Critically Appraised Topic in Trauma

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Title: ETCO2 monitoring in out of hospital traumatic brain injuries improves outcomes.

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PICO Question: In patients who are suffering from prehospital traumatic brain injury (TBI), how effective is monitoring end tidal carbon dioxide (ETCO2) in producing improved clinical outcomes?

Overview: Despite primary brain injury being considered irreversible, secondary brain injury, caused by physiological derangements, is considered preventable. Monitoring of ETCO2 could be utilised in prehospital TBI patients to improve clinical outcomes. This study aims to evaluate the current data and its validity to determine the degree to which ETCO2 monitoring impacts TBI patients' outcomes.

Search Strategy: A literature search was conducted using the medical electronic databases MEDLINE (Ovid), PubMed and Embase. The MeSH headings and keywords used in the search included: prehospital, pre-hospital, out of hospital, out-of-hospital, ambulance, emergency medical services, paramedic, EMS, emergency medical system, EMT, end-tidal, ETCO2, end tidal, end tidal carbon dioxide, capnography, head-injury, brain-injury, head-trauma, head injury, brain injury, head trauma, traumatic brain injury, TBI and traumatic head injury.

From these results, duplicate articles, replies, reviews and articles not relevant to the PICO question were excluded. Further evaluation of the text eliminated articles that did not provide information regarding study design or did not have available data. See Appendix for PRISMA flow chart (Chart 1).

Search Outcome: 5 of the 122 located sources met the inclusion criteria and were evaluated.

Author, Date	Population: Sample Characteristics	Design	Outcome	Results	Strengths and Limitations
Davis et al, 2015	Adult patients with TBI and ETCO2 levels recorded in the prehospital setting and who underwent rapid sequence intubation (RSI) and received preoxygenation from a nonrebreather mask.	Retrospective Observational Cohort Study	Testing relationship between ETCO2 intrathoracic pressure and if this was associated with poorer outcomes due to decreased preload and therefore cardiac output, impacting on cerebral perfusion.	108 patients (76 transported by ground paramedics and 32 transported by air medical crews). Mean ETCO2 in patients transported by air medical staff was 33.8mmHg, as opposed to 30.6mmHg in patients transported by ground crews. Mean intrathoracic pressure was lower in patients transported by air medical crews (8.1mmHg vs 9mmHg).	(-) Does not comment on relevance of ETCO2 monitoring when using basic airway interventions. (-) Small sample size. (-) Assumed all patients had normal lung characteristics, ignoring possibility of chest wall injury, pre-existing conditions, pneumothorax or aspiration. (+) Some other confounding variables accounted for. (-) Did not account for Boyle's law of pressure in the cohort transported by air medical crews.
Patterson and Conway, 2012	Study of HEMS missions over a 14- week period at a central London Major Trauma Centre. Patients with a head-injury and who received intubation and mechanical ventilation in the prehospital setting.	Retrospective Observational Cohort Study	Assess role of capnography in the prehospital setting for controlling ETCO2 in patients with head injury requiring mechanical ventilation.	Patients who had been identified as head-injured were more likely to have ETCO2 reading within target range following ventilation than those who were not identified as having a head injury (81.48% vs 68.75% respectively).	(-) Small sample size (-) HEMS (Helicopter Emergency Medical Service) does not represent the majority of paramedic skills. (-) Not statistically significant.

					(-) Suspected poor correlation between ETCO2 and arterial pCO2. (+) Ensured HEMS paramedics in the study received the same level of training. (+) Patients were similar in regards to known prognostic variables.
Pawlowicz et al, 2012	Adult patients with mild/moderate TBI presenting to trauma centre in Orlando.	Prospective Cohort Study	Assessing relationship between ETCO2 levels and TBI severity through investigation of indicators such as GCS and requirement of neurosurgical intervention.	Of the 11 patients with intracranial lesions (shown on CT), 10 had abnormal ETCO2 levels. Of the 5 patients who received neurosurgical intervention, 100% had abnormal ETCO2 levels. Biomarkers indicative of astrogliosis were higher in patients with abnormal ETCO2.	(-) Small sample size/ not statistically significant. (-) Other confounding variables not accounted for. (+) Mentions variation in clinical skill levels, which may impact outcome. (+) Uses multiple data points across transportation time to give a more accurate representation of ETCO2 during prehospital care.
Davis et al, 2004	Trial conducted from November 1998 to April 2002 in San Diego County. Adults with severe TBI meeting criteria (>18 years, major trauma victim, head injury	Prospective Cohort Study	Investigates the impact that monitoring of ETCO2 has on incidence of inadvertent hyperventilation, and consequently clinical outcomes, after	Severe hyperventilation (arrival pCO2 <25 mmHg) occurred in 5.6% of patients who received ETCO2 monitoring and 13.4% of patients who did not receive ETCO2 monitoring.	(+) Accounts for variables impacting mortality (mechanism, arrival pO2 and pH, intubation success rates and clinical presentation. (-) Data not transferable to patients not meeting

	determined based on mechanism or physical examination, transport time to trauma centre >10 minutes, GCS of 8 or less and inability to intubate without RSI).		RSI in prehospital TBI.	Secondary analysis revealed higher overall mortality among those patients with inadvertent severe hyperventilation and hypocapnia (56% vs 30%).	the inclusion criteria (e.g. GCS >8, age <18 or distance to hospital <10 minutes). (+) Methods well described and easy to replicate. (+) Review of procedure and GCS calculations were done within 1 hour of RSI procedure to ensure other confounding variables were accounted for. (-) Study requires significantly more patients for mortality difference to approach statistical significance. (-) Delay in obtaining ABG once at hospital may mean that pCO2 is more reflective of ventilation from trauma centre personnel as opposed to that of paramedics.
Caulfield et al, 2009	Adult patients with blunt TBI, GCS<8 and no signs of herniation, transported by flight paramedics to Level 1 trauma centre in Maryland over a 6-year period	Retrospective Case Control Study	Review looking at prehospital ETCO2 data to establish compliance with The Brain Trauma Foundation Guidelines to maintain ETCO2 between 30mmHg and	Final sample consisted of 26 females and 74 males, with mean ages being 35 years and 38 years, respectively. ETCO2 was >29mmHg in 65% of cases (suggestive of normal ventilation),	(-) Limited sample size and not statistically significant data. (+) Other major variables in worsening of secondary brain injury were accounted for (hypoxia,

	(July 1999 to June 2006).		35mmHg in TBI patients. Also investigating link between prehospital ETCO2 and mortality or functional outcome.	<29mmHg in 32% of cases (suggestive of hyperventilation) and >45mmHg in 3% of cases (suggestive of hypoventilation). Mortality in patients who achieved ETCO2 within guideline range was 29%, as opposed to 46% in those who did not achieve this.	hypotension, acidosis and ICP). (-) Study based on skill of flight paramedics, therefore data may not be transferable when other levels of prehospital care are provided. (-) No mention of paediatric patients or patients not meeting inclusion criteria. (-) ETCO2 retrieval at time of hospital arrival may not represent ventilation throughout transportation. (-) No mention of intentional hyperventilation due to oxygen saturations falling below 90%. (+) Detailed methods therefore study is relatively easy to replicate.

Comments:

- All studies concluded that ETCO2 monitoring reduced incidences of hypocapnia secondary to hyperventilation and consequently improves neurological outcomes as cerebral perfusion is more likely maintained. Mention of the impact of ETCO2 monitoring via nasal prongs, as opposed to in a closed circuit, was however absent from all studies.
- Clinical findings suggest that hyperventilation worsens neurological outcome. Interventions such as supporting perfusion and avoiding hyperventilation, through close ETCO2 monitoring and control, were identified as clinically beneficial due to cerebral hemodynamics being linked to clinical outcomes. Sufficient evidence of these improved outcomes was however lacking in some studies due to small sample sizes and lack of generalizability.
- Generally, an ETCO2 below 30mmHg was associated with worse clinical outcomes, due to decreased cerebral perfusion. There was however a lack of solid evidence that there is a reasonable correlation between prehospital ETCO2 and arterial pCO2 measured in hospital.

Considerations for Practice:

Based on the relevant articles located in the search, it is recommended that ETCO2 is monitored in prehospital TBI. Introduction of mandatory monitoring in such cases will advance the paramedic profession to provide better management of ETCO2 changes secondary to change in ventilation, perfusion and metabolic state, all of which can occur following a TBI. Despite the identified limitations of the studies and criticism of the effectiveness of ETCO2 monitoring in critically ill and paediatric patients, the rapid and non-invasive nature of capnography proves ETCO2 monitoring to be a justifiable procedure.

Further studies, with larger sample sizes, are still required to identify causative links between clinical outcome, ventilatory management and ETCO2 monitoring.

Clinical Bottom Line:

The sources explored whether ETCO2 monitoring improves clinical outcomes for patients who were being treated for traumatic brain injury in the prehospital setting. Many studies have documented a high incidence of inadvertent hyperventilation of patients in a critical condition in the prehospital setting. Hyperventilation therapeutically manipulates cerebral blood volume and ICP due to cerebral autoregulatory mechanisms, causing hypocapnia and cerebral ischemia. Despite ETCO2 monitoring not completely preventing the occurrence of severe hyperventilation, it did decrease occurrence significantly, which was associated with improved clinical outcomes.

References:

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Appendix:

Chart One: PRISMA Flow Chart Representing Search Results and Selection.