Surface Sampling Within a Pediatric Ward – How Multiple Factors Affect Cleaning Efficacy

---

Stacey Rawlinson[1], Elaine Cloutman-Green[1, 2], Faiza Asadi [2], Lena Ciric[1]

[1] University College London, Chadwick Building, Department of Civil, Environmental and Geomatic Engineering, London, UK.

[2] Great Ormond Street Hospital NHS Foundation Trust, Camellia Botnar Laboratories, Department of Microbiology, London, UK.

Corresponding Author:

Stacey Rawlinson

Department of Civil, Environmental and Geomatic Engineering

University College London

Chadwick Building, Room 222, WC1E 6BT

Ucessh6@ucl.ac.uk

Structured abstract

Objective

To assess the number of organisms present on different surfaces within a clinical environment before and after cleaning has taken place, and to identify the impact of cleaning.

Design and Setting

Extensive 2-week microbiological environmental monitoring of an entire ward before and after cleaning, within a pediatric hematology-oncology ward comprised of a day unit and outpatients ward.

Methods

Tryptone soya agar (TSA) contact plates were used to take a total of 1,160 surface samples before and after cleaning from 55 pre-determined sites. Samples were taken from representative surfaces throughout the ward, including different materials, surfaces with varying heights, different functions, distance from patients, and both high-touch and infrequently touched surfaces.

Results. Surface cleaning has been undertaken within the ward and there is a significant difference between CFU recovered before and after cleaning ($P<0.0001$). Cleaning produced an average reduction of 68% throughout the ward environment. The corridor was the most contaminated area within the ward. There is a difference in CFU between the different areas within the ward, and these were cleaned with varying efficiency. Surface material, who interacts with the surface, levels of initial contamination, perceived risk and perceived cleanability were all found to have a varying impact on how well cleaning was undertaken.

Conclusions. To the authors current knowledge, this is the only study assessing cleaning within a pediatric ward taking samples directly before and after cleaning. The standard of

cleaning undertaken within the ward is open for discussion, and these data highlight the need for an improved cleaning intervention, and can provide insight into the multitude of factors that must be considered when designing an effective training protocol.

Keywords: Surfaces; Hospital; Sampling; Infection Prevention and Control; HCAI; Cleaning

Introduction

Healthcare associated infections (HCAIs) are a known issue causing a considerable economic burden to hospitals, while putting patient safety at risk. Within Europe, it is estimated there are 2.5 million cases of HCAI each year, leading to 2.5 million disability-adjusted life years [1]. There are multiple factors contributing to HCAI, both patient-related and environmental, and often the environmental factors are overlooked [2].

Historically, there has been much debate on the role the surface environmental plays in infection transmission, and the importance of cleaning these 'non-critical' surfaces. Increased understanding of the interaction between patient and environment had led to more studies analysing this important component of infection transmission, yet there is still disagreement on the importance of environmental cleaning and the role the environment plays in transmitting HCAI [3]. Furthermore, designing and undertaking effecting cleaning interventions to impact surface cleaning can be difficult due the disagreement on implementation and content of such interventions [4].

Efficient cleaning can be a useful tool to reduce HCAI [5]. Despite this, advocating for effective cleaning interventions can be difficult, due to the multitude of factors that can influence their impact, including current antibiotic use which can change the environmental microbiome [6], the differences between invasive and non-invasive treatments in which cleaning is potentially more critical for patients undergoing invasive procedures which break the skin barrier, or other factors such as cleaning efficacy and competence, hospital design, surface type, patient subset and local choice of cleaning agents. Consideration and inclusion of all these factors within routine cleaning is often not possible. In order to explore some of these factors within a pediatric setting, the following study has been undertaken, assessing cleaning by area, surface material, who has contact with the surface, who is responsible for cleaning, perceived risk to patient and perceived cleanability.

This is the first study assessing cleaning efficacy within a pediatric ward by taking microbiological samples before and after cleaning. The nature of the selected setting, an outpatients ward, allows easy sampling before and after cleaning as terminal end of day cleaning can take place each day as patients do not remain in the ward overnight.

Methods

Study Setting

Samples were taken from 55 sites within a pediatric hematology-oncology ward, which comprised of a pediatric day unit and outpatient ward, daily after clinic over a two-week period. A total of 1,160 Tryptone Soya Agar (TSA) contact plate samples were taken. The ward area was comprised of 3 separate 4-bed bays, 3 single rooms with an ensuite bathroom, 4 treatment rooms, a playroom, a height and weight room, 6 consultation rooms and two receptions with seating areas, for the day unit and outpatients area.

Sampling sites

Sampling sites were selected to encapsulate areas across the clinical environment, including near-patient and shared ward settings. Fifty-five sites were chosen for daily sampling before and after cleaning, which were taken from sites of every area within the ward. These sites formed a daily sampling plan and remained the same both before and after cleaning, for the entirety of the study. Nine replicates of each sample were taken over a period of two weeks. Pre-cleaning samples were taken from the left side of surfaces, and post-cleaning samples taken from the right, so potential organisms were not removed during the sampling process.

Surface categories

Surfaces were assessed by separate categories to identify possible trends in surface category and cleaning efficacy. The categories were as follows; surface material, people interacting with the surface, risk to patient and perceived cleanability by staff. Perceived risk is the apparent risk to the patient from each surface. Surfaces closer to the patient and surfaces known to generally have a greater bioburden were of higher risk than surfaces within the warder environment, or surfaces known to have little contact with the patient. Cleanability was defined as how easy a surface is to clean. Factors affecting this were size of the surface, height, surface material and general shape of the surface. Surfaces with multiple components, gaps and crevices or surfaces in hard to reach areas, such as the reception telephone, were classified as more difficult than smooth, flat surfaces within easy reach, such as the reception desk. Interactions were defined as the population subset that would mostly come into contact with these surfaces. Some surfaces were touched only by clinical staff, such as surfaces within the height and weight room and the treatment room, or by other ward staff, such as the reception areas. These allocations of risk were defined following advice from Great Ormond Street Hospital Infection Control team and ward staff.

Microbiological Analysis

Samples were taken before and after the daily routine cleaning post clinic. A minimum of three hours was allowed before sampling post-cleaning, so chorine residue did not interfere with results. During this time, there was no other activity on the ward or interactions with the surfaces. Post-cleaning, surfaces were not re-contaminated as the ward was closed and no staff presented a contamination risk. Samples were taken using TSA contact plates (90mm, Oxoid, Basingstoke, UK). Plates were pressed onto surfaces for 10 seconds with firm pressure and incubated at 37$_{o}$C for 24 hours. Subsequently, colony forming units (CFU) were counted and are presented in the results as CFU per contact plate. Statistical analysis was undertaken using GraphPad 7 software.

Results

In total, 1,160 contact plate samples were taken over the course of the study. The descriptive statistics of the results are shown below in Table 1. On average, contamination was fairly low (20-33 CFU per contact plate), and there was a significant difference between CFU recovered before and after cleaning (P<0.0001).

Table 1. Descriptive statistics showing overall contamination means (of nine temporal replicates) of all surfaces samples (N = 55) as part of the study.

	Overall CFU N = 55	CFU before cleaning N = 55	CFU after cleaning N = 55	CFU percentage change after cleaning N = 55
Mean	26.67	32.93	20.40	19.85 %
Standard deviation	25.14	29.25	18.45	281.16%
Median	20.70	25.11	16.60	-30.40 %
Minimum	0.10	0.11	0.10	-90.74 %
Maximum	115.33	115.33	79.50	2015.00%

Table 1 explores the mean CFU, calculated from the means of all nine temporal replicates for each sample site, both before and after cleaning, and the overall change. Minimum and maximum percentage changes demonstrate the wide range (-90.74%, - 2015%) between how a surface has been cleaned effectively, not cleaned, or potentially had contamination redistributed within the ward. The mean shows on average, of all samples taken, surfaces were reduced from 32.93 CFU/plate to 20.40 CFU/plate following cleaning.

Figure 1 shows that all the factors assessed within this study had an impact on the amount of contamination on surfaces, to varying extents. The most considerable differences were between surface type, where metal had the lowest CFU 13.89 (±4.14). Surfaces perceived to be easy to clean were more contaminated than those perceived as difficult to clean, at 33.66 (±4.18) and 14.39 (±6.86) CFU respectively.

For surfaces cleaned by cleaners, there was a greater CFU (37.38) than surfaces cleaned by clinical (8.13) or play staff (12.76). There was some difference when considering CFU recovery by area, in which non-clinical surfaces had the highest CFU at 46.59 in comparison with all other surface types.

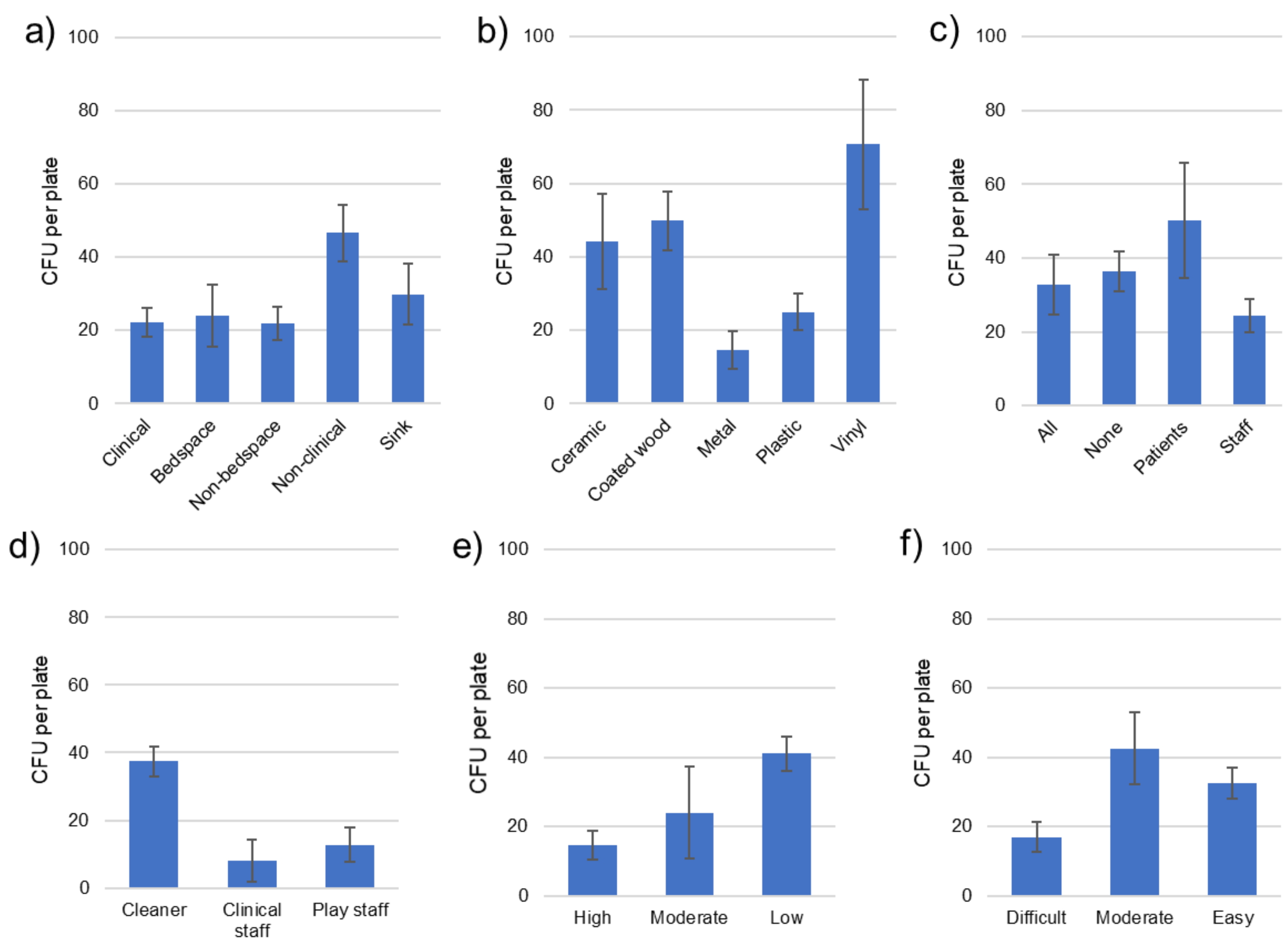

Figure 1. Mean microbiological contamination (with standard error) of all surfaces sampled in the study according to: a) the room/area sampled; b) the material of the surface; c) the group that had the most interaction with the surface; d) staff in charge of cleaning the surfaces; e) the perceived risk the surfaces poses to infection control; and f) the perceived cleanability of the surface.

Cleaning effectiveness can be measured by assessing the overall increase or decrease in CFU following cleaning. Some surfaces were cleaned more thoroughly than others, due to a variation of factors, including the area (clinical or non-clinical) surface material, person interacting with the surface most frequently, person responsible for cleaning, risk and cleanability. Of the five surfaces cleaned most effectively within the ward (bookcase in the corridor, floor in reception seating area, shelf surface in playroom, chair arm in corridor, and nurses station phone in the corridor) one was considered high risk, two medium risk and one low risk. These surfaces were all cleaned by cleaners, and three of the five were made from coated wood. Some surfaces had a large reduction in CFU, such as the floors, whereas other surfaces had a large increase in contamination, such as a bin lid and a toy, with increases of 2015% and 183% respectively.

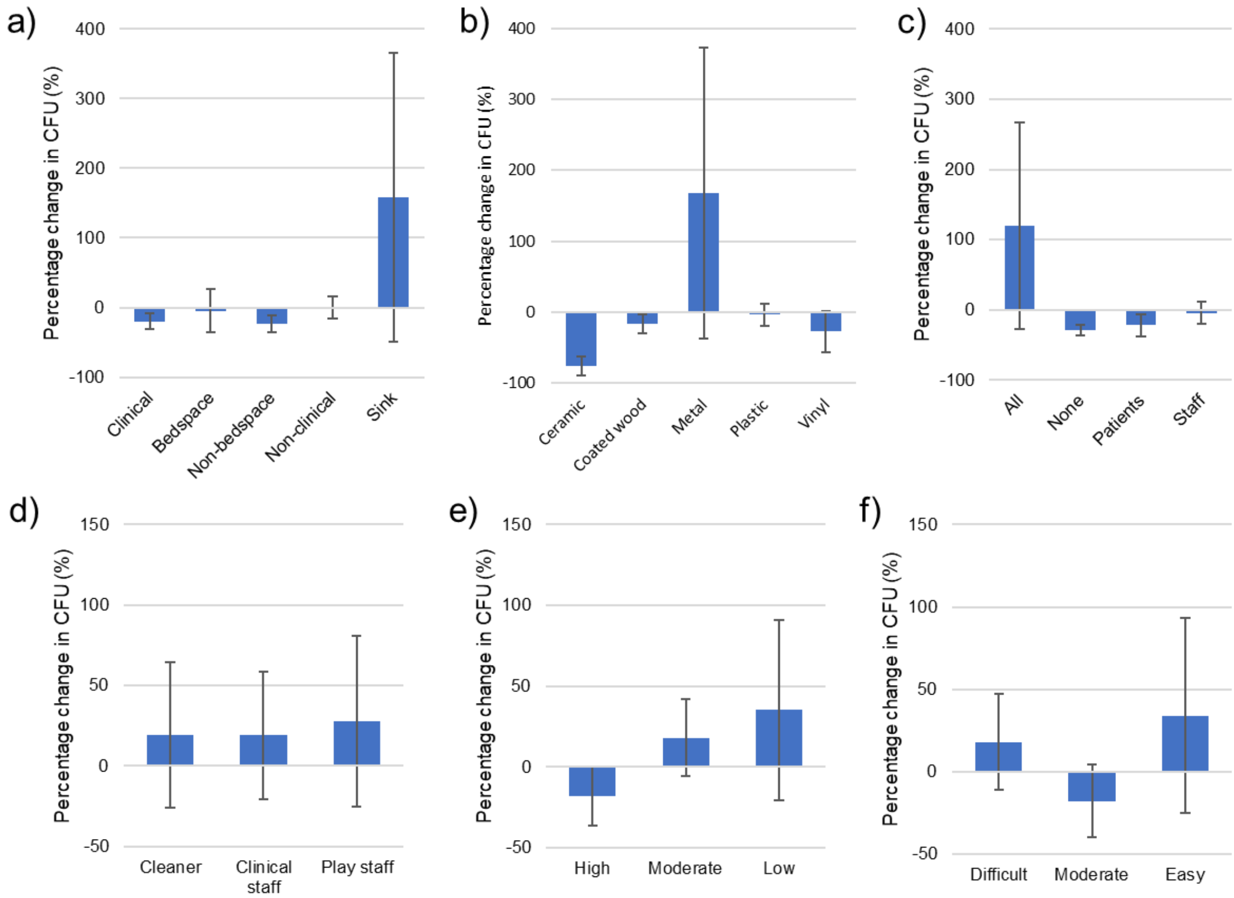

Figure 2. Mean percentage change (with standard error) in microbiological contamination of all surfaces sampled in the study according to: a) clinical and non-clinical surfaces; b) the material of the surface; c) the group that had the most interaction with the surface; d) staff member responsible for

cleaning; e) perceived risk surface poses to infection control; and f) perceived cleanability of the surface.

Figure 2 explores the different factors causing either increase or decrease in CFU following cleaning. Surface type plays a large role (figure 2b); metal surfaces, while least contaminated before cleaning as shown in figure 1, became more contaminated than other surface types following cleaning, with an increase of +168%. Surfaces with a lower perceived risk (figure 2e) had a greater risk of recontamination, becoming 35% more contaminated, whereas higher risk surfaces had a decrease of 18%. Surfaces touched (figure 2c) by staff had little to no increase in loading (reduction of -4.44%), whereas surfaces touched by none (-29.44%) of the staff groups or patients (-21.58%) had the greatest reduction. Easy to clean surfaces (figure 2f) were more contaminated (+34.12%) than their difficult to clean counterparts (18.18%) and the moderate surfaces had a reduction of 17.66%.

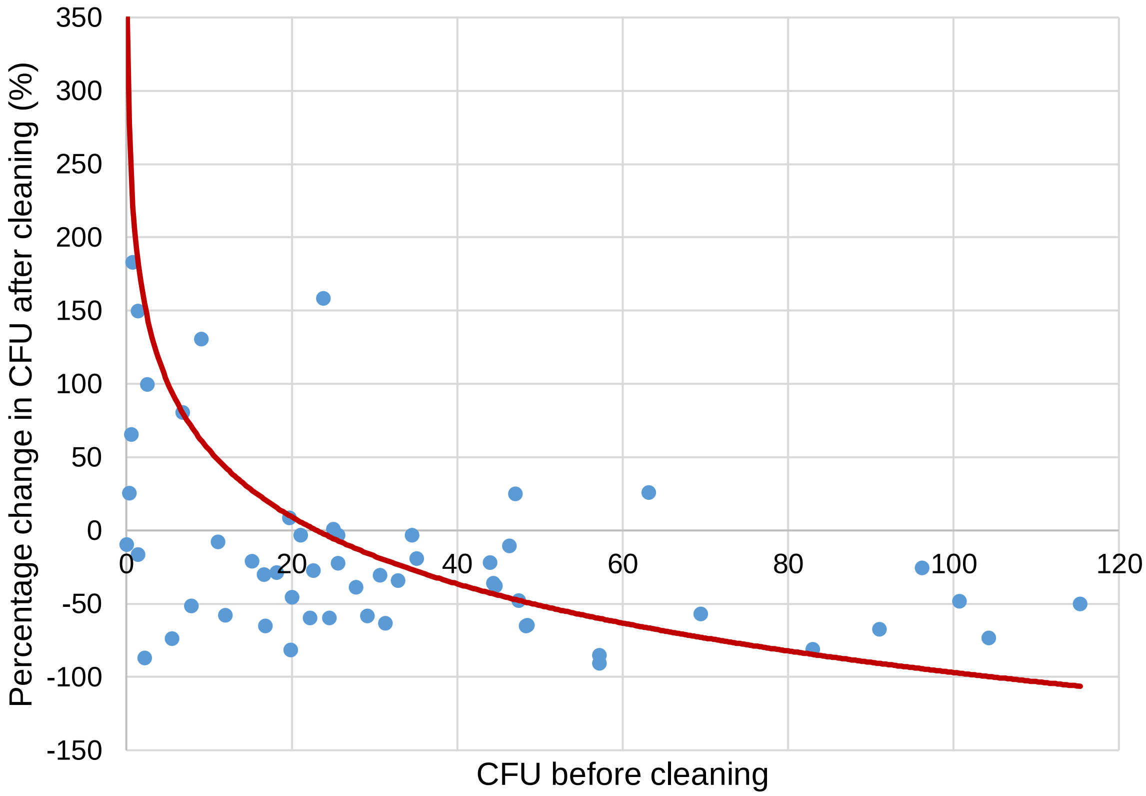

Figure 3. Relationship between CFU before cleaning and percentage change in CFU after cleaning.

Figure 3 shows the relationship between initial CFU recovery before cleaning, and change in CFU after cleaning. Surfaces that were initially more contaminated with a higher CFU (judged as >50CFU/plate) had an increased reduction in CFU after cleaning. Surfaces that were cleaner and had lower initial CFU had a greater increase in bacterial load, with some surfaces starting at <20CFU/plate had an increase of CFU of up to 180%.

Discussion

This study was a microbiological assessment of cleaning within a pediatric day ward. As far as the authors are aware, this is the first study assessing the direct impact of before and after cleaning within this setting. From the 1,160 samples taken from 11 areas, the results have demonstrated that within the ward, there is great variability in effectiveness of cleaning across the different surfaces and areas. Potential factors for these variabilities have been explored and discussed, including area sampled, surface material, interaction with the surface, perceived risk and cleanability.

Numerous other studies have shown variable compliance with cleaning and success in using cleaning and cleaning training interventions to reduce microbiological levels in hospitals [7-9]. Within this study, it has been demonstrated that there has been an average overall reduction of CFU by 68%. This reduction was linked to a variety of factors, of which caused a wide variation of change in cleaning effectiveness and bacterial loading of a surface. All surfaces were sampled before and after cleaning, so a breakdown of these factors was possible.

Generally, cleaning was moderately effective throughout the ward. Surfaces that had a low CFU prior to cleaning had an increase in bacterial load after cleaning, as shown by an increase of up to 180% for surfaces that were previously cleaner (<20 CFU/plate). Another key finding from this study was how personal perception had an impact on cleaning efficacy. Surfaces deemed difficult to clean were the least contaminated (17 CFU/plate) compared to easy to clean surfaces at 32.53 CFU/plate. Surfaces with moderate risk to patients had a higher CFU (42.58 CFU/plate) than those classified as low or high risk. These findings are consistent with other studies which consider the impact of perception and attitudes of cleaners and environmental service workers to their role. One study implementing training and a change of attitude and culture shift as part of a larger REACH (Researching Effective Approaches to Cleaning in Hospitals) intervention was an effective component that impacted cleaning [10]. Several studies have identified the importance of attitude, and feeling included and respected as part of a team as a potential source for cleaning failures, and therefore a key element to target in order to drive improvement in cleaning [8, 11, 12].

Within this study, before cleaning, the corridor and reception areas were demonstrated to have the highest levels of contamination, with average CFU's of 81.98 CFU/plate and 74.25 CFU/plate respectively. The most contaminated surfaces before cleaning were the bookcase in the corridor (115.33 CFU ±19.82), the floor in the reception seating area (104.33 CFU ±29.45) and the shelf surface in the playroom (100.78 CFU ±33.56). These results were consistent with findings throughout the study in which several factors had a direct impact on CFU recovery. Other studies support these findings, in which high levels of contamination were found from non-clinical areas [13]. All three surfaces were classified as low risk, which was linked to an increase in contamination (41.08 CFU/plate). The shelf and floor were allocated as easy to clean and the bookcase moderate, which is linked to increased CFU (32.53 and 42.58 CFU/plate). The floor and bookcase had mostly patient interaction and the shelf had interactions with all people within the hospital environment, which was linked with increased CFU (50.12 and 32.73 CFU/plate). In particular, floors are an important consideration of this study when dealing with the unique pediatric subset. Some studies argue that floors are not an important part of the surface environment and should not be considered as an important vehicle for infection transmission, as patients rarely come into contact with these surfaces [14, 15], yet within pediatrics, this patient-surface interaction is very different [16].

These findings were different to those from other studies, in which surfaces closest to the patient are more commonly sampled as these are considered the highest risk and most contaminated, in which surfaces such as bed rails [17, 18], bed tables [17, 19] and patient lockers [20] were found to be the most contaminated. While this study assessed CFU and did not undertake species identification, other studies assessing clinically significant pathogens support these findings, where the wider environments were found to be most contaminated. A wide diversity of contaminants have been isolated from public areas in other studies within the clinical environment [21-23]. Within the pediatric environment, patient interaction is more likely to occur within these communal areas due to the nature of the patient subset and unique surface interactions, such as sitting and playing on floors, and interacting with toys and other sensory objects [16].

The data suggest that surfaces which have the most interaction with patients and their parents or guardians were the most contaminated following cleaning (Figure 1c). A lower level of CFU was consistently found within the height and weight room. This area had a large amount of both staff and patient interaction. Due to this constant use throughout the day and high potential for contamination (nappy change table), these surfaces could be considered high risk, and high risk surfaces have shown more effective cleaning due to perception of risk (figure 2e). Both plastic and coated wood surfaces had a large proportion of interactions with staff (12 out of 23 and 3 out of 6 respectively) which, again, was shown to correspond with bacterial loading (figure 2c).

Surface type had the largest impact on bacterial loading, with metal surfaces increasing 167.68% following cleaning. This could be linked to metal surfaces being mostly allocated as easy to clean and therefore linked to cleaner perception. Of the 14 metal surfaces assessed within this study, 9 were classified as easy, 4 moderate and 0 difficult to clean. Surfaces allocated as easy to clean were shown to have the greatest increase in CFU (+34.12) after cleaning (figure 2f). Surfaces made from plastic and coated wood had an overall reduction, potentially due to the majority of plastic surfaces being deemed as high risk (13 out of 23 surfaces) and wood surfaces (4 out of 6) which have been shown to be linked to a decrease in contamination (figure 2e).

As some of the data are dependent on personal perceptions of different ward staff, it is important to consider the possible bias. Perceived cleanability and perceived risk of a surface will undoubtedly vary between staff members. Furthermore, these personal perceptions may also vary between the role of each staff member. In order to reduce the risk of bias, these standards were predetermined following consultation with the Great Ormond Street Hospital Infection Prevention and Control team, and all cleaning efforts were judged the same. The ward staff were not made aware that this was an area of focus within the study.

Limitations of the study include the single ward environment in which the samples were taken. Inclusion of different wards with different specialties and patient subsets could have given an indication of differences of ward environment and cleaning. Another limitation was the cleaning crew allocated to the ward. The ward sampled had a specific cleaning team, which is not always representative of subcontracted cleaning throughout the rest of the hospital and other healthcare facilities. Furthermore, there were many factors that could not be controlled, such as the inability to take samples when rooms were unavailable due to contact precautions. During the day, prior to sampling, patient, visitor and staff numbers were not recorded, all of which could have had an impact on levels of CFU. Contact plates were used for all surface samples, which were not ideal for recovering from uneven surfaces, such as door handles, or wet surfaces such as sinks [24].

Conclusion

These results show that during the sampling period, overall, a reduction of 63% in microbial load has occurred. There was considerable difference in cleaning efficacy and initial contamination levels across all surfaces sampled and between clinical and non-clinical areas, caused by a variety of factors as assessed within this study. The findings from this study suggested perception of a surfaces' risk to patient and cleanability is an important factor in cleaning efficacy. Other work has demonstrated how attitude can cause a variance in competency and is reflected within the range of results.

Some areas were consistently clean, both before and after cleaning, such as the surfaces in the height and weight room. Some areas were cleaned more effectively than others; the treatment room, on average, had an 80% reduction in contamination levels following cleaning, whereas the outpatients reception area had an increase of 12% following cleaning. Some areas, such as the sluice, were cleaner than others both before and after cleaning, while other individual surfaces had consistently higher CFU such as the bookcase in the corridor and the playroom shelf.

When considering the impact and application of these findings, the results from this study can be used to provide evidence for cleaning training with targeted components, with particular consideration to the weight that personal perception of risk and cleanability of a surface have on how well cleaning has been undertaken.

References

[1] Cassini A, Plachouras D, Eckmanns T, Abu Sin M, Blank HP, Ducomble T, et al. Burden of Six Healthcare-Associated Infections on European Population Health: Estimating Incidence-Based Disability-Adjusted Life Years through a Population Prevalence-Based Modelling Study. Plos Med. 2016;13.

[2] Al-Tawfiq JA, Tambyah PA. Healthcare associated infections (HAI) perspectives. J Infect Public Health. 2014;7:339-44.

[3] Dancer SJ. Dos and don'ts for hospital cleaning. Curr Opin Infect Dis. 2016;29:415-23.

[4] 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.

[5] Doll M, Stevens M, Bearman G. Environmental cleaning and disinfection of patient areas. Int J Infect Dis. 2018;67:52-7.

[6] Struelens M. The epidemiology of antimicrobial resistance in hospital acquired infections: Problems and possible solutions. Brit Med J. 1998;317:652-4.

[7] 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.

[8] Ni KW, Chen BB, Jin H, Kong QX, Ni XP, Xu H. Knowledge, attitudes, and practices regarding environmental cleaning among environmental service workers in Chinese hospitals. Am J Infect Control. 2017;45:1043-5.

[9] Mitchell BG, Farrington A, Allen M, Gardner A, Hall L, Barnett AG, et al. Variation in hospital cleaning practice and process in Australian hospitals: A structured mapping exercise. Infect Dis Health. 2017;22:195-202.

[10] 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.

[11] 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.

[12] Allen M, Hall L, Halton K, Graves N. Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy. Infecti, Dis Health. 2018;23:107-13.

[13] Wang YL, Chen WC, Chen YY, Tseng SH, Chien LJ, Wu HS, et al. Bacterial contamination on surfaces of public areas in hospitals. J Hosp Infect. 2010;74:195-6.

[14] Dancer SJ. Mopping up hospital infection. J Hosp Infect. 1999;43:85-100.

[15] Hardy KJ, Gossain S, Henderson N, Drugan C, Oppenheim BA, Gao F, et al. Rapid recontamination with MRSA of the environment of an intensive care unit after decontamination with hydrogen peroxide vapour. J Hosp Infect. 2007;66:360-8.

[16] Posfay-Barbe KM, Zerr DM, Pittet D. Infection control in paediatrics. Lancet Infect Dis. 2008;8:19-31.

[17] 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.

[18] Al-Hamad A, Maxwell S. How clean is clean? Proposed methods for hospital cleaning assessment. J Hosp Infect. 2008;70:328-34.

[19] Shams AM, Rose LJ, Edwards JR, Cali S, Harris AD, Jacob JT, et al. Assessment of the Overall and Multidrug-Resistant Organism Bioburden on Environmental Surfaces in Healthcare Facilities. Infect Cont Hosp Ep. 2016;37:1426-32.

[20] Claro T, O'Reilly M, Daniels S, Humphreys H. Surface microbial contamination in hospitals: A pilot study on methods of sampling and the use of proposed microbiologic standards. Am J Infect Control. 2015;43:1000-2.

[21] Flores GE, Bates ST, Knights D, Lauber CL, Stombaugh J, Knight R, et al. Microbial biogeography of public restroom surfaces. Plos One. 2011;6:e28132.

[22] Flores GE, Bates ST, Caporaso JG, Lauber CL, Leff JW, Knight R, et al. Diversity, distribution and sources of bacteria in residential kitchens. Environ Microbiol. 2013;15:588-96.

[23] D'Arcy N, Cloutman-Green E, Klein N, Spratt DA. Environmental viral contamination in a pediatric hospital outpatient waiting area: Implications for infection control. Am J Infect Control. 2014;42:856-60.

[24] 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.