Multilevel antimicrobial disinfectant coating in reducing the viability of multidrug-resistant organisms in hospital environment

HH Leung, CKC Lai, KL Yeung, JKC Kwan *, DNC Tsang

KEY MESSAGES

1. Proper training of cleaning personnel and rigorous oversight and strict enforcement of cleaning routine can improve overall cleanliness and decrease bacterial load in the ward environment.
2. Multilevel antimicrobial disinfectant coating achieves consistently low bacterial load in the ward environment independent of the cleaning regimen.
3. The number of multidrug-resistant organism (MDRO)-positive environmental samples between two cleaning regimens does not differ significantly owing to rapid surface reacquisition of MDROs.
4. The occurrence of MDROs in the environmental samples is lower on surfaces coated with the multilevel antimicrobial disinfectant coating regardless of the cleaning regimen.

Hong Kong Med J 2018;24(Suppl 6):S37-9
RFCID project number: 12111772

[1] HH Leung, [2] CKC Lai, [1,3] KL Yeung, [3,4] JKC Kwan, [2] DNC Tsang

[1] *Department of Chemical and Biomolecular Engineering, The Hong Kong University of Science and Technology*
[2] *Department of Pathology, Queen Elizabeth Hospital*
[3] *Division of Environment, The Hong Kong University of Science and Technology*
[4] *Health, Safety and Environment Office, The Hong Kong University of Science and Technology*

* Principal applicant and corresponding author: joekwan@ust.hk

Introduction

The increasing occurrence of multidrug-resistant organisms (MDROs) in hospitals is of great concern. Infections caused by MDROs can result in longer hospitalisation, increased treatment cost, and higher mortality. MDROs can survive for a prolonged period on hospital furnishings and medical items. MDROs in hospital environments have been associated with an increased risk of transmission and infection.[1] Reducing environmental contamination through improved cleaning practices reduces patient acquisition of pathogens. Regular cleaning and disinfection is important for breaking the chain of infection. Nonetheless, MDROs can still be found in frequently touched areas in hospitals. Antimicrobial coatings in these areas might reduce MDRO infection rates.

Numerous antimicrobial systems have been reported, including biocidal nanomaterials such as nanosilvers, light-activated photocatalysts based on TiO_2, surface-tethered bactericides such as quaternary ammonium compounds, and phosphonium salts. These materials impart 'contact-killing' bactericidal properties and are effective against a wide spectrum of microorganisms. Ultrahydrophobic coatings and bacteria-repelling poly(ethylene glycols) discourage bacterial adhesion and growth on surfaces. Another strategy is to store antibiotic drugs, chemical biocides, and bactericidal metal ions in bulk and coating materials for gradual release and sustained 'release-killing' bactericidal activity. Contact-killing and anti-adhesion bactericidal materials are susceptible to surface fouling that can drastically diminish their effectiveness, whereas release-killing bactericides depend on water-bridge for the transport of active compounds. Combinations of one or more of these approaches are necessary to overcome these deficiencies.

Our research team at the Hong Kong University of Science and Technology developed a multilevel antimicrobial disinfectant coating that synergistically combines 'release-killing', 'contact-killing' and 'anti-adhesion' properties to enable long-lasting disinfection of surfaces. The coating has been reported to be responsive to contamination and rapidly inactivate a panel of Gram-positive and Gram-negative bacteria (>99.99%) within 1 minute of contact with the coated surface.[2] The coating is safe and does not cause skin irritation or affect the lung function in mice. The coating can be applied by spray or wipe on variety of surfaces without altering the visual, tactile, or olfactory property of the coated surface. This study aimed to investigate the use of the multilevel antimicrobial disinfectant coating in reducing the viability of MDROs including Methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococci* (VRE), and multidrug-resistant *Acinetobacter* (MDRA) in hospital ward environment.

Methods

Four orthopaedic wards at Queen Elizabeth Hospital participated during July 2013 to January 2015 in three stages: stage 1 (July 2013 to November 2013), washout stage (December 2013 to June 2014), and stage 2 (July 2014 to January 2015). In stage 1, wards A and B were planned as the treatment group and wards C and D as the control group. The study was suspended by the occurrence of a H7N9 case in Hong Kong until late May 2014. In stage 2, wards C and D were the treatment group and wards A and B the control group. A total of 2249 environmental samples were taken from stage 1 (n=966) and stage 2 (n=1283).

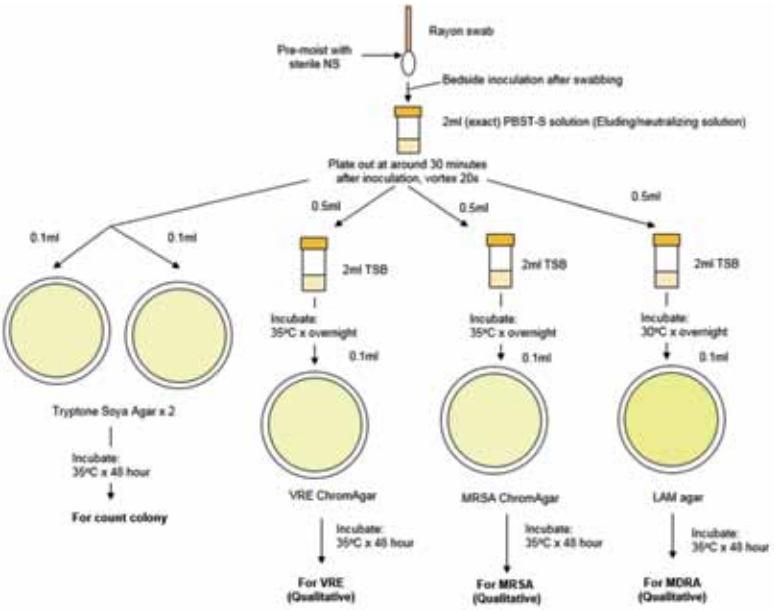

FIG 1. Workflow for assessment of bacteria and multidrug-resistant organisms in hospital environmental samples

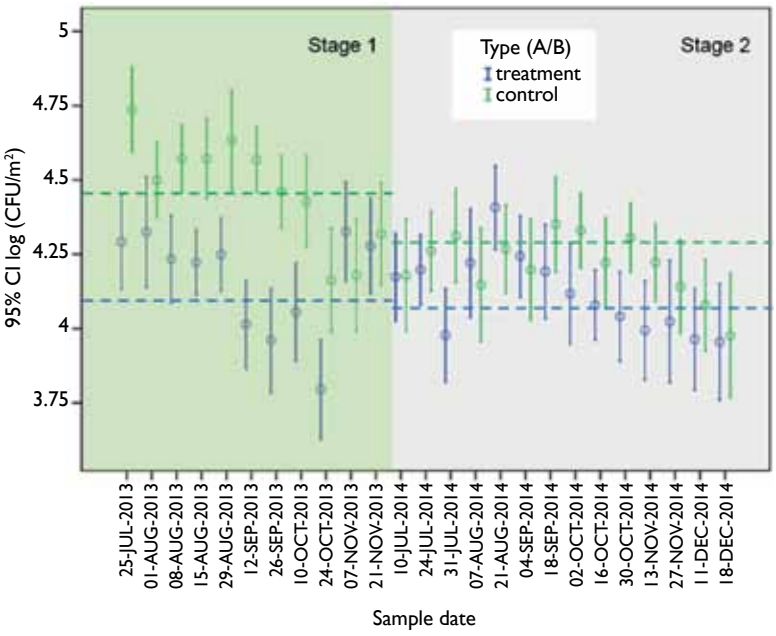

FIG 2. Viable bacteria found on select hospital surfaces in log colony forming unit (CFU)/m² over time

Daily cleaning routine in the wards was performed at 10:00 am from patients' outer surrounding to the inner zone by in-house cleaning workers using 1000 ppm sodium hypochlorite solution. Gloves and masks were worn. 10 000 ppm sodium chlorite solution was used for blood and bodily fluid spillage. Beds that were identified to contain MDRO carriers were cleaned twice a day. In stage 2, cleaning was performed by an outsource cleaning company from 9:15 am to 3:00 pm using the same protocol.

Every Tuesday, 25 beds were selected, and three items from each bed were coated, including the top surface of the hospital chest table, the top surface of the bedside cabinet, and right and left bed rails. All beds identified with MDRO carriers were included, and the remainder was selected randomly. The multilevel antimicrobial disinfectant coating was used in the treatment group, and a placebo coating that contained mainly water, dye, and dilute (0.06%) sodium hypochlorite was used in the control group.

Environmental samples were collected on Thursday every other week before the daily cleaning. Swab samples were taken from three items (225 cm^2 of the hospital chest table, 225 cm^2 of the bedside cabinet, and 225 cm^2 of the bed rails). The sterile rayon swab was moistened with 0.9 wt % sodium chloride. After sampling, the tip of the swab was severed and submerged in 2.5 mL neutralising solution for storage (0.001 M sodium thiosulphate, 0.2% Tween 80, 0.9% w/v sodium chloride) and processed within 2 hours.

To assess environmental bacteria and MDRO, the swab was vortexed to recover trapped bacteria and 100 μL of the solution was transferred to a TSA plate (Fig 1). Duplicate plates were made for consistency. The colony forming unit (CFU) on Müller-Hinton Agar represented the total aerobic bacteria count in the sample. Plates without any CFU were given a 0.5 CFU count based on the minimum detection limit of the method. Plates with considerable difference in plate counts and with evident contamination were discarded. A culture sample was prepared by transferring 0.5 mL of the remaining sample to 2-mL sterile TSB solution and incubating at 35°C. A second culture sample was prepared in similar manner but incubated at 30°C. The amplified cultures were tested for the presence of MRSA, MDRA and VRE.

Results and discussion

Environmental bacteria found during stage 1 and stage 2 are summarised in Figure 2. Blind test and use of placebo minimises bias. Comparing stage 1 and stage 2, the change in cleaning personnel and management system and stricter observance of cleaning routine had an effect on controlling microbial contamination of surfaces. The use of the multilevel antimicrobial disinfectant coating achieved consistently low viability of bacteria on treated surface. An improvement of 36.1% was observed in the treatment group, indicating that the multilevel antimicrobial disinfectant coating was more effective than cleaning alone in maintaining low bacterial load in hospital environment.

Environmental MDROs including MRSA, VRE, and MDRA were present in hospital environment. The environmental samples were sub-cultured and the amplified samples were tested for the presence of MRSA, VRE, and MDRA. This method only indicated the presence or absence of MDRO instead of the quantity of the MDROs in the sample. Of the 2249 environmental samples, 14.2% were positive for MRSA, 1.3% positive for VRE, and 2.4% positive for MDRA. Ward patients were actively screened for MRSA, VRE, and MDRA from wound, blood, and urine. The preferential inclusion of the beds of MDRO carriers and the unequal distribution of MDRO carriers among the wards mean that the ANOVA method is not strictly valid. In addition, a more vigorous cleaning routine was used for the beds of MDRO carriers. Indeed, 73.5% of samples from the beds of MRSA carriers tested negative for MRSA, and approximately 66.8% of samples containing MDROs were found from beds of non-MDRO carriers.

The MDRO dataset was categorised into 0 (negative from both environmental sample and patient bed), 1 (positive from environmental sample and negative from patient bed), 2 (negative from environmental sample and positive from patient bed), 3 (positive from both environmental sample and patient bed). Therefore, MDRO in the environment over the sampling period can be normalised as (1+*[3]*)/n, whereas MDRO carriers can be accounted by (*[2]*+*[3]*)/sampling. Thus,

$$\frac{(1+[3])/n}{([2]+[3])/\text{sampling}} = \text{MDRO (environment)} : \text{MDRO (patient)}$$

The above equation takes into account the inequality in the distribution of MDRO carriers in the wards; a decrease in the value indicates a decrease in environmental MDRO isolates in the ward. Although the bacterial load on hospital surfaces was greatly reduced during stage 2, the effect was minimal on MDRO occurrence in the environmental samples (Table). This may be due to the reacquisition of MDROs between cleaning. In contrast, the multilevel antimicrobial disinfectant coating provided sustained surface disinfection and decreased the incidence of MDROs in the environmental samples. Thus, the use of multilevel antimicrobial disinfectant coating along with strict observance of cleaning routine and hand hygiene can be effective in reducing environmental occurrence of MDROs in hospital environment.

TABLE. Ratio of environmental multidrug-resistant organisms (MDRO) to number of patients with MDRO

Parameter	Ratio of environmental MDRO to number of patients with MDRO
Change in cleaning routine	
Stage 1 (control)	0.099
Stage 2 (control)	0.095
Impact of coating	
Overall (control)	0.097
Overall (treatment)	0.088

Acknowledgements

This study was supported by the Research Fund for the Control of Infectious Diseases, Food and Health Bureau, Hong Kong SAR Government (#12111772). This work would not have been possible without cooperation and support from the microbiology laboratory and the orthopaedic wards in Queen Elizabeth Hospital.

References

1. Dancer SJ, White LF, Lamb J, Girvan EK, Robertson C. Measuring the effect of enhanced cleaning in a UK hospital: a prospective cross-over study. BMC Med 2009;7:28.
2. Li Y, Leung WK, Yeung KL, Lau PS, Kwan JK. A multilevel antimicrobial coating based on polymer-encapsulated ClO(2). Langmuir 2009;25:13472-80.