Protective Ventilation Strategies for Acute Brain Injury

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Protective ventilation strategies are aimed at minimizing ventilator-induced lung injury (VILI) while ensuring adequate oxygenation and CO_2 clearance, particularly in critically ill patients, including those with acute brain injury (ABI).

Key Components of Protective Ventilation

Low Tidal Volume (VT)

Typically 4-8 mL/kg of predicted body weight (PBW) Reduces barotrauma and volutrauma (excessive lung stretch)

Low Plateau Pressure (Pplat)

Aim for ≤ 30 cmH_2O Reduces the risk of lung overdistension and ventilator-induced lung injury

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Driving Pressure (ΔP) Optimization

ΔP = Pplat - PEEP (Positive End-Expiratory Pressure)

Recommended target: ≤ 15 cmH_2O

Higher driving pressure has been associated with worse outcomes in ICU patients

Moderate Positive End-Expiratory Pressure (PEEP)

Usually 5-8 cmH_2O in neurologically injured patients Avoiding excessive PEEP is crucial to prevent increased intracranial pressure (ICP)

Permissive Hypercapnia (With Caution in ABI)

Mild hypercapnia ($PaCO_2$ 45-55 mmHg) can be tolerated in ARDS However, in ABI patients, $PaCO_2$ control is critical to prevent cerebral vasodilation and increased ICP Adequate Oxygenation (Avoiding Hyperoxia and Hypoxia)

Target PaO_2 60-100 mmHg (SpO_2 92-96%) Hyperoxia (> 150 mmHg PaO_2) may increase oxidative stress and worsen brain injury Protective Ventilation vs. Intracranial Pressure (ICP) Concerns

In ABI patients, maintaining cerebral perfusion pressure (CPP) is essential

Sudden changes in $PaCO_2$ (due to ventilation adjustments) can affect cerebral blood flow

Avoid excessive PEEP, as it may reduce venous return and elevate ICP

Findings from the VENTIBRAIN Study (2025) Most ABI patients received protective ventilation, but practices varied significantly between countries. Higher plateau pressure (Pplat) was associated with higher ICU and 6-month mortality. Protective ventilation was not linked to neurological outcomes at 6 months.

Clinical Implications Protective lung ventilation is widely used, but its impact on neurological outcomes remains unclear.

Balancing lung protection with ICP control is crucial.

Standardized protocols could reduce variability and improve outcomes.

International, prospective, multicenter, observational studies

An international, prospective, multicenter, observational study was conducted across 74 ICUs in 26 countries, including adult patients with ABI (e.g., traumatic brain injury, intracranial hemorrhage, subarachnoid hemorrhage, and acute ischemic stroke), who required ICU admission and invasive mechanical ventilation. Ventilatory settings were recorded daily during the first week and on days 10 and 14. ICU and 6-month mortality and 6-month neurological outcomes were evaluated.

On admission, 2095 recruited patients (median age 58 [interquartile range 45-70] years, 66.1% male) had a median plateau pressure (Pplat) of 15 (13-18) cmH20, tidal volume/predicted body weight 6.5 (5.7-7.3) mL/Kg, driving pressure 9 (7-12) cmH20, and positive end-expiratory pressure 5 (5-8) cmH20, with no modifications in case of increased intracranial pressure (> 20 mmHg). Significant differences in practices were observed across different countries. The majority of these ventilatory settings were associated with ICU mortality, with the highest hazard ratio (HR) for Pplat (odds ratio 1.50; 95% confidence interval, CI: 1.27-1.78). The results demonstrated a consistent association with 6-month mortality; a less clear association was observed for neurological outcomes.

Protective ventilation strategies are commonly used in ABI patients but with high variability across different countries. Ventilator settings during ICU stay were associated with an increased risk of ICU and 6-month mortality, but not an unfavorable neurological outcome [1)].

1)

Robba C, Giardiello D, Almondo C, Asehnoune K, Badenes R, Cinotti R, Elhadi M, Graziano F, Helbok R, Jiang L, Chen W, Laffey JG, Messina A, Putensen C, Schultz MJ, Wahlster S, Rebora P, Galimberti S, Taccone FS, Citerio G; VENTIBRAIN study group. Ventilation practices in acute brain injured patients and association with outcomes: the VENTIBRAIN multicenter observational study. Intensive Care Med. 2025 Feb 24. doi: 10.1007/s00134-025-07808-1. Epub ahead of print. PMID: 39992441.