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Is it really clean? An evaluation of the efficacy of four methods for determining hospital cleanliness

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Summary An important component of effective cleaning in hospitals involves monitoring the efficacy of the methods used. Generally the recommended tool for monitoring cleaning efficacy is visual assessments. In this study four methods to determine cleaning efficacy of hospital surfaces were compared, namely visual assessment, chemical (ATP) and microbiological methods, i.e. aerobic colony count (ACC) and the presence of meticillin-resistant *Staphylococcus aureus*. Respectively, 93.3%, 71.5%, 92.1% and 95.0% of visual, ATP, ACC and MRSA assessments were considered acceptable or 'clean' according to each test standard. Visual assessment alone did not always provide a meaningful measure of surface cleanliness or cleaning efficacy. The average ATP value from 120 swabs before cleaning was 612 relative light units (RLU) (range: 72–2575) and 375 RLU after cleaning (range: 106–1071); the accepted standard is 500 RLU. In a hospital setting with low microbiological counts, the use of chemical tests such as ATP may provide additional information of cleaning efficacy and ATP trends allow identification of environmental surfaces that require additional cleaning or cleaning schedule amendments.

Introduction

The role of contaminated environmental surfaces in the transmission of healthcare-associated pathogens such as meticillin-resistant *Staphylococcus aureus* (MRSA) is supported by the fact that cleaning and/or disinfection of the environment can

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reduce the incidence of healthcare-associated colonisation or infection.[1,2] While it is recognised that hand hygiene is the most important factor in preventing healthcare-associated infection, touching contaminated surfaces may result in the acquisition of pathogens on hands. Hence, monitoring the environment as a reservoir of pathogens has recently assumed a greater priority.[3]

Environmental cleaning regimens are not standardised or regulated and monitoring of cleaning efficacy is generally based on visual assessment. This method can overestimate cleanliness, thus proposals for bacteriological standards with which to assess clinical surface hygiene in hospitals, based on those used by the food industry, have been suggested as a more effective means of hygiene monitoring.[4,5] These methods include traditional microbiological methods such as total aerobic colony count (ACC) to detect the number of bacteria on environmental surfaces, and culture of indicator organisms, as these are a potential high risk to patients in any quantities. Additionally, rapid cleanliness testing by ATP bioluminescence, which detects the bioburden present and not just the level of bacterial contamination, is a quick way to assess the cleanliness of an environmental surface. It provides a quick and sensitive test that can detect whether cleaning is inadequate.[6]

Although the goal of environmental cleaning and disinfection is not sterilisation, adequate cleaning requires sufficient removal of grime/debris/microbes and pathogens to minimise patients' risk of acquiring infections from hospital environments.[7] Current guidelines in Ireland and elsewhere for assessing hospital hygiene recommend the use of visible cleanliness as a performance criterion. In this study, visual assessment was compared with ATP bioluminescence monitoring, microbial load (ACC) and MRSA detection to determine cleaning efficacy in an Irish hospital of ten hospital ward surfaces before and after cleaning on two inpatient wards. We evaluated whether visual assessment was a sufficient means of monitoring cleaning efficacy.

Methods

Study design

To evaluate the potential use of the 3M™ ATP bioluminescence hygiene monitoring system (3M International Ltd, Brigend, UK) in a hospital environment, the surface cleanliness of ten environmental surfaces was compared before and after cleaning in two wards (a medical ward and a surgical ward) in Beaumont Hospital, a 700-bed adult tertiary referral hospital. Two high-dependency rooms on each ward (Room A with four beds and Room B with six beds) and one isolation room (with an MRSA-positive patient) were chosen for the study. The ten sites analysed include nine common hand-touch surfaces and one floor surface. Flat surfaces included the door handle/push plate, patient table, patient locker, window ledge, a random area in a treatment room, a random area on the nurse's desk/station and the toilet floor. The toilet floor was included to determine the cleanliness level of a surface that is commonly perceived as 'very dirty' or contaminated. Curved surfaces included the patient bedframe and the handle rail in the toilet. Each of these surfaces was in good condition and would pass the parameters set out in the Infection Control Nurses Association (ICNA) audit guidelines. All surfaces with the exception of the curtain are considered easy to clean. The curtains were not regularly cleaned or changed. The probability of healthcare workers touching or walking on these surfaces was high, as wards are usually full to capacity and have a heavy throughput of patients/staff and visitors. Each site was sampled with three swabs (three 10×10 cm areas beside each other were sampled); first with a Clean-Trace® swab (ATP), and then with two other saline-moistened sterile cotton swabs for ACC and MRSA culture. All ten sites were sampled early in the morning (before routine cleaning) and again in the afternoon (after routine cleaning).

Nine hundred and sixty environmental assessments were conducted including (Figure 1) 240 visual assessments, 240 ATP bioluminescence swabs, 240 total viable bacterial counts and 240 swabs for the isolation and identification of MRSA. Of each of these 240 assessments, 120 were acquired from a medical ward and 120 from a surgical vascular ward. Each of these assessments was acquired by swabbing/assessing the 10 selected environmental sites before and after cleaning. Twenty swabs/assessments were collected in three separate rooms (A, B and an isolation room). Each room was assessed twice over a period of six days, giving 120 assessments for each method.

Test standards/pass rates

The results were analysed according to various test standards selected for this study, which specify: (i) an ACC pass rate is an aerobic colony count (ACC) <2.5 cfu/cm; (ii) an MRSA pass rate results from the absence of detection of MRSA on a surface; (iii) a visual pass was based on a surface being

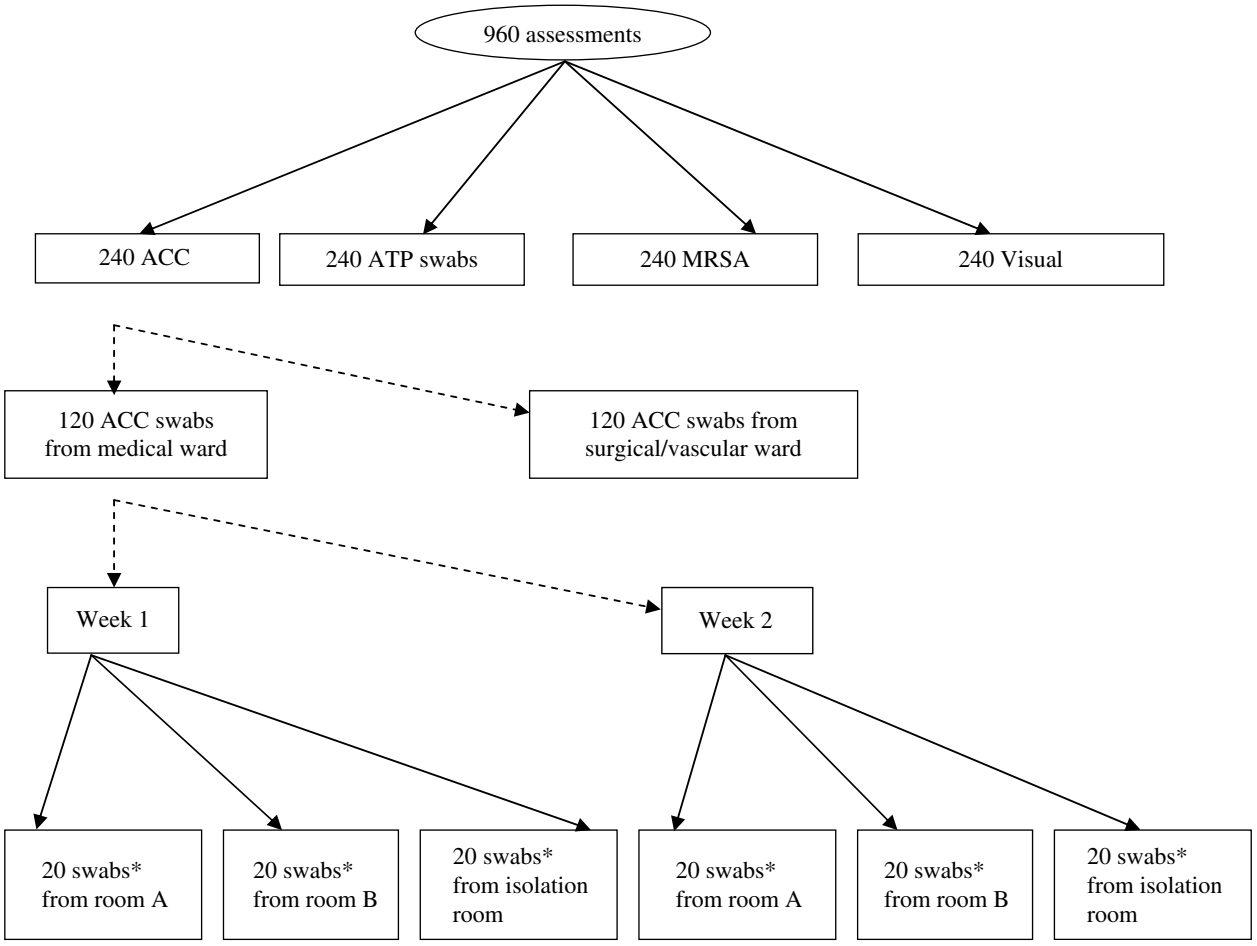

Figure 1 Flow chart for 960 environmental assessments of cleanliness, including 240 visual assessments, 240 ATP bioluminescence swabs, 240 total viable bacterial counts and 240 swabs for the isolation and identification of MRSA. ACC, aerobic colony count; MRSA, meticillin-resistant *Staphylococcus aureus*. *Ten before clean and 10 after clean.

graded as 'clean' based on the absence of visual soiling, presence of moisture, staining or poor surface condition (derived from ICNA guidelines) and (iv) an ATP pass rate was a bioluminescence result $<$500 RLU.[5,8–10]

Cleaning schedule

Routine cleaning of non-infected areas is completed using soap (Teepol) and water, while wards housing MRSA patients are disinfected with 1000 ppm hypochlorite (Presept). The cleaning schedule used is similar to that described elsewhere and includes 'mop and vacuum', 'spray clean' and a 'wet scrub'.[11] The cloths used contain antibacterial agent and are colour-coded specific to the cleaning task, i.e. toilet: blue cloth; hand basins: green; infected areas: red; etc. A flat mopping system is used and mops are also colour-coded according to the task.

3M™ ATP bioluminescence using the Clean-Trace swabs

All organic matter contains an energy molecule, ATP. ATP bioluminescence uses light to measure organic matter and this measurement can then be used as an indicator of hygiene, i.e. the absence of dirt. ATP results are expressed as relative light units (RLU). The Clean-Trace swabs were processed according to the manufacturer's instructions (10 cm^2 surface area was swabbed in a zig-zag pattern). Results were read and recorded in the Uni-Lite® NG luminometer.

Total viable counts from environmental swabs

Swabs for ACC were moistened in sterile saline solution prior to use and a 10 cm^2 surface swabbed. The swab was suspended in 1 mL sterile

saline, vortexed for 10 s and 100 μL spread on to a Columbia Blood Agar (CBA) plate (Cruinn Diagnostics, Dublin, Ireland) using a sterile spreader, and incubated for 48 h in a 37 °C incubator. Following 48 h incubation, any colony growth on the plates was counted and the ACC calculated.

MRSA isolation and identification from environmental swabs

MRSA was isolated from the environment (10 cm^2 surface) using saline-moistened cotton swabs. Swabs were inoculated into MRSA enrichment broth (Tryptone Salt Broth 6% NaCl; Cruinn), incubated overnight, before being subcultured on to chromogenic agar (MRSA Select® Chromogenic Agar, Bio-Rad 63747; Bio-Rad Life Science Group, Marnes La Coquette, France) and incubated for 24 h at 37 °C. Colonies resembling MRSA were confirmed by standard microbiology methods (purification on CBA, Staphaurex plus latex slide test (Remel, Dartford, UK), tube coagulase test using rabbit plasma. Meticillin resistance was confirmed using the oxacillin minimum inhibitory concentration evaluators or E-tests (Oxoid, Basingstoke, UK).

Results

In total 13/240 (5.5%) visual assessments of the ten selected environmental sites were graded as 'not clean'. Using the pass/fail parameters mentioned, 68/240 (28.5%) of ATP tests 'failed', 19/240 (7.9%) ACC specimens failed, and 12/240 (5%) of surfaces harboured MRSA. Thus the fail range was 5.5—28.5% depending on the method chosen to monitor surface cleanliness.

The results from the two wards were also compared. The overall mean visual, ATP, microbiological and MRSA pass rate, on the medical versus surgical ward (in brackets) was 91.7% (95%), 82% (60.9%), 96.7% (95.5%) and 97.6% (92.5%). All parameters with the exception of the visual assessment had a higher fail rate on the surgical ward. A difference in pass/fail rates before and after cleaning was apparent for all methods. Fail rates for each method (visual, ATP, microbiological, MRSA) were 5.8%, 15%, 5% and 1.6% respectively on the medical ward before cleaning whereas 2.5%, 3%, 0.8% and 0.8% failed after cleaning. Thus all testing methods showed improvement after cleaning, with ATP fail rates declining the most, by 80%. However, on the surgical ward, fail rates for each method before cleaning were 2.5%, 22.5%, 6.6% and 2.5%, and after cleaning were 2.5%, 16.6%, 2.5% and 5.0%. Notably, there was less of an improvement after cleaning on this ward, and there was increased detection of MRSA after cleaning.

ATP trends were plotted for all 10 surfaces and the results of two sites are shown in Figure 2. Two of 12 (15.6%) toilet floors processed before cleaning passed ATP standards, while 7/12 (58.3%) passed after cleaning. RLU readings from this surface were always higher than from all other surfaces tested, ranging from 1016—7658 RLU before cleaning to 551—5615 RLU after cleaning. In comparison, 11/12 (92%) nursing desks passed before and after cleaning. Figure 3 compares average ATP values for each surface before and after cleaning, highlighting surfaces that require additional cleaning, e.g. toilet floor/lockers/curtains, and enabling of comparison of cleaning efficacy between wards.

ACC and MRSA specimens from all 10 sites before and after cleaning were processed. Nineteen of 240 (7.9%) failed the $>10^3$ cfu/mL or 2.5 cfu/cm^2 ACC standard. The remaining specimens had growth of <2.5 cfu/cm^2; notably 125/240 (52%) of ACC specimens from the environment had no growth. Surfaces on the two wards had similar mean ACC of 1 cfu/cm^2. MRSA was isolated from 11/240 (4.5%) surfaces; 6/11 (55%) of these were from surfaces in isolation rooms housing MRSA patients. The MRSA isolation rate in this study, excluding the isolation rooms, was 5/240 (2.0%) of surfaces tested.

Discussion

There have been a number of publications relating to the inadequacy of visual assessment as a reliable indicator of surface cleanliness or cleaning efficacy. An early study in a Welsh hospital specifically examined concurrent visual assessment of hospital environments against chemical (bioluminescence detection) and microbiological methods of measuring organic and microbial soil.[9] While 82% of wards seemed visibly clean (after cleaning), only 30% were microbiologically clean, and 25% were free from organic soil. The authors concluded that a very basic and inadequate cleaning schedule was in place and hence subsequent studies examining the effectiveness of modified cleaning regimens were completed.[4,10] These studies demonstrated that such modifications resulted in improved ATP pass rates (from 0—14% to 86—100%) and lower bacterial counts. In comparison, our study shows that 93.3% of areas were visibly clean, 92% were microbiologically clean and 71.5% were free from organic soil, thus these initial levels are quite good. However, improvements

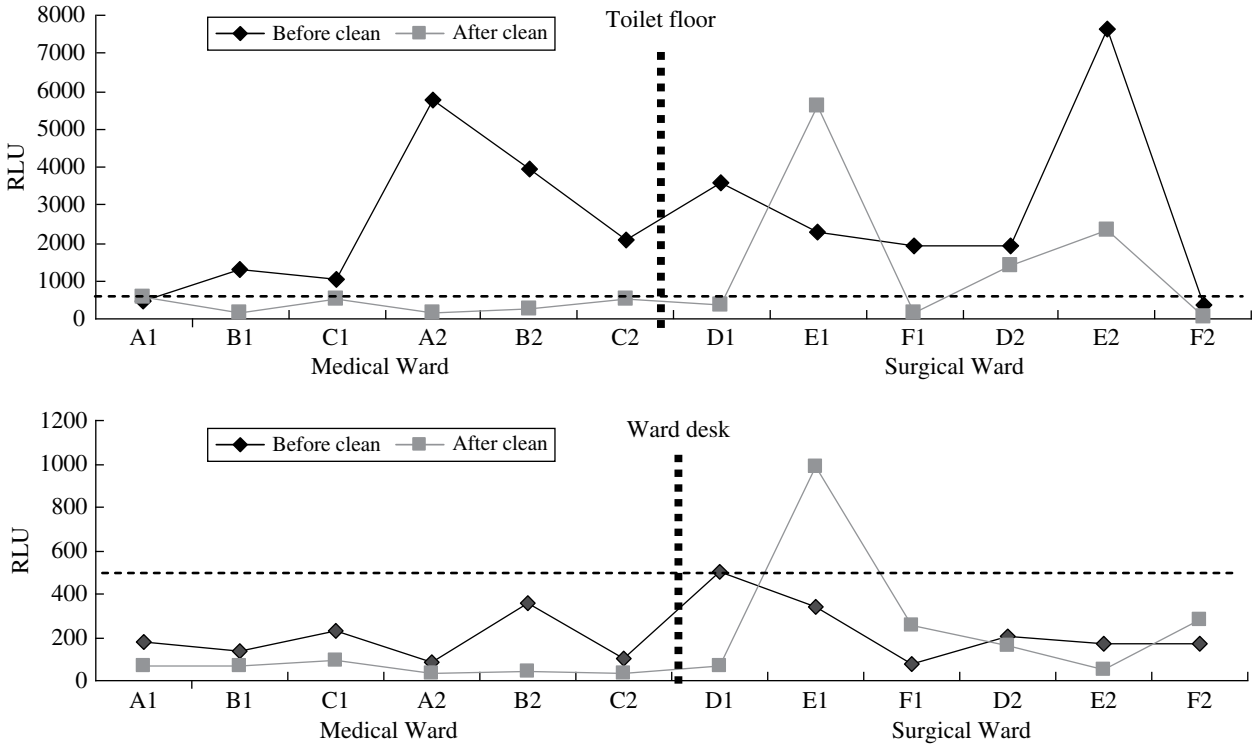

Figure 2 ATP trace, before and after cleaning, on two wards. A1, A2; B1, B2; C1, C2; corresponds to room A, B, C of the medical ward. 1 and 2 designate week 1 and 2 respectively. The same applies to D1—F2, but on the surgical ward. RLU: relative light units; ---: 500 RLU pass/fail line. Vertical dotted line represents the division of the medical and surgical ward data. Diamonds: before clean; squares: after clean.

can be made to our cleaning schedules which may improve our ATP pass level of 71.5% to something closer to that achieved in the Welsh hospital (86—100%). Also, other research has shown that best-practice cleaning procedures and a more stringent pass/fail benchmark are linked to incremental quality improvements.[12] This report suggests a revised pass/fail benchmark of 250 RLU, but our data analysis is based on the former standard of 500 RLU.[9] If a more stringent ATP benchmark were applied to this study, an overall ATP pass score of 50.4% would have been achieved. This more stringent benchmark may be useful if considering implementing novel cleaning or disinfection systems, e.g. vaporised hydrogen peroxide, but may not be achievable in such environments as hospitals housing sick and infected patients and full to capacity.

While overall failure rates provide an indication of cleaning efficacy in relation to benchmark values, they do not provide an indication of the extent of failure.[4] Thus the use of ATP technology has added value when applied to the monitoring of cleaning trends of specific surfaces. The ATP graphs plotted using 3M™ software highlight the areas in each ward that require additional attention, i.e. the floor in comparison to the nurse's desk (Figure 2). Cleaning of this surface either more frequently or more effectively is necessary. Also apparent from plotted bar charts (Figure 3A and B) is the success/failure of cleaning in the medical versus surgical ward. In the surgical ward, cleaning was less effective with as much as 50% of RLU values increasing after cleaning. This may be due to contamination of surfaces during the cleaning process on this ward, or perhaps due to the higher levels of patient movement on this ward and subsequent surface recontamination. The treatment room and window ledge are potential sources of dirt/infection here but this is not apparent on the medical ward. These graphs enable visualisation of the effectiveness of cleaning with the majority of RLU values falling after cleaning. The use of ATP to monitor cleaning efficacy is a sensitive test that reports not just the presence of microbiological, but also any organic, contamination. Whereas reporting this level of sensitivity in many hospitals is new, it is common practice in industry and has important implications for the maintenance of good manufacturing practice and product safety/sterility. The cost per test of a Biotrace swab is €2.80. Time to result after the swab has been taken is 20 s. By comparison, an ACC swab and plating on CBA is approximately €0.60

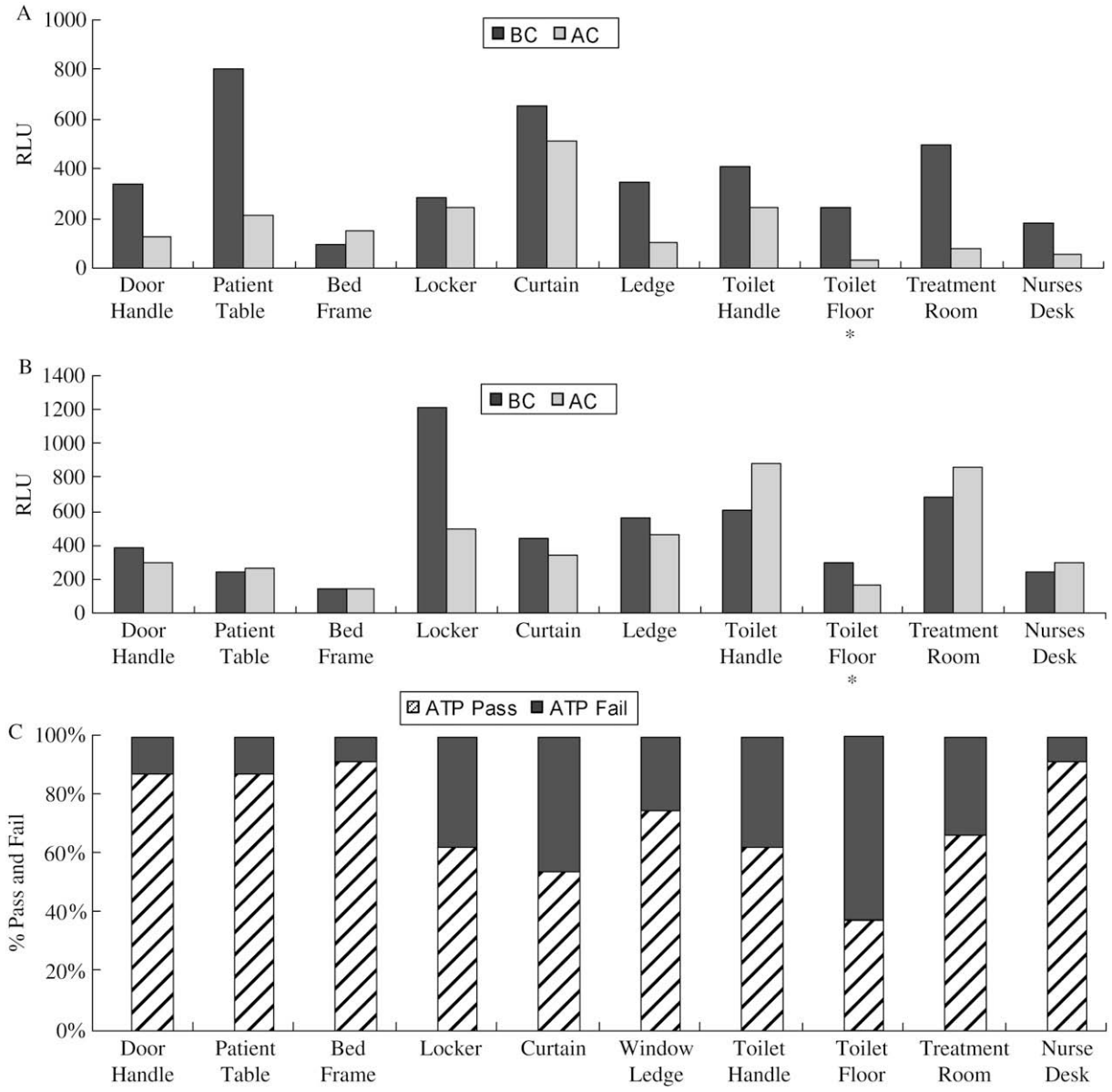

Figure 3 (A, B) ATP trace results from 10 environmental sites before (BC) and after cleaning (AC) on (A) a general medical ward and (B) a general surgical ward. *Toilet floor values require multiplication by a factor of 10. (C) Overall ATP pass/fail rates from 10 environmental sites from two wards. RLU, mean relative light units.

with time to result being 48 h. An MRSA swab/enrichment and plating test costs approximately €2 with time to a negative or preliminary positive result being a minimum of 48 h. The cost per MRSA positive test significantly increases when confirmatory tests are considered. Recent studies show that feedback of cleaning efficacy to ward and cleaning staff improves the thoroughness of cleaning and the environmental prevalence of MRSA and vancomycin-resistant enterococcus.[2,7] Considering the costs and time delays for each test type, the use of ATP swabs for monitoring may be justified. Additionally, ATP testing and data interpretation would be a useful tool when training cleaning staff, running hygiene education programmes or when used as a random audit tool. Unlike visual methods, ATP testing is not subjective.

In this study the microbial load on hospital surfaces was also assessed using ACCs and MRSA isolation. ACCs are a good indicator of general bioburden in an environment, but they are slow to process. Eight out of 120 (6.6%) ACC counts failed on the medical ward and 11/120 (9.1%) on the surgical ward. Notably, >50% of specimens processed for ACC produced no growth at all, thus ATP data have added value here for trend analysis. Further studies using contact plates/dip slides or

use of neutralising buffer swabs instead of just saline-moistened swabs may be best for sampling the environment and may recover more micro-organisms/data. This study did not show a correlation between ATP and cfu/mL values, a finding replicated by others.[13] However, as the two techniques measure different parameters, an integrated approach to monitoring cleaning regimens may be the most useful. While ACCs do not themselves relate to risk of infection, indicator organisms such as MRSA indicate contamination and do relate to potential risk of infection. It has been shown that 1—27% of general ward surfaces harbour MRSA.[14] Here, MRSA was isolated from 11/240 (4.5%) of surfaces tested, of which 55% was attributed to the immediate environs of MRSA-positive patients. Increased cleaning of isolation rooms coupled with monitoring may reduce this proportion further.

The visual assessment method used in this study, as shown by others, proved the least sensitive method for assessing cleanliness, especially when compared with such rapid hygiene-testing methods as ATP bioluminescence.[8,15,16] More recently in an attempt to improve visual assessment, fluorescent dyes have been used to coat surfaces, and their subsequent removal used as a measure of cleaning efficacy.[17] Although this method would be an improvement on simple visual methods and can assist in providing feedback to cleaning and other staff, it is qualitative, not quantitative.[7] In summary, visual methods to evaluate cleanliness are subjective and inadequate. As standard methods for the isolation of micro-organisms from the hospital environment have not been established, and as organism recovery is often low or absent, the use of rapid methods such as ATP bioluminescence monitoring in a hospital setting should be considered in conjunction with visual methods.

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Conflict of interest statement
None declared.

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