Journal of Hospital Infection 103 (2019) e16–e22

Available online at www.sciencedirect.com

Journal of Hospital Infection

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

Review

'Off the rails': hospital bed rail design, contamination, and the evaluation of their microbial ecology

M.A. Boyle [a,*,†], A. Kearney [a,†], P.C. Carling [b], H. Humphreys [a,c]

[a] *Department of Clinical Microbiology, Royal College of Surgeons in Ireland, Dublin, Ireland*
[b] *Department of Infectious Diseases, Carney Hospital and Boston University School of Medicine, Boston, USA*
[c] *Department of Microbiology, Beaumont Hospital, Dublin, Ireland*

A R T I C L E I N F O

Article history:
Received 2 May 2019
Accepted 17 June 2019
Available online 21 June 2019

Keywords:
Bed rails
Disinfection
Decontamination
Intensive care unit
High-touch objects
Study design

S U M M A R Y

Microbial contamination of the near-patient environment is an acknowledged reservoir for nosocomial pathogens. The hospital bed and specifically bed rails have been shown to be frequently and heavily contaminated in observational and interventional studies. Whereas the complexity of bed rail design has evolved over the years, the microbial contamination of these surfaces has been incompletely evaluated. In many published studies, key design variables are not described, compromising the extrapolation of results to other settings. This report reviews the evolving structure of hospital beds and bed rails, the possible impact of different design elements on microbial contamination and their role in pathogen transmission. Our findings support the need for clearly defined standardized assessment protocols to accurately assess bed rail and similar patient zone surface levels of contamination, as part of environmental hygiene investigations.

Introduction

Healthcare-associated infections (HCAIs) are responsible for considerable burdens of morbidity and mortality globally. The magnitude of this problem is especially remarkable in critical care units, with a recent European point prevalence survey observing that 8.3% of patients in such units require treatment for at least one HCAI [1]. The hospital environment is a recognized reservoir and vector of nosocomial pathogens, and plays an established role in pathogen transmission in critical care areas [2]. In research studies and in decontamination guidelines, considerable attention has been given to surfaces nearest to patients [3]. Within this near-patient environment, bed rails have been shown to be the most highly contaminated surface [4–7] and the most frequently touched by the hands of healthcare workers [4,8,9]. Bed rails are required for the majority of patients admitted in critical care, and these must be integrated to the hospital bed [10], making their presence almost inevitable within the critical care environment.

Nosocomial pathogens have been isolated from bed rails in active critical care units. These include meticillin-resistant *Staphylococcus aureus* (MRSA) [4,11–13], *Acinetobacter* spp. [14,15], vancomycin-resistant enterococci (VRE) [11,16], *Clostridium difficile* [17] and carbapenem-resistant *Klebsiella pneumoniae* (CRKP) [18]. *C. difficile* spores have been found on bed rails after routine cleaning [17]. A number of outbreak

* Corresponding author. Address: Royal College of Surgeons in Ireland, Clinical Microbiology, RCSI Education & Research Centre, Beaumont Hospital, Dublin 9, Ireland. Tel.: +35 3857351937.
E-mail address: mboyle@rcsi.ie (M.A. Boyle).
† Both authors contributed equally to this work.

https://doi.org/10.1016/j.jhin.2019.06.008
0195-6701/

Table I
Bed rail configurations and their potential impact on research studies

Bed attribute	Options	Possible effect
Clinical area	There are numerous inpatient areas which house patients with a broad spectrum of care requirements	Affects the level of interaction with the bed rail, e.g. higher bed rail use in the intensive care unit
Bed rail type	A. Full length B. Half length C. Quarter length D. Two-thirds length E. Split	1. Affects the surface area or potential area to be sampled 2. Affects where the bed rail is handled
Bed controls	A. Integrated into bed rail B. Non-integrated	Affects the level of interaction with the bed rail
Composite material	A. Metal, e.g. stainless steel B. Plastic, e.g. polypropylene	1. Affects microbial interactions with the surface 2. Affects how the surface is cleaned 3. Affects ATP recovery levels
Surface finish	A. Powder-coated steel B. Plastic-coated steel C. Injection-moulded texturing	1. Affects how cleanable the surface is 2. Affects microbial interactions with the surface

ATP, adenosine triphosphate.

reports have also documented the involvement of bed rails in transmission clusters of the causative outbreak organism, although the degree of involvement is difficult to quantify given the dynamic nature of the critical care environment [18,19].

Although the hospital bed emerged from a single standard design, its development as a medical device as well as increasing competition between manufacturers has resulted in an assortment of configurations and compositions being available (Table I). The humble bed rail, once comprised of detachable metal bars, has evolved to be more complex as well as integrated and may be composed of metal or plastic. There is no universally accepted standard design and healthcare facilities may use a variety of them in multiple departments (Figure 1).

While developing a protocol for microbial sampling of bed rails as part of a longitudinal decontamination intervention study within a critical care unit, we planned to use previously published bed rail sampling protocols. When appraising published literature, it was noted that bed rail characteristics and sampling location are rarely mentioned, making comparison of studies challenging. Accordingly, we evaluated the scientific literature to better understand the variability of modern bed rail composition and its potential impact on contamination, decontamination, and the assessment of both.

Bed rails as potential sources of infection

Observational studies show that bed rails in critical care are sites of frequent hand-touch contact by healthcare workers, with one study observing that nurses touch bed rails more than 13 times hourly [20,21]. Frequent contact with these high-touch sites often results in soiling with microbial pathogens which have the capacity to survive for long periods until adequately decontaminated by cleaning. Routine cleaning of these surfaces is often inadequate [9,22], and microbial populations tend to rebound quickly to previous levels even when decontaminated thoroughly [23].

Although many studies that include bed rails take place in critical care units, few have implicated bed rails in pathogen transmission with resultant patient infections. This is likely to be a result of the paucity of studies undertaking sufficient analysis to conclusively determine such a transmission event, rather than this outcome rarely occurring. Investigations by Dancer *et al.* recovered MRSA from the bed rail of a critical care patient not known to be colonized with MRSA [13]. They used *spa* typing and whole-genome sequencing to identify transmission pathways of *S. aureus* in a 10-bedded Scottish critical care unit under non-outbreak conditions. This included environmental sampling (including bed rails), sampling of healthcare worker hands, and screening of patients. Single nucleotide polymorphisms (SNPs) and number of days between isolate recoveries were used to determine isolate relatedness. Thirty-four transmission pathways of *S. aureus* were identified, and bed rails were implicated in five of these. Similarly, a study by Bonten *et al.* recovered VRE from the bed rails of ten patients in an endemic setting [16]. These patients were not colonized at the time. Two of these patients subsequently acquired VRE of a genotype identical to that recovered from their bed rails. The increasing prevalence and access to genomic techniques for large numbers of samples will likely further implicate fomites such as bed rails in transmission cycles of HCAI pathogens.

A study by Catalano *et al.* reported on an outbreak of *A. baumannii* on a neurosurgical intensive care unit over a four-month period [19]. Following environmental screening, isolates of the same strain were identified from one patient and one bed rail. The patient had been discharged from the unit nine days prior to recovery of the bed rail isolate, indicating that the bed rail had harboured the isolate for at least part of this time. There were no other patients colonized or being treated for infections with this strain throughout this nine-day period.

During a prolonged outbreak of CRKP in Beijing, bed rail involvement was identified in transmission clusters involving the outbreak organism [18]. Prospective sampling of patients, healthcare worker hands and gowns, and environmental sites was undertaken across five critical care units in a tertiary care centre. Isolates ($N = 64$) were recovered from patients either colonized or treated for a CRKP. Nine clusters with indistinguishable isolates were identified using pulsed-field gel electrophoresis (PFGE). Bed rails were involved in four of these nine clusters. On two occasions, isolates of the same PFGE type were recovered from a bed rail and another environmental sample from a different patient bed space on the same ward on the same date. On another occasion, CRKP was recovered from a bed rail that was linked with clinical isolates (sputum) from three patients on a separate critical care unit.

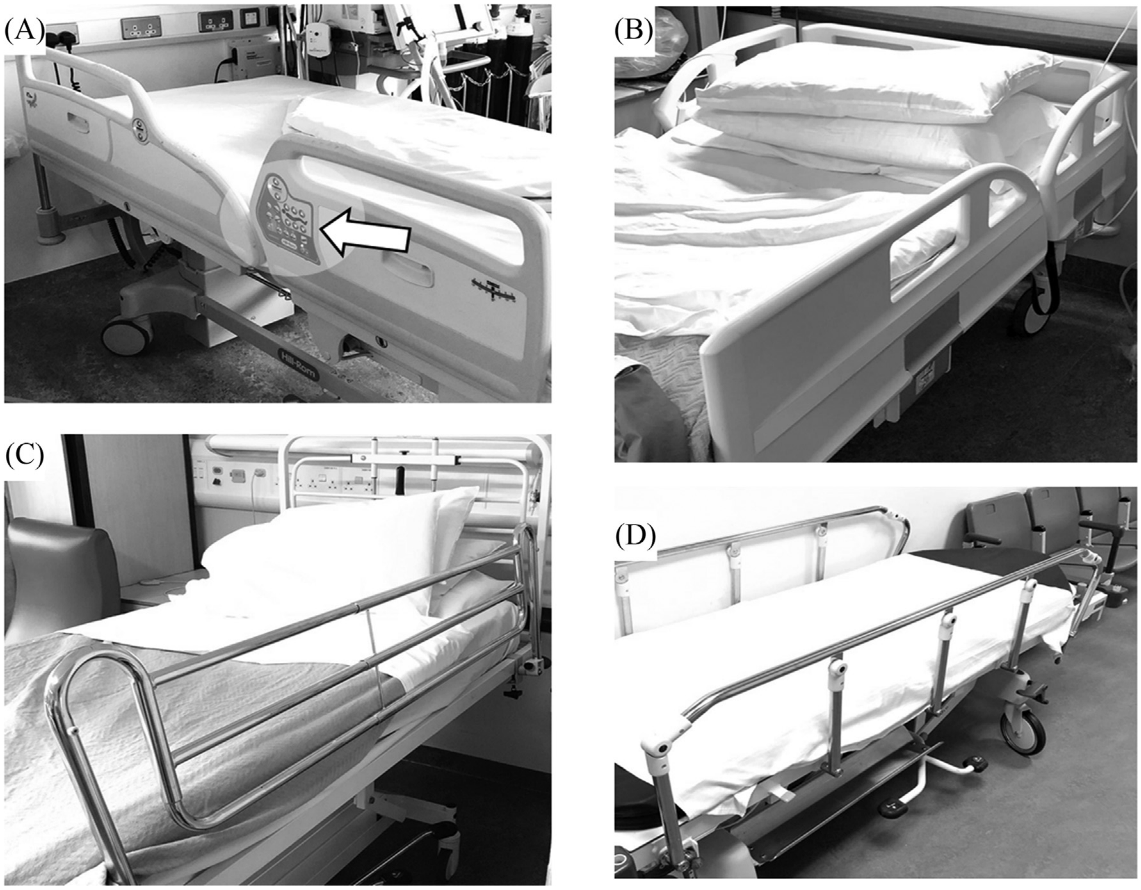

Figure 1. A selection of different bed rail designs in use in a single hospital. A and B are split bed rails made of a polymer where A has integrated controls (indicated by a white arrow). C and D are metal bed rails, C is a three-quarter length rail and D is a full-length folding bedrail.

Relevant bed rail characteristics warrant inclusion in research studies

Studies were identified that included bed rails and were set in critical care units. Although a large number of studies include bed rails from a variety of patient care areas, for illustrative purposes we focused only on those set in critical care and compared how bed rails were described or alluded to by the authors, resulting in 23 studies which are included in Table II [4,5,8,9,11,13,15,16,18,19,21,23,27–30,32,33,35–39]. Specific bed rail design elements were described in only five of these studies. Of these, two were interventions that involved copper surface installations [23,38] and one involved the installation of disposable bed rail covers comprised of a copper and silver polymer [37]. Two studies evaluating the use of ultraviolet light generators failed to describe the bed rails evaluated despite reporting high levels of contamination, including pathogenic bacteria [40,41].

An assumption about the uniformity of the hospital bed exists within the scientific literature, an idea exemplified by an interventional study where bed rails were described simply as a component of a 'standard hospital bed' [42]. Yet the 'standard hospital bed' no longer exists, as illustrated by the UK's National Health Service procurement system where there are more than 60 options [43]. Local factors, the perspectives of researchers or the study setting may also impact on the research design and hence the results. For example, mechano-electric split rail polypropylene bed rails have been in common use in the USA for many years, but are only recently gaining prominence in European critical care units. This is demonstrated by a 2012 US study which used a polypropylene bed rail [44] and five years later a UK study [33] where the bed rail material was not mentioned but a three-quarter-length metal bed rail is illustrated.

The material and physical properties of a surface may affect the likelihood that surfaces will become contaminated and the efficiency with which it can be cleaned. Traditionally, bed rails were predominantly composed of stainless steel or polished aluminium alloy. Integrated bed control panels (Figure 1) are composed of injection-moulded plastics such as polypropylene or acrylonitrile butadiene styrene (ABS) which has a higher tensile strength. Injection moulding of the plastic can provide texturing of the surface to increase the friction coefficient and allow for greater grip for certain bed models. Despite this, the type or material properties of bed rails in published research are rarely reported. Surface material affects cleanability, where it has been shown that there are differences between adenosine triphosphate (ATP) bioluminescence levels according to surface composition such as ABS and stainless steel, where there may be variance in colony-forming unit counts [45]. In a laboratory-based assessment of the adherence of bacteria to different surfaces following conventional hospital cleaning techniques and microfibre cloth, bacteria were more difficult to remove from rougher surfaces (i.e. polyurethane)

Table II
Observational and intervention studies in critical care units which assessed hospital bed rails

Year	Country	Study design	Description of bed	Image of bed	Findings	Ref.
1996	USA	Observation	None given	No	VRE was recovered from bed rails of ten patients	[16]
1999	Argentina	Observation	None given	No	Three outbreak strains of *A. baumannii* were isolated from bed rails	[24]
2008	USA	Intervention	None given	No	The bed rails were the only site to have decreased surface cleanliness after the intervention	[25]
2010	USA	Observation	None given	No	Bed rail most frequently touched object in ICU	[26]
2011	UK	Intervention	None given	No	Bed rail most frequently contaminated near-patient surface	[27]
2012	USA	Observation	InTouch Critical Care Bed (Stryker)	No	Cleaning reduced the bacterial burden on the bed rails, but the numbers of microbes rebounded quickly	[11]
2013	UK	Observation	None given	No	Bed rail most frequently contaminated near-patient surface	[8]
2013	USA	Intervention	InTouch Critical Care Bed (Stryker)	No	Cleaning reduced bacterial burden on the bed rails, but the numbers rebounded quickly	[23]
2013	UK	Observation	None given but material of bed rails described as 'metal' in supplementary material	No	Bed rails were the fourth most contaminated HTO after bed wheels, bedside table, storage trolley and alcohol hand gel	[28]
2013	USA	Intervention	None given	No	Enhanced cleaning increased removal of fluorescent marks and was associated with a non-significant reduction in the contamination of gloves and gowns	[29]
2014	USA	Intervention	None given	No	Feedback increased cleaning efficacy	[30]
2015	Australia	Observation	None given	No	Use of ATP was significantly associated with the identification of MDRO sites including the bed rail	[15]
2015	Taiwan	Intervention	None given	No	Bed rails had the lowest ATP reading of all sites	[5]
2015	China	Intervention	None given	No	Bed rails were negative for MRSA before cleaning by environmental service workers but were positive after cleaning	[31]
2016	Chile	Intervention	Polypropylene bed rails	Alternative split bed rail	99% reduction of bioburden on bed rail when using copper	[32]
2017	UK	Observation	None given	3/4 length metal bed rail	Most contaminated sites were right then left bed rails	[33]
2017	USA	Observation	None given	No	Bed rail most frequently touched object after COW	[4]
2017	China	Intervention	None given	Plastic split bed rails without inbuilt controls	16% of HTOs positive for MDROs prior to intervention vs 4.7% post	[34]
2017	Australia	Observation	None given	No	ESBL was isolated from a bed rail. Material composition of surfaces influenced the diversity of attached bacterial communities	[35]
2018	Austria	Observation	None given	No	Bed rail most frequently contaminated near patient surface	[36]

(*continued on next page*)

Table II (*continued*)

Year	Country	Study design	Description of bed	Image of bed	Findings	Ref.
2018	USA	Intervention	Hill Rom model P3200 bed made of 'standard textured polypropylene'	No	The covers on the bed rails decreased the microbial soil by >80% but this effect had diminished by day 15	[37]
2019	China	Observation	None given	No	Carbapenem-resistant *Klebsiella pneumoniae* recovered from 10/81 bed rail samples. Bed rails were involved in four transmission clusters between patients and other environmental sites.	[18]
2019	UK	Observation	None given	No	*S. aureus* including MRSA recovered from bed rails. Bed rails implicated in 5/34 transmission events	[13]

ICU, intensive care unit; HTO, high-touch object; ATP, adenosine triphosphate; MDRO, multidrug-resistant organism; MRSA, meticillin-resistant *Staphylococcus aureus*; COW, computer on wheels; ESBL, extended-spectrum β-lactamases.

than those that were smoother (i.e. stainless steel) [19]. Surface finish is closely related to composition, and this can affect both how bed rails can become and remain contaminated (bacterial transfer and survival) as well as how they are best decontaminated (ease of removal of soiling, surface roughness). Surface finish is variable from the smoothness of stainless steel to the deliberate texturing of injection-moulded plastics.

The majority of publications relating to bed rails give details of the sampling technique used, e.g. swabbing or contact plates, as recovery may vary between these methods [9]. Typically, when describing study methodology, the area size sampled is given with the corresponding results expressed in levels of contamination per area size, e.g. 5 cfu/cm^2 [6,21,33]. The specific area of the bed rail sampled is rarely addressed, though a bed rail's size and associated surface area can vary between manufacturers. Bed rail type (e.g. full-length, half-length etc.) and configuration affect the potential sampling or targeting area and will also affect where the 'hot-spots' for high-frequency hand touch are. In addition, integrated controls in a bed rail may influence how frequently the bed rail is interacted with. Even if it is assumed that the middle of the bed rail has been sampled, the split bed-rail configuration is essentially four bed rails instead of the traditional two. Sampling also rarely notes which bed rail was sampled, with few studies distinguishing between left and right bed rails.

A study by Pati *et al.* assessed the influence of whether a nurse was left- or right-handed on the side of the patient bed that was approached to deliver care [28]. Whereas handedness had some influence, external factors such as distance from the door or the position of the intravenous line were more influential. Studies that have determined which bed rail is sampled have demonstrated differences between contamination levels [17,42] and differences in the removal of ATP between left and right bed rails [31]. Dancer *et al.* found that bed rails were implicated in five out of 34 observed transmission episodes of *S. aureus* in a critical care unit. The left bed rail was involved in four of these episodes, and the right bed rail in one [13].

Conclusions and recommendations

The literature confirms that hospital bed rails are contaminated sites that are frequently touched, and therefore this has implications for HCAI transmission. The modern hospital bed is a more complex device than the traditional non-mechanized version of previous years. Unfortunately, information about hospital bed rails used in studies is not uniformly or accurately reported, possibly due to the belief that it is reasonable to assume that all hospital beds are the same. Variation in the shape, surface area and material finish of bed rails may affect levels of contamination and hospital cleaning policies, and studies often do not fully address the differences in bed rails. Many studies related to these issues have failed to clearly define the details of the structures evaluated, thereby limiting the ability to draw conclusions from these reports.

All evaluations of the microbial ecology of bed rails should describe a standardized and objectively described approach to sampling in order to optimally characterize healthcare-associated pathogen contamination. Such an approach will facilitate meaningful comparisons between studies on levels of contamination, the prevalence of key pathogens, and efficacious interventions to minimize the risk of pathogen transmission.

Conflict of interest statement

H.H. is in receipt of research funds from Astellas and Pfizer and has received a consultancy fee from Pfizer (Ireland) in the last five years. P.C. has licensed patents and is a consultant to Ecolab. M.A.B. and A.K. have no conflicts of interest to declare.

Funding source

Research related to this publication is being funded by the Health Research Board in Ireland (HRA-D12015-1141).

References

[1] European Centre for Disease Prevention and Control. Healthcare-associated infections acquired in intensive care units. Stockholm: ECDC; 2017.
[2] 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. Intens Crit Care Nurs 2005;21:94–8.
[3] World Health Organization | About Save Lives. Clean your hands. Geneva: WHO; 2013. Available at: https://www.who.int/gpsc/5may/background/5moments/en/ [last accessed February 2019].
[4] Jinadatha C, Villamaria FC, Coppin JD, Dale CR, Williams MD, Whitworth R, et al. Interaction of healthcare worker hands and portable medical equipment: a sequence analysis to show potential transmission opportunities. BMC Infect Dis 2017;17:800.
[5] Chan M-C, Lin T-Y, Chiu Y-H, Huang T-F, Chiu S-K, Liu T-L, et al. Applying ATP bioluminescence to design and evaluate a successful new intensive care unit cleaning programme. J Hosp Infect 2015;90:344–6.
[6] Bogusz A, Stewart M, Hunter J, Yip B, Reid D, Robertson C, et al. How quickly do hospital surfaces become contaminated after detergent cleaning? Healthcare Infect 2013;18:3–9.
[7] Oie S, Suenaga S, Sawa A, Kamiya A. Association between isolation sites of methicillin-resistant *Staphylococcus aureus* (MRSA) in patients with MRSA-positive body sites and MRSA contamination in their surrounding environmental surfaces. Jpn J Infect Dis 2007;60:367–9.
[8] Moore G, Muzslay M, Peter A, Wilson R, Wilson APR. The type, level, and distribution of microorganisms within the ward environment: a zonal analysis of an intensive care unit and a gastrointestinal surgical ward. Infect Control Hosp Epidemiol 2013;34:500–6.
[9] 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. Infect Control Hosp Epidemiol 2008;29:593–9.
[10] Medicines and Healthcare products Regulatory Agency. Safe use of bed rails, vol. 2014. London: MHRA; 2011.
[11] Attaway HH, Fairey S, Steed LL, Salgado CD, Michels HT, Schmidt MG. Intrinsic bacterial burden associated with intensive care unit hospital beds: effects of disinfection on population recovery and mitigation of potential infection risk. Am J Infect Control 2012;40:907–12.
[12] Sigler V, Hensley S. Persistence of mixed staphylococci assemblages following disinfection of hospital room surfaces. J Hosp Infect 2013;83:253–6.
[13] Dancer SJ, Adams CE, Smith J, Pichon B, Kearns A, Morrison D. Tracking *Staphylococcus aureus* in ICU using whole-genome sequencing. J Hosp Infect 2019 Apr 27 [Epub ahead of print].
[14] Anderson DJ, Gergen MF, Smathers E, Sexton DJ, Chen LF, Weber DJ, et al. Decontamination of targeted pathogens from patient rooms using an automated ultraviolet-C-emitting device. Infect Control Hosp Epidemiol 2013;34:466–71.
[15] Whiteley GS, Knight JL, Derry CW, Jensen SO, Vickery K, Gosbell IB. A pilot study into locating the bad bugs in a busy intensive care unit. Am J Infect Control 2015;43:1270–5.
[16] Bonten MJ, Hayden MK, Nathan C, Van Voorhis J, Matushek M, Slaughter S, et al. Epidemiology of colonisation of patients and environment with vancomycin-resistant enterococci. Lancet 1996;348:1615–9.
[17] Sjöberg M, Eriksson M, Andersson J, Norén T. Transmission of *Clostridium difficile* spores in isolation room environments and through hospital beds. APMIS 2014;122:800–3.
[18] Yan Z, Zhou Y, Du M, Bai Y, Liu B, Gong M, et al. Prospective investigation of carbapenem-resistant *Klebsiella pneumonia* transmission among the staff, environment and patients in five major intensive care units, Beijing. J Hosp Infect 2019;101:150–7.
[19] Catalano M, Quelle LS, Jeric PE, Di Martino A, Maimone SM. Survival of *Acinetobacter baumannii* on bed rails during an outbreak and during sporadic cases. J Hosp Infect 1999;42:27–35.
[20] Cheng VCC, Chau PH, Lee WM, Ho SKY, Lee DWY, So SYC, et al. Hand-touch contact assessment of high-touch and mutual-touch surfaces among healthcare workers, patients, and visitors. J Hosp Infect 2015;90:220–5.
[21] 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.
[22] Carling PC, Briggs J, Hylander D, Perkins J. An evaluation of patient area cleaning in 3 hospitals using a novel targeting methodology. Am J Infect Control 2006;34:513–9.
[23] Schmidt MG, Attaway HH, Fairey SE, Steed LL, Michels HT, Salgado CD. Copper continuously limits the concentration of bacteria resident on bed rails within the intensive care unit. Infect Control Hosp Epidemiol 2013;34:530–3.
[24] 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. Crit Care Med 2011;39:651–8.
[25] Gaudart J, Cloutman-Green E, Guillas S, D'Arcy N, Hartley JC, Gant V, et al. Healthcare environments and spatial variability of healthcare associated infection risk: cross-sectional surveys. PLoS One 2013;8:e76249.
[26] Hess AS, Shardell M, Johnson JK, Thom KA, Roghmann M-C, Netzer G, et al. A randomized, controlled trial of enhanced cleaning to reduce contamination of healthcare worker gowns and gloves with multidrug-resistant bacteria. Infect Control Hosp Epidemiol 2013;34:487–93.
[27] Rupp ME, Huerta T, Cavalieri RJ, Lyden E, Schooneveld T Van, Carling P, et al. Optimum outlier model for potential improvement of environmental cleaning and disinfection. Infect Control Hosp Epidemiol 2014;35:721–3.
[28] Xu H, Jin H, Zhao L, Wei X, Hu L, Shen L, et al. A randomized, double-blind comparison of the effectiveness of environmental cleaning between infection control professionals and environmental service workers. Am J Infect Control 2015;43:292–4.
[29] Schmidt MG, Von Dessauer B, Benavente C, Benadof D, Cifuentes P, Elgueta A, et al. Copper surfaces are associated with significantly lower concentrations of bacteria on selected surfaces within a pediatric intensive care unit. Am J Infect Control 2016;44:203–9.
[30] Adams CEE, Smith J, Watson V, Robertson C, Dancer SJJ. Examining the association between surface bioburden and frequently touched sites in intensive care. J Hosp Infect 2017;95:76–80.
[31] Gan T, Xu H, Wu J, Zhu Y, Wang L, Jin H, et al. Sequential enhanced cleaning eliminates multidrug-resistant organisms in

general intensive care unit of a traditional Chinese medicine hospital. J Crit Care 2017;41:216—21.

[32] Johani K, Abualsaud D, Costa DM, Hu H, Whiteley G, Deva A, et al. Characterization of microbial community composition, antimicrobial resistance and biofilm on intensive care surfaces. J Infect Public Health 2018;11:418—24.

[33] Wille I, Mayr A, Kreidl P, Brühwasser C, Hinterberger G, Fritz A, et al. Cross-sectional point prevalence survey to study the environmental contamination of nosocomial pathogens in intensive care units under real-life conditions. J Hosp Infect 2018;98:90—5.

[34] Esolen LM, Thakur L, Layon AJ, Fuller TA, Harrington D-J, Jha K, et al. The efficacy of self-disinfecting bedrail covers in an intensive care unit. Am J Infect Control 2018;46:417—9.

[35] Jinadatha C, Villamaria FC, Restrepo MI, Ganachari-Mallappa N, Liao I-C, Stock EM, et al. Is the pulsed xenon ultraviolet light no-touch disinfection system effective on methicillin-resistant *Staphylococcus aureus* in the absence of manual cleaning? Am J Infect Control 2015;43:878—81.

[36] 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.

[37] Reid M, Whatley V, Spooner E, Nevill AM, Cooper M, Ramsden JJ, et al. How does a photocatalytic antimicrobial coating affect environmental bioburden in hospitals? Infect Control Hosp Epidemiol 2018;39:398—404.

[38] Home | NHS Supply Chain. n.d. Available at: https://www.supplychain.nhs.uk/ [last accessed February 2019].

[39] Schmidt MG, Attaway HH, Sharpe PA, John J, Morgan A, Fairey SE, et al. Sustained reduction of microbial burden on common hospital surfaces through the introduction of copper. J Clin Microbiol 2012;50:2217—23.

[40] Shimoda T, Yano R, Nakamura S, Yoshida M, Matsuo J, Yoshimura S, et al. ATP bioluminescence values are significantly different depending upon material surface properties of the sampling location in hospitals. BMC Res Notes 2015;8:807.

[41] Ali S, Moore G, Wilson APR. Effect of surface coating and finish upon the cleanability of bed rails and the spread of *Staphylococcus aureus*. J Hosp Infect 2012;80:192—8.

[42] Claro T, Galvin S, Cahill O, Fitzgerald-Hughes D, Daniels S, Humphreys H. What is the best method? Recovery of methicillin-resistant *Staphylococcus aureus* and extended-spectrum β-lactamase-producing *Escherichia coli* from inanimate hospital surfaces. Infect Control Hosp Epidemiol 2014;35:869—71.

[43] 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.

[44] Pati D, Cason C, Harvey Jr TE, Evans J. An empirical examination of patient room handedness in acute medical-surgical settings. An example of a traditional mirror-image patient room configuration. Health Environ Res Design J 2010;4:11—33.

[45] Branch-Elliman W, Robillard ER, McCarthy Jr G, 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.