SEPSIS, BIOFILM, AND CATHETER-RELATED INFECTIONS: CONTEMPORARY CHALLENGES IN THE INTENSIVE CARE UNIT

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Abstract

Sepsis remains one of the leading causes of morbidity and mortality in Intensive Care Units (ICUs), often associated with infections related to invasive devices, particularly central venous catheters. In this context, microbial biofilm formation represents an important clinical challenge due to its ability to protect microorganisms against antimicrobial agents and host defense mechanisms. This study aimed to analyze

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contemporary challenges related to sepsis, biofilm formation, and catheter-associated infections in critically ill patients admitted to ICUs. This is a narrative literature review conducted using scientific articles published in national and international databases, including PubMed, SciELO, and the Virtual Health Library (VHL), selecting studies relevant to the topic. The results demonstrated that biofilms are a determining factor in the persistence of infections, increased microbial resistance, and development of severe septic conditions. Furthermore, factors such as prolonged catheter use, failures in healthcare protocols, and inappropriate antimicrobial use contribute to worsening the problem. It was concluded that the rigorous implementation of preventive measures, combined with continuous professional education and infection control strategies, is essential to reduce complications and improve critically ill patient safety.

Keywords: Biofilm, Catheter-associated infections, Hospital infection, Intensive Care Unit, Sepsis.

INTRODUCTION

Sepsis is one of the main causes of morbidity and mortality in hospital settings, especially in Intensive Care Units (ICUs), where critically ill patients are more vulnerable to the development of severe infections. Characterized by a dysregulated host response to an infectious process, sepsis represents a major public health problem due to its high incidence, rapid clinical progression, and significant impact on mortality rates (Singer et al., 2016). In this scenario, the use of invasive devices, particularly central venous catheters, although essential for hemodynamic monitoring, medication administration, and therapeutic support, is frequently associated with an increased risk of healthcare-associated infections (Mermel, 2000).

Among the mechanisms that favor the development of these infections, the formation of microbial biofilms on catheter surfaces stands out. Biofilms consist of structured communities of microorganisms surrounded by an extracellular matrix produced by the infectious agents themselves, providing greater

adhesion capacity, persistence, and resistance to antimicrobials. This phenomenon represents one of the greatest contemporary challenges in intensive care practice, since it hinders pathogen eradication, favors persistent infections, and may trigger severe septic conditions (Donlan; Costerton, 2002).

In this context, the following problem arises: how does biofilm formation on catheters contribute to the development of sepsis, and what are the main challenges faced by multidisciplinary teams in the prevention and control of these infections in patients admitted to ICUs? The complexity of this relationship highlights the need to deepen scientific discussions on the factors involved, considering the clinical and epidemiological impact of infections associated with invasive devices.

The general objective of this study is to analyze the contemporary challenges related to sepsis, biofilm formation, and catheter-associated infections in Intensive Care Units. Its specific objectives are to understand the mechanisms of biofilm formation on invasive devices; identify factors associated with the development of catheter-related infections; discuss the relationship between biofilms and the worsening of septic conditions; and analyze preventive strategies used in the hospital environment to reduce these complications.

The conduct of this study is justified by the clinical and scientific relevance of the topic, considering that catheter-associated infections represent an important cause of prolonged hospitalization, increased hospital costs, and higher mortality rates. In addition, the growth of microbial resistance and the complexity of therapeutic management make it necessary to expand knowledge that can support safer and more effective care practices.

The discussion of preventive measures and control strategies is also essential to strengthen patient safety and contribute to the quality of care provided in critical care units (Vincent et al., 2009).

In the theoretical field, different studies have discussed the relationship between biofilms and infections associated with medical devices. Hall-Stoodley, Costerton, and Stoodley (2004) emphasize that biofilms constitute an important microbial survival strategy, favoring resistance to host defense mechanisms and antimicrobial treatment. Donlan (2001) emphasizes that the surfaces of invasive devices

represent favorable environments for bacterial adhesion and the development of persistent microbial communities. At the same time, Singer et al. (2016), based on the updated Sepsis-3 definitions, reinforce that sepsis results from a dysregulated organic response to infectious processes and may rapidly progress to severe dysfunctions and a high risk of death. In this sense, understanding the interaction among biofilms, catheters, and sepsis becomes fundamental for the development of more effective prevention and clinical management strategies.

METHODOLOGY

RESEARCH TYPE

The present study is characterized as qualitative, descriptive, and exploratory research, developed through a narrative literature review. This type of investigation enables the expansion of knowledge about a given phenomenon, allowing the critical and interpretive analysis of existing scientific production on the topic investigated. According to Gil (2019), bibliographic research is developed based on already published materials and constitutes an important instrument for theoretical understanding and deepening regarding different scientific problems.

The choice of a narrative review is justified by the possibility of integrating different perspectives and studies on sepsis, biofilms, and catheter-related infections, allowing a broad approach to the contemporary challenges present in Intensive Care Units. According to Lakatos and Marconi (2021), research of this nature favors the critical analysis and organization of knowledge produced in different scientific contexts.

METHODOLOGICAL PROCEDURES

The research was developed based on a bibliographic survey conducted in national and international databases widely used in the health field, including the Virtual Health Library (VHL), PubMed, Scientific Electronic Library Online (SciELO), and Latin American and Caribbean Literature in

Health Sciences (LILACS). The use of these databases allows access to relevant and scientifically recognized studies on the topic investigated.

For the search for articles, descriptors in Portuguese and English were used, combined with the Boolean operators “AND” and “OR,” aiming to increase the sensitivity of the search. The descriptors used included: “sepsis,” “biofilm,” “catheters,” “hospital infection,” “intensive care unit,” “sepsis,” “biofilm,” “catheter-related infections,” and “intensive care unit.”

According to Souza, Silva, and Carvalho (2010), the use of systematized strategies in bibliographic searches contributes to greater methodological rigor and better organization of the studies analyzed. Thus, the prior definition of descriptors and databases consulted contributed to ensuring greater reliability in the process of selecting scientific material.

Inclusion and exclusion criteria

Criteria were established for the selection of studies with the aim of ensuring greater scientific relevance and alignment with the proposed topic. As inclusion criteria, full articles available free of charge were selected, published in Portuguese, English, and Spanish between 2016 and 2026, considering studies related to sepsis, microbial biofilms, catheter-associated infections, and intensive care assistance.

Duplicate studies, simple abstracts, incomplete works, editorials, letters to the editor, dissertations, theses, and articles that did not have a direct relationship with the proposed topic were excluded.

The definition of clear eligibility criteria represents a fundamental step in scientific reviews, reducing biases and strengthening the quality of the results found (Galvão; Pereira, 2014).

INSTRUMENTS AND DATA ANALYSIS TECHNIQUE

After selecting the studies, an exploratory, selective, and analytical reading of the identified materials was performed. Subsequently, the data were organized in an instrument developed by the

authors containing information regarding the study title, author, year of publication, objectives, methodology used, and main results found.

The analysis was conducted through a descriptive and interpretive approach, seeking to identify convergences, divergences, and central aspects discussed in the scientific literature regarding the relationship among biofilms, catheters, and sepsis in critically ill patients.

According to Minayo (2014), qualitative analysis makes it possible to understand the meanings, contexts, and interpretations of the phenomena studied, favoring an in-depth reading of the data produced.

GROUNDED DISCUSSION OF THE METHODOLOGY

The choice of a narrative review made it possible to broadly understand the factors associated with the development of sepsis related to invasive devices and the formation of microbial biofilms in intensive care settings. Studies indicate that patients admitted to ICUs are more susceptible to infections due to the frequent use of invasive devices and clinical severity, making the continuous investigation of preventive strategies essential (Vincent et al., 2009).

In addition, research developed by Donlan and Costerton (2002) demonstrates that biofilms present on medical devices favor infectious persistence and antimicrobial resistance, which reinforces the importance of scientific production aimed at understanding these mechanisms. In this sense, the methodology adopted made it possible to gather evidence capable of supporting critical reflections on the challenges faced by healthcare teams in the prevention and control of these complications in intensive care.

RESULTS AND DISCUSSION

The analysis of the literature showed that sepsis related to invasive devices remains an important cause of morbidity and mortality in patients admitted to Intensive Care Units (ICUs). Among the various factors involved, central venous catheter-related infections and the formation of microbial biofilms stand

out, currently recognized as important mechanisms of infectious persistence and therapeutic resistance. The selected studies demonstrated that biofilm formation on the surfaces of medical devices favors bacterial adhesion, persistent colonization, and the protection of microorganisms against antimicrobial agents and the host's immune mechanisms (Donlan; Costerton, 2002).

The literature analyzed indicates that critically ill patients admitted to ICUs have a greater predisposition to the development of these infections due to the association of multiple factors, including immunosuppression, prolonged use of invasive devices, frequent performance of procedures, and the need for complex therapies. According to Vincent et al. (2009), the high prevalence of infections in critical care units is related to the clinical severity of patients and the intensive use of healthcare technologies.

To better organize the results found in the literature, Table 1 was prepared, containing a synthesis of relevant studies used in the construction of this chapter.

Table 1

Main studies related to sepsis, biofilms, and catheter-associated infections

Author/Year	Objective	Main results
Donlan and Costerton (2002)	To investigate mechanisms of biofilm formation	Demonstrated that biofilms increase antimicrobial resistance and infectious persistence
Hall-Stoodley, Costerton, and Stoodley (2004)	To analyze biofilms in infectious diseases	Showed that biofilms function as a microbial survival strategy
Mermel (2000)	To investigate catheter-associated infections	Identified factors related to increased risk of infection

Singer et al. (2016)	To update clinical definitions of sepsis	Defined sepsis as a dysregulated host response to infection
Vincent et al. (2009)	To assess the prevalence of infections in ICUs	Demonstrated the high incidence and clinical impact of infections in critically ill patients

Source: Prepared by the authors (2026).

The results demonstrate that biofilm formation represents one of the main factors responsible for the difficulty in treating catheter-related infections. Unlike bacteria in a planktonic state, microorganisms organized in biofilms present phenotypic changes that significantly reduce the effectiveness of antimicrobials. In addition, the extracellular matrix produced by the microorganisms themselves acts as a physical and chemical barrier, hindering the penetration of medications (Hall-Stoodley; Costerton; Stoodley, 2004).

Several pathogens frequently found in catheter-related infections have a high capacity for biofilm formation. Among the main microorganisms identified are *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Candida albicans*, and species of *Enterococcus*. These species have specific mechanisms of cellular adhesion and extracellular matrix production, favoring persistent colonization on artificial surfaces.

Table 2 presents the main microorganisms associated with biofilms on catheters and their clinical characteristics described in the literature.

Table 2

Main microorganisms associated with biofilm formation on catheters

Microorganism	Main characteristic	Clinical impact
Staphylococcus aureus	High adhesion to surfaces	Greater risk of severe sepsis
Staphylococcus epidermidis	Strong biofilm production	Persistent infections
Pseudomonas aeruginosa	High antimicrobial resistance	Greater therapeutic difficulty
Candida albicans	Formation of fungal biofilms	Invasive infections
Enterococcus spp.	High adaptive capacity	Clinical persistence

Source: Adapted from Donlan (2001); Hall-Stoodley et al. (2004).

The findings reinforce that catheter colonization occurs through different routes, including migration of microorganisms present on the patient's skin, contamination of the hospital environment, and inadequate handling of the device during care procedures. Mermel (2000) highlights that prolonged catheter dwell time constitutes an important risk factor for the development of healthcare-associated infections.

In addition, microbial resistance was found to represent a growing concern in intensive care environments. The inappropriate and indiscriminate use of antimicrobials contributes significantly to the selection of multidrug-resistant microorganisms, making treatments more difficult and increasing hospital costs. Recent studies demonstrate that biofilms can increase bacterial resistance by up to hundreds of times compared with free cells, making therapeutic protocols more complex (Donlan; Costerton, 2002).

Another aspect identified refers to the clinical consequences associated with sepsis resulting from catheter-related infections. Among the main outcomes found in the literature are increased length of hospital stay, prolonged need for mechanical ventilation, higher rates of organ failure, and increased mortality. Singer et al. (2016) emphasize that sepsis results from a dysregulated inflammatory response of the organism to infection and may rapidly progress to septic shock and multiple organ dysfunction. Based on the studies analyzed, it was observed that prevention remains the most effective strategy for reducing these complications. Institutional protocols known as prevention bundles include rigorous hand hygiene, aseptic technique during device insertion, daily assessment of the need for catheter maintenance, and early removal whenever possible. Such measures have a significant impact on reducing infection rates (Mermel, 2000).

In addition to conventional strategies, recent studies also discuss technological advances involving antimicrobial surfaces, catheters impregnated with antiseptic agents, and research related to the development of substances capable of interfering with biofilm formation. These resources show promising potential, although challenges remain regarding cost, safety, and large-scale clinical applicability.

Therefore, the results found show that the interaction among biofilms, catheters, and sepsis represents a complex and multifactorial phenomenon. Understanding these mechanisms is essential for the development of more effective preventive strategies, the reduction of infectious complications, and the strengthening of patient safety in critical care environments.

CONCLUSION

The present study aimed to analyze contemporary challenges related to sepsis, biofilm formation, and catheter-associated infections in patients admitted to Intensive Care Units, seeking to understand the mechanisms involved in biofilm formation, identify factors associated with the development of infections related to invasive devices, discuss their relationship with the worsening of septic conditions, and analyze

preventive strategies used in the hospital environment. Based on the proposed objectives, it was possible to understand the complexity of this problem and its relevance to healthcare assistance.

The results showed that catheter-related infections remain among the main challenges faced in critical care units, especially due to the ability of microorganisms to form biofilms on the surfaces of invasive devices. The studies analyzed demonstrated that biofilms constitute important mechanisms of microbial survival, favoring antimicrobial resistance, infectious persistence, and therapeutic difficulty. This condition directly contributes to an increased risk of sepsis, clinical worsening of patients, prolonged hospital stay, and higher morbidity and mortality rates (Donlan; Costerton, 2002).

It was also observed that several factors contribute to the development of these complications, including prolonged catheter dwell time, failures in care protocols, inadequate handling of invasive devices, and indiscriminate use of antimicrobials. Such factors reinforce the need to adopt rigorous preventive measures, since patients admitted to ICUs present greater clinical and immunological vulnerability (Mermel, 2000).

The literature analyzed also demonstrated that preventive strategies, such as appropriate hand hygiene, use of aseptic techniques during catheter insertion and maintenance, implementation of institutional protocols, and ongoing training of multidisciplinary teams, have a significant impact on reducing healthcare-associated infections. In addition, scientific advances related to the development of antimicrobial technologies and new materials for invasive devices demonstrate promising potential in addressing this problem.

As a scientific contribution, this research expands discussions on the relationship among sepsis, biofilms, and catheter-related infections, gathering relevant evidence capable of supporting actions aimed at patient safety and the qualification of intensive care. The systematization of this information may assist professionals and researchers in understanding the factors involved and strengthening safer and more effective clinical practices.

Finally, it is suggested that future research should expand investigations into new technologies capable of preventing biofilm formation on medical devices, as well as clinical studies directed toward the development of innovative therapies for the prevention and treatment of these infections. Further research is also recommended on microbiological behavior in intensive care environments and on the impact of care protocols in reducing cases of catheter-associated sepsis. In this way, it is expected to contribute to scientific advances and the continuous improvement of care provided to critically ill patients.

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