Literature Review

ISSN: 2351-8200

JMSR 2025 Vol XII, n 2: 1486 -1495

# HEALTHCARE-ASSOCIATED INFECTIONS IN NEONATOLOGY IN MOROCCO AND WORLDWIDE: A SYSTEMATIC REVIEW

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Published in December 2025

## Abstract

**Introduction**: Healthcare-associated infections are a major public health concern, particularly in neonatology, were they contribute to significant morbidity and mortality. This review aims to describe the pathogens involved in healthcare-associated infections in neonatology and to assess their resistance to drugs. **Methods:** the current study gathered data from reputable sources, employing a systematic review approach, including PubMed, Scopus and Google Scholar databases. We customized our search to include studies published from 2015 to 2024. **Results:** of the 871 studies retrieved from the database. Twenty-seven studies were included. The overall prevalence of HAIs in neonatology ranged from 3.54% to 29%. Three infectious sites were predominant: bacteremia (21% to 91%), pneumonia (5.17% to 81.3%), and urinary tract infections (1.4% to 28.8%). The most frequently isolated pathogens were coagulase-negative Staphylococcus (27.86%), followed by Klebsiella spp (24.70%), Acinetobacter spp (13.75%), Pseudomonas spp (8.93%) and Staphylococcus aureus (6.27%).
Multidrug-resistance bacteria were mainly represented by methicillin-resistance Staphylococcus aureus with rates ranging from 0% to 100%, extended spectrum beta-lactamase-producing Enterobacteriaceae, with rates ranging from 0% for Klebsiella isolates to 91.02%, and vancomycin-resistant Enterococcus, with rates ranged from 90% to 100%. **Conclusion:** understanding the bacterial ecology and resistance profiles of neonatal healthcare-associated infections are crucial to reducing their incidence and guiding empirical antibiotic therapy. This systematic review recommends the rigorous application of hygiene measures throughout neonatal care and the reduction of the number and duration of invasive procedures to limit neonatal mortality caused by these infections.

**Keywords:** Antibiotic resistance, associated infections, Infant, Neonatology, Newborn, Morocco

## Introduction

To this day, healthcare-associated infections (HAIs) remain a significant burden for hospitals and the healthcare system as a whole. They are defined as infections that are neither present nor incubating when the patient as admitted, and which are contacted during or after the patient's care [1,2]. They are known throughout the world, affecting both developed and resource-poor countries. Their prevalence in Europe was estimated at 5.1% in 2012 [3,4]. While, their annual incidence was around 25 to 28.6% in Japan in 2008, 34% in Brazil, and 28% in Egypt in 2012 [5-7]. They constitute a real public health problem due to their frequency, severity, and socio-economic cost. They are frequent in neonatology, particularly in premature babies, due to the immaturity of their immune systems [3,8].
Several factors increase the likelihood of infection, such as premature birth, low birth weight, mother-to-child transmission, perinatal infections and inappropriate use of antibiotics [9-11].
The risk of newborns contracting a HAI has always existed, and increases proportionally with the development of care, although this care is more effective, it is often more invasive, as it can be accompanied by contamination by pathogens of various origins.
The surveillance of HAIs in neonatology is primarily based on the identification of the main germs involved in these type of infections and the assessment of their resistance to antibiotics, in order to initiate targeted antibiotic therapy and thereby limit therapeutic failures.
The current systematic falls within the scope of this surveillance them, the main aim of which was to describe the bacteriological profile of HAIs in neonatology and to assess the rate of antibiotic resistance of pathogens involved in this type of infection worldwide and particularly in Morocco. This knowledge is essential for promoting better

policies and implementing strategies to reduce neonatal mortality.

## Material and Methods

This study was carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol.

### Research strategy

A systematic search of the literature was carried out, following the analyses of different studies dealing with the subject without language restriction. We utilized databases such as PubMed, Scopus and Google Scholar. We carefully selected the following keywords: “healthcare-associated infections”, “nosocomial infections”, “cross infection”, “healthcare-related infections”, “neonatology”, “newborn”, “neonate”, “neonatal intensive care unit”, “micro-organisms”, “germs”, “antimicrobial resistance”, “antimicrobial profile”, “antimicrobial pattern”, “bacterial profile”, “Morocco”. Logical operators like AND and OR were used to combined the keywords. Grey literature data (theses and dissertations) were also included in our study. We customized our search to include studies published from 2015 to 2024.

### Inclusion and exclusion criteria

Included were studies published between 2015 and 2024, carried out on newborns who developed healthcare-associated infections and which describe the germs involved and their antibiotic resistance profiles.
Excluded were studies with insufficient or missing data, as well as those focused on maternal-fetal infections.

### Data collection process

A data extraction table was used to identify data relevant to the study such as author’s name, year of publication, study type, period of study, sample size, prevalence, infectious sites, implicated germs and their antibiotic resistance profiles.

## Results

The flowchart shown in Fig.1 details the studies selection strategy. The systematic search identified 871 studies, of which 63 were duplicates. In the end, 27 studies were considered eligible meeting our inclusion criteria (Fig.1).

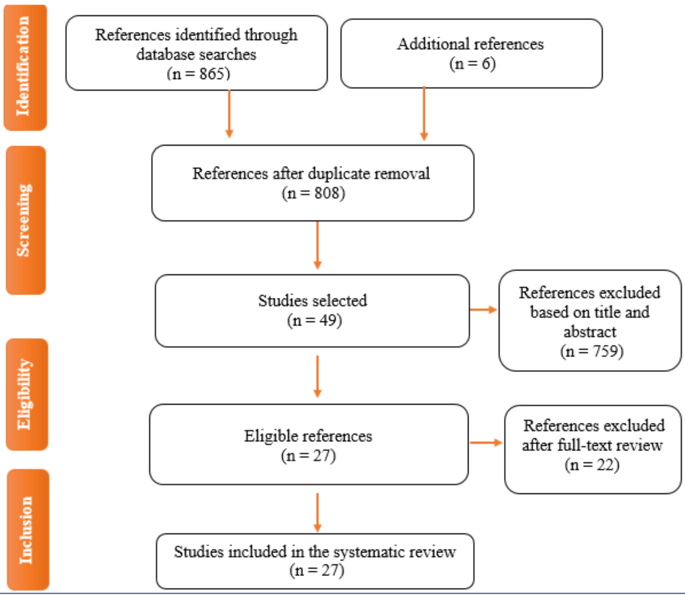


**Fig.1.**Flowchart showing the search and study selection strategy

### Characteristics of the studies included in the review

The 27 included studies were conducted took place in 16 countries: 5 studies in Morocco, one in each of Algeria, Benin, Bulgaria, Colombia, Vietnam, Congo, Belgium, Gabon, Egypt, India, and Madagascar; Two studies in each of Iran and Mexico; Four studies in Turkey and three in Italy. The sample size of the included studies ranges from 60 to 6068 patients. Most of the research was done in 2019 and in 2020, followed by 2015, 2023, 2016, 2022, 2021 and 2017 (Table I).

**Table I**: Characteristics of included studies (n=27)

| Author | publication | Country | Type of study | Study period | Sample size |
|---|---|---|---|---|---|
| Rahmouni H. [12] | 2022 | Morocco | prospective /descriptive | 13 February 2021 - 02 July 2021 | 331 |
| Abdellaoui C.[13] | 2022 | Morocco | prospective /descriptive/ observational | 27 December 2020 - 27 Mars 2021 | 440 |
| Bighoumdan K. [14] | 2020 | Morocco | retrospective /descriptive | 1st January 2016 - 31 December 2018 | 200 |
| Helyaich A. et al [15] | 2019 | Morocco | Retrospective | June 2015 -December 2016 | 920 |
| Benabbas DR, Kara S. [16] | 2019 | Algeria | Retrospective descriptive | 1st January -31 December 2018 | 229 |
| d'Almeida M et al. [17] | 2017 | Benin | Retrospective analytical | 1st November 2015-31 January 2016 | 717 |
| Ceyhun C, et al. [18] | 2015 | Turkey | prospective | 1st July 2012 -30 June 2013 | 377 |
| Kajiyazdi M, et al.[19] | 2020 | Iran | historical cohort | mars 2017 -September 2018 | 60 |
| Rangelova V, et al [20] | 2020 | Bulgaria | prospective cohort | 1st January 2017 -31 June 2018 | 507 |
| Javier Torres-Mu~noz et al.[21] | 2023 | Colombia | observational cross-sectional | August 2016 - December 2018 | 226 |
| Peters L, et al. [22] | 2019 | Vietnam | prospective cohort | march 2016 -October 2017 | 327 |
| Choobdar F, et al [23] | 2020 | Iran | descriptive cross-sectional prospective | December 2015 - December 2016 | 654 |
| Kissi Kamgaing E, et al.[24] | 2019 | Gabon | retrospective descriptive | December 2012 - December 2016 | 521 |
| Kilic A, et al. [25] | 2019 | Turkey | prospective cohort | 1st July 2011 -30 June 2012 | 352 |
| Ertugrul S, et al. [26] | 2016 | Turkey | retrospective | January 2011 - December 2014 | 126 |
| Bukasa JC, et al. [27] | 2021 | Congo | descriptive longitudinal | 1st November 2016- 1st February 2017 & 2nd February 2017- 2nd May 2017 | 6068 |
| Bedir Demirdağ T, et al.[28] | 2021 | Turkey | multicenter point- prevalence | | 849 |
| Crivaro V, et al. [29] | 2015 | Italy | retrospective | 2006-2010 | 1699 |
| El-Feky EA, et al. [30] | 2016 | Egypt | descriptive | march 2012 -September 2013 | 1053 |
| Kartikeswar G a. P,et al. [31] | 2023 | India | prospective cohort | 1st may 2017 -31 July 2019 | 1442 |
| Chabah M, el al. [32] | 2016 | Morocco | retrospective | 1st January 2012 -31 December 2013 | 1287 |
| Scamardo MS,et al.[33] | 2020 | Italy | retrospective | 2013-2017 | 1265 |
| Ceparano M, et al.[34] | 2023 | Italy | retrospective cohort | 1st march 2018 -28 February 2022 | 564 |
| Garcia H, et al [35] | 2015 | Mexico | Case-control | | 380 |
| Verstraete EH, et al. [36] | 2016 | Belgium | historical cohort | 2002 -2011 | 5134 |
| Garcia H, et al [37] | 2023 | Mexico | Case-control | May 2016-November 2017 | 213 |
| Ramanampamonjy MTM, et al.[38] | 2022 | Madagascar | Case-control | 1st January 2019 – 31 march 2021 | 1071 |

### Prevalence of Healthcare-Associated Infections (HAIs) in neonatology

The prevalence was investigated in 17 studies, four of which were carried out in Morocco, 11 in developing countries (Benin, Turkey, Iran, India, Madagascar and Algeria), and only one in a developed country (Belgium). The overall prevalence of HAIs in neonatology ranged from 3.54% in Madagascar to 29% in Morocco. It varied from 15.7% to 29% in Morocco, from 3.54% to 25.7% in developing countries and reached 6.7% in developed countries (Belgium) (Table II).

**Table II:** Prevalence of Healthcare-Associated Infections (HAIs) in the included Studies

| Etude | pays | Prevalence (%) |
|---|---|---|
| Rahmouni H. [12] | Morocco | 15,7 |
| Bighouman K.[14] | Morocco | 29 |
| Helyaich A, et al. [15] | Morocco | 17 ,39 |
| Benabbas DR, Kara S.[16] | Algeria | 22,3 |
| d'Almeida M, et al. [17] | Benin | 6,3 |
| Ceyhun C, et al.[18] | Turkey | 9 |
| Kajiyazdi M, et al.[19] | Iran | 6,12 |
| Rangelova V, et al.[20] | Bulgaria | 9,46 |
| Choobdar F, et al.[23] | Iran | 13,5 |
| Kissi Kamgaing E, et al.[24] | Gabon | 25,7 |
| Kilic A, et al.[25] | Turkey | 10,5 |
| Bedir Demirdağ T, et al.[28] | Turkey | 7,6 |
| Kartikeswar G a. P,et al. [31] | India | 9,08 |
| Chabah M,et al. [32] | Morocco | 22,37 |
| Verstraete EH, et al.[36] | Belgium | 6,7 |
| Garcia H, et al.[37] | Mexico | 33,3 |
| Ramanampamonjy MTM, et al. [38] | Madagascar | 3,54 |

### Infectious sites of HAIs in neonatology

In this review, we focused on six infectious sites: bacteremia, urinary tract infections, meningitis, surgical site infections, and enterocolitis. Three infectious sites were predominant: bacteremia in 15 studies (21% to 91%), pneumonia in 16 studies (5.17% to 81.3%) and urinary tract infections in 12 studies (1.4% to 28.8%) (Table III).

**Table III**: Infectious sites of HAIs in neonatology

| Study | Bacteremia | Pneumonia | Meningitis | Urinary tract infection | Surgical site infection | Enterocolitis |
|---|---|---|---|---|---|---|
| Abdellaoui C. [13] | 48,98 | 26,53 | 2,04 | 16,33 | | |
| Bighoumdan K. [14] | 88 | 5,17 | | 5,17 | | |
| Benabbas DR, Kara S. [16] | 21 | | | 9 | | |
| d'Almeida M, et al. [17] | | | 6,7 | | | 17,8 |
| Ceyhun C, et al.[18] | 50 | 10,3 | 20,6 | 14,7 | | |
| Kajiyazdi M, et al.[19] | 30 | 21,7 | 5 | 6,6 | | 10 |
| Rangelova V, et al [20] | 23,64 | 67,27 | | | | |
| JavierTorres-Mu~noz et al . [21] | 73 | 27 | | | | |
| Petrs L, et al. [22] | | 81,3 | | | | |
| Choobdar F, et al.[23] | 80,7 | 9 | | 2,3 | 8 | |
| Kilic A, et al.[25] | 70 | 18,3 | | 6,7 | 1,7 | |
| CrivaroV et al. [29] | | 25,5 | 1,3 | 28,8 | | |
| El-Feky EA, et al. [30] | 91 | 9 | | | | |
| Scamardo MS,et al. [33] | 69,6 | 20 | | 8,8 | | 1,6 |
| Ceparano M, et al.[34] | 69,44 | 30,55 | | | | |
| Garcia H, et al. [35] | 28 | 17 | 0,8 | 1,6 | 6,5 | |
| Garcia H, et al.[37] | 36,6 | 16,2 | | 1,4 | 9,9 | |
| Chabah M, et al. [32] | 70,6 | 8,8 | | 11,7 | | |

### Bacterial Profile of HAIs in Neonatology

2631 bacterial strains were isolated. The result of studies showed that the germs responsible for HAIs were predominantly gram-negative bacteria in 60.81% of cases, while gram-positive bacteria were responsible for 39.18% of cases.
In order of frequency, the main germs isolated were: *coagulase-negative Staphylococcus* (27.86%) followed by *Klebsiella spp* (24.70%), *Acinetobacter spp* (13.75%), *Pseudomonas spp* (8.93%), and *Staphylococcus aureus* (6.27%). Other pathogens were isolated less frequently (Table IV).
For gram-positive bacteria, the most frequently isolated pathogens were coagulase-negative *Staphylococcus* (71.02%), followed by *Staphylococcus aureus* (15.98%), *Enterococcus* (10.36%) and *Streptococcus* (1.55%). While, for gram-negative bacteria, the main isolated pathogen was *Klebsiella* (40.62%), followed by *Acinetobacter* (22.62%), *Pseudomonas* (14.68%), and *Escherichia* (8.56%) (Table IV).

**Table IV**: the pathogens responsible for HAI in neonatology

| pathogens | | | | | n (%) |
|---|---|---|---|---|---|
| **Gram-positive** | Staphylococcus | *Coagulase-negative staphylococci* | 733 | 898 | 1032(39,22%) |
| | | *Staphylococcus aureus* | 165 | | |
| | *Enterococcus* | | 107 | | |
| | *Streptococcus* | | 16 | | |
| | *Aerococcus viridans* | | 3 | | |
| | *Kocuria* | | 1 | | |
| | *Bacillus spp* | | 3 | | |
| | *Corynobacterium spp* | | 3 | | |
| **Gram-negative** | Enterobacteriaceae | *Escherichia coli* | 137 | | 983 (37,36%) |
| | | *Klebsiella spp* | 650 | | |
| | | *Enterobacter spp* | 123 | | |
| | | *Serratia marascens* | 44 | | |
| | | *Proteus mirabilis* | 1 | | |
| | | *Kluyira Ascorbata* | 3 | | |
| | | *Salmonella heidelberg* | 17 | | |
| | | *Citrobacter spp* | 8 | | |
| | Haemophilus | *Haemophilus paraphrophilis* | 1 | 3 | 3 (0,11%) |
| | | *Haemophilus influenza* | 2 | | |
| | Non fermentative Gram-négative | *Acinetobacter spp* | 362 | | 614 (23,33%) |
| | | *Pseudomonas spp* | 235 | | |
| | | *Burkholderia cepacia* | 4 | | |
| | | *Achromobacter spp* | 5 | | |
| | | *Chryseobacterum spp* | 3 | | |
| | | *Elizabethkingia spp* | 5 | | |

In Morocco, the MAIN isolated pathogens were *coagulase-negative Staphylococcus* (35, 16%), followed by *Klebsiella* (26.22%), *Acinetobacter* (14.28%), *Enterobacter* (5.49%), and *Escherichia* (4.57%). Other pathogens were isolated less frequently. In the other countries of the world, the most frequently isolated germ was *coagulase-negative Staphylococcus* (25.45%), followed by *Klebsiella* (25.11%), *Pseudomonas spp* (14.32%), *Acinetobacter spp* (13.97%) and *Escherichia spp* (5.42%). Other germs were isolated less frequently (Fig.2).

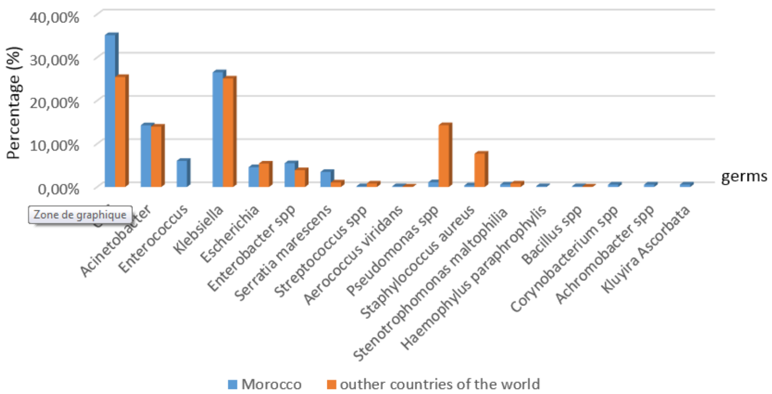


**Fig.2.** The proportion of bacterial species

## Antibiotic resistance of germs responsible of HAIs in neonatology

Of the 27 studies included in our study, only 10 reported antimicrobial resistance of pathogens.

**Resistance profile of germs to antibiotics in Morocco**

***Staphylococcus***

- The resistance rate of coagulase-negative *Staphylococcus* was 97% for levofloxacin, erythromycin, cefoxitin, and gentamicin, while the resistance rate to penicillin was 100% [12].
- In one study, the only isolated *Staphylococcus aureus* strain was susceptible to methicillin and aminoglycosides [13].

***Enterococcus***

- The vancomycin resistance rate was reported in two studies and ranged from 90% to 100%.[12,13]
- In one study, the resistance rate to tetracycline was 100% [12].

***Acinetobacter spp***

- In three studies, all *Acinetobacter* isolates were susceptible to colistin [12,13,15].
- The resistance rate to gentamicin was reported in two studies and ranged from 51% to 100% [13], [14].

***Klebsiella spp***

- The resistance rate to gentamicin and to ciprofloxacin was reported in two studies, ranged from 13% to 100% and 20% to 100%, respectively [13,14].
- The rate resistance to amoxicillin/clavulanic acid was reported in three studies, ranged from 95% to 100% [12-14].
- The resistance rate to ceftazidim was reported in two studies, ranged from 30% to 100% [13,14].

***Escherichia spp***

- In two studies, the resistance rate to amoxicillin and to amoxicillin/clavulanic acid was 100% [12,13].
- In one study the rate resistance to ceftazidim was estimated at 87.5% [13].

***Enterobacter spp***

- In two studies the rate resistance to imipenem was 0% [12,13].
- In one study the resistance rate to ceftazidime and to ceftriaxon was 100% [13].

## Resistance profile of bacteria to antibiotics in developing countries

Of the included studies conducted outside Morocco, only five reported antibiotic resistance profile. These studies were carried out in countries classified as developing, namely, Algeria, India, Turkey, and Vietnam.

***Staphylococcus***

- The resistance rate of *coagulase-negative Staphylococcus* in Benin was estimated at 100% for gentamicin and ampicillin, and 0% for fosfomycin and imipenem [17].
- The resistance of *coagulase-negative Staphylococcus* to methicillin was estimated at 75% in a study conducted in Turkey [25].

***Enterobacteriaceae***

- The resistance of *Klebsiella* to gentamicin was reported in two studies, ranging from 8.1% in Algeria to 100%in Benin, while for *Esherichia* and *Enterobacter*, this resistance affected 100% and 70% of isolates in Benin, respectively [16,17].
- The resistance rate to colistin was reported in two studies, ranging from 13.3% in India to 16.9% in Vietnam for *Klebsiella* isolates, while for *Enterobacter* and *Escherichia* isolates, the resistance rate was 0% in India [22,31].

## Non-fermenting Gram-negative bacteria

- The resistance of *Acinetobacter* to colistin was reported in two studies, ranged from 0% in India to 10.5% in Vietnam, while for *Pseudomonas* isolates, the resistance rate was 17.3% in Vietnam [22,31]. .
- - The resistance rate of *Acinetobacter* to cephalosporins, ranged from 97.2% in Vietnam to 100% in India. While, this rate ranged from 89.4% in Vietnam to 100% in India for *Pseudomonas* isolates [22,31].

## Multi-drug resistant bacteria

- In Morocco, multi-drug resistant bacteria (MDR) have been studied in three studies. The rate of methicillin- resistant *Staphylococcus aureus* (MRSA) was reported in one study and was estimated at 0% [12]. The production of extended-spectrum beta-lactamases (ESBL) by *Enterobacteriaceae* was tested in three studies, ranged from 58% to 91.02% [12,13,32].The rate of vancomycin-resistant *Enterococcus* was reported in two studies and ranged from 90% to 100% [12,13].
- Among studies conducted in other countries, the production of ESBL by Enterobacteriaceae was reported in four studies. In three of these, ESBL

rates in *Klebsiella pneumoniae* ranged from 0% to 100% [18, 25, 28], while for *Escherichia coli*, they ranged from 25% to 75% [18, 25]. In *Enterobacter spp.*, ESBL production reached 17% [25]. In the fourth study, 26 of 31 Enterobacteriaceae isolates (83.9%), mainly *Klebsiella pneumoniae* and *Salmonella heidelberg*, were identified as ESBL producers [16].

- The rate of methicillin- resistant *Staphylococcus aureus* (MRSA) was reported in three studies ranged from 50% to 100% [24,28,38].

## Discussion

The current systematic review included 27 studies.
The highest prevalence of HAIs in neonatology was recorded in Morocco in the series conducted by Bighoumdan K. and was 29% [14]. The study was performed in the pediatric intensive care unit of the Centre Hospitalier Universitaire Mohammed VI in Marrakech and included neonates admitted for perioperative management of surgical conditions. This specific case-mix is particularly relevant, as surgical neonates are inherently exposed to multiple invasive procedures; central vascular access, mechanical ventilation, and prolonged hospitalization, all of which are well established risk factors for HAIs.
The high rate observed in this Moroccan series likely reflects both the intrinsic vulnerability of surgical neonates and challenges in infection prevention in high-acuity pediatric units. These findings underscore the importance of targeted infection control strategies, including strict hygiene measures, careful management of invasive devices, and staff training, to reduce HAIs in this high-risk population.
In comparison with international reports, the prevalence reported by Bighoumdan et al. remains at the upper range, highlighting the need for continuous local surveillance and context-specific interventions.
This result was comparable to that recorded in the study by Hmmamouchi B. and al. [39] (21.9%) and higher than that reported in the series by Moulainine and al. [40] (7.2%), differences that may be explained by heterogeneity in patient populations, intensity of care, and infection prevention practices. These findings highlight the need for standardized multicenter surveillance and reinforced infection prevention strategies, particularly in high-acuity neonatal settings.
The lowest prevalence was recorded in Madagascar with rate of 3.54%. [38] Other studies reported different results, such as the study by Zinng W, and al. and the study by Sarvikivi E, and al. whose prevalence was 5.1% and 6.4%, respectively [4,41].
The predominant infectious sites were bacteremia (21% to 91%), followed by pneumonia (5.17% to 81.3%) and urinary tract infections (1.4% to 28.8%). This result is similar to that of the study by Zoukal S. and al, in which the predominant infectious sites were bacteremia (2.5 to 100%) and pneumonia (6.3 to 40%) [42].
The most common germs were *coagulase-negative Staphylococcus* (27.86%), followed by *Klebsiella* (24.70%), *Acinetobacter* (13.75%), *Pseudomonas spp* (8.93%) and *Staphylococcus aureus* (6.27%). Other germs were isolated less frequently. This bacterial profile, mainly characterized by nosocomial germs, reflects the implementation of advanced tertiary-level neonatal care, marked by the frequent use of invasive devices.
Our finding, is comparable to that of the study by Zinng W, and al. [4] and the study by Felipe Teixeira and al [43]. Were the most isolated germs was *coagulase-negative Staphylococcus*, with rates of 31% and 33.5%, respectively. However, other studies, reported different results, such as the systematic review by Zoukal S, and al. [42] in which the most frequently isolated germ was *Klebsiella pneumonia* (22.7% to 41%).
Concerning multi-drug resistant bacteria, the rate of *methicillin-resistant Staphylococcus* ranged from 0% to 100%. Other reviews reported different rates such as the study by Zoukal S. and al [42] and the study by Felipe Teixeira and al [43], where the MRSA rates ranged from 4.5% to 11.1% and from 1.2% to 28.3%, respectively. The production of ESBL by *Enterobacteriaceae* ranged from 0% for *Klebsiella* isolates to 91.02%. This result is comparable to that reported by Zoukal S and al, were the ESBLE rate was 96.9% [42] .
In the review conducted by Felipe Teixeira and al [43], the percentage of *Enterobacteriaceae* resistant to third-generation ranged from 23.3% to 36.6%.
The rate of vancomycin-resistant *Enterococcus* ranged from 90% to 100%, while Felipe Teixeira and al [43] reported in their results that only study reported one single sample of vancomycin resistant *Enterococcus sp.*

### Limitations

Several limitations should be considered when interpreting the findings of this review; the studies included varied in methodology, including differences in sample size and infection definitions, which may affect the comparability of results. In addition, the geographic variability in infection prevalence and pathogen profiles limits the generalizability of the results across different settings.

## Conclusion

HAIs are a serious public health problem. In neonatology, they are responsible for a significant morbidity and mortality. In Morocco, studies on the epidemiological and bacterial profiles of neonatal healthcare-associated infections are limited.

Updated studies to determine germs involved in this type of infections and their assesse to drugs are necessary to better address the realities of HAIs in neonatal care stings. This systematic review recommends the rigorous application of hygiene measures throughout neonatal care and the reduction of the number and duration of invasive procedures to limit neonatal mortality caused by these infections.
As a future perspective, given the extent of resistance, it is advisable to consider the development of bioactive compounds with antimicrobial properties.

**Acknowledgements**
The authors would like to express their sincere appreciation and gratitude to everyone who contributed to this review.

## References

1. Crivaro V, Bogdanović L, Bagattini M, Iula VD, Catania M, Raimondi F, Triassi M, Zarrilli R. Surveillance of healthcare-associated infections in a neonatal intensive care unit in Italy during 2006-2010. BMC Infect Dis. 2015 Mar 25;15:152. doi: 10.1186/s12879-015-0909-9. PMID: 25885702; PMCID: PMC4374496.
2. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control. 2008 Jun;36(5):309-32. doi: 10.1016/j.ajic.2008.03.002. Erratum in: Am J Infect Control. 2008 Nov;36(9):655. PMID: 18538699.
3. Johnson J, Quach C. Outbreaks in the neonatal ICU: a review of the literature. Curr Opin Infect Dis. 2017 Aug;30(4):395-403. doi: 10.1097/QCO.0000000000000383. PMID: 28582313; PMCID: PMC8020806
4. Zingg W, Hopkins S, Gayet-Ageron A, Holmes A, Sharland M, Suetens C; ECDC PPS study group. Health-care-associated infections in neonates, children, and adolescents: an analysis of paediatric data from the European Centre for Disease Prevention and Control point-prevalence survey. Lancet Infect Dis. 2017 Apr;17(4):381-389. doi: 10.1016/S1473-3099(16)30517-5. Epub 2017 Jan 13. PMID: 28089444.
5. Babazono A, Kitajima H, Nishimaki S, Nakamura T, Shiga S, Hayakawa M, Tanaka T, Sato K, Nakayama H, Ibara S, Une H, Doi H. Risk factors for nosocomial infection in the neonatal intensive care unit by the Japanese Nosocomial Infection Surveillance (JANIS). Acta Med Okayama. 2008 Aug;62(4):261-8. doi: 10.18926/AMO/30938. PMID: 18766209.
6. Távora AC, Castro AB, Militão MA, Girão JE, Ribeiro Kde C, Távora LG. Risk factors for nosocomial infection in a Brazilian neonatal intensive care unit. Braz J Infect Dis. 2008 Feb;12(1):75-9. doi: 10.1590/s1413-86702008000100016. PMID: 18553019.
7. Gadallah MA, Aboul Fotouh AM, Habil IS, Imam SS, Wassef G. Surveillance of health care-associated infections in a tertiary hospital neonatal intensive care unit in Egypt: 1-year follow-up. Am J Infect Control. 2014 Nov;42(11):1207-11. doi: 10.1016/j.ajic.2014.07.020. Epub 2014 Sep 16. PMID: 25238664.
8. Polin RA, Denson S, Brady MT; Committee on Fetus and Newborn; Committee on Infectious Diseases. Epidemiology and diagnosis of health care-associated infections in the NICU. Pediatrics. 2012 Apr;129(4):e1104-9. doi: 10.1542/peds.2012-0147. Epub 2012 Mar 26. PMID: 22451708.
9. Xu J, Zhang Y, Ma H, Zhang R, Wu J. Analysis of Factors Related to Neonatal Infection and Monitoring of Bacterial Drug Resistance. Z Geburtshilfe Neonatol. 2022 Dec;226(6):399-404. doi: 10.1055/a-1850-2475. Epub 2022 Jul 4. PMID: 35785815; PMCID: PMC9731785.
10. AL-SELWI A. G., BARKAT A. Actions based on evidence to fight against neonatal mortality, international and national data: a meta-analysis. *Chinese journal of otorhinolaryngology head and neck surgery*. 2023 Nov; 54(09): 1155-1165.
11. Hattoufi K, Kharbach A, Barkat A. Infección bacteriana neonatal de inicio temprano con localización meníngea: informe de 57 casos de recién nacidos marroquíes. *Périnatalité*, 2021; 13(4):183-189. doi: 10.3166/rmp-2021-0136.
12. Rahmouni H. *Étude prospective des bactéries impliquées dans l'infection nosocomiale au service de réanimation néonatale à l'hôpital d'enfants de Rabat* [thèse]. Rabat (Maroc) : Université Mohammed V, Faculté de Médecine et de Pharmacie de Rabat ; 2022. Disponible sur: https://toubkal.imist.ma/bitstream/handle/123456789/19195/P0172022.pdf?sequence=1
13. Abdellaoui C. Incidence et epidemiologie des infections nosocomiales en neonatologie [thèse]. Rabat (Maroc) : Université Mohammed V, Faculté de Médecine et de Pharmacie de Rabat ; 2022. Disponible sur: https://toubkal.imist.ma/bitstream/handle/123456789/19181/P0032022.pdf?sequence=1
14. Bighoumdan K. Infections nosocomiales périopératoires chez les nouveau-nés en réanimation pédiatrique [thèse]. Marrakech (Maroc) : Université Cadi Ayyad, Faculté de Médecine et de Pharmacie de Marrakech; 2020.Disponible sur: https://toubkal.imist.ma/handle/123456789/21547
15. Helyaich A, Slitine N.E. I., Bennaoui F, Soraa N , Maoulainine F. M. R. Bacterial Nosocomial Infection: Experience of the Neonatal Intensive Care Unit at the University Hospital of Marrakech. Open Infect Dis J. 2019 ; 11(1). doi: 10.2174/1874279301911010017
16. Benabbas D.R, Kara S. Etude rétrospective sur les infections nosocomiales au niveau du service de néonatologie du CHU de Constantine [Mémoire de master]. Constantine (Algérie): Université Frères Mentouri Constantine 1, Faculté des Sciences de la Nature et de la Vie, Département de Biologie Appliquée; 2019. Disponible sur: https://fac.umc.edu.dz/snv/bibliotheque/biblio/mmf/2019/Etude%20r%C3%A9trospective%20sur%20les%20infections%20nosocomiales%20au%20niveau%20du%20service%20de%20n%C3%A9onatologie%20du%20CHU%20de%20Constantine..pdf
17. D'Almeida M, Bagnan L, Silé SN, Djagoun E, Ouendo EM, Ayivi B, Bouali Rouvinez N. Infections

nosocomiales. Étude rétrospective de 45 cas à l'Unité de Néonatologie du Centre National Hospitalier et Universitaire de Cotonou. J Afr Pediatr Genet Med. 2017 ;(2):20-25.

18. Cura C, Ozen M, Akaslan Kara A, Alkan G, Sesli Cetin E. Health care-associated infection surveillance in a tertiary neonatal intensive care unit: A prospective clinical study after moving to a new building. Am J Infect Control. 2016 Jan 1;44(1):80-4. doi: 10.1016/j.ajic.2015.07.032. Epub 2015 Aug 29. PMID: 26320701.
19. Kajiyazdi M, Dasdar S, Kianfar N, Kaveh M.. Nosocomial Infection Surveillance in Neonatal Intensive Care Units of Bahrami Children's Hospital. *Arch Pediatr Infect Dis*. 2021;9(3): e108840.doi: 10.5812/pedinfect.108840.
20. Rangelova V, Raycheva R, Kevorkyan A, Krasteva M, Dermendzhiev T. Surveillance of Nosocomial Infections in a Bulgarian Neonatal Intensive Care Unit. Folia Med (Plovdiv). 2020 Dec 31;62(4):753-761. doi: 10.3897/folmed.62.e50437. PMID: 33415917.
21. Torres-Muñoz J, Hoyos IV, Murillo J, Holguin J, Dávalos D, López E, Torres-Figueroa S. Device-associated infections in neonatal care units in a middle-income country, 2016-2018. J Pediatr (Rio J). 2023 Sep-Oct;99(5):485-491. doi: 10.1016/j.jped.2023.03.004. Epub 2023 May 3. PMID: 37148912; PMCID: PMC10492145.
22. Peters L, Olson L, Khu DTK, Linnros S, Le NK, Hanberger H, Hoang NTB, Tran DM, Larsson M. Multiple antibiotic resistance as a risk factor for mortality and prolonged hospital stay: A cohort study among neonatal intensive care patients with hospital-acquired infections caused by gram-negative bacteria in Vietnam. PLoS One. 2019 May 8;14(5):e0215666. doi: 10.1371/journal.pone.0215666. PMID: 31067232; PMCID: PMC6505890.
23. Choobdar F, Vahedi Z, Khosravi N, Khalesi N, Javid A, et al. Nosocomial Infection in an Iranian Neonatal Intensive Care Unit: Hospital Epidemiology and Risk Factors.Arch Pediatr Infect Dis.2020;8(4):e96850.https://doi.org/10.5812/pedinfect.96850.
24. Kuissi KE, Minto'o RS, Mimbila M, Medza ER, Koumba MR, et al. Epidemiological Aspects and Evolution of Nosocomial Infection in the Neonatology Unit of Angondje Teaching Hospital. Neonat Pediatr Med. 2019; 5: 182. Disponible sur: https://www.researchgate.net/publication/330564234_Neonatal_and_Pediatric_Medicine_Epidemiological_Aspects_and_Evolution_of_Nosocomial_Infection_in_the_Neonatology_Unit_of_Angondje_Teaching_Hospital?enrichId=rgreq-630ffad4dc1a195bfeb60af47ac91352-XXX&enrichSource=Y292ZXJQYWdlOzMzMDU2NDIzNDtBUzo3ODQ2NTczMzU0NjM5MzZAMTU2NDA4ODI5NTE4NA%3D%3D&el=1_x_2&_esc=publicationCoverPdf
25. Kilic A, Okulu E, Kocabas BA, Alan S, Cakir U, Yildiz D, Kahvecioglu D, Akin IM, Erdeve O, Arsan S, Ince E, Atasay B. Health care-associated infection surveillance: A prospective study of a tertiary neonatal intensive care unit. J Infect Dev Ctries. 2019 Mar 31;13(3):181-187. doi: 10.3855/jidc.10688. PMID: 32040446.
26. Ertugrul S, Aktar F, Yolbas I, Yilmaz A, Elbey B, Yildirim A, Yilmaz K, Tekin R. Risk Factors for Health Care-Associated Bloodstream Infections in a Neonatal Intensive Care Unit. Iran J Pediatr. 2016 Jul 27;26(5):e5213. doi: 10.5812/ijp.5213. PMID: 28203330; PMCID: PMC5297258.
27. Bukasa JC, Muteba P, Kazadi A, Lepelletier D, Ilunga F, Mutombo A, Kamanya AN, Bandimuna A, Mbo SN, Stany W. Etude de l´incidence des infections nosocomiales et facteurs de risque dans les maternités de la ville de Mbujimayi, République Démocratique du Congo [A study of the incidence of nosocomial infections and the associated risk factors in the city of Mbujimayi, Democratic Republic of Congo]. Pan Afr Med J. 2021 Jan 28;38:95. French. doi: 10.11604/pamj.2021.38.95.15044. PMID: 33889261; PMCID: PMC8035685.
28. Bedir Demirdağ T, Koç E, Tezer H, Oğuz S, Satar M, Sağlam Ö, Uygun SS, Önal E, Hirfanoğlu İM, Tekgündüz K, Oygür N, Bülbül A, Zübarioğlu AU, Üstün N, Ünal S, Aygün C, Saygılı Karagöl B, Zenciroğlu A, Öncel MY, Çakıl Sağlık A, Okulu E, Terek D, Narlı N, Aliefendioğlu D, Gürsoy T, Ünal S, Kaynak Türkmen M, Kaya Narter F, Aladağ Çiftdemir N, Beken S, Çakır SÇ, Yiğit Ş, Çoban A, Ecevit A, Çelik Y, Kulalı F. The prevalence and diagnostic criteria of health-care associated infections in neonatal intensive care units in Turkey: A multicenter point- prevalence study. Pediatr Neonatol. 2021 Mar;62(2):208-217. doi: 10.1016/j.pedneo.2021.01.001. Epub 2021 Jan 19. PMID: 33546932.
29. Crivaro V, Bogdanović L, Bagattini M, Iula VD, Catania M, Raimondi F, Triassi M, Zarrilli R. Surveillance of healthcare-associated infections in a neonatal intensive care unit in Italy during 2006-2010. BMC Infect Dis. 2015 Mar 25;15:152. doi: 10.1186/s12879-015-0909-9. PMID: 25885702; PMCID: PMC4374496.
30. El-Feky EA, Saleh DA, El-Kholy J, Sayed AM, Mansi Y, Hashem M. Use of personal digital assistants to detect healthcare-associated infections in a neonatal intensive care unit in Egypt. J Infect Dev Ctries. 2016 Nov 24;10(11):1250-1257. doi: 10.3855/jidc.7789. PMID: 27886039.
31. Kartikeswar GAP, Parikh TB, Randive B, Kinikar A, Rajput UC, Valvi C, Vaidya U, Malwade S, Agarkhedkar S, Kadam A, Smith RM, Westercamp M, Schumacher C, Mave V, Robinson ML, Gupta A, Milstone AM, Manabe YC, Johnson J. Bloodstream infections in neonates with central venous catheters in three tertiary neonatal intensive care units in Pune, India. J Neonatal Perinatal Med. 2023;16(3):507-516. doi: 10.3233/NPM-221110. PMID: 37718859; PMCID: PMC10875914.
32. Chabah M, Chemsi M, Zerouali K, Alloula O, Lehlimi M, Habzi A, Benomar S. Healthcare-associated infections due to carbapenemase-producing Enterobacteriaceae: Bacteriological profile and risk factors. Med Mal Infect. 2016 May;46(3):157-62. doi: 10.1016/j.medmal.2015.12.015. Epub 2016 Feb 17. PMID: 26897308.
33. Scamardo MS, Dolce P, Esposito EP, Raimondi F, Triassi M, Zarrilli R. Trends, risk factors and outcomes of healthcare-associated infections in a neonatal intensive care unit in Italy during 2013-

2017. Ital J Pediatr. 2020 Mar 18;46(1):34. doi: 10.1186/s13052-020-0799-3. PMID: 32183842; PMCID: PMC7079437.
34. Ceparano M, Sciurti A, Isonne C, Baccolini V, Migliara G, Marzuillo C, Natale F, Terrin G, Villari P, The Collaborating Group. Incidence of Healthcare-Associated Infections in a Neonatal Intensive Care Unit before and during the COVID-19 Pandemic: A Four-Year Retrospective Cohort Study. J Clin Med. 2023 Mar 30;12(7):2621. doi: 10.3390/jcm12072621. PMID: 37048704; PMCID: PMC10094878.
35. García H, Torres-Gutiérrez J, Peregrino-Bejarano L, Cruz-Castañeda MA. Factores de riesgo asociados a infección nosocomial (IN) en una Unidad de Cuidados Intensivos Neonatales (UCIN) de tercer nivel [Risk factors for nosocomial infection in a level III Neonatal Intensive Care Unit]. Gac Med Mex. 2015 Nov-Dec;151(6):711-9. Spanish. PMID: 26581528.
36. Verstraete EH, Mahieu L, De Coen K, Vogelaers D, Blot S. Impact of healthcare-associated sepsis on mortality in critically ill infants. Eur J Pediatr. 2016 Jul;175(7):943-52. doi: 10.1007/s00431-016-2726-6. Epub 2016 Apr 27. PMID: 27118596.
37. García H, Miranda-Novales G, Lorenzo-Hernández LM, Luna AT. Risk factors for healthcare-associated infections in newborns after surgery in a neonatal intensive care unit. Gac Med Mex. 2023;159(2):96-102. English. doi: 10.24875/GMM.22000270. PMID: 37094234.
38. Ramanampamonjy MTM, Rasamoelison RJ, Samena HSC, Rambeloson SH, Rahajamanana VL, Robinson AL. Facteurs de risque de bactériémie nosocomiale néonatale au Centre Hospitalier Universitaire Mère–Enfant Tsaralalana, Antananarivo, Madagascar. Rev Anesth Reanim Med Urg Toxicol. 2022;14(2):1-5.
39. Hmamouchi B, Chakkouri K, Nejmi SE, Chlilek A. Épidémiologie de l'infection nosocomiale en réanimation pédiatrique. Ann Fr Anesth Reanim. 2005;24(6):699-700. doi:10.1016/j.annfar.2005.04.011
40. Maoulainine FM, Elidrissi NS, Chkil G, Abba F, Soraa N, Chabaa L, Amine M, Aboussad A. Épidémiologie de l'infection nosocomiale bactérienne dans un service de réanimation néonatale marocain [Epidemiology of nosocomial bacterial infection in a neonatal intensive care unit in Morocco]. Arch Pediatr. 2014 Sep;21(9):938-43. French. doi: 10.1016/j.arcped.2014.04.033. Epub 2014 Jun 30. PMID: 24993147.
41. Sarvikivi E, Kärki T, Lyytikäinen O; Finnish NICU Prevalence Study Group. Repeated prevalence surveys of healthcare-associated infections in Finnish neonatal intensive care units. J Hosp Infect. 2010 Oct;76(2):156-60. doi: 10.1016/j.jhin.2010.03.020. Epub 2010 Jun 25. PMID: 20579770.
42. Zoukal S, Tsoumbou-Bakana G, Traore B, Nani S, Hassoune S. Infections associées aux soins en néonatalogie dans la région du grand Maghreb. Revue systématique et méta-analyse [Neonatal healthcare associated-infections in the Maghreb. A systematic review and meta-analysis]. Rev Epidemiol Sante Publique. 2021 Apr;69(2):88-95. French. doi: 10.1016/j.respe.2021.01.007. Epub 2021 Feb 25. PMID: 33642130.
43. de Mello Freitas FT, Viegas APB, Romero GAS. Neonatal healthcare-associated infections in Brazil: systematic review and meta-analysis. Arch Public Health. 2021; 79(1):89. 10.1186/s13690-021-00611-6