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Inanimate surface and their cross-contamination potential in hospital environments: a systematic review

Larissa Gonçalves de OLIVEIRA[1], Maurício Alexander de Moura FERREIRA[2], Fernando Augusto SILVEIRA[3], Érica MANGARAVITE[1].

(1) Centro Universitário FAMINAS. Muriaé – MG, Brasil.
(2) Universidade Federal de Viçosa. Viçosa – MG, Brasil.
(3) ABC Agrícola, Campo Novo do Parecis. Mato Grosso – MG, Brasil.

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Autor correspondente:
Larissa Gonçalves de Oliveira
E-mail: larissagdeo@hotmail.com
Endereço: Av. Coronel Monteiro de Castro, 351, Barra.
Muriaé – MG. CEP: 36884-013. Brasil

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Resumo

O ambiente hospitalar é constantemente desafiado por complicações infecciosas relacionadas à assistência à saúde (HAI), principalmente por aquelas causadas por microrganismos multirresistentes. As superfícies inanimadas são potenciais fômites de infecção cruzada de patógenos de importância nosocomial e multirresistentes, sobretudo, através das mãos contaminadas. O objetivo foi coletar e avaliar artigos publicados na última década sobre a presença de patógenos em superfícies inanimadas do ambiente hospitalar, correlacionando-as com o seu potencial de contaminação cruzada dentro deste ambiente e discutindo características de resistência aos antibióticos. A busca foi realizada em quatro bases de dados de 2010 a 2020. Os artigos selecionados investigaram microrganismos presentes em superfícies inanimadas de hospitais brasileiros associados ao acometimento de HAI neste ambiente. Os dados foram tabelados e comparados sistematicamente. A partir de 17 estudos, os gêneros *Staphylococcus*, *Acinetobacter*, *Pseudomonas* e *Klebsiella* foram os mais identificados e houve alto perfil de resistência a antimicrobianos, sendo as superfícies próximas aos pacientes e as de alto contato com maior contaminação por estes patógenos. As superfícies não são valorizadas como potenciais fontes de patógenos para pacientes internados. Ações de prevenção devem ser adotadas, incluindo desde políticas informativas e de correta higienização das superfícies até políticas de fiscalização. Estudos são necessários que contemplem a identificação de microrganismos desde a recepção às UTIs dos hospitais, com identificação de genes de resistência, para investigar as fontes das contaminações e mecanismos de resistência para mitigar de forma mais eficiente as HAI.

Palavras chaves: HAI, superfícies hospitalares, higienização, multirresistência, bactérias.

Abstract

The hospital environment is constantly threatened by healthcare-associated infections, especially those caused by multi-resistant microbes. Inanimate surfaces can be potential fomites for cross-contamination of multi-resistant microbes of nosocomial importance, mainly when touched by contaminated hands. Here, it is presented a systematic review of the literature published in the last decade, about the presence of pathogens on inanimate surfaces in hospital environments and its correlation with cross-contamination potential and antibiotic resistance. Four databases were searched for articles published between 2010 and 2020. The selected articles studied microbes present on inanimate surfaces in Brazilian hospitals and their association with healthcare-associated infections. Most identified microbes fell into the genera Staphylococcus, Acinetobacter, Pseudomonas, or Klebsiella, with those being identified in 17 different studies. There was a high incidence of resistance to antibiotics, and the surface most susceptible to cross-contamination were those close to patients and those with high contact by healthcare staff.

Keywords: *Healthcare associated infection, hospital surfaces, sanitation, multi-resistance, bacteria.*

1 Introduction

The hospital environment is constantly threatened by healthcare-associated infections (HAI), also called nosocomial infections, especially those infections caused by multi-resistant pathogens (ARAÚJO and PEREIRA, 2017). The phenomenon of antibiotic resistance, along with the increase in nosocomial infections, is a problem not only related to public health but also hospital assistance, being of particular concern to hospitals due to increased morbidity and mortality, in addition to high treatment costs (CARDOSO and REIS, 2016; RENNER and CARVALHO, 2013). In Brazil, it is estimated that HAIs are responsible for 14% of hospitalizations (MINISTÉRIO DA SAÚDE, 2020), with a frequency of cross-contamination between 13,0% and 34,6% (NEVES, 2018). About 60% of those infections could have been prevented (OLIVEIRA et al., 2016).

The dissemination of HAI is complex and multifactorial, since there is not only one source of contamination and dissemination, thus making its total elimination unlikely. The spread of HAI may be related to the susceptible patient, infection and the diagnostic and therapeutic methods used (ANDRADE et al., 2000). However, they often come from cross-contamination (DREES et al., 2008), in which the transmission of infectious agents occurs through person-to-person contact, through the air, or contaminated objects (MINISTÉRIO DA SAÚDE, 1998). With the emergence of resistant bacteria and the presence of different sources of dissemination, inanimate surfaces, which are widely used in the daily routine of health professionals, can be considered a potential reservoir for the transmission of microorganisms involved in the occurrence of HAI, even if in smaller proportions (RICE, 2008).

HAIs can be minimized by interfering with the transmission chain of pathogens, mainly through measures such as hand washing, the use of personal protective equipment, and the use of local asepsis measures on these surfaces (PANDEY et al., 2010).

The identification of these microorganisms can contribute to more efficient control of these pathogens and help define control policies, such as the use of antibiotics and educating healthcare workers (GOMES et al., 2014). Thus, the identification of the hospital's microbiological profile, and more specifically the tracking of bacterial pathogens, can be of great relevance to understand, reduce and prevent HAIs (MARGARIDO et al., 2014; CHRISTOFF et al., 2020).

Systematic reviews are especially important for healthcare, as they allow the synthesis and identification of evidence to support prevention, diagnosis, treatment, and rehabilitation strategies (DE-LA-TORRE-UGARTE-GUANILO et al., 2011). Thus, this study aims, through an integrated, quantitative, and qualitative review, to collect and evaluate data that have been published in the last decade on the presence of pathogens on inanimate surfaces in different sectors of hospitals in Brazil. The specific objectives were to address the following questions: (i) which surfaces presented the largest contamination of pathogens? (ii) which hospital sector had the most contaminated surfaces? (iii) which isolated species was more frequent on these surfaces? (iv) which antibiotics were the isolated bacteria resistant to? Finally, we discuss the importance of the correct cleaning of the environment to reduce the occurrence of hospital infections.

2 Methods

The search for the articles was carried out in four databases: PubMed, the Brazilian Virtual Healthcare Library (BVS), Google Scholar and ScienceDirect, on 20 October 2020, and selected only articles published between 2010 and 2020 (including those published until the date of search), written in Portuguese and/or English, with studies carried out in Brazilian hospitals that fit the inclusion criteria. Besides, after selecting the articles for the abstract, due to the need to acquire more studies for the review, a search was made for articles related to the topic on Google with the following Portuguese sentence: "*Superfícies inanimadas como possíveis fontes de contaminações microbiológicas*" (translated as "Inanimate surfaces as possible sources of microbiological contamination"). Articles found on Google were also selected and added to the collection.

The search was performed by using the following keywords: *(Microbial) AND (surfaces) AND (infection) AND (nosocomial) AND (Brazil).* Also, when using Google Scholar, the following keywords were excluded from search results: *review, dental, food, veterinary, reusable, soil, burn, insects, nasal, Bloodstream, surfactant, Fungal, urinary, coronavirus, extracts, laser, India, China, fibrosis and hepatitis*.

The selected articles investigated microorganisms present on inanimate surfaces of Brazilian hospitals associated with the involvement of HAI in these environments. The inclusion criteria in the selection of articles were: studies published between 2010 and 20 October 2020; studies carried out in Brazil; studies written in Portuguese and/or English; studies that identify the microorganisms on inanimate surfaces; and studies addressing the potential for cross-contamination of these surfaces. The exclusion criteria were: articles with incomplete and/or inconsistent data, such as the absence of isolated microorganisms, without the description of the analysed surfaces, without the description of the samples; closed access articles; and literature or systematic reviews.

The steps for selecting articles according to the investigated theme were: (i) by title, (ii) by abstract and, (iii) by analysis of the complete article (Figure 1). Six articles related to the topic were selected outside the consulted databases and added manually to the collection.

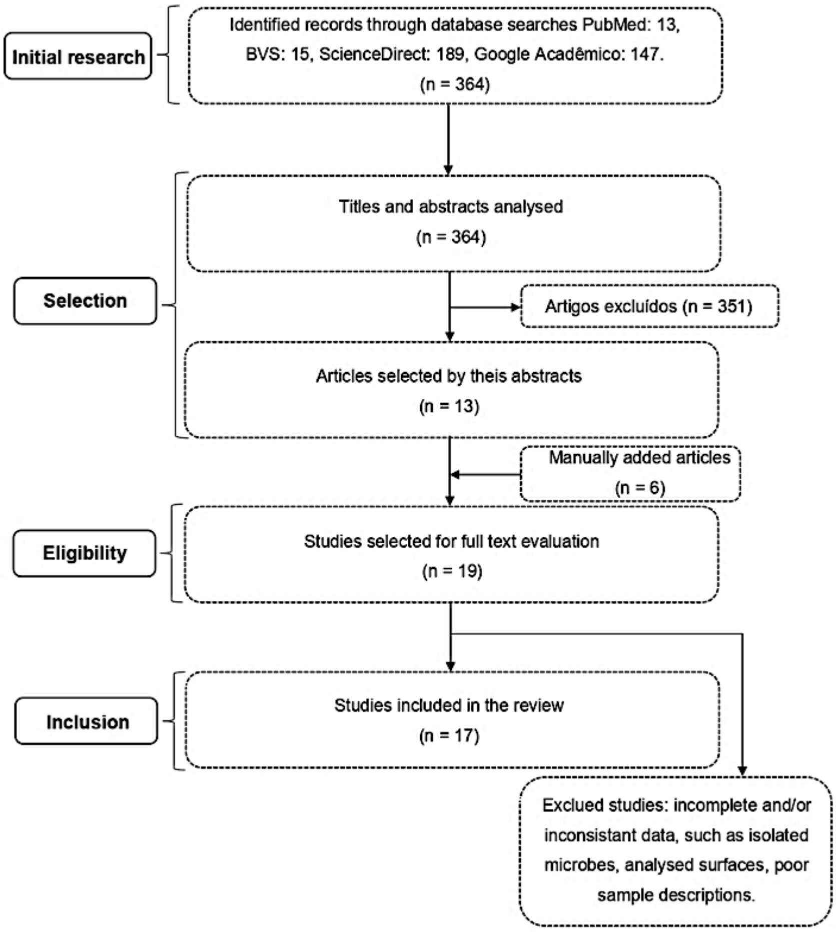

Figure 1. Flowchart with the stages of research and selection of articles for review.

The selection of articles was carried out with mutual agreement by two researchers. All data investigated in each article were tabulated for a descriptive analysis of the results. The tabulated variables, derived from each article, were: the city where the research was carried out, number of hospitals and surfaces, types of surfaces, hospital sector, whether microbes were isolated by classic methods and/or molecular methods were used for identification, the identified gene, antibiotics with known resistance and the isolated species in which it occurs. After the tabulation, the information were described and plotted in graphs and tables, so that the posed questions could be answered. For this, Google Sheets software was used.

3 Results

Seventeen articles were selected for this systematic review (Figure 1). The samples were collected from different Brazilian cities and except for Costa et al. (2019) and Campos et al. (2012), all studies analysed a hospital in these cities, totaling 19 hospitals studied in 11 different states, from all regions of Brazil (Table 1).

Table 1. Description of the 17 studies compiled for this review, including the cities where the hospitals are located, the number of hospitals, and the surfaces analysed by each author.

Reference	City-State	Number of hospitals	Analysed surfaces
Bardaquim, 2011	São Carlos-SP	1	Medication tables, Operating tables, Medicine tables, and Marble countertops
Campos et al., 2012	Vitória da Conquista-BA	2	Floors, Hospital cots, Hospital cradle control panels, Cardiac monitors, Hospital ventilator control panels, Infusion pump control panels, Blood gas analyser control panels, Hospital incubators, Telephones, Scales, Doors, Tables, Hospital beds, Cabinets, Emergency trolleys, Medicine trolleys, Computers, Air conditioners, Taps, Handles, Hospital benches, and Recipe records
Moraes et al., 2013	Goiânia-GO	1	Infusion pumps, Stethoscopes, Incubators, Multiparameter monitors, Telephones, Wash bottles, Countertops, Cribs, Handles, and Faucets
Renner and Carvalho, 2013	Santa Cruz do Sul-RS	1	Stethoscopes, Respirators, Tables, Beds, IV drip / Food Dispensers, Keyboards and Medical Records
Damaceno et al., 2014	Belo Horizonte-MG	1	Cardiac function monitor command buttons, tracheal tubes connected to the mechanical ventilator, Bed grids, Internal faucet edges, Bedside table tops, Stethoscope diaphragms and Upper sink edges
Guimarães, 2015	Palmas-TO	1	Cardiac function monitors, infusion pumps, medication tables and right-side bars
Cardoso and Reis, 2016	Goiânia-GO	1	Trays, Beds and IV drip equipment
Veloso, 2016	Goiânia-GO	1	Trays, Solution holder, Bed grids of each bed, Door handles, Sink basins, Faucets and Drains
Gil et al., 2018	Rio de Janeiro-RJ	1	Infusion pumps and bed gratings
Pádua et al., 2018	Santa Fé do Sul-SP	1	Clinical evolution table, and Drug preparation bench
Rocha et al., 2018	Recife-PE	1	Right and left side rails, Bed height adjustment buttons, Infusion pump buttons, and Overlapping table
Ribeiro et al., 2019	Ribeirão Preto-SP	1	Mattresses, Bed rails, Monitors, Infusion pumps, Ventilators, Cuffs, Computer keyboards and mouses, Door handles, Hospital cards, Medical records, Medicine posts, and Nursing cell phones
Costa et al., 2019	Goiânia-GO e Redenção-PA	2	Patient bed, Patient environment, and Fixed furniture
Freitas et al., 2019	Santo Ângelo-RS	1	Medicine trays
Souza et al., 2019	Foz do Iguaçu-PR	1	Bedside tables, Bed rails, Beds and Infusion pumps
Santos et al., 2020	Pernambuco-CE	1	Armbands, Operating tables, Multi-parameter monitors, Oximeters, Spotlights, and Anesthetist carts
Christoff et al., 2020	São Paulo-SP	1	Beds, Medical and hospital equipment, Furniture, Critical structure points, and Bed accessories

As for surfaces, 42 different surfaces were investigated, of which bed rails (9/17, 52.9%), tables (9/17, 52.9%), and infusion pumps (8/17, 47%) were the most frequently studied surfaces. A total of 3,337 surfaces were analysed in different hospitals, of which the ones next to the patient, such as bed rails, beds, and infusion pumps, showed greater contamination and variability of microorganisms; and tables, benches, doorknobs, and computers showed greater contamination among surfaces with greater contact with hospital staff.

Regards to the hospital sector, all studies investigated Intensive Care Units (ICU). In 52.94% (9/17) of the studies, only the ICU was evaluated; in 11.76% (2/17) investigated the ICU and the Neonatal Intensive Care Unit (NICU); in 5.88% (1/17) the NICU and the pediatric ICU; in 11.76% (2/17) the Surgical Centre (CC); 5.88% (1/17) to NICU, pediatric and adult ICU. Only two authors investigated inanimate surfaces in all sectors of the hospital: Pádua et al. (2018) investigated Intensive Care, Surgical Clinic, Medical Clinic, Maternity and Emergency Care Unit and De Freitas et al. (2020) renamed the sectors into units, being Unit I, which serves adult surgical patients, in the pre and postoperative periods; Unit II for the clinical treatment of adult patients using SUS; Unit III which is mixed for clinical and surgical treatment; Unit IV, which serves the Unified Health

System (SUS, from Portuguese *Sistema Único de Saúde*) users and health insurance patients, adults, undergoing clinical and surgical treatment; Unit V where care for children using SUS and Unit VI predominates, where patients in the prepartum, childbirth and the postpartum period are assisted.

Regarding the bacteria identification methods used, most studies used only classical methods such as morphological and/or biochemical identification techniques (58.82%, 10/17); followed by studies that investigated classical and molecular methods (29.41%, 5/17); and, in a better number, studies that used only molecular methods (11.76%, 2/17), using the polymerase chain reaction (PCR). Sixteen genera of bacteria were identified (Figure 2). Of these, the most frequently identified genera were: *Staphylococcus* (94.11%), *Acinetobacter* (70.58%), *Pseudomonas* (52.94%), and *Klebsiella* (35.29%). The four most identified species belong to these same genera: *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Klebsiella pneumoniae*, appearing in 64.70%, 41.17%, 35.29%, and 29.41%, respectively. The genera found in only one study (5.88%) were: *Shigella*, *Providencia*, *Citrobacter*, *Stenotrophomonas*, *Propionibacterium*, *Streptococcus*, and *Bacteroides* (Figure 2).

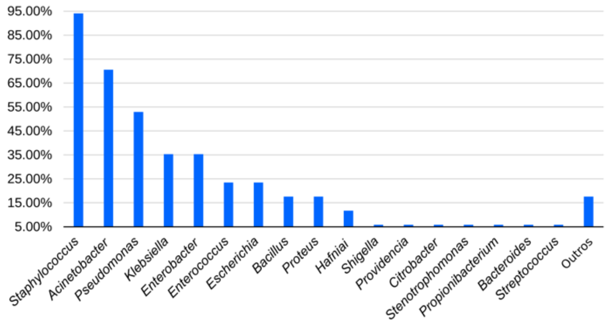

Figure 2. Percentage of bacterial genera identified in the studies.

The susceptibility profile of the isolated microorganisms was tested by 12 authors, all of whom found species resistant to some type of antibiotic. The genera that showed resistance to antibiotics were: *Acinetobacter*, *Staphylococcus*, *Enterococcus*, *Klebsiella*, *Hafniai*, *Shigella*, and *Enterobacter*. Also, four authors characterized the genotype of the isolates for antibiotic resistance (Table 2).

Table 2. Bacteria species that presented antibiotic resistance, the associated antibiotics, and resistance genes identified by each author.

Reference	Resistant species	Antibiotics	Identified genes
Bardaquim, 2011	*Staphylococcus* spp.	CLI (5,71%) TET (22,85%) CFL (11,42%)	NR
Campos et al., 2012	*Staphylococcus aureus*	MET and OXA (36%)	88,6% mecA SCCmec type III (100%)
Renner and Carvalho, 2013	*Staphylococcus aureus*	PEN (80%) OXA (60%) CFO (60%) CLIN (73,33)	NR
	Staphylococcus epidermidis	PEN (92,85%) OXA (7,14%) CFO (7,14%) CLIN (71,42%)	NR
	Enterococcus spp.	TET (100%) CIP (100%)	NR
	Klebsiella pneumoniae	CAZ (100%) CRO (100%) IMP (100%) GEN (100%)	NR
Damaceno et al., 2014	*Acinetobacter baumannii*	IPM, CIP and CRO	NR
	Staphylococcus aureus	CIP	NR
	Enterococcus faecalis	VAN and CIP	NR

Cardoso and Reis, 2016	Enterobacteria	IPM (4%) AMI (48%) GEN (48%) CIP (41%) AMC (52%) SXT (55%) CLO (65%) CAZ (75%)	NR
	Non-fermenting Gram-negative bacteria	IPM (7,85%) AMI (65,71%) GEN (47,14%) CIP (62,85%) AMC (49,28%) SXT (65,71%) CLO (83,57%) CAZ (85%)	NR
Veloso, 2016	*Staphylococcus aureus*	PEN (85,3 %) ERI (69,1 %) CLI (66,2 %) SXT (54,4 %) PEN, ERI, CLI, SXT, QD, TET, CIP, RIF, CFO (5,9 %)	SCC mec type IV(42,9%) SCC mec type I (35,7%) SCC mec type II (14,3%) SCC mec type III (7,1%) lukS F (4,4%) tst and hlb (4,4%) seh (2,9%) sec, eta and etb (1,4%)
Rocha et al., 2018	*Acinetobacter baumannii*	Carbapenem Aminoglycosides	blaOXA-23 (26,6%) blaOXA-72 (14,9%) blaOXA-253 (7,1%) blaOXA-51 (100%) aadA1 (ant (3")-Ia; aadB; aph (3')-VIa (aphA-6); strA (aph (6) -Ia); strB (aph (6) -Id) and aacA4; floR; sul2; dfrA1; mphE; msrE.
Costa et al., 2019	*Klebsiella* spp.	Producer of ESBL	NR
	Enterococcus spp.	VAN	NR
Freitas et al., 2019	*Staphylococcus aureus*	MET	NR
	Staphylococcus coagulase negative	MET	NR
Santos et al., 2020	*Acinetobacter baumannii*	SXT (100%) CPM (100%) MPM (100%) CIP (100%) AMI (100%) CRO (100%) APS (33,33%)	NR
	Enterobacter sp.	AMP (100%)	NR

Legend: OXA: oxacillin; ERI: erythromycin, CLI: clindamycin, RIF: rifampicin; GEN: gentamicin; PEN: penicillin; CIP: ciprofloxacin; SXT: sulfamethoxazole + trimethoprim; ETP: ertapenem; MEM: meropenem; CAZ: ceftazidime; CLO: chloramphenicol; CRO: ceftriaxone; TET: tetracycline; AMC: amoxicillin/ Clavulanic acid; IMP: imipenem; AMI: amikacin; CPM: cefepime; QD: quinupristin/dalfopristin; CFO: cefoxitin; VAN: vancomycin; AMP: ampicillin; APS: ampicillin/sulbactam; CFL: cephalothin; MET: methicillin; MPM: meropenem; NR: not performed.

The most used classes of antibiotics were: β-lactams, aminoglycosides, and quinolones. Ciprofloxacin was the most tested antibiotic, being present in 58.33% (7/12) of the studies, in addition to having greater microbial resistance, followed by imipenem and sulfamethoxazole + trimethoprim (33.33%, 4/12).

Christoff et al. (2020) also researched resistance genes in samples from ICU and NICU. They found that the most prevalent genes from ICU samples were *mecA*, group *bla* $_{\text{CTX-M-1}}$, *bla* $_{\text{SHV-like}}$, *bla* $_{\text{KPC-like}}$ and *vanA* were detected, while *bla* $_{\text{SPM-like}}$ and *bla* $_{\text{SPM-like}}$ genes presented less frequently. In the NICU the *mecA* gene was more frequent. The *bla* $_{\text{CTX-M-1}}$ and *bla* SHV-like groups were the most frequently identified between January 2019 and July 2019.

4 Discussion

4.1 The hospital environment

This work presents a systematic review that focused on research articles that identified microorganisms present in inanimate surfaces of hospitals in Brazil. The most researched hospital sectors were ICUs. Many studies investigating the microbiological profile of these areas show how worrying such contamination can be. ICUs are the epicenter of HAIs and a link in the epidemiological chain of transmission (GOMES et al., 2014), which leads to increased deaths, antimicrobial resistance, prolonged hospital stay, and consequently, financial costs (RIBEIRO et al., 2019).

Considering the ICU, patients are bedridden for a long time, immunosuppressed, carry serious illnesses that require invasive monitoring, and the use of broad-spectrum antibiotics, which all makes them more susceptible to HAIs (TEJEDOR et al., 2012). Infection rates in the ICU vary between 18 and 54%, about five to ten times more than in other units (OLIVEIRA and DAMASCENO, 2010). A study in the state of Piauí revealed a rate of nosocomial infection in ICUs of 43.5% (SANTOS et al., 2016). In another study conducted in the city Salvador, four hospitals revealed an infection rate of 9.4 to 46.9% in ICUs (MASCARENHAS and FERNANDES, 2018). However, we highlight the need for more comprehensive microbiological studies in hospitals, from reception desks to ICUs, to identify the origin of microorganisms on surfaces, which would allow more efficient mitigation efforts on the onset of these contaminations.

The greater contamination and variability of microorganisms in bed rails, beds, infusion pumps, and surfaces close to the patient shows the high risk of cross-contamination. The same risk is observed for tables, benches, handles, and computers that are surfaces of greater contact with health professionals. Surfaces close to patients and those frequently touched can become contaminated with epidemiologically important microorganisms, such as *S. aureus* and A. *baumanii* (MOURA et al., 2011).

In this context, we highlight two important precautions: one regarding hand cleaning of healthcare professionals, and another regarding the cleaning of the surface. When caring for patients that are in close-contact isolation, improper hand hygiene can cause contamination in touched surfaces and become a source of infection for the susceptible patient and surfaces around other patients (SALES et al., 2014). After touching a patient, healthcare professionals often do not care about the hygiene of their hands and the objects they touched, or even do it incorrectly. Resuming activities without proper hygiene may further increase the possibility of spreading microorganisms (OLIVEIRA et al., 2010). This reinforces the need to provide adequate information to healthcare professionals about the risks of spreading microbes and causing HAIs. This includes information about the correct procedure of hand hygiene. For this purpose, we prepared a guidebook, respecting the criteria of the National Health Surveillance Agency (Figures 3 and 4), to provide educational material for hospitals.

Figure 3. Educational material to be used in hospitals to guide the healthcare professionals as how to have the hands well washed.

Figure 4. Step by Step washing hands to guide the healthcare professionals.

In addition to actions directed to healthcare professionals, surfaces also need to be meticulously cleaned. Proper cleaning and disinfection contribute to the decrease of cross-contamination, and consequently, to the reduction of infection related to contact with surfaces (SANTOS et al., 2020). All the studies reported that continuing education and a microbiologically safe environment can ensure excellence in healthcare. However, in addition to informative policies and correct surface hygiene, we emphasize the need to create inspection policies within hospitals, so that healthcare professionals remain attentive to such habits. A stricter control strategy and educational effort could be devised for people visiting the patient, which can either bring more pathogens to the hospital environment or be contaminated with pathogens within the hospital environment (CANSIAN, 1997). These could be interesting strategies for minimizing the risks of HAI.

4.2 Bacteria and antibiotic resistance

This study is also committed to finding data on the most frequent species of bacteria and the resistance to antibiotics. The species which was more often isolated was *Staphylococcus aureus*, which was present in 64.70% of the studies. In Brazil, about 40 to 80% of hospital infections are caused by *S. aureus*, mainly in ICUs (ROSSI and ANDREAZZE, 2005). This species is an important pathogen due to its virulence, resistance to antimicrobials, and association with various diseases (GUIMARÃES, 2015). The *Staphylococcus* genus is among those that have undergone significant changes in antimicrobial susceptibility over the years (CAMPOS et al., 2012), with methicillin-resistant *S. aureus* (MRSA) being one of the most frequently multi-resistant pathogens isolated in hospitals worldwide (PERES et al., 2014). Considering the high frequency in which this bacterium is detected, and its resistance to antimicrobials, we suggest a greater control of antibiotics to prevent indiscriminate use, conduct that can lead to increased bacterial resistance over time due to selective pressures (CARDOSO and REIS, 2016). In addition, we highlight the need for major investments in the research and development of new drugs, as well as funding for basic research that identifies, and characterizes the mechanisms of resistance of bacteria to antibiotics.

Pathogens referred to as ESKAPE by the Infectious Disease Society of America are common causes of HAI. These are *Enterococcus* spp., *S. aureus* (gram-positives), *K. pneumoniae*, *A. baumannii*, *P. aeruginosa* and *Enterobacter* spp. (gram-negatives). These species were the six most frequently identified species in this review. They have a high resistance to antimicrobials and are of great concern due to the HAI caused by them (RICE, 2008).

Species belonging to the ESKAPE group were also found in seven hospitals in Egypt, between the years 2009 to 2015 (AHMED et al., 2019), and also in a tertiary hospital in Saudi Arabia, suggesting that these are the most prevalent genera in hospitals.

The last question we sought to answer was which antibiotics the isolated bacteria were resistant to. The most used classes of antibiotics were β-lactams, aminoglycosides, and quinolones. The structural nucleus of β-lactams, the ß-lactam ring, confers bactericidal activity. The mechanism of action of aminoglycosides is binding to the 30S subunit of ribosomes, inhibiting protein synthesis or producing defective proteins. Quinolones, on the other hand, inhibit the activity of DNA gyrase or topoisomerase II, which are enzymes essential to bacterial survival (ANVISA, 2007). Ciprofloxacin was the most tested antibiotic and the one with the highest number of cases of microbial resistance. It belongs to the fluoroquinolone class and has a broad spectrum of activity against gram-negative bacilli and some gram-positive cocci (ANVISA, 2007). The second most used antibiotics were Imipenem and sulfamethoxazole + trimethoprim. Imipenem has a broad spectrum of action for use in systemic infections and is stable to most ß–lactamases, in addition to having slightly higher activity against gram-positive bacteria (ANVISA, 2007). Sulfamethoxazole + trimethoprim, on the other hand, affects a wide spectrum of gram-positive and gram-negative pathogenic microorganisms, although the sensitivity may depend on the geographic area in which it is used (FURP, 2019).

MRSA was identified in 50% of the studies, which suggests an increase in resistance to antimicrobials in this species. *Staphylococcus aureus* gained prominence due to the multidrug resistance profile of nine types of antibiotics found at a hospital in the city of Goiânia (VELOSO, 2016). Antibiotics are among the drugs most used inappropriately and abusively, resulting in the development of resistant microorganisms. This makes it necessary to use more effective antimicrobials (PAULA et al., 2016). In another species, *A. baumannii*, the profile of susceptibility to antibiotics was evidenced in 25% of the studies. In addition, in 100% of *A. baumannii* strains identified in the Sertão do Vale do São Francisco hospital (SANTOS et al., 2020), it was detected multidrug resistance to the antibiotics SXT, COM, MPM, CIP, AMI, CRO; and, in 33.33% of the strains, resistance to PHC. Some probable explanations are that this species exhibits the ability to produce biofilms, to survive desiccation on abiotic surfaces, and to acquire exogenous genetic material through lateral gene transfer, which can favor their survival under the pressure of antibiotics and host selection (BORGES and NUNES, 2019).

Resistance to various antibiotics is given by antibiotic resistance genes (ARGs). In the genus *Staphylococcus*, the *mecA* gene is largely responsible for its resistance (SUED, 2018). This gene performs the synthesis of PBP2a (Penicillin-binding Protein 2a), being part of a genomic island called SCCmec (Staphylococcal Cassette Chromosome mec), which is currently classified into 11 types of SCCmec (SUED, 2019). The *mecA* gene was present in 88.6% of the species in the Vitória da Conquista hospital (CAMPOS et al., 2012), in which all species were SCC mec type III. However, in the city of Goiânia, MRSA SCC mec type IV was identified in 42.9% of total species, SCC mec type I in 35.7% of total species, SCC mec type II in 14.3% of total species, and SCC mec type III in 7.1% of total species. Similarly, in the United States, a study demonstrated a very low prevalence of SCC mec type III, while a high prevalence of type IV and type ll was shown (DAVIS et al., 2006).

In *K. pneumoniae* and *A. baumannii*, the identified ARGs ($bla_{OXA\text{-}23}$, $bla_{OXA\text{-}72}$, $bla_{OXA\text{-}253}$, $bla_{OXA\text{-}51}$, $bla_{CTX\text{-}M\text{-}1}$, $bla_{SHV\text{-}like}$, and $bla_{KPC\text{-}like}$) encode the enzyme carbapenemase, which confers resistance to carbapenems (CHRISTOF et al., 2020; ROCHA et al., 2018). It was also possible to observe genes for resistance to aminoglycosides [*aadA1(ant(3")-Ia*]; *aadB*; *aph(3')-VIa*(aphA-6); *strA (aph(6)-Ia)*; *strB (aph(6)-Id)* and *aacA4*); phenicol (*floR*); sulphonamide (*sul2*); trimethoprim (*dfrA1*); macrolides (*mphE*); and streptogramin B lincosamidase (*msrE*). The progression of *K. pneumoniae* resistance to antibiotics has caused great concern since the 1980s with the appearance of *K. pneumoniae* producing ß-lactamases of extended-spectrum (ESBL - class of enzymes that confer resistance to extended-spectrum cephalosporins of third-generation) (PERNA et al., 2015), with *K. pneumoniae* being observed to produce ESBL in this review.

The difference in the sampling of the hospitals being studied made it impossible to generalize the results found for the whole country. Another limiting factor was the little use of molecular techniques to identify bacteria, limiting the observation of the diversity of species, as well as the quantification of the genes involved in these mechanisms. Classic studies, using morphological and biochemical tools, still have limitations in the identification of microorganisms, such as the difficulty in distinguishing microbes with little genetic variability, and the risk of misinterpretation when a limited number of tests is used (FARBER et al., 2001). On the other hand, molecular techniques have a greater ability to distinguish samples, are generally faster, have a good detection limit, greater selectivity, greater specificity, have potential for automation, and the possibility of working with bacteria that are not cultivable in culture media normally used (GANDRA et al., 2008).

Still, this study highlights the necessity to gather more attention to the potential for contamination of inanimate surfaces in hospital environments. HAIs can lead to sepsis and are considered to be the leading cause of death in ICUs worldwide, especially in underdeveloped and developing countries, such as Brazil (CONDE et al., 2013). In addition, to the best of our knowledge, this review contains the largest number of articles analyzed that are related to this topic, in addition to being one of the first to discuss resistance and characterize the presence of ARGs. Our results show that the contamination of hospital surfaces and equipment by pathogenic microorganisms is a worldwide health problem and, like the cited authors mentioned, we emphasize the importance of hygiene, especially of the hands, to lower the rates of contamination in hospitals and consequently of HAIs. We highlight the need for further studies in hospitals in Brazil that quantify and qualify the microorganisms present on these surfaces, especially using molecular tools. Such studies will assist in the supervision of norms and routines for the prevention and control of infections, in addition to training employees and professionals of healthcare institutions regarding the correct hygiene and asepsis of hands and surfaces (MARGARIDO et al., 2014).

In summary, it was possible to verify the most frequent microorganisms on the surfaces of hospital ICUs in Brazil in the last decade, where they occurred most, and also list antibiotics and genes most associated with antibiotics resistance. Given the presence of these pathogens, we observed that surfaces are not valued as potential sources of infectious agents for patients. Therefore, it is of paramount importance to implement preventive actions that include these sites. Also, there should be informational policies about the correct cleaning of surfaces and inspection policies for professionals. Strict hygiene measures for surfaces and for patients' visitors should also be adopted. Finally, we emphasize the need for more microbiological studies in hospitals throughout Brazil that wholly analyse the environment, from reception desks to ICUs, and that also use molecular tools to identify microbes and resistance genes. This could allow to more efficiently mitigate sources of contamination and antibiotic resistance mechanisms.

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