

## Noninvasive ventilation in trauma

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**Author contributions:** Karcz MK and Papadakos PJ both contributed to this paper.

**Conflict-of-interest:** Dr. Peter J Papadakos and Dr. Marcin K Karcz have no conflicts of interest.

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Received: September 29, 2014

Peer-review started: October 2, 2014

First decision: October 28, 2014

Revised: November 3, 2014

Accepted: December 16, 2014

Article in press: December 17, 2014

Published online: February 4, 2015

are at increased risk to develop hypoxemic respiratory failure which may or may not be associated with hypercapnia. Hypoxemia in these patients is due to ventilation perfusion mismatching and right to left shunt because of lung contusion, atelectasis, an inability to clear secretions as well as pneumothorax and/or hemothorax, all of which are common in trauma patients. Noninvasive ventilation has been tried in these patients in order to avoid the complications related to endotracheal intubation, mainly ventilator-associated pneumonia. The potential usefulness of noninvasive ventilation in the ventilatory management of trauma patients, though reported in various studies, has not been sufficiently investigated on a large scale. According to the British Thoracic Society guidelines, the indications and efficacy of noninvasive ventilation treatment in respiratory distress induced by trauma have thus far been inconsistent and merely received a low grade recommendation. In this review paper, we analyse and compare the results of various studies in which noninvasive ventilation was applied and discuss the role and efficacy of this ventilator modality in trauma.

**Key words:** Acute respiratory distress syndrome; Noninvasive ventilation; Pulmonary contusion; Respiratory failure; Trauma

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### Abstract

Trauma patients are a diverse population with heterogeneous needs for ventilatory support. This requirement depends mainly on the severity of their ventilatory dysfunction, degree of deterioration in gaseous exchange, any associated injuries, and the individual feasibility of potentially using a noninvasive ventilation approach. Noninvasive ventilation may reduce the need to intubate patients with trauma-related hypoxemia. It is well-known that these patients

**Core tip:** The use of noninvasive ventilation is widely recognized as a suitable way to avoid intubation and its associated side effects. Noninvasive ventilation allows increased flexibility in the application and discontinuation of ventilator assistance and preserves airway defense mechanisms. The application of noninvasive ventilation may reduce the need to intubate patients with trauma-related hypoxemia, thereby potentially decreasing intensive care unit length of stay and preventing respiratory complications. In this review article, we summarize the results of various studies in which noninvasive ventilation was applied and discuss the role and efficacy of this ventilator modality in trauma.

Karcz MK, Papadakis PJ. Noninvasive ventilation in trauma. *World J Crit Care Med* 2015; 4(1): 47-54 Available from: URL: <http://www.wjgnet.com/2220-3141/full/v4/i1/47.htm> DOI: <http://dx.doi.org/10.5492/wjccm.v4.i1.47>

## INTRODUCTION

Nearly one hundred and forty thousand traumatic deaths occur in the United States annually<sup>[1]</sup>. The most common cause of death in up to a quarter of patients with multiple system traumas is chest trauma<sup>[2]</sup>. Pulmonary contusion is particularly common occurring in approximately seventeen percent of patients with multiple traumas<sup>[3]</sup>.

Previous studies<sup>[4,5]</sup> showed that posttraumatic respiratory failure was caused by an increased amount of interstitial and intraalveolar fluids and described the concept of the so-called "traumatic wet lung", and recommend positive airway pressure by mask to ensure adequate ventilation.

More recently, trauma management has been guided according to the mechanism of injury, its anatomic involvement, and the staging of the injury. Its main aims include pulmonary toilet, control of chest wall pain, surgical stabilization and fluid management. However, ventilator management has received little attention<sup>[6]</sup> and this is reflected by a low grade recommendation for the use of noninvasive ventilation in trauma patients by the British Thoracic Society guidelines<sup>[7]</sup> and "no recommendation" by Canadian Critical Care Trials Group/Canadian Critical Care Society Noninvasive Ventilation Guidelines Group<sup>[8]</sup> due to a lack of sufficient evidence.

There is a lack of randomized controlled trials on the use of noninvasive ventilation in the trauma population and therefore the efficacy of this treatment in the management of respiratory failure from trauma is for the most part unclear. This review will discuss the current evidence demonstrating the role and efficacy of noninvasive ventilation in trauma.

## TRAUMA EPIDEMIOLOGY

The increasing number of high-velocity blunt traumas over the last few decades has caused a progressively higher incidence of chest injuries. As many as seventy to ninety percent of chest injuries in industrialized countries, are caused by blunt trauma, with eighty to ninety percent of cases associated with multiple injuries<sup>[9]</sup>. Typical causes of severe chest trauma include high-velocity traumas such as traffic accidents or falls from a height<sup>[10]</sup>.

Flail chest involves the fracture of three or more ribs in two places or when there are multiple fractures associated with sternal fracture. The clinical significance of this condition varies, depending on the size and location of the flail segment and the extent of the underlying lung contusion. The

respiratory insufficiency associated with flail chest has been shown to be due to the underlying pulmonary contusion rather than paradoxical respiration<sup>[11]</sup> and is in fact, the most common injury identified in blunt thoracic trauma.

In severely injured patients with accompanying chest injuries and pulmonary contusion, mortality is reported to be fifteen to sixty percent, depending on the overall severity of the injury<sup>[12]</sup>. In comparison, the mortality among patients with isolated chest injuries is low and ranges from zero to five percent in young patients and ten to twenty percent in elderly patients<sup>[13]</sup>. Furthermore, pulmonary contusions often occur in the absence of rib fractures<sup>[14]</sup>.

Three mechanisms that are important in the etiology of pulmonary contusions have been reported<sup>[15]</sup>. The "inertial effect" occurs when low-density alveolar tissue is stripped from hilar structures as they accelerate at different rates whereas the "spalling effect" is due to bursting that occurs at the gas-liquid interface. Thirdly, the "implosion effect" involves the overexpansion of gas bubbles after a pressure wave passes and can tear the pulmonary parenchyma.

Pulmonary contusion promotes the development of acute lung injury (ALI), which may progress to acute respiratory distress syndrome (ARDS) secondary to elevated intrapulmonary shunting, ventilation-perfusion mismatching, increased lung water, pulmonary hemorrhage, loss of lung compliance, and the release of cytoactive modulators<sup>[14]</sup>. ARDS may develop in as much as five percent of patients with blunt trauma and the major predictors of its development have been shown to be pulmonary contusion and an Injury Severity Score higher than twenty five<sup>[16]</sup>.

## PATHOPHYSIOLOGICAL CONCEPTS OF TRAUMA

The likelihood of complications secondary to severe trauma are the consequences of the direct mechanical damage to the pulmonary parenchyma as well as the indirect systemic and pulmonary sequelae. Furthermore, the severity of pulmonary contusion correlates with the development of pulmonary infections, respiratory failure, and mortality<sup>[17]</sup> despite the fact that some studies failed to demonstrate a correlation of pulmonary contusion with more severe ALI and ARDS<sup>[18]</sup>. This lung injury is an independent risk factor for ALI/ARDS and its severity has been shown to indicate the need for ventilatory support<sup>[16]</sup>. Two different forms of posttraumatic ALI/ARDS that have been described universally in trauma patients: (1) early ALI/ARDS which is attributed to hemorrhagic shock and capillary leak and develops within 48 h; and (2) late-onset ALI/ARDS that is associated with a higher incidence of pneumonia, often in conjunction with multiple organ failure<sup>[19]</sup>.

The lung is exceedingly predisposed to the fracture of blood vessels as well as parenchymal laceration under briskly applied compressive or concussive loads such as those that occur in pulmonary contusions<sup>[14]</sup>. Mechanical injuries to the lung can occur through tissue tears when low-density alveolar tissue is stripped from the heavier hilar structures as they accelerate at different rates. The lung can also be damaged by bleeding into distant lung segments, direct laceration of the lung through displacement of fractured ribs and by chest wall compression. The combination of intraparenchymal hemorrhage, edema formation, direct mechanical damage to the lung parenchyma as well as additional indirect injuries, lead to post-traumatic ALI/ARDS.

The infiltration of the lung by polymorphonuclear leukocytes (PMNs) is the most characteristic feature of early post-traumatic ALI/ARDS<sup>[20]</sup>. This influx involves PMN retention, margination, and endothelial adhesion within the microvasculature, and migration into the alveolar space and pulmonary interstitium. Subsequently, when the PMNs are activated, they can release numerous cytotoxic products. Hoth *et al.*<sup>[21]</sup> showed that the systemic levels of certain chemokines such as monocyte chemoattractant protein-1, macrophage inflammatory protein-2 $\alpha$  (MIP-2 $\alpha$ ) and cytokine-induced neutrophil chemoattractant 1 (CINC-1) were significantly elevated at 3 h with all chemokines subsequently found to be significantly elevated at 24 h. Furthermore, the authors showed that pulmonary expression of elastase, CINC-1, tumor necrosis factor- $\alpha$ , interleukin-1 $\beta$ , intercellular adhesion molecule 1 and MIP-2 $\alpha$  were increased and activated systemic neutrophils demonstrated increased cluster of differentiation molecule 11b. This indicates that the process of innate inflammation is activated both systemically and locally.

Ultimately, the combination of proteases, elastases and reactive oxygen species damage the alveolocapillary barrier, resulting in an increased permeability and in the accumulation of protein-rich alveolar and interstitial edema. This process destabilizes airspaces by inactivating the surfactant of alveoli and terminal airways whose production and function are already significantly impaired<sup>[22]</sup>. Eventually, this culminates in a combination of several different clinical phenomena including hypoxemia, ventilation-perfusion mismatching, raised intrapulmonary shunt, and reduced functional capacity.

## EVIDENCE-BASED OVERVIEW FOR THE USE OF NONINVASIVE VENTILATION IN TRAUMA

Several systemic reviews and randomized controlled trials have shown the benefits of noninvasive

**Table 1** Contraindications to noninvasive ventilation

Trauma, deformity, facial or neurological surgery
Inability to protect airway or cooperate
High risk for aspiration and inability to clear secretions
Upper airway obstruction
Respiratory or cardiac arrest
Organ failure
Unstable cardiac arrhythmia/hemodynamic instability
Severe Encephalopathy ( <i>e.g.</i> , GCS < 10)
Severe upper gastrointestinal bleeding

Adapted from ref.<sup>[46]</sup>. GCS: Glasgow Comma Scale.

ventilation (NIV) in patients with exacerbation of chronic obstructive pulmonary disease (COPD). These advantages are mostly due to avoidance of invasive mechanical ventilation (IMV) and its complications<sup>[23]</sup>. Therefore, NIV in COPD patients with hypercapneic acute respiratory failure (ARF) is now considered a first-line intervention ahead of endotracheal intubation and IMV, providing there are no contraindications to its use (Table 1).

Numerous studies have also shown that the use of NIV in patients with hypoxemic ARF is associated with fewer complications and reduced mechanical ventilation and length of intensive care unit stay<sup>[24]</sup>. Those patients who are at high risk of nosocomial infection such as patients with hematological malignancies, with chemotherapy induced neutropenia, organ transplantation recipients as well as the immunosuppressed are likely to benefit from the use of NIV. The Infectious Diseases Society of America and the American Thoracic Society have issued high grade evidence based recommendations in their most recent guidelines for the management and prevention of nosocomial infections thereby advocating the use of NIV whenever appropriate in the management of ARF<sup>[25]</sup>.

There has been a scarcity of randomized controlled trials on ventilatory management of patients with posttraumatic hypoxemic respiratory failure. The British Thoracic Society has issued a low grade recommendation in its guidelines based on the available level C evidence for the use of NIV in multiple trauma patients<sup>[7]</sup>. Similarly, no recommendations were proposed by Canadian Critical Care Trials Group/Canadian Critical Care Society Noninvasive Ventilation Guidelines Group<sup>[8]</sup>. Two recently published systemic reviews<sup>[26,27]</sup> have confirmed the insufficiency of the available evidence on this area under discussion. We consequently aimed at investigating the available studies on the indications for NIV in trauma by selecting several major key topics related to pertinent methodological and technical issues.

Our search strategy included data from studies that enrolled adults who developed ARF as a consequence of trauma and who were admitted to the emergency department, trauma service or

**Table 2** Tabulated summary of the most significant randomized control studies depicting the use of noninvasive ventilation in posttraumatic hypoxemic respiratory failure

Ref.	No. of Patients enrolled	Study intervention per patient group	Inclusion criteria	Exclusion criteria	Analgesia	Outcomes
Bolliger <i>et al</i> <sup>[32]</sup>	69	36 - CPAP 33 - CPPV	Chest trauma with > 3 rib fractures; Insufficient cough mechanism	PaO <sub>2</sub> /FiO <sub>2</sub> < 200	Lumbar epidural catheter	Duration of treatment, ICU length of stay, complications, mortality
Tanaka <i>et al</i> <sup>[31]</sup>	59	25 - CPAP 11 - PSSB 44 - IMV/CMV	Blunt thoracic trauma with flail chest	Flail chest injury caused by CPR	Epidural analgesia	mortality, pulmonary complications
Ferrer <i>et al</i> <sup>[30]</sup>	105	51 - NIV 54 - High-concentration oxygen therapy	Chest trauma with acute respiratory failure	PaCO <sub>2</sub> > 45 mmHg; need for ETI; recent facial, esophageal, cranial trauma and surgery; ↓ GCS (≤ 11); hemo-dynamic instability; arrhythmia/MI; > 1 organ system failure	Not defined	ICU mortality, rate of intubation, incidence of septic shock
Gunduz <i>et al</i> <sup>[33]</sup>	43	22 - CPAP 21 - IPPV	Flail chest; PaO <sub>2</sub> /FiO <sub>2</sub> < 300; Acute respiratory distress	Need for ETI; hemo-dynamic instability; coma/confusion; Emergency surgery	PCA	ICU mortality, complications, improvement in oxygenation, ICU length of stay
Hernandez <i>et al</i> <sup>[34]</sup>	50	25 - NIV 25 - High flow oxygen mask	PaO <sub>2</sub> /FiO <sub>2</sub> < 200 for > 8 h while receiving oxygen by high-flow mask	PaCO <sub>2</sub> > 45 mmHg; need for emergency ETI; standard contraindications for NIV (Table 1); severe traumatic brain injury	Epidural analgesia	Intubation rate Hospital length of stay, Survival

CPAP: Continuous positive airway pressure; CPPV: Continuous positive pressure ventilation; ICU: Intensive care unit; NIV: Noninvasive ventilation; PCA: Patient controlled analgesia; IPPV: Intermittent positive pressure ventilation; CPR: Cardiopulmonary resuscitation; CMV: Continuous mandatory ventilation; IMV: Intermittent mandatory ventilation; PSSB: Pressure support on spontaneous breathing; ETI: Endotracheal intubation; GCS: Glasgow Coma Scale; MI: Myocardial infarction; PaO<sub>2</sub>: Partial pressure of O<sub>2</sub> in arterial blood; FiO<sub>2</sub>: Inspired oxygen fraction; PaCO<sub>2</sub>: Partial pressure of CO<sub>2</sub> in arterial blood.

intensive care unit and consequently treated with NIV. Studies in the pediatric population were excluded. We included randomized controlled trials, as well as observational studies, cohort, case-control and case series from previously published systematic reviews and meta-analyses in our search using MEDLINE and EMBASE, from inception until June 2014. We limited our search to studies on humans and those that were published in English. Our selected keywords were: non-invasive ventilation, continuous positive airway pressure, and trauma. These were cross-referenced with the following search terms: flail chest, pulmonary contusion, chest injury, blunt chest trauma, acute lung injury and acute respiratory distress syndrome. The following discussion is a summary of the most significant studies from our search, depicting the use of noninvasive ventilation in the setting of posttraumatic respiratory failure. Table 2 is a summation of the pertinent randomized controlled studies described below.

In a study by Trinkle *et al*<sup>[11]</sup>, the possibility that obligatory mechanical ventilation for flail chest was not necessary was first discussed. Their small retrospective review with well-matched cohorts showed that the obligatory ventilation group had a longer hospital stay, a higher mortality and a higher complication rate as compared to a pulmonary contusion (PC) group treated conservatively. In

addition, the PC group averaged only 0.6 ventilator days, indicating that the conservative management was often successful.

Another study by Schweiger *et al*<sup>[28]</sup> compared IMV to continuous positive airway pressure (CPAP) in three groups of pigs: a control group, flail chest injury group and pulmonary contusion/flail chest injury group. The authors showed that the use of ten to fifteen centimeters of CPAP was beneficial over IMV alone for correcting alveolar closure thereby minimizing shunt fraction and improving compliance significantly. The need for IMV was significantly reduced after the application of CPAP in all animals with this effect being more pronounced in the pulmonary contusion/flail chest injury group as opposed to the isolated flail chest injury group.

Antonelli *et al*<sup>[29]</sup> performed a multicenter survey in 2001, and showed that patients with posttraumatic hypoxemic respiratory failure responded favorably to NIV, with only a moderate failure rate of eighteen percent. The benefit of NIV was attributed to early inclusion of patients with hypoxemia within forty eight hours after trauma, the high prevalence of lung contusions as major underlying cause of hypoxia, and the extended length of NIV use. The authors concluded that in severe thoracic trauma-related hypoxia, early and continuous application of NIV is an effective means



for reducing the need for intubation and shortening the length of intensive care unit stay.

Ferrer *et al.*<sup>[30]</sup> carried out a multicenter randomized trial in a mixed population of patients with acute hypoxemic respiratory failure. The authors compared the efficacy of NIV versus breathing with a conventional Venturi oxygen mask at a maximal concentration to avoid intubation and to improve survival. Patients with hypercapnia were excluded. Six patients with thoracic trauma were enrolled in the NIV group vs twelve in the control group. Only one out of six patients in the NIV group required endotracheal intubation vs five out of twelve patients in the control group. No mortality in the intensive care unit was observed in the NIV group as compared to three deaths in the conventional treatment group. Despite the small sample size, the authors did observe a nonsignificant trend in reduction of the intubation rate in patients with thoracic trauma treated with NIV.

In a prospective study by Tanaka *et al.*<sup>[31]</sup>, the use of CPAP in fifty nine patients with flail chest injury was investigated. The patients in the study were compared to historical controls treated for respiratory failure primarily with mechanical ventilation and the groups were well matched in terms of extent of chest wall injury and overall injury severity. The CPAP group had a lower rate of pulmonary complications and a significantly lower rate of invasive mechanical ventilation use.

Two major randomized controlled trials depicting the use of continuous positive airway pressure in patients with severe chest trauma include one for the prevention and one for treatment of respiratory failure in patients without endotracheal intubation at the time of presentation.

Bolliger *et al.*<sup>[32]</sup> randomly allocated patients with multiple rib fractures to two groups in a prevention trial: (1) a CPAP group (thirty six patients) with lumbar epidural buprenorphine or an intercostal nerve block with bupivacaine; and (2) an endotracheal intubation and ventilation group (thirty three patients) with systemic morphine analgesia. Patients included in the study had all of the following: hospital admission within twenty four hours of injury; more than three rib fractures; and insufficient cough mechanism due to pain or pre-existing lung disease. As before, the use of CPAP was compared to intubation and mechanical ventilation. Although the group receiving noninvasive ventilation had a shorter length of stay in the intensive care unit and in hospital, the design of the study was flawed. It did not reflect current clinical practice since endotracheal intubation is not usually used prophylactically for patients similar to those as in this control group. Furthermore one of the exclusion criteria was severe lung contusion. Since no computed tomography chest images had been obtained, it is likely that patients with multiple rib fractures had underlying

pulmonary contusion not detected by plain chest radiographs. On the whole, the two groups were similar at the five percent significance level except for injury severity score which was higher in the intubated group. The authors justified that this was due to the greater number of blunt abdominal injuries in the intubated group, and that the abdominal injuries were considered less severe than the chest injuries in both groups. It was deemed that the difference was not clinically significant.

Gunduz *et al.*<sup>[33]</sup> executed a randomized comparison of mask CPAP to intermittent positive pressure ventilation *via* endotracheal intubation in fifty two patients in a treatment study. The results showed that CPAP led to a lower mortality (20% vs 33%,  $P < 0.01$ ) and nosocomial infection rate (18% vs 48%,  $P = 0.001$ ). However, a difference in the length of intensive care unit stay could not be demonstrated and the small number of patients enrolled as well as single-centre design raised concerns regarding generalizability.

Hernandez *et al.*<sup>[34]</sup> investigated chest trauma-related hypoxemia and randomized patients to remain on high-flow oxygen mask (twenty five patients) or to receive NIV (twenty five patients) using bi-level positive airway pressure (BiPAP; Respironics Inc.; Murrysville, PA). Patients on oxygen by high-flow mask within the first forty eight hours after thoracic trauma with  $\text{PaO}_2/\text{FiO}_2$  ratio less than or equal to two hundred for more than or equal to eight hours were included. The primary end point was intubation and secondary end points length of hospital stay and survival. The protocol utilized for the usage of bi-level positive airway pressure was well outlined, and the intubation criteria were similarly acceptably defined. The study findings showed that the Acute Physiology and Chronic Health Evaluation II (APACHE II) score was higher in the NIV group ( $P = 0.02$ ). It was nonetheless discontinued early due to a significant difference in the intubation rate, in terms of less frequent intubations ( $P = 0.02$ ) and later intubations ( $P < 0.01$ ) in the NIV group. It is therefore evident from the above discussion, that despite the application of NIV over last several decades, there are still insufficient randomized control studies that support its use in trauma patients who have or are at risk for acute respiratory distress or failure.

## APPLICATION OF NIV AS A VENTILATION STRATEGY

The diversity of the injuries to the trauma population means that they are especially at high risk of developing ALI/ARDS<sup>[35]</sup> and though the management of decreased alveolar ventilation is usually straightforward and is less challenging than that of posttraumatic ALI/ARDS, delayed or inappropriate management may still precipitate

complications.

One of the most important factors contributing to the development of posttraumatic pulmonary complications is atelectasis. Atelectasis causes ventilation-perfusion mismatch and hypoxemia refractory to supplemental oxygen when compensatory mechanisms such as hypoxic pulmonary vasoconstriction become insufficient. The pulmonary and extra-pulmonary damage can potentially lead to increased morbidity and mortality<sup>[36]</sup>. Atelectasis also interferes with the clearance of bacteria, such as *Streptococcus pneumoniae*, *Staphylococcus aureus* and *Klebsiella pneumoniae*, which are frequent pathogens in early posttraumatic pneumonia<sup>[37,38]</sup>. Such a deleterious interaction together with the cyclic recruitment and derecruitment of lung units within atelectatic regions, partly explains why injured patients who frequently present with substantial atelectasis are so prone to develop early nosocomial pneumonia<sup>[39,40]</sup>.

The identification of patients who should be managed with NIV is challenging, partly because there are few reliable selection criteria. According to the British Thoracic Society guidelines<sup>[7]</sup> and the findings of various studies discussed previously, a prudent approach is suggested, and it seems sensible to exclude patients who have multiorgan dysfunction or are poor candidates for NIV by virtue of inability to cooperate or protect the airway or because of excessive secretions (Table 1). NIV should clearly be avoided in patients with shock, severe hypoxemia, or acidosis. A further issue is to agree on a threshold of severity for hypoxemia and acidosis beyond which NIV should be considered as being contraindicated. There are no clear recommendations on this dilemma, and the application of NIV in such patients with posttraumatic ALI/ARDS should be limited to those that are mostly hemodynamically stable or alternatively who can be closely monitored in the intensive care unit, where endotracheal intubation would be promptly available.

The application of optimal levels of NIV can improve oxygenation, relieve dyspnea and dramatically reduce inspiratory muscle effort since patients with posttraumatic ALI/ARDS have diffuse alveolar damage and represent those with the most severe form of hypoxemic respiratory failure<sup>[41]</sup>. One has to balance NIV to improve oxygenation on the one hand and increase the pressure support above the CPAP to augment the tidal volume on the other. The clinical endpoints of all these effects are in the diminution of intubation rates.

A reasonable approach would be to use NIV judiciously in trauma patients. Although the optimal duration of the initial NIV trial remains uncertain, a reasonable expectation would be a response within 1 to 4 h of therapy initiation. Patients who are failing an NIV trial should be promptly intubated and mechanically ventilated as any delays in

endotracheal intubation in patients managed with NIV have been associated with decreased survival<sup>[42]</sup>.

An early conversion to more invasive mechanical ventilation is supported by the finding that the longer atelectasis is tolerated, the higher the transpulmonary pressures required to reinflate them will be. Furthermore, oxygenation goals accepted in some patient populations may not be acceptable in the trauma patient population. Hypoxemia on admission is an independent predictor of poor outcome in these patients which is in contrast to the results of the ARDS Network data. Thus tolerating borderline arterial oxygen tension values such as 55 mmHg can pose a serious threat to patients with cerebral injuries and intracranial hypertension or patients at risk of significant bleeding<sup>[43]</sup>.

It has been shown that many of these patients deteriorate rapidly on the second or third post-traumatic day, and thus intubation and mechanical ventilation become necessary to ensure adequate oxygenation. This protracted respiratory decompensation corresponds to descriptions of the later-onset ALI/ARDS in trauma victims demonstrating how the coexistence of several predisposing factors may culminate in respiratory failure<sup>[19,44]</sup>. Early aggressive mechanical ventilatory support to prevent worsening of arterial oxygenation and progressive atelectasis is therefore recommended by several authors<sup>[12]</sup>. Controlled or assisted ventilatory modes can be chosen if patients need to be intubated and ventilated invasively. Putensen *et al.*<sup>[45]</sup> described another concept focused on the maintenance of spontaneous breathing stating that diaphragmatic contractions will recruit dependent atelectatic lung regions and in so doing improve both the distribution of ventilation and ventilation-perfusion matching.

In conclusion, despite the heterogeneity of the studies on NIV for the treatment of respiratory failure associated with trauma and the scarcity of available randomized control data, recently published systematic reviews and meta-analysis<sup>[26,27]</sup> suggest that NIV could be useful in this setting. It can potentially be associated with a significant reduction in the incidence of overall complications, endotracheal intubation rate, length of intensive care unit stay and mortality. Therefore, the role of NIV in managing respiratory insufficiency associated with trauma may become significant if applied to the properly selected patient at an earlier stage of lung injury by appropriately trained and experienced personnel.

## CONCLUSION

The use of NIV is widely recognized as a suitable way to avoid intubation and its associated complications and side effects. NIV allows increased flexibility in the application and discontinuation of ventilator assistance and preserves airway defense

mechanisms as well as speech and swallowing. Ventilatory management in the trauma population however is more challenging because of the difficulty in achieving a balance between the avoidance of further harm to the lungs and sufficient ventilation. Guidelines for the use of NIV in patients with trauma recommend continuous positive airway pressure in those patients who remain hypoxic despite regional anesthesia<sup>[7]</sup>. This recommendation is currently rated as low grade, mostly due to the lack of randomized controlled trials in this specific patient population<sup>[6,7]</sup>. Given the disappointing results of various trials and meta-analyses<sup>[8]</sup>, selection of appropriate patients is crucial for optimizing NIV success rates and resource utilization. Extensive application of NIV in trauma-associated ALI/ARDS may otherwise be challenging. Thus, although it has become part of routine care for many patients with acute respiratory failure, implementing NIV for some of them may prove inadequate and may simply prolong the time to an inevitable endotracheal intubation. Close monitoring of its efficacy is therefore mandatory as delaying the time to endotracheal intubation often leads to further respiratory instability. Consequently, patients who do not respond to NIV are burdened by an increased mortality risk when intubation is delayed. The proper identification of patients who are likely to benefit from NIV and simultaneously avoiding the potential complications of a delayed endotracheal intubation remains a challenging issue.

Clinical trials are starting to appear, potentially signaling a reduction in mortality and pulmonary infections based on the less frequent intubations. More research is nonetheless required to determine the role of NIV in respiratory dysfunction stratification with the appropriate inclusion and exclusion criteria. The use of NIV represents one of the goals in investigating the role of ventilatory support to improve outcomes in trauma victims.

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P- Reviewer: Czaplik M, Hsu CW, Kuan YH, Willms D  
S- Editor: Song XX L- Editor: A E- Editor: Wu HL







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