Brain Trauma Foundation (BTF) Recommendations:

BTF levels of Recommendations (I, II, III) are derived from Class of Evidence (I, II, III).

Recommendations:
Level I:  high degree of clinical certainty
Level II:  moderate degree of clinical certainty
Level III:  degree clinical certainty not established
The patient sustained a **closed head injury** in a motorcycle accident one hour ago. He is booked for an emergency craniotomy.

**PMHx:**
- Illnesses: previously healthy
- Surgeries: none
- Meds: none
- Habits: smokes with a 10 pack/year history, drinks alcohol regularly
- Allergies: none

**Family history:**
- No anesthetic complications

**Physical exam:**
- Thin male, lethargic and somewhat combative, vomiting
  - Wt: 75 Kg  HR: 52  BP: 196/102  RR: 20
  - Airway: Receding mandible, severe overbite
  - Lungs: clear to auscultation
  - Heart: sinus bradycardia, hypertension
  - **Neuro:** does not open his eyes to noise or pain, Pupils right 5/4, left 3/2, moans and groans, withdraws right arm and leg to painful stimuli, does not move left arm or leg.

**Labs:**
- Normal

**X-Ray:**
- Cervical fractures ruled out

**NPO:**
- Consumed large burger and fries, and 6 beers one hour prior to injury.
CT Scan of our patient

Principles of Neurological Surgery, 3rd Ed., online
Based on this patient's exam, his intracranial pressure is likely to be …?

1. High
2. Normal
3. Low
Sorry – I disagree

Try again
Symptoms of increased ICP

- Headache
- Nausea and Vomiting
- Pupillary changes
- Depressed Level of Consciousness
- Irregular Breathing
- Hypertension
- Bradycardia

Cushing’s Triad
What is the threshold to treat ICP?

1. 10 – 15 mmHg
2. 15 – 20 mmHg
3. 20 – 25 mmHg
4. 25 – 30 mmHg
Sorry – I disagree

Try again
CORRECT !!

Next slide
Treatment of increased ICP

increased ICP is defined as >15 mmHg
Symptoms occur at 18 – 25 mmHg ICP
Herniation can occur at 20 – 25 mmHg ICP
Symptoms are dependent on CBF and CPP

BTF: Level II

Current data support 20 – 25 mmHg as an upper threshold above which treatment to lower ICP should generally be initiated
Our patient has an increased ICP of 30 mmHg. What would be the lowest MAP that you could tolerate?

1. 90 – 100 mmHg
2. 50 – 60 mmHg
3. 60 – 70 mmHg
4. 70 – 80 mmHg
5. 80 – 90 mmHg
Sorry – I disagree

Try again
CORRECT !!

Next slide
CPP Threshold for treatment

Lower CPP limit: 50 – 60 mmHg

CPP = MAP – ICP or CPP = MAP – CVP
(take the higher of ICP or CVP)

CPP of 50 mmHg is considered the ischemic threshold for most patients and lower levels should be avoided

BTF: Level III

CPP of < 50 mmHg should be avoided
Cerebral blood flow (CBF) autoregulation: For a cerebral perfusion pressure (CPP) value between 50 and 150 mm Hg, global CBF is maintained at 50mL/100g/min.
What would be the maximum CPP you should aim for in our patient?

1. 60 mmHg
2. 70 mmHg
3. 80 mmHg
4. 90 mmHg
5. 100 mmHg
Sorry – I disagree

Try again
CPP Threshold

Upper CPP limit: 70 mmHg
CPP = MAP – ICP or CVP
(use the greater of ICP or CVP)

BTF: Level II
Aggressive attempts to maintain CPP above 70 mmHg with fluids and vasopressors should be avoided because of a higher risk to develop ARDS
What is the critical lower threshold for CBF?

1. 10 ml/100g/min
2. 20 ml/100g/min
3. 30 ml/100g/min
4. 40 ml/100g/min
5. 50 ml/100g/min
Sorry – I disagree

Try again
CORRECT !!

Next slide
Regional Cerebral Blood Flow (rCBF)

Overall cerebral blood of 50 ml/100gm/min is usually maintained for a CPP between 50 – 150 mmHg

18-20 ml/100mg/min = critical rCBF
15 ml/100mg/min = iso-electric EEG
10 ml/100mg/min = metabolic failure

Penumbra (15-20ml/100mg/min): Semi-stable cells that can be saved for a full recovery with appropriate treatment, including optimal anesthetic management
What is the patient’s GCS?

1. 14 – 15
2. 12 – 13
3. 10 – 11
4. 8 – 10
5. ≤ 8
Sorry – I disagree

Try again
CORRECT !!
# GCS – Glasgow Coma Scale

## Eye Opening
- **None** 1 = Even to supra-orbital pressure
- **To Pain** 2 = Pain from sternum/limb/supra-orbital pressure
- **To Speech** 3 = Non-specific response, not necessarily to command
- **Spontaneous** 4 = Eyes open, not necessarily aware

## Motor Response
- **None** 1 = To any pain; limbs remain flaccid
- **Extension** 2 = Shoulder adducted and shoulder and forearm internally rotated
- **Flexor Response** 3 = Withdrawal response or assumption of hemiplegic posture
- **Withdrawal** 4 = Arm withdraws to pain, shoulder abducts/flexion
- **Localizes Pain** 5 = Arm attempts to remove supra-orbital/chest pressure
- **Obeys Commands** 6 = Follows simple commands

## Verbal Response
- **None** 1 = No verbalization of any type
- **Incomprehensible** 2 = Moans/groans, no speech
- **Inappropriate** 3 = Intelligible, no sustained sentences
- **Disoriented** 4 = Convereses but confused, disoriented
- **Oriented** 5 = Convereses and oriented
Clinical Signs and GCS

Glasgow coma scale is helpful to summarize clinical signs in patients with increased ICP. GCS is a useful measure for the severity of TBI.

- Severe TBI: GCS < 8
- Moderate TBI: GCS 9-12
- Minor TBI: GCS 13-15
Given our patients H+P, what is the likely side of the subdural hematoma?

1. Right side
2. Left side
Sorry – I disagree

Try again
CORRECT !!

Next slide
TBI – History and Physical

The patient sustained a closed head injury in a motorcycle accident one hour ago.

PMHx: Illnesses: previously healthy
Surgeries: none
Meds: none
Habits: smokes with a 10 packyear history, drinks alcohol regularly
Allergies: none

Family history: No anesthetic complications

Physical exam: Thin male, lethargic and somewhat combative, vomiting
Wt: 75 Kg    HR: 52    BP: 196/102    RR: 20
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Heart: sinus bradycardia, hypertension
Neuro: does not open his eyes to noise or pain, Pupils right 5/4, left 3/2, moans and groans, withdraws right arm and leg to painful stimuli, does not move left arm or leg.

Labs: Normal
X-Ray: Cervical fractures ruled out
NPO: Consumed large burger and fries, and 6 beers one hour prior to injury.
right sided subdural hematoma
with midline shift and compression of
left lateral ventricle
Herniation – Sites

1 – Cingulate herniation
2 – Tentorial (uncal) herniation
3 – Central herniation
4 – Tonsillar herniation

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Herniation – Symptoms

- Eye abnormalities
- Autonomic dysfunction
- Motor dysfunction
- Other (nausea, vomiting, level of consciousness…)

Diagram:
- Cingulate herniation
- Tentorial (uncal) herniation
- Central herniation
- Tonsillar herniation
Symptoms of Subfalcine Herniation

Trapping of one or both anterior cerebral arteries, causing infarction of the paramedian cortex

- Leg paralysis

Expansion of infarcted area

- Edema

- Increased intracranial pressure

- Increased risk of transtentorial herniation

- Central herniation

- or both
Symptoms of **Transtentorial Herniation**

- Compression of ipsilateral 3rd cranial nerve
  - Unilateral dilated, fixed pupil
  - Oculomotor paresis

- Compression of the posterior cerebral artery
  - Contralateral homonymous hemianopia
  - Absence of blinking reflex

- Compression of the contralateral 3rd cranial nerve and cerebral peduncle
  - Contralateral dilated pupil and oculomotor paresis
  - Ipsilateral hemiparesis

- Compression of the ipsilateral cerebral peduncle
  - Contralateral hemiparesis

- Compression of the upper brain stem and the area in and around the thalamus
  - Impaired consciousness
  - Abnormal breathing patterns
  - Fixed, unequal pupils

- Further compromise of the brain stem
  - Loss of oculocephalic reflex
  - Loss of oculovestibular reflex
  - Loss of corneal reflexes
  - Decerebrate posturing
Symptoms of Central Herniation

Both temporal lobes herniate because of bilateral mass effects or diffuse brain edema.

Bilateral damage to the midbrain

Pupils fixed in midposition

Decerebrate posturing

Same symptoms as transtentorial herniation

Further compromise of the brain stem

Loss of all brain stem reflexes

Disappearance of decerebrate posturing

Cessation of respirations

Brain death
Symptoms of Tonsillar Herniation

- Compression of the brain stem
- Obstruction of CSF flow
- Acute hydrocephalus
  - Impaired consciousness
  - Headache
  - Vomiting
  - Meningismus
- Dysconjugate eye movements
- Respiratory and cardiac arrest
A linear relationship between CBF exists for ...?

1. PaCO2
2. ICP
3. PaO2
4. CPP
Sorry – I disagree

Try again
CORRECT!!
There is a linear relationship between PaCO2 and CBF for PaCO2 values between 20 and 80 mmHg
Level II or III recommendations for this patient include all of the following, except...?

1. Avoid Hypoxia with SpO2 < 90%
2. Provide prophylactic Hyperventilation to 25 mmHg
3. Avoid Hypotension with SBP < 90 mmHg
4. Avoid Hypoxia with PaO2 < 60 mmHg
Sorry – I disagree

Try again
CORRECT !!

Next slide
Blood Pressure and Oxygenation

Avoid BOTH: HYPOTENSION and HYPOXIA

Hypotension: avoid BP < 90 mmHg
BTF: Level II
Blood pressure should be monitored and hypotension (SPB < 90 mmHg) avoided

Hypoxia: avoid SpO2 < 90%, paO2 < 60 mmHg
BTF: Level III
Oxygenation should be monitored and hypoxia (paO2 < 60 mmHg or O2 Sat. < 90 %) avoided
CBF is more affected by decrease in ABP than by increase in ICP. For the same CPP of 40 mmHg, an increase in ICP lead to a CBF of 90%, whereas hypotension decreased CBF to 60%.
What would be the least desirable iv fluid to restore hypovolemia in this patient?

- Normal Saline
- Lactated Ringers
- PRBC with symptomatic anemia
- Balanced E’lyte solution (Plasmalyte)
Sorry – I disagree

Try again
CORRECT !!

Next slide
**i.v. fluids**

First choice:
- Normal Saline NS (308 mosmol/L)
- Balanced electrolyte solutions - Plasmalyte (312 mosmol/L)

AVOID the following hypotonic solutions, that can increase ICP by increasing cerebral edema
- Hypotonic solutions
- Glucose containing solutions
  High Glc. is associated with bad outcome
  Glc. is metabolized, free water remains, hypotonic solution is the result.
- Avoid Lactated Ringers (275 mosml/L, slightly hypotonic)

Albumin is associated with increased mortality in TBI
HES still under debate (FDA black box warning for increased mortality and severe renal injury, and additional warning on risk of bleeding)
Should this patient be hyperventilated?

1. Always until ICP normalizes
2. As needed for a brief period
3. Never
Sorry – I disagree

Try again
CORRECT !!

Next slide
Hyperventilation and Rebound effect

Miller's Anesthesia, 7th edition, online

Paco2, cerebral blood flow (CBF), and cerebrospinal fluid (CSF) pH changes with prolonged hyperventilation. Although the decreased arterial Paco2 (and the systemic alkalosis) persist for the duration of hyperventilation, the pH of the brain and CBF return toward normal over 8 to 12 hours.

Rebound increase in CBF and ICP after discontinuation of Hyperventilation. Hyperventilation should only be a temporary measure to avoid herniation.
Summary

Avoid secondary injury
Recognize signs and symptoms of increased ICP / brain herniation
Glasgow Coma Scale useful in grading of severity of TBI
Maintain Normotension
Maintain Normovoleemia (avoid hypoosmotic solutions)
Maintain Oxygenation
Avoid Hypercarbia but hyperventilate only as a temporary measure
Hypotension and Hypoxemia associated with worse outcomes