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High-Flow Nasal Oxygen Versus Noninvasive Ventilation after Extubation in High-Risk ICU Patients: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Abstract **Original Research Article**

Background. Extubation failure in high-risk ICU patients is associated with increased mortality. Guidelines favour prophylactic noninvasive ventilation (NIV), yet high-flow nasal oxygen (HFNO) is better tolerated and widely used. We compared HFNO with NIV for preventing reintubation and postextubation respiratory failure in high-risk adults. ***Methods.*** Systematic review and meta-analysis of randomized controlled trials (RCTs) enrolling adults at high risk of extubation failure who received HFNO or NIV immediately after planned extubation. The primary outcome was reintubation at the trial's primary time point. Secondary outcomes were postextubation respiratory or treatment failure, mortality and device tolerance. Risk ratios (RR) were pooled with a DerSimonian–Laird random-effects model, with Hartung–Knapp and prediction intervals as sensitivity measures. ***Results.*** Eight RCTs (1,628 patients; 808 HFNO, 820 NIV) were included in the primary analysis. Reintubation occurred in 21.9% with HFNO and 19.8% with NIV (RR 1.06, 95% CI 0.75–1.51; $I^2 = 61\%$; prediction interval 0.39–2.89). Heterogeneity was driven by one COPD trial; without it, HFNO was associated with more reintubation (RR 1.24, 95% CI 1.00–1.54; $I^2 = 8\%$). In very-high-risk, obese or prolonged-ventilation populations, HFNO increased reintubation (3 RCTs; RR 1.62, 95% CI 1.14–2.31), whereas no difference was seen in general high-risk populations (RR 1.09, 0.85–1.40). Postextubation respiratory or treatment failure was less frequent with HFNO (4 RCTs; RR 0.70, 95% CI 0.59–0.84; $I^2 = 0\%$), largely reflecting NIV intolerance. Mortality did not differ (4 RCTs; RR 0.67, 0.38–1.18). Adding HIGH-WEAN (NIV alternating with HFNO vs HFNO alone) did not change the conclusions. ***Conclusions.*** Across high-risk adults, HFNO and NIV give similar reintubation rates overall, and HFNO is better tolerated. In patients at very high risk — those with several risk factors, obesity or prolonged ventilation — NIV appears superior and should remain the first choice, with HFNO as an alternative when NIV is not tolerated. Certainty of evidence is low to moderate.

Keywords: high-flow nasal oxygen; noninvasive ventilation; extubation failure; reintubation; weaning; meta-analysis.

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INTRODUCTION

Reintubation after planned extubation occurs in about 10–20% of ICU patients and in more than 20% of those with risk factors such as age over 65 years, chronic cardiac or respiratory disease, obesity or prolonged mechanical ventilation [1–3]. Extubation failure is independently associated with higher mortality, longer ICU stay and ventilator-associated pneumonia [1,4]. Preventing postextubation respiratory failure is therefore a central goal of weaning.

Prophylactic noninvasive ventilation (NIV) applied immediately after extubation reduces respiratory failure and reintubation in high-risk and hypercapnic patients [5–7]. On this basis, the ERS/ATS and ACCP/ATS guidelines recommend preventive NIV in high-risk patients [8,9]. NIV, however, requires a tight interface, causes discomfort, skin injury and intolerance, and consumes staff time; intolerance leads to discontinuation in a large share of patients [10].

High-flow nasal oxygen (HFNO) delivers heated, humidified gas at up to 60 L/min. It provides a low, flow-dependent positive airway pressure, washes

out anatomical dead space, improves secretion clearance and is generally better tolerated than a mask [11,12]. HFNO reduces reintubation compared with conventional oxygen in low-risk patients [13]. In high-risk patients, the large multicentre trial by Hernández *et al.,* found HFNO noninferior to NIV [10]. Later trials in patients with four or more risk factors, obesity or prolonged ventilation suggested that NIV may be superior [14–16], while trials in COPD and sepsis populations reported similar or better results with HFNO [17–19]. The HIGH-WEAN trial showed that NIV alternating with HFNO reduced reintubation compared with HFNO alone [20].

Given these conflicting results and the new trials published since 2022, we performed a systematic review and meta-analysis of RCTs comparing HFNO with NIV after planned extubation in high-risk ICU patients. Our primary objective was to compare reintubation rates; secondary objectives were to compare postextubation respiratory failure, mortality and tolerance, and to explore whether the effect differs by patient phenotype.

METHODS

This review follows the PRISMA 2020 statement [22].

Eligibility criteria (PICOS)

- **Population:** adults (≥18 years) in the ICU, mechanically ventilated, who passed a spontaneous breathing trial and underwent planned extubation, and who were defined by the trial as high risk of extubation failure (≥1 predefined risk factor: age >65 years, APACHE II >12 on extubation day, BMI >30 kg/m², chronic heart failure or COPD, hypercapnia, ineffective cough or secretions, difficult or prolonged weaning, ventilation >7 days, airway patency problems, or a disease-defined high-risk population such as hypercapnic COPD or sepsis).
- **Intervention:** HFNO started immediately after extubation.
- **Comparator:** prophylactic NIV (bilevel or pressure-support NIV via a face mask) started immediately after extubation.
- **Outcomes:** primary — reintubation at the trial's primary time point (72 h or 7 days); secondary — postextubation respiratory failure or treatment failure as defined by each trial, mortality at the longest follow-up reported, and device intolerance.
- **Study design:** parallel-group RCTs published in full in peer-reviewed journals, any language.

We excluded trials of curative (rescue) treatment of established postextubation respiratory failure, postoperative trials in patients not intubated in the ICU, paediatric trials, crossover physiological studies and trials without a high-risk inclusion criterion. HIGH-WEAN [20], which compared NIV alternating with HFNO against HFNO alone, was prespecified for a sensitivity analysis only, because its experimental arm combined both devices.

Information sources and search

MEDLINE (PubMed), Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science and ClinicalTrials.gov are searched from inception to October 2026, together with the reference lists of included trials and previous meta-analyses [28–30].

Study selection and data extraction

Two reviewers independently screen titles and abstracts, then full texts, and resolve disagreements by discussion with a third reviewer. Using a piloted form, they extract: first author, year, country, setting, number of centres, inclusion criteria, sample size per arm, device settings and duration, outcome definitions and time points, and event counts by arm. When a count is reported only as a percentage, it is back-calculated from the arm denominator and checked against the reported effect size. Analyses follow the intention-to-treat population.

Risk of bias and certainty of evidence

Risk of bias is assessed with the Cochrane RoB 2 tool [23] across five domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement and selection of the reported result. Certainty of evidence for each outcome is rated with GRADE [26].

Statistical analysis

The effect measure is the risk ratio (RR, HFNO vs NIV) with 95% confidence intervals (CI); RR >1 favours NIV. Trials are pooled with a DerSimonian–Laird random-effects model [24]; a 0.5 continuity correction is applied to trials with a zero cell. Heterogeneity is quantified with Cochran's Q, I^2 and τ^2. Because the number of trials is small, we also report Hartung–Knapp–Sidik–Jonkman (HKSJ) confidence intervals and 95% prediction intervals [25].

Prespecified subgroups, defined by the trial population, are: (1) general high-risk patients (≥1 risk factor, or sepsis); (2) COPD with hypercapnic respiratory failure; (3) very high-risk patients (≥4 risk factors), obesity or prolonged mechanical ventilation (≥14 days). Subgroup differences are tested with a Q test for interaction. Sensitivity analyses: leave-one-out; exclusion of any statistically outlying trial identified by leave-one-out; use of 7-day rather than 72-h reintubation where both are reported; and addition of HIGH-WEAN. Funnel plots and Egger's test are not performed because fewer than 10 trials are pooled. Analyses were run in Python 3 (NumPy, SciPy) using standard inverse-variance formulas; a two-sided $p < 0.05$ defines statistical significance.

RESULTS

Study selection

Eight RCTs (1,628 patients: 808 HFNO, 820 NIV) met the inclusion criteria for the primary analysis [10,14–19,21], and HIGH-WEAN (641 patients) was added in sensitivity analyses [20]. The PRISMA flow diagram (Figure 1) records the screening: records identified [n], duplicates removed [n], full texts assessed [n], excluded [n] with reasons. Trials excluded at full-text stage included BiPOP (post-cardiothoracic surgery, mixed curative and prophylactic use) [27], a three-arm trial without a high-risk inclusion criterion [32], and a pilot trial reporting only physiological end points [31]. One completed trial in high-risk patients (NCT07630766) has no published results yet.

Characteristics of included trials

Trials were published between 2016 and 2025 and enrolled 40 to 604 patients. Three enrolled general high-risk or septic patients, two enrolled hypercapnic COPD patients, and three enrolled very-high-risk (≥4 risk factors), obese or prolonged-ventilation patients. Device support lasted 24–48 h in most trials. Primary end points were reintubation at 72 h (four trials) or at 7 days (two), a composite treatment failure (one), and reintubation without a stated time window in the abstract (one).

Table 1: Characteristics of included randomized controlled trials

Trial	Setting	High-risk population	N HFNO / NIV	HFNO protocol	NIV protocol	Primary end point
Hernández 2016 [10]	Spain, 3 ICUs	≥1 risk factor (age >65, APACHE II >12, BMI >30, COPD, heart failure, prolonged MV, etc.)	290 / 314	Titrated, mean ≈50 L/min, 24 h	Face mask, 24 h	Reintubation and PERF at 72 h
Tan 2020 [17]	China, 2 ICUs	COPD with hypercapnic respiratory failure, extubated at PIC window	44 / 42	50 L/min start, 37 °C	S/T mode, full-face mask, IPAP ≥8 / EPAP ≥4 cmH_2O	Treatment failure (reintubation or switch)
Tongyoo 2021 [19]	Thailand, 1 centre	Sepsis, MV ≥48 h	112 / 110	30–50 L/min, 24 h	BiPAP 8/5 cmH_2O, IPAP ≤20, 24 h	Reintubation at 72 h
Hernández 2022 [14]	Spain, 2 ICUs	≥4 risk factors (very high risk)	90 / 92	Up to 60 L/min, 48 h	Actively humidified NIV, 48 h	Reintubation at 7 days
Magdy 2023 [18]	Egypt, 1 centre	High-risk COPD	120 / 110	Not detailed in abstract	Face mask	Reintubation at 72 h
Tseng 2023 [16]	Taiwan, 1 centre	Prolonged MV ≥14 days	20 / 20	50 L/min start	IPAP 12–16 / EPAP 4–6 cmH_2O	Reintubation at 72 h
Hernández 2025 [15]	Spain, 2 ICUs	BMI ≥30 with ≤2 other risk factors	72 / 72	Up to 60 L/min, 48 h	Actively humidified NIV, 48 h	Reintubation at 7 days
EJHM 2025 [21]	Egypt	High risk, MV ≥24 h	60 / 60	Not detailed in abstract	Not detailed in abstract	Reintubation
HIGH-WEAN 2019 [20]	*France, 30 ICUs*	*Age >65 or chronic cardiac / respiratory disease*	*302 / 339*	*HFNO alone, ≥48 h*	*NIV ≥12 h/day alternating with HFNO, 48 h*	*Reintubation at 7 days*

PERF: postextubation respiratory failure; MV: mechanical ventilation; PIC:pulmonary infection control. Italic row: sensitivity analysis only.

Risk of bias

All trials were open-label, so every trial had at least some concerns for deviations from intended interventions; reintubation criteria were prespecified in all trials, which limits but does not remove this bias. Tan 2020 was rated high risk because 10 of 96 randomized patients were excluded after randomization.

Table 2: Risk of bias (RoB 2). L: low; S: some concerns; H: high

Trial	Randomization	Deviations	Missing data	Outcome measurement	Reporting	Overall
Hernández 2016	L	S	L	S	L	S
Tan 2020	L	S	H	S	L	H
Tongyoo 2021	L	S	L	L	L	S
Hernández 2022	L	S	L	S	L	S
Magdy 2023	S	S	L	S	S	S
Tseng 2023	L	S	L	S	L	S
Hernández 2025	S	S	L	S	L	S
EJHM 2025	S	S	L	S	S	S
HIGH-WEAN 2019	L	S	L	S	L	S

Primary outcome: reintubation

Reintubation did not differ between HFNO and NIV overall: 177/808 (21.9%) vs 162/820 (19.8%), RR 1.06 (95% CI 0.75–1.51; p = 0.74; Figure 2). This corresponds to 12 more reintubations per 1,000 patients with HFNO (from 49 fewer to 101 more). Heterogeneity was substantial (I^2 = 61%, τ^2 = 0.136); the HKSJ interval was 0.65–1.73 and the 95% prediction interval 0.39–2.89.

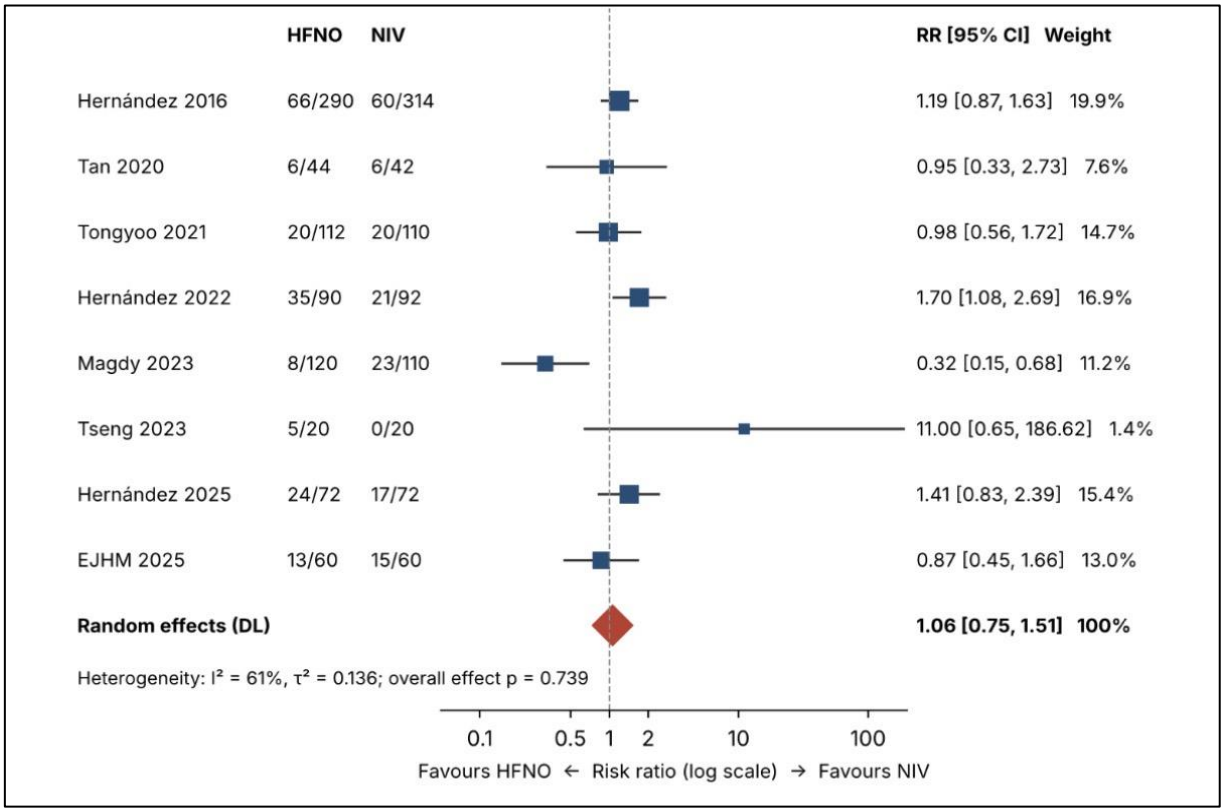

Figure 1: Reintubation at each trial's primary time point. Risk ratios >1 favour NIV. Tseng 2023 includes a 0.5 continuity correction for a zero cell

Leave-one-out analysis identified Magdy 2023 as the single source of heterogeneity. Without it, I^2 fell to 8% and HFNO was associated with more reintubation (RR 1.24, 95% CI 1.00–1.54; p = 0.049), although the HKSJ interval crossed 1 (0.95–1.63). Removing any other trial left the pooled RR between 0.96 and 1.09 and non-significant.

The effect differed by population (test for subgroup differences p = 0.06). In very-high-risk, obese and prolonged-ventilation patients, HFNO increased reintubation (RR 1.62, 95% CI 1.14–2.31; I^2 = 3%), or about 128 more reintubations per 1,000 patients (29 to 271 more). There was no difference in general high-risk and septic patients (RR 1.09, 0.85–1.40; I^2 = 0%). In hypercapnic COPD the two trials disagreed (RR 0.52, 0.18–1.51; I^2 = 64%).

Table 3: Subgroup and sensitivity analyses for reintubation (random effects)

Analysis	Trials	RR (95% CI)	p	I^2	HKSJ 95% CI
Primary analysis	8	**1.06 (0.75–1.51)**	0.74	61%	0.65–1.73
Subgroup: general high-risk / sepsis	3	1.09 (0.85–1.40)	0.49	0%	0.75–1.59
Subgroup: hypercapnic COPD	2	0.52 (0.18–1.51)	0.23	64%	—
Subgroup: very high-risk, obese, prolonged MV	3	1.62 (1.14–2.31)	0.008	3%	0.74–3.55
Excluding Magdy 2023 (outlier)	7	1.24 (1.00–1.54)	0.049	8%	0.95–1.63
Tongyoo 2021 at 7 days instead of 72 h	8	1.02 (0.71–1.46)	0.91	65%	0.62–1.68
Adding HIGH-WEAN (NIV + HFNO vs HFNO)	9	1.13 (0.84–1.53)	0.43	60%	0.75–1.71

With two or three trials per subgroup, HKSJ intervals are wide and subgroup findings are hypothesis-generating.

Secondary outcome: postextubation respiratory or treatment failure

Four trials reported respiratory or treatment failure [10,17–19]. It occurred less often with HFNO: 145/566 (25.6%) vs 210/576 (36.5%), RR 0.70 (95% CI 0.59–0.84; $p < 0.001$; $I^2 = 0\%$; HKSJ 0.63–0.79; Figure 3). This is about 109 fewer failures per 1,000 patients. The definitions differed: Hernández 2016 counted NIV intolerance as respiratory failure, Tan 2020 counted any switch of device, and Tongyoo 2021 counted rescue therapy. Much of the benefit therefore reflects NIV intolerance rather than better gas exchange, which is consistent with the absence of a difference in reintubation. Adding HIGH-WEAN, in which HFNO alone had more failures than NIV alternating with HFNO (29.1% vs 20.9%), removed the effect and introduced heterogeneity (RR 0.85, 0.60–1.19; $I^2 = 77\%$).

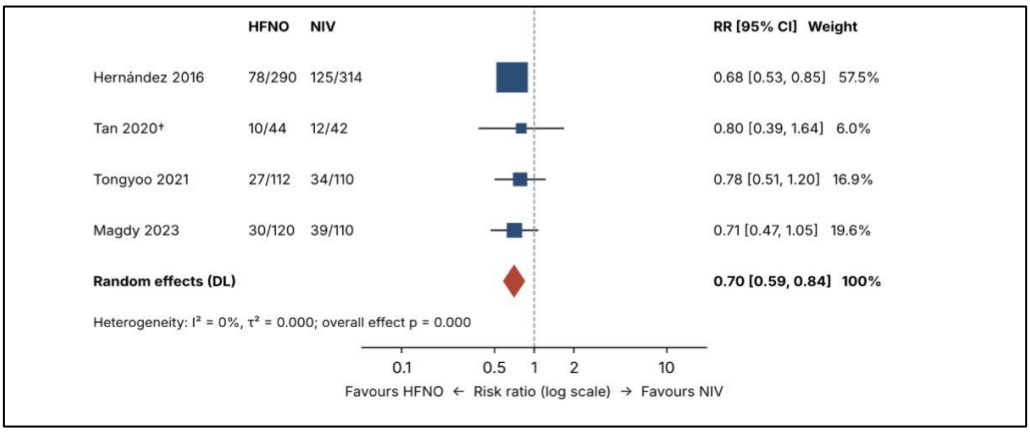

Figure 2: Postextubation respiratory or treatment failure, as defined by each trial. † Tan 2020: composite of reintubation or switch of device

Secondary outcome: mortality

Four trials reported mortality with event counts by arm, at 28 to 90 days [16–19]. Mortality was 23/296 (7.8%) with HFNO and 34/282 (12.1%) with NIV, RR 0.67 (95% CI 0.38–1.18; $p = 0.16$; $I^2 = 15\%$; Figure 4). The point estimate depends mainly on Magdy 2023; the other three trials were individually null. Hernández 2022 and Hernández 2025 reported no significant difference in mortality [14,15].

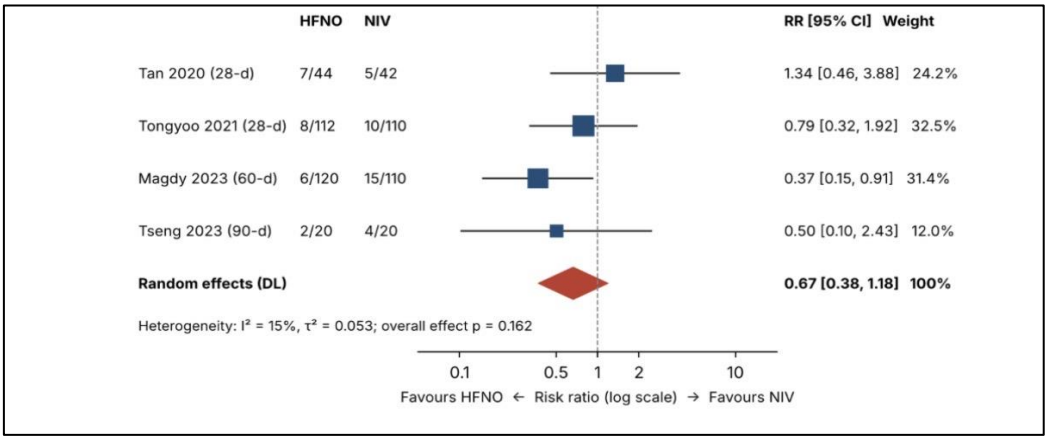

Figure 3: Mortality at the longest follow-up reported (28, 60 or 90 days)

Tolerance and length of stay

Every trial reporting tolerance favoured HFNO. In Hernández 2016, adverse effects required withdrawal of therapy in none of the HFNO patients vs 42.9% with NIV [10]. Intolerance was 4% vs 15% in Hernández 2025 [15] and 3.3% vs 15% in the 2025 Egyptian trial [21]. In Tan 2020, HFNO gave higher comfort scores (median 7 vs 5), fewer airway-care interventions and no facial skin breakdown (0% vs 9.6%) [17]. Effects on length of stay were inconsistent: ICU stay was shorter with HFNO in Hernández 2016 (median 3 vs 4 days) and Hernández 2025 (6.5 vs 11 days), whereas hospital stay was shorter with NIV in Hernández 2022 (20 vs 26.5 days).

Certainty of evidence

Table 4: GRADE summary of findings (HFNO compared with NIV)

Outcome	Trials (patients)	Relative effect (95% CI)	Absolute effect per 1,000	Certainty	Reasons
Reintubation, all high-risk	8 (1,628)	RR 1.06 (0.75–1.51)	12 more (49 fewer to 101 more)	Low	Inconsistency, imprecision
Reintubation, very high-risk / obese / prolonged MV	3 (366)	RR 1.62 (1.14–2.31)	128 more (29 to 271 more)	Low	Open-label, imprecision
Respiratory / treatment failure	4 (1,142)	RR 0.70 (0.59–0.84)	109 fewer (150 to 58 fewer)	Moderate	Indirectness (definitions include intolerance)
Mortality	4 (578)	RR 0.67 (0.38–1.18)	40 fewer (75 fewer to 22 more)	Very low	Imprecision, risk of bias

DISCUSSION

In this meta-analysis of eight RCTs including 1,628 high-risk adults, HFNO and NIV applied immediately after planned extubation gave similar reintubation rates overall (RR 1.06). HFNO reduced respiratory or treatment failure by about 30%, mainly because NIV was poorly tolerated, and mortality did not differ. The overall estimate, however, hides a consistent pattern: in patients at very high risk, with obesity or after prolonged ventilation, NIV prevented reintubation better than HFNO (RR 1.62), whereas no difference was seen in general high-risk and septic populations.

Comparison with previous meta-analyses

Our overall result agrees with earlier syntheses. Granton *et al.,* found no difference in reintubation between HFNO and NIV (RR 1.16, 95% CI 0.86–1.57) and a non-significant reduction in respiratory failure with HFNO [28]. A 2026 meta-analysis restricted to high-risk patients reported RR 1.22 (0.83–1.80) for 72-h reintubation [29]. The HIGH-FLOW OXY meta-analysis found a higher reintubation risk with HFNO in very-high-risk (OR 1.63) and non-operative obese patients (OR 2.52), and a significant harm signal once high-risk-of-bias trials were removed (OR 1.32) [30]. Our subgroup and outlier-excluded estimates (RR 1.62 and 1.24) are very close to these figures, which strengthens the conclusion that the benefit of NIV is concentrated in the sickest patients.

Physiological interpretation

NIV delivers a controlled inspiratory pressure and PEEP of 5–8 cmH_2O, which unloads the respiratory muscles, recruits atelectatic lung and reduces left-ventricular afterload. These effects matter most when respiratory load is high: obesity with reduced end-expiratory lung volume, weaning-induced pulmonary oedema, diaphragm weakness after prolonged ventilation, and multiple coexisting risk factors [14–16]. HFNO generates only 2–5 cmH_2O of flow-dependent pressure, which falls when the mouth is open, but it washes out dead space, humidifies secretions and is comfortable. These properties explain why HFNO performs as well as NIV when the load is moderate and why patients tolerate it far better. The two most recent trials using actively humidified NIV for 48 h [14,15] suggest that tolerance of NIV can be improved, which may widen its advantage.

The COPD question

The two COPD trials point in opposite directions. Tan 2020 found similar failure rates with HFNO and NIV [17], while Magdy 2023 reported a large reduction in reintubation and 60-day mortality with HFNO [18]. The latter effect (RR 0.32) is larger than any other in this field, conflicts with the strong physiological rationale for NIV in hypercapnia [7], and is the only source of statistical heterogeneity. Until it is replicated, HFNO should not be considered superior to NIV in hypercapnic COPD; it remains a reasonable option for patients who do not tolerate the mask.

Combined NIV–HFNO strategies

HIGH-WEAN shows that the choice need not be binary: NIV sessions alternating with HFNO reduced 7-day reintubation compared with HFNO alone (11.8% vs 18.2%) [20]. Combining the pressure support of NIV with the comfort of HFNO between sessions is a pragmatic way to deliver NIV to very-high-risk patients without the intolerance seen with continuous mask use.

Strengths and limitations

This review includes trials published up to 2025, separates standalone NIV from combined strategies, and explores the population effect with prespecified subgroups and robust variance estimators. Several limitations apply. First, the number of trials is small and subgroups contain two or three trials each, so the interaction test was borderline ($p = 0.06$) and HKSJ intervals were wide. Second, all trials were open-label; reintubation decisions may have been influenced by knowledge of the device despite prespecified criteria. Third, definitions of high risk, respiratory failure, device settings and outcome windows (72 h vs 7 days) differed between trials. Fourth, data for three trials were taken from abstracts or open-access summaries, several event counts were back-calculated from percentages, and the risk-of-bias judgements are provisional. Fifth, publication bias could not be assessed formally with fewer than 10 trials. Finally, mortality and length of stay were inconsistently reported.

Clinical implications

1. In high-risk patients with one to three risk factors, HFNO is an acceptable alternative to NIV after extubation, with equal reintubation rates and much better tolerance.
2. In patients with four or more risk factors, obesity (BMI ≥30 kg/m²) or ventilation ≥14 days, prophylactic NIV — preferably with active humidification, or alternating with HFNO — should be the first choice.
3. In hypercapnic COPD, NIV remains the reference; HFNO is a fallback when NIV is not tolerated.
4. Future trials should stratify by risk phenotype, blind outcome adjudication where possible, report reintubation at 7 days, and compare combined NIV–HFNO strategies with NIV alone.

CONCLUSIONS

After planned extubation in high-risk ICU patients, HFNO and NIV result in similar reintubation rates overall, and HFNO is better tolerated and associated with less treatment failure. In very-high-risk, obese and prolonged-ventilation patients, NIV reduces reintubation and should be preferred. The certainty of evidence is low to moderate, and adequately powered, risk-stratified trials are needed.

REFERENCES

1. Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L. Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med. 2011;39(12):2612–2618.
2. Esteban A, Frutos-Vivar F, Muriel A, *et al.,*Evolution of mortality over time in patients receiving mechanical ventilation. Am J Respir Crit Care Med. 2013;188(2):220–230.
3. Thille AW, Richard JC, Brochard L. The decision to extubate in the intensive care unit. Am J Respir Crit Care Med. 2013;187(12):1294–1302.
4. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. Chest. 1997;112(1):186–192.
5. Nava S, Gregoretti C, Fanfulla F, *et al.,*Noninvasive ventilation to prevent respiratory failure after extubation in high-risk patients. Crit Care Med. 2005;33(11):2465–2470.
6. Ferrer M, Valencia M, Nicolas JM, *et al.,*Early noninvasive ventilation averts extubation failure in patients at risk: a randomized trial. Am J Respir Crit Care Med. 2006;173(2):164–170.
7. Ferrer M, Sellarés J, Valencia M, *et al.,*Non-invasive ventilation after extubation in hypercapnic patients with chronic respiratory disorders: randomised controlled trial. Lancet. 2009;374(9695):1082–1088.
8. Rochwerg B, Brochard L, Elliott MW, *et al.,*Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. Eur Respir J. 2017;50(2):1602426.
9. Ouellette DR, Patel S, Girard TD, *et al.,*Liberation from mechanical ventilation in critically ill adults: an official ACCP/ATS clinical practice guideline. Chest. 2017;151(1):166–180.
10. Hernández G, Vaquero C, Colinas L, *et al.,*Effect of postextubation high-flow nasal cannula vs noninvasive ventilation on reintubation and postextubation respiratory failure in high-risk patients: a randomized clinical trial. JAMA. 2016;316(15):1565–1574.
11. Papazian L, Corley A, Hess D, *et al.,*Use of high-flow nasal cannula oxygenation in ICU adults: a narrative review. Intensive Care Med. 2016;42(9):1336–1349.
12. Rochwerg B, Einav S, Chaudhuri D, *et al.,*The role for high flow nasal cannula as a respiratory support strategy in adults: a clinical practice guideline. Intensive Care Med. 2020;46(12):2226–2237.
13. Hernández G, Vaquero C, González P, *et al.,*Effect of postextubation high-flow nasal cannula vs conventional oxygen therapy on reintubation in low-risk patients: a randomized clinical trial. JAMA. 2016;315(13):1354–1361.
14. Hernández G, Paredes I, Moran F, *et al.,*Effect of postextubation noninvasive ventilation with active humidification vs high-flow nasal cannula on reintubation in patients at very high risk for extubation failure: a randomized trial. Intensive Care Med. 2022;48(12):1751–1759.
15. Hernández G, Dianti J, Paredes I, *et al.,*Humidified noninvasive ventilation versus high-flow therapy to prevent reintubation in patients with obesity: a randomized clinical trial. Am J Respir Crit Care Med. 2025;211(2):222–229.
16. Tseng CW, Chao KY, Wu HL, Lin CC, Hsu HS. Effectiveness of high-flow nasal cannulae compared with noninvasive positive-pressure ventilation in

preventing reintubation in patients receiving prolonged mechanical ventilation. Sci Rep. 2023;13:4689.
17. Tan D, Walline JH, Ling B, *et al.,*High-flow nasal cannula oxygen therapy versus non-invasive ventilation for chronic obstructive pulmonary disease patients after extubation: a multicenter, randomized controlled trial. Crit Care. 2020;24:489.
18. Magdy DM, Metwally A. Effect of high-flow nasal cannula versus non-invasive ventilation in preventing re-intubation in high-risk chronic obstructive pulmonary disease patients: a randomised controlled trial. Lung India. 2023;40(4):312–320.
19. Tongyoo S, Tantibundit P, Daorattanachai K, *et al.,*High-flow nasal oxygen cannula vs. noninvasive mechanical ventilation to prevent reintubation in sepsis: a randomized controlled trial. Ann Intensive Care. 2021;11:135.
20. Thille AW, Muller G, Gacouin A, *et al.,*Effect of postextubation high-flow nasal oxygen with noninvasive ventilation vs high-flow nasal oxygen alone on reintubation among patients at high risk of extubation failure: a randomized clinical trial. JAMA. 2019;322(15):1465–1475.
21. Page MJ, McKenzie JE, Bossuyt PM, *et al.,*The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
22. Sterne JAC, Savović J, Page MJ, *et al.,*RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898.
23. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7(3):177–188.
24. IntHout J, Ioannidis JPA, Borm GF. The Hartung-Knapp-Sidik-Jonkman method for random effects meta-analysis is straightforward and considerably outperforms the standard DerSimonian-Laird method. BMC Med Res Methodol. 2014;14:25.
25. Guyatt GH, Oxman AD, Vist GE, *et al.,*GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008;336(7650):924–926.
26. Stéphan F, Barrucand B, Petit P, *et al.,*High-flow nasal oxygen vs noninvasive positive airway pressure in hypoxemic patients after cardiothoracic surgery: a randomized clinical trial. JAMA. 2015;313(23):2331–2339.
27. Granton D, Chaudhuri D, Wang D, *et al.,*High-flow nasal cannula compared with conventional oxygen therapy or noninvasive ventilation immediately postextubation: a systematic review and meta-analysis. Crit Care Med. 2020;48(11):e1129–e1136.
28. Jing G, Li J, Hao D, *et al.,*Comparison of high flow nasal cannula with noninvasive ventilation in chronic obstructive pulmonary disease patients with hypercapnia in preventing postextubation respiratory failure: a pilot randomized controlled trial. Res Nurs Health. 2019;42(3):217–225.
29. Elghonemy AAAM, Korraa E, Mohammed RM. Effectiveness of high-flow nasal cannula versus noninvasive ventilation and conventional oxygen therapy in patients weaned from invasive mechanical ventilation. Egypt J Bronchol. 2024;18. doi:10.1186/s43168-024-00350-6.