Journal of Microbiology, Immunology and Infection (2017) 50, 737–746

Available online at www.sciencedirect.com

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ORIGINAL ARTICLE

Bio-Kil, a nano-based disinfectant, reduces environmental bacterial burden and multidrug-resistant organisms in intensive care units

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Received 24 December 2015; received in revised form 14 April 2016; accepted 25 April 2016
Available online 13 May 2016

KEYWORDS
Bio-Kil;
environmental decontamination;
healthcare-associated infections;
multidrug-resistant organisms

Abstract *Background/Purpose:* This prospective before-after study was intended to investigate the effect of Bio-Kil on reducing environmental bacterial burden and healthcare-associated infections (HAIs) in intensive care units (ICUs) at the Municipal Wan-Fang Hospital, Taipei, Taiwan in 2014.
Methods: Four rooms in the medical and surgical ICUs were investigated and designated as study rooms ($n = 2$) or control rooms ($n = 2$). Routine disinfection was performed during the pre-intervention period in both room types. Bio-Kil was applied to the fomites and surroundings of the study rooms during the intervention period. Total bacterial burden and proportion of colonization of fomites and surroundings by multidrug-resistance organisms (MDROs) were determined before and after the intervention. The demographic characteristics, underlying conditions, and clinical outcomes of patients were analyzed.

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http://dx.doi.org/10.1016/j.jmii.2016.04.008

Results: After application of Bio-Kil, the bacterial burden declined in both groups, although the reduction was greater in the study rooms as compared with the control rooms ($p = 0.001$). During the pre-intervention period, 16 patients were admitted to control rooms and 18 patients to study rooms. After the intervention, 22 patients were admitted to control rooms and 21 patients to study rooms. The number of cases of new-onset sepsis declined in the intervention group (from 33% to 23.8%), but increased in the control group (from 25% to 40.9%); however, there was no significant difference in incidence of new-onset sepsis between the study and control rooms after intervention.

Conclusion: Application of Bio-Kil reduced the environmental bacterial burden and MDROs in ICUs. Further studies are needed to evaluate the efficacy of this nanotechnology-based disinfectant in reducing HAIs.

Introduction

There is compelling evidence that contaminated inanimate surfaces are major sources of hospital-acquired infections (HAIs).[1–4] Many important nosocomial pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), carbapenem-resistant *Enterobacteriaceae* (CRE), carbapenem-resistant *Pseudomonas aeruginosa* (CRPA), and carbapenem-resistant *Acinetobacter calcoaceticus-baumannii* complex (CRAB), can survive for days to weeks on dry inanimate surfaces.[5] Patients admitted to rooms previously colonized with these pathogens are at increased risk of colonization or infection.[6–8] Additionally, previous research found that the frequency of MRSA contamination was similar for healthcare personnel who either had direct contact with a colonized/infected patient or with contaminated surfaces.[9] Therefore, decontamination and disinfection of hospital environmental surfaces is an important infection-control measure.

Environmental decontamination involves the use of water, detergents, and, increasingly, a disinfectant or microbiocide, although the effectiveness of any agent depends on how it is applied and the meticulousness of the decontamination. A previous study of environmental disinfection of intensive care units (ICUs) indicated that $< 50\%$ of surfaces were cleaned adequately; however, after implementation of an infection-control intervention program, including the use of ultraviolet monitors as surrogate markers for bacterial contamination, $\sim 82\%$ of fomites were adequately disinfected.[10] Other studies revealed that many room surfaces remained inadequately disinfected.[11,12] Several manufacturers have developed room-disinfection units that can decontaminate environmental surfaces and objects by non-touch methods that employ either UV radiation[13] or hydrogen-peroxide vapor.[14] These methods, however, can only be used for terminal disinfection of a discharged room and cannot be used for daily room disinfection.[11,15] Recently, self-disinfecting surfaces were developed to reduce the biological burden on environmental surfaces during hospitalization.[16]

Bio-Kil [3-(Trimethoxysilyl) propyloctadecyldimethyl ammonium chloride; Cargico Group, Taipei, Taiwan) is an antimicrobial nanomaterial consisting of inorganic metal components and organic quaternary ammonium components.[17] Bio-Kil molecules have a high-affinity structure and a strong electric field that attracts pathogens. The strong electrical charge damages the membrane proteins of microorganisms, thereby killing the pathogens. Bio-Kil forms a permanent covalent bond with the surface of many products, including plastic, paint, and textiles.[17] Previous research indicated that use of Bio-Kil in an ICU effectively reduced the bacterial burden in that environment[18,19]; however, the effect of this reduction in bacterial burden on the incidence of HAIs has not yet been documented. Therefore, we performed this prospective before–after study to determine the efficacy of Bio-Kil on HAIs and bacterial colonization in ICUs.

Methods

Study design and setting

This prospective, open-label, before-after study with control and intervention groups was conducted in the Medical and Surgical ICUs (MICUs and SICUs) of the Municipal Wan-Fang Hospital, a 750-bed teaching hospital in Taipei, Taiwan, from May 2014 to October 2014. Two rooms each from the MICU (MICU-15 and MICU-16) and SICU (SICU-21 and SICU-22) were selected for study. MICU-16 and SICU-22 were designated as the study rooms, and MICU-15 and SICU-21 served as the control rooms. These rooms were selected for the study, because they were situated at the far end of the ICU and were separated from the other rooms. The primary objective of this study was to assess the efficacy of Bio-Kil in reducing bacterial burden in ICUs. The secondary objective was to evaluate whether reducing bacterial burden in patient surroundings prevented nosocomial infections. The study protocol was approved by the Taipei Medical University-Joint Institutional Review Board (study protocol TMU-JIRB 201311029).

The three periods of this study were the pre-intervention period (from May 1, 2014 to July 22, 2014), the Bio-Kil-setup period (from July 29, 2014 to August 4, 2014), and the intervention period (from August 4, 2014 to October 20, 2014). During the pre-intervention period, environmental samples were collected from 17 sites from each study area and from patients twice weekly. During the