

Comparative Analysis of Neonatal Intensive Care Units (NICUs) Performance Indicators: A Systematic Review

Analyse comparative des indicateurs de performance des unités de soins intensifs néonataux (USIN) : Une revue systématique

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Abstract :

Objectives: To evaluate the key performance indicators of neonatal intensive care units (NICUs), including length of stay (LOS), neonatal mortality rates, admission and occupancy rates, to identify factors influencing outcomes and resource utilization.

Methods: A systematic review was conducted using the PRISMA 2020 guidelines and a pre-registered protocol on PROSPERO (CRD42024612635). Articles published between January 2013 and December 2024 were searched in PubMed, Scopus, and Web of Science. Inclusion criteria focused on observational studies reporting NICU key performance indicators. Two reviewers independently selected articles and assessed their quality using the NHLBI and MMAT tools.

Results: Out of 8,416 identified articles, 14 studies were included, representing high-income countries (64.29%) and middle to low-income countries (35.71%). Length of stay (LOS) was longest for preterm and low birth weight newborns, influenced by infections and clinical practices. Neonatal mortality rates ranged from 0.7% for term infants to 6.1% for preterm infants, with improvements linked to interventions like thermoregulation protocols. Admission rates varied by neonatal and maternal characteristics, with preterm infants comprising a significant share. Average occupancy rates highlighted resource utilization challenges, especially for high-risk populations, with quality improvement initiatives showing potential to optimize LOS and reduce overcrowding.

Conclusion: This review highlights disparities in NICU performance across different contexts and identifies critical factors influencing outcomes. The findings underscore the importance of targeted strategies to improve neonatal outcomes and optimize resource utilization in NICUs.

Keywords : Neonatal Intensive Care Units; NICU; Length of stay; Mortality; Admission rate.

Résumé :

Objectifs : Évaluer les indicateurs clés de performance des unités de soins intensifs néonataux (USIN), notamment la durée de séjour (LOS), les taux de mortalité néonatale, les taux d'admission et d'occupation, afin d'identifier les facteurs influençant les résultats cliniques et l'utilisation des ressources.

Méthodes : Une revue systématique a été réalisée conformément aux recommandations PRISMA 2020, à partir d'un protocole préenregistré sur PROSPERO (CRD42024612635). Les articles publiés entre janvier 2013 et décembre 2024 ont été recherchés dans PubMed, Scopus et Web of Science. Les critères d'inclusion concernaient les études observationnelles rapportant les indicateurs clés de performance des USIN. Deux évaluateurs ont sélectionné indépendamment les articles et évalué leur qualité à l'aide des outils NHLBI et MMAT.

Résultats : Sur 8 416 articles identifiés, 14 études ont été incluses, représentant des pays à revenu élevé (64,29 %) et des pays à revenu intermédiaire ou faible (35,71 %). La durée de séjour était plus longue chez les nouveau-nés prématurés et de faible poids de naissance, influencée par les infections et les pratiques cliniques. Les taux de mortalité néonatale variaient de 0,7 % pour les nouveau-nés à terme à 6,1 % pour les prématurés, avec des améliorations associées à des interventions telles que les protocoles de thermorégulation. Les taux d'admission variaient selon les caractéristiques néonatales et maternelles, les prématurés représentant une part importante des admissions. Les taux moyens d'occupation soulignaient les défis liés à l'utilisation des ressources, en particulier pour les populations à haut risque, tandis que les initiatives d'amélioration de la qualité montraient un potentiel pour optimiser la durée de séjour et réduire la surpopulation.

Conclusion : Cette revue met en évidence les disparités de performance des USIN selon les contextes et identifie les facteurs critiques influençant les résultats néonataux. Les résultats soulignent l'importance de stratégies ciblées pour améliorer la prise en charge néonatale et optimiser l'utilisation des ressources dans les USIN.

Mots clés : Unités de soins intensifs néonataux ; USIN ; Durée de séjour ; Mortalité ; Taux d'admission.

Introduction

Neonatal Intensive Care Units (NICUs) are hospital units specifically designed to care for newborns who are ill or born prematurely. They play a crucial role in reducing neonatal mortality and morbidity, offering advanced medical support during the earliest and most fragile stages of life. Globally, neonatal conditions, including preterm birth and infections, remain a significant concern, with an estimated 2.4 million neonatal deaths occurring annually, accounting for approximately 47% of all under-five deaths (UNIGME, 2024).

To assess and improve the performance of NICUs, healthcare systems rely on key performance indicators. These include Length of Stay (LOS), mortality rates, admission rates, and occupancy rates. Each of these metrics provides essential insights into the quality of care delivered and the efficiency of resource use. However, recent studies have highlighted significant variability in these key performance indicators across different healthcare settings, which highlights the need for a deeper understanding of these disparities (Profit et al. 2013, Ismail Mohamed et al. 2024). Previous studies have highlighted the influence of public financing on performance indicators in various sectors, such as education (Mezene et al., 2020). This underscores the need to examine how funding mechanisms affect NICU performance metrics.

Prolonged LOS in NICUs not only increases the risk of complications for newborns but also places a significant financial and emotional burden on families. Factors such as birth weight, gestational age, and neonatal conditions, including sepsis, bronchopulmonary dysplasia, and retinopathy of prematurity, can influence LOS (Fu et al. 2023). Moreover, prolonged LOS strains NICU resources and impacts post-discharge outcomes, emphasizing the need for standardized care protocols to minimize variability (Mehretie et al. 2024, Edwards et al. 2024). Advances in neonatal care have improved survival rates globally, but challenges remain. Extremely preterm infants, particularly those born at 22 weeks, still face poor survival rates, with only about 25% making it. Even at 25 weeks, survival often comes with long-term health complications (Edwards et al., 2024). Admission rates to NICUs also differ significantly between hospitals due to variations in demographics, maternal health conditions, and local policies. This variation raises questions about resource use, especially for lower-risk newborns who may not require intensive care (Harrison et al. 2015, Braun et al. 2020). This raises a broader questioning: What explains the wide disparities in NICU performance across countries and healthcare systems? To what extent do clinical practices, available resources, or policy frameworks account for these variations?

Occupancy rates are another critical performance indicator, offering insights into NICU resource utilization. High occupancy rates can strain resources, reduce care quality, and increase risks for neonates, particularly those requiring prolonged stays (Beltempo et al., 2023). However, simply increasing NICU capacity doesn't always lead to better outcomes. In some cases, it results in higher admissions for less critical cases, without improving survival rates (Goodman et al., 2024).

Given these challenges, there is a need for a comprehensive review to better understand the factors contributing to these disparities. To address these questions, we systematically reviewed observational studies published between 2013 and 2024, following the PRISMA 2020 guidelines and based on a pre-registered protocol. The selected studies were evaluated using validated quality assessment tools to ensure methodological rigor. This systematic review aims to analyze trends, identify gaps, and provide actionable insights into NICU performance indicators such as LOS, mortality, admission, and occupancy rates. These findings will support evidence-based recommendations to standardize care practices and improve neonatal outcomes globally.

The remainder of this article is structured as follows: the Methods section outlines the eligibility criteria, search strategy, and quality assessment process. The Results section presents the characteristics of included studies and a detailed analysis of NICU performance indicators, including length of stay, neonatal mortality, admission rates, and occupancy rates. The Discussion interprets the findings in relation to existing literature, addresses limitations, and proposes strategic and policy-level recommendations to improve neonatal intensive care practices.

1. METHODS

We conducted a systematic review to evaluate the performance of neonatal intensive care units (NICUs) by analyzing key performance indicators across various countries. The review adhered to the 2020 update of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supplementary file 1) (Page et al., 2020). It was conducted based on a protocol registered in PROSPERO (CRD42024612635) (Boutib et al., 2024).

1.1. Eligibility criteria

The inclusion criteria for selecting studies were as follows: 1) Observational studies, specifically cohort and cross-sectional designs; 2) Studies presenting key performance indicators of NICUs, such as neonatal mortality rate, length of stay (LOS), admission rates, and

average occupancy rate; 3) Neonatal populations admitted to NICUs across diverse healthcare settings; 4) Publications in English and French; 5) Studies published between January 2013 and December 2024. Duplicate records were identified and removed. To ensure the electronic search was comprehensive, each reviewer independently verified the inclusion of relevant studies by examining the reference lists of key articles. Any differences or possibly missed studies were discussed collaboratively to prevent the exclusion of eligible research.

Studies were excluded if they did not report NICUs performance indicators, were not observational studies (e.g., qualitative studies or randomized controlled trials), focused on neonatal care outside NICUs, or fell outside the defined publication timeframe.

1.2. Information Sources and Search Strategy

In November 2024, two reviewers conducted systematic searches throughout PubMed, Web of Science, and Scopus. The PICO's statement (population, intervention/exposition, control, and outcomes) was the basis for developing the research question (Harrison et al., 2020). Consequently, a research equation was created by combining equivalent free terms as follows: ("Neonatal intensive care units " OR " NICUs " AND " performance indicators " OR " admissions " OR " neonatal mortality rate " OR " length of stay " OR " occupancy rate").

1.3. Data Extraction and Quality Assessment

Following the removal of duplicates, titles and abstracts were initially screened using the Rayyan platform. Two reviewers (HL and AB) independently assessed all identified studies for eligibility. Any uncertainties or disagreements were resolved with the help of a third reviewer (ABa). Subsequently, the full text of studies deemed potentially eligible was reviewed by the same pairs of reviewers, with disagreements resolved through discussions involving the third reviewer. Additionally, the reference lists of included studies were reviewed to identify any eligible studies that may have been missed during the search process. Data extraction was carried out independently by the same two reviewers (HL and AB).

The extracted data from the included studies were organized using a standardized form, capturing details such as the first author, publication year, country, aim of the study, study design, sample size, key performance indicators (neonatal mortality rate, length of stay, admission rates, and average occupancy rate), and the main findings related to NICU performance. Two authors (HL and AB) assessed the methodological quality of the included studies using The National Heart, Lung, and Blood Institute (NHLBI) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (14 items), and the Mixed Methods

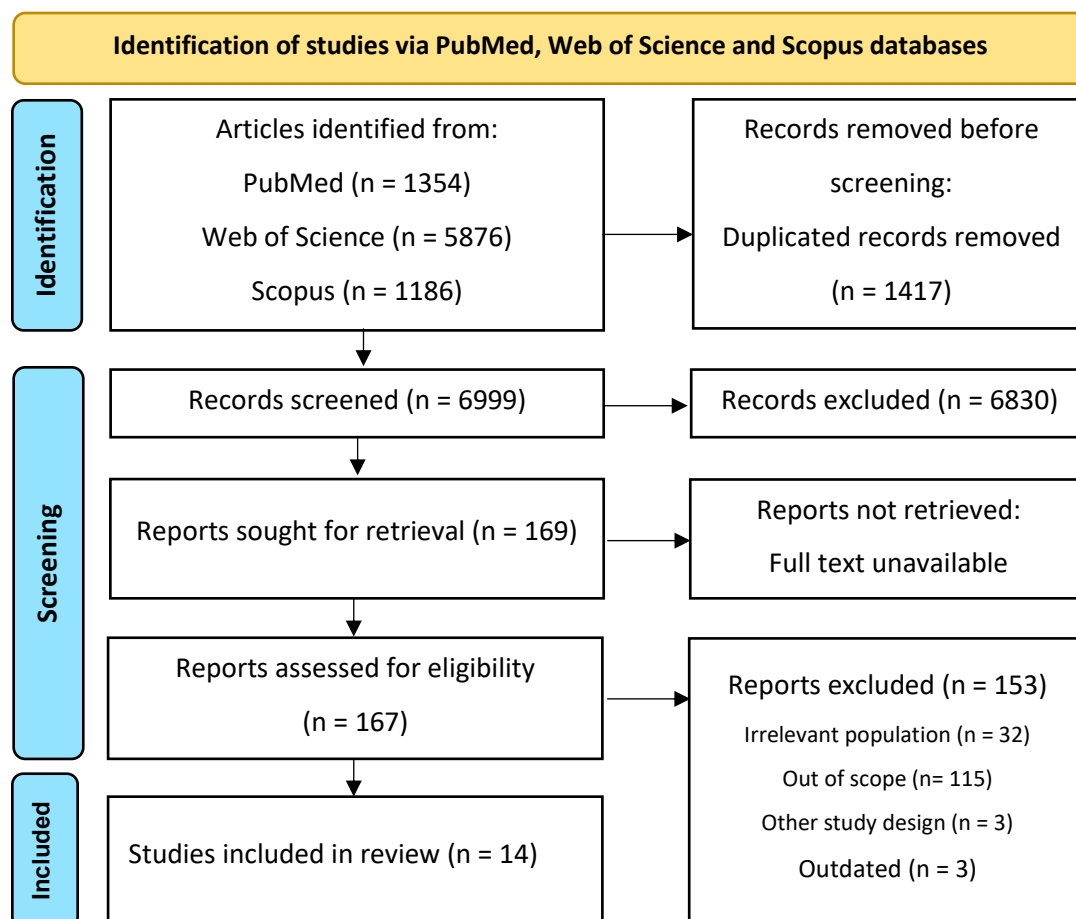
Appraisal Tool (MMAT) for evaluating Pre/Post-Intervention and development and validation studies (5 criteria) (Hong et al., 2018).

2. RESULTS

2.1. Search strategy

Our search strategy to evaluate the performance of the NICUs identified 8416 articles (1354 in PubMed, 1186 in Scopus, and 5876 from Web of Sciences). After removing 1417 duplicate records, we screened the titles and abstracts of 6999 unique studies. From this initial screening, 167 articles were selected for full-text review to determine eligibility. Ultimately, 14 studies met the inclusion criteria for this systematic review (Figure 1).

Figure N°1 : Flow chart showing the methodology for selecting articles on the performance indicators of neonatal intensive care units (NICUs)



Source: Authors

2.2.Characteristics of the included studies

The included studies represent various countries, providing a comprehensive overview of NICUs performance across healthcare settings. Among the included studies, 64.29% are from high-income countries such as the United States, Israel, and China. In comparison, the remaining 35.71% represent middle- to low-income countries, including Jordan, Zimbabwe, Vietnam, Iran and Ethiopia (Table 1).

Table N°1 : Basic characteristics of the included articles

Author, Year	Country	Aim of the Study	Study design	Sample size	key performance indicators	Findings
Profit et al., 2013	USA	To evaluate the influence of varying definitions of mortality on performance ratings of NICUs	Cross-sectional study	5289 very low birth weight (VLBW) infants	Risk-adjusted neonatal mortality rates using four different definitions of mortality	The time frame used to define mortality had minimal effect on NICU performance rankings. NICU rankings remained stable across different definitions, with significant variations in risk-adjusted mortality among NICUs.
Kaempf et al., 2015	USA	To develop a risk-adjusted composite morbidity and resource utilization score for VLBW infants, enabling NICUs to evaluate their performance in	Retrospective cohort study	15,961 VLBW infants	Composite morbidity score, length of stay, and resource utilization score	The composite morbidity and value metrics showed significant improvement over 12 years. However, increased length of stay reduced

		continuous quality improvement (CQI) projects				the improvements in value metrics. NICUs demonstrated varying levels of CQI proficiency, emphasizing the need for cost-efficient strategies to address interconnected morbidities.
Lee et al., 2016	USA	To develop models predicting the LOS for neonates in NICUs based on birth weight categories and assess whether NICU performance rankings vary across these groups	Retrospective cohort study	23,551 neonates	LOS stratified by birth weight categories (<1,000g, 1,000–1,500g, 1,500–2,499g, and ≥2,500g)	LOS prediction models were most effective for the smallest neonates (<1,000g). NICUs with shorter LOS for one birth weight group tended to show shorter LOS for others. Risk factors affecting LOS varied by birth weight strata, highlighting the importance of stratification in predictive models.
Zhu et al., 2020	China	To estimate the initial hospitalization charges for	Retrospective study	441 extremely preterm infants (gestational age < 28 weeks)	Total hospitalization charges, charge per day, LOS, survival	Median LOS was 70 days, with a median total charge of

		extremely preterm infants in China over ten years and analyze variations by gestational age, discharge year, survival status, and major morbidities			rates, and costs associated with major morbidities	\$20,770.70. Costs increased significantly over the decade, reflecting more intensive care and new technologies. Major morbidities significantly raised costs, with BPD, NEC, and sepsis being the costliest. Charges per day decreased with increasing gestational age.
Guri et al., 2020	Israel	To study the impact of third-generation cephalosporin-resistant Enterobacteriaceae (3GCR-EB) on length of hospital stay (LOS) and mortality in neonates and young infants	Retrospective cohort study	31,921 neonates and young infants (2,647 with positive Enterobacteriaceae cultures, of which 290 were 3GCR-EB)	LOS, Mortality rates (overall and by birth weight categories)	Neonates with 3GCR-EB had a median LOS 2.8 times longer than those with 3GCS-EB (susceptible) cultures (20 vs. 6 days). Mortality was significantly higher in 3GCR-EB cases. The impact of 3GCR-EB on LOS and mortality was more significant in normal birth weight neonates

						compared to LBW subgroups.
						The main indications for admission were prematurity (33.3%), respiratory distress syndrome (41.2%), and maternal PROM (21.1%). Significant differences in outcomes between term and preterm infants, with higher mortality and morbidity in preterm neonates. The mortality rate aligns with WHO Sustainable Development Goal targets. Recommendations include addressing the rising rates of cesarean sections and late preterm deliveries to improve neonatal outcomes.
Khasawneh et al., 2020	Jordan	To assess the prevalence and clinical profile of neonatal admissions and outcomes at King Abdullah University Hospital in Jordan	Retrospective cross-sectional descriptive study	1,444 neonates	Neonatal mortality rate, LOS, Respiratory distress syndrome, Rate of bronchopulmonary, Incidence of sepsis	

Singh et al., 2020	USA	To assess the impact of the EMPOWER antenatal program and rooming-in care for mothers with opioid use disorder (OUD) and their infants	Prospective observational cohort study	431 substance-exposed newborns (SENs)	NICU admission rates, Use of pharmacotherapy for neonatal opioid withdrawal syndrome (NOWS), Length of NICU and hospital stay, Breastfeeding initiation and continuation rates	Participation in EMPOWER and RI programs was associated with reduced pharmacotherapy, shorter NICU stays, and higher breastfeeding rates than historical controls.
Braun et al., 2020	USA	To describe population-based trends in NICU admissions, NICU patient-days, readmissions, and mortality in the birth population of a large integrated healthcare system	Retrospective cohort study	320 340 mothers with their neonates	NICU admission rates, Readmissions, mortality rates, Patient-days	Admission rates to the NICU and the number of NICU patient-days decreased over the study period without an increase in readmissions or mortality. The observed decrease was associated with the high Gestational Age and Birth Weight of the newborn population.
Gannon et al., 2021	Zimbabwe	To implement and evaluate the NeoTree beta app as a digital platform to improve newborn	Pre/post-intervention study	3,222 newborns	Turnaround time for blood culture results. Capture of neonatal admissions,	The NeoTree app successfully replaced paper-based documentation, improving data

		care in a low-resource setting, specifically focusing on improving infection management, reducing turnaround time for blood culture results, and supporting real-time data capture and quality improvement efforts			discharges, and deaths using the NeoTree app. Reduction in unnecessary antibiotic prescriptions. Improvement in data availability.	collection and supporting quality improvement projects. Reduction in NICU overcrowding. Blood culture turnaround time was initially reduced from 6 days to 3 days but was not sustained due to supply and staffing challenges. Antibiotic stewardship improved significantly, with reduced unnecessary prescriptions. However, challenges persisted in the laboratory component of the project.
Tran et al., 2021	Vietnam	To assess the impact of Early Essential Newborn Care (EENC) on newborn outcomes following	Pre/post-intervention study	16,927 newborns	NICU admissions before and after EENC introduction. Incidence of hypothermia and	NICU admissions decreased from 16.7% to 11.8% post-EENC implementation.

		caesarean section births in a tertiary hospital, particularly focusing on NICU admissions, hypothermia, sepsis, and breastfeeding outcomes			sepsis among NICU admissions. Rates of exclusive breastfeeding and kangaroo mother care (KMC)	Hypothermia cases declined from 5.0% to 3.7%. Sepsis cases decreased from 3.2% to 0.8%. Exclusive breastfeeding increased from 46.1% to 85.8% among NICU admissions. KMC among preterm newborns <2000 g increased from 50% to 67%.
Wang et al., 2022	China	To evaluate the efficacy of a quality improvement project implementing a temperature bundle to reduce admission hypothermia in VLBW infants in three tertiary NICUs in China	Pre/Post- intervention study	530 VLBW infants	Incidence of admission hypothermia. Mortality rate of VLBW infants. Mean body temperature on admission.	The incidence of hypothermia significantly decreased from 92.3% to 62% after implementing the temperature bundle. The mean admission temperature increased significantly from 35.5°C to 36.0°C ± 0.7°C. The mortality rate decreased

significantly from 16.1% in the pre-QI group to 8.8% in the post-QI group.

A temperature bundle, including measures such as a transport incubator, prewarmed hats, polyethylene wrap, team training, and standardized temperature documentation, improved outcomes for VLBW infants.

Kermani et al., 2023	Iran	To develop and validate a case-based reasoning system to predict neonatal survival and LOS in NICUs	Development and validation study	Development Phase: 1,682 neonates External Validation Phase: 92 neonates	Neonatal Survival Prediction Accuracy and LOS Prediction	The system accurately predicted neonatal survival with an F-score of 0.993.
						The LOS prediction system had an RMSE of 3.27 days, indicating good prediction accuracy. The usability score of the system was 80.71,

						suggesting high usability and acceptance by neonatologists.
						External validation results were consistent with the retrospective evaluation, confirming the robustness of the predictive model.
Frostig et al., 2023	Israel	To create a generalizable and robust model to predict the LOS of preterm newborns in NICUs to improve hospital planning, resource allocation, and parental support	Development and validation study	Development Phase: 5,362 newborns. External Validation: 8,768 newborns.	LOS prediction using a high-order quantile regression model.	The developed model outperformed existing models, achieving better accuracy for predicting LOS in preterm infants. The model achieved an MAE of 6.26 days, showing reliable prediction accuracy that can be used for NICU planning and parental support. A web-based application, calcuLOS, was also created to allow NICU staff

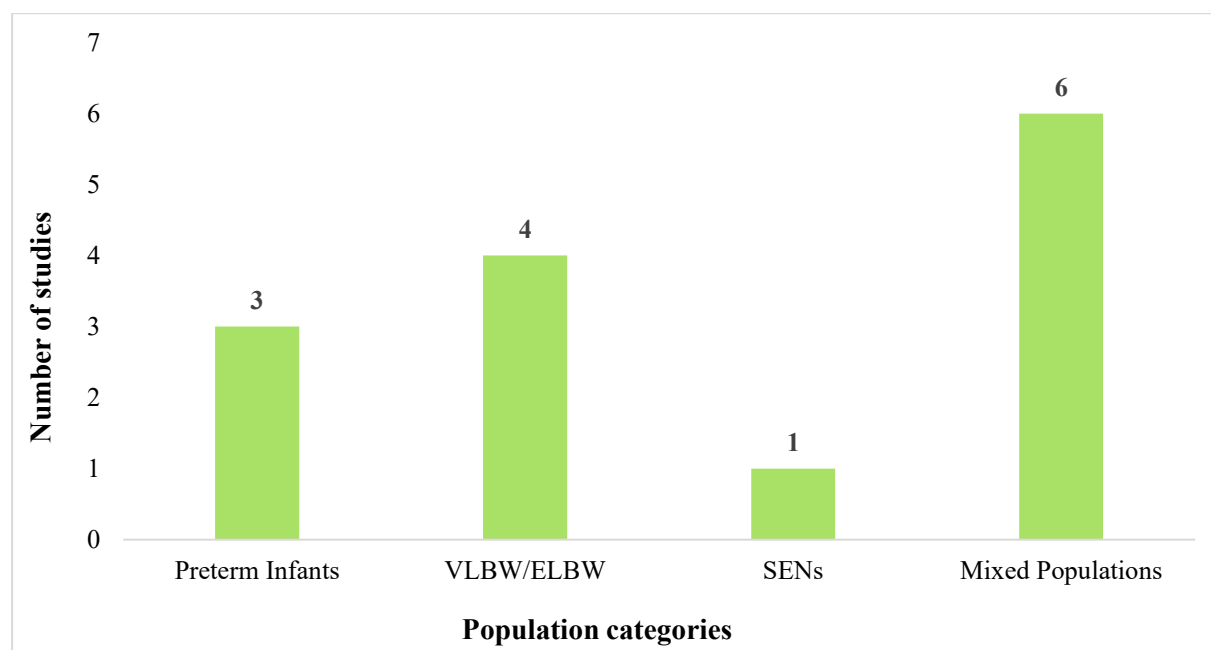
						and parents to use the model for estimating LOS in real time.
Mehretie et al., 2024	Ethiopia	To identify the length of hospital stay and associated factors among very-low-birth-weight preterm neonates	Cross-sectional study	110 VLBW preterm neonates	The length of hospital stay identification.	The median birth weight was 1370 g. The mean gestational age was 32.30±1.79 weeks. The median LOS was 24 days. The gestational age, type of initial management given, and presence of complications had a significant association with LOS for VLBW preterm neonates.

Source: Authors

Most studies (64.29%) employed a retrospective cohort design, allowing for an analysis of past NICUs performance across various indicators. A further 21.43% used a pre/post-intervention approach to evaluate the effects of specific changes, such as introducing early essential newborn care protocols. Additionally, 14.29% of the studies focused on developing and validating predictive models to assist healthcare professionals in NICUs management.

The populations included in these studies predominantly consist of high-risk neonates. Three of the studies focused on preterm infants born before 37 weeks of gestation. Four of the studies specifically addressed low birth weight (LBW) and extremely low birth weight (ELBW) infants, who require intensive monitoring due to their vulnerability. One study examined substance-exposed neonates (SENs), while six studies included mixed gestational age populations or neonates affected by specific conditions like sepsis (**Figure 2**).

Figure N°2 : Distribution of Study Populations Across Included NICU Studies



Preterm Infants: <37 weeks of gestation; VLBW: very low birth weight; ELBW: Extremely low birth; SENs: substance-exposed neonates

Source : Authors

2.3.Quality assessment for the included studies

Table 2 presents the quality assessment of seven studies, which include various observational designs such as cross-sectional, retrospective, and prospective cohort studies, conducted using the NHLBI Quality Assessment Tool. Most studies had clearly defined research questions and populations but lacked participation rate reporting, sample size justification, and comparison groups, affecting validity.

While eligibility criteria and time frames were consistent, none reported blinding, and exposure assessments were limited. Three studies were rated as "Good" (Mehretie et al. 2024, Braun et al. 2020, Lee et al. 2016) and six as "Fair" (Profit et al. 2013, Kaempf et al. 2015, Zhu et al. 2020, Guri et al. 2020, Khasawneh et al. 2020, Singh et al. 2020) with key weaknesses in comparison groups and blinding impacting overall reliability.

Table N° 2 : Quality assessment for observational studies included in the review

Criteria	Profit et al., 2013	Kaempf et al., 2015	Lee et al., 2016	Zhu et al., 2020	Guri et al., 2020	Khasa wneh et al., 2020	Singh et al., 2020	Braun et al., 2020	Mehre tie et al., 2024
Research Question	YES	YES	YES	YES	YES	YES	YES	YES	YES
Study Population	YES	YES	YES	YES	YES	YES	YES	YES	YES
Participation Rate	N/R	N/R	YES	N/R	N/R	N/R	N/R	YES	YES
Comparison Groups	NO	NO	YES	NO	NO	NO	NO	N/A	NO
Uniform Eligibility	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sample Size Justification	NO	NO	NO	N/R	N/R	NO	NO	YES	YES
Exposure Before Outcome	YES	YES	YES	YES	YES	N/A	N/A	YES	YES
Time Frame Sufficient	YES	YES	YES	YES	YES	YES	YES	YES	YES
Different Exposure Levels	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/R	NO
Exposure Measures	YES	YES	YES	YES	YES	N/R	N/R	YES	YES
Repeated Exposure	NO	NO	NO	NO	NO	NO	NO	N/R	NO
Outcome Measures	YES	YES	YES	YES	YES	YES	YES	YES	YES

Blinding of Outcome Assessors	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	NO
Follow-up Rate	N/R	N/R	YES	YES	YES	YES	YES	YES	YES
Overall Quality	Fair	Fair	Good	Fair	Fair	Fair	Fair	Good	Good

N/A, not applicable; N/R, not reported

Source : Authors

Regarding pre/post-intervention and development/validation studies, the MMAT indicated good quality across all included studies, with scores of 4.0 to 4.5. Pre/post-intervention studies (Gannon et al. 2021, Tran et al. 2021, Wang et al. 2022) consistently scored 4.0, showing strong methodology but limited by inconsistent adherence and generalizability issues. Development/Validation studies (Kermani et al. 2023, Frostig et al. 2023) were also well-rated, with the study of Tzviel Frostig et al. (2023), scoring the highest (4.5) due to strong external validation. Overall, studies with robust validation were rated more favorably, highlighting the value of thorough validation in enhancing reliability (**Table 3**).

These assessments underscore the importance of well-defined research questions, systematic data collection, and external validation in ensuring study quality. However, the lack of blinding and comparison groups remains a critical limitation across multiple studies, impacting their potential reliability and generalizability.

Table N° 3 : Quality assessment for Pre/Post-Intervention and development and validation studies included in the review

Study reference	Study design	Strengths	Limitations	MMAT Score
Hannah Gannon et al., 2021	Pre/Post-Intervention	Clear research question, Iterative improvements	Inconsistent adherence to intervention	4/5
Hoang Thi Tran et al., 2021	Pre/Post-Intervention	Clear data collection, Measurable improvement	Limited generalizability due to intervention variability	4/5

Li Wang et al., 2022	Pre/Post- Intervention	Robust temperature management interventions	Inconsistent execution across different centers	4/5
Farzaneh Kermani et al., 2023	Development and validation	Comprehensive data collection, Robust validation	Small usability sample size affecting generalizability	4/5
Tzviel Frostig et al., 2023	Development and validation	Strong external validation, Clear model evaluation	Complexity in data imputation, Potential biases	4.5/5

Source : Authors

2.4.Key Performance Indicators Analysis

2.4.1. Length of Stay (LOS)

The LOS varied widely across the included studies, reflecting differences in the populations under study, the type of NICUs care, and other influencing factors.

Figure 3 presents LOS data across various neonatal groups from the included studies. This figure summarizes the median LOS for each study population, showing the variation among preterm infants, VLBW infants, SENS, and mixed neonatal populations.

Across the thirteen studies analyzed, preterm and LBW infants consistently demonstrated longer LOS. For example, Frostig et al. (2023) reported a median LOS of 18.6 days for preterm infants with gestational age (AG) between 23 and 36 weeks, and 5.9 days for full-term infants (>36 weeks AG). In contrast, Zhu et al. (2020) reported a median LOS of 70.0 days for extremely preterm (EP) infants (<28 weeks AG). In particular, survivors born at 24 weeks had a median LOS of 125 days, compared to 74 days for those born at 27 weeks, highlighting the variability in LOS based on AG. Lee et al. (2016) also noted that lower birth weight significantly influenced LOS, even within stratified birth weight groups. For infants weighing <1,000 g, the median LOS was 79 days, whereas infants between 1,000 and 1,500 g had a median LOS of 46 days, and those weighing 1,500 to 2,500 g had a median LOS of 21 days. The shortest median LOS was observed in infants $\geq 2,500$ g, at 8 days (Lee et al., 2016). In another study in Ethiopia, the median LOS for VLBW preterm infants was 24 days, and it was associated with gestational age, presence of complications, and type of initial management given (Mehretie et al., 2024). Guri et al. (2020) found that LBW neonates with Third Generation

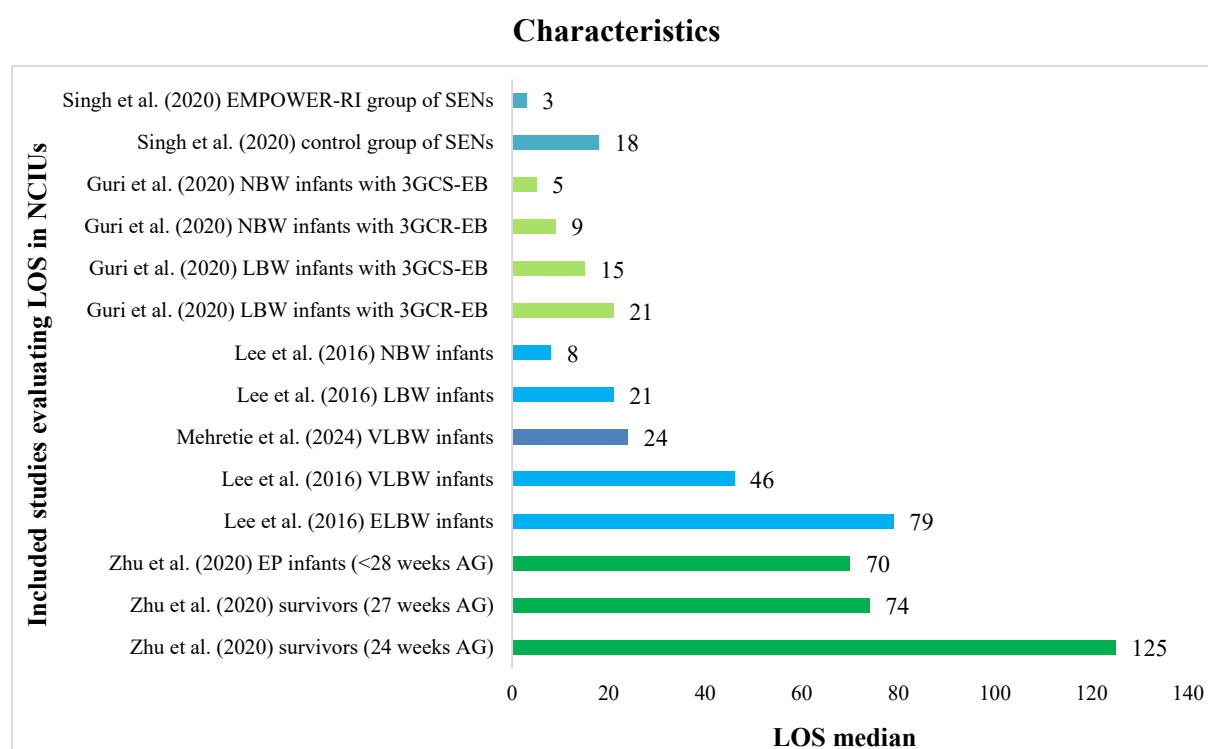
Cephalosporin Resistant Enterobacteriaceae (3GCR-EB) had a median LOS of 21 days, compared to 15 days for those with susceptible infections. For neonates born at normal birth weight, the LOS ranged from 9 days for those with 3GCR-EB to 5 days for susceptible cases (Guri et al., 2020).

Singh et al. (2020) showed that implementing the Engaging Mothers for Positive Outcomes with Early Referral (EMPOWER), an antenatal program to support mothers in their pregnancy, along with subsequent mother-infant dyad participation in rooming-in (RI) significantly reduced LOS for SENs from 18 days in the control group to 3 days in the intervention group ($p < 0.001$). Overall hospital LOS also decreased from 20 to 13 days (Singh et al., 2020).

Braun et al. (2020) reported a mean NICU patient-day decrease from 1.50 patient-days per birth in 2010 to 1.40 patient-days per birth in 2018, reflecting a 7% relative decrease in average LOS over the study period. This decrease was particularly observed in newborns of high gestational age and birth weight, who accounted for most of the change (Braun et al., 2020).

Kermani et al. (2023) developed a predictive model to estimate the LOS in NICUs, demonstrating high accuracy. The model's predictions deviated by an average of only 3.27 days when tested on a separate dataset, highlighting its potential to optimize NICU resource planning and improve efficiency (Kermani et al., 2023).

Figure N°3 : Comparison of Length of Stay Across NICUs by Study and Population



SENs: substance-exposed neonates; NBW: Normal birth weight ≥ 2500 g; LBW : Low birth weight 1500g - <2500g; VLBW: very low birth weight 1000g - <1500 g; ELBW: Extremely low birth <1000g; EP: Extremely Preterm Infants <28 weeks of gestation;

Source: Authors

2.4.2. Neonatal mortality rates

Neonatal mortality rates varied significantly across the included studies, reflecting differences in healthcare settings, population characteristics, and medical practices (**Table 4**).

Mortality rates ranged from 0.7% in term infants to 6.1% in preterm neonates, with gestational age and birth weight being critical determinants of survival (Khasawneh et al., 2020). Zhu et al. (2020) highlighted improvements in survival rates among extremely preterm infants (<28 weeks gestation), increasing from 56.7% in 2010 to 83.1% in 2019 (Zhu et al., 2020). Infection-related factors also played a substantial role; neonates with antibiotic-resistant infections had higher mortality rates compared to those with susceptible infections (62.1 vs. 22.1 per 1,000 live births) (Guri et al., 2020). Interventions like thermoregulation quality improvement project reduced in-hospital mortality from 16.1% to 8.8% (Wang et al., 2022). Braun et al. (2020) reported that neonatal mortality rates remained stable between 0.25% and 0.32% over nine years (2010–2018) in a large integrated healthcare system, with no significant trends or changes over time (P for trend = 0.88). Their findings highlight the relative consistency of mortality rates, even as NICU practices evolved (Braun et al., 2020). Furthermore, Profit et al. (2013) underscored the influence of NICU-specific factors, demonstrating that risk-adjusted mortality rates varied significantly across units, highlighting the impact of care protocols and resource availability on neonatal outcomes (Kermani et al., 2023).

Table N° 4 : Summary of neonatal mortality rates and associated findings

Study	Mortality Rate (%)	Population Characteristics	Key Findings and Observations
Khasawneh et al., 2020	6.1	Preterm neonates (<37 weeks gestation)	Higher mortality among preterm neonates compared to term neonates (0.7%).
Zhu et al., 2020	17.0	Extremely preterm (<28 weeks gestation)	Survival rates improved over time (56.7% in 2010 to 83.1% in 2019).

Guri et al., 2020	6.21	Neonates with antibiotic-resistant infections	Mortality is significantly higher in resistant cases (62.1/1,000) vs. susceptible cases (22.1/1,000).
Wang et al., 2022	8.8	NICU population (post-intervention)	Reduction in-hospital mortality from 16.1% to 8.8% after quality improvement intervention.
Profit et al., 2013	4.1	Neonates (12–28 days post-birth)	Mortality varied significantly across NICUs, influenced by site-specific factors.
Braun et al., 2020	0.25 – 0.32	Neonates in a large integrated health care system (from 2010 to 2018)	No significant trends in neonatal mortality over time. Mortality rates remained stable between 0.25% and 0.32%.

Source: Authors

2.4.3. Admission and average occupancy rates

Admission rates varied across studies, reflecting differences in neonatal populations, maternal factors, and healthcare systems. Late preterm neonates accounted for 37.7% of NICUs admissions, while term infants were often admitted due to conditions such as prolonged rupture of membranes (21.1%) (Khasawneh et al., 2020). Maternal and neonatal factors significantly influenced admission rates. Braun et al. (2020) reported a decrease in NICU admission rates from 14.5% in 2010 to 10.9% in 2018, a 25% relative decrease, attributed primarily to changes in the care of newborns with high gestational age (≥ 35 weeks) and birth weight (≥ 2000 g). This decrease was supported by quality improvement initiatives to reduce unnecessary NICU admissions, particularly for well-appearing newborns (Izulla et al., 2023). Tran et al. (2021) demonstrated that Early Essential Newborn Care (EENC) protocols effectively reduced NICUs admissions among neonates born via cesarean section, decreasing from 16.7% to 11.8%. Average occupancy rate data, though less frequently reported, highlighted the strain on NICUs resources imposed by high-risk neonates. Preterm and LBW infants contributed to NICUs occupancy due to prolonged stays (Zhu et al., 2020). Additionally, antibiotic-resistant infections extended hospital stays and increased average occupancy rates, as noted by Guri et al. (2020). Gannon et al. (2021) introduced the NeoTree app, which supported quality improvement efforts and data-driven management, contributing to reduced NICUs overcrowding and improved antimicrobial stewardship. Kaempf et al. (2015) reported increased LOS for VLBW infants from 64 to 71 days over 12 years, alongside

significant improvements in NICUs quality metrics, reflecting a focus on continuous care improvement. Quality improvement interventions, such as the temperature bundle implemented by Wang et al. (2022), demonstrated the potential for optimizing the average occupancy rate by reducing the length of stay and improving neonatal outcomes.

3. DISCUSSION

This systematic review synthesized evidence from 13 studies to evaluate key performance indicators of NICUs across various healthcare settings. The analysis revealed significant variability in key performance indicators, including LOS, mortality, admission rates, and average occupancy rates. LOS was consistently prolonged among high-risk neonates, particularly preterm and LBW infants, and was further influenced by infection status. Mortality rates also varied, with improvements linked to interventions such as thermoregulation protocols. Admission rates reflected differences in neonatal populations and maternal factors, while occupancy rates data highlighted resource utilization challenges, particularly for NICUs serving high-risk populations.

The variability in LOS observed in this review aligns with existing evidence highlighting the complex interplay of gestational age, birth weight, infection status, and clinical practices in determining NICUs stay duration. Across the studies in this review, preterm and low birth weight infants consistently demonstrated longer stays, reflecting their increased vulnerability to complications and need for intensive care. These findings are supported by existing literature, which identifies gestational age and birth weight as critical predictors of LOS. For instance, a systematic review emphasized that lower gestational age and birth weight strongly contribute to prolonged NICUs stays (Fu et al. 2023), a conclusion consistent with studies included in this review. In line with this, Braun et al. (2020) reported a relative decrease in mean NICU patient-days, indicating a reduction in length of stay. This decrease was primarily attributed to changes in the care of newborns with high gestational age and birth weight and the implementation of quality improvement initiatives aimed at reducing unnecessary NICU admissions. These findings underscore the importance of standardized care protocols in optimizing resource utilization and reducing LOS (Braun et al., 2020). Infection-related factors significantly contributed to LOS variability, as highlighted in this review. For instance, Guri et al. (2020) demonstrated the impact of antibiotic-resistant infections on prolonged hospital stays, also Mehretie et al. (2024) found that neonates managed with continuous positive airway pressure and antibiotics were highly likely to stay longer than neonates only given supportive care (Mehretie et al. 2024). These findings are consistent with studies from other settings, such as a cohort study in Vietnam, which showed that infections with multidrug-resistant gram-negative bacteria increased LOS by an average of 2.1 days for each additional resistance encountered (Peters et al., 2019). Variations in clinical practices, such as discharge criteria and quality improvement initiatives, significantly contribute to LOS variability.

Standardized care protocols, as demonstrated by Singh et al. (2020) and Seaton et al. (2016), effectively reduce LOS by minimizing practice variability and optimizing resource utilization.

The variability in neonatal mortality rates observed in this review reflects a complex interplay of factors, including gestational age, birth weight, infection status, and the quality of care provided. Preterm birth and low birth weight are consistently identified as significant risk factors for neonatal mortality, as these infants are more susceptible to complications such as respiratory distress and infections (Zhu et al. 2020, Khasawneh et al. 2020). This finding is consistent with existing literature, which underscores the critical role of these factors in neonatal outcomes (Wang et al., 2022). Infection status, particularly the presence of antibiotic-resistant organisms, further exacerbates mortality risk. The studies included in this review highlight the impact of such infections on neonatal outcomes, underscoring the importance of effective infection control measures (Guri et al., 2020). This is consistent with broader research indicating that nosocomial infections significantly contribute to neonatal mortality (Kermani et al., 2020). The quality of neonatal care also plays a pivotal role in improving survival rates. While interventions like EENC protocols show promise in improving care practices, further evidence is needed to confirm their direct impact on reducing neonatal mortality rates, particularly in post-cesarean-section newborns. For example, while EENC is associated with improved early newborn care practices, further data are needed to confirm whether these improvements translate into expected reductions in neonatal mortality, particularly in post-cesarean-section newborns (Tran et al., 2021). Izulla et al. (2023) demonstrated that specific quality improvement initiatives can significantly reduce neonatal deaths, highlighting the importance of targeted interventions. However, Braun et al. (2020) remind us that despite quality efforts, mortality rates can remain resistant to change, showing the multifaceted nature of neonatal mortality determinants. These findings underscore the need for comprehensive strategies that address medical, social, and systemic factors to enhance neonatal survival rates and highlight the importance of context-specific approaches in improving outcomes.

The variability in NICUs admission rates observed in this review aligns with findings from existing literature, which highlight the role of neonatal demographics, maternal health, and clinical practices. Late preterm neonates contribute significantly to admissions, while term infants are often admitted due to complications such as prolonged membrane rupture (Khasawneh et al., 2020). Studies have shown that standardized interventions, like EENC, effectively reduce admission rates without compromising outcomes (Tran et al., 2021).

Average occupancy rates reflect NICUs resource utilization and is heavily influenced by the prolonged stays of high-risk neonates, particularly preterm and LBW infants. This aligns with evidence indicating that high occupancy rates strain resources and are associated with increased mortality and morbidity among very preterm infants (Beltempo et al., 2023).

The transferability of effective NICU practices to low-resource settings remains a key challenge. Interventions such as thermoregulation bundles or discharge protocols may require adaptation to local

constraints. Tailored strategies are needed to ensure both feasibility and sustainability in low- and middle-income countries.

Conclusion

In summary, this systematic review highlights the significant variability in key performance indicators of NICUs, including LOS, mortality, admission, and occupancy rates, emphasizing the multifactorial nature of neonatal outcomes. While targeted interventions, such as standardized care protocols and quality improvement initiatives, show promise in addressing these challenges, further research is needed to validate their impact across diverse healthcare settings. Addressing systemic and clinical barriers, along with ensuring equitable resource distribution, is essential for improving NICU outcomes. Policymakers and health system leaders should prioritize investments in neonatal care infrastructure, strengthen training and staffing strategies, and implement national quality standards. In addition, promoting cross-sectoral collaboration and integrating NICU performance goals into broader maternal and child health policies can help reduce disparities and enhance care quality across all settings.

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