Management of Intracranial Pressure Crises During Prone Positioning in Traumatic Brain Injury Patients with Respiratory Failure

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Introduction

Traumatic brain injury (TBI) remains a leading cause of emergency admissions in the United States, accounting for approximately 586 hospitalizations and 190 deaths daily[1]. Acute respiratory failure complicates about 17% of TBI cases and substantially increases in-hospital mortality[2]. Since the COVID-19 pandemic, prone positioning has become standard care for patients with severe respiratory failure. However, in individuals with TBI and elevated intracranial pressure (ICP), proning may precipitate abrupt ICP deterioration despite maximal medical management.

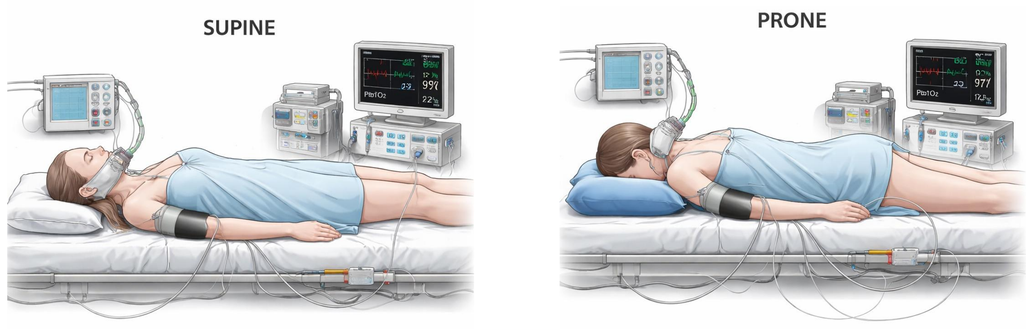
Illustrative Case Presentation

A 17-year-old female was admitted following a high-speed motor vehicle collision. She was found unresponsive with emesis at the scene and was intubated for airway protection. In the emergency department, she developed a generalized tonic–clonic seizure treated with levetiracetam. Initial head CT demonstrated small right basal temporal hyperdensities consistent with traumatic subarachnoid hemorrhage, without mass effect or midline shift. The patient was admitted to the trauma ICU with a persistently low Glasgow Coma Scale score (≤4). Serial CT imaging showed no hemorrhage progression but evolving cerebral edema. On post-injury day 2, multimodal neuromonitoring was initiated for intracranial pressure (ICP), cerebral tissue oxygenation, and metabolic guidance. ICP values were initially within normal limits, and EEG showed no ongoing epileptic activity. Diffuse axonal injury was suspected; MRI could not be performed due to monitoring device incompatibility. On hospital day 5, the patient developed worsening hypoxemia secondary to pulmonary secretions and ventilator dysfunction, progressing to severe acute respiratory distress syndrome from post-traumatic pulmonary contusions, pneumonia, and atelectasis. Escalation of ventilatory support was required. Prone positioning resulted in refractory intracranial hypertension (ICP up to 31 mmHg) and was aborted. Due to persistent hypoxemia and ICP instability, veno-venous extracorporeal membrane oxygenation (ECMO) was initiated, enabling reduction of FiO_2 and stabilization of cerebral tissue oxygenation.

Discussion

Prone positioning may increase intracranial pressure due to:

- **impaired cerebral venous outflow,**
- **hypercapnia-induced cerebral vasodilation,**
- **altered cerebrospinal fluid dynamics**
- **transient reductions in cerebral perfusion pressure.**



Careful positioning, ventilation control, and hemodynamic monitoring are essential to minimize ICP elevation, particularly in high-risk patients.

In cases of refractory hypoxemia or hypercapnia, or when prone positioning leads to ICP instability, veno-venous ECMO represents an effective rescue therapy in accordance with ELSO/ATS/ERS guidelines.

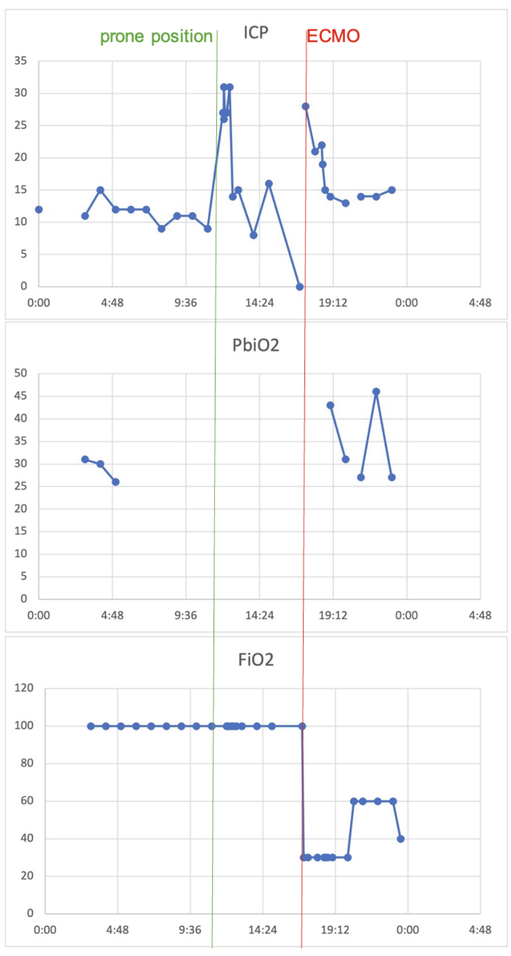


Figure 1.: Timecourse of ICP, PbiO2, FiO2 and SpO2 before and after proning. Scattergraph of ICP, PbiO2, FiO2 and SpO2 monitoring before proning, after proning and back in supine position under ECMO (red line).

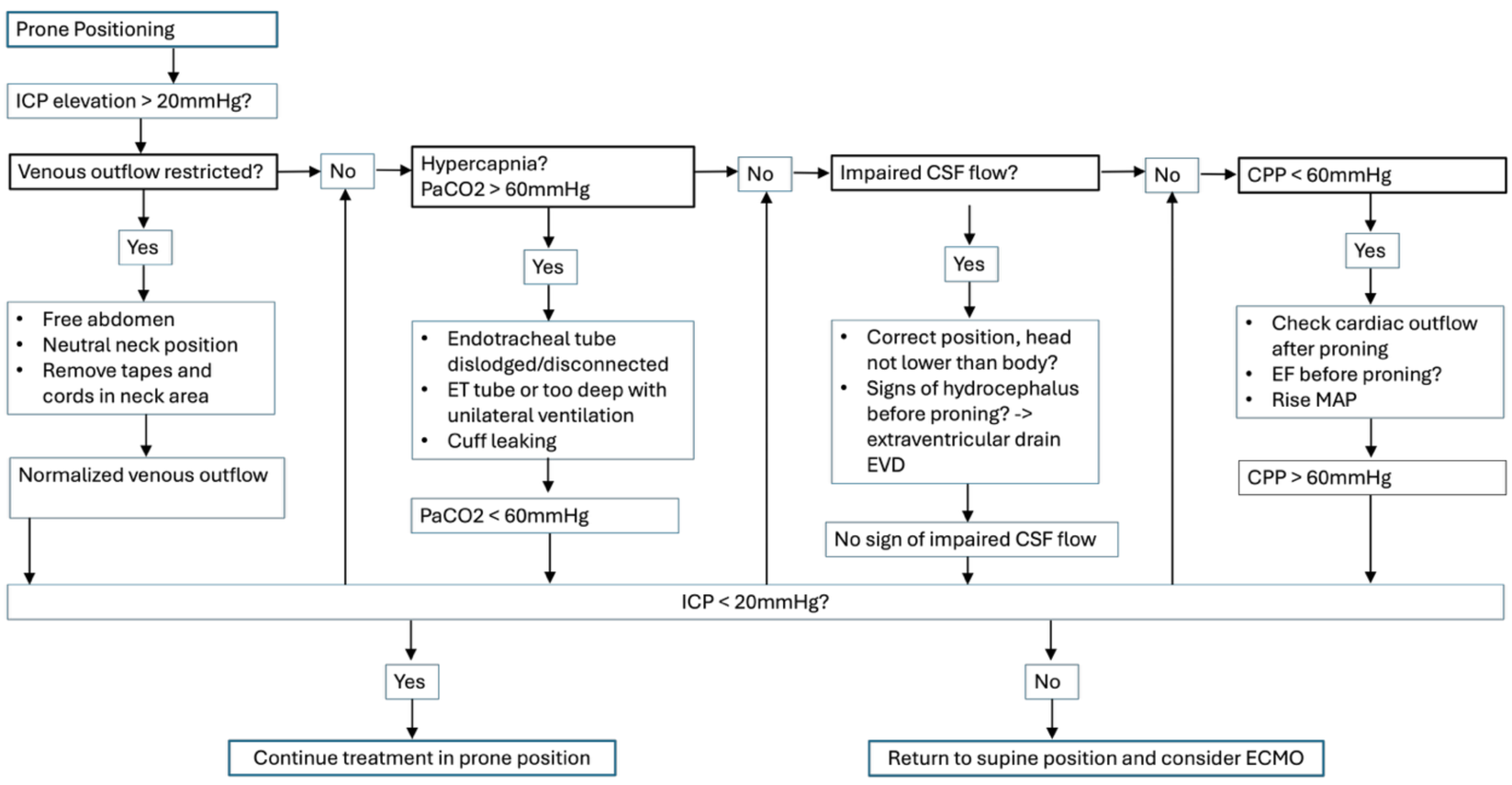


Figure 2.: Management of ICP crisis after proning. Flowchart illustrating the principal causes of intracranial pressure (ICP) elevation in patients positioned prone and the corresponding corrective measures.

Conclusion

Patients with respiratory failure benefit significantly from prone positioning, a strategy that became widely adopted during the COVID-19 pandemic. However, prone positioning carries the risk of increased intracranial pressure (ICP) in traumatic brain injury patients, particularly in patients with concomitant thoracic, cervical, or abdominal trauma. When ICP elevation occurs after prone transfer, we recommend following the management steps outlined in figure 2. If these measures fail to restore ICP to physiological levels, the patient should be returned to the supine position, and extracorporeal membrane oxygenation (ECMO) should be considered without timely delay.

References

1. Multiple Cause of Death Data on CDC WONDER. https://wonder.cdc.gov/mcd.html.
2. Factors associated with acute respiratory distress syndrome in brain-injured patients: A systematic review and meta-analysis. *J. Crit. Care* **77**, 154341 (2023).
- Guérin, C. *et al.* Prone Positioning in Severe Acute Respiratory Distress Syndrome. *The New England Journal of Medicine* https://www.nejm.org/doi/full/10.1056/NEJMoa1214103 (2013) doi:10.1056/NEJMoa1214103.
- Galiatsou, E. *et al.* Prone Position Augments Recruitment and Prevents Alveolar Overinflation in Acute Lung Injury. *Am. J. Respir. Crit. Care Med.* (2012) doi:10.1164/rccm.200506-899OC.
- Mancebo, J. *et al.* A Multicenter Trial of Prolonged Prone Ventilation in Severe Acute Respiratory Distress Syndrome. *Am. J. Respir. Crit. Care Med.* (2012) doi:10.1164/rccm.200503-353OC.
- Combes, A. *et al.* Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome. *N. Engl. J. Med.* (2018) doi:10.1056/NEJMoa1800385.
- Peek, G. J. *et al.* Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. *The Lancet* **374**, 1351–1363 (2009).