DOI: 10.17058/reci.v13i4.18271

ORIGINAL ARTICLE

Microbiological environmental contamination in a Pediatric Intensive Care Unit

Contaminação ambiental microbiológica em uma Unidade de Terapia Intensiva Pediátrica

Contaminación ambiental microbiológica en una Unidad de Cuidados Intensivos Pediátricos

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Submitted: 03/15/2023
Accepted: 05/02/2023

ABSTRACT

Background and objectives: inanimate surfaces and equipment in the hospital environment are considered reservoirs of resistant and pathogenic microorganisms. In Pediatric Intensive Care Units, the risk of infection is also related to the severity of pathologies associated with the immaturity of the immune system of this population. This study aimed to investigate microbiological environmental contamination in a Pediatric Intensive Care Unit. **Method:** this is an exploratory cross-sectional study, carried out in a Pediatric Intensive Care Unit of a highly complex university hospital, located in southern Brazil. To assess environmental contamination, sterile swabs were rubbed on surfaces corresponding to the patient unit and in the common area. **Results:** twenty-eight surfaces were analyzed, 12 of which were located in units occupied by patients at the time of collection and 16 surfaces in the common use area. In the total number of surfaces analyzed by microbiological cultures, the patient unit showed

66.67% contamination by microorganisms, while surfaces in the common area showed 56.25%. Regarding the microbiological profile, all isolated microorganisms were Gram-positive and showed resistance, namely *Staphylococcus aureus* and coagulase-negative *Staphylococcus*. **Conclusion:** there was evidence of a high frequency of contamination on inanimate surfaces and equipment near and far from patients, essentially by pathogenic and multi-resistant microorganisms to antimicrobials.

Keywords: *Nosocomial Infection; Multiple Bacterial Pharmacoresistance; Pediatric Intensive Care Unit; Hospital Cleaning Service; Nursing.*

RESUMO

Justificativa e Objetivos: superfícies e equipamentos inanimados do ambiente hospitalar são considerados reservatórios de microrganismos resistentes e patogênicos. Em Unidades De Terapia Intensiva Pediátrica, o risco de infecção também se relaciona à gravidade das patologias associadas à imaturidade do sistema imunológico dessa população. O objetivo deste estudo é investigar a contaminação ambiental microbiológica em uma Unidade de Terapia Intensiva Pediátrica. **Métodos:** trata-se de estudo transversal exploratório, realizado em uma Unidade de Terapia Intensiva Pediátrica de um hospital universitário de alta complexidade, localizado no Sul do Brasil. Para avaliar a contaminação ambiental, foram atritados *swabs* estéreis nas superfícies correspondentes à unidade do paciente e na área de uso comum. **Resultados:** foram analisadas 28 superfícies, sendo 12 localizadas nas unidades ocupadas por pacientes no momento da coleta e 16 superfícies da área de uso comum. No total de superfícies analisadas por culturas microbiológicas, a unidade do paciente apresentou 66,67% de contaminação por microrganismos, enquanto as superfícies da área comum apresentaram 56,25%. Com relação ao perfil microbiológico, todos os microrganismos isolados eram Gram-positivos e apresentaram resistência, sendo eles *Staphylococcus aureus* e *Staphylococcus* coagulase negativa. **Conclusão:** evidenciou-se uma alta frequência de contaminação em superfícies e equipamentos inanimados próximos e distantes ao paciente, essencialmente por microrganismos patogênicos e multirresistentes aos antimicrobianos.

Descritores: *Infecção Hospitalar; Farmacorresistência Bacteriana Múltipla; Unidade de Terapia Intensiva Pediátrica; Serviço Hospitalar de Limpeza; Enfermagem.*

RESUMEN

Justificación y Objetivos: las superficies y equipos inanimados del entorno hospitalario se consideran reservorios de microorganismos resistentes y patógenos. En las Unidades de Cuidados Intensivos Pediátricos el riesgo de infección también se relaciona con la gravedad de patologías asociadas a la inmadurez del sistema inmunológico de esta población. El objetivo de este estudio es investigar la contaminación ambiental microbiológica en una Unidad de Cuidados Intensivos Pediátricos. **Método:** este es un estudio exploratorio transversal, realizado en una Unidad de Cuidados Intensivos Pediátricos de un hospital universitario de alta complejidad, ubicado en el Sur de Brasil. Para evaluar la contaminación ambiental se frotaron hisopos estériles en las superficies correspondientes a la unidad de pacientes y en el área común. **Resultados:** se analizaron 28 superficies, 12 de las cuales estaban ubicadas en unidades ocupadas por los pacientes al momento de la recolección y 16 superficies en el área de uso común. Del total de superficies analizadas por cultivos microbiológicos, la unidad de pacientes presentó un 66,67% de contaminación por microorganismos, mientras que las superficies del área común presentaron un 56,25%. En cuanto al perfil microbiológico, todos los microorganismos aislados fueron Gram positivos y presentaron resistencia, concretamente *Staphylococcus aureus* y *Staphylococcus* coagulasa negativo. **Conclusión:** se evidenció una alta frecuencia de contaminación en superficies inanimadas y equipos cercanos y lejanos del paciente, fundamentalmente por microorganismos patógenos y multirresistentes a los antimicrobianos.

Palabras clave: *Infección Nosocomial; Farmacorresistencia Bacteriana Múltiple; Unidad de Cuidados Intensivos Pediátricos; Servicio de Limpieza Hospitalaria; Enfermería.*

INTRODUCTION

Inanimate surfaces and equipment in hospital environments are considered reservoirs of resistant and pathogenic microorganisms. Given this reality, environmental contamination constitutes an important source of dissemination of multidrug-resistant organisms (MDRO) in hospital environments.[1]

These pathogens are generally located on surfaces and equipment close to patients such as bed rails, bedside tables, cardiac monitors and infusion pumps and can be transmitted to patients through cross-contamination by the hands of healthcare professionals and companions.[1, 2]

In Pediatric Intensive Care Units (PICU), the risk of cross-contamination increases as these sectors accommodate critical patients who undergo various invasive procedures and require prolonged care due to their clinical condition. Therefore, they are more susceptible to acquiring healthcare-associated infections (HAIs) due to MDRO.[3] Furthermore, the risk of infection in the pediatric population is also related to the severity of underlying pathologies associated with the immaturity of the immune system in this population. [4, 5]

HAIs represent risks to patient safety, especially those involving microorganisms resistant to antimicrobials.[6] In this regard, surfaces and equipment in healthcare services are considered fomites of resistant and pathogenic microorganisms, and may represent risks to pediatric patients' clinical condition and survival.

Given the situation exposed, the question arises: what is the frequency of microbiological environmental contamination in a PICU? To answer this question, the present study aimed to investigate microbiological environmental contamination on inanimate surfaces and equipment in a PICU.

METHOD

Study design

This is an exploratory cross-sectional study that used data obtained from environmental microbiological samples from the aforementioned surfaces.

Study setting

The study was carried out in a non-profit tertiary university hospital in southern Brazil, which has 431 beds, being a municipal and state reference for highly complex care in the Brazilian Health System.

The institution has a PICU, with the availability of 7 patient units/beds for children aged between one month and 12 years. The study used microbiological samples collected from surfaces in the patient unit and the common area of PICU.

Study sample

Samples were included from surfaces in the patient unit and the common area of the PICU that were occupied, at the time of collection, by children hospitalized for a minimum period of 48 hours. Unoccupied units and units in which patients were hospitalized for less than the aforementioned minimum period were excluded from the sample.

To select the surfaces and equipment for the patient unit, the standardization of the Brazilian National Health Regulatory Agency (ANVISA (*Agência Nacional de Vigilância Sanitária*), 2012) was considered as well as selection based on proximity to patients and frequency of contact with the hands of professionals and companions.[7, 8] In this way, the surfaces and equipment that made up the patient unit were divided into three groups: Group 1, composed of the patient unit fixed structures (gas panel, IV pole, shelf or bench, and side table); Group 2, consisting of equipment (mechanical ventilator, infusion pump and cardiac monitor); Group 3, consisting of bed rails and headboard, with the exception of mattress, as its disinfection occurs during patients' bath, in accordance with the standards of the study institution.

Surfaces and equipment in the area of common use between companions and professionals were selected according to the frequency of contact with the hands of professionals and companions.[7, 8] Therefore, alcohol gel dispensers, armchairs, administrative benches, door handles and drawers of nursing station furniture, emergency cart, scales for measuring children's weight, portable x-ray equipment, x-ray board, telephones, computer keyboards and mice were investigated.

Some of the equipment listed above was grouped when there was more than one unit in the sector. In these cases, the microbiological sample was collected using a single swab, applied to the surfaces of alcohol gel dispensers in patient units (2 units), alcohol gel dispensers in the common area (2 units), computer mice (4 units), computer keyboards (4 units), telephones (2 units) and scales (2 units), thus generating 6 grouped samples of surfaces.

Variables and data collection instrument

Data and microbiological sample collection took place on a single day, in September 2020, with data collected using an instrument including items identifying patients (name, medical record number, date of birth and hospitalization), unit (equipment and inanimate surfaces investigated) and results of the microbiological investigation of the surfaces.

Procedure for collecting microbiological cultures from environments

Environmental microbiological samples from the patient unit and common area were collected by a team of researchers previously trained to carry out this procedure. Collection was carried out in a single moment in the common area and at the pre-disinfection moment of the patient unit, which occurred in just one day.

Cultures were collected by rubbing sterile swabs (Olen Kasvi®) moistened with 0.9% saline solution on the surface, prioritizing the friction of the swab in areas of greatest contact with the hands, such as buttons, handles, touch screens of devices between others. After sample collection, the swabs were placed in Stuart medium and sent to the microbiology laboratory within a maximum period of 4 hours.

To identify the species and antimicrobial sensitivity profile, the swabs were inoculated into three tubes containing trypticase soy broth ((TSB), Kasvi®), the first with 6.5% NaCl, the second containing cefotaxime (8 µg/mL) and the third containing vancomycin. After incubation for 8 hours at 35 ºC, the vancomycin-resistant broth (VRE) was replicated on VRE agar (OXOID®, England), containing 6 µg/mL of vancomycin, 6 µg/mL of ciprofloxacin and colistin. TSB was replicated on Mac Conkey agar (Acumedia®) containing 8 µg/mL of cefotaxime, and the NaCl broth on salted mannitol agar. The identification of microorganisms was carried out using the manual methodology recommended by Jorgensen (2015). Antimicrobial susceptibility was determined by the disk diffusion method following recommendations from the Clinical and Laboratory Standards International (2019), including verification of disk test (D-test) among isolates. The D-test allows the detection of inducible resistance to clindamycin, as the resistance mechanism is not detected through the sensitivity test routinely used in laboratories, and the induction test, called the D-test, is recommended.[9]

Data analysis

The database was built in an electronic spreadsheet using MicrosoftExcel® and subsequently analyzed using Epi Info™ version 7.2.2.6 (Centers for Disease Control and Prevention, Atlanta, USA). Variables were described in measures of central tendency and frequency distribution, with the results presented in descriptive tables. A 95% confidence interval was considered when necessary. The results of microbiological mapping were presented in illustrations created in the softwares Paint.Net 2021 version 4.2.16 and Inkcape 2021 version 1.1.1.

Ethical considerations

This study is linked to the project entitled "*Investigação da contaminação ambiental em áreas críticas hospitalares e avaliação da efetividade da desinfecção*", and complied with the ethical precepts established by the Ministry of Health (Resolutions 466/2012, 510/2016 and 580/2018 of the Brazilian National Health Council), being approved by the institution's Research Ethics Committee on February 14, 2020, under Opinion 3.839.405 CAAE (*Certificado de Apresentação para Apreciação Ética* - Certificate of Presentation for Ethical Consideration) 28169520.0.0000.5231.

RESULTS

A total of 28 surfaces were analyzed, 12 of which were located in the units occupied by patients at the time of collection and 16 surfaces in the common area of the PICU.

Regarding the patient unit, four units were investigated, corresponding to 57.14% occupancy in the sector. Patients occupying the units analyzed had a mean hospitalization of 31.75 days (SD 15.54), with a minimum of 9 and a maximum of 44 days, with a median of 37 days.

In each patient unit, samples were collected from three groups of surfaces, totaling 12 groups of surfaces between the four units studied.

Of the total surfaces in the patient unit, 66.67% showed contamination by microorganisms, of which patient units B and C obtained contamination in all groups analyzed. As for the surface groups, Group 3 was contaminated in all patient units. Groups 1 and 2 showed the same frequency of contamination (50%) (Figure 1).

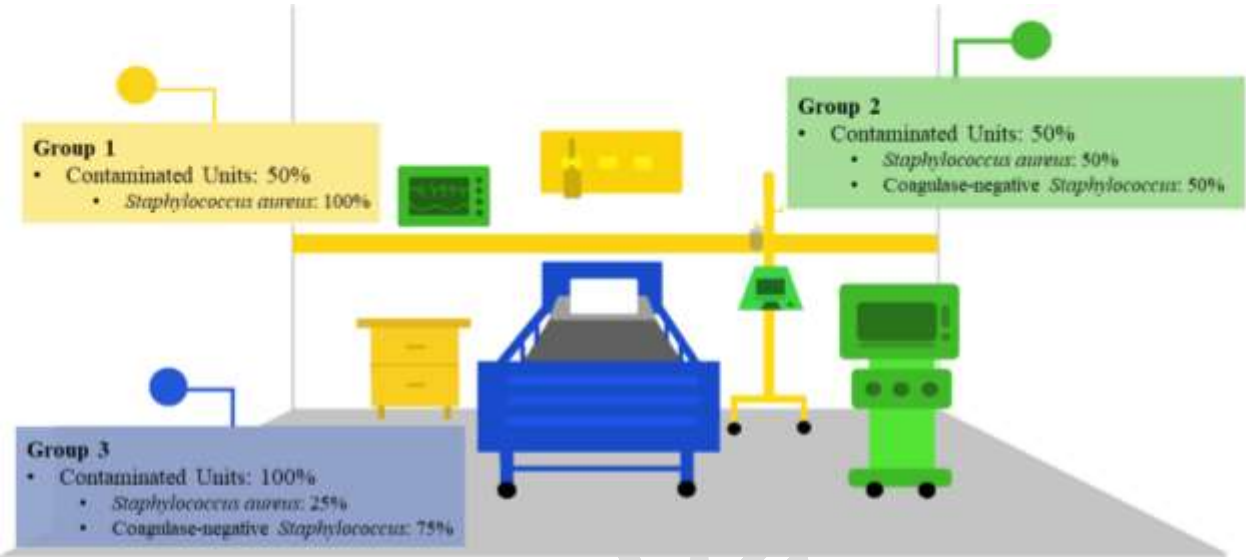

Figure 1. Distribution of environmental contamination by microorganisms in groups of surfaces in Pediatric Intensive Care Patient Units. Londrina, PR, Brazil, 2020
Group 1 = gas panel, IV pole, benches/shelves and side table; Group 2 = mechanical ventilator, infusion pump and cardiac monitor; Group 3 = bed rails and headboard.
Source: the author (2021).

Regarding the surfaces in the common area, 16 surfaces were analyzed, of which 56.25% showed contamination by microorganisms, including companion seats, administrative counters, cabinet handles in the nursing station, emergency cart, scales, x-ray plate, phones and keyboards (Figure 2).

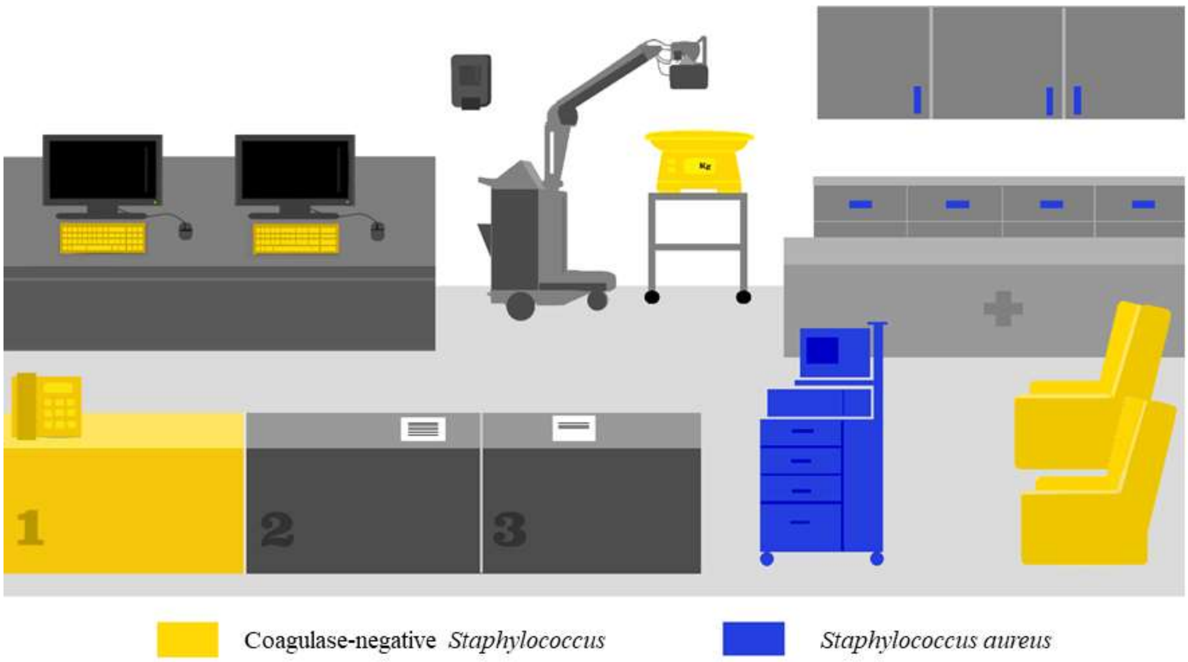

Figure 1. Distribution of environmental contamination of microorganisms isolated from cultures carried out on surfaces and equipment in the area of common use among companions and professionals in a Pediatric Intensive Care Unit. Londrina, PR, Brazil, 2020
Source: the author (2021).

Regarding the microbiological profile, all isolated microorganisms were Gram-positive. Coagulase-negative *Staphylococcus* (CNS) accounted for 50.0% of contamination in patient units and 77.8% on common area surfaces. *Staphylococcus aureus* was isolated in 50.0% of patient units and 22.2% of common area surfaces (Table 1).

Table 1. Distribution of the resistance profile of microorganisms isolated from surfaces in the patient unit at the pre-disinfection time (N=08) and on surfaces and equipment (N=09) in the common use area in a Pediatric Intensive Care Unit. Londrina, PR, Brazil, 2020

	Resistance frequency			
	Patient unit		**Common use area**	
Antimicrobial agents	***S. aureus*** **(4)**	**Coagulase-negative *Staphylococcus*** **(4)**	***S. aureus*** **(2)**	**Coagulase-negative *Staphylococcus*** **(7)**
	%	**%**	**%**	**%**
Clindamycin	25.0	100	100	71.4
Erythromycin	25.0	100	100	85.7

Penicillin	75.0	100	100	100
Oxacillin	50.0	100	100	100
Cefoxitin	50.0	100	100	100
Gentamicin	N	50.0	N	57.1
Ciprofloxacin	N	75.0	50.0	57.1
Teicoplanin	N	N	N	N
Tigecycline	N	N	N	N
Linezolid	N	N	N	N
Levofloxacin	N	50.0	N	42.8
Rifampicin	N	N	N	42.8
Sulfamethoxazole + Trimethoprim	50.0	50.0	50.0	46.8
Total microorganisms	4 (50.0%)	4 (50.0%)	2 (22.22%)	7 (77.78%)

N = negative culture.
Source: the author (2021).

Regarding the resistance profile of microorganisms isolated from surfaces in the patient unit, S. *aureus* isolates expressed 75.0% resistance to penicillin and 50.0% resistance to oxacillin, cefoxitin and sulfamethoxazole/trimethoprim. Among the CNS, all expressed resistance to clindamycin, erythromycin, penicillin, oxacillin and cefoxitin, followed by resistance to ciprofloxacin (75.0%). Among the microorganisms isolated from microbiological samples from the common use area, all S. *aureus* expressed resistance to clindamycin, erythromycin, penicillin, oxacillin and cefoxitin. Regarding CNS, all isolates were resistant to penicillin, oxacillin and cefoxitin, and 85.71% were resistant to erythromycin, and 71.43% were resistant to clindamycin, as shown in Table 3. Among the CNS resistant to erythromycin and clindamycin, one isolate presented a positive D-test.

DISCUSSION

Contamination of inanimate surfaces and equipment in healthcare services contributes to the spread of pathogenic and resistant microorganisms, favoring cross-transmission and development of HAIs, especially among hospitalized patients in critical sectors.[3]

The present study showed the contamination of multiple inanimate surfaces and equipment by pathogenic and multi-resistant microorganisms in hospital environments, both in patient units and in the common use area of pediatric intensive care.

In patient units, more than half of bed rails and headboards were contaminated by microorganisms. Brazilian studies carried out in adult ICUs showed that the frequency of contamination on the guardrails of patients' beds was high, ranging from 45.5% to 81.8%.[10, 11] This high level of contamination may indicate that bed rails are considered a potential vehicle for microorganisms, mainly due to the high frequency of handling by healthcare professionals and family members.[2] However, another study with a similar methodology presented divergent results, which demonstrated that medication infusion pumps were the equipment most contaminated by microorganisms compared to bed rails.[12]

The surfaces analyzed in the common use area are not used in direct patient care, but they assist in the health team's work process, constituting an important source of dissemination of these microorganisms during healthcare. As in this study, in a university hospital in France, they observed the growth of Gram-positive bacteria on surfaces analyzed in the research, such as computer keyboards and mice.[13]

As these are surfaces used with high frequency and collectively, they pose a risk of transmitting pathogens to patients. Thus, protocols for hand hygiene for healthcare professionals and family members within healthcare services are recommended. The World Health Organization recommends hand hygiene in five moments as a strategy to prevent the spread of microorganisms.[1]

In addition to hand hygiene, it is necessary to disinfect these areas on a scheduled basis, following institutional protocols based on ANVISA recommendations, which recommends the use of 70% ethyl alcohol as the main disinfectant used to disinfect surfaces.[14]

Regarding the species of microorganisms in this research, all isolates were Gram-positive, with a predominance of CNS, followed by S. *aureus*. A study in Eastern Ethiopia, which investigated contamination in stethoscopes and sphygmomanometers in some hospital units, indicated the Adult ICU as the sector with the highest prevalence of contamination by microorganisms in the objects analyzed. In relation to isolates, there was a higher frequency of Gram-positives, including S. *aureus* and multi-resistant CNS[15], corroborating data from the current research.

Regarding the resistance profile of microorganisms, it was possible to identify in patient units and in the area of common use CNS and S. *aureus* resistant to more than one class of antimicrobial agents, with a predominance of *Staphylococcus* spp. resistant to penicillin and oxacillin, while all CNS isolates also expressed resistance to clindamycin and erythromycin.

CNS and S. *aureus* are microorganisms that colonize human skin and mucous membranes, and have a high potential to cause HAIs and bacteremia, especially in patients with immune system deficits or who use invasive devices, in addition to being related to formation of biofilms and broad spectrum of antimicrobial resistance.[1, 16, 17]

Research in Saudi Arabia analyzed frequently touched surfaces in PICU and Adult ICU, 65% of samples demonstrated growth of the ESKAPE group (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter* species), including S. *aureus* and *Enterococcus* spp. Furthermore, there was environmental contamination in a PICU by Methicillin-resistant S. aureus on a chair, stethoscope, clipboard, keyboard and calculator.[18] A Brazilian study conducted in a PICU detected bacterial growth with a prevalence of S. *aureus* (51.9%) on stethoscopes, incubators, respirators, tables and monitors. Among all S. *aureus* isolates, the majority were resistant to oxacillin.[19]

Another study from southern Brazil analyzed environmental contamination by *Staphylococcus* spp. in an Adult ICU, which showed bacterial growth of CNS and S. *aureus* on surfaces close (infusion pump and side table) and distant (telephone and computer keyboards) to patients. Among the microorganisms, 85.7% were resistant to erythromycin, 71.4% resistant to penicillin and 57.1% resistant to clindamycin, while S. *aureus* isolates 83.3% were resistant to penicillin, 66.7% to erythromycin and 50% to oxacillin and clindamycin, respectively.[20]

Staphylococcus spp. is one of the main pathogens associated with hospital infections in ICUs.[21] Bacteria from the *Staphylococcaceae* family have the ability to survive on inanimate surfaces and equipment in healthcare services, generally close to patients, and despite being part of man's endogenous microbiota, they can contaminate surfaces, which makes cross-transmission possible.[22]

In Jeddah, Saudi Arabia, samples were collected in Adult ICUs and PICUs, in which Gram-positive isolates had a higher frequency of contamination compared to Gram-negative ones. The surfaces with the greatest contamination were nursing stations and patients' beds by S. *aureus*.[23]

Bacterial resistance represents a global challenge, which brings implications and concerns, mainly due to the high rate of development of HAIs due to MDRO.[6] Among the consequences of resistance, we can mention the prolongation of hospitalization time, therapeutic failure of antimicrobials due to resistance and financial impact on public healthcare services.[24]

Therefore, disinfection in healthcare services is a process that destroys microorganisms on surfaces and equipment, being essential to prevent and control the spread of MDRO, with ethyl alcohol at 70% and sodium hypochlorite at a concentration of 0.02% to 1% of the most used sanitizers in the disinfection of non-critical articles to eliminate MDRO.[1]

Considering the results found in this research, it was possible to observe the high potential for contamination of inanimate surfaces and equipment in hospital environments by both pathogenic microorganisms and those that are multi-resistant to antimicrobial agents. The evidence from this study can guide nursing actions, mainly by the Hospital Infection Control Committee to develop cleaning and disinfection protocols, in order to prevent and control hospital infections.

The reduced number of microbiological samples and collection in a single unit are limitations of this study. This situation is partly due to limited financial resources and beds in the pediatric unit at the hospital under study. The need for new studies with a larger number of samples is highlighted.

The results of this study demonstrate a high frequency of contamination on inanimate surfaces and equipment close and far from patients, essentially by pathogenic microorganisms that are multi-resistant to antimicrobials, which are mainly harmful to the health of patients with immaturity of the immune system, like the population of this research. Considering the above, it is necessary that hand hygiene and cleaning and disinfection protocols in healthcare institutions are standardized and rigorously assessed as a means of preventing and controlling MDRO infections.

ACKNOWLEDGMENTS

The work was supported by the Araucária Foundation to Support the Scientific and Technological Development of Paraná (FA - *Fundação Araucária de Apoio ao Desenvolvimento Científico e Tecnológico do Paraná*).

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Authors' contributions:

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Renata Pires de Arruda Faggion, Ana Carolina Souza de Lima contributed to article writing or relevant critical review of intellectual content;

Gilselena Kerbauy contributed to final approval of the version to be published;

Tiago Danelli, Gilselena Kerbauy and **Márcia Regina Eches Perugini** contributed to all aspects of the work in ensuring the accuracy and integrity of any part of the work.

All authors approved the final version to be published and are responsible for all aspects of the work, including ensuring its accuracy and integrity.