



# Effect of surface coating and finish upon the cleanability of bed rails and the spread of *Staphylococcus aureus*

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## SUMMARY

**Background:** Bacterial reservoirs in the near-patient environment are likely vectors of healthcare-acquired infection.

**Aim:** To conduct a laboratory-based study to confirm a previous clinical finding of higher numbers of bacteria on plastic than on painted steel bed rails.

**Methods:** Six different surfaces were inoculated with *Staphylococcus aureus* suspended in a range of synthetic soils. Aerobic colony counts and ATP bioluminescence were used to assess the efficacy of cleaning with microfibre cloths and antibacterial wipes. The ease with which *S. aureus* was transferred between fingertips and each bed rail was also investigated.

**Findings:** Antibacterial wipes reduced bacterial numbers to below detectable levels on all rails but were less effective than microfibre cloths in removing organic debris. Surfaces that were comparatively easy to clean were more likely to transfer *S. aureus* on contact. If inadequately disinfected these rails could pose the greatest risk in terms of cross-transmission. In the absence of contaminating soil, bacterial transfer from fingertips to rail ranged from 38% to 64%. Transfer from rail to fingertip ranged from 22% to 38%. Surface material and rugosity were important factors in determining cleanability and transfer rate. However, the presence of organic soils affected bacterial transfer from all bed rails regardless of material or finish.

**Conclusion:** Bed rails can become heavily contaminated. Regular wiping with antibacterial wipes could be a cost-effective means of maintaining low numbers of bacteria near to the patient. To minimize the risk of cross-transmission, cleaning protocols should be validated to ensure effective removal of microbial and non-microbial surface contamination.

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## Introduction

Nosocomial pathogens can be transferred from a colonized patient to a non-infected patient either directly through

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contact with the hands of staff or indirectly via an environmental surface. It has been suggested that additional cleaning of near-patient surfaces can reduce methicillin-resistant *Staphylococcus aureus* (MRSA) infection.<sup>1</sup> However, in a much larger critical care study, no significant effect of high level cleaning on MRSA acquisition was demonstrated, despite reductions in hand contamination.<sup>2</sup>

Bed rails are frequently contaminated and handled by patients and staff, so may be implicated in cross-infection.<sup>2,3</sup>

The type of surface can influence the level of contamination in ward use.<sup>4</sup> This study aimed to determine the transfer rate of *S. aureus* between fingertips and different bed rail surfaces in the presence and absence of organic soil. The effect of surface coating and finish upon the cleanability of bed rails was also investigated.

## Methods

Six surface finishes associated with five National Health Service (NHS) bed rails (four having been supplied by the manufacturer) were tested (Figure 1). Before testing, the topography of each was assessed using a non-contact three-dimensional measuring system (Proscan 1000, Scantron, Taunton, UK) and its average surface roughness ( $R_a$ -value) determined (Professor J. Knowles, University College London; personal communication):

- Rail A: polypropylene footboard,  $R_a = 9.78 \mu\text{m}$
- Rail B: polypropylene foot rail (visually rough),  $R_a = 9.32 \mu\text{m}$
- Rail C: polypropylene foot rail (visually smooth),  $R_a = 7.54 \mu\text{m}$
- Rail D: stainless steel side rail,  $R_a = 2.48 \mu\text{m}$
- Rail E: polyester-coated steel side rail,  $R_a = 0.66 \mu\text{m}$
- Rail F: polypropylene and calcium carbonate (10%) side rail,  $R_a = 12.57 \mu\text{m}$

Each bed rail was marked with fifty  $1.5 \times 1$  cm test areas. Before inoculation, each bed rail was scrubbed with detergent,

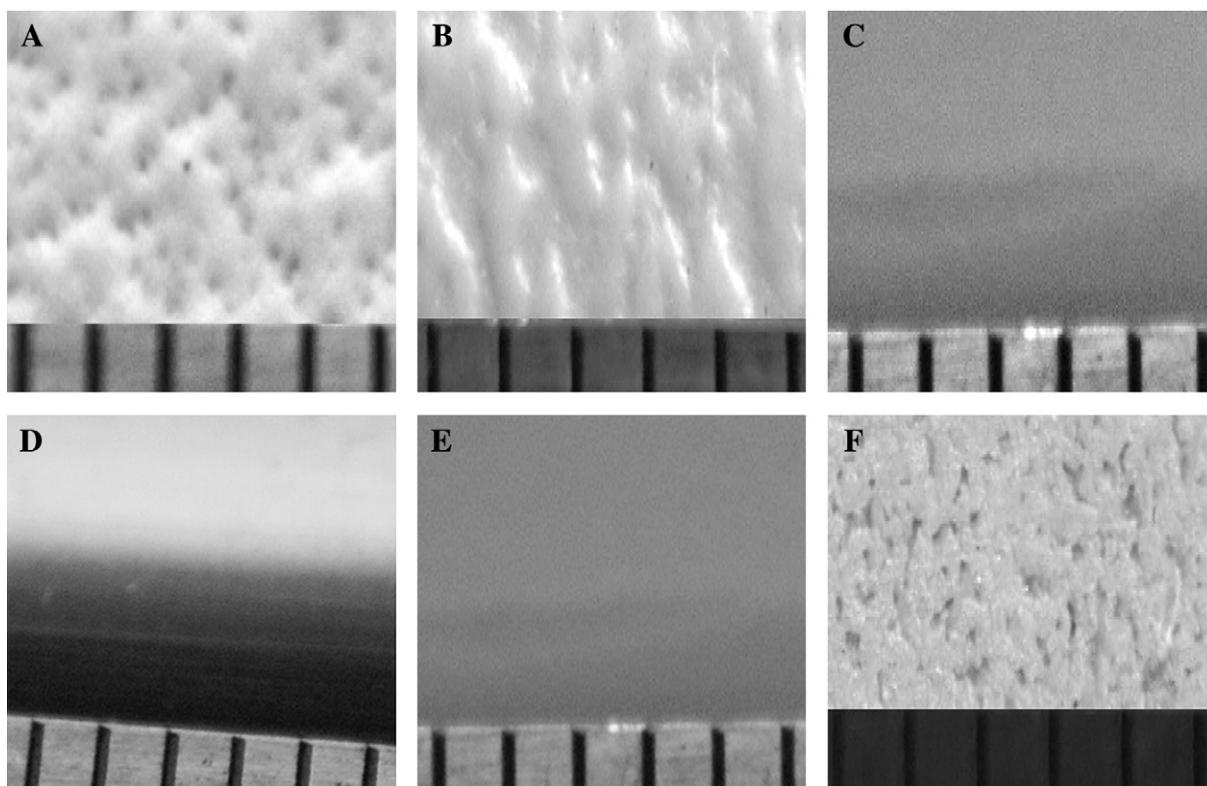
rinsed three times with boiling water and disinfected using 70% alcohol. The efficacy of this cleaning protocol was assessed using agar contact plates and residual microbial numbers were consistently reduced to below detectable levels.

## Preparation of test suspension

A single colony of meticillin-susceptible *Staphylococcus aureus* (MSSA; NCTC 6571) was placed in 10 mL nutrient broth (Oxoid, Basingstoke, UK) and incubated at 37 °C for 24 h. These culture conditions were found to yield  $\sim 10^8$  cfu/mL. After incubation the overnight culture was centrifuged at 3000 rpm for 10 min. The pellet was then resuspended in 10 mL of one of six synthetic soils.

- Soil 1, control: quarter-strength Ringer solution (Oxoid)
- Soil 2: tryptone soya broth and 5% horse serum (TSB + HS; Oxoid)<sup>5</sup>
- Soil 3: synthetic urine<sup>6</sup>
- Soil 4: synthetic faeces: 5% tryptone (w/v), 5% bovine serum albumin (w/v) and 0.4% mucin (w/v) (Sigma–Aldrich, St Louis, MO, USA)<sup>7</sup>
- Soil 5: blood (sterile oxalated horse blood; Oxoid)
- Soil 6: protein–bovine serum albumin (0.6% w/v)<sup>8</sup>

Each bacterial suspension was mixed well and a tenfold dilution series prepared using the corresponding test soil. Standard plate counts were performed to determine cfu/mL of test suspension.



**Figure 1.** Visual appearance of the six bed rail finishes. (A) Plastic-covered footboard; (B) plastic-covered foot rail (upper surface\*); (C) plastic covered foot rail (underside surface\*); (D) stainless steel side rail; (E) nylon polyester painted mild steel side rail; (F) plastic covered (polyurethane) side rail]. Each graduation on the scale represents 2 mm. \*Different surface finishes associated with the same bed rail.

### Cleanability of contaminated bed rails

The ease with which microbial and non-microbial contamination was removed during cleaning was measured using aerobic colony counts and ATP bioluminescence respectively.<sup>5</sup> Between each experiment, the rails were cleaned using the protocol described above (i.e. scrubbed with detergent and disinfected using 70% alcohol). Forty cleaned and disinfected squares were used for each experiment.

*S. aureus* was resuspended and diluted 10-fold in TSB + HS. Ten microlitre of the suspension (containing  $\sim 10^5$  cfu of *S. aureus*) was spread over each of forty 1.5 cm<sup>2</sup> test areas. Immediately after inoculation, ten adjacent test areas were sampled using ATP bioluminescence (Clean-Trace™, 3M Healthcare Ltd, Loughborough, UK) and ten using a pre-moistened cotton-tipped swab. ATP swabs were activated, placed in a Clean-Trace™ NG Luminometer (3M Health Care Ltd) and the reading in relative light units (RLU) recorded. Cotton-tipped swabs were rinsed in 9 mL of quarter-strength Ringer solution and 100 µL of the resulting suspension was plated onto pre-poured blood agar plates (Oxoid).

A clean 15 cm × 15 cm microfibre cloth was pre-moistened with 25 mL tap water and used to clean the remaining 20 test areas. To reduce technique bias, one individual performed all wiping (two left to right cleaning strokes).<sup>5</sup> Immediately thereafter, ten adjacent test areas were sampled using Clean-Trace™ ATP swabs and ten using pre-moistened cotton-tipped swabs.

The experiment was repeated using antibacterial wipes (active ingredients: peroxides, benzalkonium chloride; VWR International, Lutterworth, UK). As before, wiping involved two left-to-right cleaning strokes. During sampling, to neutralize the antimicrobial effect of the wipes, swabs were rinsed in 9 mL neutralizing solution [phosphate-buffered saline incorporating 3% (w/v) Tween 80, 0.3% (w/v) lecithin, 0.1% (w/v) sodium thiosulphate].

Experiments to assess the ability of microfibre cloths and antibacterial wipes to remove adsorbed soils were also conducted. Rather than being cleaned immediately, the bed rails were cleaned 24 h after inoculation.

### Transfer of *S. aureus* from contaminated fingertips to bed rail surface

Ethical approval for the inoculation of *S. aureus* onto the fingertips of the investigator was given by the Moorfields & Whittington Research Ethics Committee 09/H0721/42.

Fingertips were cleaned with soap followed by 70% alcohol. *S. aureus* was resuspended and diluted 10-fold in one of the six synthetic soils. Ten microlitre of the suspension (containing  $\sim 10^5$  cfu) was inoculated onto the index fingertip of the investigator and spread over the finger pad. The fingertip was immediately dipped into 9 mL quarter-strength Ringer solution and agitated to release the bacteria (fingertip 1; pre-surface contact). A second fingertip was inoculated, pressed onto one of the 1.5 cm<sup>2</sup> test areas and sampled similarly (fingertip 2; post-surface contact). Rinse suspensions were diluted 10-fold and plated onto pre-poured blood agar plates. Each experiment comprised ten replicate samples and was repeated using each bed rail and each test suspension. The efficacy of the hand-washing procedure in removing background skin flora was confirmed via the rinsing of un-inoculated 'control' fingertips. All agar plates were incubated at 37 °C for 24 h.

As porosity and surface roughness increases, more bacteria become attached and/or entrapped within topographical features of the surface material. During sampling, this reduced accessibility can reduce the number of bacteria recovered from a surface and falsely decrease transfer rate.<sup>9</sup> Thus, the transfer rate from fingertip to bed rail was defined as:

$$\text{Transfer rate (\%)} = \frac{[(\text{cfu recovered from fingertip 1 pre-surface contact} - \text{cfu recovered from fingertip 2 post-surface contact}) / \text{cfu inoculated onto fingertip}] \times 100$$

### Transfer of *S. aureus* from a contaminated bed rail surface to fingertips

*S. aureus* was resuspended and diluted 10-fold in one of the six synthetic soils. Ten microlitre of the *S. aureus* suspension ( $\sim 10^5$  cfu) was inoculated onto a 1.5 cm<sup>2</sup> test area and spread over the surface using a sterile, disposable 'L-shaped' spreader. A sanitized fingertip was pressed onto the test surface and sampled as before. Each experiment comprised ten replicate samples and was repeated using each bed rail and each test suspension.

To simulate a lack of cleaning, 10 µL of *S. aureus* suspension ( $\sim 10^5$  cfu) was applied to each test area in either blood or TSB + HS and allowed to adsorb to the surface for 24 h. A sanitized fingertip was then pressed onto the surface and sampled as before. The transfer rate from bed rail to fingertip was defined as<sup>10</sup>:

$$\text{Transfer rate(\%)} = (\text{cfu recovered from fingertip} / \text{cfu inoculated onto rail}) \times 100$$

### Analysis of results

Median transfer rates were based on ten replicate samples. Intergroup comparisons were made with the Kruskal–Wallis or Mann–Whitney tests conducted using SPSS version 17.0. One-tailed tests were used for all analyses and sample data were considered statistically significant when  $P < 0.05$ .

## Results

### Cleanability of contaminated bed rails

Cleaning significantly reduced the number of bacteria recovered from each surface (Table I). Microfibre cloths reduced bacterial numbers on rails B, C and E to below detectable levels (i.e. cleaning achieved  $>3.50 \log_{10}$  reduction). Rails A, D and F were less effectively microbiologically cleaned. After the inoculum had been allowed to adsorb to the surface for 24 h, microfibre cloths removed all detectable organisms from rails A, B, C and D but achieved just a 1.5  $\log_{10}$  reduction on E and F. Antibacterial wipes reduced bacterial numbers to below detectable levels in all cases.

When cleaned immediately after inoculation, both cleaning methods reduced the amount of ATP on all rails to levels equating to  $<250$  RLU – a previously proposed cleaning standard.<sup>11</sup> Antimicrobial wipes were less effective in removing adsorbed (i.e. post 24 h) soils from rails A, B, D and E (Table II).

**Table I**

Median ( $N = 10$ ) number of *S. aureus* ( $\log_{10}$  cfu) recovered from each bed rail before and after they were cleaned using a pre-moistened microfibre cloth or an antimicrobial wipe

Bed rail	Surface roughness ( $R_a$ )	Median (IQR) no. of <i>S. aureus</i> recovered from surface ( $\log_{10}$ cfu)					
		0 h			24 h		
		Pre-clean	Microfibre cloth	Antimicrobial wipe	Pre-clean	Microfibre cloth	Antimicrobial wipe
A	9.78	5.42 (5.41–5.44)	2.26 (<2–2.50)	<2	4.87 (4.85–4.88)	<2	<2
B	9.32	5.41 (5.38–5.44)	<2	<2	4.82 (4.81–4.86)	<2	<2
C	7.54	5.27 (5.23–5.29)	<2	<2	4.13 (4.10–4.16)	<2	<2
D	2.48	5.17 (5.10–5.25)	2.8 (2.56–2.94)	<2	4.13 (4.09–4.18)	<2	<2
E	0.66	5.35 (5.33–5.37)	<2	<2	4.52 (4.50–4.60)	3.28 (3.18–3.42)	<2
F	12.57	5.10 (5.07–5.11)	2.93 (2.87–2.98)	<2	4.43 (4.41–4.49)	3.18 (3.10–3.31)	<2

IQR, interquartile range.

Cleaning was performed immediately after contaminating the bed rails (0 h) or after the inoculum was allowed to dry for 24 h.

#### Transfer of *S. aureus* from contaminated fingertips to bed rail surface

In the absence of contaminating soils (i.e. when *S. aureus* was suspended in Ringer's solution), significantly fewer bacteria were transferred to rails A and F than to other rails ( $P < 0.05$ ) (Figure 2). By comparison with Ringer's solution, the presence of TSB + HS significantly increased bacterial transfer to rails A, E and F but reduced it to the others ( $P < 0.05$ ). Synthetic urine reduced transfer to rails B and E and synthetic faeces reduced transfer to B, C and D. Urine and faeces increased bacterial transfer to rails A and E respectively. Blood

reduced transfer to A, D, E and F ( $P < 0.05$ ). Albumin increased transfer to rail F but reduced it to A.

#### Transfer of *S. aureus* from bed rail surface to fingertips

In the absence of contaminating soil, significantly more bacteria were transferred to fingers from rails A, B and C than from other rails ( $P < 0.01$ ) (Figure 3). By comparison with Ringer solution, bacterial transfer from all rails significantly increased in the presence of blood. Similarly, transfer significantly increased from rails A, B and E with TSB + HS ( $P = 0.01$ ), from B,

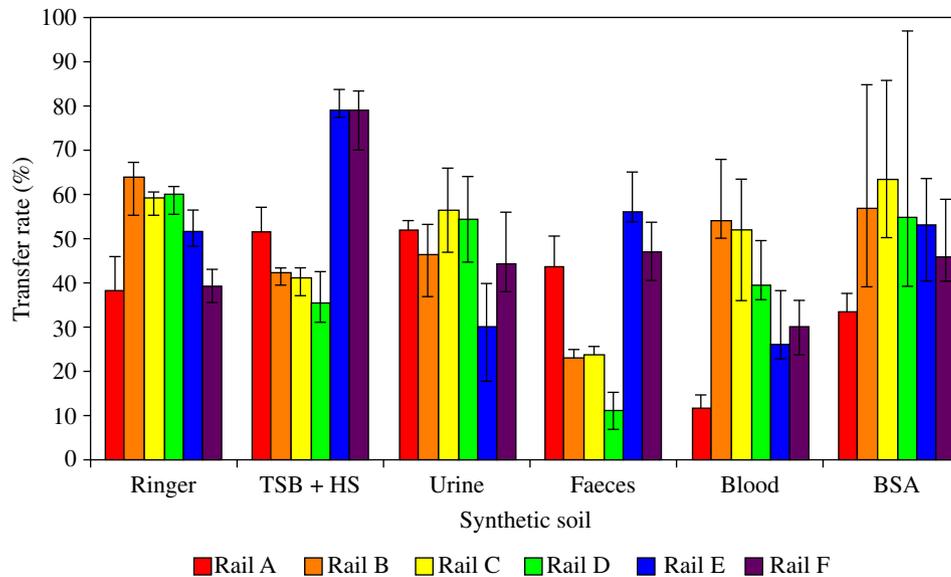
**Table II**

Median ( $N = 10$ ) ATP reading obtained from each bed rail before and after they were cleaned using a pre-moistened microfibre cloth or an antimicrobial wipe

Bed rail	Surface roughness ( $R_a$ )	Median (IQR) ATP bioluminescence light signal (RLU)					
		0 h			24 h		
		Pre-clean	Microfibre cloth	Antimicrobial wipe	Pre-clean	Microfibre cloth	Antimicrobial wipe
A	9.78	3133 (2627–3368)	55 (48–64)	44 (37–46)	864 (740–1046)	78 (64–85)	202 (157–231)
B	9.32	2580 (2062–2637)	81 (56–102)	110 (99–173)	2233 (2141–2778)	152 (118–171)	300 (200–329)
C	7.54	1855 (1628–2118)	7.5 (5–20)	81 (36–120)	1130 (821–1477)	23.9 (23.1–24.6)	44 (43–44)
D	2.48	1627 (1340–1836)	68 (59–75)	145 (59–75)	944 (775–1267)	39 (33–43)	211 (152–224)
E	0.66	1318 (930–1404)	8 (7–8)	36 (30–45)	2688 (2082–3654)	40 (30–45)	249 (200–409)
F	12.57	2670 (2314–2874)	80 (73–109)	155 (104–247)	2082 (1774–2397)	259 (219–274)	111 (99–132)

IQR, interquartile range; RLU, relative light units.

Cleaning was performed immediately after contaminating the bed rails (0 h) or after the inoculum was allowed to dry for 24 h.



**Figure 2.** Median ( $N = 10$ ) transfer of *S. aureus* from contaminated fingertips to different bed rail surfaces. Error bars indicate the interquartile range. TSB + HS, tryptone soya broth and 5% horse serum; BSA, bovine serum albumin.

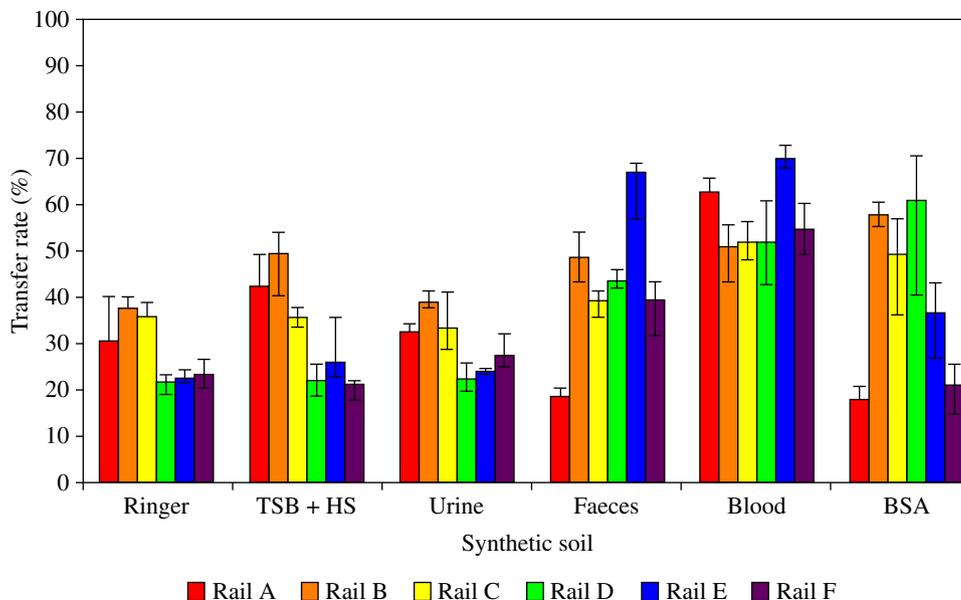
D, E and F with faecal soil, from F with synthetic urine ( $P = 0.005$ ) and from B, D and E with albumin ( $P < 0.002$ ). Faecal soil and albumin reduced transfer from A ( $P < 0.001$ ). In blood or TSB + HS, transfer to fingers was lower from adsorbed soil than from a freshly inoculated surface and significantly more bacteria were transferred from rail B than from any other rail (Figure 4).

## Discussion

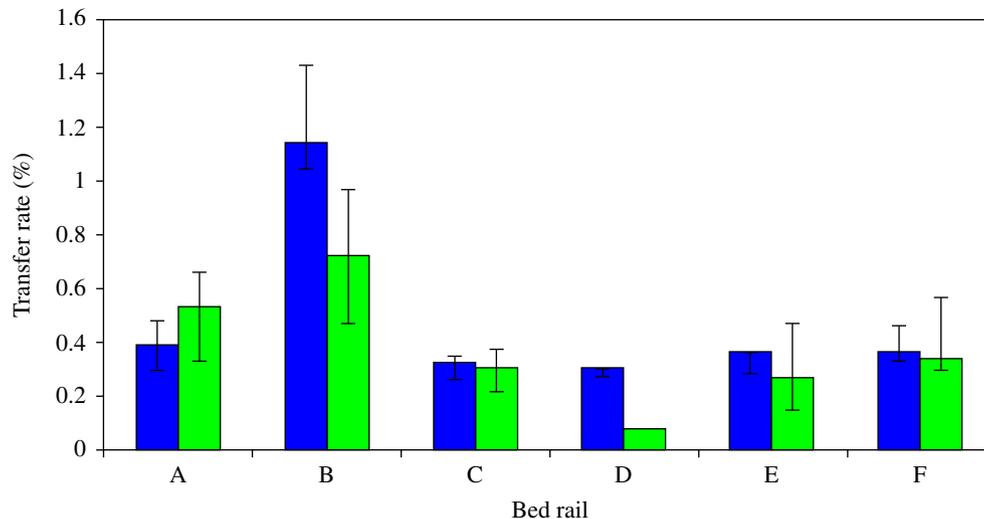
The bed rail is one of the few surfaces in the ward environment that is touched by patients, staff and visitors. Bed rails can become heavily contaminated and potentially form a significant reservoir of pathogenic bacteria near to the patient. During our previous study, 2.8% of all bed rails sampled ( $N = 3360$ ) were contaminated with MRSA, demonstrating that if

inadequately decontaminated the bed rail can pose a risk of infection to patients.<sup>2</sup> Bed rails are generally considered to be 'easy to clean'.<sup>3</sup> However, few studies have assessed the cleanability of surfaces in the healthcare environment. This laboratory-based study was designed to assess whether surface coating and/or finish can affect the ease with which bacteria are removed from bed rails during cleaning. How surface material can influence the number of bacteria transferred from a contaminated bed rail to hands during contact was also investigated.

Rail F had the highest  $R_a$ -value ( $12.57 \mu\text{m}$ ) and when using microfibre cloths was the most difficult rail from which to remove contaminating organisms (Table I). The painted stainless steel rail (rail E) had the lowest  $R_a$ -value ( $0.66 \mu\text{m}$ ) and microfibre cleaning reduced microbial numbers to below



**Figure 3.** Median ( $N = 10$ ) transfer of *S. aureus* from contaminated bed rails to fingertips ( $N = 10$ ). Error bars indicate the interquartile range.



**Figure 4.** Median ( $N = 10$ ) transfer of *S. aureus* when bed rails (A–F) contaminated with tryptone soya broth and 5% horse serum (blue bars) or blood (green bars) were allowed to dry for 24 h prior to touching with fingertips. Error bars indicate the interquartile range.

detectable levels. During our previous clinical study, MRSA was more often recovered from rails of type F than from those of type E (odds ratio: 0.25; 95% confidence interval: 0.09–0.65).<sup>2</sup> Differences in the cleanability of these two rail types probably contributed to the observed differences in MRSA contamination.

Whereas an increase in surface roughness would be expected to increase the retention of micro-organisms, the microscopic irregularities caused by abrasion or impact damage also influence the cleanability of a surface.<sup>12,13</sup> By comparison with rails B and C, microfibre cleaning was less effective in removing *S. aureus* from rail D despite its comparatively smooth surface finish ( $R_a = 2.48 \mu\text{m}$ ). Irregularities on the surface of stainless steel rails may offer organisms protection from the action of microfibre cloths.

Antibacterial wipes reduced bacterial numbers to below detectable levels on all rails (Table I), suggesting that frequent wiping could be a cost-effective means of maintaining low levels of microbial contamination. However, although the wipes were effective in disinfecting the bed rails, they were less effective in reducing residual ATP levels (i.e. removing organic debris) (Table II).

Hospital bed rails are likely to come into contact with fluids containing various levels of organic and inorganic molecules (e.g. blood, faeces, food). Such soil elements rapidly adsorb to a surface and their presence can facilitate the survival of micro-organisms by protecting against desiccation and/or by reacting with antimicrobial agents and reducing their bioavailability.<sup>14,15</sup> The ease with which pathogens can be picked up from environmental surfaces by the hands of healthcare workers and transferred to patients and/or other environmental surfaces has been demonstrated.<sup>16</sup> Prolonged microbial viability, therefore, represents a sustained risk of cross-infection.

Bacterial transfer is largely determined by adhesion forces between cell and surface(s). For transfer to occur, bacteria must detach from one surface and adhere to another. The entrapment and immobilization of cells within topographical features of a surface encourages attachment.<sup>17</sup> Furthermore, bacteria colonizing these irregularities will not come into

contact with the recipient surface.<sup>18</sup> Thus, as surface roughness increases, bacterial transfer is reduced. In the absence of contaminating soils, significantly fewer bacteria were transferred from rail F (the roughest rail) than from rails A, B and C (Figure 2). However, despite its comparatively high  $R_a$ -value ( $12.57 \mu\text{m}$ ), the number of bacteria transferred from rail F did not significantly differ from that transferred from the two steel rails [D ( $R_a = 2.48 \mu\text{m}$ ) and E ( $R_a = 0.66 \mu\text{m}$ )]. A lower contact area also results in fewer bacteria being transferred to a rougher surface, yet the number of bacteria transferred to rails B ( $R_a = 9.32 \mu\text{m}$ ) and C ( $R_a = 7.54 \mu\text{m}$ ) did not significantly differ from that transferred to rails D and E (Figure 3).<sup>19</sup> These results suggest that in the absence of contaminating soils, surface type rather than surface rugosity is the more dominant factor determining transfer rate.

Staphylococci reportedly adhere poorly to polyurethane and polypropylene but have relatively high adherence to polyether-block amide.<sup>20,21</sup> Similarly, whereas *S. aureus* readily transfers to hydrophilic surfaces (e.g. stainless steel), strong adhesion forces reduce its potential to transfer from such surfaces.<sup>15</sup> Nonetheless, many serum and tissue proteins impair bacterial adhesion and their presence can increase bacterial transfer regardless of surface material.<sup>22</sup> The presence of simulated body fluids affected the number of bacteria transferred to and from all bed rails (Figures 2 and 3). Transfer rate varied with the different soil-surface combinations but, on sum-of-rank basis, the greatest numbers of bacteria were transferred to and from rail C and B respectively.

When proteinaceous soils were allowed to adsorb to the different bed rails (i.e. to simulate a lack of cleaning) bacterial transfer was significantly lower than when the fingers came into contact with a freshly inoculated surface. This reduction may have resulted from a considerable loss of viability of the suspended bacteria. However, when the bed rails were inoculated with a suspension comprising *S. aureus* and TSB + HS and held under ambient conditions for 24 h, recovered cell numbers declined by between 0.55 (rail A) and 1.14 (rail C) log-values (Table I). Thus, the presence of TSB + HS likely facilitated the survival of *S. aureus* and the observed reduction in

bacterial transfer was more likely due to the adsorbed soils promoting bacterial adhesion.<sup>14</sup> Despite median transfer rates ranging from just 0.08% to 1.14%, fingers still became contaminated with a potentially infectious dose (as few as 15 staphylococci can cause infection in an open wound or abrasion) and significantly more bacteria were transferred from rail B than from any of the other rail types (Figure 4).<sup>23</sup>

Cleaning and the removal of proteinaceous soils from bed rails is important, not only to inhibit bacterial growth and survival but also to minimize the spread of bacteria within the ward environment. Rail F was the most difficult of the rails to clean and this rail type could represent a significant reservoir of potentially pathogenic bacteria. To improve cleaning efficacy, bed rails could be modified in order to improve their cleanability. The results of this study suggest that the material(s) used should have low surface roughness ( $R_a$ -value), be free of microscopic irregularities and be resistant to impact and abrasion damage. Although it was comparatively easy to remove contaminating organisms from rail B, this rail was more likely to transfer *S. aureus* to fingertips. Thus, if cleaning is inadequate, this rail type could pose the greatest risk in terms of cross-transmission both immediately and several hours after initial contamination. Regardless of its cleanability, therefore, the risk posed by a contaminated bed rail will depend upon the efficacy of the cleaning procedures employed. High-contact surfaces can become re-contaminated within 4 h of cleaning.<sup>2</sup> However, twice-daily cleaning can maintain low levels of contamination throughout the day.<sup>2</sup> Regular wiping with antibacterial wipes could be a cost-effective means of maintaining low numbers of bacteria near to the patient (Table I). It is therefore recommended that bed rails are wiped twice daily using antibacterial wipes of a type demonstrated to be effective against the range of micro-organisms likely to be present within the ward environment.

#### Conflict of interest statement

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