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Review Article

Strategies for infection control in neonatal intensive care units: an integrative review

Estratégias para controle de infecções em unidades de terapia neonatal: uma revisão integrativa
Estrategias para el control de infecciones en unidades de hospitalización neonatal: una revisión integradora

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ABSTRACT

Background and Objective: Healthcare-associated infections (HAIs) in neonatal intensive care units (NICUs) represent a significant challenge to the quality and safety of neonatal care, especially for premature and low birth weight newborns, whose immunological vulnerability and exposure to invasive procedures increase the risk of morbidity and mortality. The objective of this study was to analyze the main strategies used to control HAIs in NICUs, highlighting their effectiveness and impact on improving neonatal care. **Methods:** This is an integrative review conducted in the LILACS, SciELO, and PubMed databases, encompassing original articles published between 2019 and March 2025. The articles were selected and organized considering title, authors, country, year of publication, the proposed interventions, and their main results. **Conclusion:** The findings revealed that adherence to hand hygiene, associated with training and multimodal strategies, represents one of the most effective and lowest-cost measures to prevent HAIs. Implementing antimicrobial stewardship programs and protocols to control methicillin-resistant *Staphylococcus aureus* (MRSA) and invasive device-associated infections has demonstrated a significant impact on reducing infection rates and length of stay. Initiatives such as the SAFH protocol and the Comprehensive Unit-based Safety Program (CUSP) have stood out for improving the safety culture and optimizing neonatal care. The integration of control strategies, continuing education, and interdisciplinary commitment is a key factor to improving care quality and reducing HAIs in NICUs, promoting greater safety and better outcomes for critically ill neonates.

Keywords: Infection Control. Clinical Protocols. Neonatal Intensive Care Units.

RESUMO

Justificativa e Objetivo: As Infecções Relacionadas à Assistência à Saúde (IRAS) em Unidades de Terapia Intensiva Neonatal (UTIN) representam um desafio à segurança do cuidado neonatal, especialmente para recém-nascidos prematuros e de baixo peso, cuja vulnerabilidade imunológica e exposição a procedimentos invasivos elevam o risco de morbimortalidade. O objetivo deste estudo foi analisar as principais estratégias utilizadas para o controle das IRAS em UTIN, destacando sua eficácia e impacto na melhoria dos cuidados neonatais. **Método:** Revisão integrativa conduzida nas bases de dados LILACS, SciELO e PubMed, abrangendo artigos originais publicados entre 2019 e março de 2025. Os artigos foram selecionados e organizados considerando-se título, autores, país, ano de publicação, intervenções propostas e principais resultados. **Conclusão:** Os achados revelaram que a adesão à higiene das mãos, associada a treinamentos e estratégias multimodais, representa uma das medidas mais eficazes e de menor custo para prevenir IRAS. A implementação de programas de gestão de antimicrobianos, protocolos para controle de *Staphylococcus aureus* resistente à metilina (MRSA) e infecções associadas a dispositivos invasivos demonstrou impacto significativo na redução das taxas de infecção e do tempo de internação. Iniciativas como o protocolo SAFH e o *Comprehensive Unit-based Safety Program* (CUSP) destacaram-se na melhoria da cultura de segurança do paciente e na otimização do cuidado neonatal. A integração de estratégias de controle, educação contínua e compromisso interdisciplinar evidencia-se como fator-chave para melhorar a qualidade do atendimento, reduzir IRAS nas UTIN e promover maior segurança e melhores desfechos para neonatos críticos.

Descritores: Controle de Infecções. Protocolos Clínicos. Unidades de Terapia Intensiva Neonatal.

RESUMEN

Justificación y Objetivo: Las infecciones asociadas a la atención de la salud (IAAS) en unidades de cuidados intensivos neonatales (UCIN) representan un reto para la calidad y seguridad de la atención neonatal, especialmente en neonatos prematuros y de bajo peso, cuya vulnerabilidad inmunológica y exposición a procedimientos invasivos aumentan el riesgo de morbilidad y mortalidad. El objetivo de este estudio fue analizar las principales estrategias utilizadas para controlar las IAAS en UCIN, destacando su efectividad e impacto en la mejora de la atención neonatal. **Métodos:** Revisión integradora realizada en LILACS, SciELO y PubMed, que incluyó artículos originales publicados entre 2019 y marzo de 2025. Los estudios fueron seleccionados y organizados considerando título, autores, país, año de publicación, intervenciones propuestas y resultados. **Conclusión:** Los hallazgos revelaron que la adherencia a la higiene de manos, junto con capacitación y estrategias multimodales, representa una de las medidas más eficaces y de menor costo para prevenir IAAS. La implementación de programas de administración de antimicrobianos y de protocolos para *Staphylococcus aureus* resistente a la metilina (SARM) e infecciones asociadas a dispositivos invasivos mostró un impacto en la reducción de las tasas de infección y del tiempo de hospitalización. Iniciativas como el SAFH y el *Comprehensive Unit-based Safety Program* (CUSP) mejoraron la cultura de seguridad del paciente y la atención neonatal. La integración de estrategias de control, educación continua y compromiso interdisciplinario es clave para mejorar la calidad de la atención, reducir IAAS en UCIN y promover mayor seguridad y mejores resultados en neonatos críticos.

Palabras Clave: Control de Infecciones. Protocolos Clínicos. Unidades de Cuidado Intensivo Neonatal.

INTRODUCTION

In Brazil, concern about healthcare-associated infections (HAIs) intensified from the 1990s onward, when documents on the subject began to be published, and studies on their occurrence were initiated.^{1,2} HAIs are among the most frequent adverse events associated with healthcare and represent a serious public health problem, as they increase morbidity, mortality, and related costs, in addition to negatively affecting patient safety and the quality of services.³ A Brazilian study estimated that the daily cost per patient with HAIs was 55% higher than for patients without these conditions.⁴

Nurses working in neonatal intensive care units (NICUs) must understand that they are dealing with highly vulnerable lives, which requires sharp clinical perception, proper training, constant attention, and, above all, respect for patients who are adapting to the extrauterine environment.⁵ Newborns (NBs), especially preterm infants, are highly vulnerable and require intensive care and assistance from a multidisciplinary team. This vulnerability makes them more prone to hospital-associated infections, which are often associated with invasive procedures and limitations in the newborns' immune development.⁵

According to the Ministry of Health,⁶ most infections in NICUs are considered hospital-associated infections, except for those transmitted transplacentally. Under this definition, infections of maternal origin are clinical manifestations that occur within the first 48 hours of life; after this period, infections are classified as acquired in the neonatal unit.⁷

In NICUs, there are several risk factors, notably invasive procedures, length of hospital stay, and low birth weight. All of these factors can increase the spread of HAIs, impairing the newborn's recovery and quality of life. Due to the length of their hospital stays, newborns often undergo various invasive procedures, increasing their risk of infection. These procedures include arterial and venous catheterization, parenteral nutrition, peripherally inserted central catheter (PICC) placement, chest drainage, and mechanical ventilation. Despite advances in clinical care, the risk of infection for newborns persists, exacerbated by their immature immune systems.^{7,8} Furthermore, causes of death during the neonatal period were found to be associated with lower gestational age, lower birth weight, low vitality at birth, as well as the use of surfactant and the presence of pulmonary hemorrhage.⁹

The objective of this study was to analyze the main strategies used to control HAIs in NICUs, highlighting their effectiveness and impact on improving neonatal care.

METHODS

This was an integrative literature review, designed according to the framework adapted from Souza, Silva, and Carvalho, with the aim of synthesizing and analyzing the strategies used to control HAIs, in comparison with standard practices or no intervention, and assessing the outcomes of these practices in improving neonatal care over time in NICUs, using different data sources.¹⁰ It was developed based on the PICOT strategy: (P) population; (I) intervention; (C) comparison between intervention types or absence of intervention; (O) outcomes of the interventions; (T) effect of the intervention over time (Figure 1).¹¹

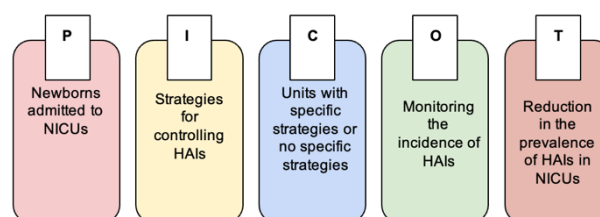


Figure 1. Flowchart of the PICOT construction process.

The review was conducted in March 2025 using the following databases: Latin American and Caribbean Health Sciences Literature (LILACS), Scientific Electronic Library (SciELO), and PubMed (PMC). The search terms were selected based on a consultation of the Health Sciences Descriptors (DeCS) and Medical Subject Headings (MeSH). Broad descriptors were selected to cover different aspects related to healthcare-associated infections, clinical protocols, and neonatal intensive care units, in Portuguese. The corresponding English terms used were: healthcare-associated infections, clinical protocols, and neonatal intensive care unit, allowing for a broader and more detailed approach to the topic. To refine the search, the Boolean operator AND was used to combine the search terms efficiently.

The following inclusion criteria were defined: original articles with abstracts available online, published within the last five years, from 2019 to March 2025, in English or Portuguese. Articles that required payment, were incomplete, were duplicates, or did not address the research question were excluded. After extracting the information from the selected articles, it was organized concisely in a spreadsheet. Once the studies were identified, they were critically analyzed with regard to their methods and then organized in sequential order in a spreadsheet containing the following items: title; authors; results; country; database; and year. After organizing the data, the types of interventions used to control HAIs in NICUs were analyzed, resulting in a flowchart of the stages of the article selection process (Figure 2).

RESULTS AND DISCUSSION

After selecting articles from the relevant databases, 1,170 articles were identified for the initial analysis. After applying the established inclusion criteria, 15 articles were included, of which approximately 33% were produced in Brazil. The screening process was conducted in three sequential stages: first, the titles were reviewed, and those that did not meet the previously established inclusion criteria were excluded; next, the abstracts of the potentially eligible studies were reviewed; finally, the full texts of the selected articles were analyzed in their entirety to confirm eligibility, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist recommendations (Figure 2).

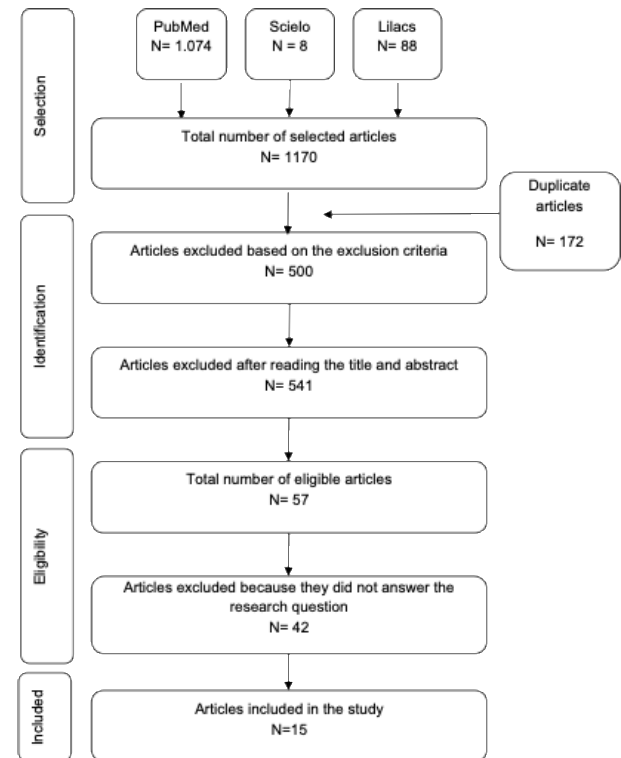


Figure 2. Flowchart of the steps in the methodological process.

After reviewing the selected articles, they were compiled into a table containing the information to be analyzed, including the articles' titles, authors, results, countries, databases, and year of publication. Approximately 60% of the articles were published in 2022 and 2024, and were retrieved from PubMed (Table 1).

Table 1. Characteristics of studies eligible for the integrative review on the control of HAIs in NICUs.

Title	Authors	Results	Country	Database	Year
Adapting lean management to prevent healthcare-associated infections: a low-cost strategy involving Kamishibai cards to sustain bundles' compliance ¹⁵	Saavedra Bravo MA, Santos GCSD, Petenate AJ, Westphal PJ, Souza LGA, Marques RG, Morosov EDM, Gushken AKF, Franco FF, Silva WG, Moura RM, Lima AL, Santos RG, Andrade KC, Hamada APS, Cristalda, CMR, Ue LY, Barros CG, Vernal S	Two indicators were calculated: the percentage of ICUs, both adult and pediatric/neonatal, in which K-boards were being implemented, and whether bundle compliance was addressed on the K-board. Audit data were recorded in "SimpleQL." After 17 months of this initiative, 177 (93.7%) participating ICUs had incorporated this visual management tool into their daily care routines. When more than 94 (>50%) ICUs posted data on the K-board, the average compliance rate of the bundles for each healthcare-associated infection remained above 85%.	Brazil	PubMed	2023
<i>Adesão à higienização das mãos: impacto de uma intervenção educativa em unidade de terapia intensiva neonatal</i> (Hand hygiene compliance: Impact of an educational intervention in a neonatal intensive care unit) ¹²	Lopes, CG	In the pre-intervention phase, healthcare professionals performed hand hygiene (HH) 41.2% of the time; this figure increased to 59.7% after the simulation. Compliance with the HH technique increased from 76.6% to 85.2%. Nail and extremity hygiene remained the technique's greatest weakness. All professional categories showed an increase of between 17% and 19% in adherence to hand hygiene.	Brazil	Lilacs	2019
Effects of implementation of healthcare associated infection surveillance and interventional measures in the neonatal intensive care unit: Small steps matter ¹³	Rakshit P, Nagpal N, Sharma S, Mishra K, Kumar A, Banerjee T	There was a significant reduction in cases of primary bloodstream infection (BSI) in the post-intervention period ($p < 0.05$). Mortality and BSI were significantly higher in the pre-intervention period, although the proportion of low birth weight neonates was significantly higher in the post-intervention period ($p < 0.05$). The HAI rate for primary BSI in the NICU was 10.82 per 1,000 patient-days. The overall adherence rate to HH among all healthcare professionals was 10.68% (complete) and 73.35% (partial). HAI rates changed in tandem with changes in HH rates.	India	PubMed	2023
Cost-effectiveness analysis of alcohol handrub for the prevention of neonatal bloodstream infections: Evidence from HAI-Ghana study ²⁶	Fenny AP, Otioku E, Labi KA, Asante FA, Enemark U	The analysis shows that the alcohol-based hand rub program was effective in reducing the cost per patient with neonatal HAIs by 41.7% and the hospital cost attributable to neonatal HAIs by 48.5%. In addition, deaths attributable to neonatal HAIs and the length of hospital stay decreased by 73% and 50%, respectively. Furthermore, the post-intervention evaluation revealed that the alcohol-based hand rub program contributed to a 16% decline in the incidence of HAIs.	Ghana	Lilacs	2022
SafeHANDS: A multimodal hand hygiene intervention in a resource-limited neonatal unit ¹⁴	Dramowski A, Erasmus LM, Aucamp M, Fataar A, Cotton MF, Coffin SE, Bekker A, Whitelaw AC	A total of 2,430 hand hygiene (HH) opportunities were observed: 1,002 (41.3%) at baseline, 630 (25.9%) during the initial phases, and 798 (32.8%) during the intensive phases of the study. At baseline, the overall hand hygiene compliance rate was 61.6%, the use of alcohol-based hand rub was 70 mL/patient-day, and the Hand Hygiene Self-Assessment Framework score, a strategy promoted by the WHO, was "basic" (165) at baseline. The score improved to the "intermediate" level (262).	South Africa	Lilacs	2022

Title	Authors	Results	Country	Database	Year
Analysis of antimicrobial consumption and healthcare-associated infections after an antimicrobial stewardship program implantation in a neonatal intensive care in Rio de Janeiro ²⁰	Araujo da Silva AR, Almeida AT, Arantes IV, de Oliveira JVM, Schwarzer LT	The median total antimicrobial consumption was 1,580 DOT (number of days a patient received an antimicrobial)/1,000 PD (number of patient-days in the unit), with no upward trend. Carbapenem consumption was reduced (p = 0.07) compared with the first six months. Eight cases of healthcare-associated infections were recorded, corresponding to an incidence rate of 3.6 per 1,000 patient-days.	Brazil	PubMed	2020
Quality improvement in neonatal care through enhanced patient safety and clinical risk management: a before-and-after study about neonatal sepsis ²⁵	Ferorelli D, Goffredo VM, Graziano E, Mastrapasqua M, Telegrafo M, Vinci A, Visci P, Benevento M, Zotti F, Foglianese A, Panza R, Solarino B, Dell'Erba, A, & Laforgia, N	Implementation of the protocol resulted in a notable reduction in umbilical venous catheter infections (p = 0.018) and a shorter length of hospital stay. Blood and urine cultures showed no significant changes in microbial patterns after implementing the protocol.	Italy	PubMed	2024
Sustaining the continued effectiveness of an antimicrobial stewardship program in preterm infants ²¹	Zini T, Miselli F, D'Esposito C, Fidanza L, Cuoghi Costantini R, Corso L, Mazzotti S, Rossi C, Spaggiari E, Rossi K, Lugli L, Bedetti L, Berardi A	There were 111, 119, and 100 very low-birth-weight infants during periods I. "baseline" (2011–2012), II. "intervention" (2016–2017), and III. "maintenance" (2020–2021), respectively. During the "intervention period," antibiotic use decreased, as measured by days of antibiotic therapy per 1,000 patient-days (215 vs. 302, p < 0.01). During the "maintenance period," culture-confirmed sepsis cases increased. However, antibiotic exposure among uninfected very low birth weight infants was lower, and no sepsis-related deaths occurred. Furthermore, antibiotic use for so-called culture-negative sepsis decreased (22% vs. 11% vs. 6%, p = 0.002), especially in infants with birth weights between 1,000 and 1,499 grams.	Italy	PubMed	2024
Impact of MRSA transmission and infection in a neonatal intensive care unit in China: A bundle intervention study during 2014-2017 ²²	Huang H, Ran J, Yang J, Li P, Zhuang G	Through a bundle of interventions, adherence to isolation protocols for MRSA infection increased from 55.88% to 92.86%, and adherence to hand hygiene increased from 90.07% to 93.23% (p < 0.05). HAI rates decreased from 1.87% to 1.71%, and the detection rate of MRSA-related HAIs decreased from 2.63% to 1.00%.	China	PubMed	2019
Healthcare worker perceptions of the implementation context surrounding an infection prevention intervention in a Zambian neonatal intensive care unit ¹⁶	Cowden C, Mwananyanda L, Hamer, DH, Coffin SE, Kapasa ML, Machona S, Szymczak JE	Interviews were conducted with 17 NICU staff members (5 physicians and 12 nurses), who believed the intervention components were easy to use, well designed, and facilitated improved performance. Four organizational characteristics that facilitated infection transmission were identified: lack of admission protocols, physical crowding, staff shortages, and equipment shortages. The interviewees suggested that resource constraints reflected a social ethos that devalues infant medical care. Despite the challenges, the interviewees were highly motivated to prevent HAIs and believed this was an achievable goal. They welcomed the bundle enthusiastically but expressed serious concerns about its sustainability after the study.	Zambia	PubMed	2020
Quality improvement initiative 'S-A-F-H' to reduce healthcare-associated neonatal sepsis in a tertiary neonatal care unit ¹⁷	Kallimath A, Patnaik SK, Malshe N, Suryawanshi P, Singh P, Gareghat R, Nimbre V, Ranbishe K, Kamble AG, Ambekar V	Within a few months, the team managed to reduce the incidence of HAIs by 50%, a reduction that was sustained for over a year. Compliance with various aspects of the SAFH protocol improved.	India	PubMed	2024
Implementation of the comprehensive unit-based safety program to improve infection prevention and control practices in four neonatal intensive care units in Pune, India ¹⁸	Johnson J, Latif A, Randive B, Kadam A, Rajput U, Kinikar A, Malshe N, Lalwan S, Parikh TB, Vaidya U, Malwade S, Agarkhedkar S, Curless MS, Coffin SE, Smith RM, Westercamp M, Colantuoni E, Robinson ML, Mave V, Gupta A, Milstone AM	A total of 144 healthcare professionals and administrators completed the Comprehensive Unit-based Safety Program (CUSP) training. All sites held at least 75% of their monthly meetings. The odds of compliance with HH increased by 6% per month [OR 1.06 (95% CI 1.03–1.10)]. Providers completed insertion checklists for 68% of newborns with a central line; 83% of the checklists were fully completed. The domains of patient safety culture that showed the greatest improvement were management support for patient safety (+7.6%), teamwork within units (+5.3%), and organizational learning–continuous improvement (+4.7%). The overall workload increased from a mean score of 46.28 ± 16.97 at baseline to 65.07 ± 19.05 at follow-up (p < 0.0001).	India	PubMed	2022
Health care related infections in neonates weighing less than 1500g: etiology, risk factors and forms of prevention ²⁴	Silva GLV, Xavier HMD, Roder DVDB	Practices such as promoting breastfeeding, reducing the duration of use of invasive devices, strict adherence to hand hygiene protocols, and disinfecting the hospital environment have proven effective in controlling HAIs in critically ill newborns.	Brazil	Lilacs	2020
Determinants of late neonatal nosocomial infection: a case-control study in Ceará ¹⁹	Lima CSSDC, Rocha HAL, Araújo DABS, Silva C	Of the 1,132 participants, 37.7% developed late-onset HAIs. Of these, 12.6% had positive blood cultures, of which 14.9% contained multidrug-resistant bacteria. In preterm infants, late-onset infections were 18 times more likely in those with a gestational age of less than 30 weeks and four times more likely in those weighing less than 1,500 g. Mechanical ventilation increased the risk of infection more than sevenfold; the same was true for cases of parenteral nutrition, central venous catheters, the number of catheters used, surgery, and length of hospital stay. The association between preterm infants with a gestational age of less than 30 weeks; mechanical ventilation; central venous catheters; and length of hospital stay remained significant after adjustment. Among the deaths, 41 (55.4%) were associated with late-onset infections.	Brazil	Lilacs	2022

Abbreviation: BSI: primary bloodstream infections; CUSP: Comprehensive Unit-based Safety Program; DOT: number of days the patient received antimicrobial therapy; HAIs: healthcare-associated infections; HH: hand hygiene; ICU: intensive care unit; MRSA: methicillin-resistant *Staphylococcus aureus* infection; NICU: Neonatal Intensive Care Unit; PD: number of patient-days in the unit; SAFH: Protocol for scrub the hub, aseptic non-touch technique, five moments of hand hygiene, and hand hygiene.

Figure 3 summarizes the main interventions described in the articles analyzed.



Figure 3. Interventions used to control HAIs in NICUs.

Hand hygiene is recognized as one of the most effective and low-cost measures for preventing HAIs in NICUs. Several studies show that educational interventions focused on this practice improve healthcare professionals' adherence, which directly translates into lower infection rates among newborns. This evidence reinforces the need for ongoing educational initiatives and a culture of safety focused on neonatal care, involving both the healthcare team and family members.^{12,13}

A study implementing a multimodal intervention in a NICU produced concrete improvements, including a 0.7% increase in hand hygiene compliance and an 11% increase in alcohol-based hand rub use. The actions included training sessions with explanatory videos, distribution of individual bottles of alcohol-based hand rub, production of educational materials, regular feedback, and awareness campaigns. Notably, mothers participated most actively and showed the highest compliance rate at the end of the intervention.¹⁴

Another promising approach was the incorporation of lean management tools, such as Kamishibai cards, which use visual aids to reinforce desired behaviors, such as hand hygiene. This technique, combined with the lean philosophy, which aims to eliminate waste and optimize processes, proved effective and cost-effective, especially in resource-constrained settings.¹⁵

A study conducted in a NICU in Zambia identified factors that compromise infection control, including the absence of protocols for newborn admission, overcrowding, excessive workloads, and a shortage of appropriate equipment. These limitations reveal a challenging structural context and an underestimated social perception of the importance of neonatal care, even though healthcare professionals recognize the prevention of HAIs as a plausible goal.¹⁶

In addition to hand hygiene, other control measures have been implemented. A protocol involving compliance with scrubbing the hub, the aseptic non-

touch technique, the five moments of hand hygiene, and hand hygiene steps (SAFH) increased adherence to aseptic technique from 70% to 90% and reduced the incidence of HAIs from 16.1% to 8.4% across the study phases. Antibiotic use also declined, from 419 to 345 days of use per 1,000 patient-days, representing a 17.7% reduction, although this was less pronounced than the reduction in infections.¹⁷

In India, the Comprehensive Unit-based Safety Program (CUSP) was adopted, prioritizing best practices in hand hygiene, invasive procedures, and intravenous medication preparation. Patient safety culture improved significantly, particularly in institutional support (+7.6%), teamwork (+5.3%), and continuous learning (+4.7%). However, the workload increased, as evidenced by the NASA TLX scale, which rose from an average of 46.28 to 65.07 points.¹⁸ The judicious use of invasive devices has also contributed to the decline in HAIs.¹⁹

Controlling the use of antimicrobials is another essential aspect. The implementation of antimicrobial stewardship programs (ASP), which include audits, restrictions on targeted antimicrobials, monitoring of DOT per 1,000 PD, and rapid reporting of culture results, has helped preserve bacterial susceptibility, avoid prolonged treatments, and optimize therapy. In addition, the ongoing sharing of data among healthcare professionals promotes the rational use of antibiotics.^{20,21}

Measures to prevent infections caused by MRSA have also been evaluated. Implementing a series of measures, such as triage, isolation precautions, training, and environmental decontamination, increased adherence to isolation practices from 55.88% to 92.86% and compliance with hand hygiene from 90.07% to 93.23%. Despite a slight decrease in infection rates (from 1.87% to 1.71%) and MRSA detection rates (from 2.635% to 1%), the results were not statistically significant ($p > 0.05$).²¹ Understanding the risk factors associated with HAIs, such as prematurity, low birth weight, and maternal characteristics, is essential for reducing neonatal morbidity and mortality, containing hospital costs, and slowing the rise of antimicrobial resistance.^{23,24}

At the University of Bari Polyclinic Hospital, a comprehensive protocol was adopted to prevent HAIs, including ventilator-associated pneumonia, catheter-related bloodstream infections, and epidemic outbreaks. The strategy involved the entire healthcare team and family members, covering everything from diagnosis to preventive interventions. The results showed a significant reduction in umbilical catheter-associated infections ($p = 0.018$), with a direct impact on reducing the length of hospital stay.²⁵

In terms of cost-effectiveness, a study compared alcohol-based hand hygiene with conventional care. The

optimal strategy reduced the incidence of bloodstream infections by 16% and also generated significant savings: the average cost of hospitalization fell from \$1,026 to \$598.63. There was also a 50% reduction in the average length of stay, allowing for the admission of up to 171 additional newborns per year.²⁶

In light of the growing body of scientific evidence, new proposals are currently under consideration. One example is the use of sensors to continuously monitor abdominal and foot temperature over a 28-day period to detect early signs of infection.²⁷ The “Prevention of Transmissions by Effective Colonization Tracking-Neo” project aims to map transmission events and identify risk factors in NICUs.²⁸ There are also studies investigating the early use of probiotics, which have shown a reduction in feeding intolerance, a lower incidence of necrotizing enterocolitis, and a reduction in overall mortality among newborns.^{29,30,31}

This study has limitations related to the heterogeneity of the contexts presented in the selected publications, which encompass different structural, cultural, and economic realities, thereby limiting the generalizability of the results to the Brazilian setting. In addition, there is a scarcity of up-to-date national studies on specific interventions for the prevention of HAIs in NICUs.

CONCLUSION

The literature review demonstrated that HAIs in NICUs continue to pose a significant challenge to patient safety and the quality of neonatal care. The immunological vulnerability of newborns, especially preterm and low-birth-weight infants, combined with the complexity of intensive care, contributes to the occurrence of these infections. Evidence reinforces that adherence to hand hygiene is one of the most effective, low-cost measures with a direct impact on reducing HAIs. Educational interventions and multimodal strategies, such as videos, distribution of alcohol-based hand rub, continuous feedback, and involving parents in care processes, significantly increase compliance among healthcare professionals and family members. Other recommendations include implementing programs such as the SAFH protocol, CUSP, and ASP, which have also proven effective in reducing infections, curbing inappropriate antibiotic use, and shortening hospital stays.

Specific protocols aimed at preventing MRSA and catheter-related infections have proven effective in reducing infection rates and optimizing healthcare resources. In addition, some of the articles reviewed point to the potential of emerging strategies, such as predictive analytics with vital sign monitoring and the early use of probiotics, opening new avenues for addressing HAIs. Cost-effectiveness analysis also reinforces that investing in preventive practices is

economically viable, resulting in shorter hospital stays and greater bed availability.

Therefore, it is essential that healthcare professionals work in an integrated and continuous manner to implement safe practices, with regular training, well-defined protocols, and a focus on continuous improvement. Controlling HAIs in NICUs depends not only on advanced technologies but also on the team's daily commitment, guided by knowledge, protocols, and a patient-centered culture of safety.

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AUTHORS' CONTRIBUTIONS

Izabelle de Menezes Siqueira contributed to the literature review, drafting of the abstract, introduction, methodology, discussion, interpretation and description of the results, preparation of tables, conclusions, proofreading, and statistics. **Murilo Soares Costa** contributed to project management, literature review, drafting of the abstract, introduction, methodology, discussion, interpretation and description of the results, conclusions, revision, and statistics. **Isabela Lorencini** contributed to the drafting of the abstract, review, and statistics.

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

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