Journal of Hospital Infection 113 (2021) 104–114

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Review

Practical recommendations for routine cleaning and disinfection procedures in healthcare institutions: a narrative review

O. Assadian [a,b,*], S. Harbarth [c], M. Vos [d], J.K. Knobloch [e], A. Asensio [f], A.F. Widmer [g]

[a] *Regional Hospital Wiener Neustadt, Wiener Neustadt, Austria*
[b] *Institute for Skin Integrity and Infection Prevention, School of Human and Health Sciences, University of Huddersfield, Huddersfield, UK*
[c] *Infection Control Programme and Division of Infectious Diseases, University of Geneva Hospitals and Faculty of Medicine, Geneva, Switzerland*
[d] *Department of Medical Microbiology and Infectious Diseases, Erasmus MC University Medical Centre Rotterdam, Rotterdam, The Netherlands*
[e] *Institute for Medical Microbiology, Virology and Hygiene, Department for Infection Prevention and Control, University Medical Centre Hamburg-Eppendorf, Hamburg, Germany*
[f] *Preventive Medicine Department, University Hospital Puerta de Hierro-Majadahonda, Madrid, Spain*
[g] *Division of Infectious Diseases and Hospital Epidemiology, University Hospital Basel, University of Basel, Basel, Switzerland*

ARTICLE INFO

Article history:
Received 25 November 2020
Accepted 10 March 2021
Available online 17 March 2021

Keywords:
Disinfection
Frequently touched surfaces
Environmental cleaning
Healthcare-associated infections
Practical recommendation

SUMMARY

Healthcare-associated infections (HAIs) are the most common adverse outcomes due to delivery of medical care. HAIs increase morbidity and mortality, prolong hospital stay, and are associated with additional healthcare costs. Contaminated surfaces, particularly those that are touched frequently, act as reservoirs for pathogens and contribute towards pathogen transmission. Therefore, healthcare hygiene requires a comprehensive approach whereby different strategies may be implemented together, next to targeted, risk-based approaches, in order to reduce the risk of HAIs for patients. This approach includes hand hygiene in conjunction with environmental cleaning and disinfection of surfaces and clinical equipment. This review focuses on routine environmental cleaning and disinfection including areas with a moderate risk of contamination, such as general wards. As scientific evidence has not yet resulted in universally accepted guidelines nor led to universally accepted practical recommendations pertaining to surface cleaning and disinfection, this review provides expert guidance for healthcare workers in their daily practice. It also covers outbreak situations and suggests practical guidance for clinically relevant pathogens. Key elements of environmental cleaning and disinfection, including a fundamental clinical risk assessment, choice of appropriate disinfectants and cleaning equipment, definitions for standardized cleaning processes and the relevance of structured training, are reviewed in detail with a focus on practical topics and implementation.

* Corresponding author. Address: Regional Hospital Wiener Neustadt, Wiener Neustadt, Austria. Tel.: +43 (0)2622 9004 20102.
E-mail address: ojan.assadian@wienerneustadt.lknoe.at (O. Assadian).

https://doi.org/10.1016/j.jhin.2021.03.010

Background

Healthcare-associated infections (HAIs) are the most common adverse outcomes due to the delivery of care [1]. Patients suffer from HAIs from endogenous or exogenous sources. Endogenous HAIs arise from the patients' own microbial flora that become invasive due to favourable conditions, whereas exogenous HAIs are acquired from foreign pathogens to which patients are exposed while being treated for medical or surgical diseases. In Europe, 5–20% of all HAIs are considered to be exogenous infections [2]. However, in general, these infections are difficult to treat, particularly if the nosocomial pathogen is multi-drug resistant, leading to prolonged hospital stay, long-term disability, increasing resistance to antimicrobial agents, higher costs, and increased morbidity and mortality [1].

Approximately half a century ago, contaminated surfaces were considered to play a negligible role in the transmission of HAIs, predominantly in Anglo-American countries. However, numerous studies over the past 50 years have changed this view, and scientific evidence has accumulated [3,4]. Micro-organisms can persist for long periods on surfaces, and spread to patients following direct contact with near-patient surfaces or indirectly via the hands of healthcare workers (HCWs), particularly as hand hygiene compliance among HCWs is, at best, approximately 40% [4–6]. Pathogens that survive on dry surfaces – such as meticillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Acinetobacter* spp. and norovirus – can be isolated from near-patient surfaces and frequently touched surfaces in the healthcare environment [7,8]. Indeed, several studies have shown that subsequent patients are at risk of acquiring the same pathogen as the previous patient if residual surface contamination is not removed by terminal cleaning and disinfection [3,4,9–16]. The Researching Effective Approaches to Cleaning in Hospitals (REACH) trial clearly showed the important role of thorough environmental cleaning in the prevention of HAIs [17]. The study demonstrated that the implementation of a multi-modal cleaning bundle – consisting of component training, technique, product, audit and communication – not only improved the performance, knowledge and attitude of the environmental services staff, but may also reduce the occurrence of clinically important hospital pathogens [17–19]. Thus, although hand hygiene remains the key to success in combatting HAIs, healthcare hygiene should be seen as multi-modal (i.e. as a comprehensive process in which different strategies work together) [7,20–23].

Donskey *et al.* reviewed studies in improved cleaning and disinfection that resulted in reduced HAIs [24]. In addition, Dancer *et al.* were able to show that introducing an additional environmental services staff member for enhanced cleaning of hand-touch sites in surgical wards with endemic *S. aureus* (both MRSA and meticillin-susceptible *S. aureus*) reduced microbial contamination levels by 32.5% and new MRSA infections by 26.6% compared with control wards [25]. Another prospective study by Rutala *et al.* found a 35% reduction in colonization and/or infection with epidemiologically important pathogens when the contamination was reduced by 94% due to enhanced terminal cleaning [26]. Further studies confirmed the positive impact of enhanced environmental cleaning and disinfection protocols on infection and/or colonization rates of MRSA [27], VRE [17,28,29] and *Clostridioides difficile* [16,30–34].

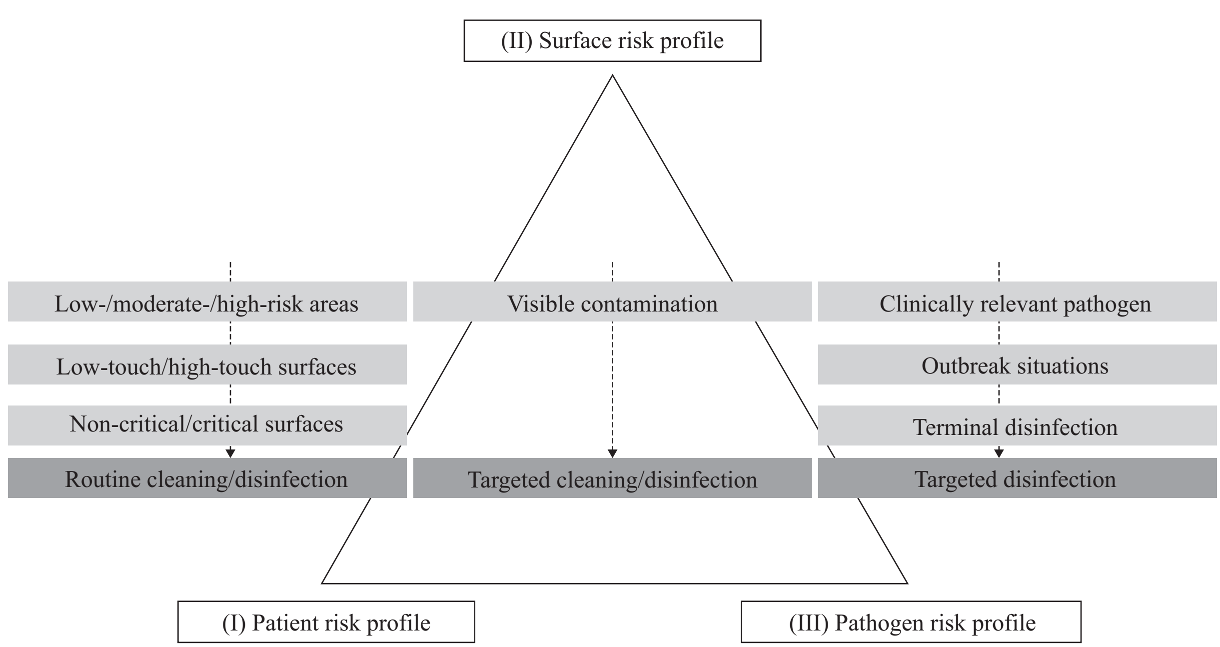

Figure 1. Comprehensive overview of the fundamental principles of a risk analysis.

At present, there are no universally agreed European or global guidelines or practical recommendations for routine surface cleaning and disinfection in hospitals. Some national guidelines do exist, but they differ largely in content and are sometimes incomplete. International cooperation and a societal paradigm shift are needed to recognize the importance of environmental hygiene [35]. Standard principles for cleaning and disinfection must be defined, and compliance should be ensured by measures such as standard operating procedures, adequate training, and suitable audit and monitoring systems [36–38]. In this context, the clean hospitals initiative was founded – a coalition of international stakeholders – with the goal of making healthcare facilities safer through improved environmental hygiene [38].

This review focuses on practical recommendations for routine environmental cleaning and disinfection on general wards, as well as expert guidance for clinically relevant pathogens and outbreak situations (Table III). In some situations, evidence for a strong recommendation is lacking, but HCWs and environmental services staff need guidance, even if sufficient evidence has not been generated to date. Key components are summarized for good cleaning practice on general wards with regard to risk assessment, cleaning processes, disinfectants, equipment and staffing aspects (e.g. training, monitoring, feedback and communication).

Key components

Risk assessment

A generally applicable evidence-based procedure for conducting a risk analysis is not available to date. Theoretical models and scoring systems exist but are generally difficult to implement in practice [29]. Therefore, it is the consensus of the expert panel that the basis of any risk analysis is an overall assessment consisting of three essential factors:

- patient risk profile (vulnerability of patients to infections or colonization);
- surface risk profile (probability of contamination with pathogens and potential for exposure and/or indirect transmission, and frequency of hand contacts); and
- pathogen risk profile (persistence, antibiotic resistance and primary mode of transmission) [39–41].

These three cornerstones are interdependent and must not be understood separately from each other in practice. Figure 1 summarizes a comprehensive overview of these fundamental principles of any risk analysis in the context of cleaning and disinfecting. Once the inter-relationship between the three cornerstones is well understood, an individual risk analysis of hospital wards, areas and surfaces can be performed. Generally, moderate- and high-risk areas are defined by the type of patients accommodated – with patient rooms and bathrooms on general wards considered as moderate-risk areas; and wards that accommodate immunosuppressed and/or critical care patients, as well as bone marrow transplantation units, operating theatres and clean rooms considered as high-risk areas. In the latter, surfaces and/or equipment are frequently and heavily contaminated with potential infectious material, and the risk of infection in these areas is considered high. It is important to note that so-called 'high-risk rooms' may also be located in areas with an otherwise moderate risk. This applies, for example, for a patient room previously occupied by a patient with multi-drug-resistant organisms or *C. difficile*, in which newly admitted patients are at increased risk of infection and in which case terminal disinfection is indicated (for details, see below) [39,40,42,43]. Furthermore, specific items or inventory can be of high risk but situated in a low-risk environment, such as sinks or beds in a general patient room.

In the context of assessing the risks for patients, staff and pathogen transmission, a distinction must be made between high-touch and low-touch surfaces, as well as critical and non-critical surfaces. Low-touch surfaces are not handled by the patient or HCWs and are unlikely to come into contact with the skin. Typical examples are floors, walls or environmental surfaces out of reach or outside the patient zone. High-touch surfaces, on the other hand, are usually close to the patient, are frequently touched by the patient or nursing staff, come into contact with the skin and, due to increased contact, pose a particularly high risk of transmitting pathogens [44–46]. Examples include bedrails, door handles, bedside tables, computer tables and keyboards, medical equipment, call bells and light switches. Areas and surfaces outside the patient zone, such as the hospital canteen, cash machine or lift buttons, should not be disregarded [40,42,47]. However, not all high-touch surfaces pose an equally high risk of infection, which is why a distinction is made between critical and non-critical surfaces. While non-critical surfaces only come into contact with intact skin and thus pose a low risk of infection, critical surfaces come into direct contact with either blood or mucous membranes, or critical items such as needles and intravenous catheters, thus carrying a high risk of infection [37,48,49]. Using the example of surfaces that are used for care procedures or the preparation of intravenous medication, it is clear that even low-touch surfaces can become critical and pose a high risk.

By definition, cleaning comprises the physical removal of dust and soil using water, with or without detergent and mechanical action, until visibly clean. In contrast, the disinfection process aims to eliminate many or all pathogenic micro-organisms to reduce the risk of infection and cross-contamination [38,42,50]. Disinfection goes with cleaning on beforehand to reduce the contamination load and interfering organic matter. Therefore, routine cleaning and disinfection is a combined approach which is usually carried out once a day on general wards, and also as a targeted measure immediately after contamination of a surface with blood or other body fluids [40,42,51,52]. It serves the purpose of removal of organic soil using a neutral detergent or microfibre cloth, followed by application of disinfectant if required. Disinfectants cannot achieve their full potential in the presence of residual surface soil. As there are no universal guidelines and the evidence is unclear, the question arises whether once-daily cleaning and disinfection is sufficient to minimize the risk of transmission, particularly with regard to high-touch surfaces. Terminal cleaning and disinfection of a patient room takes place after a patient has been discharged to prevent potential pathogens on surfaces from spreading to the next patient to occupy the room. Terminal cleaning and disinfection comprises routine cleaning plus cleaning of surfaces that are not accessible in an occupied room, such as the mattress, and surfaces that are generally ignored when a patient is *in situ* (e.g. walls). In addition, bed linen, curtains and disposable items are

Table I
General overview of chemical disinfectants used for environmental disinfection

	Alcohol	Aldehyde	Amine	Chlorine	Oxidative	Phenol	QACs
Antimicrobial spectrum[a]	+−++[a]	++	+/−	++	++	++	+/−
Speed of action[a]	++	−	−	+−++[a]	+−++[a]	−	−
Sporicidal activity[b]	None	Yes	None	Yes	Yes	None	None
Skin compatibility	+	−	−	−	−	−	+
Readily biodegradable[d]	++	+	+	++	++	+	+
Inactivation in presence of proteins	Yes	Yes	None	Yes	Yes	None	None
Material compatibility	May harden rubber and cause deterioration of glues and translucent polymers	Good	Corrosive to metals and rubber, and may cause deterioration of polymers and silicones	Corrosive to metals	May be corrosive to metals	May be absorbed by rubber, and leaves residual film	Good
Typical indication	Small environmental surfaces and insensitive medical device surfaces	Environmental surfaces and medical devices	Environmental surfaces and medical devices	Environmental surfaces and water treatment	Environmental surfaces and medical devices	Rarely used	Environmental surfaces and medical devices
Limitations	Flammable[c]	Potential strong allergen and respiratory irritation	/	Short shelf life and strong odour; occupational health issues for users; formation of by-products possible; respiratory irritation	Respiratory irritation	Not suitable for nurseries or food contact surfaces	Potential irritant

QACs, quaternary ammonium compounds; ++, very good; +, good; +/−, intermediate; −, basic (antimicrobial spectrum)/low (speed of action, skin compatibility).
[a] Depending on formulation (e.g. pH concentration and co-formulants can influence efficacy).
[b] Depending on active ingredient and concentration.
[c] Comply with fire safety regulations.
[d] Readily biodegradable: ability of a chemical compound to decompose after interactions with biological/organic elements.

Table II
General principles of cleaning

Start from least soiled to most soiled areas and from higher to lower levels
Clean nearest to the patient (e.g. bedside table) first and furthest from the patient (e.g. bathroom) last
Prioritize cleaning of hand-touch sites and work through a checklist
Wipe systematically, e.g. in an S-shape, without going over the same area twice
Follow the principle 'one wipe, one site, one direction'
Use a clean/different cloth or wipe for each patient zone (e.g. bed) and throw away wipes/cloths or dispose of them for reprocessing after each site or when visibly dirty
Do not double-dip cloths or leave cloths soaking in solution
Be aware of cross-contamination (e.g. between gloves and cloths) and change cloths frequently
Use detergent to remove soil and disinfectant to kill germs
Remove soil with detergent before using disinfectant if required
Use freshly prepared cleaning fluids according to manufacturer's instructions and change frequently to avoid cross-contamination
Clean bathrooms after cleaning the patient room: start with sink, then the grid, continue with shower/bath, and clean toilet last. Always use new cloth between sink, shower/bath and toilet
Floor cleaning should be performed last
Place warning signs before starting floor cleaning and warn passers-by verbally when floors are wet

removed, and special devices for patient care are cleaned and disinfected. In the case of long-term patients, 'terminal cleaning' (i.e. intensified cleaning) may take place regularly (e.g. monthly) [51].

Disinfectants and equipment

In addition to well-known disinfectants such as alcohol, chlorine, aldehyde, amine, oxidatives (e.g. hydrogen peroxide, peracetic acid), phenolic and quaternary ammonium compounds, a variety of new products such as improved hydrogen peroxide liquid disinfectants, peracetic acid–hydrogen peroxide combinations, electrolysed water and polymeric guanidine are available or in development. Combined cleaning/disinfectant products also exist. Only products approved by regulatory authorities should be used, and the manufacturer's instructions should be followed [38,42,53]. As well as an appropriate spectrum of activity, suitable cleaning/disinfectant products need to comply with occupational health and safety regulations, and must be acceptable to users, staff and patients. A differentiated and comprehensive discussion of occupational safety, toxicity and environmental compatibility issues is beyond the scope of this review. Nevertheless, the expert panel wishes to provide readers with an overview of which characteristics are crucial from a hygiene and patient safety perspective. Table I depicts a summary of benefits and disadvantages of the most commonly used chemical disinfectants for environmental disinfection today.

'No-touch' technologies such as hydrogen peroxide vapour, ozone and unltraviolet-C light technologies are supplementary options, usually for terminal disinfection and outbreak situations. However, the convenience of using these technologies for routine cleaning and disinfection is limited due to cost considerations, regulatory requirements and the need for prior conservative wipe disinfection. Importantly, as pointed out recently in a study comparing the effectiveness of automated room decontamination devices under real-life conditions, further research and development is necessary to gain knowledge about toxicity, efficacy and safety for use in complex hospital conditions, and achieve meaningful integration in cleaning procedures, in order to have a positive effect on disinfection performance [54]. Further advantages and disadvantages of such technologies are discussed elsewhere [37,38,55].

Apart from complex cleaning machines, the usual cleaning and disinfection equipment consists of cloths, wipes, mops (including mop heads, disposable or reusable), buckets and sponges. When choosing the appropriate equipment, as well as hygienic aspects, ergonomic aspects should also be considered. While floors are usually wet-mopped with reusable mops, sinks and toilet seats are preferably cleaned with a cloth, wipe, sponge or similar fabric that may also be disposable [47,51,56]. Reusable mop heads and cloths need to be disinfected thermally by machine washing after use to decrease the risk of potential pathogen transmission. In addition, reprocessing should be standardized, with attention to any wear and tear of items. In some countries, a colour-coding system for identifying equipment for various areas (e.g. red for bathrooms, blue for general areas, green for food-associated areas, yellow for isolation areas) has become well established [42,47,57]. In general, the selected equipment should generate as little dust or aerosol as possible. In addition, all reusable equipment needs to be reprocessed adequately and dried daily. Also, the equipment should be reprocessed and stored in a designated area [51].

Pre-soaked disinfecting wipes have also proven useful (e.g. for rapid decontamination of high-touch surfaces) and, depending on the product, offer advantages such as combined cleaning and disinfection process, fewer application errors, defined concentrations of active ingredients and ease of use. In addition, pre-soaked disinfecting wipes are designed for single use and are disposable, thereby reducing the potential risk of cross-contamination [58–60]. Nevertheless, certain parameters should not be neglected. Methods for efficacy testing need further standardization, and the disinfection performance depends on the disinfectant used, the wipe material and possible interactions between them. Also, the storage time and environmental conditions must be taken into account, and if reusable dispenser systems are used, additional attention must be paid to their regular reprocessing to avoid increased risk of contamination [58,61,62].

Cleaning process and adequate training

Given the lack of detailed protocols and global guidance for the cleaning process, Dancer and Kramer put together a simple four-step protocol (Look, Plan, Clean, Let Dry) for daily cleaning [56]. The most important aspects of the process are summarized in Table II, and readers should refer to the original article for more details. It is the experts' opinion that in order to enable effective cleaning and disinfection of the hospital environment, good management of all personnel-related aspects is extremely important. This includes adequate staffing ratio, remuneration, equipment, training, supervision and team communication. As demonstrated in the REACH trial, communication is one of the key aspects to improve environmental cleaning processes [17–19,38]. However, environmental services staff are often no longer employed directly at the hospital, but are outsourced in many countries [63]; this fragments the ward team and complicates team communication. It is also assumed that the working conditions of outsourced environmental services staff are worse and therefore the motivation is lower [64]. The communication gap between the environmental services staff and HCWs may even be amplified by language barriers because environmental services staff often originate from other countries [38]. Therefore, training materials and protocols should be adapted to the language and educational level of the staff, and should be easy to understand. High-quality training is essential so that environmental services staff understand the importance of proper environmental cleaning and the associated work processes [65]. Regular training and monthly face-to-face feedback help ensure that performance is optimized and good performance is maintained [38,66].

A good training programme ideally consists of different modules, and utilizes various educational techniques based on adult learning theory. Several training methods have been described in the literature as useful to complement written materials (e.g. DVDs, audience response systems, videos, demonstrations, role playing and graphics) [66,67]. Again, training should not only focus on technical aspects but also on communication. For example, it has been proposed that environmental services staff should create a 'customer service' atmosphere when they communicate with patients [65]. To train this, simulation-based communication training with role play and observing interactions between environmental services staff and patients may be suitable [68].

Assessment of cleanliness

In order to maintain the success achieved in the improvement of cleaning performance and for educational purposes, it is necessary to regularly assess the cleaning process as well as surface cleanliness after the cleaner has gone. Both should be defined using validated and risk-assessed strategies. Various methods for the assessment of cleanliness are available today. As all methods have advantages and disadvantages and examine different aspects of the cleaning process, they are best used in reasonable combinations [42,55].

Visual inspection alone is not sufficient because it is subjective and cannot take the patients' risk of infection into account. Other scientific methods should also be used to assess cleanliness in terms of contamination [37,65].

Direct observation or supervision during cleaning with subsequent feedback is particularly suitable for training purposes [42,65,69,70]. It can be used to assess the extent to which the observed environmental services staff adhere to the standardized cleaning process, and which employees have increased training needs. Optimally, observation should take place regularly [42]. The observer can either be on site or observe covertly; the latter, however, is more difficult to accomplish [65,69]. Monitoring should be done on a regular basis and by independent persons who do not belong to the environmental services team (e.g. hospital epidemiologists or infection preventionists) [71,72].

Established methods to assess cleanliness include microbiological sampling and adenosine triphosphate (ATP) bioluminescence assays. Microbiological sampling is commonly used in practice to assess cleanliness in hospitals and food and related industries. Even where standardization is in place, its usefulness in routine monitoring of hospital cleanliness can be limited due to delayed results [37,65,70,73,74]. ATP assays allow the detection of ATP, a fundamental energy source in every living organism, and thereby the direct assessment of cleaning effectiveness and cleanliness. This method is used increasingly in the hospital environment because it is convenient and allows rapid feedback to the environmental services staff [37,42,70,75]. Its routine use, however, remains controversial.

Measuring the cleaning process may also be performed using fluorescent markers; this is a relatively new and easy-to-use strategy. The markers can be applied to high-touch surfaces before the cleaning process. After cleaning, residues that indicate insufficient removal can be made visible using a portable ultraviolet light source [18,37,70,76,77].

In addition to these key components for routine cleaning, it may be necessary to adapt the cleaning due to particular situations that require a change of measures. This primarily relates to pathogens that can occur in the hospital and may cause an outbreak.

Management of clinically relevant pathogens

Some pathogens, such as norovirus or the spores of *C. difficile*, can persist for several weeks in the environment and are relatively tolerant to conventional surface disinfectants. As both environmental infections and patient-to-patient transmission may increase proportionally with the degree of environmental contamination, special efforts must be made to prevent and manage these outbreaks [4,5,45]. In particular, so-called 'marker' multi-drug-resistant organisms, such as MRSA, VRE, *C. difficile* and *Acinetobacter baumannii*, which can be brought into the hospital by asymptomatic persons, can become a major hygiene challenge for hospitals and spread easily through the environment [9]. In the case of norovirus, even the cleaning of contaminated floors can produce infectious aerosols containing viral particles, which patients, employees or visitors ingest, or which settle on surfaces [78].

This review primarily addresses routine cleaning and disinfection on general wards to prevent HAIs. If there is evidence or justified suspicion of contamination with clinically relevant pathogens, special cleaning and disinfection procedures must be used in accordance with the recommendations for the respective pathogen. An exemplary overview of frequently

Table III
Examples of clinically relevant pathogens, required disinfection efficacy and practical recommendations

Organism	Required efficacy	Practical recommendations
Bacteria		
Meticillin-susceptible *Staphylococcus aureus* and other non-drug-resistant staphylococci and enterococci *Escherichia coli* *Klebsiella pneumoniae* and other non-drug-resistant Enterobacterales	S	Standard cleaning/disinfection procedure[a,b]
Bacteria causing gastroenteritis (other than *Clostridioides difficile*), e.g. non-typhoidal *Salmonella* spp., *Campylobacter* spp. or *Shigella* spp.	S	Disinfection of isolation rooms[c] and terminal room disinfection
Bacteria causing respiratory tract infections (other than *Mycobacterium tuberculosis*): *Streptococcus pneumoniae*, *Bordetella pertussis*	S	Disinfection of isolation rooms[c] and terminal room disinfection
Neisseria meningitidis	S	Disinfection of isolation rooms[c] and terminal room disinfection
Multi-drug-resistant bacteria [90–93]		
Meticillin-resistant *Staphylococcus aureus* Vancomycin-resistant enterococci Multi-drug-resistant Gram-negative bacilli	S	Disinfection of isolation rooms and terminal room disinfection Consider complementary decontamination methods (UV-C, H_2O_2 vaporization) for some species or during outbreaks (e.g. vancomycin-resistant enterococci, *Acinetobacter baumannii*)
Mycobacteria		
Mycobacterium tuberculosis	(S); change to T/M [94,95]	Without visible contamination, standard cleaning/disinfection procedure may be sufficient[a]
Spore-forming bacteria		
Clostridioides difficile	Change to SP [96,97]	Disinfection of isolation rooms and terminal room disinfection Consider complementary decontamination methods (UV-C/H_2O_2 vaporization) during outbreaks
Fungi		
Candida albicans *Candida auris*	S	Standard cleaning/disinfection procedure[a,b] Disinfectant with proven yeasticidal efficacy may be sufficient[a]
Viruses		
Enveloped viruses		
SARS-CoV-2 HBV HIV Enveloped viruses causing respiratory tract infections, e.g. respiratory syncytial virus, influenza viruses (A–C) etc.	S incl. envV	Disinfection of isolation rooms and terminal room disinfection Standard cleaning/disinfection procedure[a,b]
Non-enveloped viruses		
Non-enveloped viruses causing gastroenteritis, e.g. norovirus, adenovirus Non-enveloped viruses causing respiratory tract infections, e.g. adenovirus	change to lsV [98–100]	Disinfection of isolation rooms and terminal room disinfection Disinfectant with proven lsV or V efficacy

envV, virucidal activity against enveloped viruses (EN 14776); HBV, hepatitis B virus; HIV, human immunodeficiency virus; lsv, limited spectrum virucidal activity (EN 14476); S, standard efficacy for application in healthcare institutions (bactericidal activity EN 13727, yeasticidal activity EN 13624); SARS-CoV-2, severe acute respiratory syndrome coronavirus-2; SP, sporicidal activity against *Clostridioides difficile* spores (EN 17126); T/M, tuberculocidal activity (*Mycobacterium terrae* EN 14348, mycobactericidal EN 14348); V, virucidal activity (EN 14476); UV-C, ultraviolet C. Recommendations based on guidelines as of 25.09.2020 [40,52,88,89]. Local regulations and guidelines may vary.

[a] According to risk assessment.
[b] Always disinfect high-touch surfaces and visible contamination.
[c] When isolation precautions are indicated.

occurring clinically relevant pathogens and practical recommendations by the expert panel can be found in Table III. There is increasing evidence highlighting that improved environmental hygiene as part of a bundle approach can be a valuable tool to control outbreak situations (e.g. *C. difficile*, VRE, MRSA, multi-drug-resistant Gram-negative bacilli and norovirus) [79–87].

In conclusion, the evidence for environmental cleaning and disinfection to prevent transmission of pathogens is well established, particularly for MRSA, VRE, *C. difficile* and a range of Gram-negative bacteria. This review highlights the need for a bundle of activities, including clinical risk assessment, hand hygiene, evidence-based environmental cleaning and disinfection procedures, structured training for environmental services staff, and timely feedback from cleaning and cleanliness monitoring. Furthermore, there are clear indications for selection of the most appropriate disinfectant and cleaning procedures for clinically relevant pathogens to limit the risk of pathogen transmission from environmental reservoirs. Choosing the right product or method requires not only the appropriate active substance, but also testing of compatibility with the surface and compliance with national and/or local technical and legal requirements. This expert guidance advocates that healthcare hygiene should be seen as a comprehensive approach in which different strategies interrelate to ultimately reduce the number of HAIs.

Acknowledgements

The authors wish to thank Professor Stephanie Dancer (NHS Lanarkshire, Glasgow, UK) for critically reviewing and commenting on the manuscript. Assistance with medical writing was provided by Dr Julia Dittmann (Dittmann Medical Writing, Hamburg, Germany) and financed by BODE Chemie GmbH, a company of the HARTMANN group (Hamburg, Germany).

Conflict of interest statement
None declared.

Funding source
BODE Chemie GmbH provided financial support for the organization of one expert meeting during which the authors discussed the content of this review, and additionally covered the costs of making this publication available in open access format. The content of the article is solely the opinion of the experts. The sponsor had no influence on the content of the article.

References

[1] World Health Organization. The burden of health care-associated infection worldwide. Geneva: WHO; 2011. Available at: https://www.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf?ua=1 [last accessed June 2020].
[2] Gastmeier P. From 'one size fits all' to personalized infection prevention. J Hosp Infect 2020;104:256–60.
[3] Mitchell BG, Dancer SJ, Anderson M, Dehn E. Risk of organism acquisition from prior room occupants: a systematic review and meta-analysis. J Hosp Infect 2015;91:211–7.
[4] Otter JA, Yezli S, French GL. The role played by contaminated surfaces in the transmission of nosocomial pathogens. Infect Control Hosp Epidemiol 2011;32:687–99.
[5] Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infect Dis 2006;6:130.
[6] Sunkesula VCK, Kundrapu S, Knighton S, Cadnum JL, Donskey CJ. A randomized trial to determine the impact of an educational patient hand-hygiene intervention on contamination of hospitalized patient's hands with healthcare-associated pathogens. Infect Control Hosp Epidemiol 2017;38:595–7.
[7] Dancer SJ. The role of environmental cleaning in the control of hospital-acquired infection. J Hosp Infect 2009;73:378–85.
[8] Ledwoch K, Dancer SJ, Otter JA, Kerr K, Roposte D, Rushton L, et al. Beware biofilm! Dry biofilms containing bacterial pathogens on multiple healthcare surfaces; a multi-centre study. J Hosp Infect 2018;100:e47–56.
[9] Chen LF, Knelson LP, Gergen MF, Better OM, Nicholson BP, Woods CW, et al. A prospective study of transmission of multidrug-resistant organisms (MDROs) between environmental sites and hospitalized patients – the TransFER study. Infect Control Hosp Epidemiol 2019;40:47–52.
[10] Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. Arch Intern Med 2006;166:1945–51.
[11] 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. Infect Control Hosp Epidemiol 2011;32:201–6.
[12] Nseir S, Blazejewski C, Lubret R, Wallet F, Courcol R, Durocher A. Risk of acquiring multidrug-resistant Gram-negative bacilli from prior room occupants in the intensive care unit. Clin Microbiol Infect 2011;17:1201–8.
[13] 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. Infect Control Hosp Epidemiol 2011;32:185–7.
[14] Wu Y-L, Yang X-Y, Ding X-X, Li R-J, Pan M-S, Zhao X, et al. Exposure to infected/colonized roommates and prior room occupants increases the risks of healthcare-associated infections with the same organism. J Hosp Infect 2019;101:231–9.
[15] Datta R, Platt R, Yokoe DS, Huang SS. Environmental cleaning intervention and risk of acquiring multidrug-resistant organisms from prior room occupants. Arch Intern Med 2011;171:491–4.
[16] 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. Lancet 2017;389:805–14.
[17] Mitchell BG, White N, Farrington A, Allen M, Page K, Gardner A, et al. Changes in knowledge and attitudes of hospital environmental services staff: the Researching Effective Approaches to Cleaning in Hospitals (REACH) study. Am J Infect Control 2018;46:980–5.
[18] Mitchell BG, Hall L, White N, Barnett AG, Halton K, Paterson DL, et al. An environmental cleaning bundle and health-care-associated infections in hospitals (REACH): a multicentre, randomised trial. Lancet Infect Dis 2019;19:410–8.
[19] Hall L, White NM, Allen M, Farrington A, Mitchell BG, Page K, et al. Effectiveness of a structured, framework-based approach to implementation: the Researching Effective Approaches to Cleaning in Hospitals (REACH) Trial. Antimicrob Resist Infect Control 2020;9:35.
[20] Dancer SJ. Visualising the invisible: why cleaning is important in the control of hospital acquired infections. Evid Based Nurs 2019;22:117.
[21] Protano C, Cammalleri V, Romano Spica V, Valeriani F, Vitali M. Hospital environment as a reservoir for cross transmission: cleaning and disinfection procedures. Ann Ig 2019;31:436–48.

[22] Han JH, Sullivan N, Leas BF, Pegues DA, Kaczmarek JL, Umscheid CA. Cleaning hospital room surfaces to prevent health care-associated infections: a technical brief. Ann Intern Med 2015;163:598–607.
[23] Storr J, Twyman A, Zingg W, Damani N, Kilpatrick C, Reilly J, et al. Core components for effective infection prevention and control programmes: new WHO evidence-based recommendations. Antimicrob Resist Infect Control 2017;6:6.
[24] Donskey CJ. Does improving surface cleaning and disinfection reduce health care-associated infections? Am J Infect Control 2013;41:S12–9.
[25] 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.
[26] Rutala WA, Kanamori H, Gergen MF, Knelson LP, Sickbert-Bennett EE, Chen LF, et al. Enhanced disinfection leads to reduction of microbial contamination and a decrease in patient colonization and infection. Infect Control Hosp Epidemiol 2018;39:1118–21.
[27] Garvey MI, Wilkinson MAC, Bradley CW, Holden KL, Holden E. Wiping out MRSA: effect of introducing a universal disinfection wipe in a large UK teaching hospital. Antimicrob Resist Infect Control 2018;7:155.
[28] Grabsch EA, Mahony AA, Cameron DRM, Martin RD, Heland M, Davey P, et al. Significant reduction in vancomycin-resistant enterococcus colonization and bacteraemia after introduction of a bleach-based cleaning-disinfection programme. J Hosp Infect 2012;82:234–42.
[29] Ko J-H, Kim S-H, Lee NY, Kim Y-J, Cho SY, Kang C-I, et al. Effects of environmental disinfection on the isolation of vancomycin-resistant enterococcus after a hospital-associated outbreak of Middle East respiratory syndrome. Am J Infect Control 2019;47:1516–8.
[30] Orenstein R, Aronhalt KC, McManus Jr JE, Fedraw LA. A targeted strategy to wipe out *Clostridium difficile*. Infect Control Hosp Epidemiol 2011;32:1137–9.
[31] Mayfield JL, Leet T, Miller J, Mundy LM. Environmental control to reduce transmission of *Clostridium difficile*. Clin Infect Dis 2000;31:995–1000.
[32] Wilcox MH, Fawley WN, Wigglesworth N, Parnell P, Verity P, Freeman J. Comparison of the effect of detergent versus hypochlorite cleaning on environmental contamination and incidence of *Clostridium difficile* infection. J Hosp Infect 2003;54:109–14.
[33] Hacek DM, Ogle AM, Fisher A, Robicsek A, Peterson LR. Significant impact of terminal room cleaning with bleach on reducing nosocomial *Clostridium difficile*. Am J Infect Control 2010;38:350–3.
[34] 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.
[35] Tyan K, Cohen PA. Investing in our first line of defense: environmental services workers. Ann Int Med 2020;173:306–7.
[36] Gebel J, Exner M, French G, Chartier Y, Christiansen B, Gemein S, et al. The role of surface disinfection in infection prevention. GMS Hyg Infect Control 2013;8:Doc10.
[37] Dancer SJ. Controlling hospital-acquired infection: focus on the role of the environment and new technologies for decontamination. Clin Microbiol Rev 2014;27:665–90.
[38] Peters A, Otter J, Moldovan A, Parneix P, Voss A, Pittet D. Keeping hospitals clean and safe without breaking the bank; summary of the Healthcare Cleaning Forum 2018. Antimicrob Resist Infect Control 2018;7:132.
[39] Centers for Disease Control and Prevention, Infection. Control Africa Network. Best practices for environmental cleaning in healthcare facilities in resource-limited settings. Atlanta, GA: CDC; 2019. Available at: https://www.cdc.gov/hai/prevent/resource-limited/index.html and http://www.icanetwork.co.za/icanguideline2019/ [last accessed September 2020].
[40] Christiansen B, Dettenkofer M, Becker EM, Eickmann T, Exner M, Heeg P. Anforderungen an die Hygiene bei der Reinigung und Desinfektion von Flächen-Empfehlung der Kommission für Krankenhaushygiene und Infektionsprävention beim Robert-Koch-Institut (RKI). Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz 2004;47:51–61.
[41] Centers for Disease Control and Prevention. Appendix A: Risk assessment. Atlanta, GA: CDC; n.d. Available at: https://www.cdc.gov/hai/prevent/resource-limited/risk-assessment.html [last accessed October 2020].
[42] Provincial Infectious Diseases Advisory Committee (PIDAC). Best practices for environmental cleaning for prevention and control of infections in all health care settings. 3rd ed. Ontario: Public Health Ontario; 2018 Available at: https://www.publichealthontario.ca/-/media/documents/B/2018/bp-environmental-cleaning.pdf [last accessed June 2020].
[43] Anderson DJ, Moehring RW, Weber DJ, Lewis SS, Chen LF, Schwab JC, et al. Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *Clostridium difficile*: a secondary analysis of a multicentre cluster randomised controlled trial with crossover. Lancet Infect Dis 2018;18:845–53.
[44] Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. A quantitative approach to defining 'high-touch' surfaces in hospitals. Infect Control Hosp Epidemiol 2010;31:850–3.
[45] 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. Am J Infect Control 2010;38:S25–33.
[46] Adams CE, Smith J, Watson V, Robertson C, Dancer SJ. Examining the association between surface bioburden and frequently touched sites in intensive care. J Hosp Infect 2017;95:76–80.
[47] Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR Recomm Rep 2003;52:1–48.
[48] Friedman MM. Designing an infection control to meet JCAHO standards. Caring 1996;15:18–25.
[49] Rutala WA, Weber DJ. Surface disinfection: should we do it? J Hosp Infect 2001;48(Suppl. A):S64–8.
[50] Centers for Disease Control and Prevention. Introduction, methods, definition of terms guideline for disinfection and sterilization in healthcare facilities. Atlanta, GA: CDC; 2008. Available at: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/introduction.html [last accessed October 2020].
[51] World Health Organization. Implementation manual to prevent and control the spread of carbapenem-resistant organisms at the national and health care facility level: interim practical manual supporting implementation of the guidelines for the prevention and control of carbapenem-resistant organisms. Geneva: WHO; 2019. Available at: https://apps.who.int/iris/handle/10665/312226 [last accessed June 2020].
[52] Centers for Disease Control and Prevention. Guideline for disinfection and sterilization in healthcare facilities. Atlanta, GA: CDC; 2008 (updated May 2019). Available at: https://www.cdc.gov/Infectioncontrol/Pdf/Guidelines/Disinfection-Guidelines [last accessed September 2020].
[53] Boyce JM. Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals. Antimicrob Resist Infect Control 2016;5:10.
[54] Knobling B, Franke G, Klupp EM, Belmar Campos C, Knobloch JK. Evaluation of the effectiveness of two automated room decontamination devices under real-life conditions. Front Public Heal 2021;9:131.

[55] Dancer SJ. Dos and don'ts for hospital cleaning. Curr Opin Infect Dis 2016;29:415–23.
[56] Dancer SJ, Kramer A. Four steps to clean hospitals: LOOK, PLAN, CLEAN and DRY. J Hosp Infect 2018;103:e1–8.
[57] NHS Trust Foundation. Cleaning and disinfection procedure. ICPr001. London: NHS Trust Foundation; 2020. Available at: https://www.nhft.nhs.uk/download.cfm?doc=docm93jijm4n1414 [last accessed June 2020].
[58] Song X, Vossebein L, Zille A. Efficacy of disinfectant-impregnated wipes used for surface disinfection in hospitals: a review. Antimicrob Resist Infect Control 2019;8:139.
[59] Siani H, Wesgate R, Maillard J-Y. Impact of antimicrobial wipes compared with hypochlorite solution on environmental surface contamination in a health care setting: a double-crossover study. Am J Infect Control 2018;46:1180–7.
[60] Sattar SA, Maillard J-Y. The crucial role of wiping in decontamination of high-touch environmental surfaces: review of current status and directions for the future. Am J Infect Control 2013;41:S97–104.
[61] Bloss R, Meyer S, Kampf G. Adsorption of active ingredients of surface disinfectants depends on the type of fabric used for surface treatment. J Hosp Infect 2010;75:56–61.
[62] Kampf G, Degenhardt S, Lackner S, Jesse K, von Baum H, Ostermeyer C. Poorly processed reusable surface disinfection tissue dispensers may be a source of infection. BMC Infect Dis 2014;14:37.
[63] Davies S. Fragmented management, hospital contract cleaning and infection control. Policy Polit 2010;38:445–63.
[64] Toffolutti V, Reeves A, McKee M, Stuckler D. Outsourcing cleaning services increases MRSA incidence: evidence from 126 english acute trusts. Soc Sci Med 2017;174:64–9.
[65] Leas BF, Sullivan N, Han JH, Pegues DA, Kaczmarek JL, Umscheid CA. Environmental cleaning for the prevention of healthcare-associated infections. Rockville, MD: Agency for Healthcare Research and Quality; 2015.
[66] Rupp T, Sholtz L, Lyden E, Carling PMEF. Maintain the gain program to sustain performance improvement in environmental cleaning. Infect Control Hosp Epidemiol 2014;35:866–8.
[67] Martin EK, Salsgiver EL, Bernstein DA, Simon MS, Greendyke WG, Gramstad JM, et al. Sustained improvement in hospital cleaning associated with a novel education and culture change program for environmental services workers. Infect Control Hosp Epidemiol 2019;40:1024–9.
[68] Rock C, Cosgrove SE, Keller SC, Enos-Graves H, Andonian J, Maragakis LL, et al. Using a human factors engineering approach to improve patient room cleaning and disinfection. Infect Control Hosp Epidemiol 2016;37:1502–6.
[69] Doll M, Stevens M, Bearman G. Environmental cleaning and disinfection of patient areas. Int J Infect Dis 2018;67:52–7.
[70] Deshpande A, Donskey CJ. Practical approaches for assessment of daily and post-discharge room disinfection in healthcare facilities. Curr Infect Dis Rep 2017;19:32.
[71] Knelson LP, Ramadanovic GK, Chen LF, Moehring RW, Lewis SS, Rutala WA, et al. Self-monitoring by environmental services may not accurately measure thoroughness of hospital room cleaning. Infect Control Hosp Epidemiol 2017;38:1371–3.
[72] Guh A, Carling P. Options for evaluating environmental cleaning. Atlanta, GA: Centers for Disease Control and Prevention; 2010. Available at: https://stacks.cdc.gov/view/cdc/47423 [last accessed June 2020].
[73] Rawlinson S, Ciric L, Cloutman-Green E. How to carry out microbiological sampling of healthcare environment surfaces? A review of current evidence. J Hosp Infect 2019;103:363–74.
[74] Smith J, Adams CE, King MF, Noakes CJ, Robertson C, Dancer SJ. Is there an association between airborne and surface microbes in the critical care environment? J Hosp Infect 2018;100:e123–9.
[75] Smith PW, Beam E, Sayles H, Rupp ME, Cavalieri RJ, Gibbs S, et al. Impact of adenosine triphosphate detection and feedback on hospital room cleaning. Infect Control Hosp Epidemiol 2014;35:564–9.
[76] Rutala WA, Weber DJ. Best practices for disinfection of non-critical environmental surfaces and equipment in health care facilities: a bundle approach. Am J Infect Control 2019;47S:A96–105.
[77] Eckstein BC, Adams DA, Eckstein EC, Rao A, Sethi AK, Yadavalli GK, et al. Reduction of *Clostridium difficile* and vancomycin-resistant enterococcus contamination of environmental surfaces after an intervention to improve cleaning methods. BMC Infect Dis 2007;7:61.
[78] Ciofi-Silva CL, Bruna CQM, Carmona RCC, Almeida A, Santos FCP, Inada NM, et al. Norovirus recovery from floors and air after various decontamination protocols. J Hosp Infect 2019;103:328–34.
[79] Lai CK, Wong SY, Lee SS, Siu HK, Chiu CY, Tsang DN, et al. A hospital-wide screening programme to control an outbreak of vancomycin-resistant enterococci in a large tertiary hospital in Hong Kong. Hong Kong Med J 2017;23:140–9.
[80] Brown NM, Reacher M, Rice W, Roddick I, Reeve L, Verlander NQ, et al. An outbreak of meticillin-resistant *Staphylococcus aureus* colonization in a neonatal intensive care unit: use of a case-control study to investigate and control it and lessons learnt. J Hosp Infect 2019;103:35–43.
[81] Bharadwaj S, Ho SK, Khong KC, Seet A, Yeo KC, Chan XY, et al. Eliminating MRSA transmission in a tertiary neonatal unit – a quality improvement initiative. Am J Infect Control 2019;47:1329–35.
[82] Baier C, Ipaktchi R, Ebadi E, Limbourg A, Mett TR, Vogt PM, et al. A multimodal infection control concept in a burn intensive care unit – lessons learnt from a meticillin-resistant *Staphylococcus aureus* outbreak. J Hosp Infect 2018;98:127–33.
[83] Denton M, Wilcox MH, Parnell P, Green D, Keer V, Hawkey PM, et al. Role of environmental cleaning in controlling an outbreak of *Acinetobacter baumannii* on a neurosurgical intensive care unit. J Hosp Infect 2004;56:106–10.
[84] Greig JD, Lee MB. A review of nosocomial norovirus outbreaks: infection control interventions found effective. Epidemiol Infect 2012;140:1151–60.
[85] Casini B, Righi A, De Feo N, Totaro M, Giorgi S, Zezza L, et al. Improving cleaning and disinfection of high-touch surfaces in intensive care during carbapenem-resistant *Acinetobacter baumannii* endemo-epidemic situations. Int J Environ Res Public Health 2018;15:2305.
[86] Doidge M, Allworth AM, Woods M, Marshall P, Terry M, O'Brien K, et al. Control of an outbreak of carbapenem-resistant *Acinetobacter baumannii* in Australia after introduction of environmental cleaning with a commercial oxidizing disinfectant. Infect Control Hosp Epidemiol 2010;31:418–20.
[87] Kreidl P, Mayr A, Hinterberger G, Berktold M, Knabl L, Fuchs S, et al. Outbreak report: a nosocomial outbreak of vancomycin resistant enterococci in a solid organ transplant unit. Antimicrob Resist Infect Control 2018;7:86.
[88] Infektionsprävention im Rahmen der Pflege und Behandlung von Patienten mit übertragbaren Krankheiten. Empfehlung der Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz 2015;58:1151–70.
[89] Centers for Disease Control and Prevention. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. Atlanta, GA: CDC; 2007 (updated July 2017). Available at: https://www.cdc.gov/Infectioncontrol/Pdf/Guidelines/Isolation-Guidelines-HPdf [last accessed September 2020].
[90] Hygienemaßnahmen bei Infektionen oder Besiedlung mit multiresistenten gramnegativen Stäbchen. Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz 2012;55:1311–54.
[91] Ruscher C. Empfehlungen zur Prävention und Kontrolle von Methicillinresistenten Staphylococcus aureus-Stämmen (MRSA)

in medizinischen und pflegerischen Einrichtungen [Erratum in Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2015;58:654]. Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz 2014;57:696–732.

[92] Siegel JD, Rhinehart E, Jackson M, Chiarello L. Management of multidrug-resistant organisms in health care settings, 2006. Am J Infect Control 2007;35:S165–93.

[93] Hygienemaßnahmen zur Prävention der Infektion durch Enterokokken mit speziellen Antibiotikaresistenzen. Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz 2018;61:1310–61.

[94] Ziegler R, Just H-M, Castell S, Diel R, Gastmeier P, Haas W, et al. Tuberculosis infection control – recommendations of the DZK. Gesundheitswes 2012;74:337–50.

[95] Jensen PA, Lambert LA, Iademarco MF, Ridzon R. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care settings, 2005. MMWR Recomm Reports Morb Mortal Wkly Report Recomm Reports 2005;54:1–141.

[96] McDonald LC, Gerding DN, Johnson S, Bakken JS, Carroll KC, Coffin SE, et al. Clinical practice guidelines for *Clostridium difficile* infection in adults and children: 2017 update by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA). Clin Infect Dis 2018;66:987–94.

[97] Hygienemaßnahmen bei Clostridioides difficile-Infektion (CDI). Empfehlung der Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2019;62:906–23.

[98] MacCannell T, Umscheid CA, Agarwal RK, Lee I, Kuntz G, Stevenson KB. Guideline for the prevention and control of norovirus gastroenteritis outbreaks in healthcare settings. Infect Control Hosp Epidemiol 2011;32:939–69.

[99] DIN EN14476. Chemical disinfectants and antiseptics – Quantitative suspension test for the evaluation of virucidal activity in the medical area – Test method and requirements (Phase 2/Step 1) (includes Amendment: 2019).

[100] Schwebke I, Eggers M, Gebel J, Geisel B, Glebe D, Rapp I, et al. Prüfung und Deklaration der Wirksamkeit von Desinfektionsmitteln gegen Viren zur Anwendung im human-medizinischen Bereich: Stellungnahme des Arbeitskreises Viruzidie beim Robert Koch-Institut. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2017;60:353–63.