Review Article

Management and weaning from mechanical ventilation in neurologic patients

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Abstract: In the early phase following severe brain injury (BI), mechanical ventilation (MV) is often needed to prevent airway from aspiration, control $PaCO_2$ and PaO_2 and avoid secondary brain insults. Although patients with BI are frequently hospitalized in the intensive care unit (ICU) without respiratory problems, they display longer durations of MV and a challenging weaning process compared to other ICU populations. Historically, the MV settings of BI patients associated high tidal volume with low or no positive end-expiratory pressure (PEEP), for neurological reasons. The extensive data about the beneficial effects of protective ventilation in patients without acute respiratory distress syndrome, have questioned the consequences of such management in BI patients. Recent studies suggest that protective ventilation is safe and could even bear significant impact on morbidity in these patients. The MV weaning process is also challenging, since these patients display a high rate of extubation failure. Recently, new clinical scales of successful extubation have been highlighted combining airway and neurologic operators. A minimal level of arousal should be achieved before extubation, but the Glasgow Coma Score has been inconsistently associated with successful extubation, probably owing to the challenging quantification in intubated patients. Early tracheostomy seems to bear positive effects on morbidity in BI patients. Nonetheless the level of evidence remains poor and no strong recommendations can be made on this topic. Overall, the respiratory bundle of care in BI patients could be readapted with the new data available in the literature. Even if they bear positive impact on morbidity in ICU, their consequences on neurological recovery have yet to be adequately assessed.

Keywords: Ventilator-induced lung injury; weaning, traumatic brain injury (TBI); subarachnoid haemorrhage (SAH); intra-cranial haemorrhage

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Background

Brain injured (BI) patients such as traumatic brain injury (TBI), subarachnoid haemorrhage (SAH) intra-cranial haemorrhage or stroke are often admitted in the intensive care unit (ICU) for neurological surveillance (1). Whenever arousal is importantly impaired, mechanical ventilation (MV) becomes mandatory in order to protect the airway from aspiration and prevents hypoxemia and hypercapnia. These respiratory complications are major systemic factors of secondary brain insults, and thus impair the outcome (2). Patients with severe BI display a prolonged

MV duration, compared to other ICU patients. In an observational multi-centre nationwide study (3), patients with BI displayed a high duration of MV compared to other ICU subgroups. These findings were witnessed in all types of BI injury: TBI, stroke and SAH compared to the general ICU population. Other studies in the neuro-ICU field (4,5) still suggested long duration of MV, although there was no comparison with the general ICU population. Although the management of MV is of daily concern for attending physicians, there is currently little data in patients undergoing severe BI. The weaning process of MV in these patients, once the neurological management acute phase is over, remains poorly described and the latest guidelines on the subject did not propose any specific recommendations in patients with BI (6). Recently, new data have highlighted specific extubation and weaning management of patients with TBI and SAH (7-9).

In this review, we will discuss the latest data about the MV management and potential new weaning strategies in patients with BI.

MV management

After BI, one of the priorities is to secure the airway when the Glasgow Coma Score (GCS) is ≤8 (2). Endotracheal intubation prevents aspiration and enables ventilatory management with MV. Second, in the first days following BI, hypoxemia and hyper/hypocapnia lead to secondary brain insults, which alter the outcome (10). Treatment of hypoxemia can be modulated via FiO_2 to ensure a PaO_2 target >60 mmHg (2). Moreover, PaO_2 could be modulated with the help of $PtiO_2$ monitoring in order to avoid cerebral ischemia (11,12). $PaCO_2$ is the second respiratory parameter that must be controlled because it is a powerful determinant of cerebral blood flow. $PaCO_2$ directly controls cerebral blood vessels dilation and contraction and has immediate effects on intra-cranial pressure (2). An adequate control of $PaCO_2$ within a 35–45 mmHg range is a therapeutic target all along the course of MV during BI (2). Nonetheless, the latest guidelines in TBI patients (2) did not propose any recommendation to manage $PaCO_2$, and both tidal volume and respiratory rates are left at the physician's discretion. The fear of hypercapnia in these patients, has lead practitioners to set the tidal volume at 9 mL/kg of ideal predicted body weight in patients with BI (3). Moreover, in this large observational study, a significantly lower proportion of patients with BI received protective ventilation compared to the non-neurologic patients (3). The respiratory management of patients with BI could nonetheless bear major clinical impact on the outcome. High tidal volume leads to ventilator-induced lung injury (13), and in neuro-ICU studies high tidal volume is associated with an increased rate of acute respiratory distress syndrome (ARDS) which alters patient's outcome (14,15).

Recently, the safety and efficacy of protective ventilation in BI patients was tested in two before-after studies. The first study was monocentric in 2 ICUs and included 499 patients with TBI, SAH and stroke (5). The bundle of care associated a protective ventilation strategy [tidal volume between 6–8 mL/kg of ideal predicted bodyweight and positive end-expiratory pressure (PEEP) >3 cmH_2O] and early extubation with a GCS ≥10 (5). There was a significant increase in the number of ventilatory-free days during the intervention period. However, another before-after multi-centre study performed in a large population of patients with BI did no confirm these results (4). Indeed, protective ventilation (≤7 mL/kg of ideal predicted body weight and a PEEP between 6–8 cmH_2O) associated with early extubation in 749 BI patients showed no differences in the number of ventilatory-free days in the intervention period. However, in the sub-group of patients receiving both protective ventilation and early extubation there was a significant improvement of the number of ventilatory-free days and the mortality rate. In both studies (4,5), protective ventilation did not alter the outcome and did not bear clinically relevant effects on intracranial pressure. In the end, it remains mandatory to monitor the level of $PaCO_2$ within normal ranges. These new data highly suggest that protective ventilation with a moderate tidal volume (6–8 mL/kg of ideal body weight) could be safely applied in BI patients and could bear significant positive effects, while keeping $PaCO_2$ in normal range by adjusting the respiratory rate as recommended by the current international guidelines (2).

Another issue regarding the ventilatory settings is the level of PEEP that should be set: PEEP increases the intra-thoracic pressure and may impair central venous return, leading to increased intracranial pressure. However, this assumption has been poorly documented in the ICU literature. One study driven in a small sample of nine patients with BI (16), showed a positive correlation between PEEP and intra-cranial pressure. In another study including patients with SAH (17), PEEP impaired cerebral blood flow but through a mean arterial pressure decreased and without modifying intracranial pressure. Considering these data, it was therefore advocated to use a low or zero PEEP in patients with BI to avoid intracranial pressure increase.

Table 1 Predictive factors of successful extubation in patients with brain injury

Visage score
Age <40
Glasgow Coma Score the day of extubation >10
Swallowing attempts
Visual pursuit
Other successful predictors
Negative fluid balance
Presence of cough
Positive gag reflex

Factors identified with predictors of successful extubation in patients with brain injury. For the VISAGE score, the presence of each feature counts as one. A score of 3, predicts extubation success in 90% of patients (7).

Pelosi *et al.* confirmed that a vast majority of patients with BI were delivered a PEEP ≤5 cmH_2O (3). The concept of "low/zero PEEP" was challenged by recent data showing the safety of moderate levels of PEEP. In a pilot prospective study performed in 20 patients with TBI, the results suggested that a PEEP increase to 15 cmH_2O could have beneficial effects on brain tissue oxygenation evaluated with $PtiO_2$ (18). Our group confirmed that PEEP >5 cmH_2O did not alter the intracranial pressure in severe BI patients (4,5). In definite, it seems that the zero-PEEP policy should be abandoned in neuro-ICUs and that an increase of PEEP could be safely applied in patients with BI, provided normovolemia in patients.

Weaning from MV and extubation

In series of BI patients, the extubation failure rate was up to 38% (19), but other descriptive studies also suggest that the extubation failure rate is high in this specific ICU population (7). Like for MV management, the latest guidelines on the subject did not describe the weaning management of BI patients (6). Observational studies also suggest that extubation is often delayed, probably because of the physician's inability to accurately evaluate the level of arousal during the recovery phase (20). The burden of both delayed extubation and extubation failure is high in patients with BI: nosocomial pneumonia, longer MV duration, increased ICU length of stay and higher mortality (7,8,20).

The level of arousal to safely perform extubation remains controversial. Coplin *et al.* have pointed out that delaying extubation in order to obtain sustained neurological improvement during the recovery phase, would not guarantee successful extubation (20). Such strategy is also associated with morbidity (20). A algorithm-based extubation (GCS ≥8 with audible cough during suctioning) was tested in a randomized-controlled study, and improved the extubation success rate (21). Namen *et al.* showed that a GCS of 8 had the highest area under the receiver operating curve for predicting successful extubation (19). However, all authors do not retrieve the GCS as a predictive factor of successful extubation (8,9). A possible explanation is that the GCS has never been validated in intubated patients, and it should be kept in mind that the quantification of the verbal component is impossible and often arbitrarily scored. This could explain why the GCS used alone has been inconsistently pointed out as a factor of extubation success.

Recent data have evaluated new physical features compatible with successful extubation in patients with severe BI. In a multi-centric study in 437 patients, age <40 years old, visual pursuit, attempts of swallowing and a GCS >10 on the day of extubation were predictors of successful extubation (7). Based on these items the VISAGE score was built. When 3 items are present, the score predicts more than 90% of extubation success. Other observational studies have found similar results for these clinical signs [visual pursuit and preserved upper airway reflexes (8), younger age (9)], but also new factors [negative fluid balance and the presence of cough (9,22)] were described as good predictors of extubation success (*Table 1*). Overall, it seems that the presence sub-optimal consciousness level with at least one functional airway operators help to decrease the rate of delayed extubation without inducing a higher rate of extubation failure.

Several issues still remain regarding extubation success. All these cohorts creating new scores of extubation success or failure lack external validation, which renders the generalizability of the results questionable. Second, although the elaboration of bundles of care are mandatory to improve outcomes (23), they remain complicated to apply at bedside in a daily practice (4). Further studies could be driven to confirm the findings of the latest studies, in order to confirm which markers are predictive of successful extubation.

The indications and timing of tracheostomy after BI

Tracheostomy appears an interesting therapeutic alternative in the case of complicated weaning process like in patients with BI. In a monocentric retrospective study in a TBI population (24), a propensity score analysis suggested a benefit of early tracheostomy in the first 5 days after intubation, with fewer pneumonia, lower MV duration and ICU length of stay. In a second retrospective study performed in a large multi-centre data-bases (25), the propensity score analysis also favoured early tracheostomy. The mortality rate was similar between patients with early and late tracheostomy in both studies. The main drawback of non-specific databases studies, is that the indication of tracheostomy remains unknown and it is hard to select the best candidates for early tracheostomy in daily practice. In one randomized-controlled study with patients with stroke and SAH, early tracheostomy did not result in a reduction of the ICU length of stay but resulted in lower mortality (26). These results should be cautiously interpreted since mortality was a secondary outcome.

To this day there are no guidelines regarding the management of tracheostomy in patients with BI. Tracheostomy could be a part of therapeutic arsenal be should definitely be performed according to written local protocols.

Conclusions

Patients undergoing BI from trauma or intra-cranial haemorrhage display a high prevalence of respiratory complications longer durations of MV and high rates of extubation failure, compared to other ICU patients. New data about MV management have been tested in the neuro-ICU setting. It is now clear that PEEP has minor effects on cerebral perfusion pressure. Protective ventilation with low tidal volumes (6–8 mL/kg of ideal body weight), could be safely applied to BI patients, but its benefits has not been formally proven. Extubation remains challenging in the neuro-ICU setting. Very simple clinical signs like visual pursuit, cough, swallowing have been described as good predicting factors of successful extubation and could be useful in guiding extubation. Finally, the exact timing and indications of tracheostomy remains uncertain and should be better delineated.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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