eTable 1 – Neurology vs. Non-neurology trainees across all assessments.

<table>
<thead>
<tr>
<th>Pre-Curriculum Assessment</th>
<th>Assessment #1</th>
<th>Assessment #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurology trainee</td>
<td>Non-Neurology trainee</td>
<td>Neurology trainee</td>
</tr>
<tr>
<td>Group 1</td>
<td>36</td>
<td>17</td>
</tr>
<tr>
<td>Group 2</td>
<td>35</td>
<td>12</td>
</tr>
</tbody>
</table>
eTable 2. Engagements per Tweetorial.

<table>
<thead>
<tr>
<th>Tweetorial</th>
<th>Engagements (total number of times a user has interacted with a tweet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>#1-20 Median (IQR)</td>
<td>181 (148-275)</td>
</tr>
<tr>
<td>#1</td>
<td>606</td>
</tr>
<tr>
<td>#2</td>
<td>488</td>
</tr>
<tr>
<td>#3</td>
<td>313</td>
</tr>
<tr>
<td>#4</td>
<td>178</td>
</tr>
<tr>
<td>#5</td>
<td>263</td>
</tr>
<tr>
<td>#6</td>
<td>170</td>
</tr>
<tr>
<td>#7</td>
<td>166</td>
</tr>
<tr>
<td>#8</td>
<td>241</td>
</tr>
<tr>
<td>#9</td>
<td>409</td>
</tr>
<tr>
<td>#10</td>
<td>185</td>
</tr>
<tr>
<td>#11</td>
<td>145</td>
</tr>
<tr>
<td>#12</td>
<td>141</td>
</tr>
<tr>
<td>#13</td>
<td>149</td>
</tr>
<tr>
<td>#14</td>
<td>256</td>
</tr>
<tr>
<td>#15</td>
<td>130</td>
</tr>
<tr>
<td>#16</td>
<td>151</td>
</tr>
<tr>
<td>#17</td>
<td>99</td>
</tr>
<tr>
<td>#18</td>
<td>121</td>
</tr>
<tr>
<td>#19</td>
<td>232</td>
</tr>
<tr>
<td>#20</td>
<td>370</td>
</tr>
</tbody>
</table>
## eTable 3. Countries of International Participants

<table>
<thead>
<tr>
<th>Countries of International Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
</tr>
<tr>
<td>Austria</td>
</tr>
<tr>
<td>Bangladesh</td>
</tr>
<tr>
<td>Brazil</td>
</tr>
<tr>
<td>Canada</td>
</tr>
<tr>
<td>China</td>
</tr>
<tr>
<td>Colombia</td>
</tr>
<tr>
<td>Ecuador</td>
</tr>
<tr>
<td>Egypt</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>India</td>
</tr>
<tr>
<td>Indonesia</td>
</tr>
<tr>
<td>Israel</td>
</tr>
<tr>
<td>Kenya</td>
</tr>
<tr>
<td>Lebanon</td>
</tr>
<tr>
<td>Lithuania</td>
</tr>
<tr>
<td>Malaysia</td>
</tr>
<tr>
<td>Pakistan</td>
</tr>
<tr>
<td>Philippines</td>
</tr>
<tr>
<td>Saudi Arabia</td>
</tr>
<tr>
<td>Spain</td>
</tr>
<tr>
<td>United Kingdom</td>
</tr>
</tbody>
</table>
An 18 yo woman suffered a motorcycle accident. Initial GCS is 7(E2V2M3). Pupils are anisocoric. Head CT is shown below:

If an external ventricular drain is placed in the left lateral ventricle and opened at 5 mmHg what is the most likely theoretical risk:

a. Precipitation of further uncal herniation.

b. Precipitation of further upwards transtentorial herniation.

c. Precipitation of further central herniation.

d. Precipitation of further transcalvarial herniation.

In this 1st #ncctweetorial we’ll explore:

1. What is intracranial pressure (ICP)
2. Treatment options for ICP
3. Monitoring strategies for ICP

Intracranial pressure (ICP) is the pressure within the cranial vault & reflects the pressure of components within it: brain, CSF and blood. It normally is <15 mmHg in healthy subjects. Intracranial hypertension thus is a sustained ICP >20mmHg.

The units that ICP is reported in matter! Many institutions will set EVDs in terms of cmH2O & we measure the OP of a LP in cmH2O. This is NOT a 1:1 conversion to mmHg!

For more: [https://twitter.com/caseyalbin/status/1374188249867038724?s=20](https://twitter.com/caseyalbin/status/1374188249867038724?s=20)

Since the cranial vault is rigid, there is a fixed volume of what can be inside. Hence, any additional element (hemorrhage, tumor, etc) will displace one of these contents. This is known as the Monroe-Kelly doctrine, which underpins all of ICP management!

6. CSF and venous blood volume are the first contents that are compressed to compensate for intracranial pathology (purple “mass” in diagram below).

As these are compressed, intracranial compliance \( I \), and further increases in pathology, may lead to intracranial hypertension.

![Diagram of intracranial pressure states](https://www.grepmed.com/images/10484)

**Fig. 2** Pressure-volume curve of the craniospinal compartment. This figure illustrates the principle that in the physiological range, i.e. near the origin of the x-axis on the graph (point a), intracranial pressure remains normal in spite of small additions of volume until a point of decompression (point b), after which each subsequent increment in total volume results in an ever larger increment in intracranial pressure (point c).


7. Clinical signs of increased ICP: headache, emesis, decreased level of awareness, visual disturbances, focal neurological deficits due to vascular or parenchymal compression (the herniation syndromes), and in late stages Cushing’s triad:
   - Bradycardia
   - Hypertension
   - Irregular respirations

8. Why does ICP matter? Two main reasons
   1. Very high ICP will lead to cerebral herniation and death
   2. Elevated ICP may impair cerebral perfusion & result in secondary brain injury by ischemia

9. Understanding point 2 relies on understanding the Cerebral Perfusion Pressure. CPP is the pressure gradient driving blood to the brain and depends directly on ICP by the formula:
10. As long as the CPP stays between ~50-150mmHg, the healthy brain is able to maintain a fairly stable cerebral blood flow (CBF).

This is accomplished by autoregulation and the cerebrovascular resistance (CVR).

$$\text{CBF} = \frac{\text{CPP}}{\text{CVR}}$$

11. For example: when CPP \(\uparrow\), arterioles constrict and CVR \(\uparrow\), thus CBF stays constant and the brain receives the blood needed.

CVR (and thus CPP is) regulated by PaCO2, wall tension in blood vessels, and local metabolism.


12. This is why hyperventilation helps reduce ICP! It \(\downarrow\) PaCO2, resulting in cerebral vasoconstriction and subsequent \(\downarrow\) blood flow. Thus, the “Blood” component of ICP decreases.

It must be a temporary measure since it can lead to ischemia or rebound vasodilation.
13. Note that cerebral vasoregulation relies on ATP and often becomes dysregulated in injured tissue. Thus, the relationships between ICP, CPP, CBF is not always straightforward. But maintaining an ICP <22mmHg has been suggested to prevent 2nd injury by the Brain Trauma Foundation.

14. So how do you measure ICP? There are several ways but the two most common devices to monitor ICP are the external ventricular drain (EVD) and the parenchymal probe:

**Main Intracranial Pressure Monitors**

<table>
<thead>
<tr>
<th>EVD</th>
<th>Parenchyma Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tip goes in the third ventricle.</td>
<td>Less invasive, depth of insertion is 1.5-2cm.</td>
</tr>
<tr>
<td>Gold standard for pressure measurement.</td>
<td>May give compartmentalized ICP reads.</td>
</tr>
<tr>
<td>Allows for periodic recalibration.</td>
<td>Zero drifts over time.</td>
</tr>
<tr>
<td>Allows for CSF drainage.</td>
<td>Does not allow for CSF drainage.</td>
</tr>
<tr>
<td>Higher risk of infection and hemorrhage.</td>
<td>Lower risk of infection and hemorrhage.</td>
</tr>
</tbody>
</table>

Source: Cerebral Herniation Syndromes and Intracranial Hypertension. Matthew Koenig

15. When to monitor ICP in TBI?
   - If GCS <8 (severe TBI) + abnormal HCT
   - OR GCS < 8 +normal head CT + at least 2 of following: hypotensive, >40 yo, posturing.
   - Consider when reliable exams are unobtainable.

16. Non-TBI? No consensus! Below are some guidelines

**When to monitor ICP in non-TBI patients?**

- Consider in high-grade aneurysmal subarachnoid hemorrhage
- Intraparenchymal hemorrhage >30mL with shift
- Posterior fossa hemorrhage with symptomatic hydrocephalus
  - It is typically used as a bridge therapy until the patient goes to the OR for decompressive craniectomy.
  - Always remember to open the EVD at ~20 mmHg in order to decrease the risk of upward herniation.
- Large volume intraventricular hemorrhage.
- Consider it in liver failure with brain edema.


17. Back to our case, she was intubated for airway protection, stabilized and taken to the OR for subdural hematoma evacuation. If an ICP monitor would have been in place when she was supine for the intubation, which pattern of ICP waveforms would you have expected to observe?

- Option A
- Option B
18. An advantage of ICP monitoring is that the device provides an ICP tracing.

- **P1/**percussion wave= arterial pulsations
- **P2/**tidal wave= intracranial compliance
- **P3/**dicrotic wave= venous pulsations

\[ P_1 > P_2 > P_3 = \text{normal} \]
\[ P_2 > P_1 > P_3 = \text{poor compliance (worry about ICP!)} \]

**Figure 1:** Intracranial pressure (ICP) waveforms. Percussion wave (P1) represents arterial pulsation, tidal wave (P2) represents brain tissue compliance, and dicrotic wave (P3) is due to closure of aortic valve. Under normal conditions, P1 > P2, indicative of normal compliant brain. In ABI brain compliance starts decreasing resulting in reversal of P1: P2 ratio (i.e., P2 > P1) which is a sensitive predictor of poor brain compliance.

ABI: Acute brain injury. Source: [https://brainmd.files.wordpress.com/2016/02/img_1237.jpg](https://brainmd.files.wordpress.com/2016/02/img_1237.jpg)

19. Finally, treatment of high ICP should obey a tiered approach following the Monro Kellie doctrine. Head of bed elevation and hyperventilation [↑] blood component; EVD [↑] CSF component; osmotherapy [↑] brain component. Craniectomy alters the doctrine by making the skull not-fixed anymore.


20. Back to our first tweet, if the patient had an EVD opened “too low” it could worsen her right subdural hematoma (due to increased R to L pressure gradient) and causing more R-> L midline shift. ICP treatment should always be tailored to what is driving increased ICP!

21. Understanding ICP is of supreme importance in Neurocritical Care! Please let us know if you have any question. Check out our next #NeurocritMedEd Tweetorial on Ischemic Stroke next Thursday!
eAppendix 2: Pre-Educational Curriculum Assessment Questions

1. What is the indication for seizure prophylaxis in traumatic brain injury?
   a. To prevent late onset seizures
   b. To prevent early and late onset seizures
   c. To prevent early seizures
   d. There is no indication for prophylactic antiepileptics in traumatic brain injury.

2. What is the most common cerebrovascular complication of penetrating brain injury?
   a. Venous thrombosis
   b. Arterial dissection
   c. Arterial occlusion
   d. Traumatic pseudoaneurysm

3. Which of the following is the strongest indicator of cerebrovascular injury in penetrating brain injury?
   a. Presence of intraventricular hemorrhage
   b. Retained bullet fragments
   c. Early seizures
   d. Skull base fracture

4. In order to meet Hunter Toxicity Criteria for serotonin syndrome, a patient must have taken a serotonergic agent and have which symptom?
   a. Increased bowel sounds
   b. Tremor plus hyperreflexia
   c. Fever and diaphoresis
   d. Rigidity and hyperreflexia

5. A 64-year-old male previous smoker with past medical history of HTN, COPD on 2L home oxygen, and Myasthenia Gravis (on home pyridostigmine, and oral steroid) has been hospitalized with COPD exacerbation for 3 days. During his hospitalization, he develops drooping of his eyelids, double vision, proximal muscle weakness, difficulty chewing, and increased shortness of breath today. What additional steps will assist you in triaging if this patient will need admission to Neuro ICU versus general wards?
   a. Performing a STAT arterial blood gas and lactate level
   b. Obtain a neurological examination focusing on cranial nerves to further evaluate diplopia
   c. Obtain a neurological examination and respiratory parameters including NIF/VC
   d. Order Intravenous Immunoglobulin for STAT administration

6. A 22-year-old college student presents with new seizure activity. He is accompanied by his roommate who says he was complaining of a headache for the past 3 days and feeling tired. Then this morning he awoke to the patient having seizure activity in his bed so he called 911. Seizure stopped and patient has been following commands, but remains confused and complaining of headache. What is the best treatment?
a. Empirc meningitis coverage with vancomycin, ceftriaxone, acyclovir, and ampicillin
b. Empirc meningitis coverage with vancomycin, ceftriaxone, and acyclovir
c. Empirc meningitis coverage with vancomycin, ceftriaxone, and ampicillin
d. Empirc meningitis coverage with vancomycin, and ceftriaxone

7. What type of isolation is required for someone who is suspected to have Neisseria Meningitidis?
   a. Droplet
   b. Contact
   c. Airborne
   d. Enteric

8. What defines tonic-clonic status epilepticus?
   a. Seizure activity lasting >15 minutes
   b. Seizure activity lasting >5 minutes
   c. Seizure activity lasting >30 minutes
   d. There are no time limits associated with the definition; status epilepticus is defined only by the number of anti-seizure medications it takes to stop the seizure

9. A 76-year-old male with a history of coronary artery disease, type 2 diabetes and myelodysplastic syndrome presents to the emergency department with acute onset of expressive aphasia, right facial droop and right sided hemiplegia. A non-contrast computed tomography (CT) scan demonstrates a moderate sized left hemispheric intraparenchymal hemorrhage with an unremarkable CT angiogram. The patient’s home medications include aspirin, clopidogrel and metformin. His blood pressure on presentation was 183/97 and his bloodwork reveals a platelet count of 97 x 10⁹/L with an otherwise normal blood panel. What is the next best step in management?
   a. Platelet transfusion
   b. Nicardipine
   c. Desmopressin
   d. Dexamethasone

10. A 39-year-old otherwise healthy female presents to the emergency department with dysartria and a left facial droop, and a GCS of 15. Initial blood pressure is 145/70 with otherwise normal vitals. Bloodwork is unremarkable. A non-contrast computed tomography (CT) scan demonstrates a small right midline frontal parenchymal hemorrhage and CT angiography is notable for an empty delta sign. What is the most important step in management?
    a. Initiate anti-coagulation
    b. Consult neuroradiology for thrombectomy
    c. Initiate blood pressure lowering therapies
    d. Start a prophylactic anti-seizure medication

11. A 45-year-old female was found to have a subarachnoid hemorrhage after presented to the hospital with a thunderclap headache. A non-contrast computed tomography (CT)
scan demonstrated a subarachnoid hemorrhage with a Modified Fisher Scale of 2. CT angiography is notable for a 1 cm right middle cerebral artery (MCA) aneurysm. The patient’s initial blood pressure is 177/102, her GCS is 14 (E4V4M6) and her World Federation of Neurological Surgeons Scale grade is 2. What is this patient’s biggest risk in the first 48 hours?
   a. Rebleeding
   b. Vasospasm and/or delayed cerebral ischemia
   c. Seizure
   d. Neurogenic pulmonary edema

12. A 50-year-old man with a history of atrial fibrillation, type 2 diabetes mellitus, and CKD stage 4 was admitted after IV thrombolysis for an acute left middle cerebral artery stroke. During the next 24 hours, he subsequently developed acute on chronic kidney injury (serum creatinine rising to 6.0 mg/dL; BUN 126 mg/dL; K 6.7 mEq/L). The decision is made to commence renal replacement therapy (RRT). What would be the appropriate RRT modality for this patient?
   a. Continuous renal replacement therapy (CRRT)
   b. Acute intermittent hemodialysis
   c. Acute peritoneal dialysis
   d. Prolonged Intermittent Renal Replacement Therapy (PIRRT)
   e. Isolated ultrafiltration

13. A 28-year-old woman, feeling unwell after finishing a marathon, was brought to the medical tent near the finish line. She had run three marathons in the past two years. She was confused, but not hypotensive; pulse was 130 beats/min; her weight was 4.5 kgm higher than at the start of the race. Electrolyte measurements on site included a serum sodium concentration of 118 mEq/L. The most likely proximate reason for the hyponatremia is:
   a. Cerebral salt wasting
   b. Salt-losing nephropathy
   c. Excessive intake of hypotonic fluid
   d. Inappropriate ADH secretions
   e. Excessive salt loss through sweat

14. Which of the following is a risk factor for posterior reversible encephalopathy syndrome?
   a. Severe hypotension
   b. Immunosuppressive therapy
   c. Acute respiratory distress
   d. Menopause

15. Which of the following is an inappropriate treatment of posterior reversible encephalopathy syndrome?
   a. Controlled reduction of blood pressure
   b. Removal of an immunosuppressive/cytotoxic agent
   c. Nitroglycerin
   d. Delivery of the baby
e. Anti-epileptic drugs

16. A 68 year-old man with a past medical history of mechanical mitral valve replacement on warfarin is brought to the emergency department after the sudden onset of decrease level of awareness. While performing a neurological examination you appreciate minimal withdraw to pain in 4 extremities, ocular bobbing with small and minimally reactive pupils. A head CT shows a pontine hemorrhage. His last INR was 2.9 and it was checked yesterday. You discuss with the pharmacist about the best medication available to reverse his INR, what treatment would you recommend for immediate INR reversal?
   a. Cryoprecipitate
   b. Prothrombin complex contrate
   c. Protamine sulfate
   d. Vitamin K

17. During a domestic dispute, a 22-year-old man is hit multiple times in the neck with a baseball bat. On exam, he is unable to move and he is unable to feel pain or temperature but has vibration sense and proprioception. What is the most likely diagnosis?
   a. Central spinal cord syndrome
   b. Posterior spinal cord syndrome
   c. Anterior spinal cord syndrome
   d. Posterior spinal artery syndrome
   e. Central spinal artery syndrome

18. A 68-year-old woman with metastatic breast cancer to the liver and lung, currently treated with docetaxel, presents to the emergency department by ambulance after been found down and unresponsive by her sister. She was intubated in the field for a GCS of 3. Collateral from her sister reveals that the patient reported progressive left arm weakness and global headaches that were more severe when lying flat for the past week. CT scan of the head reveals a large, contrasting-enhancing solitary lesion at the grey-white junction of the right fronto-parietal lobe with extensive vasogenic edema and mass effect, resulting in leftward midline shift and early herniation. Which of the following medical therapies would be most effective in relieving the mass effect caused by the brain metastasis?
   a. Dexamethasone
   b. Hypertonic Saline
   c. Mannitol
   d. Docetaxel

19. Which of the following types of cerebral edema is corrected matched with its associated pathogenesis?
   a. Osmotic edema: Na+ K+ ATPase pump failure
   b. Cytotoxic edema: Impaired CSF absorption
   c. Vasogenic edema: Disruption of the blood-brain-barrier
   d. Interstitial edema: Increased osmolality in the brain
20. A 29-year-old man with no significant medical history present to the emergency department with rapidly ascending bilateral weakness from his feet to his proximal legs and difficulty breathing. His symptoms occurred 1 week after receiving the influenza vaccination. Initial examination was notable for lethargy with 0/5 strength in all muscle groups in bilateral lower extremities, areflexia, and use of accessory muscles for breathing. His negative inspiratory force was -10 cm H₂O and vital capacity was 20 ml/kg. The patient subsequently became obtunded. ABG revealed pH 7.12 PO₂ 80 PCO₂ 65. The patient was intubated with the following ventilator settings AC/VC Vt: 400 RR: 12 FiO₂: 60 PEEP: 5. Repeat ABG 1 hours post intubation revealed pH 7.16 PO₂ 75 PCO₂ 55. Which of the following ventilator adjustments can be made to further improve this patient’s respiratory acidosis?
   a. Increase Inspiratory to Expiratory ratio
   b. Increase respiratory rate
   c. Decrease PEEP
   d. Decrease tidal volume
eAppendix 3 Assessment #1 Questions

1. A 55-year-old man suffers a motor vehicle accident. When paramedics arrived, his Glasgow Coma Scale was 10 (E3V3M4). His blood pressure was 200/120 mmHg. Upon arrival to the emergency department, the patient deteriorates to a Glasgow Coma Scale of 4 (E1V1M2). An acute intracranial process is suspected. He is intubated and his respiratory rate is set at 26 per minute to decrease intracranial pressure. What is the mechanism for hyperventilation to decrease intracranial pressure?
   a. Hyperventilation decreases viscosity of the blood
   b. Hyperventilation causes osmotic shift of fluids
   c. Hyperventilation causes cerebral vasoconstriction.
   d. Hyperventilation increases oxygen delivery.

2. You are taking care of a 22-year-old man who suffered a motor vehicle accident. His initial head CT showed small bifrontal contusions. On day 3 of his hospitalization, he remains with a poor neurological examination. Repeated head CT showed expected evolution of bifrontal contusions but no evidence of increased intracranial pressure. You suspect this is a case of diffuse axonal injury. What test would help you in diagnosing diffuse axonal injury?
   a. CT angiography of intra and extracranial vasculature.
   b. MRI of the brain
   c. MRA of the head
   d. Continuous EEG

3. What is the most common etiology for pontine hemorrhage?
   a. Cerebral amyloid angiopathy
   b. Chronic arterial hypertension
   c. Trauma
   d. Venous thrombosis

4. What vital signs suggest impending herniation?
   a. Bradycardia
   b. Tachycardia
   c. Hypotension
   d. Hypoxia

5. What are the current guidelines for seizure prophylaxis in the setting of spontaneous, non-traumatic intracerebral hemorrhage?
   a. Levetiracetam 500 mg BID
   b. Lacosamide 100 mg BID
   c. No prophylaxis for spontaneous, non-traumatic ICH
   d. Phenytoin 100 mg TID

6. You are consulted on a patient in the medical ICU who develops hyperthermia, agitation, and tremor. Her past medical history of bipolar disorder, depression, who was just
recently given fentanyl for pain. On exam, she has hyperreflexia with clonus, increased bowel sounds and rigidity. What is the most likely diagnosis?
   a. Serotonin syndrome
   b. Neuroleptic malignant syndrome
   c. Malignant hyperthermia
   d. Anticholinergic poisoning

7. A 55-year-old female with a history of DVT/PET and Myasthenia Gravis on oral immunosuppressants presents to your hospital in myasthenic crisis. She is then intubated and admitted to the Neurocritical Care Unit. What is the treatment modality of choice for this patient?
   a. Intravenous Immunoglobulin
   b. Plasma Exchange
   c. Intravenous stress dose steroids
   d. Increase dose of home mestinon

8. A 9-year-old boy, previously healthy, suddenly loses consciousness while playing soccer with his brother. Parents started CPR immediately and EMS was called. After 10 minutes of CPR without a shockable rhythm, ROSC was achieved and the patient was transferred to a community hospital with no access to pediatric neurology. You are called to provide suggestions before flying the patient to a tertiary care pediatric hospital. Your initial recommendations to the ED provider include:
   a. This patient should be placed on telemetry immediately as cardiac arrest in children is most often due to ventricular fibrillation leading to circulatory collapse.
   b. Continuous EEG is generally not recommended in children following a cardiac arrest and seizures should be monitored clinically since treating electrographic seizures does not necessarily result in improved long term outcomes,
   c. Therapeutic hypothermia (33°C for 48 hr) should be started ASAP following any in- or out-of-hospital cardiac arrest to reduce mortality or improve 1-year functional outcome.
   d. Early hypotension should be avoided as it has been associated with lower survival to hospital discharge

9. Prior to proceeding with the clinical brain death examination, which of the following prerequisites must be met?
   a. Obtain consent from the family to proceed with brain death
   b. Establish an irreversible cause of coma
   c. Completion of apnea testing
   d. Achieve systolic blood pressure >120mmHg

10. You suspect a patient with severe TBI has progressed to brain death, but they have severe facial trauma that prevents you from fully assessing the right pupillary response to light. How do you proceed?
    a. Complete the remainder of the clinical brain death exam, and if all other reflexes are absent proceed with apnea testing
b. Defer clinical examination, and obtain radionuclide brain imaging for confirmation of brain death

c. Complete the remainder of the clinical brain death exam, as well as apnea testing, and confirm brain death via ancillary testing (ex: cerebral angiography, transcranial ultrasounds, radionuclide brain imaging, EEG, or SSEPs)

d. None of the above; brain death testing cannot be completed if there is facial trauma that interferes with brainstem reflex testing given the examiner’s inability to evaluate all brainstem reflexes

11. Spinal reflexes are often seen in patients who are brain dead. Which of the following is NOT consistent with a spinal reflex?
   a. Undulating toe flexion triggered by plantar tactile stimulation
   b. Myoclonus of the arm and leg in response to the examiner manipulating the limbs
   c. Triple flexion of lower extremity (flexion of the thigh, leg, and foot) triggered by noxious stimuli application to the supraorbital notch
   d. Pronator extension reflex triggered by head-turning

12. Which of the following is consistent with a positive apnea test?
   a. Post-testing ABG with PaCO2 < 60mm Hg
   b. Rise in PaCO2 from 36mm Hg pre-apnea testing to 58mm Hg post-apnea testing
   c. Post-testing ABG with PaO2 <40mm Hg
   d. Drop in PaO2 from 120mm Hg pre-apnea testing to 50mm Hg post-apnea testing

13. Which of the following pathophysiologic changes are responsible at a cellular level for evolution of seizure into status epilepticus, and maintenance of status epilepticus?
   a. Decrease in excitatory AMPA receptors
   b. Increase in excitatory NMDA receptors
   c. Increase in inhibitory GABA_A β2, β3, and γ2 subunits
   d. Decrease in inhibitory glutamate receptors

14. A 20-year-old man is noted to be febrile and have a depressed level of consciousness. His roommate brings him to the emergency room in his car, and while en route, he had a tonic clonic seizure that lasted for 5 minutes. By the time he reaches the emergency room, he has not regained consciousness. You arrive to bedside and the patient starts having generalized tonic clonic seizures once again. Besides ventilatory and hemodynamic support, which of the following is an appropriate sequence of antiseizure medication treatment?
   a. Lorazepam → levetiracetam → ketamine → phenytoin
   b. Fosphenytoin → lorazepam → phenobarbital → repeat fosphenytoin
   c. Lorazepam → midazolam → pentobarbital → fosphenytoin
   d. Lorazepam → fosphenytoin → ketamine → phenobarbital
   e. Lorazepam → lorazepam → fosphenytoin → midazolam

15. A 41-year-old female presents to the emergency department 10 hours after the onset of a sudden severe headache. She is otherwise healthy but endorses using recreational marijuana. Her neurologic examination is unremarkable, though she appears in pain.
Initial non-contrast computed tomography (CT) is unremarkable. What is your next step in management?
   a. Perform a lumbar puncture
   b. Discharge the patient home with pain management
   c. Order MRI brain
   d. Order CT angiogram

16. A 40-year-old man is in the hospital 3 days after an aneurysmal subarachnoid hemorrhage. He has hyponatremia (serum sodium concentration of 115 mEq/L) with decreased skin turgor and elevated hematocrit. His urine sodium is elevated (60 mEq/L). His vital signs are unremarkable and chloride is within the reference range. What is the most likely diagnosis?
   a. Cerebral salt wasting syndrome
   b. Decreased solute intake due to poor appetite
   c. Syndrome of inappropriate secretion of antidiuretic hormone (SIADH)
   d. Excessive water intake
   e. Diabetes insipidus

17. A 65-year-old man with known small cell lung cancer presents to the emergency department following a generalized tonic-clonic seizure. His serum sodium is found to be 120 mEq/L. The most appropriate immediate treatment for this patient is which of the following:
   a. Fluid restriction
   b. Tolvaptan
   c. Normal (0.9%) saline
   d. Hypertonic saline with co-administration of DDAVP
   e. 0.45% saline

18. A 53-year-old woman develops polyuria within 24 hours after transsphenoidal surgery to remove a pituitary tumor. What test result is consistent with a diagnosis of central diabetes insipidus:
   a. Serum sodium < 150 mEq/L
   b. Urine output < 200 mL/h
   c. Urine osmolality < 600 mOsm/kg
   d. Urine osmolality rises by <100% in response to desmopressin
   e. Urine specific gravity > 1.010

19. A 38-year-old man sustains a cerebral hemorrhage in a motor vehicle accident. He requires emergent intubation with subsequent mechanical ventilation. Medications required during ventilator support include propofol for sedation control, fentanyl for pain control, and rocuronium for neuromuscular blockade. For elevated intracranial pressure, IV hypertonic saline and mannitol infusion are initiated by the critical care team. To maintain cerebral perfusion pressure, norepinephrine is given. On ICU day four, he develops acute kidney injury, along with severe metabolic acidosis, hemodynamic instability, elevated troponin, and ST depressions in the anterolateral leads. Urinalysis reveals the presence of blood with no red blood cells. Creatinine phosphokinase is 45,489
U/L. Which of the following medications is most likely responsible for the acute kidney injury?
   a. Propofol
   b. Rocuronium
   c. Norepinephrine
   d. Fentanyl
   e. Midazolam

20. A 44-year-old woman with a history of prior stroke and atrial fibrillation, and who takes dabigatran for anticoagulation, is admitted to the hospital for management of a large intracerebral hemorrhage. She is intubated for lethargy and admitted to the ICU. Vital signs are: blood pressure 175/98 mm Hg, heart rate 108 beats/min, respiratory rate 22 breaths/min, and temperature 36.7°C (98°F). Her Glasgow Coma Scale score is 7. What is the most appropriate treatment to reverse her anticoagulation?
   a. Idarucizumab
   b. Prothrombin complex concentrate
   c. Vitamin K
   d. Factor VII
   e. Fresh frozen plasma
1. A 65-year-old woman with a past medical history significant for hypertension and substance abuse is brought to the emergency department after she was found down in the street. Vital signs are remarkable for heart rate of 110 x’, blood pressure of 140/90 mmHg and a respiratory rate of 16 x’. Her initial Glasgow Coma Score is 9 (E2V3M4). Her pupils are asymmetric with the left one being 8 mm and the right one being 4 mm. Only the left pupil reacts to light stimulation. Head CT shows a left basal ganglia intraparenchymal hemorrhage causing uncal herniation. Based on the Monroe-Kelly doctrine, you intend to perform an intervention to decrease the intracranial venous blood volume. What is the maneuver that will allow you to do so?
   a. Lower the blood pressure
   b. Elevate the head of the bed at 30 degrees
   c. Intubate the patient for airway protection and proceed with hyperventilation.
   d. Provide adequate sedation and analgesia to the patient.

2. A patient is brought to emergency department by EMS after he was assaulted with a bat. His initial Glasgow Coma Scale is 6 (E1V1M4). Vital signs are remarkable for heart rate of 115 x’, blood pressure of 100/70 mmHg and a respiratory rate of 14 x’. A head CT shows extensive bifrontal contusions along with diffuse sulci effacement. Based on these findings, you recommend placing an intraparenchymal monitor as well as an arterial line. The trauma resident on call asked you about the relationship between cerebral perfusion pressure, intracranial pressure and cerebral blood flow. You explain to him that cerebral autoregulation can maintain cerebral blood flow as long as cerebral perfusion pressure (CPP) stays within a certain range. Under normal circumstances, which limits of cerebral perfusion pressure is the normal brain able to maintain adequate blood flow via cerebral autoregulation?
   a. CPP between 50-150 mmHg.
   b. CPP between 30-50 mmHg
   c. CPP between 150-180 mmHg
   d. There is no correlation between CPP and cerebral blood flow.

3. A middle age woman is currently admitted to the Neuro Intensive Care Unit for management of traumatic brain injury. The head of the bed is elevated at 30 degrees, neck is midline, CO2 concentration is 35, her temperature is normal and sedation and analgesia seem to be adequate. Despite this, an external ventricular drain placed in the third ventricle is measuring an intracranial pressure of 28 mmHg. You decide to start osmotherapy with hypertonic saline at 14.6% concentration. What is true about hypertonic saline?
   a. It is more effective in decreasing intracranial pressure compared to mannitol
   b. It has a shorter half life
   c. It has a greater risk of rebound increased intracranial hypertension
   d. It has an osmotic coefficient of <1

4. A patient currently admitted to the Neuro ICU for management of severe TBI. The patient’s intracranial pressure is being monitored via an external ventricular drain. On
day 3, his ICP increases to 35 mmHg for more than 5 minutes. Other than tachycardia, his vital signs are normal. The head of the bed is at 30 degrees and the neck is midline. The patient is already on adequate sedation and analgesia. A recent blood gas reported a CO2 of 32 mmHg. What would be your next step in the management of this patient?

a. Muscle paralysis
b. Therapeutic hypothermia
c. Osmotherapy
d. Surgical evaluation
e. Pentobarbital induced coma

5. A 45-year-old female with history of Myasthenia Gravis presents to the emergency department with shortness of breath, proximal muscle weakness, and difficulty chewing and swallowing her dinner tonight with a choking spell. On evaluation, she is sitting up and using accessory muscles, her neck is unable to lift off the bed, her nostrils are flared, she is drooling, and she is unable to speak more than one word at a time. The ED sent an arterial blood gas and lactate which are pending. What is the appropriate course of action?

a. Wait for the ABG results to determine best next step
b. Place on non-invasive ventilatory support
c. Order Intravenous Immunoglobulin for STAT administration
d. Intubate the patient

6. A 48-year-old female with history of breast cancer presents with intractable headache, blurry vision, lethargy, and low grade fever. On evaluation CT Head in within normal limits, papilledema is found on funduscopic examination, and LP reveals elevated opening pressure to 35 cm H20 and following CSF profile: < 3 RBC, and 100 WBC, lymphocytic predominant, 55 protein, 26 glucose. What class of organism is highly suspected based on the CSF profile?

a. Bacterial
b. Viral
c. Fungal
d. Autoimmune

7. Which of the following statements about Pediatric Stroke are true?

a. The most common risk factors for pediatric stroke include vasculopathies and cardiac disease.
b. Multiple clinical trials in children have shown that, among highly selected children with acute ischemic stroke and large vessel occlusion, thrombectomy improves 90-day survival without disability over standard medical therapy
c. In children with intracranial vascular stenosis such as moyamoya and in those with focal cerebral arteriopathies, permissive hypotension is preferred due to high risk of hemorrhagic transformation.
d. Similar to adults, the vast majority of children presenting to an ED with an acute neurological syndrome have an acute ischemic stroke.
8. A 7-year-old girl is brought to the ED by her mother after losing consciousness following a bike accident in which he was not wearing a helmet. After falling, the patient hit her head and was difficult to arouse. Her past medical history is unremarkable. In the ED, the patient appears agitated and had an episode of emesis. A noncontrast CT scan of the head demonstrates an epidural hematoma and small intraparenchymal bleeds. Which of the following statements about Pediatric TBI are true?
   a. Based on low quality evidence, initiation of early enteral nutritional support in children (within 72 hr from injury) increases the risk of aspiration and poor outcome
   b. In the pediatric age range, there may be an age-related CPP threshold between 30-40 mm Hg (infants CPP< adolescents CPP)
   c. Mannitol is more effective than HTS in children to control refractory increased ICP, decrease mortality and improve long-term outcomes.
   d. The occurrence of electrographic seizures following severe TBI is higher in children than adults

9. As reported by the Established Status Epilepticus Treatment Trial (ESETT), which of the following antiseizure medications and its associated dose is considered effective to cause seizure cessation in benzodiazepine-refractory status epilepticus?
   a. Levetiracetam 80mg/kg
   b. Fosphenytoin 20mg/kg
   c. Valproate 60mg/kg
   d. Ketamine 3mg/kg

10. An 82-year-old female was brought to the emergency department (ED) by her daughter for confusion which began 18 hours prior to her presentation to the ED. She is independent at baseline and has not seen a medical professional in 30 years. Her initial neurologic examination is notable for a GCS of 15 with no focal neurologic deficits, though she has mild inattention. Her initial blood pressure was 201/105. A non-contrast computed tomography (CT) scan demonstrates a small right thalamic hemorrhage with intraventricular hemorrhage (IVH) involving the right lateral ventricle with extension to both the third and fourth ventricles. There is no evidence of hydrocephalus, and a CT angiogram is unremarkable. You initiate blood pressure lower therapies and admit the patient to the neurocritical care unit. What is your next step in management?
   a. Consult neurosurgery for placement of an external ventricular drain
   b. Start hyperosmolar therapy
   c. Order tranexamic acid
   d. Monitor the patient clinically and repeat a CT scan in 4-6 hours

11. A 57-year-old male presents to the hospital with a thunderclap headache. A non-contrast computed tomography (CT) scan demonstrates a subarachnoid hemorrhage and a right posterior communicating artery aneurysm is seen on CT angiography. His initial blood pressure is 175/100, his Hunt and Hess Scale grade is 3 and his GCS is 13 (E3V4M6). He is admitted to the neurocritical care unit and is scheduled for coiling of his aneurysm in 2 hours. While waiting for neurocritical care unit and is scheduled for coiling of his aneurysm in 2 hours. While waiting for coiling, what is another important management step?
   a. Induce hypertension to prevent delayed cerebral ischemia
b. Insert an ICP monitor
c. Lower the patient’s blood pressure
d. Start an antifibrinolytic agent

12. A 62-year-old male with a history of type 2 diabetes and dyslipidemia has been admitted to the neurocritical care unit with a subarachnoid hemorrhage secondary to an anterior communicating artery aneurysm. He was managed with successful coiling of the aneurysm and nimodipine was initiated. He is now post-admission day 8, and he has been monitored closely in the neurocritical care unit with no evidence of seizures or hydrocephalus. While you are on-call, this patient develops new right arm weakness. Other etiologies have been excluded and you suspect delayed cerebral ischemia. What is your next step in management?
   a. Call the interventional neuroradiology team for consideration of intra-arterial calcium channel blockers
   b. Induce hypertension
   c. Initiate high dose intravenous magnesium sulfate
   d. Start hyperosmolar therapy

13. An 82 yo male patient with history of atrial fibrillation currently taking Coumadin wakes up with aphasia and right sided weakness, last known well makes him candidate for alteplase, which tests are required prior to deciding whether or not to give tPA?
   a. CT brain
   b. CT brain and finger-stick glucose
   c. CT brain, CT angiogram
   d. CT Brain, finger-stick glucose, INR
   e. CT brain, finger stick glucose, INR, Basic Metabolic Panel

14. The same patient continues to progress, it is confirmed that 3 hours prior to his arrival to the ED he spoke with his daughter and his speech was fluent, per the latest guidelines what's is the INR cut off in order to be able to administer intravenous thrombolysis.
   a. 2
   b. 1.7
   c. 1.5
   d. 1
   e. No cut off is an emergency and patient is within window for tpa

15. A 69 year old female patient with history of atrial fibrillation (not on anticoagulation) presented with left gaze, aphasia, right sided weakness. The last known normal was 5 hours ago. The vascular neurologist calculates the the alberta stroke programme early ct score and states that there are early ischemic changes noted in the insula, putamen, frontal operculum, as well as anterior thalamus. A CT angiogram shows a L M1 occlusion. Per AHA guidelines, what is the next best step in management
   a. administer intravenous tPA
   b. admit to a neurocritical care unit
   c. proceed with mechanical thrombectomy
   d. administer intravenous heparin
16. A 35-year old woman was admitted to the neurointensive care unit with an aneurysmal subarachnoid hemorrhage. Three days after aneurysm coiling, she become nauseated and confused. Her serum sodium is found to be 115 mEq/L. Which of the following features is consistent with a diagnosis of SIADH?
   a. Hypovolemia
   b. Reduction in body weight
   c. Urine osmolality < 100 mOsm/kg
   d. Raised serum uric acid
   e. High urinary sodium (> 40 mEq/L)

17. A 55-year-old man with a past medical history of renal transplant on tacrolimus, presents to the emergency department with altered mental status. Upon evaluation by the ED team, he had a 2 minutes generalized tonic clonic seizure. His blood pressure is 200/110 mmHg. You suspect this is a case of posterior reversible encephalopathy syndrome, what imaging pattern is not typically associated with posterior reversible encephalopathy syndrome?
   a. Vasogenic edema predominantly in the parieto-occipital lobes
   b. Vasogenic edema mainly along the anterior and media watershed region located in the deep superior frontal sulcus
   c. Vasogenic edema located in both anterior and posterior, medial and lateral watershed zones
   d. Vasogenic edema located predominantly in the cerebellum

18. A 55-year-old man with a past medical history significant for chronic kidney disease and hypertension is currently admitted to the Stroke service for management of a right internal capsule infarct. He is currently on aspirin 81 mg and atorvastatin 80 mg along with blood pressure medications. On day 3 of his hospitalization, he suddenly becomes tachypneic and his O2 saturation is 88%. Emergent work up reveals a right pulmonary artery embolism. The team decides to start anticoagulation with a heparin drip and the patient is transferred to the Neuro ICU for close monitoring. That evening, you are called to bedside for sudden exam change. The patient is now unresponsive, and his pupils are anisocoric with the right one being larger. An urgent head CT shows a large right basal ganglia hemorrhage with downward herniation. In addition to stopping the heparin drip, protect airway and address intracranial hypertension, how would you reverse his anticoagulation?
   a. Transfuse cryoprecipitate
   b. Administer vitamin K
   c. Administer prothrombin complex concentrate
   d. Administer protamine sulfate
   e. Administer desmopressin

19. What are the most common side effects of dexmedetomidine?
   a. Ventricular arrhythmias and renal failure
   b. Hypertension and pulmonary edema
   c. Hypotension and bradycardia
20. A 36-year-old male involved in a high speed motor vehicle accident is found on exam to have Grade 2 of 5 motor strength in 80% of his key muscle groups in his lower extremity. His perianal sensation and rectal tone are intact. A bulbocavernosus reflex is present. His sensation is decreased from a point at the intersection of the mid-clavicular line and the 4th intercostal space at the level of the nipples distally. Based on the American Spinal Injury Association (ASIA) classification system, what ASIA grade is he?

a. ASIA A  
b. ASIA B  
c. ASIA C  
d. ASIA D  
e. ASIA E

d. Bone marrow suppression and infections