Optimal end-tidal carbon dioxide range in the prehospitally intubated adult TBI patient

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Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability following trauma globally, impacting 69 million individuals annually (1-3). In 2023, injuries ranked as the sixth leading burden of disease in Australia (4) with head injuries accounting for 17% of the deaths within the burden of disease (5-7). Primary injury results from initial mechanical forces causing shearing and compression of neuronal, glial, and vascular tissues, while secondary injury (SI) arises from subsequent physiological disturbances (9). Prehospital management focuses on preventing SI, primarily by correcting hypoxia and hypotension (9-13). Endotracheal intubation (ETI) is the gold standard for maintaining effective oxygenation and ventilation in critically injured adult TBI patients, with end-tidal carbon dioxide ($EtCO_2$) often guiding ventilation strategies (14-17). Although normal ventilation is recommended, uncertainty remains regarding the optimal $EtCO_2$ range (15). This literature review aims to determine the optimal $EtCO_2$ range for adult TBI patients intubated in the prehospital setting.

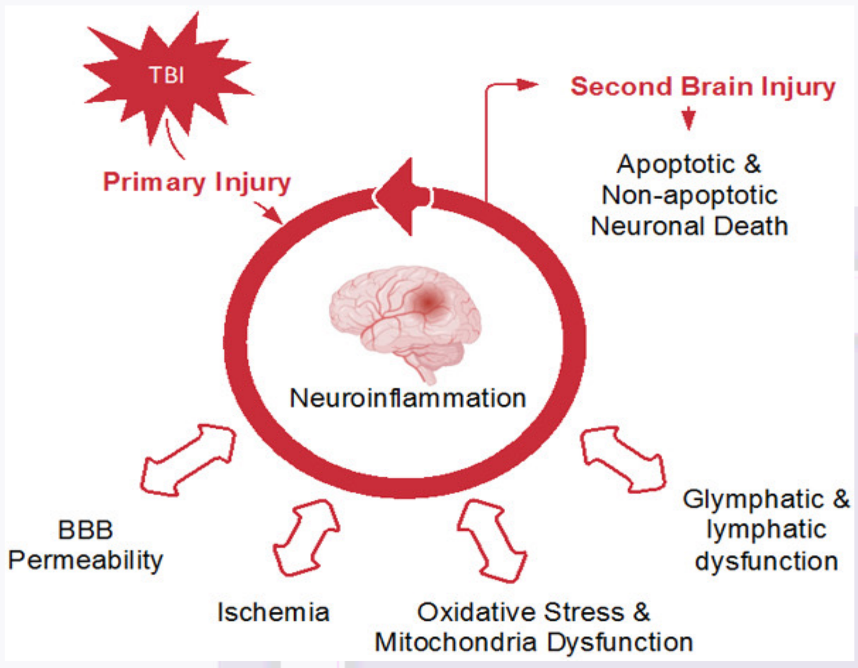

Figure 1: Primary and Secondary Brain Injury (8)

Methods

A search of the literature was conducted in August 2023 using the Ovid MEDLINE electronic database. MeSH headings and keywords used included: paramedic, EMS, ambulance, emergency medical services, emergency medical technicians, first aid, pre-hospital, head injury, TBI, traumatic brain injury, head injury, prehospital ventilation management, ETI, endotracheal intubation, $EtCO_2$, end-tidal carbon dioxide, carbon dioxide (CO_2), capnography, and end-tidal CO_2.

Peer-reviewed articles between January 2003 and August 2023 were included if patient $EtCO_2$/ $PaCO_2$ values and ventilation strategies were available for adult (>16 years old) TBI patients that were ETI in the prehospital setting. Patient outcome data was also required for articles to be included. Articles were excluded if they involved medical emergencies, in-prehospital settings, systematic reviews, meta-analyses, and non-English articles.

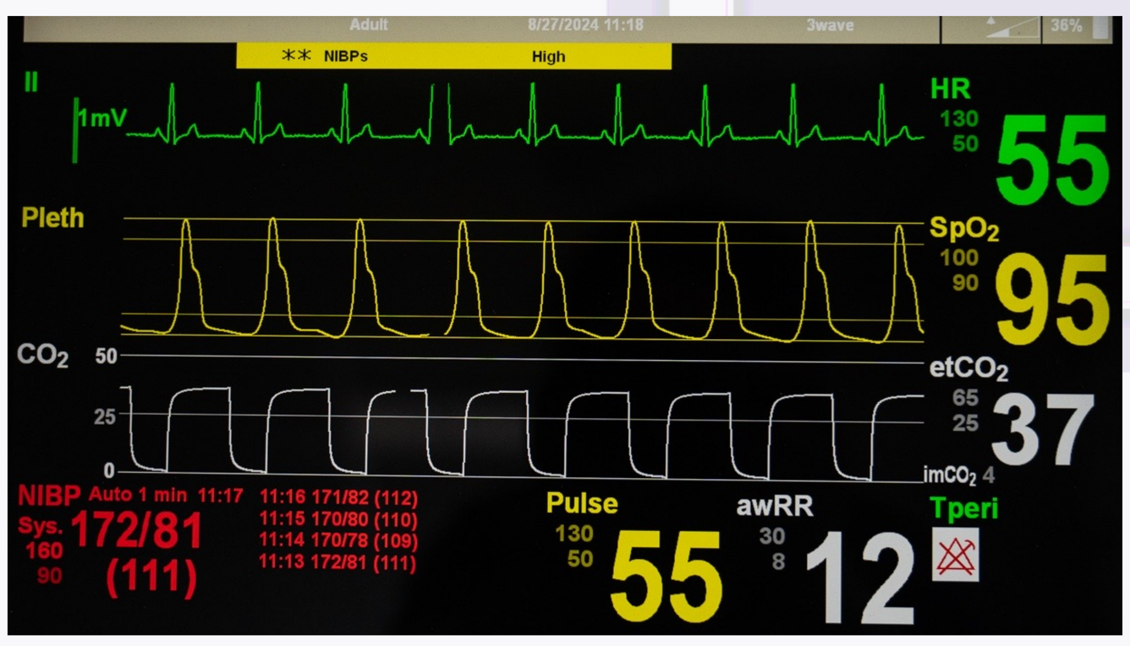

Figure 2 & 3: $EtCO_2$ Monitoring on a TBI Patient and Vital Signs

Results

Initially, 503 articles were identified. After a title and abstract review, 466 were removed as they did not meet the inclusion criteria with an additional 30 removed after a full-text review as they did not meet the inclusion criteria, leaving seven articles for inclusion in the review (10, 11, 13, 18-21).

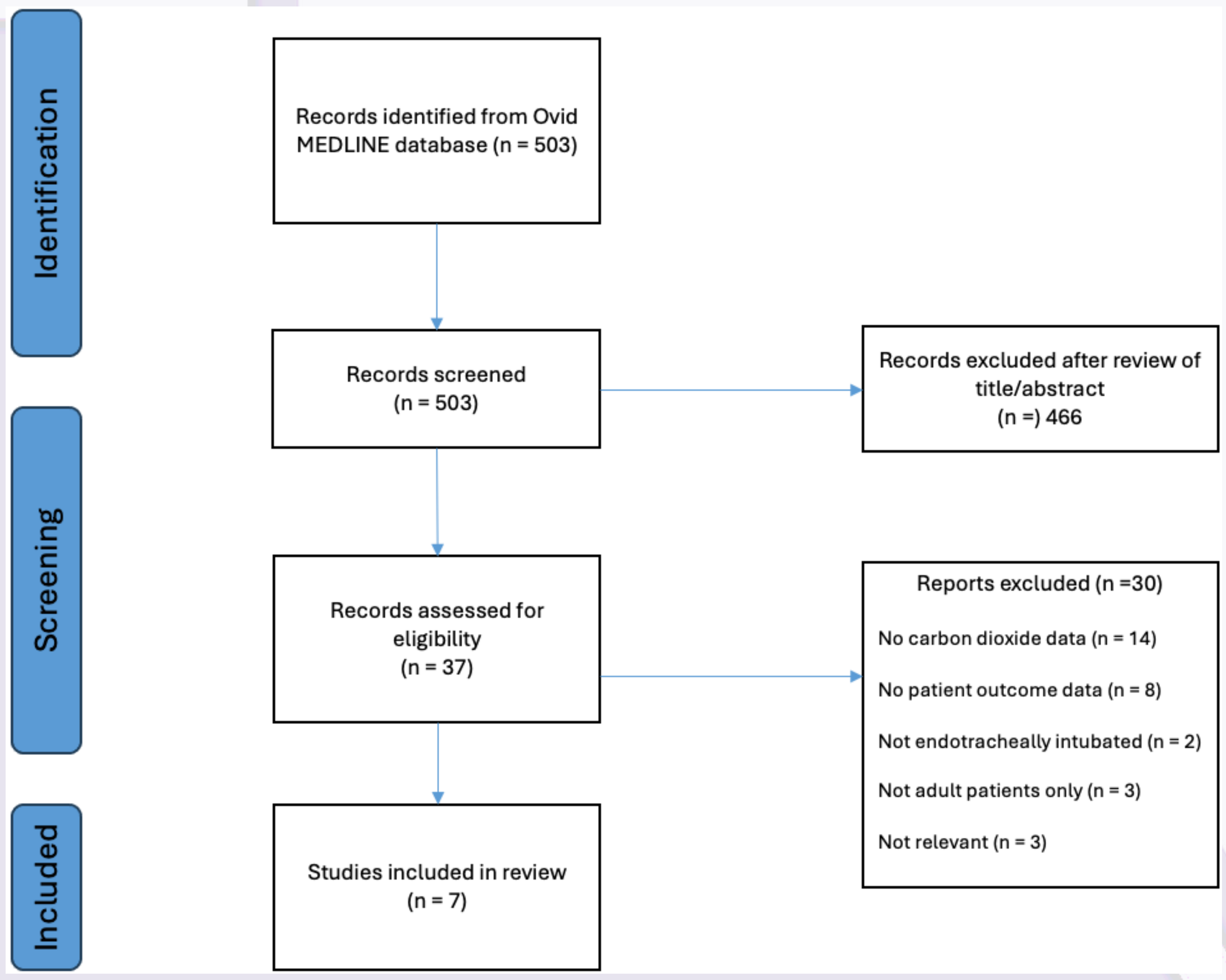

Figure 4: PRISMA Search Flow Diagram

Discussion

The findings from this review on the prehospital literature suggest that an $EtCO_2$ range of between 35 and 45 mmHg should be targeted for improved TBI patient outcomes, consistent with Brain Trauma Foundation (BTF) guidelines (11, 13, 20, 21). This range is widely supported by the majority of the literature, which emphasises that both hypercapnia and hypocapnia can lead to detrimental effects, including increased ICP and cerebral ischemia, respectively (10, 11, 13, 18, 19, 22).

However, emerging evidence highlights discrepancies between $EtCO_2$ and $PaCO_2$, with differences typically around 5 to 6 mmHg, sometimes higher in certain circumstances, particularly in unstable patients with ventilation-perfusion mismatch, acid-base disturbances, or hemodynamic instability (10, 18, 21, 23). These discrepancies may lead to significant gradients resulting in the misclassification of CO_2 levels, complicating TBI management (10, 18, 23). It is important to note that this emerging evidence is largely based on in-hospital studies and should be interpreted with caution when extrapolating to the prehospital setting (18, 23). This is particularly concerning given that precise control of $PaCO_2$ is crucial for managing cerebral blood flow and reducing mortality (18, 19, 23). In isolated TBI, accounting for this discrepancy is more straightforward and easier to manage in the prehospital setting (18, 23).

Due to this emerging evidence, adult TBI patients may benefit from targeting the lower end of the normal $EtCO_2$ range (35-40 mmHg), particularly in cases with suspected increased A-a gradients (10, 18, 23). Given that $PaCO_2$ measurement is limited in the prehospital setting, understanding these discrepancies is crucial to mitigate risks and optimise patient outcomes (11, 18, 23). Further studies are needed to validate these findings and refine prehospital ventilation strategies.

References

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