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High-flow nasal cannula versus non-invasive ventilation following planned extubation in critically ill adults: a systematic review of clinical outcomes

Khalid Obaid Alanazi[1], Khalid Hamdan Alanazi[1], Mohammed Saad Aldosari[1], Osama Ibrahim Almujalli[1], Yazeed Mohammed Alkhalifah[2], Abdullah Hassan Asiri[2], Alwaleed Ahmed Amri[1]

[1] Respiratory Therapist, Respiratory Care Services, Intensive Care Unit, King Saud University Medical City (KSUMC), Riyadh, Saudi Arabia.

[2] Respiratory Therapist, Respiratory Care Section, Critical Care Department, King Saud University Medical City (KSUMC), Riyadh, Saudi Arabia.

Abstract

Background: Planned extubation in critically ill adults remains followed by clinically important rates of respiratory failure, reintubation, pneumonia, prolonged intensive care stay, and death. High-flow nasal cannula provides heated humidified gas, stable oxygen delivery, washout of upper airway dead space, and low-level positive airway pressure, while non-invasive ventilation provides pressure support and expiratory pressure through a mask interface. Objective: This systematic review compared high-flow nasal cannula with non-invasive ventilation, including alternating strategies, after planned extubation in critically ill adults. Methods: PubMed, Scopus, Web of Science, and Cochrane Library were searched from inception to 2025 for adult studies evaluating high-flow nasal cannula versus non-invasive ventilation after planned extubation. Randomized trials and comparative observational studies were eligible. Outcomes included reintubation, postextubation respiratory failure, treatment failure, mortality, gas exchange, comfort, intolerance, complications, and intensive care length of stay. Results: Fourteen original studies were included. In broad high-risk intensive care

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populations, high-flow nasal cannula showed similar reintubation outcomes to non-invasive ventilation in one large trial, while combined high-flow nasal oxygen plus non-invasive ventilation reduced reintubation compared with high-flow nasal oxygen alone. In COPD, hypercapnia, obesity, and very high-risk groups, evidence favored individualized selection rather than a single universal device. Conclusion: High-flow nasal cannula represents a practical alternative after planned extubation for many critically ill adults, while non-invasive ventilation is important for hypercapnic, obese, and very high-risk phenotypes.

Keywords
High-flow nasal cannula; non-invasive ventilation; extubation; reintubation; intensive care unit; COPD; postextubation respiratory failure; systematic review.

Introduction

Extubation failure is a major intensive care problem because reintubation is linked with longer ventilation, increased pneumonia, longer stay, and higher mortality in medical intensive care patients. Risk is higher in older adults and in patients with chronic cardiac disease, chronic respiratory disease, weak cough, abundant secretions, and prolonged ventilation, making preventive support after planned extubation clinically important. This review focuses on planned extubation rather than rescue therapy for established postextubation failure, because delayed reintubation after failed rescue support is associated with harm in vulnerable patients (1).

High-flow nasal cannula delivers warmed humidified oxygen at high flow rates, improves oxygenation, reduces inspiratory resistance, decreases anatomic dead space, and provides a small positive pressure effect during expiration (2). Non-invasive ventilation provides inspiratory pressure support and positive end-expiratory pressure, which directly unload respiratory muscles and improves alveolar ventilation in selected patients (3). Current European guidance recognizes both high-flow nasal cannula and non-invasive ventilation as postextubation supports, with non-invasive ventilation retaining a specific role in high-risk and hypercapnic phenotypes (3,4).

Early postextubation trials comparing high-flow nasal cannula with conventional oxygen supported its role in low-risk and hypoxemic extubated populations, creating a rationale for direct comparison with non-invasive ventilation (5,6). Systematic reviews indicate that high-flow nasal cannula reduces reintubation compared with conventional oxygen, while direct comparisons with non-invasive ventilation remain more dependent on baseline risk, hypercapnia, and protocol design (7). COPD-focused synthesis also highlights similar reintubation prevention with better tolerance for high-flow nasal cannula across several extubation trials (8).

The clinical question remains important because high-flow nasal cannula and non-invasive ventilation differ in mechanism, tolerance, nursing workload, humidification, secretion clearance, and patient interface burden (3,4). A patient with hypoxemia and intact ventilation differs from a patient with COPD-related hypercapnia, obesity hypoventilation, heavy secretion load, or very high-risk extubation profile (3,8). This systematic review summarizes original comparative evidence on high-

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flow nasal cannula versus non-invasive ventilation after planned extubation in critically ill adults and

Method

This systematic review was designed according to PRISMA principles. The review question was structured by population, intervention, comparator, and outcomes. The population was critically ill adults undergoing planned extubation after invasive mechanical ventilation. The intervention was high-flow nasal cannula or high-flow nasal oxygen delivered immediately or early after extubation. The comparator was non-invasive ventilation, non-invasive positive pressure ventilation, or a protocol alternating non-invasive ventilation with high-flow nasal oxygen. Outcomes were reintubation, postextubation respiratory failure, treatment failure, mortality, gas exchange, comfort, intolerance, adverse effects, and intensive care unit length of stay.

PubMed, Scopus, Web of Science, and Cochrane Library were searched from inception to 2025 (Fig 1). Search terms combined “high-flow nasal cannula,” “high-flow nasal oxygen,” “HFNC,” “HFNO,” “non-invasive ventilation,” “NIV,” “NIPPV,” “planned extubation,” “postextubation,” “reintubation,” “critical care,” “intensive care,” “COPD,” “hypercapnia,” and “obesity.” Reference lists of included reviews, trials, and guidelines were screened to identify additional studies. Only peer-reviewed sources with traceable journal details, DOI, PubMed record, or full-text source were retained.

Eligible original studies included randomized controlled trials, post hoc analyses of randomized trials, prospective comparative studies, and evaluates reintubation, respiratory failure, mortality, comfort, and safety outcomes.

retrospective comparative studies in adults after planned extubation. Studies were excluded when they evaluated rescue treatment for established extubation failure without prophylactic or immediate postextubation support, pediatric patients, tracheostomy-only populations, emergency department acute respiratory failure before intubation, or non-comparative device reports. Retracted articles were not included in the evidence table.

Data extraction included author, year, setting, design, sample size, population, intervention, comparator, follow-up time, and main outcomes. Risk of bias was considered qualitatively using randomization, allocation process, baseline comparability, open-label design, protocolized reintubation criteria, attrition, crossover, and selective outcome reporting. Greater confidence was assigned to multicenter randomized trials with predefined reintubation criteria and lower attrition. Lower confidence was assigned to single-center, retrospective, post hoc, or narrowly selected subgroup analyses. Formal meta-analysis was not performed because populations, comparator definitions, treatment duration, COPD enrichment, rescue strategies, and outcome time points differed across studies. Findings are presented as a

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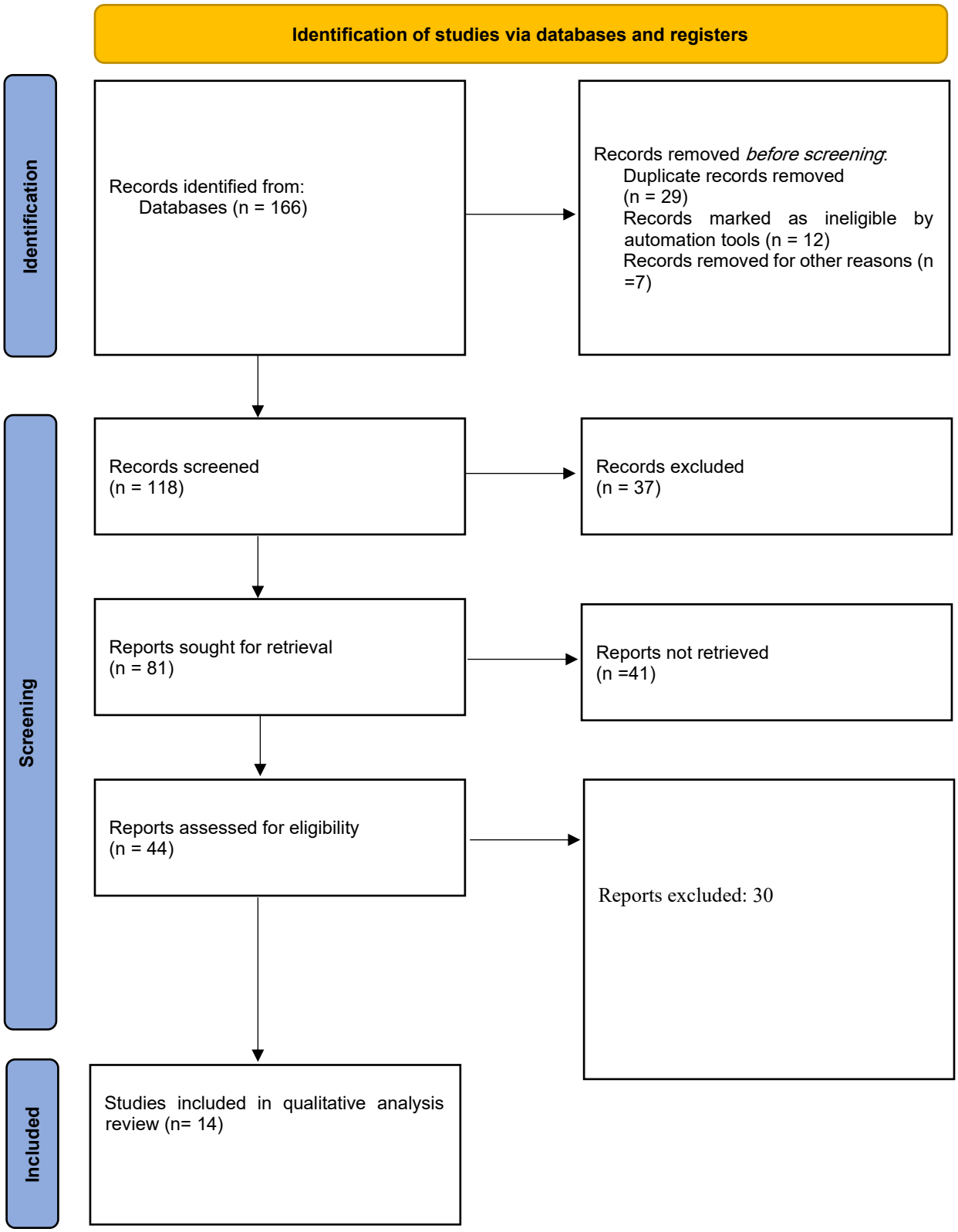
Fig 1: PRISMA flow chart



structured narrative synthesis with two summary tables.

Results

The evidence base included fourteen original comparative studies and eight supporting sources, with original studies covering general high-risk ICU patients, post-cardiothoracic surgery patients, COPD or hypercapnic patients, sepsis, difficult weaning, very high-risk patients, and obesity (9-22). Randomized trials formed the main evidence base, while post hoc and retrospective studies added phenotype-specific data for COPD, hypercapnia, and obesity (9-22). The overall direction of effect was not uniform across all populations, because trials compared different strategies, including high-flow nasal cannula alone, non-invasive ventilation alone, and combined or alternating therapy (9-22) (Table 1&2).

Table 1. Characteristics of included studies

Study	Design and population	Comparison	Key clinical outcomes
Hernández 2016 (9)	Multicenter RCT, 604 high-risk adults after planned extubation	HFNC for 24 h versus NIV for 24 h	Reintubation at 72 h was 22.8% with HFNC and 19.1% with NIV; postextubation respiratory failure was lower with HFNC, 26.9% versus 39.8%.
Stéphan 2015 (10)	Multicenter RCT, 830 hypoxemic cardiothoracic surgery patients	HFNC versus NIV	Treatment failure was 21.0% with HFNC and 21.9% with NIV, supporting noninferiority in this postoperative group.
Tan 2020 (11)	Multicenter RCT, COPD with hypercapnic respiratory failure after extubation	HFNC versus NIV	Treatment failure was 22.7% with HFNC and 28.6% with NIV, with better comfort and tolerance for HFNC.
Jing 2019 (12)	Pilot RCT, COPD patients with hypercapnia after extubation	HFNC versus NIV	HFNC improved comfort and facilitated airway care, while gas-exchange outcomes were broadly comparable.
Zhang 2018 (13)	Comparative COPD study after extubation	Sequential HFNC versus NIV	HFNC was reported as safe and effective, with no clear increase in mortality or reintubation.
Fang 2021 (14)	Comparative severe AECOPD study after early extubation	Sequential HFNC versus NIPPV	HFNC improved compliance and reduced device-related complications in severe COPD-related respiratory failure.
Tongyoo 2021 (15)	RCT in sepsis patients after extubation	HFNC versus NIV	The trial evaluated reintubation prevention after extubation in sepsis, with no consistent mortality signal favoring either device.
Thille 2019 (16)	Multicenter RCT, 641 high-risk ICU patients	HFNO plus NIV versus HFNO alone	Reintubation at day 7 was lower with HFNO plus NIV, 11.8% versus 18.2%, and postextubation respiratory failure was also lower.

Study	Design and population	Comparison	Key clinical outcomes
Thille 2021 (17)	Post hoc COPD analysis from the 2019 RCT	NIV alternating with HFNO versus HFNO alone	Reintubation was 13% with NIV plus HFNO and 27% with HFNO alone among COPD patients.
Hernández 2022 (18)	RCT, very high-risk extubation group	Humidified NIV versus HFNC	NIV with active humidification reduced reintubation compared with HFNC in very high-risk patients.
Liu 2023 (19)	Retrospective COPD hypercapnia analysis	HFNC versus NIV	HFNC was compared with NIV in hypercapnic COPD after extubation, adding real-world data to RCT findings.
Magdy 2023 (20)	RCT, high-risk COPD patients	HFNC versus NIV	Postextubation respiratory failure and 60-day mortality were lower in the HFNC group in this single-center trial.
Wang 2021 (21)	Comparative study in difficult weaning	Sequential HFNC and NIV versus NIV-centered support	Sequential support influenced respiratory mechanics after extubation in difficult-weaning patients.
Hernández 2025 (22)	RCT, obese intermediate-risk adults	Humidified NIV versus HFNC	Reintubation was numerically lower with NIV than HFNC, 23.6% versus 33.3%, without statistical significance.

Direct HFNC versus NIV comparisons in high-risk adults showed broadly similar reintubation outcomes, with the Hernández high-risk trial showing noninferiority for HFNC and fewer postextubation respiratory failure episodes than NIV (9). Post-cardiothoracic surgery evidence also supported comparable effectiveness, because treatment failure rates were nearly identical between HFNC and NIV in a large multicenter trial (10). COPD trials were more heterogeneous, with several studies supporting HFNC as an alternative to NIV and showing better comfort, tolerance, airway care, and fewer interface-related problems (11-14,19,20).

Combined or alternating strategies changed the interpretation of a simple device-versus-device comparison (16,17). In the HIGH-WEAN trial, adding NIV sessions to high-flow nasal oxygen reduced reintubation compared with high-flow nasal oxygen alone in high-risk adults, and the COPD post hoc analysis showed an even larger absolute difference favoring NIV plus high-flow nasal oxygen (16,17). Very high-risk and obese subgroups also pointed toward a persistent role for humidified NIV, especially when ventilatory unloading is needed rather than oxygenation support alone (18,22).

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Table 2. Outcome synthesis in clinical phenotypes

Phenotype	Main finding	Interpretation
General high-risk ICU adults	HFNC was not inferior to NIV for reintubation in the largest direct RCT (9).	HFNC is a reasonable primary prophylactic option when hypercapnia or very high-risk features are absent.
Post-cardiothoracic surgery hypoxemia	HFNC and NIV produced similar treatment failure rates (10).	HFNC offers simpler delivery with comparable effectiveness in selected postoperative patients.
COPD or hypercapnia	HFNC was often comparable with NIV, while NIV plus HFNO reduced reintubation in COPD post hoc data (11-14,17,19,20).	COPD is not a single group; persistent hypercapnia and ventilatory load favor NIV or alternating support.
Sepsis after extubation	Evidence was limited and did not establish a dominant device (15).	Selection requires respiratory mechanics, mental status, secretion burden, and hemodynamic stability.
Very high-risk extubation	Humidified NIV performed better than HFNC in a randomized trial (18).	NIV retains priority when several risk factors cluster.
Obesity	NIV showed a numerical advantage over HFNC in an obesity RCT (22).	Obesity-related ventilatory load supports close monitoring and early NIV use in selected patients.

The most consistent patient-centered advantage of HFNC was tolerance (11,12,14). Mask-related discomfort, claustrophobia, air leak, skin injury, and interruptions for eating or communication reduce NIV adherence in routine care, whereas HFNC preserves speech, oral intake, secretion clearance, and bronchoscopy access (11,12,14). Safety findings across trials did not indicate excess adverse respiratory events with HFNC in appropriately selected patients, while very high-risk and hypercapnic groups required closer surveillance for delayed ventilatory failure (9,11,16-18).

Discussion

This systematic review shows that high-flow nasal cannula and non-invasive ventilation are not interchangeable labels for the same post-extubation goal, because HFNC mainly supports oxygenation, humidification, secretion clearance, and comfort, while NIV provides active ventilatory unloading (2-4). The balance between these mechanisms explains why HFNC performed similarly to NIV in broad high-risk populations and cardiothoracic surgery patients, while NIV or combined NIV plus HFNO gained importance in hypercapnic, COPD, obese, and very high-risk populations (9-11,16-18,22). The evidence supports a phenotype-based approach rather than routine use of one device for every planned extubation (7,8).

The strongest direct adult ICU trial reported HFNC as not inferior to NIV for reintubation in high-risk patients, with lower postextubation respiratory

failure and fewer interface-related adverse effects in the HFNC group (9). This finding is clinically important because comfort and continuous use influence real delivered treatment after extubation (9). Cardiothoracic surgery data also align with this interpretation, since HFNC achieved noninferior treatment failure results compared with NIV in hypoxemic postoperative adults (10).

COPD and hypercapnia represent a more complex area, because some trials support HFNC as an alternative after extubation, while data from alternating NIV plus HFNO support lower reintubation in COPD patients at high risk (11-14,17,19,20). HFNC improves tolerance and secretion management, which matters in COPD patients with cough, sputum, and mask intolerance (11,12,14). NIV retains physiological relevance when elevated PaCO2, respiratory acidosis tendency, obesity-related hypoventilation, or high inspiratory effort persists after extubation (3,17,18,22).

The combined strategy deserves special attention, because it is not simply NIV against HFNC (16). Alternating NIV with HFNO reduced reintubation compared with HFNO alone in high-risk adults and COPD subgroup analysis, suggesting that continuous oxygenation and humidification between NIV sessions increases postextubation support quality (16,17). This approach also avoids long periods on conventional low-flow oxygen between mask sessions, which was a limitation of older NIV protocols (16,17).

The main limitation of the evidence is clinical heterogeneity (7,8). Trials used different definitions of high risk, different treatment durations, different reintubation time points, variable rescue strategies, and open-label device allocation (7,9,16). Another limitation is that comfort, secretion burden, delirium, aspiration risk, cough strength, and nursing workload were not measured uniformly despite their direct effect on postextubation success (11,12,14).

For clinical practice, HFNC fits extubated adults needing oxygenation support, humidification, comfort, secretion clearance, and continuous therapy without a tight mask (4,9,10). NIV fits patients needing positive pressure ventilation, especially those with hypercapnia, COPD with high ventilatory demand, obesity hypoventilation physiology, or clustered high-risk features (3,17,18,22). Alternating NIV and HFNO appears attractive for selected high-risk patients because it combines ventilatory unloading with continuous humidified high-flow support (16,17).

Conclusion

High-flow nasal cannula is an effective postextubation support option for many critically ill adults after planned extubation. Non-invasive ventilation retains an important role in patients with hypercapnia, COPD with high ventilatory load, obesity-related hypoventilation physiology, and very high-risk extubation profiles. Alternating non-invasive ventilation with high-flow nasal oxygen appears beneficial in selected high-risk and COPD groups. The review supports bedside selection by phenotype rather than routine device substitution. Future trials need standardized risk stratification, uniform reintubation criteria, patient-centered tolerance outcomes, and phenotype-specific treatment algorithms.

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List of abbreviations

AECOPD: acute exacerbation of chronic obstructive pulmonary disease.
COPD: chronic obstructive pulmonary disease.
HFNC: high-flow nasal cannula.
HFNO: high-flow nasal oxygen.
ICU: intensive care unit.
NIPPV: non-invasive positive pressure ventilation.
NIV: non-invasive ventilation.
PaCO2: arterial partial pressure of carbon dioxide.
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
RCT: randomized controlled trial.

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