Research article

Assessment of surface cleaning and disinfection in neonatal intensive care unit

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ABSTRACT

Background: Surveillance for healthcare-associated infections (HAI) is a priority in the neonatal intensive care unit (NICU), given the critical immune status of patients. The aim of this study was to assess surface bacterial contamination before and after improving cleaning and disinfection practices.
Materials and methods: This was a cross-sectional study conducted in March 2018. Surface samples were taken from the same areas in three steps: after cleaning, after "improved" cleaning, and after terminal disinfection using hydrogen peroxide vapor (VHP). Sampling and culture was carried out according to standard ISO14698-1: 2004. Results interpretation was based on the thresholds defined by good hospital pharmacy practice. Statistical analysis was performed by SPSS 21.0 and a *P-value < 0.05* was considered to be significant.
Results: In total, 290 samples were taken from different zones: fixed equipment (69%), aseptic washbasins (12%), pneumatic system (9%), computer equipment (6%) and mobile equipment (4%). Prevalence of non-compliances after cleaning and disinfection was 75%, 10% after "improved" cleaning, and 0% after automated VHP (*P < 0.0001*). Median of CFU was 24[EI (0–625)] after standard cleaning, 2[EI (0–35)] after "improved" cleaning and 0 [EI (0–3)] after VHP (*P < 0.0001*). Isolated germs were *coagulase-negative Staphylococcus* (31.2%), *Acinetobacter baumannii* (26%), *Staphylococcus aureus* (19.5%), *Pseudomonas aeruginosa* (9%), *Klebsiella pneumoniae* (9%), *E. coli* (4%) and *Enterobacter sp* (1.3%).
Conclusion: Improved cleaning and disinfection practices associated to VHP give microbiological satisfactory results. It is important to educate cleaning staff for effective surface cleaning and disinfection operations to control HAI.

1. Introduction

Infections associated with neonatal care present a real public health problem responsible for increased neonatal morbidity and mortality. Literature reports a prevalence of health-care associated infections (HAI) in neonatal intensive care unit (NICU) varying from 8.7% to 74.3% [1, 2, 3]. The incidence of NICU HAI in Europe is 25.6% [4].

In NICU, babies are often premature, at a low weight and undergo invasive procedures with a frequent use of medical devices [5]. All these factors may be at a risk for developing a HAI. Overall mortality rate varies between 20% and 80% depending on the risk factors [6].

Therefore, NICU is at a high infectious risk that requires multiple cleaning and disinfection operations daily. Today, there is evidence that environmental disinfection reduce HAI [7]. Only an effective cleaning and disinfection can avoid the spread of micro-organisms and prevent HAI. In our hospital, an outbreak has been reported in NICU (January 2018) with Gram-negative multidrug resistant bacteria (*Acinetobacter baumanii* and *K. pneumonia*) with culture-confirmed infection. Environmental monitoring by microbiological samples was used to identify the source of the outbreak [8]. In our conditions, the investigation leads to a contaminated environment and to a temporary closure of the ward with disinfection operation.

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In this context, the aim of this study was to evaluate the effectiveness of improved surface cleaning to reduce environmental bacterial burden in NICU.

2. Methods

2.1. Settings

This cross-sectional study was conducted inNICUof a tertiary care hospital in Oujda Morocco on March 2018.

2.2. Risk assessment of surfaces using Failure and Mode Effects Analysis FMEA)

Assessment of surfaces to be sampled was first conducted according to FMEA within collaboration of two health care professionals (a nurse and a doctor) of the department concerned.

FMEA method was used to identify the most critical surfaces to be sampled. Critical areas were identified on the result of the score combining the probability of detection, severity and frequency [9, 10, 11].

2.3. Sampling methods

Sampling was carried out according to the standard ISO 14698-1: 2004 [12]which describes the microbiological sampling methods for clean rooms in controlled environments such as NICU in the zone after cleaning and out of activity.

Samples were taken from surfaces of 25 cm^2. Most sampled surfaces were not flat, so we preferred swab method. Sterile swabs were impregnated with isotonic "saline water" containing neutralizing substance (Polysorbate 80 (Tween 80®) + lecithin5% diluted) to negate the effect of any residual disinfectants on a surface to avoid having false negative cultures [13]. The swab is applied in close parallel streaks to the surface to be sampled by rotating the swab slightly: usually, an angle of 45 °C, a constant pressure and a sweeping of the surface are recommended, repeat the sampling of the same area by streaks perpendicular to the first.

2.4. Sampling sequence

Intensive care unit is 430 m^3, with nine incubators, six heating tables, does not contain individual isolation box.

2.5. Routine cleaning

All surfaces, floors and walls were cleaned by a disinfectant based on didecyldimethylammonium chloride (N° CAS 7173-51-5 : 25 mg/g) used with lint-free cloths. High surface Cleaning was carried out by the nursing aids. Floors and walls cleaning and disinfection was done by housekeepers. Nursing aids and housekeepers are paid by an external company. Two hours later, 100 surface samples were taken.

2.6. Improved cleaning

Next day, cleaning was redone with several improvements. The disinfection intervention consists of: introduction of a traceability sheet, respect for operators' clothing hygiene, use of single-use wipes instead of reusable cloths for high surfaces, floors and walls, respect for contact time of disinfectant products. For equipments, single-use wipes containing didecyldimethylammonium chloride and polyhexamethylene biguanide hydrochloride were used. After 2 h, we took another 100 samples from the same area collected areas collected in the routine cleaning.

2.7. Improved cleaning and VHP procedure

On the third day, the improved cleaning and disinfection operations were redone and VHP (1200ppm) was used by an autonomous mobile and fully automatic aerosol generator.

Accordance with manufacturer's recommendations, the appliance has been placed in center of the room, all external doors have been closed, and air handling and ventilation system has been shut down. Decontamination cycle has been initiated and lasted 4 h. Two hours later, a series of 90 samples were taken from the same area on the second and first day, except 10 samples for the pneumatic system since it is installed outside the service and who have not been subjected to VHP procedure.

Samples were immediately transported to the laboratory under conditions that do not alter viability or number of microorganisms. Each swab was inoculated on a non-selective solid standard culture medium (Trypticase Soya Agar TSA) at 22 °C during24–48 h. The result has been assessed quantitatively in Colony-Forming Unit (CFU).

Complete biochemical identification of bacteriawas carried out by the BD Phoenix™ 100 instrument (Becton Dickinson MicrobiologySystems).

The results wereinterpreted on the guidelines defined by the good practices of hospital pharmacy version 2001. A number of CFUs greater than 5 means a non-compliant result.

Antibioticsusceptibilitytestingwasconducted in accordance with recommendations of EuropeanCommittee on AntimicrobialSusceptibilityTesting (EUCAST) [14].

2.8. Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 21.0. All variables were summarized using descriptive statistics. Qualitative variables were described in terms of proportions, and the quantitative variables were described in terms of median and interquartile range. Univariate analysis was performed using Chi-square test for qualitative variables and the Kruskal-Wallis for quantitative variables. A $P < 0.05$ was considered to be significant.

3. Results

3.1. Critical areas of surfaces using FMEA method

Using FMEA method, we were able to prioritize the most critical areas with five samples each:

Newborns incubators, heating table, Aseptic washbasins, Monitor screen, Drug cart, Pneumatic system.

3.2. Assessment of surface biocontamination

Overall, we assessed 290 samples in three different steps (Table 1).

Non-compliant samples were classified into three categories according to the number of CFU: from six to 100 CFU, from 101 to 1000 CFU,

Table 1. Repartition of Samples and qualitative assessment of surface microbial contamination.

	Samples taken N (%)	Rate of non-compliance	P
After cleaning and disinfection	100 (34.5)	75%	P < 0.0001
After « improved » cleaning and disinfection	100 (34.5)	10%	
After cleaning and disinfection coupled with aerial terminal automated disinfection	90 (31)	0%	
Total	**290 (100)**		

Table 2. Quantitative assessment of microbial contamination.

	CFUs Median, IQR	P	Intervals of CFU		
			6–100	101–1000	1001–10^6
After standard cleaning and disinfection	24 [0–625]	P < 0.0001	**60**	**15**	0
After « improved » cleaning and disinfection	2 [0–35]		**10**	0	0
After cleaning coupled with automated terminal disinfection	0 [0–3]		0	0	0
Total			**70**	**15**	0

The bold figures represent the samples for which the number of CFUs is the highest according to the iontervals of the CFUs.

and from 1001 to 10^{6}CFU. Table 2 summarizes quantitative assessment of microbial contamination.

The most important median of CFUs was observed in the first day samplesafter a "standard" cleaning and disinfection operation (24 IQR [0–625]).

After education of the cleaning and disinfection staff, we observed a significant reduction of CFU in the second day samples (2, IQR [0–35]). The microbial contamination disappeared definitelyin the samples of the 3rd day after coupling cleaning and disinfection to VHP:(0 IQR [0–3]) (P < 0.0001).

Five categories of areas were sampled, fixed equipment was the most contaminated area (52%), followed by aseptic washbasins (14.5%), mobile equipment (example: Newborns incubators, pneumatic system) (14.5%), door handles (11%) and computer equipment (8%), (P < 0.0001).

3.3. Bacteria identification and resistance

Taking into account the morphological and biochemical specific characteristics of different species, isolated microorganisms were as follows: *Coagulase-negative staphylococci, Acinetobacterbaumannii, Staphylococcus aureus, Pseudomonas aeruginosa, Klebsiellapneumoniae, Escherichia coli, EnterobacterSp* (Table 3). After improvement of cleaning and disinfection operations in the second day, no pathogens were isolated.

Antibiotic susceptibility testing was conducted for four species pathogenic bacteria: *Staphylococcus aureus, Escherichia coli, Acinetobacterbaumannii,* and*Klebsiella pneumonia.*

60% of *Staphylococcus aureus* strains were Methicillin-resistant (MRSA). 75% of *Acinetobacterbaumannii* were "multidrug-resistant" (MDR). 42.8% of *Klebsiella pneumonia* were producing ESBL. (Table 3).

4. Discussion

Distribution of isolated bacteria showed high contamination by coagulasenegative staphylococcus, which is mentioned in other similar studies [15, 16], but Multidrug-resistant gram-negative bacilliwere strongly presentand which are directly related to nosocomial infections in newborns; *A. baumanni, K. pneumonia.*

In neonatal intensive care unit, several patients who were hospitalized within two months before study had HAI of *A. baumanni* and *K. pneumonia*. These pathogens were mainly isolated in our study.

Surface cleaning and disinfection operations are particularly influenced by "human errors" for example, inappropriate use, and omission of several sensitive areas [16]. After a site visit at the neonatal intensive care unit, we found several errors in Surface cleaning and disinfection procedures; a very low frequency of cleaning and disinfection operations with no traceability, the negligence of several critical surfaces, the non-respect of indications and contact time of the biocidesin accordance with the manufacturers' recommendations. The most shocking remark was the use of a single cloth for cleaning all surfaces of babies' incubators. All these errors were corrected on the second day of the study, and the statistically significant results show the effectiveness of our actions.

The importance of surface cleaning in interrupting the development of nosocomial bacteria in NICU and in the elimination of reservoirs of potential pathogens was emphasized [17, 18].

Thus, surface cleaning and disinfection procedures, written by a qualified staff and applied by and educated staff, are necessary to prevent the spread of pathogens in this delicate environment.

Generally, all objects and equipment used in the NICU environment constitute a reservoir for microbial transmission. In other studies, the results showed thatmobile phones are a major source of transmission of multi-resistant nosocomial bacteria [19, 20, 21].

The total bacterial counts on the hands of health care workers ranged from 3.9×10^4 to 4.6×10^6 CFU/cm^2 [22]. In a survey of hand hygiene practices in the same ward that we conducted on March 2018, the overall adherence rate of health-care workers did not exceed 34.5%. Poor hand hygiene promotes cross-contamination of surfaces.

Isolated bacteria in the neonatal intensive care unit confirms the impact of bad and poor cleaning and negligence of hand hygiene procedures by medical staff on the increase of HAI [23].

Table 3. Isolated microorganisms and resistance.

	Bacterial species	N (%)	Resistance to Antibiotics
Gram-positive cocci (n 39; 50.64%)	*Coagulase-negative staphylococci*	24 (31.2%)	Not tested
	Staphylococcusaureus	15 (19.5%)	(n = 9) 60% of the strains were Methicillin-resistant *Staphylococcus aureus* (MRSA). All isolates were sensitive to glycopeptides
Gram-negative bacilli (n 38; 49.36%)	*Acinetobacterbaumannii*	20 (26%)	75% (n = 15) were resistant to carbapenems, these strains corresponded to "multidrug-resistant" (MDR), 25% of strains were "extensively drug-resistant" (XDR) and no strain was "pandrug-resistant" " (PDR) since they were all sensitive to colistin.
	Pseudomonas aeruginosa	7 (9%)	Not tested
	Klebsiellapneumoniae	7 (9%)	3 strains (42.8%) were producing ESBL and one (14.2%) producing carbapenemase. 85.7% of *K. pneumoniae* also had resistance to sulfamethoxazole/trimethoprim, (71.4%) to gentamicin, (42.8%) to fluoroquinolones, and (14.2%) to Amikacin.
	Escherichia coli	3 (4%)	(n = 1) 33.3%of the *E. coli* isolated were broad spectrumbetalactamase « producingExtended Spectrum Beta-Lactamases (ESBL) »
	Enterobacter sp	1 (1.3%)	Not tested

VHP decontamination systems have proven effective in the eradication of environmental contamination and the resulting acquisition of infection [24], and against MRSA, gram-negative multi-resistant bacilli [25, 26].

During an epidemic of *C. difficile* infection, decontamination with VHP has been associated with negativity of environmental samples of *C. difficile* from 11/43 (25%) to 0/37 (0%) [27]. this method has also demonstrated its effectiveness for decontamination of environment following an outbreak of *Serratia marcescens* in a neonatal intensive care unit in United Kingdom [28].

Our results show that eradication of gram-negative bacilli isolated in neonatal intensive care unit surfaces has been observed after correction of cleaning and disinfection errors even before using VHP.

This study aimed to convince and raise awareness among healthcare professionalsof importance of proper and effective cleaning and disinfection in control against transmission of HAI in their ward.

Suppression of environmental reservoirs of these multi-resistant germs could undoubtedly break the chain of transmission of pathogens and control HAI.

To date, improvements in surface cleaning and disinfection are respected by neonatal intensive care unit staff. VHP is practiced once a month (after the transfer of all hospitalized patients).

In conclusion, results of our study were shared with the neonatal intensive care unit team. The bacteriological profile of the HAI at neonatal intensive care unit correlates with the report of microbiological control of environment, which proves that environment monitoring of infectious riskis mandatory and the importance of education of health care workers and cleaning staff.

Declarations

Author contribution statement

M. Chiguer: conceived and designed the experiments; performed the experiments; contributed reagents, materials, analysis tools or data; wrote the paper.

Z. Alami: conceived and designed the experiments; contributed reagents, materials, analysis tools or data; wrote the paper.

A. Maleb: performed the experiments; analyzed and interpreted the data; contributed reagents, materials, analysis tools or data; wrote the paper.

N. Abda: analyzed and interpreted the data.

R. Amrani: performed the experiments.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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