Environmental Biodecontamination: When a Procedure Performed by the Nursing Staff has an Economic Impact in ICU Rooms

Ragusa R[1-3]*, **Lombardo A**[1,2,4], **Bruno A**[4], **Sciacca A**[2,6] and **Lupo L**[1,7]

[1]*Heath Technology Assessment Committee, University Hospital, Italy*

[2]*Committee against nosocomial infection, University Hospital "G. Rodolico" Catania, Italy*

[3]*Direzione Medica di Presidio, University Hospital "G. Rodolico" Catania, Italy*

[4]*Nursing for the Control of Hospital Infections, University Hospital "G. Rodolico" Catania, Italy*

[5]*Science of Health Professions Technical Diagnostic, University of Catania, Italy*

[6]*Department of Biomedical and Biotechnological Sciences, University of Catania, Italy*

[7]*Department of Medical and Surgical Sciences and advanced technologies, University of Catania, Italy*

*****Corresponding author:** Rosalia Ragusa, Via Rosso di San Secondo, 3 - Catania 95128 Italy, Tel: + 39 329 3178086; Fax: + 39 095 445745; E-mail: ragusar@unict.it

Abstract

Objective: The transmission of hospital-acquired infections most commonly occurs by means of healthcare workers coming into contact with contaminated surfaces or patients during routine care and the lack of or poor implementation of hygiene procedures. We present this study to assess the efficacy of a new environmental infection control system, managed by a nurse in charge of infection control, in terms of safety, clinical outcome and hospital/healthcare costs.

Methods: The following is an observational retrospective study performed at University Hospital of Catania; containing data on HAI infections from years 2013 and 2014, before and after a new disinfection procedure was introduced. The procedure used a no-touch technology for the indoor environment, using micronebulized hydrogen peroxide and silver cations. Cases of infections concerned adult inpatients with hospitalization time being greater than three days. The efficacy of the procedure was evaluated by comparing the decrease in number of infections, related deaths, and changes in antimicrobial load, whereas economic impact of the new procedure was assessed by a cost-effectiveness analysis. User satisfaction and environmental safety issue were also addressed.

Results: A total of 489 patients were hospitalized in the ICU between January 1, 2013 and December 31, 2014. The introduction of the procedure coincided with a significant decrease overall in infection-related deaths, as well as hospital days (16.95 ± 20.46 (mean $\pm$ SD) to 11.55 ± 10.03 (mean $\pm$ SD: p value <0.05). Bacterial load in samples from CVC and from broncho-alveolar lavage decreased, as well.

The incremental cost-effective ratio resulted in € 807.80 to be added for each infection-related death avoided.

Conclusion: We demonstrated that HyperDRYMist technology with hydrogen peroxide and silver cations is effective, safe and cost-effective without evidence of safety risk. Biodecontamination performed by motivated and experienced nurses could be useful in reducing microbial load and nosocomial infections. The system can contribute to improving the ICU patient's final outcome.

Keywords: Nosocomial infection; Biodecontamination; Infections control nurse; Cost-effectiveness analysis; Hydrogen peroxide; Indoor environment; Economic impact; ICER

Introduction

Nosocomial infections are among the most frequent causes of morbidity and mortality in the hospital environment accounting for a 5-10% increased risk of infection, and a ten-fold further increase in critical care departments, such as in the ICU, where invasive, diagnostic and therapeutic procedures are more frequent, and where patients receiving immunosuppressive therapies are more vulnerable.

The transmission of hospital-acquired infections (HAI) most commonly occurs by means of healthcare workers coming into contact with contaminated surfaces or patients during routine care and the lack of/or poor implementation of hygiene procedures [1-3].

Moreover, the long-term persistence and selection of resistant infections (Meticillin-resistant *Staphylococcus aureus*, *Clostridium difficile*, *Acinetobacter baumanii*, Vancomycin-Resistant Enterococci, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Mycobacterium tuberculosis*) is further fostered by the extensive administration of unnecessary antibiotic therapy and the consequent selection of resistant strains, making their eradication throughout hospital wards more difficult [4-6].

Approximately 30% of care-associated infections are preventable by adopting specific care practices such as hand hygiene, prudent

antibiotic prescription, isolation of infected patients and appropriate use of gloves and other equipment [7].

Conventional cleaning is generally achieved by use of ammonium (or other surfactant-based) detergents applied by housekeeping staff to high-touch surfaces, such as bathrooms and floors and surfaces surrounding patients, but has proven to be inadequate (difficult-to-reach multiplanar surfaces, incorrect dilution of detergent, cleaning rounds, variability of materials used to manufacture components/ surfaces of furniture and devices) and in some cases, even inducing vegetative forms of virus that can survive for many months in the environment.

The issue of environmental disinfection has been addressed by a large number of studies which have evidenced that best results are achieved on several levels starting from educating cleaning staff and, implementing consistent cleaning protocols, to adopting more effective environmental disinfection control systems such as aerosolized hydrogen peroxide (aHP) systems, H_2O_2 vapor systems, ultraviolet C radiation (UVC) systems, and NTD system based on pulsed-xenon UV (PX-UV) radiation [8,9].

In the attempt to reduce avoidable costs and the improve the quality of healthcare services provided in our hospital, we decided to evaluate the effectiveness of an indoor nebulisation system using hydrogen peroxide and silver cations as an alternative to conventional decontamination procedures [10-13]. The infections control nurse has been trained in the use of the device.

Hence, the aim of the present study was to compare clinical and economic impact of this system in the intensive care unit before (2013 data) and after (2014 data) introducing the new procedure for environmental decontamination.

Methods

The presented work was a prospective observational study performed at the ICU of the University Hospital "G. Rodolico", considering data from January–December, 2014 and the previous year January-December, 2013 (control). The environmental disinfection procedure under evaluation was adopted and implemented throughout 2014 and was performed for all rooms that had been occupied by patients showing clinical manifestations of infection (after at least 3 days from admission, in accordance with definition of nosocomial infections), as soon as the room became vacant.

The ICU was composed of 3 rooms with 2 beds each. Whenever an infection was suspected, patient was isolated, while the patient occupying the other bed was transferred to another room.

Hygiene status of ICU was periodically monitored by sampling in areas throughout the ward (hallways, patient rooms and service room). Efficacy of disinfection procedure was evaluated by difference in microbial load (measured as CFU/cm^2), before and after decontamination.

The nursing staff of the department collected samples for most high-touch surfaces (specifically: bedrails, bell switches, servant tables, blood pressure cuffs, intravenous pumps, urinary collection bags) and sent them to the Microbiological Laboratory for analysis.

Efficacy of clinical outcome was evaluated by difference in frequency and type of infections occurring in 2014 in comparison to 2013 when the procedure was still not in use.

Data was collected from medical records for patients admitted to the ICU between 2013 and 2014 and included age, days in hospital, positive microbial cultures, outcome/death, treatment and therapies. In 2013 a total of 244 patients were hospitalized in the ICU (88 patients>3 day stay; 48 infection-related deaths). In 2014 a total of 245 patients (98 patients>3 day stay; 42 infection-related deaths) were hospitalized. Samples for patients with a suspected infection came from blood, bronchoalveolar lavage (BAL) and central venous catheter (CVC), as representatives of supposedly sterile sources and which are most often associated with adverse outcome; specimens from urine and stool were not considered. All cultures with positive outcome were clinically defined as sepsis.

For our pharmaco-economical evaluation, we assessed the consumption of drugs (Defined Daily Dose, DDD) for HAI treatment over the two-year period and the cost of the drugs used for second level infections. Drugs considered for the evaluation were those used in treatments: teicoplanin, tigecycline, daptomycin, colistin, anidulafungin, voriconazole, vancomycin, fluconazole.

Environmental disinfection procedure

After the doctor's report of a case of infectious disease or "alert organism" isolation, nursing staff of the ICU rooms, required the infection control nurse to perform the decontamination.

Environmental decontamination was performed using the 99MA system manufactured by 99 Technologies (Lugano, Switzerland). This system employs the new HyperDRYMist® technology, which nebulises a mix of hydrogen peroxide in the concentration of 5-8% and silver cations at a concentration of 60 mg/L. The highly-reactive hydroxyl free radical of hydrogen peroxide acts on the microorganism's membrane lipids, DNA and other important cellular components, while the silver cations inhibit microbial protein synthesis.

Before decontamination, room doors and vents were sealed and the air ventilation was turned off. The disinfectant solution was prepared according to the manufacturer's instructions, in order to achieve the required concentration of 7 ppm. The device was positioned in a corner facing the room. Time of treatment was established based on the room volume (application time is directly proportional to volume, thus the bigger the volume to decontaminate, the longer the time for treatment). At the end of the process, the room was reopened and ventilation or air-conditioning system reactivated.

Finally, we assessed user-satisfaction by administering a structured questionnaire to the nursing and cleaning staff, enquiring on the presence of any perceived irritation to eyes, skin or respiratory tract.

Statistical analysis

The normality distribution of the variables was tested by the Kolmogorov-Smirnov test. Proportions and means were obtained using the X^2 and Mann–Whitney tests, respectively. All variables are expressed as mean and standard deviation.

Cost-effectiveness measures and outcomes

Clinical outcomes (number of infections and deaths) were compared for the two years in order to perform an economic evaluation of the decontamination procedure. The X^2 test was used and data was summarized using averages and standard deviation.

Cost-effectiveness analysis for the economic impact was performed, and Incremental Cost Effectiveness Ratio (ICER) was calculated. This indicator is calculated using the following formula: ICER=(C1-C2)/(E1-E2) where C indicates the cost and E indicates the effectiveness of the treatment [14,15].

To assess the costs, we calculated the differential between the costs borne in the two years for the following parameters: C1 (2013): cost drugs; C2 (2014): cost drugs+cost device+cost material+hourly cost of staff; E1: number deaths in 2013; E2: number deaths in 2014.

Results

Microbiological environmental data

We measured the efficacy of the procedure in the reduction of the bacterial and fungal load in the environment. The most heavily contaminated areas in the ICU rooms were servant tables, urine collection bags, buzzers and bed linens (Table 1). After treatment with 99T, contaminated residues had been completely eliminated.

Surfaces Analyzed Using Environmental Swabs	TBC 37°C (cfu/cm^2)		TBC 22°C (cfu/cm^2)		M (cfu/cm^2)	
	PRE (a)	POST(b)	PRE (a)	POST(b)	PRE (a)	POST(b)
Bedrails	3	0.1	2,6	0	1.8	0
Bedlinen	2.2	0.2	3,2	0.3	0.7	0
Table servant	7.4	0.4	6,6	0	6.8	0
Blood pressure cuffs	3.4	0	2	0.1	1.4	0.1
Intravenous pumps	1.6	0	0.8	0.1	1	0
Nurse call buttons	4.5	0	3.7	0.1	4.2	0
Bag of urine collection	8	0.3	8.5	0.1	4	0

Table 1: Bacterial and mycetic load measured throughout the intensive care before and after use of the 99MA System, Legend a) before use of 99MA System, b) after use of 99MA System, TBC, Total Bacterial Count; M, total mycetum count, For each sampling, different temperatures allowed to evidence bacterial load originating from environmental infections and those from human host.

Clinical outcome

The patient population admitted to the ICU between 2013 and 2014 was quite homogeneous in reference to demographic and clinical characteristics (Table 2).

Clinical Characteristics	Year	Year
	2013	2014
No. of total admitted patients	244	245
No. of patient >3 days stay	88	98
No. of total deaths	68	60
No. of deaths patients >3 days	48	42
Days of hospitalization	1796	1431
Average hospital stays	7.4 ± 14.2	5.8 ± 7.9
Average patient age	64 ± 17	65 ± 18
Male	147	147
Female	97	98

Table 2: Clinical patient characteristics of total ICU patient population.

As compared to 2013, in 2014 there was a significant decrease in number of deaths caused by infections compared to deaths for other causes—decreasing from 59% to 38% (χ^2=4,02; P= 0,045) (Figure 1). In 2013, out of 34 patients with positive cultures, 8 were found with multiple infections (7 deaths, 1 survival) whereas in 2014, only 5 were multiple infections.
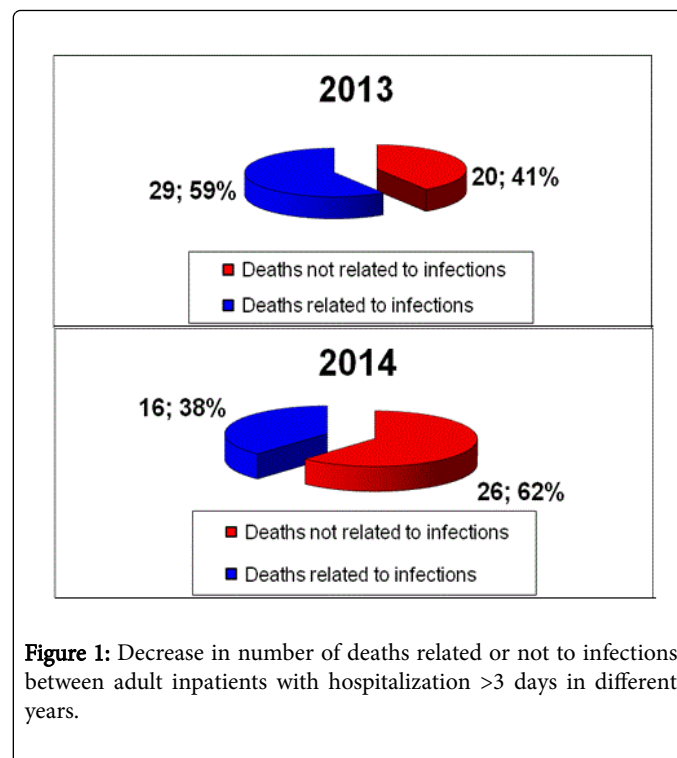

Figure 1: Decrease in number of deaths related or not to infections between adult inpatients with hospitalization >3 days in different years.

The causative agents most frequently isolated were *A. baumannii*, followed by *S. epidermidis*, *Candida* spp., *P. aeruginosa*, *E. coli*, *S. maltophiliae*, *K. pneumoniae*.

As compared to 2013, the Mann-Whitney test showed a significant reduction in 2014 in hospitalization days (Figure 2), which decreased from 16.95 ± 20.46 (mean ± SD) to 11.55 ± 10.03 (mean ± SD: p value<0.05).
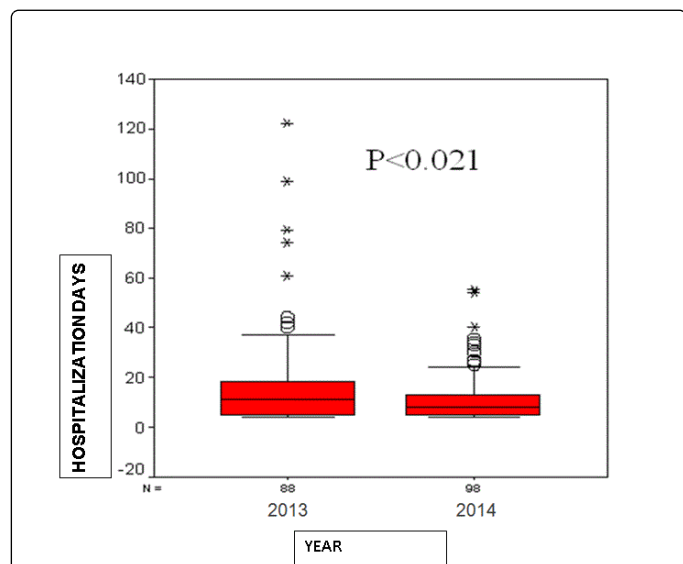

Figure 2: Mann Whitney test showed a significant reduction in hospitalization days between 2013 and 2014.

The number of disinfection interventions performed with HyperDRYMist in 2014 was 44 (approximately one after each death).

Assessment cost-effectiveness

To calculate ICER the following costs were identified: (i) Cost of drugs dedicated to the treatment of infections of the 2nd and 3rd level claimed in patients hospitalized for at least three days. Cost of antibiotics treatment from the first day to the third was excluded. (ii) Device cost (depreciation charge=25% yearly); (iii) Cost of consumables; (iv) Hourly cost of personnel responsible for biodecontamination.

ICER was calculated as follows: ICER=(C1-C2)/(E1-E2) where C1-C2 is the differential cost and E1-E2 is the efficacy differential.

C1 cost in 2013 was €54,620; C2 cost in 2014 was €49,773 (€47,223 for drugs, €1,500 for device, €600 for consumables, €540 for the personnel dedicated to the bio-decontamination). Differential Cost (C1-C2) was €4,847.

As an effectiveness indicator, we considered the number of patients who died after three days of hospitalization. In 2013 the number of deaths was 48 (E1) and in 2014 the number of deaths amounted to 42 (E2). Efficiency differential, E1-E2, is equal to:

Efficacy Differential (E1-E2)=48 deaths-42 deaths=6 deaths

The ratio between the cost differential and the efficacy differential returns ICER, the incremental costs for saving on deaths in infected ICU patients, is €807.83 per death-related infection.

Figure 3 illustrates that ICER value is positioned in the first quadrant, thus confirming the study to be cost-effective, as it has higher costs but is more effective.
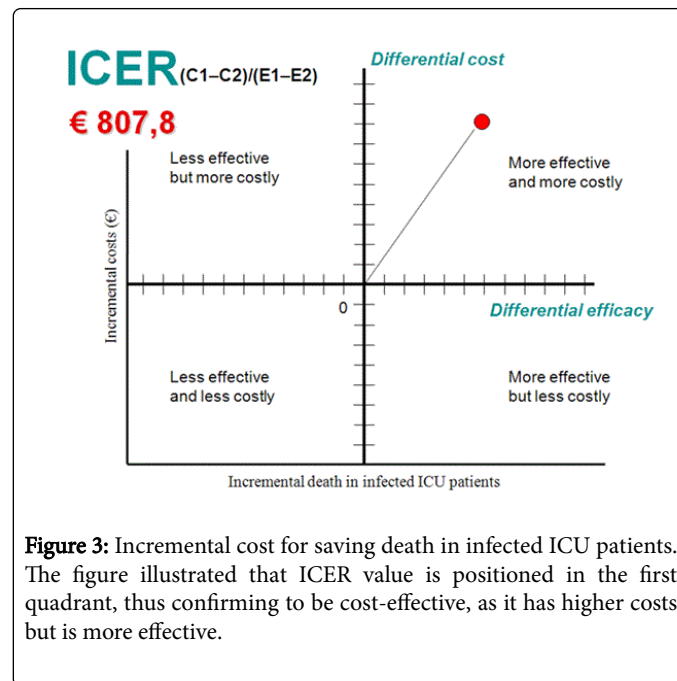

Figure 3: Incremental cost for saving death in infected ICU patients. The figure illustrated that ICER value is positioned in the first quadrant, thus confirming to be cost-effective, as it has higher costs but is more effective.

Discussion

A high frequency of nosocomial infections is an indicator of poor quality of health services provided and a source of avoidable costs.

Since 2011 in our Hospital there has been a hand-hygiene protocol, as suggested by WHO recommendations, focusing on high risk transmission practice.

Sometimes the isolation procedure cannot be performed, the disinfection of hands is not properly done, or the proper use of gloves is not properly performed, even in the presence of severe infectious disease [16]. Despite many interventions, hand disinfection rate remains very bad, as described by observation or more recently by videotaping [17].

Our study aimed to evaluate the efficacy of a new system to reduce HAIs, in particular infections brought by most common resistant and threatening infections that can further compromise the conditions of already critically ill patients.

Accurate cleaning and decontamination of hospital environments is essential to reduce contamination, but does not completely remove the bacteria from all surfaces [18].

This may depend on many factors, including the efficacy of the decontamination protocols in use, the poor observance by the operators, the inefficacy of the treatments on the surfaces complex shapes, the improper use and choice of agents in relation to the materials and environments undergoing decontaminated.

Environment plays a central role in the transmission of pathogens acquired in the hospital. Some bacteria can survive for several months in a hospital setting —particularly in those areas most in proximity of patients (bedrails, bed linen, table's servant, blood pressure cuffs,

intravenous pumps, nurse call buttons, bags of urine collection) — adapting and becoming resistant to antimicrobial actions [1,2,19-21].

Hence it is important to choose an easy-to-implement and effective method, that is less operator dependent and that acts on bacterial walls in a relatively short time, without leaving pollutants or residues in the air.

A number of studies in literature have reported the use of hydrogen peroxide in several disinfection systems and its effectiveness in significantly reducing environmental microbial load [22-24].

Indeed, our data confirms a decrease in the number of infections since the introduction of this new technology. In general, 2014 did not show infections of *S. epidermidis*, *Candida* spp., or *P. aeruginosa*, although it appears that infection by *A. baumannii* remained steady over 2013 and 2014. However, these infections did not appear to be linked to each other and their frequency of occurrence could be due to an increased epidemiological trend of this agent in 2014.

A health technology assessment for see a global evaluation of effectiveness, safety, costs [25] and organizational impact was done; our results showed a significant decrease in infections and confirmed safety and user satisfaction of the procedure. Satisfaction with the ease of use of the equipment and environmental safety has been highlighted by the questionnaire to operators and nursing staff, after the intervention of disinfection.

A strong support by this system can certainly be given in hospital clustering of cases, when infection occurs in multiple bedrooms or eventually at discharge of patients infected or colonized with resistant germs or multiple microorganisms. ICER Value confirms that the new approach is cost effective as it has higher costs but is more effective: environmental biodecontamination has reduced costs in the global management of the ICU rooms.

In conclusion we can say that this practice, coordinated by the nursing staff, can be useful for reducing microbial load and nosocomial infections and it is also an opportunity to increase communication between medical and nursing staff.

The infection control nurse, that acquired the knowledge base to use the biodecontamination device, became aware of its role and could increase the active practice of decontamination in the proper manner.

This procedure could improve global quality of care and the final outcomes.

We intend to adopt this system in other critical care units.

Acknowledgement

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