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ORIGINAL ARTICLE

The role of non-invasive ventilation in blunt chest trauma: systematic review and meta-analysis

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Abstract
Purpose Respiratory support is the mainstay for the management of patients with pulmonary contusion following blunt chest trauma. In patients not requiring immediate intubation and ventilation, the optimal respiratory management strategy is not clear. This systematic review and meta-analysis aimed to determine the efficacy of non-invasive ventilation (NIV), as compared to traditional respiratory support strategies (i.e., high-flow facemask oxygen or pre-emptive intubation and ventilation), in adult patients with blunt chest trauma.
Methods We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing NIV to traditional forms of respiratory support (i.e., facemask oxygen or intubation and ventilation) in an adult trauma population. For each eligible trial, we extracted the outcomes of all-cause mortality, length of intensive care unit (ICU) stay, length of hospital stay, and pneumonia.
Results We identified 643 citations, selected 17 for full-text evaluation, and identified three eligible RCTs. Patients receiving NIV had a non-significant reduction in the risk of death (OR 0.55; 95 % CI 0.18–1.70; $I^2 = 0$ %), but significant reductions in length of ICU stay (mean difference −2.45 days; 95 % CI −4.27 to −0.63; $I^2 = 66$ %), length of hospital stay (mean difference −4.60 days; 95 % CI −8.81 to −0.39; $I^2 = 85$ %), and risk of pneumonia (OR 0.20; 95 % CI 0.09–0.47; $I^2 = 0$ %).
Conclusion This meta-analysis suggests that NIV is superior to both high-flow facemask oxygen or pre-emptive intubation and ventilation in patients with blunt chest trauma who have no contraindication to NIV.

Keywords Blunt chest trauma · Non-invasive ventilation · Thorax injury · Artificial ventilation · Positive pressure ventilation

Introduction

Blunt chest trauma in civilian populations is commonly seen after vehicular collisions and falls and is associated with significant mortality and morbidity [1–3]. A recent review of a United Kingdom level 1 trauma unit from 1999 to 2003 reported an overall mortality rate of 18.7 % [4]. Blunt chest trauma may cause injury to the thoracic wall, pleura, lung parenchyma, airway structures, major vessels, heart and pericardium, diaphragm and other mediastinal structures. Rib fractures commonly occur and, when three or more adjacent ribs are each fractured in at least two or more places, may present as a flail chest [5].

In these patients pulmonary contusion is the primary determinant of acute and long term respiratory dysfunction and a predictor of morbidity and mortality. Patients may present with tachycardia, tachypnoea, haemoptysis, hypotension, confusion, hypoxaemia, hypercarbia and increased work of breathing. Examination of the overlying thoracic

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cage may reveal contusion and rib fractures or even a flail chest. Later signs may include decreased air entry, crackles or wheeze. Once a diagnosis of pulmonary contusion has been made, guidelines suggest that support of the respiratory system is the mainstay of patient management. This includes adequate pain management, pulmonary toilet and careful fluid management [6]. Surgical repair of the unstable chest wall remains a controversial management strategy [7].

While patients with severe respiratory compromise may require intubation and ventilation there is a subset of patients with pulmonary contusion who are conscious, maintaining an airway, haemodynamically stable, co-operative, do not need immediate surgery and have no indication for immediate intubation. The optimal respiratory management strategy in these patients is not clear and traditionally these patients receive either high-flow face-mask oxygen or pre-emptive intubation and ventilation [3, 6, 8]. Recently the use of non-invasive ventilation (NIV) in a subset of patients has been suggested as an alternative to these traditional respiratory support strategies. This systematic review and meta-analysis aimed to determine the efficacy of NIV, as compared to traditional respiratory support strategies, in adult patients with blunt chest trauma and no contraindication for NIV.

Methods

Trial eligibility and identification

Only randomized controlled trials comparing NIV to traditional forms of respiratory support (i.e., facemask oxygen or intubation and ventilation) in an adult trauma population were considered eligible. Trials were included regardless of language, sample size, publication status, or date of publication. We searched six databases (EMBASE, OVID Health Star, Ovid Medline, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, ProQuest Dissertations and Theses A&I) using the MESH search terms for Medline, OVID Health Star and the Cochrane data bases i.e., positive-pressure respiration.mp; wounds and injuries.mp. For the EMBASE search the terms used were: thorax injury.mp; and artificial ventilation.mp. An example of the search strategy used is shown in Appendix 1.

Eligibility assessment

The title and abstract of each citation was independently screened by both SR and RR to identify potentially eligible trials. If either reviewer felt the citation may contain a relevant trial, the article was retrieved to undergo full text evaluation. Full texts of all citations identified as being potentially relevant were then independently evaluated by both SR and RR to determine eligibility. Disagreements were solved by consensus. Chance corrected inter-observer agreement for trial eligibility was tested using kappa statistics.

Data collection, assessment of trial quality and outcomes

Trial quality was evaluated with the following criteria: randomization methodology, completeness of patient follow-up, method of patient follow-up, blinded outcome assessment, consistent end-point assessment, and the use of intention to treat analysis.

For each eligible trial we extracted the outcomes of all-cause mortality, length of intensive care unit (ICU) stay, length of hospital stay, and pneumonia. Meta-analysis was conducted using a random effects model in Review Manager Version 5.1. (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2011). Heterogeneity was assessed using I^2 and Chi squared analysis. Pooled dichotomous outcomes were reported as odds ratios (OR) and 95 % confidence intervals (CI). Continuous outcomes were reported as mean difference and 95 % CI. We constructed a funnel plot to assess for the possibility of publication bias.

Results

Trial identification and selection

The trail selection process is shown in Fig. 1. We identified 643 citations, from which 17 were selected for full-text evaluation [9–25]. From these we identified three eligible randomized controlled trials [15, 21, 24]. Inter-observer agreement for trial eligibility was good ($\kappa = 0.75$).

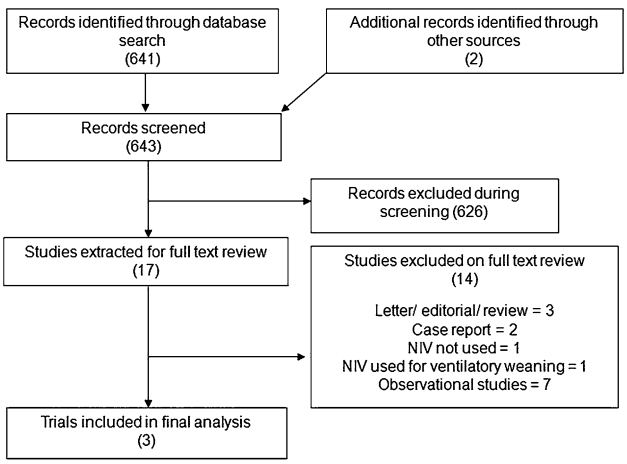

Fig. 1 Trial selection process used for the systematic review. *NIV* non-invasive ventilation

Trial quality and characteristics

The quality characteristics of the three eligible randomised controlled trials are reported in Table 1. All trials achieved complete patient follow-up, and conducted an intention to treat analysis, but none reported the use of blinded outcome assessment thereby raising concerns about potential bias.

Table 2 reports the characteristics of the included trials. All trials enrolled patients with blunt chest trauma and respiratory dysfunction and all excluded patients with absolute contra-indications to NIV. Table 3 provides details of the different respiratory support strategies. For the NIV strategy two trials made use of continuous positive airway pressure (CPAP) [15, 21] while one used bi-level

Table 1 Quality characteristics of included trials

References	Randomization	Patients with complete follow-up (%)	Method of patient follow-up	Blinded outcome assessment	Consistent end-point assessment	Intention to treat analysis
Bolliger and Van Eeden [15]	Sequential pairwise randomization	69 (100 %)	Direct patient contact	No	Yes	Yes
Gunduz et al. [21]	Sequential randomization	43 (100 %)	Direct patient contact	No	Yes	Yes
Hernandez et al. [24]	Sequential randomization with a block size of 10	50 (100 %)	Direct patient contact	No	Yes	Yes

Table 2 General characteristics of included trials

References	No. of patients	Average age (years)	Eligibility	Exclusions
Bolliger and Van Eeden [15]	69	46.5	All of the following: three rib fractures, and admission within 24 h of injury, and insufficient cough or preexisting lung pathology	Any one of: depressed level of consciousness or facial fractures or base of skull fractures or severe lung contusion (alveolar infiltrate on CXR underlying fracture and PaO2 <8 kPa on 40 % oxygen) or need for spinal surgery, general surgery or contra-indication to regional analgesia
Gunduz et al. [21]	43	49	All of the following: ≥5 rib fractures in a row, or ≥3 segmental (two fractures in one rib) rib fractures on CXR or CLT and confirmed by the presence of a flail segment (paradoxical motion of the chest wall), and acute respiratory distress and severe dyspnoea with respiratory rate 25/min, and SpO2 <90 % while breathing 10 l/min oxygen in the ER, and PaO2/FiO2 ≤300 while receiving FiO2 ≥0.5 in the ICU	Any one of: requiring ETI immediately on admission for any cause or emergency surgery following admission or non-cooperative patients unable to use the face mask or coma or confusion or inability to protect the airway or severe acidosis, significant co-morbidity or vomiting or obstructed bowel or haemodynamic instability
Hernandez et al. [24]	50	43	All of the following: age older than 18 years, and early (first 48 h after trauma) and persistent (>8 h) severe hypoxemic respiratory failure [PaO2/FiO2 <200 mm Hg while receiving oxygen by high-flow (>10 L/min) mask]	Any one of: hypercapnia (PaCO2 >45 mm Hg) on study entry or ETI for another reason or need for emergency intubation or standard contraindications for NIMV (active gastrointestinal bleeding, low level of consciousness, multiorgan failure, airway patency problems, lack of cooperation, or hemodynamic instability) or severe traumatic brain injury or facial trauma with pneumocephalus, skull base fracture, orbit base fracture, or any facial fracture involving a sinus; cervical or injury when treatment contraindicated a facial mask or bronchopleural fistula or gastrointestinal trauma

CXR chest X-ray, *CLT* computed lung tomography, *ER* emergency room, *ICU* intensive care unit, *ETI* endotracheal intubation, *NIMV* non-invasive mechanical ventilation

Table 3 Respiratory support strategies

References	NIV support	NIV failure	Traditional support	Analgesia in NIV group	Treatment duration
Bolliger and Van Eeden [15]	CPAP—maximum of 10 cm H_20 Target: SaO_2 >90 % and PCO_2 ≤6 kPa	PaO_2 <8 kPa with FiO_2 = 0.4, PCO_2 >6.5 kPa, RR >35 bpm, FVC <10 ml/kg, reduction in consciousness	Intermittent mandatory ventilation Target: SaO_2 >90 % and PCO_2 ≤6 kPa	Epidural. Inter-costal nerve blocks with unilateral fractures	At least 48 h, decision by physician in charge
Gunduz et al. [21]	CPAP 8–15 cm H_20 Target: FiO_2 ≤0.6	PaO_2/FiO_2 <200 on FiO_2 = 1, SpO_2 <90 % on 10 L/min O_2, RR >25 bpm	Intermittent positive pressure ventilation Target: FiO_2 ≤0.6 and end tidal PCO_2 4.2–5 kPa	Morphine PCA	Decision by physician in charge
Hernandez et al. [24]	BiPAP: IPAP of 10 cmH_20 (step increases of 2 cm H_2O), EPAP of 6 cm H_2O (step increases of 1 cm H_2O) Target: SpO_2 >92 % or PaO_2 >65 mm Hg, HR <25 bpm, Vt ≥8 ml/kg	Cardiorespiratory arrest, respiratory pauses or HR <50 bpm with LOC or gasping, major agitation, clinical signs suggestive of respiratory-muscle fatigue, massive aspiration or inability to manage respiratory secretions appropriately, hemodynamic instability unresponsive to fluids and vasopressors, refractory hypoxemia (SpO_2 <85 % despite the use of a high FiO_2); or respiratory acidosis (persistent pH <7.25)	High-flow high-concentration facemask oxygen Target: SpO_2 >92 % or PaO_2 >65 mm Hg	Epidural. Remifentanil if epidural contraindicated	Decision by physician in charge

NIV non-invasive ventilatory, *CPAP* continuous positive airway pressure, *RR* respiratory rate, *FVC* forced vital capacity, *PCA* patient controlled analgesia, *BiPAP* bilevel positive airway pressure, *IPAP* inspiratory positive airway pressure, *EPAP* expiratory positive airway pressure, *HR* heart rate, *Vt* tidal volume, *LOC* loss of consciousness

positive airway pressure (BiPAP) [24]. The traditional respiratory support strategies were preemptive intubation and ventilation in two trials [15, 21] and high-flow high-concentration facemask oxygen in the remaining trial [24].

Study outcomes

The outcomes of all cause mortality, length of ICU, length of hospital stay, and pneumonia are reported in Figs. 2, 3, 4 and 5, respectively. Patients receiving NIV had a non-significant reduction in the risk of death (OR 0.55; 95 % CI 0.18–1.70; $I^2 = 0$ %) but significant reductions in length of ICU stay (mean difference −2.45 days; 95 % CI −4.27 to −0.63; $I^2 = 66$ %), length of hospital stay (mean difference −4.60 days; 95 % CI −8.81 to −0.39; $I^2 = 85$ %), and risk of pneumonia (OR 0.20; 95 % CI 0.09–0.47; $I^2 = 0$ %).

Discussion

Blunt chest trauma causes compression, tearing, laceration, and shearing (due to inertia differences between low density alveolar tissue and higher density hilar tissue) of lung tissue [26]. In blast injuries a spalling effect (shearing/bursting at an interface between a gas and liquid) and implosion effect (rebound overexpansion of gas as a pressure wave passes) may also occur [27]. These patients present with respiratory compromise and are at risk of acute respiratory distress syndrome (ARDS) and death [4, 28].

A subset of blunt chest trauma patients present with respiratory compromise but are conscious, maintaining an airway, haemodynamically stable, co-operative, do not need immediate surgery and have no other indication for immediate intubation. This systematic review and meta-analysis suggests that in these patients a respiratory management approach using NIV in conjunction with high quality analgesia reduced ICU length of stay, hospital length of stay, and the incidence of pneumonia as compared to either high-flow facemask oxygen or preemptive intubation and ventilation. In addition, the point estimate for the outcome of mortality suggested potential benefit with the use of NIV.

Strengths and weaknesses

The strengths of this systematic review lie in its rigorous methodology which include a comprehensive search,

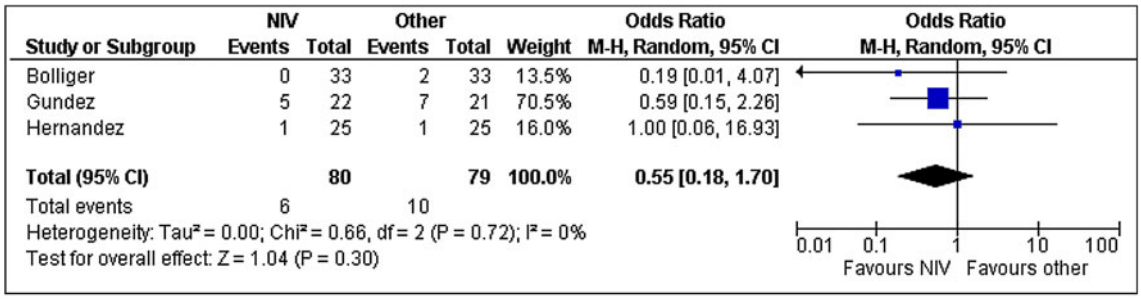

Fig. 2 Meta-analysis of the efficacy of NIV, compared to alternate respiratory support strategies, on the outcome of mortality. *NIV* non-invasive ventilation, *M-H* Mantel-Haenszel, *CI* confidence interval

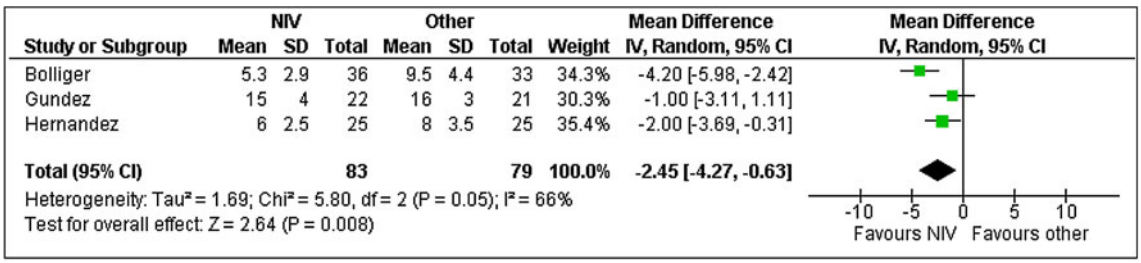

Fig. 3 Meta-analysis of the efficacy of NIV, compared to alternate respiratory support strategies, on the outcome of ICU length of stay. *ICU* intensive care unit, *NIV* non-invasive ventilation, *M-H* Mantel-Haenszel, *CI* confidence interval

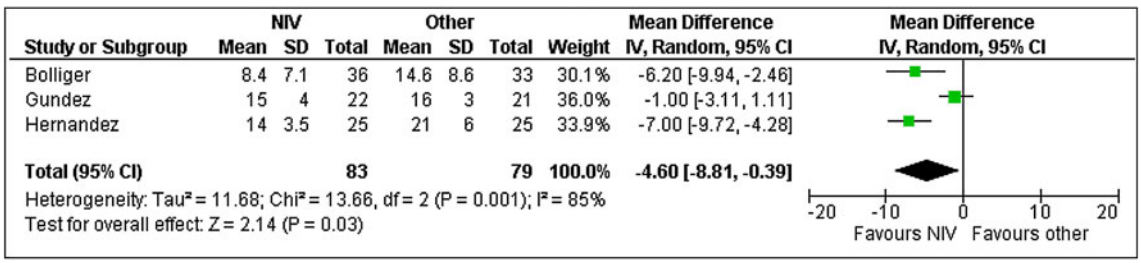

Fig. 4 Meta-analysis of the efficacy of NIV, compared to alternate respiratory support strategies, on the outcome of hospital length of stay. *NIV* non-invasive ventilation, *M-H* Mantel-Haenszel, *CI* confidence interval

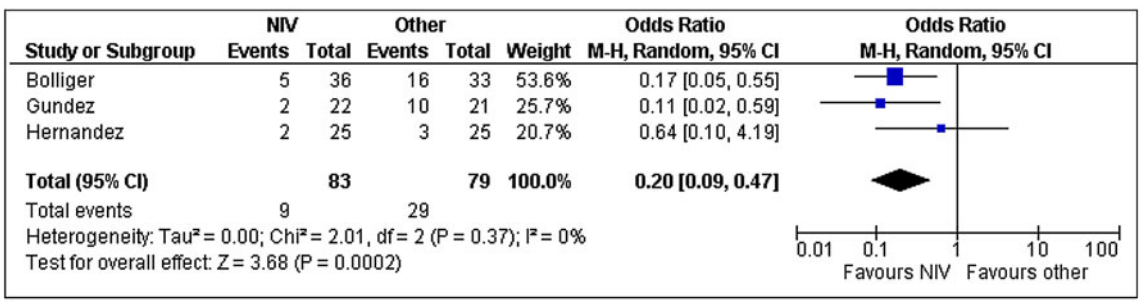

Fig. 5 Meta-analysis of the efficacy of NIV, compared to alternate respiratory support strategies, on the outcome of pneumonia. *NIV* non-invasive ventilation, *M-H* Mantel-Haenszel, *CI* confidence interval

duplicate citation screening and data extraction with good agreement, and reporting according to reporting standards for meta-analyses [29].

There are several weaknesses of our systematic review. The review contains only three randomised controlled trials with a total of 162 patients, none of which reported that

they made use of blinded outcome assessment. This raises concerns about potential bias in our results. In addition there was substantial heterogeneity for both ICU and hospital length of stay outcomes. However, the homogeneity for the outcomes of all-cause mortality and pneumonia, together with the beneficial point estimate for all four outcomes, suggests that these results are credible.

Interpretation and implication for further research

Our results suggest that in patients with blunt chest trauma and respiratory dysfunction, NIV may be the preferred management strategy in patients without contraindications to its use. It is however vital that the selected nature of these patients be appreciated. As evidenced in the exclusion criteria shown in Table 2, great care was taken to exclude patients in whom there was an indication for immediate intubation and ventilation or in whom NIV was deemed to be contraindicated. In addition, it is important to keep in mind the small total number of patients included in this analysis. Further large confirmatory trials in this field are warranted and should attempt to quantify an optimal NIV strategy.

Conclusion

This meta-analysis suggests that for the outcomes of ICU length of stay, hospital length of stay, and pneumonia, NIV is superior to both high-flow facemask oxygen or pre-emptive intubation and ventilation in patients with blunt chest trauma who have no contraindication to NIV.

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Conflict of interest Dr's Roberts, Skinner, Biccard and Rodseth declare that they have no conflict of interest.

Appendix 1: Search strategy and databases

Database searches were conducted on 18 September 2012 using the OvidSP search engine (Ovid Technologies, Inc., New York, NY 2009) for the following databases:

1. EMBASE 1979–2012 September 17
2. OVID Health Star (1966–August 2012)
3. Ovid MEDLINE(R) In-Process and Other Non-Indexed Citations and OVID MEDLINE(R) 1946 to present
4. Cochrane Central Register of Controlled Trials (September 2012)
5. Cochrane Database of Systematic Reviews (September 2012)

The MESH search terms used in Medline, OVID Health Star, and the Cochrane data bases were (1) Positive-Pressure Respiration.mp; and (2) Wounds and Injuries.mp. The EMBASE search terms used were: (1) Thorax injury.mp; and (2) artificial ventilation.mp.

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