

EMS Care of moderate and severe TBI
Treatment and Monitoring Guidelines/Protocols
Infants and Children

--Definitions:

--Age Definitions for Monitoring and Management:¹

--“Infant”: Age 0-24 months

--“Child”: Age 2-14 years

--“Late adolescence”: 15-17 years

--The prehospital identification of moderate or severe TBI: Anyone with physical trauma and a mechanism consistent with the *potential* to induce a brain injury and:

--Any injured patient with loss of consciousness, especially those with GCS <15 or confusion

OR

--Multisystem trauma requiring intubation whether the primary need for intubation was from TBI or from other potential injuries

OR

--Post-traumatic seizures, whether they are continuing or not

OR

--In infants (where GCS may be difficult to obtain or interpret), decreased level of consciousness, decreased responsiveness, or *any* deterioration of mental status.

--Overall approach to monitoring and continuous evaluation:

--Continuous O₂ saturation (sat) via pulse oximetry, continuous quantitative end-tidal CO₂ (ETCO₂) monitoring in intubated patients and systolic blood pressure (SBP) every 3-5 minutes.

--Specific, guideline-based therapy:

I. Management of airway/oxygenation:

--CLINICAL AXIOM: A *single* non-spurious O₂ sat of <90% is *independently* associated with a *doubling* of mortality. Hypoxia kills neurons!

A. Management is initiated by continuous high-flow O₂ for all *potential* TBI cases. Emphasis is placed on prevention, identification, and treatment of hypoxia (O₂ sat <90% and/or cyanosis).¹⁻⁷ If high-flow O₂ fails to correct hypoxia, basic maneuvers for airway repositioning will be attempted, followed by reevaluation. If this does not restore O₂ sat to 90% or greater, or if there is inadequate ventilatory effort, bag-valve-mask (BVM) with a pressure-controlled bag (PCB) and a ventilation rate timer (VRT) will be performed using appropriate airway adjuncts (e.g., oropharyngeal airway). It should be noted that most infants and children can have their airway managed well using basic maneuvers and BVM.

B. If airway compromise or hypoxia persists after these interventions, ETI will be performed when an experienced ALS provider is available.^{1-3,6,8-13} Following ETI, tube placement will be confirmed via multiple means including ETCO₂ detection and/or capnography.

II. Management of ventilation: Special emphasis is placed on identifying and treating hypoventilation as well as preventing hyperventilation when assisting ventilation.

--CLINICAL AXIOM: In intubated patients, hyperventilation is *independently* associated with *at least* a doubling of mortality and some studies have shown

that *even moderate* hyperventilation can increase the risk of dying by *six* times. Hyperventilation kills neurons!

--COROLLARY: It has been shown repeatedly that inadvertent hyperventilation happens *reliably* if not meticulously prevented by proper external means. No one, no matter how experienced, can properly ventilate without ventilatory adjuncts (Pressure-Controlled Bags-PCBs, Ventilation Rate Timers—VRTs, ETCO₂ monitoring, ventilators). PCBs/VRTs should be used immediately after intubation and until the patient can be placed on a mechanical ventilator even if this will only take 3-5 minutes (note: that's all the hyperventilation it takes to begin killing neurons).

- A. Hypoventilation [ineffective respiratory rate for age, shallow or irregular respirations, periods of apnea, or measured hypercarbia (elevated ETCO₂)]: If there is evidence of hypoventilation despite high-flow O₂ therapy, assisted ventilation will be performed via BVM and, if ineffective, ETI will be performed if an experienced ALS provider is present.^{1-3,12-15}
- B. Intubated patients: After ETI, use PCB/VRT immediately for ventilation and ETCO₂ levels will be strictly maintained between 35 and 45 mmHg when monitoring is available (target = 40)^{1-3,15-17}
1. All agencies are strongly encouraged to use PCBs/VRTs. In agencies without ETCO₂ monitors, maintain age-appropriate ventilatory rates and decrease the risk of inadvertent hyperventilation.^{1-3,11,14,15,18-26} Agencies with ETCO₂ monitors should use PCBs/VRTs for the *initial* rate of manual ventilation and then gently modify the ventilation to obtain the target ETCO₂ of 40 mmHg. Beware of the tendency to only use the ETCO₂ monitor to verify tube placement and then to fail to carefully maintain ETCO₂ in target range.
--Target ventilatory rates from the National TBI Guidelines:^{1,27}
 - Infants: (age 0-24 months): 25 breaths per minute (bpm);
 - Children: (age 2-14): 20 bpm;
 - Older adolescents: (age 15-17): 10 bpm (same as adults)
 2. Whenever possible, ventilators should be used post-intubation to optimize ventilatory parameters and O₂ therapy.^{1,14,15,28-30} This is the *best* way to care for an intubated TBI patient. PCBs/VRTs should be used immediately after intubation and until the patient is placed on the ventilator even if this will only take several minutes.
--Target tidal volume (TV) will be 7cc/kg with rates adjusted to keep the ETCO₂ within target range (35-45 mmHg).
--Note: This is consistent with the TBI guidelines and the recent literature showing that intrathoracic pressure, lung mechanics, hemodynamics, and ICP are optimized by this TV compared to the "classic" 10-12 cc/kg that remains common in many settings.^{14,18,30-37}
- C. Impending cerebral herniation:
--The EPIC guidelines do not encourage even mild hyperventilation for "impending cerebral herniation" for the following reasons:
 - There is *no evidence* that it improves outcome in *any* setting
 - There is *much evidence* that even mild hyperventilation harms moderate and severe TBI patients

--The “practical application” of this “treatment” is that many patients who *do not have* actual impending herniation end up being hyperventilated since the real-world interpretation often ends up thinking...“The worse a TBI is, the faster you should ventilate.” Thus, many patients who will be *harmed* by hyperventilation may end up with the misapplication of this “treatment.”

D. Non-intubated patients: All relevant monitoring/treatment will be applied except ETCO₂ monitoring.

III. Management of blood pressure: In patients with a *potential* for TBI, strong emphasis is placed on preventing and *aggressively* treating even a *single* episode of hypotension.

--CLINICAL AXIOM: A *single* episode of hypotension is *independently* associated with *at least* a doubling of mortality. Amazingly, repeated episodes of hypotension can increase the risk of dying by as much as *eight* times.
Hypotension kills neurons!

--Hypotension will be defined as systolic blood pressure (SBP) below the 5th percentile for age. This will be estimated using the following formula:^{1,38}

--Infants/children age <10: 70 mmHg + (age X 2)

--Children age ≥10: 90 mmHg (same as adults)

--Good “rules of thumb” to remember:

--Infant = 70 mmHg

--5 year old = 80 mmHg

--10 and older = 90 mmHg

A. Treatment of hypotension: Even a *single* hypotensive measurement (for age) will initiate intravenous (IV) fluid resuscitation. For hypotension or other signs of shock, IV normal saline will be given. Sufficient volume (via 20cc/kg boluses every 5 minutes) will be given to return SBP to at least the 5th percentile estimate.
--Once hypotension has been corrected, IV administration of NS should occur at sufficient rate to keep the patient non-hypotensive.

--Note: If the rapid infusion of the initial bolus of crystalloid does not correct the hypotension, do not hesitate to continue aggressive fluid resuscitation.

--Note: Do not wait for the patient to become hypotensive. If the SBP is dropping, or if there are any other signs of compensated shock such as increasing heart rate with decreasing SBP, begin aggressive treatment *before* the patient becomes hypotensive.

--Intraosseous access should be attempted if all three of the following criteria are met: 1) there is hypotension or other signs of shock, 2) peripheral venous access cannot be quickly established, and 3) the patient’s mental status is such that they can tolerate the procedure without undue pain.

B. Treatment of hypertension: In TBI, treatment of acute hypertension is not recommended.^{1-3,39} However, IV fluids will be restricted to a minimal “keep open” rate in infants/young children with SBP ≥100 mmHg and in older children/adolescents with SBP ≥130 mmHg.

IV. Assessment and management of hypoglycemia: In patients with any alteration in mental status, *always* check for hypoglycemia early in the clinical course. Hypoglycemia can *mimic* TBI as a cause of altered mental status.

--Obtain fingerstick or serum glucose level. If glucose level is $<70\text{mg/dl}$ then:

1. Administer dextrose IV:
 - Newborn (birth to 2 months):
 - Administer 5ml/kg of D10 solution IV
 - Infants and toddlers (3 months to 3 years):
 - Administer 2ml/kg of D25 solution, max dose = 100ml (25 g).
 - Children age 4 and older:
 - Administer 1ml/kg of D50 solution, max dose = 50ml
2. Repeat blood sugar in 10 minutes and, if still $<70\text{mg/dl}$, repeat dose x 1.
 - If no response then contact medical direction
3. If IV access unsuccessful, dextrose may be given IO.
4. If IV and IO unsuccessful, administer Glucagon 0.03mg/kg IM, max dose 1mg

--NOTES:

- A. If there are differences between your regional/agency protocols/standing orders for treating hypoglycemia in the setting of TBI, you may use either the EPIC protocol above or your regional/local protocol. If in doubt, check with your medical director.
- B. All dosing of dextrose and glucagon may be determined by length-based resuscitation tape rather than weight estimations if that is preferred by the agency/medical director
- C. Mix D25 or D10 using either your regional/local protocols or the following:
 - D25: Make D25 by removing 25CC from a 50CC bag and inject 25 CCs of D50 into the bag. Then remove an appropriate amount of the D25 and administer volume according to weight.
 - D10: Make D10NS by removing 50CC from a 250CC bag of NS and then injecting one amp (50CC) of D50 into the bag. Then remove an appropriate amount of the D10NS and administer volume according to weight.

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