long-term acute care facility. AM J INFECT CONTROL 2015;43:1350-3.
- (45) Anderson DJ, Chen LF, Weber DJ, Moehring RW, Lewis SS, Triplett PF, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. The Lancet 2017;389:805-14.
- (46) Pegues DA, Han J, Gilmar C, McDonnell B, Gaynes S. Impact of ultraviolet germicidal irradiation for no-touch terminal room disinfection on *Clostridium difficile* infection incidence among hematology-oncology patients. INFECT CONTROL HOSP EPIDEMIOL 2017;38:39-44.
- (47) Haas JP, Menz J, Dusza S, Montecalvo MA. Implementation and impact of ultraviolet environmental disinfection in an acute care setting. AM J INFECT CONTROL 2014;42:586-90.
- (48) Hosein I, Madeloso R, Nagaratnam W, Villamaria F, Stock E, Jinadatha C. Evaluation of a pulsed xenon ultraviolet light device for isolation room disinfection in a United Kingdom hospital. AM J INFECT CONTROL 2016;44:e157-e161.
- (49) Levin J, Riley LS, Parrish C, English D, Ahn S. The effect of portable pulsed xenon ultraviolet light after terminal cleaning on hospital-associated *Clostridium difficile* infection in a community hospital. AM J INFECT CONTROL 2013;41:746-8.
- (50) Vianna PG, Dale CR, Simmons S, Stibich M, Licitra CM. Impact of pulsed xenon ultraviolet light on hospital-acquired infection rates in a community hospital. AM J INFECT CONTROL 2016;44:299-303.
- (51) Louh IK, Greendyke WG, Hermann EA, Davidson KW, Falzon L, Vawdrey DK, et al. *Clostridium difficile* infection in acute care hospitals: systematic review and best practices for prevention. INFECT CONTROL HOSP EPIDEMIOL 2017;38:476-82.
- (52) Goldenberg SD, Patel A, Tucker D, French GL. Lack of enhanced effect of a chlorine dioxide-based cleaning regimen on environmental contamination with *Clostridium difficile* spores. J HOSP INFECT 2012;82:64-7.

- (53) Conlon-Bingham G, Aldeyab M, Kearney MP, Scott MG, Baldwin N, McElnay JC. Reduction in the incidence of hospital-acquired MRSA following the introduction of a chlorine dioxide 275 ppm based disinfecting agent in a district general hospital. *European Journal of Hospital Pharmacy* 2016;23:28-32.
- (54) Cadnum JL, Jencson AL, O'Donnell MC, Flannery ER, Nerandzic MM, Donskey CJ. An increase in healthcare-associated *Clostridium difficile* infection associated with use of a defective peracetic acid-based surface disinfectant. *INFECT CONTROL HOSP EPIDEMIOL* 2017;38:300-5.
- (55) Deshpande A, Mana TSC, Cadnum JL, Jencson AC, Sitzlar B, Fertelli D, et al. Evaluation of a sporicidal peracetic acid/hydrogen peroxide-based daily disinfectant cleaner. *INFECT CONTROL HOSP EPIDEMIOL* 2014;35:1414-6.
- (56) Smith A, Taggart LR, Lebovic G, Zeynalova N, Khan A, Muller MP. *Clostridium difficile* infection incidence: impact of audit and feedback programme to improve room cleaning. *J HOSP INFECT* 2016;92:161-6.
- (57) Carling PC, Parry MM, Rupp ME, Po JL. Improving cleaning of the environment surrounding patients in 36 acute care hospitals. *INFECT CONTROL HOSP EPIDEMIOL* 2008;29:1035-41.
- (58) Clifford R, Sparks M, Hosford E, Ong A, Richesson D, Fraser S, et al. Correlating cleaning thoroughness with effectiveness and briefly intervening to affect cleaning outcomes: how clean is cleaned? *PLoS ONE* 2016;11:e0155779.
- (59) Dramowski A, Whitelaw A, Cotton MF. Assessment of terminal cleaning in pediatric isolation rooms: options for low-resource settings. *AM J INFECT CONTROL* 2016;44:1558-64.
- (60) Branch-Elliman W, Robillard E, McCarthy J, Gupta K. Direct feedback with the ATP luminometer as a process improvement tool for terminal cleaning of patient rooms. *AM J INFECT CONTROL* 2014;42:195-7.
- (61) Sitzlar B, Deshpande A, Fertelli D, Kundrapu S, Sethi AK, Donskey CJ. An environmental disinfection odyssey: evaluation of sequential interventions to improve disinfection of *Clostridium difficile* isolation rooms. *INFECT CONTROL HOSP EPIDEMIOL* 2013;34:459-65.