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REVIEW ARTICLES

Non-invasive ventilation for weaning, avoiding reintubation after extubation and in the postoperative period: a meta-analysis

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Editor's key points

- The role of non-invasive ventilation (NIV) to aid weaning and avoid reintubation has been studied in the past.
- This meta-analysis selected 16 relevant randomized controlled trials.
- The use of NIV reduced the length of stay in intensive care unit and the rate of reintubation.
- This important meta-analysis provides strong evidence in favour of using NIV during weaning from mechanical ventilation.

Summary. Non-invasive ventilation (NIV) is a supportive therapy that improves mortality in acute respiratory failure (RF). It may also be used in patients recently extubated in intensive care units (ICUs), after operation, and to aid weaning from mechanical ventilation (MV) by reducing the morbidity and mortality associated with further MV. A meta-analysis of the available evidence was performed on the use of NIV in three areas: weaning, reduction in reintubation rates post-extubation on ICU, and reduction in RF after major surgery. Sixteen relevant randomized controlled trials were identified by three reviewers after a detailed search of identified medical databases. A meta-analysis of summary statistics relating to predetermined endpoints (ICU and hospital length of stay, ICU and hospital mortality, reintubation, pneumonia) was performed. NIV reduced the ICU length of stay when used for weaning (5.12 days) and post-surgery (0.44 days). NIV reduced reintubation rates post-surgery [odds ratio (OR) 0.24, 95% confidence interval (CI) 0.12–0.50] and the incidence of pneumonia in weaning (OR 0.12, 95% CI 0.05–0.31) and post-surgery (OR 0.27, 95% CI 0.09–0.77). There was insufficient evidence to suggest that NIV improves ICU survival, but an increased hospital survival in weaning (OR 0.55, 95% CI 0.31–0.98) and post-surgery (OR 4.54, 0.95% CI 1.35–15.31) was seen. A meta analysis of NIV use in selected subgroups of recently extubated patients suggests that the judicious NIV use may reduce ICU and hospital length of stay, pneumonia, and reintubation rates and hospital survival.

Keywords: complications, respiratory; intensive care, pulmonary; mechanical ventilation; weaning

Tracheal intubation and mechanical ventilation (MV) are supportive interventions that may be life saving in critically ill patients but also introduce significant risk of morbidity and mortality, including volutrauma, barotrauma, ventilator-associated pneumonia (VAP), and the complications associated with sedation. VAP is associated with poor clinical and economic outcomes, with a large data registry series from the USA quoting rates of VAP in ventilated intensive care unit (ICU) patients of 9.3% and demonstrating increased morbidity and ICU length of stay.[1] Timely extubation is one way of minimizing this morbidity,[2] but premature or inappropriate extubation may in itself be detrimental, and the need for reintubation may be associated in some patient groups with a hospital mortality of up to 40%.[3]

Non-invasive ventilation (NIV) refers to the delivery of ventilatory support via the patient's upper airway using a mask or similar device.[4] Non-invasive respiratory support ranges from basic continuous positive airway pressure (CPAP) to non-invasive positive pressure ventilation (NPPV) in which varying levels of pressure support can be applied during patient inspiration. The use of NIV has increased considerably over the last 20 yr as a viable alternative to tracheal intubation and MV in patients with respiratory failure (RF). It has been demonstrated to reduce the need for tracheal intubation[5] and ventilation in several patient groups,[6] including exacerbations of chronic obstructive pulmonary disease (COPD),[7] cardiogenic pulmonary oedema,[8] the immunocompromised,[9] and those in whom invasive MV has been deemed inappropriate.[10]

More recently, NIV has been used in a wider variety of clinical situations, such as ICU patients who have recently been extubated after a period of MV,[11] patients who are difficult to wean from MV,[12] and postoperative surgical patients.[13] This population of recently extubated patients all have increased morbidity and mortality should they develop RF and require reintubation and may therefore benefit from the use of NIV to prevent this progression. Results of studies examining the use of NIV in these situations in the general critical care population have been inconclusive, and there remains no clear consensus opinion regarding the use of NIV after extubation. Many of the trials also focus on patient mortality as their primary endpoint and apportion less attention to the impact that NIV may have on important health economic outcomes such as ICU and hospital length of stay and rates of nosocomial pneumonia.

Therefore, we performed a systematic review and meta-analysis of the currently available literature on the use of NIV after extubation, specifically considering patients difficult to wean from MV, patients in the immediate postoperative period, and critically ill patients within the ICU with the aim of assessing the potential benefits that the use of NIV may have in these situations compared with standard medical therapy.

Methods

Papers were identified from a literature search of Ovid Medline, NHS Evidence Embase, Web of Science, and The Cochrane Library and DARE libraries for various different key phrases and restrictions to identify randomized control trials (RCTs) reported in English that looked at using NIV in either post-extubation, weaning, or postoperative patient populations compared with standard care. The interchangeable use of the term 'NIV'—which in some instances referred to solely NPPV and in others both NPPV and CPAP—did raise some difficulties in performing the searches. We were unable to identify any studies in adult populations where CPAP was used in post-ICU extubation and weaning patients; however, the use of CPAP is more prevalent than NPPV in postoperative populations. For this reason, we ran a second search of postoperative patients using the search term 'continuous positive airways pressure' to ensure that any studies performed in this area were not excluded from our analysis. For the purposes of analysis, we subdivided the papers into three subgroups in which NIV may be used in recently extubated patients, namely post-extubation in ICU, weaning of patients from MV, and postoperative patients. Table 1 gives the details of the search strategies used and the results obtained.

Each identified paper was reviewed and assessed independently by three clinicians against the following criteria for inclusion:

- Searches repeated by three authors (A.J.G., D.C.B., and G.H.M.).
- Papers identified that related directly to the use of NIV post-ICU extubation, in weaning, or in postoperative patients.
- Of the remaining papers, only those that reported RCTs were retained for inclusion.

Table 1 Search strategies used and results obtained

	Search term	Database				
		Ovid Medline (1950–2012)	NHS Evidence EMBASE	Web of Science	Cochrane	DARE
1	Intubation intratracheal	26 162	−216	0	—	—
2	Respiration artificial	47 870	—	1643	—	—
3	Respiratory insufficiency	43 817	—	3702	—	—
4	Weaning/ventilator weaning 9199	—	19 936	—	—	—
5	Positive pressure respiration 16 519	—	—	—	—	—
6	1 or 2 or 3 or 4 or 5	110 778	—	—	—	—
7	Non-invasive ventilation	715	2028	2409	2	13
8	6 and 7	658	—	—	—	—
9	Limit 8 to abstracts and English language and years 1980–present and clinical trials	80	—	—	—	—
10	1 or 2 or 3 or 5	103 737	—	—	—	—
11	Continuous positive airways pressure	1931	—	—	—	—
12	Postoperative complications 335 016	—	—	—	—	—
13	1 and 10 and 11 81	—	—	—	—	—
14	Artificial ventilation	20 915	—	—	—	—
15	7 and 14	925	—	—	—	—
16	Limit 15 to abstracts and humans >18 yr	—	307	—	—	—
17	Controlled clinical trial >100 000	— —	181 320 —			
18	15 and 17	—	62	—	—	—
19	1 or 2 or 3	—	24 540	—	—	—
20	7 and 19	—	—	377	—	—
21	20 excluding paediatrics and neurological disorders and English only	—	216	—	—	—
22	17 and 18	—	—	39	—	—

Table 2 Studies selected for inclusion in the meta-analysis

Group	Paper	Sample size (*n*)	
		Control	Treatment
NIV for weaning	Nava and colleagues[22]	25	25
	Girault and colleagues[23]	16	17
	Ferrer and colleagues[12]	22	21
	Trevisan and colleagues[24]	37	28
	Girault and colleagues[20]	69	69
Post-ICU extubation	Keenan and colleagues[25]	42	39
	Esteban and colleagues[11]	107	114
	Nava and colleagues[26]	65	65
	Ferrer and colleagues[27]	83	79
	Ferrer and colleagues[18]	52	54
	Khilnani and colleagues[28]	20	20
Post-surgery	Auriant and colleagues[29]	24	24
	Bohner and colleagues[30]	105	99
	Squadrone and colleagues[13]	104	105
	Kindgen-Milles and colleagues[17]	25	25
	Zarbock and colleagues[16]	236	232

- Review of methodology in each paper by A.J.G., D.C.B., and G.H.M. and studies only included if thought to be methodologically robust by two or more of the reviewers.
- Where there were disagreements regarding the inclusion of papers, discussions were undertaken by the clinicians to clarify whether a paper should be included or excluded from the final analysis.

We included only RCTs, in adults, that had been published in the English language up to January 2012. We only accepted studies that directly compared NIV as an intervention with standard medical therapy and aimed to use NIV for at least 12 h after extubation. We also reviewed the methodology and conduct, statistical analysis, and reporting of results in each study included. Of the papers identified, 16 were found to meet the criteria for inclusion—five in weaning patients, six in recently extubated ICU patients, and five in postoperative patients—and details of these are given in Table 2. The papers were then grouped into these subgroups to allow separate analysis of the three areas.

Summary statistics *n*, mean (μ), and standard deviation (SD δ) were recorded on the length of stay in ICUs and hospital as reported in each paper. The numbers of cases and controls surviving ICU stay, surviving hospital stay, and the number developing pneumonia were recorded from publications that provided them. Reintubation rates, where displayed in the results of the paper, were also recorded.

These data were imported into the statistical software Stata 11.1 StataCorp [2009] and meta-analyses were performed using the metan routine (as per Harris and colleagues, 2008[14]), which implements the meta-analysis methods described by Higgins and colleagues in 2003.[15] A meta-analysis of the mean length of stay in both ICU and hospital was performed using the unstandardized means for each of the three subgroups. The endpoints of risk [measured by odds ratio (OR)] for reintubation, pneumonia, surviving ICU, and hospital stay stratifying for the scenario under which NIV was used were also analysed via meta-analysis.

Results

A summary of both the ICU and hospital length of stay reported by each paper is provided in Table 3 with the meta-analysis results for ICU and hospital length of stay shown in Figures 1 and 2. A summary of the OR, confidence intervals (CIs), and associated *P*-values for reintubation, pneumonia, ICU survival, and hospital survival outcomes are shown in Table 4 with the meta-analysis results shown in Figures 3–6.

ICU and hospital length of stay

There was a reduction in the ICU length of stay for those who received NIV when used for weaning [−5.12 days (95% CI −7.91 to −2.32)] but not post-ICU extubation [0.05 (95% CI −0.86 to 0.96)], and a nominal reduction was seen when used post-surgery [−0.04 days (95% CI −0.05 to −0.03)] as shown in Figure 1.

Analysis of the effects of NIV on hospital length of stay for each subgroup revealed that a reduction of 6.45 days was seen in the weaning group (95% CI −12.41 to −0.48) but not in the NIV post-extubation subgroup [−0.67 (95% CI −1.18 to 0.54)] as shown in Figure 2. There was also a reduction seen in the post-surgery group [−1.03 days (95% CI −1.13 to −0.93)], although the findings of one study in this subgroup[16] had a strong influence due to the large sample size in comparison with the other studies.

Whether the length of stay in ICU or hospital is being considered, there is a high degree of heterogeneity reported by the studies, so while there is a reduction in the length of stay, the number of days lengths of stay are reduced is highly variable.

Reintubation

NIV reduced the risk of reintubation when used post-surgery [combined OR 0.24 (95% CI 0.12–0.50)] but not when used for weaning [combined OR 0.96 (95% CI 0.50–1.83)] or post-ICU extubation [combined OR 0.72 (95% CI 0.51–1.02)] as shown in Figure 3.

Pneumonia

The risk of pneumonia is decreased by NIV when used for weaning [combined OR 0.12 (95% CI 0.05–0.31)] and post-surgery [combined OR 0.27 (95% CI 0.09–0.77)], but not when used post-ICU extubation [combined OR 0.72 (95% CI 0.42–1.25)] as shown in Figure 4.

Table 3 Summary of reported statistics on ICU and hospital length of stay after NIV

Group	Paper	Sample size (*n*)		ICU length of stay		Hospital length of stay	
		Control	Treatment	Control	Treatment	Control	Treatment
NIV for weaning	Nava and colleagues[22]	25	25	24.00 (13.70)	15.10 (5.40)		—
	Girault and colleagues[23]	16	17	14.06 (7.54)	12.35 (6.82)	27.69 (13.09)	27.12 (14.33)
	Ferrer and colleagues[12]	22	21	25.00 (12.50)	14.10 (9.20)	40.80 (21.40)	27.80 (14.60)
	Trevisan and colleagues[24]	37	28	20.80 (10.90)	18.90 (11.30)	42.40 (24.50)	34.50 (20.60)
	Girault and colleagues[20]	69	69	—	—	—	—
Post-ICU extubation	Keenan and colleagues[25]	42	39	19.40 (25.00)	15.10 (10.90)	29.80 (28.40)	32.20 (25.40)
	Nava and colleagues[26]	65	65	11.60 (14.90)	8.90 (5.70)	25.50 (21.40)	23.30 (16.40)
	Esteban and colleagues[11]	107	114	18.00 (.)	18.00 (.)	—	—
	Ferrer and colleagues[27]	83	79	13.00 (11.00)	11.00 (8.00)	29.00 (18.00)	30.00 (23.00)
	Ferrer and colleagues[18]	52	54	10.00 (9.00)	11.00 (13.00)	24.00 (17.00)	29.00 (27.00)
	Khilnani and colleagues[28]	20	20	1.55 (0.82)	2.05 (2.18)	6.37 (2.33)	5.53 (1.74)
Post-surgery	Auriant and colleagues[29]	24	24	14.00 (11.10)	16.65 (23.60)	22.80 (10.70)	27.10 (19.50)
	Bohner and colleagues[30]	105	99	2.83 (7.09)	1.91 (1.63)	11.81 (18.61)	9.45 (6.79)
	Squadrone and colleagues[13]	104	105	2.60 (4.20)	1.40 (1.60)	17.00 (15.00)	15.00 (13.00)
	Kindgen-Milles and colleagues[17]	25	25	12.00 (2.00)	8.00 (1.00)	34.00 (5.00)	22.00 (2.00)
	Zarbock and colleagues[16]	236	232	1.17 (0.07)	1.13 (0.07)	14.00 (0.60)	13.00 (0.50)

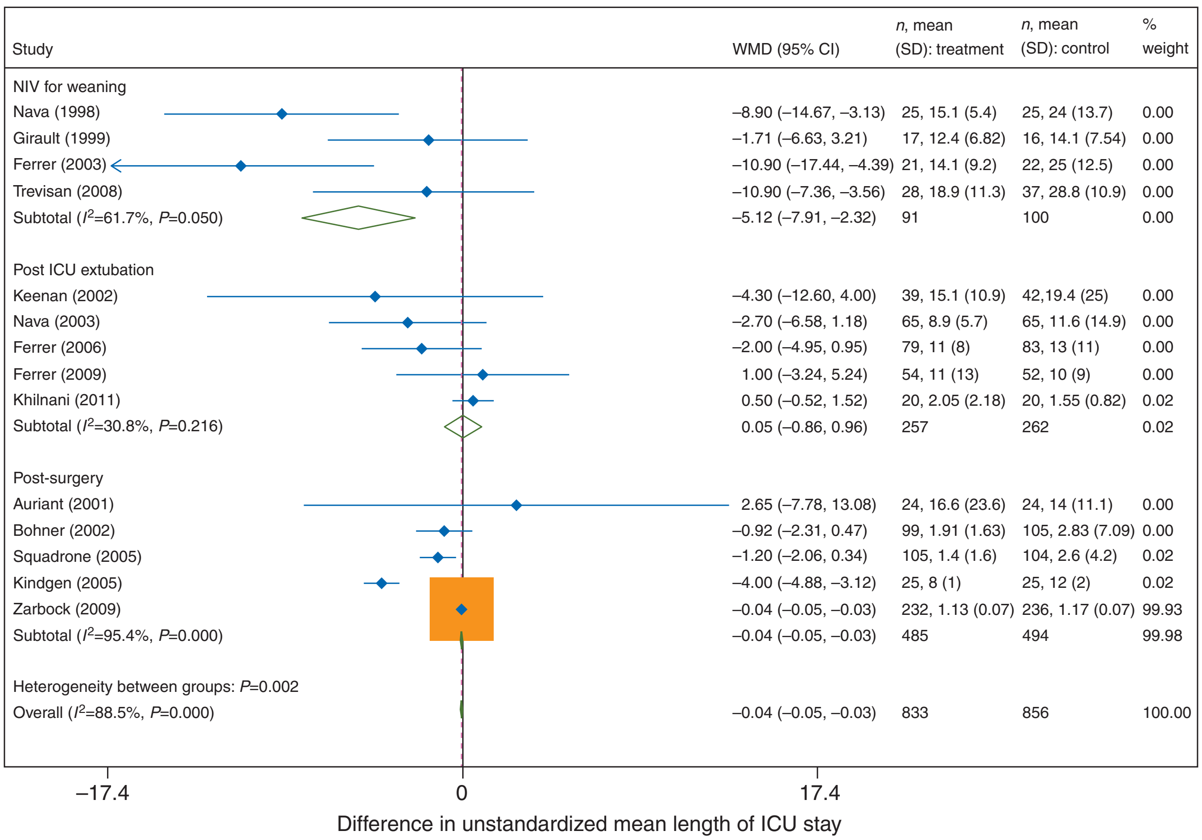

Fig 1 Effect of NIV *vs* standard therapy on unstandardized ICU length of stay.

ICU survival

ICU survival was not increased when NIV was used for weaning [combined OR 0.83 (95% CI 0.44–1.58)], or when used post-ICU extubation [combined OR 1.24 (95% CI 0.84–1.85)] as shown in Figure 5. There were insufficient data to assess whether it made any difference post-surgery as only one paper reported data[17] and all individuals survived.

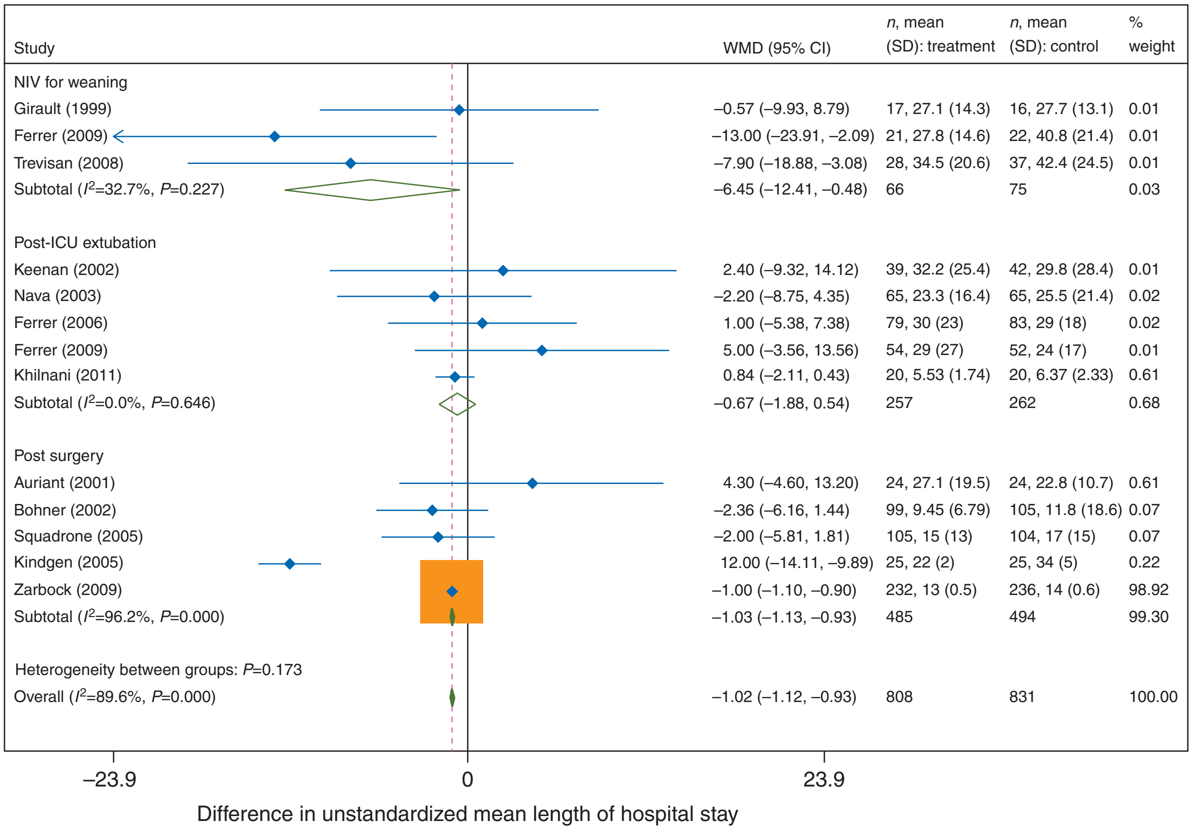

Fig 2 Effect of NIV *vs* standard therapy on unstandardized hospital length of stay.

Table 4 Summary of reported statistics on risk of complications after extubation

Group	Paper	Sample size (*n*)		Odds ratio (95% CI)			
		Control	Treatment	Reintubation	ICU survival	Hospital survival	Pneumonia
NIV for weaning	Nava and colleagues[22]	25	25	—	—	—	—
	Girault and colleagues[23]	16	17	—	—	—	0.94 (0.05–16.37)
	Ferrer and colleagues[12]	22	21	0.44 (0.10–2.07)	6.58 (1.22–35.53)	0.22 (0.06–0.81)	0.22 (0.06–0.81)
	Trevisan and colleagues[24]	37	28	—	0.69 (0.22–2.14)	0.78 (0.27–2.29)	0.04 (0.01–0.36)
	Girault and colleagues[20]	69	69	1.15 (0.55–2.37)	0.34 (0.11–1.00)	0.50 (0.20–1.22)	—
Post-ICU extubation	Keenan and colleagues[25]	42	39	1.14 (0.44–2.97)	1.72 (0.56–5.28)	1.01 (0.39–2.59)	1.02 (0.42–2.48)
	Nava and colleagues[26]	65	65	0.29 (0.09–0.95)	1.41 (0.68–2.91)	0.63 (0.21–1.89)	—
	Esteban and colleagues[11]	107	114	1.02 (0.60–1.74)	0.62 (0.32–1.20)	—	—
	Ferrer and colleagues[27]	83	79	0.46 (0.19–1.11)	6.51 (1.41–30.09)	1.51 (0.69–3.30)	0.80 (0.34–1.88)
	Ferrer and colleagues[18]	52	54	0.52 (0.18–1.57)	1.42 (0.30–6.66)	2.15 (0.73–6.31)	0.28 (0.07–1.10)
	Khilnani and colleagues[28]	20	20	0.53 (0.11–2.60)	—	—	—
Post-surgery	Auriant and colleagues[29]	24	24	0.26 (0.07–0.94)	—	4.20 (0.97–18.18)	—
	Bohner and colleagues[30]	105	99	0.20 (0.02–1.78)	—	—	0.41 (0.08–2.18)
	Squadrone and colleagues[13]	104	105	0.09 (0.01–0.72)	—	—	0.32 (0.03–3.16)
	Kindgen-Milles and colleagues[17]	25	25	0.22 (0.02–2.11)	—	—	—
	Zarbock and colleagues[16]	236	232	0.50 (0.12–2.03)	—	—	0.20 (0.02–1.73)

Hospital survival

Hospital survival was increased when NIV was used for weaning [combined OR 0.55 (95% CI 0.31–0.98)] and post-surgery [combined OR 4.54 (95% CI 1.35–15.31)], but not when used post-ICU extubation [combined OR 1.24 (95% CI 0.78–1.98)] as shown in Figure 6.

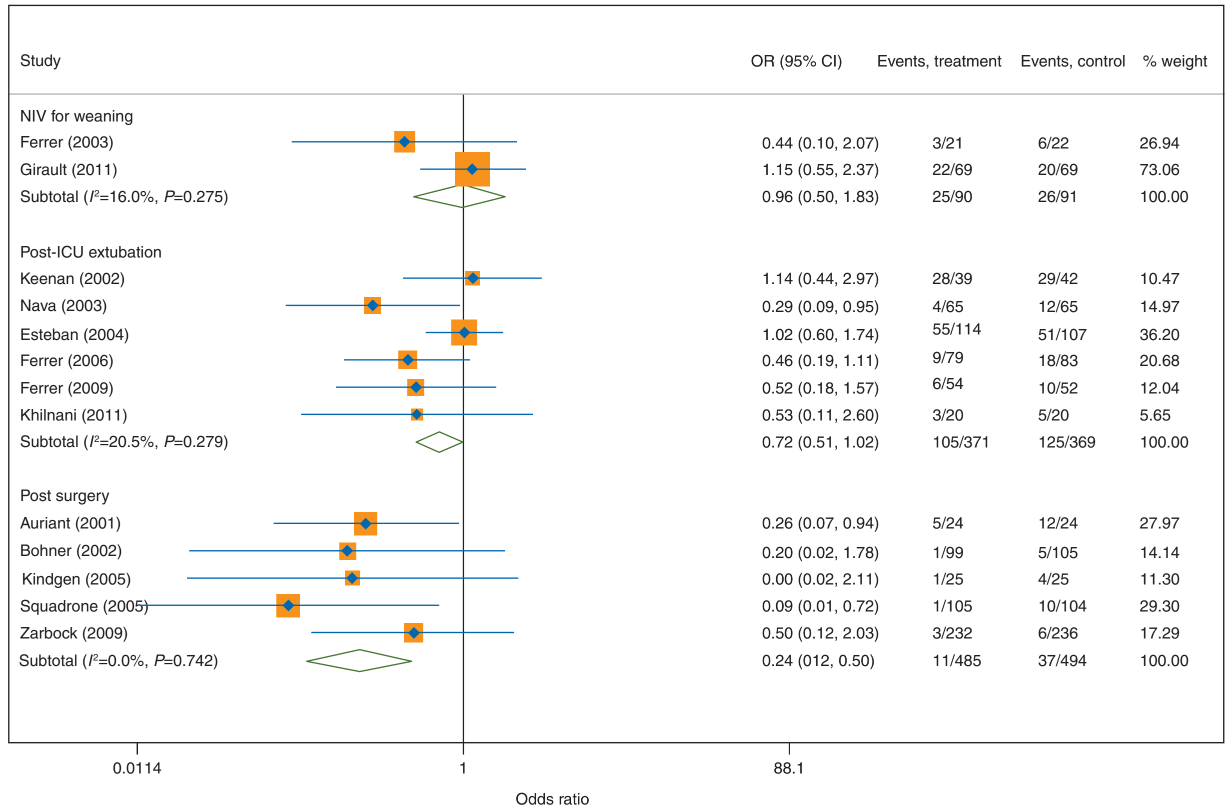

Fig 3 Effect of NIV *vs* standard therapy on OR for reintubation.

Discussion

This meta-analysis sought to analyse the effects of NIV in several related patient populations of recently extubated patients. The length of stay in ICU was reduced in weaning and post-surgical patients who received NIV after extubation, with the most pronounced effect seen when NIV was used to wean patients from MV. This is an important finding, in particular in weaning patients who often have prolonged ICU stays and may suffer morbidity and mortality as a result. Given the higher cost of provision of ICU care compared with ward-based care, this finding also has important economic implications. There was also a reduction in the hospital length of stay in patients weaned using NIV, which is again an important finding for the reasons discussed before.

This meta-analysis also demonstrated a reduction in rates of reintubation when used in post-surgery patients, and pneumonia in post-surgery, and weaning patients when compared with standard medical therapy. It is highly likely that the reduction in reintubation will impact on rates of pneumonia by removing the attendant risks of VAP in the groups studied. Again this is an important finding from a patient safety, morbidity, and economic perspective. The reduction in rates of reintubation and pneumonia were not evident in the post-ICU extubation subgroup. However, it is important to note that this group included studies where NIV was used for both prevention and treatment of post-extubation RF. The individual studies consistently demonstrate that the use of NIV to treat rather than prevent post-extubation RF is at best ineffective, and indeed may increase the rates of reintubation, which may have influenced the outcomes in this subgroup.

The use of NIV had no effect on ICU survival when compared with standard therapy in either weaning patients or post-ICU extubation patients. As only one trial in the post-surgery subgroup reported ICU survival, insufficient data were available to provide meaningful analysis in this group. Hospital survival was increased in weaning and post-surgical patients who received NIV, but not in post-ICU extubation patients.

During our review of the data provided, we encountered some anomalies relating to terminology and reporting of results within the literature that required minor amendments before performing the meta-analysis. This included reporting of the OR for reintubation from the Ferrer and colleagues[18] paper as 1.90 (95% CI 0.64–5.68). While not significant, this did initially suggest that those receiving NIV in this study were more likely to require reintubation than those not receiving NIV, a finding that contradicted other similar papers. This prompted further scrutiny of the paper and the realization that the risk of reintubation associated with not

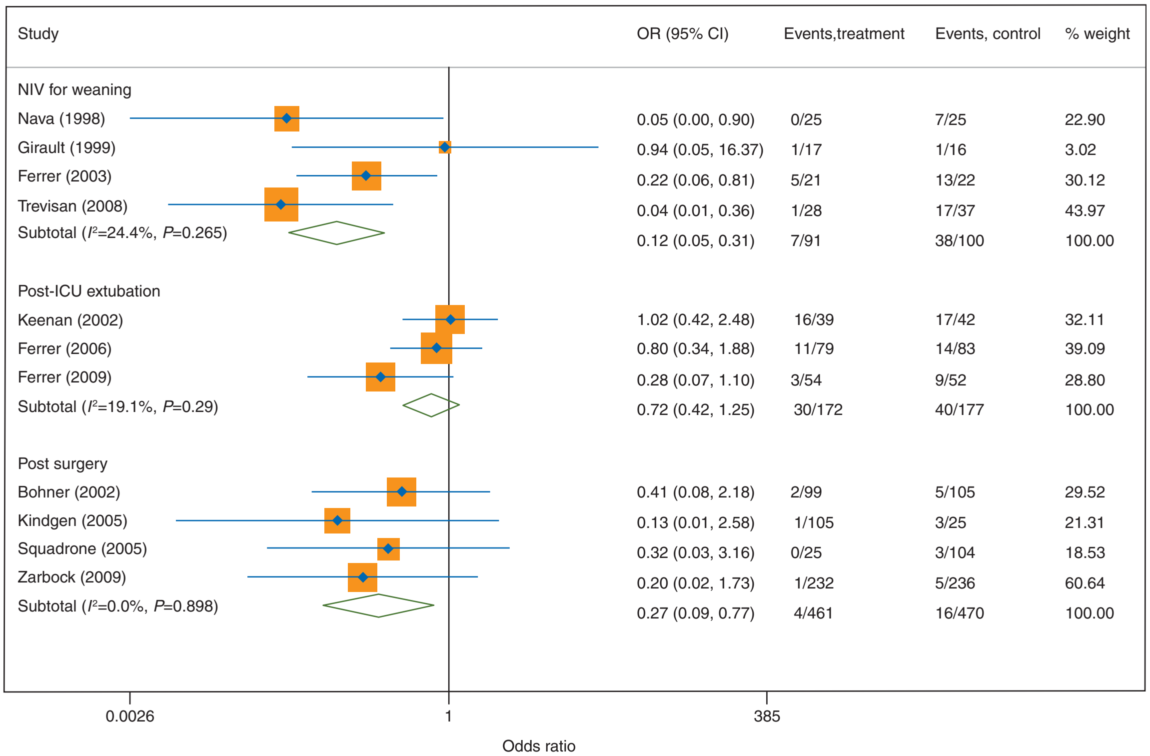

Fig 4 Effect on NIV *vs* standard therapy on OR for pneumonia.

being on NIV compared with being on NIV had been quoted by the authors—essentially the 'flip-side of the coin'. It was therefore decided to recheck the recorded ORs and CIs and to recheck the raw numbers of treatment and control individuals in each study and the number of events for each of the outcomes of interest. These numbers were then used to calculate the ORs and CIs for each study in the same manner, assessing the risk associated with being on NIV for all outcomes of interest. At the same time, the mean and SD of the length of stay in ICU and hospital were also rechecked and, after discussion with the authors of the original papers, adjusted where necessary before performing the final meta-analysis.

Closer scrutiny of published results also identified a number of other inconsistencies with quoted statistics for direct comparison between studies, for example, relative risk being reported as opposed to OR, 90 day survival as opposed to hospital survival. Where possible, missing statistics were recalculated from the raw data. If this was not possible, then the authors were contacted directly by A.J.G. for clarification.

Our analysis has several potential weaknesses. In broad terms, this meta-analysis examines three separate groups of patients who have all undergone a period of invasive ventilation and then been extubated who are all at risk of developing RF, requiring reintubation, and suffering increased morbidity and mortality as a result. The value of this analysis is that it includes patients from diverse backgrounds with differing pathologies representing the wider general critical care population, rather than a specific group such as COPD (where we already know NIV is frequently effective). We only included studies in this analysis that compare standard treatment of these groups against an additional intervention—in the form of NIV—in an attempt to determine the potential impact that this intervention alone may have on patient outcomes in several similar and related clinical situations.

Analysis of each of the three subgroups individually allows for a greater understanding of the potential benefits of NIV in defined clinical situations and provides an insight into the benefits to patient care that may be gained from the use of NIV.

Two marginally different search strategies were used in the identification of papers for inclusion in the analysis. This was performed as we wanted to include all forms of non-invasive respiratory support in our searches, and simply by using the term 'non-invasive ventilation', several studies using CPAP as an intervention were not identified. Although we did not identify any studies where CPAP was used post-extubation or in weaning, this was of particular relevance in the postoperative patient populations where in many of the major studies, CPAP and not NPPV is the preferred form of non-invasive respiratory support. Thus, by

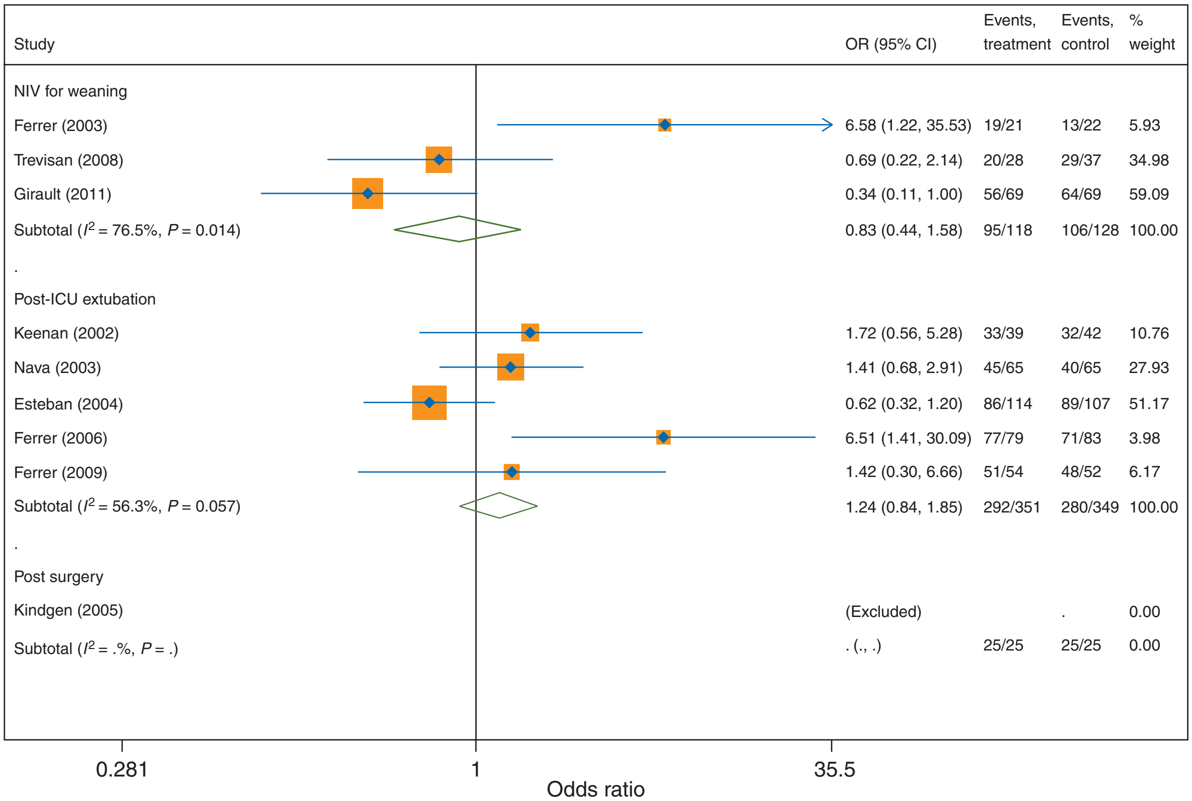

Fig 5 Effect of NIV *vs* standard therapy on OR for ICU survival.

broadening the search terms, we felt that a greater scope of studies were considered for inclusion in the analysis.

We grouped together studies that used both CPAP and NPPV in post-surgical patients as we feel that there is a sound economic and practical basis for this. The use of NIV *per se* is an added level 2 resource that may be needed in the postoperative period, and the interchangeable use of the two modalities reflects actual clinical practice and individual clinician preference. Patients requiring NIV support are managed in the same care areas regardless of whether they receive CPAP or NPPV, and thus the cost and resource implications remain the same. Therefore, we feel that it is reasonable to view and analyse NIV as a sole intervention that may influence outcomes on this particular group of patients. Future work that compares the individual merits of CPAP against NPPV would, in our opinion, be warranted.

Some of the studies included in this meta-analysis used differing protocols for the use of NIV as an intervention in recently extubated patients. The mode of NIV used differed between some of the papers, with CPAP being used more prominently after operation, and the levels of pressure support used with NPPV also varied between trials. The duration of the use of NIV was not standardized between trials, and its indication for use—as in the treatment of RF or as prophylaxis against this—also varied between studies. These differences may have some impact on the efficacy and success of NIV as a therapeutic intervention in the patient groups studied.

How does our meta-analysis add to the currently available literature in each of the three areas examined? The area of the use of NIV in post-ICU extubation remains a contentious area, with earlier ‘prophylactic’ use seemingly preferential to treatment of established RF in this group of patients. There is also no consensus regarding the optimal time period to provide NIV after extubation, and the findings of our meta-analysis reflect and reinforce the uncertainty over the use of NIV in this area.

The use of NIV for weaning has previously been meta-analysed by Burns and colleagues[19] and found NIV to reduce mortality, rates of VAP, and ICU and hospital length of stay. Our analysis found less compelling evidence to support the use of NIV in the general ICU population but included fewer studies and a smaller number of patients overall than the previous analysis. The Burns and colleagues meta-analysis focused predominantly on patients with COPD in whom the potential benefits of using NIV in many different clinical settings have been demonstrated. There has also been an RCT published and included in our meta-analysis that failed to demonstrate a benefit for using NIV to wean patients from MV when compared with either continued MV or high flow oxygen.[20]

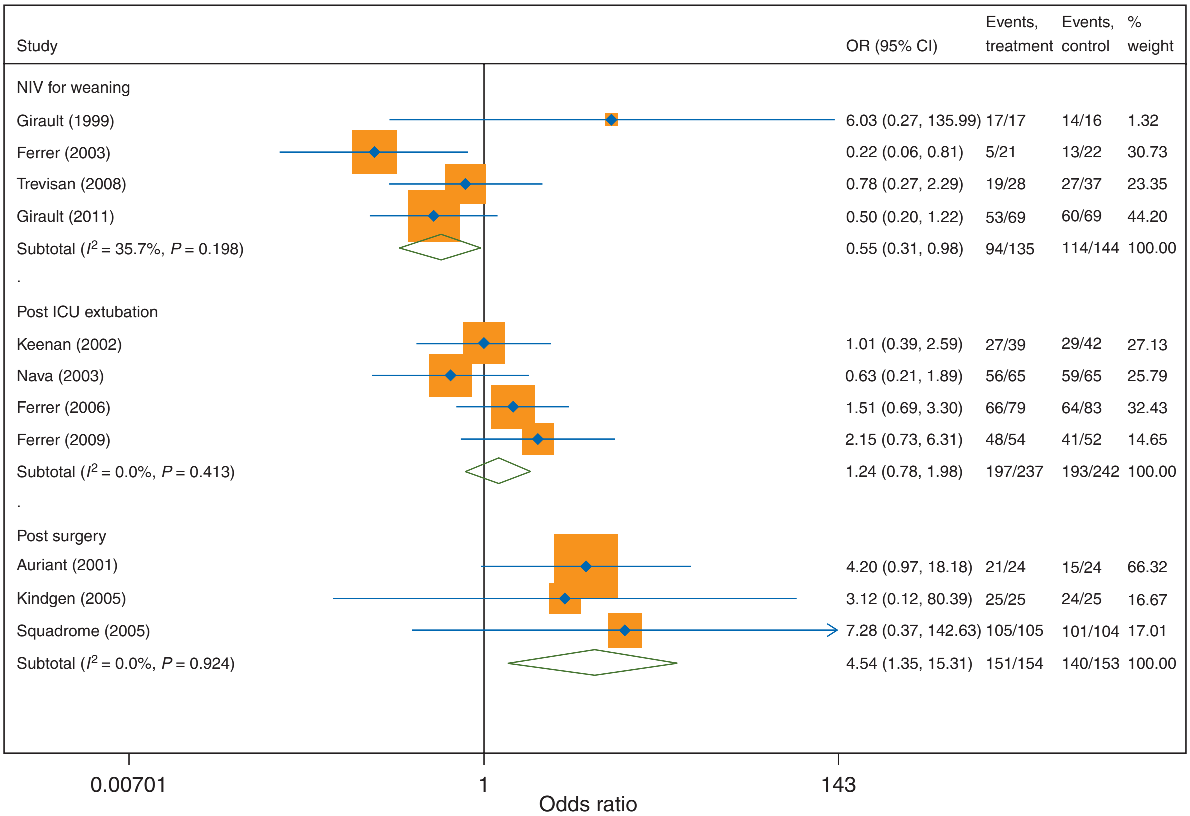

Fig 6 Effect of NIV *vs* standard therapy on OR for hospital survival.

Perhaps, of most interest and relevance are the findings of our analysis with regard to post-surgery patients. Previous work in this area has suggested that NIV may be beneficial in treating and preventing RF in patients who have recently undergone major surgery, but have been very specific in the patient populations studied. By demonstrating the benefits of NIV in reducing morbidity in post-surgery patients pooled from several different surgical specialities, we provide further evidence to support the theory that NIV is perhaps underutilized in postoperative populations.[21]

Conclusions

A meta-analysis of the use of NIV as an intervention compared with standard medical therapy in three separate divisions of the general ICU population who have been recently extubated has demonstrated that NIV is beneficial in reducing ITU length of stay in weaning and post-surgery patients. NIV also reduces the incidence of pneumonia in post-surgery and weaning patients, reintubation, and length of hospital stay in post-surgery patients and improves hospital survival in weaning and post-surgery patients. The findings of this study support the judicious use of NIV in selected post-extubation patient groups, especially those patients at risk of deterioration after major surgery, and suggest a potential benefit to patient morbidity, patient safety, and the economic burden of ICU care.

Declaration of interest

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