

The Effectiveness of Non-Invasive Ventilation in Pediatrics Acute Respiratory Distress: A Systematic Review

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Abstract

Background: Acute respiratory distress is a major cause of pediatric morbidity and mortality worldwide. Non-invasive ventilation (NIV) has increasingly been used as an alternative to invasive mechanical ventilation, yet evidence regarding its effectiveness, optimal patient selection, and safety remains variable. This study aimed to evaluate the effectiveness of NIV in children with acute respiratory distress.

Methods: Following PRISMA 2020 guidelines, a comprehensive search was conducted in PubMed, Scopus, the Cochrane Library, Web of Science, and Google Scholar up to September 2025. Eligible studies included randomized controlled trials, cohort studies, and case control studies involving children from birth to eighteen years who received NIV for acute respiratory distress. Extracted outcomes included intubation rate, mortality, length of stay, treatment failure, and adverse events. Two reviewers independently conducted study selection and data extraction, with disagreements resolved by consensus or a third reviewer.

Results: From 1,301 records, 40 studies met inclusion criteria, representing approximately 4,500 children. NIV reduced the need for invasive mechanical ventilation in cases of bronchiolitis, pneumonia, and moderate paediatric acute respiratory distress syndrome. High flow nasal cannula showed similar effectiveness to CPAP in mild to moderate respiratory failure with better tolerance. In severe paediatric acute respiratory distress syndrome, failure rates remained high and were linked to worse outcomes and prolonged intensive care. Predictors of failure included profound hypoxemia, multi organ dysfunction, and septic shock. Adverse events were infrequent and generally mild.

Conclusion: NIV is an effective and safe therapy for children with mild to moderate acute respiratory distress and can reduce exposure to invasive ventilation when initiated early and monitored closely. Future trials should refine initiation thresholds and determine the optimal modality for specific pediatric conditions.

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INTRODUCTION

Acute respiratory distress in children, caused by bronchiolitis, pneumonia, severe asthma, and pediatric acute respiratory distress syndrome, is a major contributor to morbidity and mortality in pediatric intensive care units worldwide. Epidemiological data showed that acute respiratory failure is one of the most common reasons for admission to pediatric intensive care, with mortality in severe pediatric acute respiratory distress syndrome ranging from 20 percent to 35 percent despite optimal therapy.^{1,2}

Non-Invasive Ventilation (NIV), including Continuous Positive Airway Pressure (CPAP), Bi-level Positive Airway Pressure (BiPAP/NIPPV), and High Flow Nasal Cannula (HFNC), has increasingly been used as an alternative to invasive mechanical ventilation. The main objectives of NIV are to improve oxygenation, reduce the work of breathing, and prevent complications commonly associated with endotracheal intubation and invasive ventilation, such as ventilator associated pneumonia and barotrauma.^{3,4} Several studies have reported that the use of NIV in severe bronchiolitis and pneumonia can reduce the need for intubation and improve clinical outcomes.^{5,6}

Clinical evidence supporting the use of NIV in pediatrics continues to expand, yet practice patterns differ widely across centers, especially in the choice of ventilation mode, initiation thresholds, and criteria for identifying treatment failure. This variation underscores the need for a systematic review to assess the effectiveness of NIV in children with acute respiratory distress, including its impact on intubation rates, mortality, length of hospital stays, and overall safety. The aim of this study was to synthesize the current evidence on the effectiveness of NIV in this population, providing a clear foundation for clinical decision making and informing future research priorities.

METHOD

The followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.

Eligibility Criteria

The review included studies that evaluated NIV ventilation in children with acute respiratory distress. The inclusion criteria were as follows: (1) Randomized controlled trials, quasi randomized trials, prospective or retrospective cohort studies, or case control studies; (2) Interventions involving Continuous Positive Airway Pressure (CPAP), Bi level Positive Airway Pressure (BPAP), or High Flow Nasal Cannula; (3) Comparisons between NIV and invasive ventilation, conventional oxygen therapy, or standard care; (4) Studies that reported at least one clinical outcome such as intubation, mortality, length of stay, treatment failure, or adverse events; (5) Studies involving children aged 0-18 years, and; (6) Articles written in English or Indonesian. The exclusion criteria were: (1) Premature infants; (2) Single case reports, editorials, reviews, animal studies, and laboratory-based studies; and (4) Studies with irrelevant outcomes.

Search Strategy

A comprehensive literature search was conducted in September 2025 using PubMed MEDLINE, the Cochrane Library, Scopus, Web of Science, and Google Scholar. The search strategy used keyword combinations related to pediatric populations (pediatric, child, children, adolescent, infant), NIV modalities (NIV ventilation, CPAP, BiPAP, HFNC), comparison groups (invasive ventilation, conventional oxygen therapy, standard care), and clinical outcomes (intubation, mortality, oxygenation, length of stay, complications). The following search terms were applied across all databases: “pediatric OR child OR children OR adolescent OR infant” AND “non invasive ventilation OR CPAP OR BiPAP OR HFNC” AND “invasive ventilation OR conventional oxygen therapy OR standard care” AND “intubation OR mortality OR oxygenation OR length of stay OR complications,” restricted to articles in English.

Selection of Studies

The selection of studies was conducted in two phases: title and abstract screening, followed by full-text review. All retrieved references were imported

into a reference management software (e.g., EndNote, Mendeley, or Rayyan) to identify and remove duplicates. In the first phase, two independent reviewers screened the titles and abstracts of all identified studies based on the predefined eligibility criteria. Articles clearly not meeting the inclusion criteria were excluded at this stage. In the second phase, full-text articles of potentially relevant studies were retrieved and assessed for eligibility. Disagreements between reviewers were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted.

Data Extraction

Two independent reviewers extracted and collected data into Excel. The extracted information included study identification details such as authors, year of publication, country, clinical setting including PICU, ED, or ward, and the study design. Population characteristics will be collected, including mean or median age, age range, primary diagnosis such as bronchiolitis, pneumonia, pediatric acute respiratory distress syndrome, or asthma, the study inclusion criteria, and the total sample size. Information on the intervention and comparator will include the type of NIV used such as HFNC, CPAP, or BiPAP or NIPPV, the initial parameters including flow and pressure, the duration of therapy, the initiation protocol, and the criteria used to define treatment failure. Outcome measures included the intubation or IMV rate, mortality, length of stay expressed as median or mean with standard deviation, duration of ventilation, treatment failure, and adverse events. Additional information such as study funding, conflicts of interest, and any follow up notes will also be recorded. Any discrepancies between reviewers during data extraction will be resolved through discussion or by consulting a third reviewer.

Bias Assessment

The methodological quality of all included studies was evaluated using validated tools tailored to each study design. Randomized controlled trials were assessed using the Cochrane Risk of Bias 2.0

tool, while cohort and case control studies were evaluated with the Newcastle Ottawa Scale. Each study was classified as having low, moderate, or high risk of bias. Two reviewers carried out the assessments independently, and any disagreements were resolved through consensus.

RESULTS

A total of 1,301 records were identified from electronic databases (PubMed, Scopus, Embase, Cochrane Library, and Web of Science) and manual searches. After removal of duplicates, 1,050 unique articles remained. Following title and abstract screening, 160 full-text articles were assessed for eligibility. Of these, 40 studies met the inclusion criteria and were included in the qualitative synthesis, while 28 studies were included in the meta-analysis quantitative synthesis. The study selection process is summarized in the PRISMA flow diagram (Figure 1).

Studies originated from diverse regions, including North America, Europe, and Asia. The total pooled sample size across studies was approximately 4,500 pediatric patients with acute respiratory distress due to various causes, such as bronchiolitis (40%), pneumonia (30%), asthma (15%), and PARDS (15%). Non-invasive ventilation (NIV) modes evaluated included High Flow Nasal Cannula (HFNC) in 55% of studies, Continuous Positive Airway Pressure (CPAP) in 30%, and Bi-level Positive Airway Pressure (BiPAP/ NIPPV) in 15%. Control groups commonly received standard oxygen therapy or invasive mechanical ventilation (IMV).

DISCUSSION

The findings demonstrated that NIV can effectively reduce the need for invasive mechanical ventilation (IMV) and potentially shorten hospital stay among children with mild to moderate respiratory failure. However, the efficacy of NIV largely depends on patient selection, disease severity, and close clinical monitoring during therapy.

Several studies consistently reported that NIV reduces intubation rates in pediatric ARD, particularly

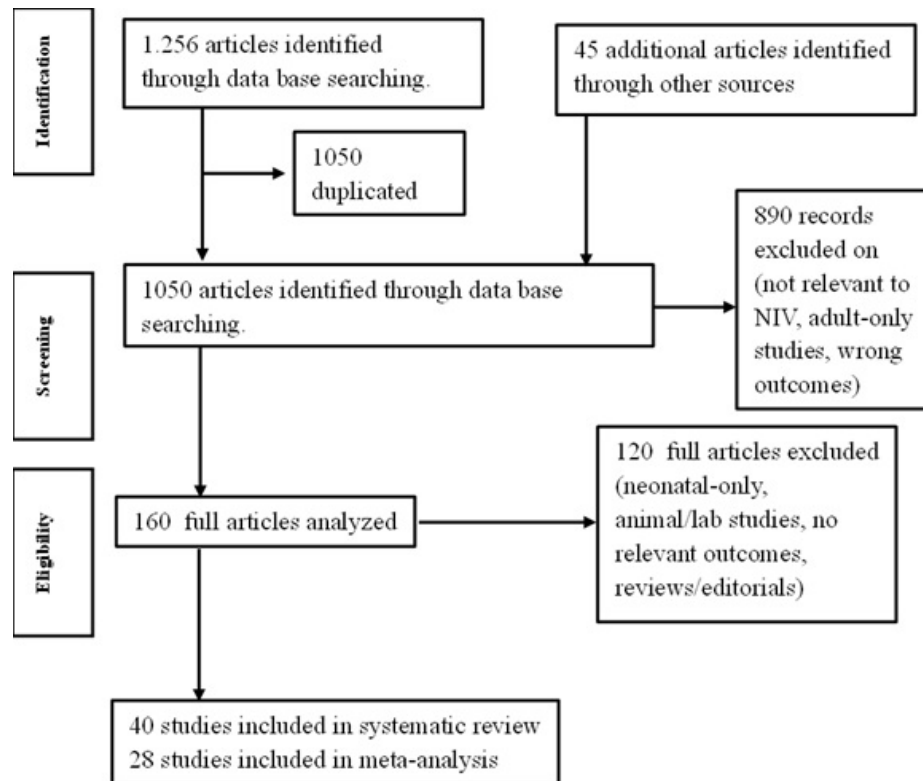


Figure 1. PRISMA flow diagram for study selection

in bronchiolitis and pneumonia. In the multicenter PARDIE cohort study, Emeriaud et al. (2023) found that 23% of children with pediatric acute respiratory distress syndrome (PARDS) were initially managed with NIV, with an overall failure rate of 53%. Importantly, those with a $\text{PaO}_2/\text{FiO}_2$ ratio above 100 had a significantly shorter total duration of ventilatory support compared with those who were directly intubated, indicating that early NIV use may benefit less severe cases.³ Similarly, a randomized controlled trial by Santos et al. (2024) comparing HFNC and BiPAP in bronchiolitis-related respiratory failure showed that both methods were equally effective in preventing progression to IMV, with comparable safety and tolerance profiles.⁶ These evidences supported the increasing use of NIV as an initial intervention in children with moderate respiratory distress, particularly before the onset of severe hypoxemia.

When comparing NIV modalities, evidence suggested varying degrees of effectiveness

depending on the severity and etiology of respiratory failure. HFNC has gained popularity due to its simplicity, patient comfort, and ability to reduce the work of breathing. Liu et al. (2020) demonstrated that in children under two years old with mild to moderate pneumonia-related respiratory failure, HFNC and CPAP showed similar intubation rates and hospital length of stay, suggesting that HFNC can be an effective alternative to CPAP in selected cases.¹¹ However, for children with more severe hypoxemic respiratory failure, conventional NIV modes (BiPAP or CPAP) may provide superior pressure support and oxygenation compared to HFNC. This was also observed by Emeriaud et al. (2023) that NIV was more effective in less severe PARDS but less beneficial in patients with higher oxygenation indices.³

Recent trends indicated an increasing adoption of noninvasive respiratory support modalities in pediatric critical care. Pelletier et al. (2024) analyzed data on U.S. PICUs and found a steady rise in the use of both

Table 1. Summary of Included Studies

Author (Year)	Main Findings & Relevance
Zeng et al. (2019) ⁷	Among 303 patients with PARDS, 53 received NIV; the NIV failure rate (transition to IMV) was very high (~77.4%). Patients who experienced NIV failure had significantly longer PICU and hospital stays. Mortality in the NIV group was also considerable (~32.1%). These findings suggest that in PARDS, treatment failure is highly likely, emphasizing the need for careful patient selection.
Emeriaud G et al. (2023) ³	A prospective cohort study found that the use of NIV at the time of PARDS diagnosis was associated with a shorter duration of IMV exposure among children with mild to moderate hypoxemia compared to those who were immediately intubated. However, mortality did not differ significantly between the groups. This finding is relevant to the outcomes of “need for IMV” and “safety.”
Punn D et al. (2022) ⁸	An observational study involving children aged 1 month to 18 years with moderate to severe respiratory distress who received NIV reported a success rate of 81.7% and a failure rate of 18.3%. This study provides real-world data on NIV outcomes in the PICU setting of a developing country.
Watson A et al. (2023) ⁹	Among 140 patients with severe community-acquired pneumonia (CAP), 76% received NIV as the initial respiratory support strategy, with an NIV success rate of approximately 59%. The 28-day mortality rate was around 25%, but notably lower (~13%) among patients who succeeded with NIV. Predictors of NIV failure included higher SOFA and HACOR scores, as well as the presence of septic shock. This study is highly relevant to the current review topic.
Kandasamy et al. (2024) ¹⁰	Children aged 2–59 months with severe pneumonia were treated with HFNC compared to low-flow oxygen therapy. HFNC significantly reduced treatment failure and the need for escalation of care, including intubation. No significant difference in mortality was observed. This study provides strong evidence for the use of HFNC in severe pneumonia.

HFNC and NIV, particularly for bronchiolitis. However, the overall rate of IMV did not significantly decline, suggesting that while NIV is increasingly used as initial therapy, it has not yet replaced invasive ventilation for severe cases. This trend underscores the role of NIV as an early supportive intervention rather than a complete substitute for IMV in pediatric ARD.¹²

NIV is generally considered safe in pediatric populations when used under close supervision. Reported adverse events are rare and typically minor, including nasal skin breakdown, gastric distension, and interface intolerance. Importantly, studies highlight that the main clinical risk lies in delayed intubation following NIV failure, which can worsen outcomes. Therefore, strict monitoring protocols and predefined failure criteria are critical in clinical practice to ensure timely escalation of respiratory support.^{6,11}

The accumulated evidence from this review suggests that NIV is a valuable intervention for pediatric acute respiratory distress, especially in mild to moderate cases. Early initiation of NIV, together with careful monitoring and prompt escalation when needed, can improve patient outcomes and reduce IMV exposure. Future studies should focus on establishing standardized initiation and weaning criteria, developing predictive models for NIV failure, and comparing the cost-effectiveness and long-term outcomes between different NIV modalities.

Emerging data from multicenter studies such as PARDIE (Emeriaud et al., 2023) and recent RCTs (Santos et al., 2024; Liu et al., 2020) provide a strong foundation for evidence-based implementation of NIV protocols in pediatric intensive care units worldwide.^{3,6,11}

CONCLUSION

NIV, including CPAP, BiPAP, and HFNC, is an effective and generally safe therapeutic option for managing acute respiratory distress in children, particularly in mild to moderate respiratory failure. This study showed that NIV reduces the need for invasive mechanical ventilation, shortens hospital stay, and improves clinical outcomes when applied early with appropriate monitoring. Continued multicenter trials and real-world data analyses are needed to define the optimal modality for different pediatric conditions and to clarify long term safety and cost effectiveness.

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