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Review Article

Contamination of surfaces located in intensive care units and operating rooms: a systematic review of the literature

Contaminação de superfícies localizadas em unidades de terapia intensiva e salas de cirurgia: uma revisão sistemática da literature

La contaminación de las superficies situadas en las unidades de cuidados intensivos y las salas de operaciones: una revisión sistemática de la literatura

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ABSTRACT
Background and Objectives: Contamination of surfaces in the hospital environment can contribute to the incidence of nosocomial infections through cross-contamination by health care professionals. The objective of this study was to describe, through a literature review, the main microorganisms found on surfaces and/or equipment of two areas considered critical in hospitals. **Contents:** A systematic literature review was carried out using the PubMed, Scientific Electronic Library Online (SciELO) and Latin American and Caribbean Literature in Health Sciences (LILACS) databases, using descriptors related to the topic. A total of 73 articles were found, but after applying the inclusion and exclusion criteria, 14 articles were selected for the review. In relation to the microorganisms found, *Staphylococcus* spp., *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* were more frequently reported in ICU settings, a predominant place of study among the studies of this review. In the operating rooms, the presence of coagulase-negative *Staphylococcus*, *P. aeruginosa* and *Streptococcus* spp. stands out. **Conclusion**: The bacteria found on the surfaces assessed in this review were, in the most part, pathogens related to nosocomial infections, and their presence was reported at higher frequencies on surfaces often touched by the medical team, corroborating the incidence of cross-contamination.
KEYWORDS: Surgical center. Environmental Contamination. Hospital Infection. Intensive Care Units.

RESUMO
Justificativa e Objetivos: A contaminação de superfícies no ambiente hospitalar pode contribuir para a incidência de infecções hospitalares através da contaminação cruzada por parte dos profissionais da saúde. Assim, o objetivo deste estudo foi descrever, por meio de uma revisão da literatura, os principais microrganismos presentes em superfícies e/ou equipamentos de dois ambientes considerados críticos em unidades hospitalares. **Conteúdo:** Realizou-se uma revisão sistemática da literatura nas bases de dados indexadas PubMed, *Scientific Electronic Library Online* (SciELO) e Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS), utilizando descritores relacionados ao tema. Foram encontrados 73 trabalhos, porém após aplicação dos critérios de inclusão e exclusão, foram selecionados 14 artigos para a revisão. Em relação aos microrganismos encontrados, *Staphylococcus* spp., *Acinetobacter baumannii*, *Pseudomonas aeruginosa* e *Klebsiella pneumoniae* foram relatados com maior frequência em ambientes de UTI, local de estudo predominante entre os trabalhos desta revisão. Em sala de cirurgia destacam-se a presença de *Staphylococcus* coagulase negativa, *P. aeruginosa* e *Streptococcus* spp. **Conclusão:** As bactérias encontradas nas superfícies avaliadas nesta revisão eram, em sua maioria, patógenos relacionados com infecções nosocomiais, e foram relatados com maior frequência em superfícies frequentemente manipuladas pela equipe médica, corroborando para a incidência de contaminação cruzada.
DESCRITORES: Centro cirúrgico. Contaminação ambiental. Infecção hospitalar. Unidade de terapia Intensiva.

RESUMEN
Justificación y Objetivos: La contaminación de superficies en el ambiente hospitalario puede contribuir a la incidencia de infecciones hospitalarias a través de la contaminación cruzada por parte de los profesionales de la salud. Así, el objetivo de este estudio fue describir, por medio de una revisión de la literatura, los principales microorganismos presentes en superficies y / o equipos de dos ambientes considerados críticos en unidades hospitalarias**.** **Contenido:** Se realizó una revisión sistemática de la literatura en las bases de datos indexadas PubMed, Scientific Electronic Library Online (SciELO) y Literatura Latinoamericana y del Caribe en Ciencias de la Salud (LILACS), utilizando descriptors relacionados al tema. Se encontraron 73 trabajos, pero después de la aplicación de los criterios de inclusión y exclusión, se seleccionaron 15 artículos para la revisión. En cuanto a los microorganismos encontrados, *Staphylococcus* spp., *Acinetobacter baumannii*, *Pseudomonas aeruginosa* y *Klebsiella pneumoniae* fueron reportados con mayor frecuencia en ambientes de UTI, lugar de estudio predominante entre los trabajos de esta revisión. En la sala de cirugía se destacan la presencia de *Staphylococcus* coagulasa negativa, *P. aeruginosa* y *Streptococcus* spp. **Conclusión:** Las bacterias encontradas en las superficies evaluadas en esta revisión eran, en su mayoría, patógenos relacionados con infecciones nosocomiales, y fueron reportados con mayor frecuencia en superficies frecuentemente manipuladas por el equipo médico, corroborando para la incidencia de contaminación cruzada.
PALABRAS CLAVE: Centros quirúrgicos. Contaminación ambiental. Infección hospitalaria. Unidades de Cuidados Intensivos.

INTRODUCTION

The health service environment, especially critical areas where there are debilitated patients, can contribute to the multiplication and dissemination of potentially pathogenic microorganisms, and even multiresistant bacteria and, thus, favor the incidence of

Healthcare-Acquired Infections (HAIs).[1-3] Intensive Care Units (ICUs) account for less than 10% of total beds in most hospitals in the USA; however, more than 20% of all hospital-acquired infections are acquired in the ICUs. Infections and sepsis acquired in the ICU are responsible for considerable morbidity, mortality and expenses in health services.[4]

Factors such as the ability of microorganisms to survive on inanimate surfaces, the difficulty in removing pathogens, and the lack of specific cleansing of these environments contribute to reinforce evidence that hospital surfaces represent sources of colonization and dissemination of pathogens.[5,6]

Surfaces have a low risk of direct transmission of infection but contribute to secondary cross-contamination through contact with the hands of health professionals and of instruments or equipment with such surfaces, which could be contaminated and subsequently, result in the contamination of patients and other frequently touched locations.[3,7,8]

Therefore, equipment, feeding utensils, bedpans, thermometers, washbasins, bedding and clothes for personal use can also be considered reservoirs of pathogenic microorganisms, and since they are frequently handled objects, they collaborate for pathogen transmission.[9-11]

The occurrence of nosocomial infection is related to several factors, including the patient's health conditions, with the immunocompromised being the most affected ones, and the environmental conditions of where the patient is located, which can be sources of both the infection origin and transmission.[12,13]

The main environmental sources are ventilators, blood and urinary catheters.[4,14] Due to this fact, the highest rates of HAIs are found in elderly patients and patients with an impaired immunological system, who are usually in the oncology, surgical services and intensive care units (ICUs), exactly where the use of potent broad-spectrum antimicrobials is more common and more invasive procedures occurs, making the patient more susceptible to infections.[1,6,10,15,16] Therefore, infection cases in the ICU are more frequent, when compared to other hospital divisions.[1,6]

In the ICU environment, health professionals become the most frequent means of infection transmission, due to contact with contaminated environments or equipment, facilitating the incidence of cross infections.[1,7,8] Whereas in the surgical environment, the main route of microorganism transmission is through direct contact, through the manipulation of the patient's tissues, either contaminated or not. However, indirect transmission can also occur through the contact of contaminated instruments and equipment with the surgical site.[9,17] Data indicate that although there has been a steady decline in North-American ICU contamination from 2012 to 2016, the reported incidence is 2.0 cases for each 1,000 patients.[18,19]

Therefore, the objective of this review is to describe the main microorganisms present in surfaces and/or equipment in two environments considered critical in hospital units: the intensive care unit and operating rooms.

METHODS

A systematic review of the descriptive literature with a qualitative and quantitative approach was carried out, based on the research of the combination of the following descriptors: “hospital infection” AND “hospital environment” AND “surfaces” AND “intensive care unit” and “hospital infection” AND “hospital environment” AND “surfaces” AND “surgery”. The equivalent terms in Portuguese and Spanish were also researched in the indexed databases: PubMed, Scientific Electronic Library Online (SciELO) and Latin American and Caribbean Literature in Health Sciences (LILACS). We searched for articles that included the chosen keywords in the title or abstract and were published between the years 2005 and 2016. We chose studies published in this period because, even though this is a subject of great relevance, it is not frequently researched.

The selection of the articles found in the different databases was based primarily on the reading of all titles and, subsequently, on all abstracts that met the study inclusion criteria, which consisted of the identification of contamination present on hospital surfaces, operating rooms and /or adult or pediatric intensive care units. During the selection process, studies of which samples did not include hospitals for human subjects, studies that were not carried out in the critical areas proposed by the present study, duplicate articles, in addition to those published as editorials, interviews, projects, clinical notes and reviews, were excluded.

Regarding the environment where the samples were collected, the articles with results obtained from intensive care units were considered, being these neonatal, pediatric or adult ICUs, as well as Burn Intensive Care Units, as they are considered critical hospital areas, where the risk of contamination is higher. The same criterion was used for operating rooms.

After the abstracts were read, the selected studies were submitted to an exploratory reading, where inclusion and exclusion criteria were once again applied, discarding articles that did not differentiate the surfaces and / or microorganisms found. Finally, the main data of the selected articles were extracted, which are depicted in tables.

RESULTS AND DISCUSSION

The search in the databases resulted in a total of 73 articles that included the descriptors used in the research. After applying the inclusion and exclusion criteria, 14 were selected and included in this review, as shown in Figure 1, which contained the necessary information to develop the analysis of results.

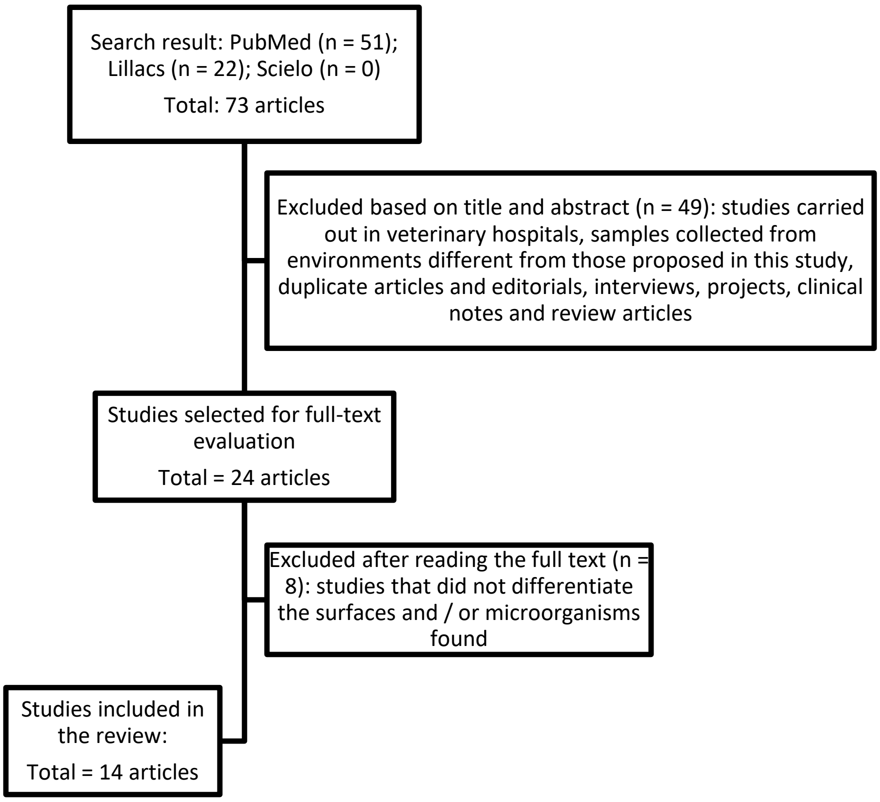

Figure 1 – Flowchart of articles selected for review.

The main data extracted from the articles were described and depicted in two different tables, classified according to the type of microorganism analysis in their respective articles: the ones that performed a random analysis of the main microorganisms found, as described in Table 1, and the ones of which analysis was based specifically on one or more bacterial species, as shown in Table 2.

In the studies analyzed in Table 1, the described results refer to the main bacteria found, which showed a higher incidence and / or greater relevance in each study, as well as the surfaces described in the results of the two tables, of which only those that showed some type of contamination were mentioned, not being the ones that were analyzed, in some cases.

Table 1 – Main results of articles used in the review that randomly analyzed the presence of microorganisms.

Study	Analyzed environment	Analyzed surfaces that showed contamination	Main identified microorganisms
1. Chen KH, et al., 2014[20]	ICU and operating room	Medical records	Coagulase-negative *Staphylococcus, S. aureus,* Methicillin-resistant *S. aureus*, *Escherichia coli*, *Klebsiella pneumoniae* and *Acinetobacter baumannii*
2. Yun CH, et al., 2012[21]	Burn Intensive Care Unit.	Bed rails, doorknobs, sink faucets, IV pumps, computer keyboards and mouses	Coagulase-negative *Staphylococcus, S. aureus, Klebsiella pneumoniae, Enterobacter* spp., *Pseudomonas* spp., *Acinetobacter* spp., *Candida* spp., *E. coli, Streptococcus* spp.
3. Rastogi S, et al., 2012[22]	Neonatal Intensive Care Unit.	Sink faucets and computer keyboards	Coagulase-negative *Staphylococcus*, *P. aeruginosa, Stenotrophomonas maltophilia and Sphingomonas paucimobilis*
4. Ferreira AM, et al., 2011[23]	Intensive Care Unit.	Bed rails, hand cranks, bedside tables and infusion pump buttons.	*S. aureus* and Methicillin-resistant *S. aureus.*
5. Damasceno QS, 2010[11]	Intensive Care Unit.	Stethoscopes, mechanical ventilators, faucets, sink, bed rails, bedside tables and cardiac monitors.	Vancomycin-resistant *Enterococcus faecalis*, *S. aureus*, *S epidermidis*, Multiresistant *Acinetobacter baumannii*, Imipenem-resistant *P. aeruginosa*
6. Nwankwo E, 2012[24]	Operating rooms	Floor, sink, suction catheter and operation beds.	Coagulase-negative *Staphylococcus*, *P. aeruginosa*, *Streptococcus* spp., *Escherichia coli*, *Proteus mirabilis*, *Proteus vulgaris*, *S. aureus*, *E. faecalis* and *Salmonella choleraesuis*

Table 2. Main results of articles used in the review that analyzed the presence of bacterial species.

Study	Analyzed environment	Analyzed surfaces that showed contamination	Identified microorganisms

7. Moore G, et et al., 2015[25]	Intensive Care Unit.	Bed rails, storage trolley, monitor, computer keyboard, telephone and apron dispensers.	Methicillin-resistant *S. aureus*
8. Lin R, et al., 2012[26]	Neonatal Intensive Care Unit.	Incubators and gastric tubes.	ESBL-producing *Klebsiella pneumoniae*
9. Campos GB, et al., 2012[27]	Intensive Care Unit.	Floors, beds, cardiac monitors, ventilator control panels, infusion pump control panels, incubators, telephone, scales, doors, hospital tables and benches, cabinets, emergency carts, medicine trolleys, computers, air conditioners, knobs, faucets and prescription records.	Oxacillin-resistant *S. aureus*
10. McConnell MJ, et al., 2011[28]	Intensive Care Unit.	Bed rail, bedside table, alcohol dispenser, intravenous valves, bedside chairs, equipment trolleys, infusion pumps, folders, doorknobs, keyboards, storage cabinets, nursing station.	*Acinetobacter baumannii*
11. Yakupogullari Y, et al., 2008[29]	Intensive Care Unit.	Tip and the surface of antiseptic bottles, liquid soap containers and mechanical ventilators.	Pan-resistant *P. aeruginosa*
12. Barbolla RE, et al., 2008[30]	Intensive Care Unit.	Bed rail, bed cranks, mechanical ventilation equipment, antiseptic dispenser, workstations, cushions, mattresses and stethoscopes.	*Acinetobacter baumannii*
13. Markogiannakis A, et al., 2008[31]	Intensive Care Unit.	Bed headboards, footboards, tables, external surfaces of endotracheal tubes.	Imipenem-resistant *Acinetobacter baumannii*
14. Moraes CL, et al., 2013[32]	Intensive Care Unit.	Infusion pumps, stethoscopes, incubators, multiparametric monitors, benches, cribs, doorknobs and faucets.	Coagulase-negative *Staphylococcus*

The publication dates of the selected articles ranged from 2008 to 2015. Regarding the critical areas analyzed, ICU settings were the study sites assessed in most articles (13), whereas only two of the selected studies assessed surgical-room environments.[20,24]

As for the analyzed surfaces, many different sites were assessed, but the ones that were assessed and showed more frequent contamination were beds, bed rails, faucets, computer keyboards, hospital tables and benches and doorknobs.

Among the articles that carried out a random screening of surface contamination, *Staphylococcus aureus* was the most frequently identified microorganism on different surfaces, appearing in five of the seven performed studies, followed by coagulase-negative *Staphylococcus* (CNS), *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Acinetobacter baumannii*. [11,16,17,20-24]

As for the studies of which analysis focused on one or more bacterial species, *Acinetobacter baumannii* was the most frequently screened for and identified microorganism, followed by Methicillin-resistant *Staphylococcus aureus* (MRSA), resistant *Pseudomonas aeruginosa* and ESBL-producing *Klebsiella pneumoniae*.[25-31]

The contamination reported by the studies of this review showed that its higher incidence in fomites where the sites that have more contact with health professionals, such as bed rails, faucets, keyboards, monitors and doorknobs, which is related to the fact that high-touch surfaces make them more contaminated areas.[3,7]

Several studies have indicated the hands of health care professionals as the main sources of dissemination and colonization of pathogens, since it often occurs that after touching a patient or manipulating potentially contaminated utensils and equipment, these professionals will return to their activities without proper hand hygiene, without considering the possibility of transferring microorganisms to other places that show a high manipulation.[5,20,23,25-27]

Therefore, other regularly manipulated surfaces such as medical files, antiseptic dispensers, stethoscopes, and heart rate monitors also have great potential to act as bacterial vectors.[11,20,29,30,32] Moreover, some studies in this review, in addition to analyzing the contamination present on the surfaces, associated the similarity of the strains found in the environment with results from clinical samples obtained from infected patients, finding strains with a high degree of similarity, and even clones, indicating the transference of these microorganisms from the environment to the patient or vice-versa.[11,24,27,29,31]

Microorganisms that belong to the normal human microbiota, such as coagulase-negative *Staphylococcus* (CNS), *S. aureus*, *Corynebacterium* spp., and *Bacillus* spp., located on the skin and mucous membranes and frequently found on several surfaces in the studies assessed in this review, are considered relatively non-virulent. However, in certain situations, these microorganisms can acquire pathogenicity and cause infections and, therefore, are characterized as opportunistic pathogens.[6,20,32]

Invasive procedures that cause trauma to the skin barrier, medical implants, use of intravenous catheters combined with the patients' immune system impairment, for instance, are factors that make them more vulnerable, favoring the incidence of this type of infection.[20,21,32]

Staphylococcus spp. bacteria are commonly found in hospital settings and even though *S. aureus* remains the most clinically relevant species among them, CNS has become a very common hospital pathogen in the environment of critical areas, which already harbor multiresistant species, demonstrating they are opportunistic agents of hospital importance, both for the ability to cause infections and to develop antimicrobial resistance.[23,32]

In the study by Damesceno, *Staphylococcus epidermidis* strains detected in lateral bed rails and stethoscopes from an isolation unit had 60% similarity with strains isolated from blood cultures of patients admitted to an adult ICU.[11] However, although both are able to develop multidrug resistance, strains of methicillin-resistant *S. aureus* (MRSA), which are resistant to most beta-lactam antimicrobials, show high pathogenicity and are responsible for high rates of infection, contributing to the increase in hospital morbidity and mortality.[23,27]

Also considered an opportunistic pathogen, which seldom causes infections in a healthy immune system, the detection of *Pseudomonas aeruginosa* in faucets and sinks, surfaces with a higher water concentration, is related to its affinity for moist places.[11,21,22,29] Such microorganism can be carried by water and colonize faucets and pipes, forming a biofilm, which in addition to promoting resistance, can make the water potentially contaminated, making it a risk, if ingested by debilitated individuals.[11] Therefore, the contamination of imipenem-resistant *Pseudomonas aeruginosa* in faucets, sinks and other easily accessible surfaces can increase the risk of contamination of the professionals' hands during hand hygiene, making it necessary for professionals to disinfect their hands with alcohol gel, even after they are clean and dried.[11,29]

Regarding the presence of *Klebsiella* spp. and *A. baumanii* reported in the articles included in this review, it is worth mentioning that the presence of Gram-negative bacilli in clinical isolates is a matter of concern and has generated several studies aimed at eliminating their presence, due to their high potential to cause severe hospital infections, which very often result in ICU outbreaks.[11,20,21,24,26,28,30,31]

Acinetobacter baumannii has become one of the most challenging nosocomial infection causative agents due to its ability to survive on hospital surfaces and to become resistant to antibiotics, resulting in the global emergence of multiresistant strains, which are resistant to multiple classes of antibiotics.[11,20,21,28,30,31]

The presence of resistant strains of *A. baumannii* show high virulence rates associated with bacteria and sepsis, leading to considerably longer hospital length of stay, or even septic shock, which are usually fatal.[30,31] Their presence on surfaces, endotracheal tubes, beds and several inanimate objects indicate the occurrence of cross-contamination among patients.[11,30,31]

Also, regarding the infections caused by *A. baumannii* in the study by Markogiannakis et al., it was possible to determine that colonized intravenous catheters may have acted as sources of contamination in some bacteremia cases, emphasizing the importance of the fact that contaminated surfaces and objects close to the affected patient may temporarily colonize the hands of health professionals and contribute to the incidence of infections.[31]

Thus, aiming to reduce the dissemination of pathogens in the hospital environment and prevent cross-contamination, all the studies included in this review emphasized that efforts must be made to ensure strict practices of surface disinfection, which must be regularly and adequately cleaned and disinfected, evaluating the appropriate use of disinfectants, while respecting their concentration, ways of using them and contact time, since some resistant bacteria might not be affected by these antimicrobials.[11,20-32] Additionally, they emphasize the importance of adherence to hand hygiene practices by the medical team, aiming to prevent the dissemination of pathogens and prevent cross-contamination.

CONCLUSION

The environment contamination assessed in the studies of this review has shown to be associated with surfaces where there is greater contact with health professionals, such as bed rails, faucets, keyboards and monitors. Among the identified microorganisms, the presence of *Staphylococcus* spp., *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* in ICU environments is noteworthy, whereas the operating rooms showed the presence of coagulase-negative *Staphylococcus*, *P. aeruginosa* and *Streptococcus* spp. Some studies demonstrated the similarity between strains found in patients and those isolated from the environment surfaces, indicating that high-touch surfaces near contaminated patients may be directly related to the transmission of these pathogens in the hospital environment.

Therefore, measures related to the control of microorganism dissemination should be performed regularly, including adequate disinfection of surfaces, as well as hand hygiene practices by health professionals, aiming to prevent cross-contamination, since critical environments such as ICUs and operating rooms are the places where intensive care patients are usually found, with a higher risk of infection.

It is worth mentioning that the present study has some limitations regarding the specificity of the results, since the sampling of the environments was performed in a generalized manner, presenting only the main data. Thus, it is important to carry out the complete reading of each study to obtain more information.

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