



Antimicrobial Medical Textile - An Important Part of the Complex Infection Control Measures in the Burn Units

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Keywords

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Introduction

Burn wound infections are one of the most important and potentially serious complications that occur in the acute period following injury. Infection and sepsis are among the most significant causative factors in burn related mortality and morbidity. The improved techniques for burn patient management and effective hospital infection control measures increase survival rate for severely burned patients. The burned patient is at high risk for Nosocomial Infections (NCI) and is susceptible to colonization from organisms in the environment and have propensity to disperse organisms into surrounding environment [1]. The colonized patients are a main reservoir for the pathogen strain. Invasive interventions including intravenous and urinary catheterization, and intubation pose a further risk of nosocomial infections [2-4]. The primary modes of cross-contamination of pathogens between burns patients are believed to be direct and indirect contact either from the hospital environment and equipment, or via staff. Other important sources include contaminated equipment such as hospital textile which poses unique risk for cross-contamination in burn care environment [2,5,6]. The healthcare worker's uniforms are a potential reservoir of infection and their contamination can be directly attributed to patients [7]. Although the person-to-person transmission route is the most likely, the role of the environment should not be ignored, and hospital linen may contribute to the spread of nosocomial infections. Routine nursing activities such as dressing and bed changes increase bacterial dispersal

from burns patients, potentially contaminating health-care workers. In this way, they could become vectors for transmission of nosocomial infection between patients [8-10]. The focus of medical care has to be the infection prevention [11,12]. Strict infection control practices and appropriate empirical antimicrobial therapy are essential to help reducing the incidence of infections due to antibiotic resistant microorganisms [13]. Emerging bacterial resistance to multiple drugs is an increasing problem in burn wound management. The prevention and control of infectious diseases among immunocompromised burned patients present a specialized problem, as the environment in burn units can become contaminated with resistant organisms [1,3,14,15].

Hospital textiles include bed sheets, blankets, towels, personal clothing, patient apparel, uniforms, and gowns. Textiles are a common material in healthcare facilities; therefore, it is important that they do not pose as a vehicle for the transfer of pathogens to patients or hospital workers. Contaminated textiles and fabrics often contain

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high numbers of microorganisms from body substances, including blood, skin, stool, urine, vomitus, and other body tissues and fluids and provide an excellent environment for the growth of microorganisms because of their large surface area and the ability to retain moisture [5,16-19]. The important future focus is the use of particles with antimicrobial activity for textile modification in order to enhance antimicrobial properties of medical textiles without adding antimicrobial agents into textiles which can have possible harmful or toxic effects [20-22]. Different strategies for antimicrobial finishing for textiles have been studied as a way to control microbe's growth and cross contamination. Application of chemicals in textiles has been used to impart antimicrobial activity to textile materials for medical environments [23-25]. There is a growing awareness of the use of antibacterial fabrics in the form of medical clothes, protective garments, and bed spreads to minimize the chance of the nosocomial infections [26,27]. In the recent years metal oxides nanoparticles coated onto cotton fibers represent important composites that are increasingly being developed for use in novel health-related applications. These coated fabrics do not possess skin irritation and sensitization properties. The ability of the impregnated textile on the reduction of microbial growth or elimination of microorganisms is useful in wound dressings, medical staff uniforms, bed sheets and others [24,26-29]. The aim of new technologies such as antimicrobial textiles is to support the efforts of burn care team to limit bioburden and prevent transmission of infection among burn patients. Antibacterial textile has to be part of the strict infection control protocol [4,5,30].

Although it is well known that contaminated textiles in healthcare facilities can be a source of substantial numbers of pathogenic microorganisms, reports of healthcare associated diseases linked to contaminated fabrics are a few. In the present pilot prospective study, we assess, analyze and discuss the efficacy and safety of the antibacterial and antifungal medical textiles (bed sheets, covers, pillows and patient's gowns), produced on the bases of sonochemical process [31]. The improvement of the original sonochemical process for the synthesis and simultaneous deposition of metal oxide NPs on fabrics is making the synthetic route safer and more cost efficient using water instead of ethanol:water solution. Previously, the metal oxide NPs were prepared by the basic hydrolysis of the corresponding metal acetates in 9:1 ethanol:water (v:v). The introduction of ignitable ethanol in an industrial plant not only requires special protective equipment, but is also costlier than using water as the only solvent. When water replaced the ethanol:water solution, the amount of oxides on the textile was smaller, however, the particle size was also reduced and as a result the antibacterial activity was not hampered [31].

The aim of the present study is to examine the antimicrobial efficiency, comfort and safety of the antibacterial and antifungal (ZnO) coated by sonochemical process medical textile in comparison to conventional, non-antimicrobial linen in a clinical trial in a Burn department. The patients were dressed, and lied on antibacterial (ZnO) coated fabrics - NP-coated bed sheets, patient gowns, pillow cover, and bed covers.

Materials and Methods

A pilot prospective study was conducted in a Burn department in UMHATEM "N.I. Pirogov", Sofia, Bulgaria, between May and August 2013. The protocol adhered to the provisions of the Declaration of Helsinki, and was approved by the institutional review board committee. *Thirty-seven* patients were enrolled in the study immediately after hospitalization with burns and different soft tissue lesions spread on 5 to 30% of Total Body Surface Area (TBSA). The study group were dressed, and lied on antibacterial ZnO coated fabrics and their propensity to bacterial infection was monitored and compared to control patient group using uncoated conventional textiles. The conventional textile used in the hospital has no antibacterial treatment and contains 65% cotton and 35% polyester. It stands washing at 90 °C and dry sterilization at 135 °C. The material endures at least 200 washes without any linear deformation and able to absorb blood and body fluids. The patients were divided into two groups: Studied (21 using coated textiles) and controlled (16 using standard type of hospital textiles). A set of sonotextile was applied to each patient and it was changed every 12 hours (7 am & pm). The characteristics of the washing are as follows: Duration of washing-60 min; temperature 60 °C; The ECOS laundry detergent kept a neutral pH level. The following parameters are observed and analyzed for a seven day period - demographic, biochemical, antibacterial effect as well as evaluation for side effects. The number and type of adverse experiences like itch, skin *erythema and rash were reported as none, mild, moderate and severe*. Microbiological samples were collected for both groups from the throat, nose, armpit, perineum and also collected from the hospital textile on the 1st, 4th and 7th day. Quantitative and *qualitative* analyses of all isolated pathogens were performed. The body site's samples were taken using cotton-tipped sterile swabs and transported to the microbiological laboratory within 30 minutes or in Steward's transport medium. Cultures were done using standard procedures on blood agar, on the selective medium Endo agar and on Sabouraud agar/Chromagar Candia (BD - Becton Dickinson, USA). After overnight incubation at 35-37 °C for 18-24 h, the cultures were inspected for microbial growth. The identification of the isolated strains was done using conventional procedures

or the automated system Vitek-2 Compact, Bio-Merieux (France). Contact plates - Contact E, Merck (Merck EAD Sofia, Bulgaria), were used to take samples from the textile, put into incubator for 18-24 h at 35-37 °C and then examined for microbial growth. The microbial growth was both qualitatively assessed for the presence of pathogens and quantitatively analyzed for determination of the total microbial number of all growing microorganisms. The following breakpoints were used: no microbial growth; 1 CFU/cm² - very weak growth; 3.5 CFU/cm² - weak growth; 17 CFU/cm² - moderate growth; 58 CFU/cm² - heavy growth; above 140 CFU/cm² - very heavy growth. The target pathogens included: *Staphylococcus aureus*, *beta-hemolytic streptococci of various serological groups*, *Enterococcus spp.*, *Enterobacteriaceae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, other Non-Fermentative Gram-negative bacteria and Fungi [2,5,32,33].

Data were entered and processed with statistical package SPSS 13.0. The statistic significant level for rejecting the null hypothesis was chosen as $p < 0.05$. The following statistical methods were applied: Descriptive analysis; Variation analysis; Graphic analysis; alternative analysis; exact test of Fisher; Nonparametric test of Shapiro-Wilk for determining the type of distribution; Student's t-test for two independent samples; Student's t-test for two related samples; U test of Mann-Whitney for two independent samples; Mauchly's test of sphericity; Repeated measures ANOVA (Analysis of Variance), Nonparametric test of Friedman; Wilcoxon signed rank test for two related samples.

Results and Discussion

The age of the included patients varies from 23 to 86 years. The two groups (study group with coated textile and control group with conventional textile) are statistically equal in terms of gender ($p = 1.000$, exact test of Fisher). There is no statistical significant difference between two groups by weight, height and Body Mass Index as could be seen on Table 1.

Blood biochemistry and haematology assays were conducted to identify any indications of adverse effects arising

from absorption of the ZnO nanoparticles. Serum levels of Zn were not evaluated due to its proved lack of toxicity and widely spread use including children [34,35]. The levels of platelets, MCV and eosinophils were dynamically studied for the observed period. The values of these parameters are very important for toxicity evaluation of the examined textile. There were statistic significant changes during the study in the next hematological characteristics: Thrombocytes (among study group), MCV (among controls and study group), bilirubin (among controls), ALAT (among study group), GGTP (among study group) and eosinophils (among controls and study group). The changes of renal and liver function were strictly followed: Aspartate Aminotransferase (ASAT), Alanine Aminotransferase (ALAT), Gamma-Glutamyl Transferase (GGT), serum albumin, creatinine, urea, creatinine clearance and bilirubin. Both groups do not show typical changes of liver and kidney toxicity based on extrapolated data of the observed parameters [21,22,36,37]. Many haematological and biochemical parameters lay outside the normal range for all participants during the study period, and the majority of parameters return to normal range by the end of the study. The registered deviations are connected with the burn disease and surgical interventions but not as a toxicity manifestation [1,36].

The appearance of itch, skin erythema and rash with varied intensity were registered during the study period. As can be seen at Table 2 there were not statistic significant changes during the study and there was not statistic significant difference between study group and control group during the study.

Depending on the extent and nature of the burn injury the susceptibility to infection increases. The type and amount of the microbial burden colonizing the wound influence the risk of morbidity and mortality. The leading nosocomial pathogens that colonize and infect burn wounds are *Acinetobacter baumannii*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* [38]. Their resistance to various antimicrobial agents increases. The predominant burn wounds flora changes during hospitalization from Gram-positive bacteria such as *Staphylococci*, *Streptococci*, *Enterococci* to Gram-negative bacteria like *Enterobacteriaceae*, *Acinetobacter*

Table 1: Population characteristics of patients and controls.

Characteristics	Controls		Patients		p Value
	Mean	SD	Mean	SD	
Age [years]	60.75	17.57	52.62	18.16	0.180
Weight [kg]	77.88	12.99	85.05	13.85	0.118
Height [m]	1.73	0.08	1.72	0.08	0.609
Body mass index [kg/m ²]	25.86	3.63	29.06	6.21	0.068
	Frequence (%)				
Sex					1.000
Male	9	(56.3)	12	(57.1)	
Female	7	(43.8)	9	(42.9)	

Table 2: Itches, Skin erythemas and Skin rashes dynamic during the study.

Characteristics	Group	Category	Day 1		Day 4		Day 7	
			n	%	n	%	n	%
Itch	Controls	None	15	93.8 ^a	15	93.8 ^a	15	93.8 ^a
		Mild	0	0 ^a	0	0 ^a	0	0 ^a
		Moderate	1	6.3 ^a	1	6.3 ^a	1	6.3 ^a
		Severe	0	0 ^a	0	0 ^a	0	0 ^a
	Study group	None	19	90.5 ^a	20	95.2 ^a	21	100.0 ^a
		Mild	1	4.8 ^a	1	4.8 ^a	0	0 ^a
		Moderate	1	4.8 ^a	0	0 ^a	0	0 ^a
		Severe	0	0 ^a	0	0 ^a	0	0 ^a
Skin erythema	Controls	None	15	93.8 ^a	16	100.0 ^a	16	100.0 ^a
		Mild	0	0 ^a	0	0 ^a	0	0 ^a
		Moderate	1	6.3 ^a	0	0 ^a	0	0 ^a
		Severe	0	0 ^a	0	0 ^a	0	0 ^a
	Patients	None	20	95.2 ^a	20	95.2 ^a	21	100.0 ^a
		Mild	0	0 ^a	0	0 ^a	0	0 ^a
		Moderate	1	4.8 ^a	1	4.8 ^a	0	0 ^a
		Severe	0	0 ^a	0	0 ^a	0	0 ^a
Skin rash	Controls	None	15	93.8 ^a	16	100.0 ^a	16	100.0 ^a
		Mild	1	6.3 ^a	0	0 ^a	0	0 ^a
		Moderate	0	0 ^a	0	0 ^a	0	0 ^a
		Severe	0	0 ^a	0	0 ^a	0	0 ^a
	Patients	None	20	95.2 ^a	20	95.2 ^a	21	100.0 ^a
		Mild	0	0 ^a	1	4.8 ^a	0	0 ^a
		Moderate	0	0 ^a	0	0 ^a	0	0 ^a
		Severe	1	4.8 ^a	0	0 ^a	0	0 ^a

^a - The same letters by horizontals mean that there was no statistic significant difference, and the different - that there was statistic significant difference (p < 0.05).

baumannii and *Pseudomonas aeruginosa* [39-41].

Staphylococcus aureus, both Methicillin Susceptible (MSSA) and Resistant Strains (MRSA) frequently colonizes the nostrils, throat and other skin sites of human population. *Staphylococcus aureus* remains the principal etiological agent of burn wound infection and, along with *Acinetobacter baumannii* - a common cause of early burn wound infection in many burn centers [42,43]. Over recent decades and with the liberal use of broad-spectrum antibiotics, Methicillin-Resistant *S. aureus* (MRSA) has become the predominant pathogen in the *Intensive Care Unit* (ICU) [44-46]. In order to successfully prevent and control the MRSA and MSSA infections in burn patients it is necessary to reveal their primary reservoirs and models of transmission. There are two main models of transmission of *S. aureus*: Endogenous - from one to another body site of the same patient and exogenous - from one to another patient or from hospital environment to the patients [47,48]. A study from the Netherlands found that two-thirds of patients whose burn wounds were colonized with methicillin-susceptible *S. aureus* had acquired the organism exogenously [49]. During the hospital stay of each patient, his linen usually and very fast becomes colonized with his own normal, resident microflora as well as with nosocomial pathogens.

Table 3: Spectrum and rates of the microbial species isolated in the study.

Bacterial species	No. strains	%
<i>S. aureus</i>	116	56.9
<i>Streptococcus pyogenes</i>	2	1.0
<i>E. coli</i>	2	1.0
<i>Klebsiella pneumoniae</i>	2	1.0
<i>Klebsiella pneumoniae</i> ESBL(+)	5	2.4
<i>Klebsiella oxytoca</i>	1	0.5
<i>Enterobacter cloacae</i>	2	1.0
<i>Serratia marcescens</i>	5	2.4
<i>Proteus mirabilis</i>	10	4.9
<i>Pseudomonas aeruginosa</i>	5	2.4
<i>Acinetobacter baumannii</i>	54	26.5
Total	204	100

In Sofia burns unit, the most common bacterial species in the last 5 years is *S. aureus* - 23.7% of all isolated pathogens and MSSA prevail. The rates of MRSA constantly fall and now is 7.6%. Gram (+) flora as a whole has a tendency to decrease and now it is 37.9% and Gram (-) flora predominates - 62.1%.

The main nosocomial pathogens isolated in our study from various body sites and the hospital textile were *S. aureus* and *A. baumannii* (Table 3).

All the *S. aureus* isolates were MSSA and all the *A.*

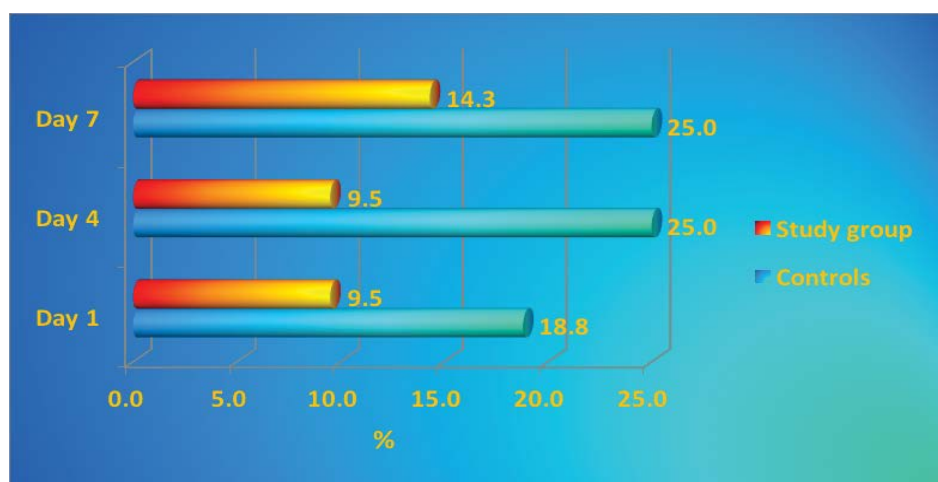


Figure 1: Throat *S. aureus* MSSA rate dynamics during the study.

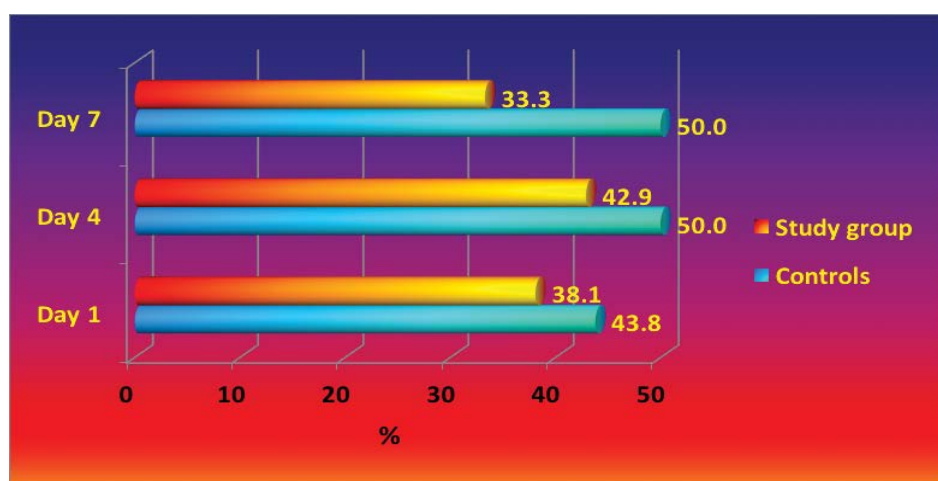


Figure 2: Nose *S. aureus* MSSA rate dynamics during the study.

baumannii isolates were Multidrug-Resistant - MDR (resistant to all the beta-lactam antibiotics including carbapenems, aminoglycosides, fluoro-quinolones and trimetoprim/sulfamethoxazole, susceptible only to tigecyclin and colistin).

The throat and nose colonization with *S. aureus* and its dynamics during the study is presented in Figure 1 and Figure 2. Throughout the study period higher percentage of controls were colonized with *S. aureus* in comparison with the patients with antibacterial textile. The study group throat contamination remained at stable levels, while in the control group increased from day 0 to day 4 and 7. Nasal colonization in controls increased from day 1 to day 7, while in the study group the levels of colonization decreased.

During the study period, the percentage of the textile colonized with *S. aureus* in controls is twice as higher as it is in the study group (Figure 3) [50-52].

Acinetobacter baumannii is a Gram-negative bacillus that is aerobic, pleomorphic and non-motile. *Acinetobacter*

baumannii is an opportunistic bacterial pathogen and one of the leading pathogens responsible for hospital-acquired infections. *A. baumannii* has become a great concern to scientists and clinicians and the focus of significant attention, because of its ability to rapidly develop extensive antibiotic resistance spectrum [53-55]. This has led to the emergence of Multidrug-Resistant *A. baumannii* Strains (MDRAB) and Pandrug-Resistant *A. baumannii* Strains (PDRAB). This pathogen has become one of the most common colonizing pathogens in immunocompromised burn patients with a high incidence among them, particularly those who have a prolonged hospital stay. *A. baumannii* survives in the hospital environment for a prolonged period, even on dry surfaces and the hands of health care personnel, and the carriage of MDRAB in human hosts may also be prolonged, which can facilitate transmission and outbreaks of this opportunistic bacterial pathogen [56-58]. Commonly associated with aquatic environments, it has been shown to spread in healthcare facilities colonizing the skin as well as being isolated in high numbers from the respiratory and oropharyngeal secretions of infected individuals.

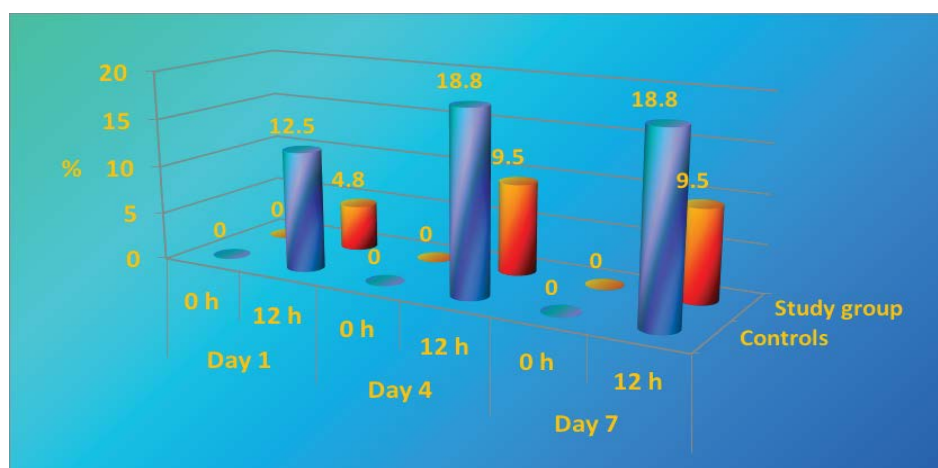


Figure 3: Colonization of textiles with *S. aureus* (MSSA) during the study.

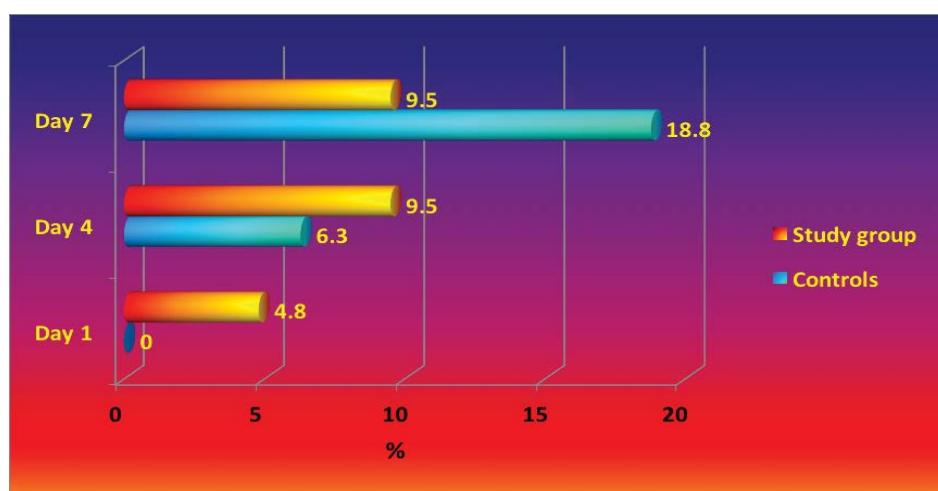


Figure 4: Perineum *Acinetobacter baumannii* rate dynamics during the study.

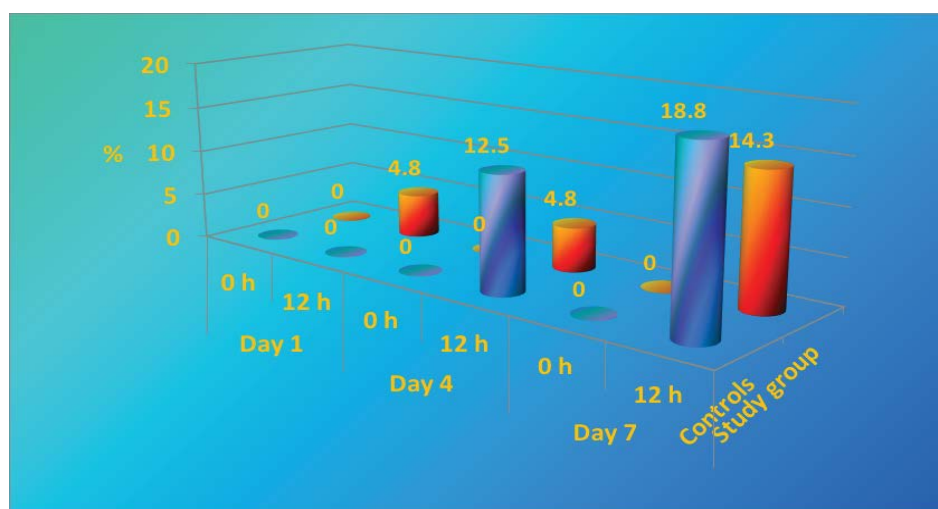


Figure 5: Colonization of textiles with *A. baumannii* during the study.

A. baumannii is the second leading pathogen causing for nosocomial infection in our Burns Department and it's rate raised to about 18% of all isolated pathogens

in the last 3 years. *A. baumannii* nosocomial strains, isolated in the department are resistant to most of the antibiotics. As it is presented in Figure 4, perineum

colonization of the controls with *A. baumannii* increase progressively from day 1 to day 7 from 0% to 18.8%. In the beginning the number of colonized patients in study group is significantly higher than controls, however after day 4 the study group remain stable [43,59,60].

Colonization of control's bed linen with *Acinetobacter baumannii* increased significantly from Day 1 to Day 7 (from 0% to 18.8%), while in study group remained comparatively stable with small increase in the end of the study period (Figure 5). It is important to underline that *A. baumannii* is one of the most difficult to manage nosocomial pathogens, not affected by lots of the known antiseptics and antibiotics [46].

Before its first use hospital linen is sterile. After the patients have contact with the linen its colonization begins initially with their own microflora and usually after about 4 days with nosocomial flora [13,15]. In our study, as show in Figure 6, at 12 h on day 1, the colonization in study group is significantly lower than controls ($p < 0.01$) and on day 7 higher rate of study group remains without

microbial growth ("sterile") than controls with statistic significant difference $p < 0.05$, i.e. There is no growth in 23.8% of the samples in the study group and there is no growth in 0% in the controls (all samples in the control group are contaminated at 12 h on day 7).

The results of the quantitative assays demonstrated that when or as colonization of the linen has occurred, the coated textiles (the study group) had higher percentage of the weak microbial growth (1-3.5 CFU/cm²) in comparison with standard textiles at 12 hours on day 7 (Figure 7).

In the controls linen, the percentage of the assays with moderate growth (17 CFU/cm²) is statistic significantly higher than in the study group (Figure 8).

In the controls, there was a statistically significant increase in the cases with heavy growth (58 CFU/cm²) at days 4 and 7 while in the study group such cases were rare (Figure 9).

As it can be seen in controls (Figure 10) there is an increase in share of tests with heavy growth. On day 7

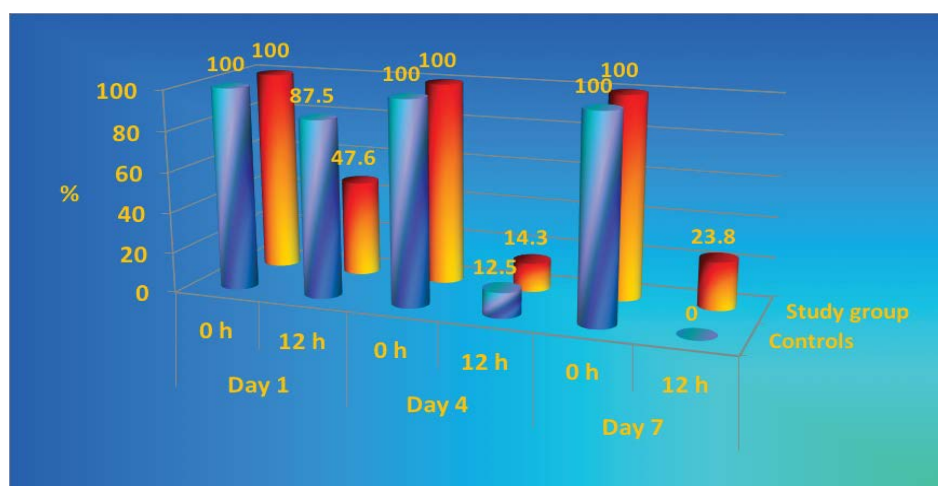


Figure 6: No growth ("sterile") samples during the study.

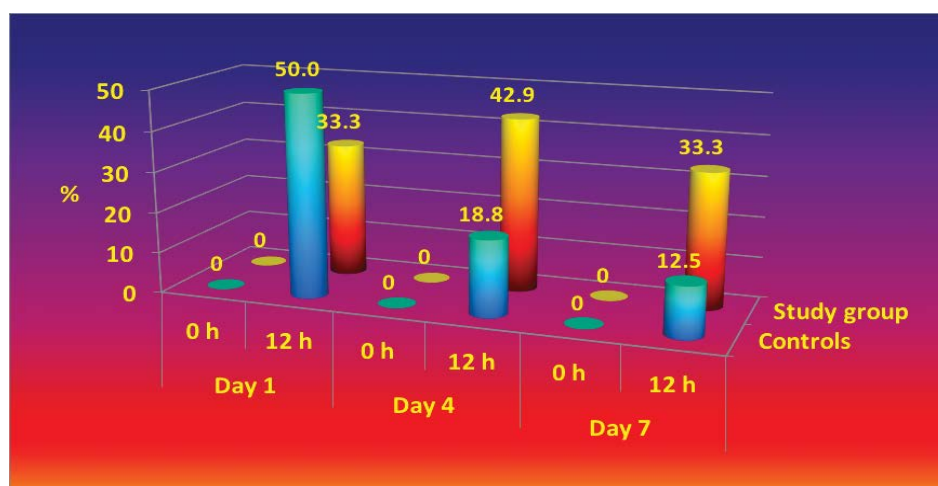


Figure 7: Percentage of the textile with weak growth: 1-3.5 CFU/cm².

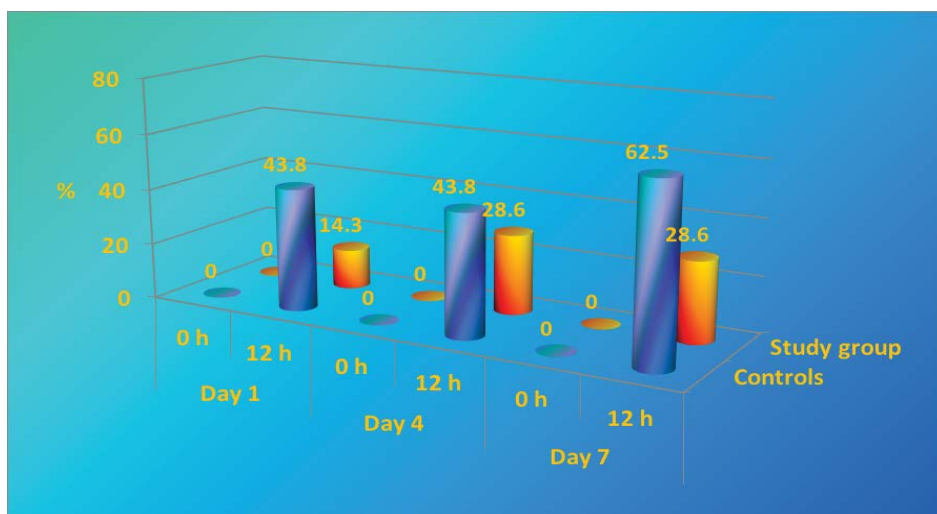


Figure 8: Percentage of the textile with moderate growth: 17 CFU/cm².

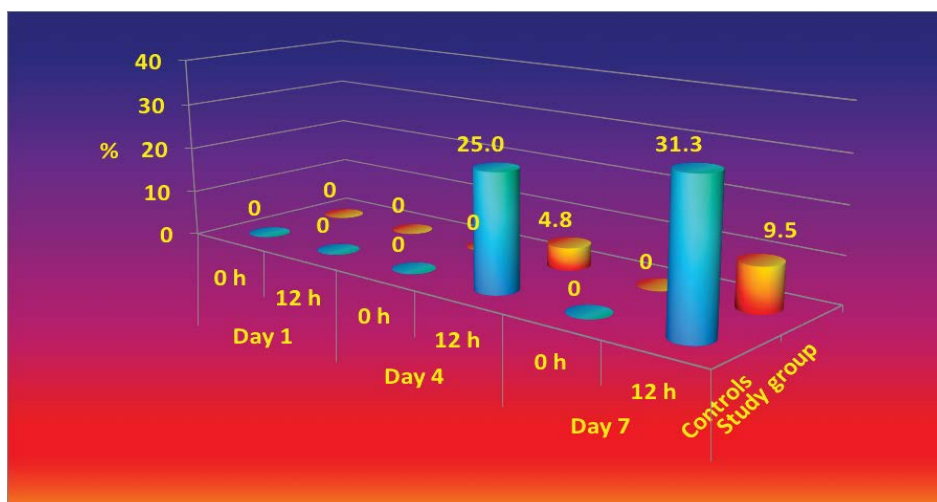


Figure 9: Percentage of the textile with heavy growth - 58 CFU/cm².

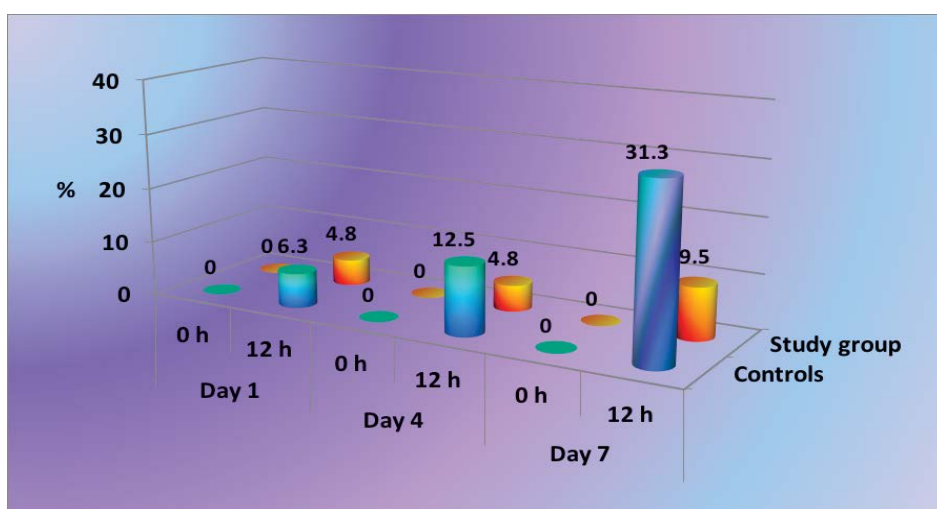


Figure 10: Dynamics of the pillow samples with heavy growth (58 CFU/cm²) during the study.

the increase is statistically significant and covers almost 1/3 of all tests. Patients in study group register a much

weaker (10%) and later (only on day 7) increase of tests with heavy growth.

The cases with very heavy growth (above 140 CFU/cm²) were quite rare for both groups. Quantitative and qualitative analyses of all isolated pathogens in both groups confirms the antimicrobial effect of the impregnated with new sonotechnology textile against one of the most common pathogens for nosocomial infection in Burns Departments - *S. aureus* and *A. baumannii*. The ZnO coated textiles possess noticeable antibacterial effect, as they maintained lower contamination level and better microbiological characteristics both on the patients and the bed linen in comparison with conventional linen even regard multidrug-resistant *A. baumannii*. The high percentage of study group patients without microbial growth ("sterile") during the study (23.8%) demonstrates this effect. According to the results the new ZnO coated textile does not show toxicity. Side effects as itching, erythema and rash were observed in both groups without significant difference. We did not discover any publications in literature, analysing results of clinical tests of antibacterial hospital bed linen. In this aspect, in our opinion, this is the first such publication. More researches are necessary in order to prove the necessity of use of antibacterial hospital bed linen in clinical practice as part of measures for infection control in Burns Departments and ICU. A comprehensive concept is required to control the spread and transmission of all multi-drug resistant microorganisms on a burn unit [26,56].

Conclusion

The negative financial effect of nosocomial infections is due to the high cost of their treatment, uncertain treatment success, prolonged hospital stay, long term disability, and increased antimicrobial resistance. The frequency of multiple antimicrobial resistances is increasing throughout. The programs controlling the spread of NCI among the patients and the medical staff have proven their effect over the occurrence and the price of the treatment. The reduction of the microbial contamination of the hospital environment is a challenge to burn team. The complete eradication of the infection in burned patients is impossible. The infection control program where a new antimicrobial textile is used in burn patients could reduce infection and mortality rates in burn centers. The ZnO coated textile possesses antibacterial effect, as it managed to maintain lower contamination level and better microbiological characteristics both in the patients and bed linen in comparison with the conventional linen. The results of this study clearly demonstrate that the use of the antibacterial textile can be an option in the measures taken in burn centers to reduce an important source of nosocomial pathogens. One of the most important advantages compared with conventional linen is its ability to sustain a comparatively stable and low growth level of MDR-*Acinetobacter baumannii*, one of the nosocomial pathogens which are extremely difficult to eradicate.

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