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ORIGINAL ARTICLE

Silver-embedded screens in the intensive care unit. A new tool to control multi-drug resistant bacterial cross-transmission

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Abstract The purpose of this study was to assess the effectiveness of silver-embedded surfaces (BactiBlock®) to prevent surface colonization by multi-resistant bacteria (MRB) and to reduce the incidence of MRB colonization and infection in patients admitted to an intensive care unit (ICU). A 6-month prospective observational study in a 24-bed mixed ICU divided into two identical subunits (12 beds each) was designed. Seven solid mobile screens were placed in one of the subunits while in the other cloth screens remained. Solid screens were constructed with high-density polyethylene embedded in Bactiblock®. To evaluate the effectiveness of screens coated with Bactiblock®, number of MRB isolates on screens were compared for 6 months. Likewise, numbers of new patients and ICU-stays with MRB colonization in the two subunits were compared. One hundred forty screen samples were collected in 10-point prevalent days. MRB were detected on 28 (20.0%) samples. Over the 70 samples taken on cloth folding screens, MRB were detected in 25 (35.7%), while only 3 (4.3%) of the 70 samples taken on Bactiblock® screens were positive for MRB ($p < 0.001$). The unit with Bactiblock® screens presented fewer number of ICU stays with MRB colonization (27.8% vs 47.1%; $p < 0.001$). No significant differences were found in the global incidence of MRB nosocomial infection. The presence of Bactiblock® embedded in solid folding screens avoided MRB surface colonization and reduced MRB transmission to patients admitted to critical care units, proving to be an useful tool in the control of MRB.

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Introduction

During the past 20 years, there has been a global exponential increase in antibiotics resistance [1]. The annual data gathered in Europe and the United States describes a general increase of antimicrobial resistance in gram-negative bacteria *Escherichia coli*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* [2, 3]. It is estimated that nosocomial infections caused by multi-resistant bacteria (MRB) generate about 25,000 deaths per year in Europe, with associated costs close to seven billion euros [4]. This phenomenon is particularly relevant for the intensive care units (ICU), where the selection of multi-resistant strains by the widespread use of antimicrobials and their transmission among patients is a common phenomenon.

The management and control of the MRB dissemination requires a comprehensive approach, including the strategy implementation to identify those patients at risk to be carriers of multi-resistant strains, and the application of appropriate isolation and prevention measures on colonized patients. Among the latter, patient hygiene and the control of environmental reservoirs play key roles.

It is known that near-patient surfaces can be a reservoir of bacterial pathogens from which the patients can be colonized, either directly or through the hands of health care workers [5–7]. Several technology companies are developing surfaces that reduce or eliminate the presence of these bacterial niches. These surfaces can reduce the presence of environmental reservoirs, thus having a potential impact to reduce the colonization of patients and the development of nosocomial infections [5].

One of the most studied elements is the impregnation of surfaces with silver ions (Ag +). Silver has a good bactericidal action at relatively low concentrations, having verified its efficacy and safety in the prevention of infections associated with various short- and long-term devices [8–10].

The objective of this study was to evaluate the effectiveness of silver-embedded surfaces to avoid environmental bacterial colonization and to reduce the incidence of patient colonization and infection by MRB in a critical care unit.

Material and methods

A prospective observational study was designed. The study was carried out from April to September 2015 in a 24-bed mixed ICU in a referral university hospital (Hospital Universitario y Politécnico La Fe, Valencia, Spain). The ICU is divided into two subunits (12 beds each), with an average of 1,665 admissions per year in the last 3 years. Despite current recommendations our ICU doesn't have separate rooms. Cloth screens on a metal frame separate beds and the same device is used to safeguard the privacy of patients during their daily bath. Fabrics are sloughed three times a week and the shells are cleaned with disinfectant products at the same time.

Our ICU has an infection control programme that includes an antimicrobial stewardship programme, specific bundles to prevent device associated infections, a weekly screening to detect patients colonized by MRB, a hand washing monitoring plan (following the World Health Organization recommendations [11]) and an educational programme in infection control. However, multi-drug resistant bacteria, mainly extended betalactamase and carbapenem resistant *Klebsiella pneumoniae*, keep on being an epidemiological problem in our ICU. Therefore we decided to evaluate the possible existence of environmental reservoirs. From all checked surfaces cloth screens were found to be colonized. Consequently we searched for an intervention to replace the cloth screens.

In April of 2015, seven solid mobile screens were placed in one of the subunits (subunit 1) while in the other the cloth screens remained (subunit 2). Solid screens were constructed with high-density polyethylene embedded in Bactiblock®. Bactiblock® innovative aspect is the use of purified and modified phyllosilicate clay as performance-enhancing carrier of a silver antimicrobial agent. This creates strong synergies between the two materials, especially in terms of efficiency and durability and prevents oxidation/reduction and controls the environmental release. Bactiblock® screens were cleaned by drag technique at patient discharge and every day if the adjacent patients were MRB carriers.

Over 6 months the two subunits were compared in the number of MRB isolates in the screens. The primary endpoint was the incidence of MRB colonization of solid screens embedded in Bactiblock® and fabric screens. Secondary endpoints included the incidence of patients colonized by MRB (number of new colonized patients and number of stays with MRB colonization) as well as the incidence of nosocomial infections and days of invasive mechanical ventilation.

Definitions

Multi-resistant bacteria The following pathogens were considered multi-resistant bacteria, according to international consensus of experts [12]: *Methicillin-resistant Staphylococcus aureus* (MRSA), extended spectrum β-lactamase (ESBL)-producing Enterobacteriaceae or carbapenem and non-fermenting Gram-negative bacilli (which are resistant to two or more antimicrobial agents), including *Acinetobacter baumannii* and *Pseudomonas aeruginosa*.

Nosocomial infections Infection diagnosis was established according to the CDC criteria. In summary, infection diagnosis requires the presence of some clinical criteria followed by a microbiological confirmation [13]. For ventilator-associated pneumonia (VAP) two or more of the following should be present: temperature greater than 38 °C, leukocytosis greater than $12,000/mm^3$ or leucopenia lower than $4000/mm^3$, or purulent respiratory secretions; plus a new or progressive pulmonary infiltrate on chest X-ray. VAP confirmation was defined by the quantitative culture of tracheobronquial aspirate $\geq 10^5$ cfu/ml [2], bronchoalveolar lavage with $\geq 10^4$ cfu/ml or mini bronchoalveolar lavage $\geq 10^3$ cfu/ml [14].

Data collection protocol

After 7 days from the placement of the screens, one sample was taken from every screen with thioglycolate-soaked gauzes over the entire surface of the screens, being particularly hardy in the high-touch areas at the patient's level. Sampling was repeated every 15-days over 6 months (10-point prevalent days).

Demographic and clinical data were recorded from patients admitted throughout the study to subunits 1 and 2. Nosocomial infections and MRB colonized patients were documented.

Microbiological study

Samples from screens were analysed in the microbiology laboratory. Microbiologists did not know if the samples come from one or other type of display. Gauzes were grown in enriched media (chromID™ CARBA SMART, chromID™ ESBL, chromID™ MRSA, bioMérieux) to detect the presence of multi-resistant bacteria.

Statistical analysis

Data analysis was carried out through Stata v.13.0 software. The baseline characteristics of the patients included in both subunits were compared using parametric tests (Fischer's test, Student's *t*-test) or nonparametric test (chi-square, Mann–Whitney *U*-test) according to the normality test of the sample. For the comparison of the proportion of isolates between

Table 1 Characteristics of patients included in the study

Characteristic	Total	Subunit 1 (BB[a])	Subunit 2 (standard)	p-value
Total admissions	587	284	303	0.484
Male (%)	62.90%	61.70%	64.00%	0.546
Mean age (SD)	60.2 (15.6)	60.7 (15.7)	59.5 (15.5)	0.293
SAPS-III (mean; SD)	54.9 (0.6)	54.7 (0.8)	55.0 (1.0)	0.216
APACHE-II (mean; SD)	17.2 (0.3)	17.4 (0.5)	16.9 (0.5)	0.439
Origin				
Emergency room	48.20%	50.30%	46.20%	0.315
Other hospitals	16.20%	13.70%	18.50%	0.118
Hospital ward	35.60%	36.00%	35.30%	0.232
Hematologic (%)	4.08%	4.90%	3.30%	0.992
Renal replacement therapy (%)	4.40%	3.00%	6.40%	0.325
Mechanical ventilation (%)	26.40%	29.70%	22.89%	0.061
Length of stay (media; SD)	8.0 (3.1)	5.4 (0.5)	10.4 (6.0)	0.430
Mortality (%)	15.40%	12.80%	17.80%	0.090

[a] High density polyethylene embedded in Bactiblock®

different screens and the rate of colonization and nosocomial infection in both subunits the Fisher's exact test was used. We performed a multivariate analysis with colonization and nosocomial infection as dependent variable. We selected the following independent variables: age, sex (%), APACHE-II score, mechanical ventilation (%), origin (hospitalization or emergency room), hematologic disease and renal replacement therapy. We adopted a stepwise method for model construction. Those variables with a p value < 0.2 in the univariante analysis were included in a multivariate analysis.

Results

During the study period, a total of 587 patients were admitted to our ICU. Baseline characteristics of the patients in each of the subunits are reflected in Table 1. Any significant difference was found in any of the variables. No differences were found between the rate of compliance with handwashing

between both subunits [subunit 1 (range): 58.7% (40.0–71.4%); subunit 2: 59.1% (41.1–70.0%); $p = 0.905$].

During the 6-months study period a total of 140 samples from ten samplings were taken. In 28 (20%) of these samples MRB were detected: *K pneumoniae* (14 samples, 10.%), *Enterobacter cloacae* MR (10, 7.1%), *Acinetobacter baumannii* (7, 5.0%) and *Escherichia coli* (1, 0.7%). Seventy samples were taken from the fabric screens, and MRB were detected in 25 (35.7%) samples; 70 samples were taken from the Bactiblock® screens and MRB were detected only in 3 (4.3%) samples ($p < 0.001$).

The incidence of MRB patient colonization and the nosocomial infection incidence during the study period are reflected in Table 2. Subunit 1, the one with Bactiblock® screens, presented fewer number of ICU stays with MRB colonization (27.8% vs 47.1%; $p < 0.001$). However, no significant differences were found in the global incidence of nosocomial infection by MRB between the two boxes (3.87% vs 3.33%; $p = 0.725$). Multivariate analysis did not reflect a significant effect of Bactiblock® screens on number of patients

Table 2 Colonized and infected patients during the study

Parameter	Subunit 1 (BB[a])	Subunit 2 (Standard)	p-value
Patients colonized by MRB (%)	71 (25.0)	68 (22.4)	0.459
Hospital-stays colonized by MRB (%)	430 (27.8)	620 (47.1)	<0.001
Days of mechanical ventilation (mean; SD)	7.06 (1.02)	7.92 (1.39)	0.614
Nosocomial infection by MRB (%)	11 (3.87)	10 (3.33)	0.725
VAP/VAT	4 (1.41)	3 (0.99)	0.639
UTI	2 (0.70)	2 (0.66)	0.953
CRB	5 (1.76)	5 (1.65)	0.918

MRB multidrug-resistant bacteria, *VAP* ventilated associated pneumonia, *VAT* ventilator-associated tracheobronchitis, *UTI* urinary tract infection, *CRB* catheter-related bacteremia

[a] High density polyethylene embedded in Bactiblock®

Table 3 Multivariate analysis of risk factors for MRB colonization and nosocomial infection

Parameter	Colonization		Nosocomial infection	
	OR (95%CI)	p-value	OR (95%CI)	p-value
BB[a] screens	0.92 (0.54–1.57)	0.771	0.86 (0.32–2.35)	0.762
APACHE II >15	2.80 (1.38–5.69)	0.004	1.67 (0.43–6.49)	0.455
Age >65 years	0.80 (0.46–1.38)	0.426	0.60 (0.21–1.67)	0.356
Hemofiltration	10.1 (3.2–31.6)	<0.001	4.21 (1.24–7.76)	0.023
Mechanical ventilation	4.9 (2.8–10.3)	<0.001	7.65 (1.92–17.8)	0.0027

MRB multi-resistant bacteria[a] *BB* Bactiblock®

colonized by MRB or total nosocomial infections (Table 3). No differences in number of days with mechanical ventilation were found [mean (SD): 7.06 (1.02) vs 7.92 (1.39); $p = 0.614$].

Discussion

According to the results of this study, the incorporation of embedded silver ions in solid screens is able to reduce the environmental reservoir of multi-resistant bacteria, as well as to reduce the number of stays of colonized patients admitted to critical care units.

The design of critical care units with individual boxes for each patient has proven to be an effective strategy to minimize cross-transmission and infection by MRB [15, 16], and is considered a quality standard for these units. However, many intensive care units are still completely opened or mixed, presenting only some separated rooms. Therefore, this will require the use of movable dividers between patients causing the existence of a new potential MRB reservoir. On the other hand, even in single room ICUs, cross-transmission of pathogens may still be high and it may be associated with other factors such as prior room occupancy by a colonized or infected patient [17, 18].

Numerous publications have shown that MRB environmental reservoirs can cause nosocomial infection outbreaks [19–21]. Therefore it is necessary to develop new strategies to avoid MRB colonization.

Bactiblock® screens were effective in avoiding MRB screen colonization and even showed a benefit in evading patient colonization. High workload and high costs of MRB colonized patient isolation along with the availability of the evaluated materials makes this strategy highly cost-effective [22, 23].

We could not demonstrate a positive effect on nosocomial infection incidence. However, many factors influence the development of these infections and probably our study was not designed to evaluate this association. Moreover, the small number of events has made it difficult to obtain an appropriate statistical model. Another limitation of our study was the absence of a concomitant study of other potential environmental reservoirs. However, screens were the only reservoir detected in the initial screening and the study intervention was the only structural difference between the two subunits.

In conclusion, the presence of Bactiblock® to avoid screen MRB colonization is a potential tool to reduce bacterial cross-transmission between patients admitted to critical care units. Therefore Bactiblock® solid screens should be considered as an additional tool in the ICU nosocomial infection control programme.

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