

SYSTEMATIC REVIEW

A Systematic Review on the Effectiveness and Safety of Non-Invasive Ventilation (CPAP, BiPAP, and HFNC) for Acute Respiratory Distress in Pediatric Emergency Care

Revisión sistemática sobre la eficacia y seguridad de la ventilación no invasiva (CPAP, BiPAP y HFNC) para el tratamiento de la dificultad respiratoria aguda en la atención pediátrica de urgencias

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ABSTRACT

Introduction: non-invasive ventilation therapies such as Continuous Positive Airway Pressure (CPAP), High Flow Nasal Cannula (HFNC), and Bilevel Positive Airway Pressure (BiPAP) are commonly used in children with acute respiratory failure and adult ICU patients. However, the effectiveness and tolerability of each method remain a subject of debate.

Objective: this systematic review compares the effectiveness, safety, and comfort of using CPAP, HFNC, and BiPAP in pediatric patients with respiratory disorders and adult patients with acute respiratory failure in the ICU.

Method: included randomized controlled trials (RCTs), observational cohort studies, and retrospective studies comparing CPAP, HFNC, and BiPAP in pediatric and adult populations. Data on treatment outcomes, failure, physiological parameters, patient comfort, and mortality were systematically analyzed.

Results: CPAP tends to improve acid-base parameters (pH, PCO₂, P/F ratio) more quickly than HFNC, but HFNC provides better oxygen saturation (SpO₂, PaO₂) and higher patient comfort. The rate of CPAP treatment failure is lower than that of HFNC, though not significantly so. In patients with severe bronchiolitis, HFNC is more tolerable with fewer side effects. In COVID-19 ICU patients, BiPAP and CPAP have equivalent efficacy and safety with no significant differences in mortality and treatment failure. Pre-hospital NIV therapy is also proven to be safe and effective.

Conclusion: CPAP and HFNC are both effective for treating respiratory failure in children, with CPAP providing faster physiological improvement and HFNC being more comfortable. BiPAP and CPAP are equally effective and safe in adult patients with acute respiratory failure, particularly COVID-19. Therapy selection should consider the patient's clinical condition and tolerability.

Keywords: Acute Respiratory Failure; CPAP; HFNC; BiPAP.

RESUMEN

Introducción: las terapias de ventilación no invasiva, como la Presión Positiva Continua en las Vías Respiratorias (CPAP), la Cánula Nasal de Alto Flujo (HFNC) y la Presión Positiva Bilevel en las Vías Respiratorias (BiPAP),

se utilizan comúnmente en niños con insuficiencia respiratoria aguda y en pacientes adultos en la UCI. Sin embargo, la eficacia y la tolerabilidad de cada método siguen siendo objeto de debate.

Objetivo: esta revisión sistemática tiene como objetivo comparar la eficacia, seguridad y comodidad del uso de CPAP, HFNC y BiPAP en pacientes pediátricos con trastornos respiratorios y en pacientes adultos con insuficiencia respiratoria aguda en la UCI.

Método: se incluyeron estudios que comprendían ensayos controlados aleatorizados (ECA), estudios de cohortes observacionales y estudios retrospectivos que comparaban CPAP, HFNC y BiPAP en poblaciones pediátricas y adultas. Se analizaron sistemáticamente los datos sobre los resultados del tratamiento, el fracaso terapéutico, los parámetros fisiológicos, la comodidad del paciente y la mortalidad.

Resultados: la CPAP tiende a mejorar los parámetros ácido-base (pH, PCO₂, relación P/F) más rápidamente que la HFNC, pero la HFNC proporciona una mejor saturación de oxígeno (SpO₂, PaO₂) y mayor comodidad para el paciente. La tasa de fracaso del tratamiento con CPAP es menor que con HFNC, aunque no de manera significativa. En pacientes con bronquiolitis grave, la HFNC es más tolerable y presenta menos efectos secundarios. En pacientes con COVID-19 en la UCI, BiPAP y CPAP tienen una eficacia y seguridad equivalentes, sin diferencias significativas en la mortalidad ni en el fracaso terapéutico. La terapia NIV prehospitalaria también ha demostrado ser segura y eficaz.

Conclusión: CPAP y HFNC son ambas eficaces para tratar la insuficiencia respiratoria en niños, siendo CPAP más rápida en la mejora fisiológica y HFNC más cómoda. BiPAP y CPAP son igualmente eficaces y seguras en pacientes adultos con insuficiencia respiratoria aguda, especialmente en casos de COVID-19. La selección de la terapia debe considerar la condición clínica y la tolerabilidad del paciente.

Palabras clave: Insuficiencia Respiratoria Aguda; CPAP; HFNC; BiPAP.

INTRODUCTION

Acute respiratory distress is recognized as one of the significant causes of morbidity and mortality among children who present to the emergency department.^(1,2) This condition often progresses rapidly if not managed appropriately, leading to respiratory failure that requires invasive mechanical ventilation.^(3,4) Therefore, early identification and timely therapeutic intervention are critical to prevent deterioration and improve outcomes. In emergency care, where immediate access to invasive ventilation may be limited, the use of effective non-invasive strategies becomes increasingly important.^(5,6) Clinical guidelines also emphasize the role of structured assessment and escalation protocols to reduce complications. Consequently, the selection of optimal respiratory support modalities plays a crucial role in pediatric emergency practice.^(7,8)

Non-invasive ventilation (NIV) has emerged as a first-line intervention for acute pediatric respiratory failure, particularly in emergency settings.^(9,10) NIV encompasses modalities such as Continuous Positive Airway Pressure (CPAP) and Bilevel Positive Airway Pressure (BiPAP), which are widely accepted for their clinical benefits. In addition, High-Flow Nasal Cannula (HFNC) is increasingly categorized under NIV, even though it does not fully meet the classical definition of positive pressure ventilation.^(11,12) The widespread clinical use of HFNC is primarily attributed to its ease of application, reduced invasiveness, and enhanced patient comfort. Despite these advantages, debates persist regarding the comparative effectiveness of HFNC and traditional NIV modalities. This highlights the need for continuous reassessment of clinical practices and definitions within pediatric respiratory care.^(13,14)

Several meta-analyses and network meta-analyses on acute respiratory infections in children have reported that CPAP and HFNC significantly reduce the risk of treatment failure and intubation compared with standard oxygen therapy.^(15,16) However, these studies consistently indicate that there is no significant difference in in-hospital mortality between the two modalities.^(17,18) This finding suggests that while NIV reduces the immediate need for invasive procedures, long-term survival outcomes may depend on additional clinical factors. Meanwhile, research specifically addressing BiPAP in pediatric populations remains limited. The small number of available studies and the predominance of indirect evidence make it difficult to establish firm conclusions regarding its role. Therefore, the need to consolidate existing knowledge through systematic evaluation is evident.⁽¹⁹⁾

Observational studies and randomized controlled trials (RCTs) have compared CPAP and HFNC in pediatric respiratory conditions such as bronchiolitis and asthma. CPAP has been shown to improve gas exchange parameters but is often associated with early treatment failure due to patient discomfort, mask intolerance, and mucosal ulceration. In contrast, HFNC demonstrates better tolerability, reduced patient distress, and higher compliance in clinical practice. Nevertheless, some patients who initially receive HFNC may eventually require rescue CPAP if the response is insufficient.^(20,21) This reflects the clinical trade-off between physiological effectiveness and patient comfort. Hence, both modalities remain essential, with their application dependent on patient-specific conditions and resource availability.^(22,23)

Given the inconsistent results across studies and the limited evidence on BiPAP in pediatric populations, a comprehensive systematic review is urgently required. Such a review would directly compare the efficacy and safety profiles of CPAP, BiPAP, and HFNC in managing acute respiratory distress among children in emergency settings. By systematically analyzing existing RCTs and observational studies, clinicians can obtain more reliable insights to guide evidence-based practice.^(24,25) Moreover, synthesizing current data can help inform future clinical guidelines and standardize therapeutic approaches. Ultimately, a systematic review will clarify the relative benefits of these modalities and support the development of patient-centered treatment strategies.

METHOD

Research Design

This study is designed as a systematic review that aims to summarize and critically evaluate the scientific evidence available regarding using non-invasive ventilation (NIV) in pediatric acute respiratory distress. The primary focus is on comparing the effectiveness and safety of three primary NIV modalities, namely Continuous Positive Airway Pressure (CPAP), Bilevel Positive Airway Pressure (BiPAP), and High-Flow Nasal Cannula (HFNC), within the specific setting of the emergency department (ED). The systematic review approach was selected because it allows for structured integration of diverse research findings, including randomized controlled trials, observational studies, and retrospective analyses. The review seeks to identify consistent trends and address knowledge gaps in pediatric emergency respiratory care by consolidating data from multiple sources. Additionally, this design helps ensure that evidence-based recommendations can be formulated to guide clinical decision-making. Ultimately, the review intends to provide clinicians with a comprehensive reference for optimizing respiratory support strategies in children with acute respiratory distress in emergency conditions.

Search Methode

The literature search for this systematic review was conducted across three primary scientific databases, namely PubMed, ScienceDirect, and Google Scholar. These databases were selected because they provide broad coverage of biomedical, clinical, and multidisciplinary research, ensuring comprehensive retrieval of relevant studies. The search strategy employed a structured combination of keywords and Boolean operators, specifically: (“non-invasive ventilation” OR “NIV” OR “CPAP” OR “BiPAP” OR “HFNC”) AND (“pediatric” OR “children” OR “infant” OR “neonate”) AND (“acute respiratory distress” OR “respiratory failure”) AND (“emergency department” OR “emergency care” OR “acute care”). This search formula was designed to maximize sensitivity while maintaining specificity for pediatric acute respiratory conditions studies. The inclusion period was set between January 2015 and December 2025 to ensure that both recent and relevant evidence were captured. All retrieved records were systematically exported and organized using Zotero software to facilitate proper citation management and duplicate removal. This structured approach was intended to improve the literature selection process’s transparency, reproducibility, and reliability.

Eligibility Criteria for Study Selection

The eligibility criteria for study selection in this systematic review were established to ensure the inclusion of high-quality and relevant research. Studies were included if they specifically evaluated the effectiveness or safety of Continuous Positive Airway Pressure (CPAP), Bilevel Positive Airway Pressure (BiPAP), or High-Flow Nasal Cannula (HFNC) in pediatric patients aged 0-18 years presenting with acute respiratory distress. Eligible studies were required to be conducted in emergency departments, acute care units, or intensive care units (ICUs), ensuring the focus remained on acute and critical clinical settings. Only studies employing robust research designs, such as randomized controlled trials (RCTs), cohort studies, case-control studies, and other observational methodologies, were considered appropriate for inclusion. Furthermore, the selected articles had to be published in English between 2015 and 2025 and have full-text availability to allow comprehensive evaluation. On the other hand, exclusion criteria were equally important to maintain methodological rigor. Studies involving adult populations, animal experiments, or laboratory-based research were excluded, as were editorials, opinion pieces, single case reports, and narrative reviews that lacked empirical data. Additionally, articles without full-text access or those that did not explicitly address CPAP, BiPAP, or HFNC as primary interventions were excluded from the final analysis.

Study Selection

The article selection process in this systematic review is presented in figure 1, which outlines each stage of identification, screening, eligibility, and inclusion. Initially, 549 records were identified from electronic databases, while no additional records were obtained from registers. Before screening, 189 duplicate records and 125 records automatically marked as ineligible by automation tools were removed, leaving 235 articles for initial screening. During the screening stage, 217 articles were excluded after reviewing titles and abstracts, and only 18 reports were sought for full-text retrieval. Four reports could not be retrieved, resulting in 14 articles

being assessed for eligibility. At this stage, seven articles were excluded, specifically three literature reviews and four articles published in languages other than English, which did not meet the inclusion criteria. Finally, seven studies fulfilled all eligibility criteria and were included in the final synthesis of this systematic review. This rigorous and transparent selection process demonstrates a structured approach to ensure methodological integrity and reduce bias.

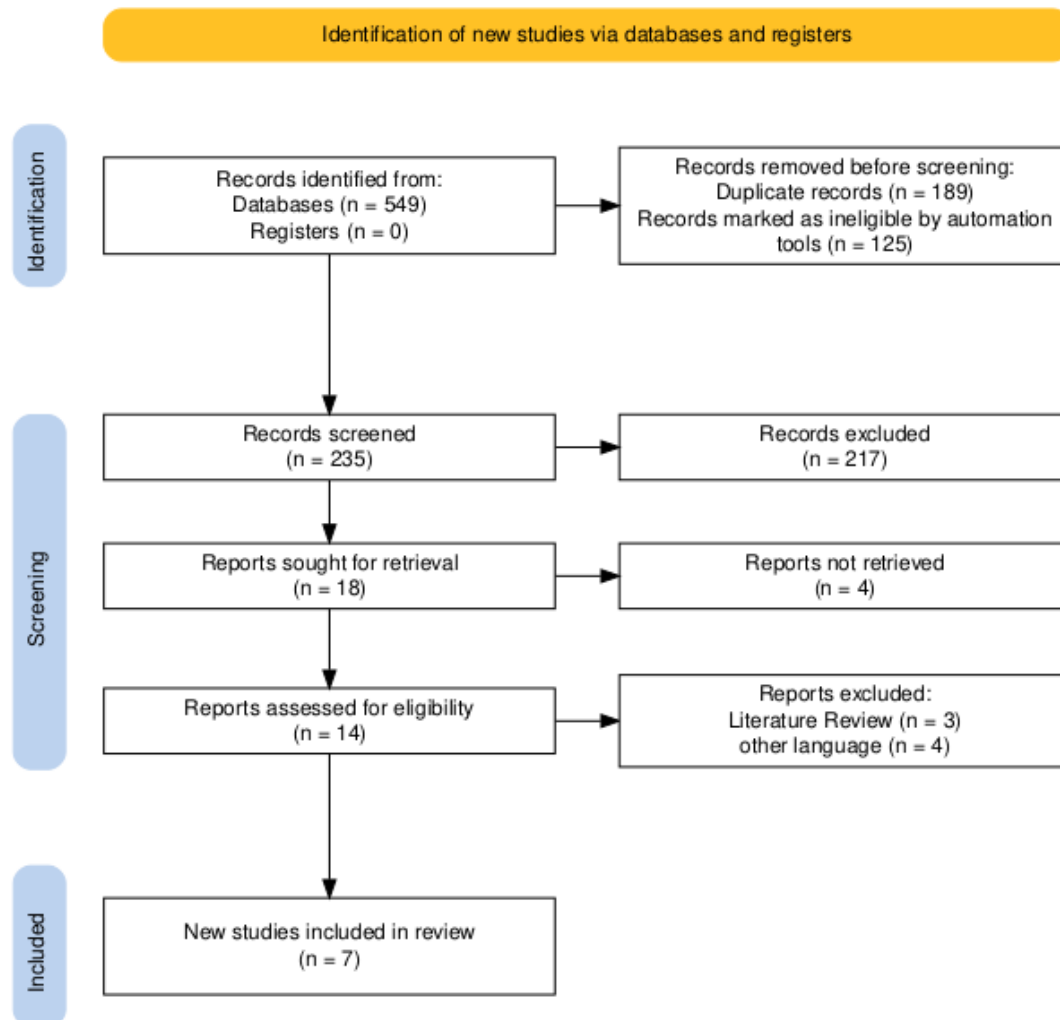


Figure 1. PRISMA Flowchart of Study Selection Process

Data Extraction

The data extraction process in this systematic review was structured and systematic using a pre-designed extraction table to ensure consistency across studies. For each article that met the inclusion criteria, essential information was recorded, including author names, year of publication, study design, sample size and characteristics, participant age, and the country where the research was conducted. In addition, data were collected on the type of non-invasive intervention applied, specifically Continuous Positive Airway Pressure (CPAP), Bilevel Positive Airway Pressure (BiPAP), or High-Flow Nasal Cannula (HFNC), along with details of intervention parameters, treatment protocols, comparison groups, and the primary outcomes assessed. The outcomes were categorized into two major domains: effectiveness indicators, such as improvements in oxygenation, reduction in intubation rates, and ventilator-free days; and safety indicators, including the occurrence of side effects, complications, and device-related discomfort. To ensure reliability and minimize bias, two researchers carried out the extraction process independently. In cases where discrepancies were identified between the reviewers, discussions were held until consensus was achieved. All extracted data were then analyzed descriptively and compared across studies to identify patterns, emerging trends, and significant differences in the effectiveness and safety of the various NIV modalities in pediatric emergency care.

Risk of Bias Assessment

The risk of bias assessment in this systematic review was conducted using the Robvis software, which is

based on the R programming environment and developed by the National Institute for Health Research (NIHR) as a visualization tool for bias assessment. The evaluation of bias followed the Cochrane Risk of Bias Tool guidelines, which address five primary domains: selection, performance, detection, attrition, and reporting. Selection bias was examined through the clarity of participant selection methods and the appropriateness of sampling techniques. Most studies utilized a cross-sectional design and clearly described their methods for participant selection, although some failed to provide comprehensive details regarding the sampling procedures. Performance bias, also called implementation bias, was assessed by analyzing whether external factors or researcher influence could have impacted the completion of data collection, particularly questionnaires. In most of the included studies, self-administered instruments were used, resulting in a relatively low risk of performance bias. Detection bias was evaluated based on the consistency and reliability of measurement tools for assessing knowledge, attitudes, and practices, with most studies employing standardized questionnaires despite not consistently reporting formal validity tests. Attrition bias was considered minimal or almost nonexistent, given that cross-sectional studies generally did not encounter data loss during collection. Finally, reporting bias was analyzed by examining the alignment between predefined research objectives and the results presented, and most studies demonstrated adequate consistency by reporting outcomes according to the intended variables.

RESULTS

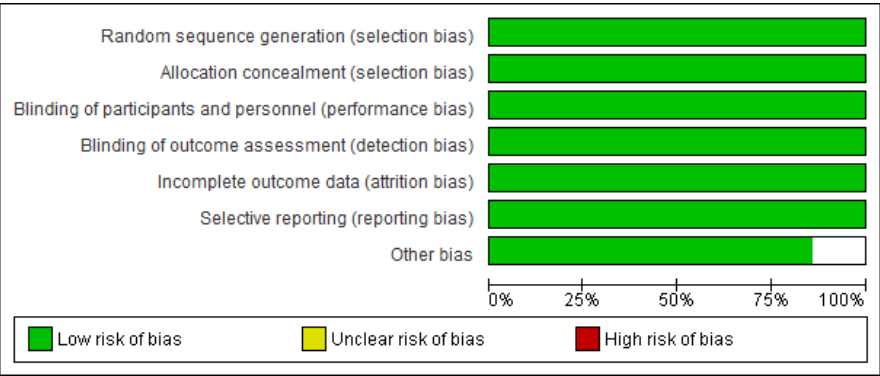


Figure 2. Risk of Bias Assessment of Included Studies: (a) Overall risk of bias across all domains

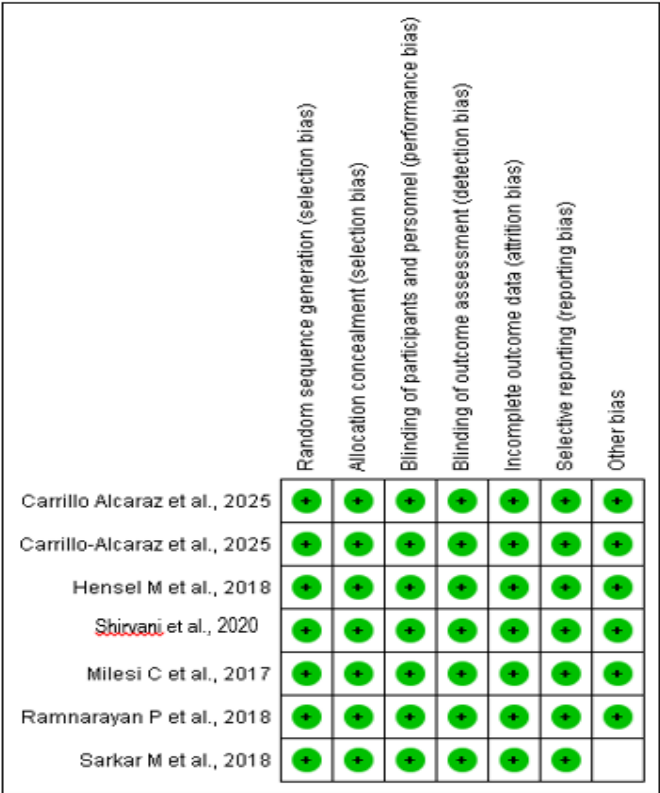


Figure 3. Risk of Bias Assessment of Included Studies (b) Risk of bias summary for individual studies

Risk of Bias

Based on the findings from the risk of bias assessment, all of the included studies (6-10) were rated as having a low risk of bias across the domains evaluated. These domains consisted of random sequence generation and allocation concealment, which reflect selection bias; blinding of participants and personnel, representing performance bias; and blinding of outcome assessment, which addresses detection bias. Furthermore, incomplete outcome data were analyzed to detect potential attrition bias, while selective reporting was assessed to identify the risk of reporting bias. An additional domain called “other bias” was also evaluated to capture any methodological limitations not covered by the primary categories. The graphical summary presented in figure 2 illustrates that all domains were predominantly assessed as low risk, with almost no uncertainty or high-risk classifications. Similarly, the detailed study-level assessment presented in figure 3 confirms that each included study maintained consistent methodological rigor across all domains. These findings demonstrate that the body of evidence synthesized in this review is of high methodological quality, thereby supporting the internal validity and reliability of the conclusions drawn.

Table 1. Summary of Included Studies on Non-Invasive Ventilation (CPAP, BiPAP, and HFNC) in Pediatric and Adult Acute Respiratory Distress

Author	Study Design	Subject	Intervention	Result	Conclusion
Vitaliti et al. ⁽¹²⁾	et RCT	60 children aged 1-24 months (pneumonia, asthma, bronchiolitis)	CPAP helmet vs HFNC	CPAP improves pH, PCO ₂ , and P/F ratio more quickly; HFNC improves SpO ₂ and PaO ₂ more effectively	Both are effective; CPAP improves the condition faster
Milési et al. ⁽¹⁷⁾	RCT	142 infants <6 months with moderate-severe bronchiolitis	CPAP vs HFNC (2 L/kg/min)	CPAP treatment failure rate: 31 %; HFNC: 50,7 % (not significant)	CPAP fails less often, but not significantly
Ramnarayan et al. ⁽¹⁸⁾	Multi-centre RCT pilot	113 children 36 weeks-<16 years	CPAP vs HFNC	Intubation after 72 hours was more common with HFNC, while ventilator-free days were higher with CPAP (not significant)	CPAP is slightly superior but not significantly
Sarkar et al. ⁽²¹⁾	RCT pilot	31 infants 1-12 months with severe bronchiolitis	CPAP vs HFNC	HFNC had better comfort scores, lower heart rate, and fewer nasal injuries	HFNC is more tolerable in bronchiolitis
Hensel al. ⁽²⁴⁾	et Observational cohort	545 pediatric patients with pre-hospital acute respiratory failure	Pre-hospital NIV	NIV is safe and effective even with short distances to the hospital, reducing respiratory work	Pre-hospital NIV can be considered even if the transport distance is short
Shirvani al. ⁽²⁵⁾	et RCT	60 preterm neonates (<34 weeks gestational age, <2000 g birth weight) with mild to moderate RDS (RSS 4-7)	HFNC vs CPAP	Both groups experienced improvement; NCPAP was more effective in reducing the need for escalation of therapy, while HHFNC was more comfortable to use.	NCPAP remains the primary standard for RDS in premature neonates, but HHFNC may be considered an alternative in some instances.
Carrillo-Alcaraz et al. ⁽²⁶⁾	Observational retrospective, propensity score-matched	429 COVID-19 ICU patients with acute respiratory failure	BiPAP dan CPAP	There was no significant difference in device failure rate (OR 1,37; 95 % CI: 0,72-2,62) and in-hospital mortality (OR 1,57; 95 % CI: 0,73-3,42); common complications: claustrophobia / discomfort.	BiPAP and CPAP are equally effective and safe in managing COVID-19-related ARF in the ICU.

Table 1 summarizes the main characteristics of the studies included in this systematic review, presenting details of study design, population, interventions, outcomes, and conclusions. This tabulation provides a structured overview of the available evidence, allowing for clear comparison across different research contexts.

The table highlights the diversity of methodologies and patient groups investigated by consolidating data from randomized controlled trials, observational studies, and retrospective analyses. It also emphasizes the clinical relevance of non-invasive ventilation in pediatric and adult populations, particularly in acute and emergency settings. This summary table is the foundation for the subsequent analysis and discussion, ensuring that the evidence synthesis remains transparent and systematically organized.

Several clinical studies have evaluated the effectiveness and safety of non-invasive ventilation (NIV: CPAP, BiPAP, and HFNC) in children with acute respiratory disorders. A survey by Vitaliti *et al.* (2016) involving 60 children aged 1-24 months with pneumonia, asthma, and bronchiolitis showed that CPAP more quickly improved physiological parameters such as pH, PCO₂, and P/F ratio compared to HFNC, while HFNC was superior in improving SpO₂ and PaO₂.⁽¹²⁾ This indicates that both are effective, but CPAP provides faster improvement in the condition. Similar results were reported by Milesi *et al.* (2017) in 142 infants with moderate to severe bronchiolitis. The treatment failure rate was lower in the CPAP group (31 %) compared to HFNC (50,7 %), although the difference was not statistically significant.⁽¹⁷⁾ In a multicenter pilot RCT by Ramnarayan *et al.* (2018) involving 113 children aged 36 weeks to <16 years, CPAP showed more ventilator-free days compared to HFNC, while the intubation rate within 72 hours was higher in the HFNC group.⁽¹⁸⁾ However, this difference was also insignificant, so CPAP was slightly superior. The study by Sarkar *et al.* on 31 infants with severe bronchiolitis found that HFNC was exceptional in comfort, reducing heart rate, and minimizing nasal injury compared to CPAP. These findings suggest that HFNC is better tolerated in patients with bronchiolitis.⁽²¹⁾

In the context of pre-hospital use, Hensel *et al.* (2018) studied 545 pediatric patients with acute respiratory failure and found that NIV was safe and effective even with short transport distances to the hospital.⁽²⁴⁾ These results reinforce the potential for NIV application in emergencies before patients reach healthcare facilities. A study on preterm neonates by Shirvani *et al.* compared CPAP with HFNC in 60 infants with mild-to-moderate RDS.⁽²⁵⁾ Both effectively improved respiratory status, but NCPAP was superior in reducing the need for therapy escalation, while HFNC was more comfortable to use. Thus, NCPAP remains the primary standard for preterm neonates, although HFNC can be an alternative in some instances. Additionally, Carrillo-Alcaraz *et al.* studied the use of CPAP and BiPAP in 429 pediatric patients with acute respiratory failure related to COVID-19 in the ICU.⁽²⁶⁾ The results showed no significant difference in device failure rates or in-hospital mortality between the two modalities. The most common side effects were discomfort and claustrophobia. This indicates that CPAP and BiPAP are equally effective and safe in cases of ARF caused by COVID-19.

DISCUSSION

The results of this systematic review indicate that non-invasive ventilation (NIV) in the form of CPAP, HFNC, and BiPAP has varying effectiveness in managing acute respiratory distress in children, including premature neonates with RDS. In general, CPAP demonstrates superiority in improving physiological parameters, particularly pH, PaCO₂, and P/F ratio. Studies by Vitaliti *et al.* and Milesi *et al.* found that the CPAP therapy failure rate was lower than HFNC, although the differences were not always statistically significant. This reinforces CPAP as the initial therapy for patients with severe respiratory distress, especially when the primary goal is to stabilize blood gas levels.^(12,17) Conversely, HFNC is superior in terms of patient comfort and tolerability. Sarkar *et al.* and Shirvani *et al.* demonstrated that HFNC yields better comfort scores, significant reductions in heart rate, and fewer nasal injuries compared to CPAP. HFNC is also often considered for neonates because it does not cause nasal trauma, which is one of the complications of CPAP.

In neonates with RDS, several studies confirm that NCPAP and HHFNC have comparable therapeutic effects.⁽²⁷⁾ A study in Iran found no significant differences in therapy failure rates or clinical conditions between NCPAP and HHFNC.^(21,25,28) These results are consistent with the findings of Sreenan *et al.* and Fernández-Álvarez *et al.*, who reported that both modalities provide equivalent clinical outcomes.⁽²⁹⁾ However, Vitaliti *et al.* and Milési *et al.* demonstrated that NCPAP is more efficient than HFNC in neonatal RDS. At the same time, Yoder *et al.* found more extended hospital stays in the HFNC group than the CPAP group. These differing results underscore the need for patient selection and intervention adjustment based on clinical condition. Meanwhile, BiPAP remains under-evaluated in the pediatric population. A retrospective study by Carrillo-Alcaraz *et al.* showed that BiPAP and CPAP have comparable efficacy in patients with acute respiratory failure due to COVID-19, with no significant differences in treatment failure rates or mortality.⁽²⁶⁾ However, BiPAP is associated with complications such as discomfort and claustrophobia, limiting its application in children.

Variations in findings across studies may be influenced by differences in age (neonates, infants, older children), clinical conditions (bronchiolitis, pneumonia, ARDS, RDS, COVID-19), and intervention parameters such as CPAP pressure levels, HFNC flow, and the type of interface used. Additionally, the research setting plays a role, for example, pre-hospital NIV, as demonstrated by Hensel *et al.*, who reported the effectiveness of NIV despite short transport durations.⁽²⁴⁾ From a safety perspective, CPAP is often associated with mask discomfort and mucosal injury, while HFNC is more tolerable with minimal side effects.⁽³⁰⁾ BiPAP is relatively safe, but evidence in pediatrics remains limited. The clinical implications of these findings are that CPAP remains the

primary standard when rapid improvement in physiological status is required. At the same time, HFNC may be prioritized when patient comfort is the primary consideration, especially in neonates and children with bronchiolitis. BiPAP shows promise as an alternative but requires further research. The limitations of this review include small sample sizes in many studies, a predominance of pilot RCTs or observational studies, and the lack of large-scale multicenter trials directly comparing CPAP, HFNC, and BiPAP in pediatric populations. Therefore, further research with multicenter RCT designs and focusing on long-term outcomes are urgently needed.

LIMITATIONS

This systematic review has several significant limitations that must be acknowledged. First, there was a notable heterogeneity across the included studies regarding patient population, underlying causes of acute respiratory distress, severity levels, and clinical settings such as the emergency department, pediatric intensive care unit (PICU), pre-hospital transport, and adult ICU. Such variability may reduce the generalizability of the findings to broader pediatric populations. Second, most of the studies involved relatively small sample sizes, which limited the statistical power to detect significant differences between Continuous Positive Airway Pressure (CPAP), High-Flow Nasal Cannula (HFNC), and Bilevel Positive Airway Pressure (BiPAP). Third, variations in device settings—including flow rates, pressure levels, and fraction of inspired oxygen (FiO₂) adjustments—and differences in treatment protocols across studies, made direct comparisons challenging. Fourth, the reliance on retrospective and observational study designs in several cases may have introduced potential biases, such as selection bias and confounding factors. Finally, the broad age range of pediatric patients, from neonates to adolescents, likely influenced therapeutic responses and safety outcomes, making it more challenging to establish standardized conclusions.

Another limitation of this review is related to the reporting of safety outcomes. Many included studies did not systematically record adverse events, restricting the ability to draw firm conclusions about complication rates. In addition, long-term consequences, such as hospital readmission, post-discharge respiratory function, and health-related quality of life, were rarely assessed. This lack of data on extended follow-up limits understanding of the broader impact of non-invasive ventilation in pediatric populations.

For future research, there is a clear need for large-scale, multicenter, and high-quality randomized controlled trials (RCTs) directly comparing CPAP, HFNC, and BiPAP in pediatric patients with well-defined acute respiratory distress. Such studies should adopt standardized protocols for device settings, monitoring strategies, and outcome parameters to improve trial comparability. In addition, comprehensive safety assessments should be integrated into study designs, with long-term follow-up to capture immediate and extended clinical outcomes. Future investigations should also examine cost-effectiveness and patient or caregiver comfort, as these factors are highly relevant for decision-making in real-world clinical practice. Ultimately, well-designed studies with robust methodologies are essential to establish more unmistakable evidence regarding the optimal use of non-invasive ventilation in pediatric emergency care.

CONCLUSION

This systematic review demonstrates that CPAP, HFNC, and BiPAP are effective and relatively safe non-invasive ventilation modalities for managing acute respiratory distress in pediatric populations in emergency and intensive care settings. CPAP generally provides faster physiological improvement, particularly regarding pH, PaCO₂, and P/F ratio. At the same time, HFNC is superior in patient comfort and tolerability and reduces the risk of nasal injury. BiPAP demonstrates comparable effectiveness to CPAP in some instances, particularly in patients with COVID-19-related respiratory failure, without significant differences in treatment failure rates or mortality. Although there is variability in study results, most studies report that all three modalities can reduce the need for invasive intubation, with an acceptable safety profile. The selection of a non-invasive ventilation type should consider the patient's clinical condition, comfort, device availability, and medical staff expertise. However, limitations such as small sample sizes, study design heterogeneity, and lack of long-term safety data highlight the need for large-scale controlled clinical trials with standardized protocols to ensure more valid and clinically applicable comparisons.

REFERENCES

1. Viscusi CD, Pacheco GS. Pediatric emergency noninvasive ventilation. *Emerg Med Clin*. 2018;36(2):387-400.
2. Bonnesen B, Jensen JUS, Jeschke KN, Mathioudakis AG, Corlateanu A, Hansen EF, et al. Management of covid-19-associated acute respiratory failure with alternatives to invasive mechanical ventilation: High-flow oxygen, continuous positive airway pressure, and noninvasive ventilation. *Diagnostics*. 2021;11(12):1-13.
3. Iyer NP, Rotta AT, Essouri S, Fioretto JR, Craven HJ, Whipple EC, et al. Association of Extubation Failure

Rates with High-Flow Nasal Cannula, Continuous Positive Airway Pressure, and Bilevel Positive Airway Pressure vs Conventional Oxygen Therapy in Infants and Young Children: A Systematic Review and Network Meta-Analysis. *JAMA Pediatr.* 2023;177(8):774-81.

4. Santos ACEZ, Caiado CM, Lopes AGD, de França GC, Eisen AKA, Oliveira DBL, et al. Comparison between high-flow nasal cannula (HFNC) therapy and noninvasive ventilation (NIV) in children with acute respiratory failure by bronchiolitis: a randomized controlled trial. *BMC Pediatr.* 2024;24(1).

5. Abe T, Takagi T, Fujii T. Update on the management of acute respiratory failure using non-invasive ventilation and pulse oximetry. *Crit Care.* 2023;27(1):1-7.

6. Ovtcharenko N, Ho E, Alhazzani W, Cortegiani A, Ergan B, Scala R, et al. High-flow nasal cannula versus non-invasive ventilation for acute hypercapnic respiratory failure in adults: a systematic review and meta-analysis of randomized trials. *Crit Care.* 2022;26(1):1-14.

7. Šitum I, Erceg A, Lovrić D. Application of Noninvasive Ventilation in Emergency Medicine: Current Strategies and Challenges. *Ann Med Urgent.* 2025;1(1):15-8.

8. Wang Z, He Y, Zhang X, Luo Z. Non-Invasive Ventilation Strategies in Children With Acute Lower Respiratory Infection: A Systematic Review and Bayesian Network Meta-Analysis. *Front Pediatr.* 2021;9.

9. Zevallos-Villegas A, Gonzalez-Rubio J, Neria Serrano F, Gallego-Rodriguez B, Lorente-Gonzalez M, Najera A, et al. Factors associated with the effectiveness of high-flow therapy in patients with acute hypoxemic respiratory failure: An observational study. *Intensive Crit Care Nurs.* 2025;86:103874.

10. Frat JP, Pape S Le, Coudroy R, Thille AW. Noninvasive Oxygenation in Patients with Acute Respiratory Failure: Current Perspectives. *Int J Gen Med.* 2022;15:3121-32.

11. Al-Mukhaini KS, Al-Rahbi NM. Noninvasive ventilation and high-flow nasal cannulae therapy for children with acute respiratory failure an overview. *Sultan Qaboos Univ Med J.* 2018;18(3):e278-85.

12. Vitaliti G, Vitaliti MC, Finocchiaro MC, Di Stefano VA, Pavone P, Matin N, et al. Randomized comparison of helmet CPAP versus high-flow nasal cannula oxygen in pediatric respiratory distress. *Respir Care.* 2017;62(8):1036-42.

13. Sakuraya M, Okano H, Masuyama T, Kimata S, Hokari S. Efficacy of non-invasive and invasive respiratory management strategies in adult patients with acute hypoxaemic respiratory failure: a systematic review and network meta-analysis. *Crit Care.* 2021;25(1):1-16.

14. Muhammad Reza Arifin, Indra Yovi, Sri Indah Indriani. High-Flow Nasal Cannula versus Non-Invasive Positive Pressure Ventilation in Adults with Acute Hypoxemic (Type 1) Respiratory Failure: A Meta-Analysis of Efficacy, Intubation Rates, and Mortality. *Biosci Med J Biomed Transl Res.* 2025;9(8):8232-50.

15. Thille AW, Balen F, Carteaux G, Chouihed T, Frat JP, Girault C, et al. Oxygen therapy and noninvasive respiratory supports in acute hypoxemic respiratory failure: a narrative review. *Ann Intensive Care.* 2024;14(1).

16. Carratalá JM, Diaz-Lobato S, Brouzet B, Más-Serrano P, Rocamora JLS, Castro AG, et al. Efficacy and safety of high-flow nasal cannula therapy in elderly patients with acute respiratory failure. *Pulmonology.* 2024;30(5):437-44.

17. Milési C, Essouri S, Pouyau R, Liet JM, Afanetti M, Portefaix A, et al. High flow nasal cannula (HFNC) versus nasal continuous positive airway pressure (nCPAP) for the initial respiratory management of acute viral bronchiolitis in young infants: a multicenter randomized controlled trial (TRAMONTANE study). *Intensive Care Med.* 2017;43(2):209-16.

18. Ramnarayan P, Lister P, Dominguez T, Habibi P, Edmonds N, Canter RR, et al. FIRST-line support for Assistance in Breathing in Children (FIRST-ABC): A multicentre pilot randomised controlled trial of high-flow nasal cannula therapy versus continuous positive airway pressure in paediatric critical care. *Crit Care.* 2018;22(1):1-11.

19. Xu Z, Zhu L, Zhan J, Liu L. The efficacy and safety of high-flow nasal cannula therapy in patients with COPD and type II respiratory failure: a meta-analysis and systematic review. *Eur J Med Res.* 2021;26(1):1-9.
20. Kadafi KT, Yuliarto S, Monica C, Susanto WP. Clinical review of High Flow Nasal Cannula and Continuous Positive Airway Pressure in pediatric acute respiratory distress. *Ann Med Surg.* 2022;73:103180.
21. Sarkar M, Sinha R, Roychowdhury S, Mukhopadhyay S, Ghosh P, Dutta K, et al. Comparative study between noninvasive continuous positive airway pressure and hot humidified high-flow nasal cannulae as a mode of respiratory support in infants with acute bronchiolitis in pediatric intensive care unit of a Tertiary Care Hospital. *Indian J Crit Care Med.* 2018;22(2):85-90.
22. Long B, Liang SY, Lentz S. High flow nasal cannula for adult acute hypoxemic respiratory failure in the ED setting: A narrative review. *Am J Emerg Med.* 2021;49:352-9.
23. Frat JP, Marchasson L, Arrivé F, Coudroy R. High-flow nasal cannula oxygen therapy in acute hypoxemic respiratory failure and COVID-19-related respiratory failure. *J Intensive Med.* 2023;3(1):20-6.
24. Hensel ME, Negron M, Arenas-Gamboa AM. Brucellosis in dogs and public health risk. *Emerg Infect Dis.* 2018;24(8):1401-6.
25. Shirvani M, Kesserwani G, Richmond P. Agent-based simulator of dynamic flood-people interactions. *J Flood Risk Manag.* 2021;14(2):1-17.
26. Carrillo-Alcaraz A, Guia M, Lopez-Gomez L, Bayoumy P, Higon-Cañigral A, Carrasco González E, et al. Comparison of non-invasive ventilation on bilevel pressure mode and CPAP in the treatment of COVID-19 related acute respiratory failure. A propensity score-matched analysis. *Med Intensiva.* 2025;50:2146.
27. Holleman-Duray D, Kaupie D, Weiss MG. Heated humidified high-flow nasal cannula: Use and a neonatal early extubation protocol. *J Perinatol.* 2007;27(12):776-81.
28. Fernandez-Alvarez JR, Gandhi RS, Amess P, Mahoney L, Watkins R, Rabe H. Heated humidified high-flow nasal cannula versus low-flow nasal cannula as weaning mode from nasal CPAP in infants ≤ 28 weeks of gestation. *Eur J Pediatr.* 2014;173(1):93-8.
29. Sreenan C, Lemke RP, Hudson-Mason A, Osiovič H. High-flow nasal cannulae in the management of apnea of prematurity: a comparison with conventional nasal continuous positive airway pressure. *Pediatrics.* 2001;107(5):1081-3.
30. Yoder BA, Stoddard RA, Li M, King J, Dirnberger DR, Abbasi S. Heated, humidified high-flow nasal cannula versus nasal CPAP for respiratory support in neonates. *Pediatrics.* 2013;131(5):e1482-90.

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CONFLICT OF INTEREST

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