Incorporating Neuroimaging in Prognostication Post-Cardiac Arrest

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Disclosures

- Board member of the American Society of Neuroimaging, have received dues reimbursement as ASN representative to the AMA House of Delegates

Objectives

- Describe the importance in timing of obtaining neuroimaging in anoxic brain injury
- Describe CT findings in anoxic brain injury
- Describe MRI findings in anoxic brain injury
- Use case-based learning to illustrate neuroimaging findings of patients with anoxic brain injury
- Discuss the role of neuroimaging in brain death determination

Selective Vulnerability

- Some neurons are more susceptible to anoxic brain injury than others
  - Cortical layers 3, 5, 6
  - Hippocampus
  - Purkinje layer of the cerebellum
  - Caudate and putamen (striatum)
- Also
  - Pons
  - Border zones between major arterial territories (ex: MCA/PCA junction)

CT Findings in Anoxic Brain Injury

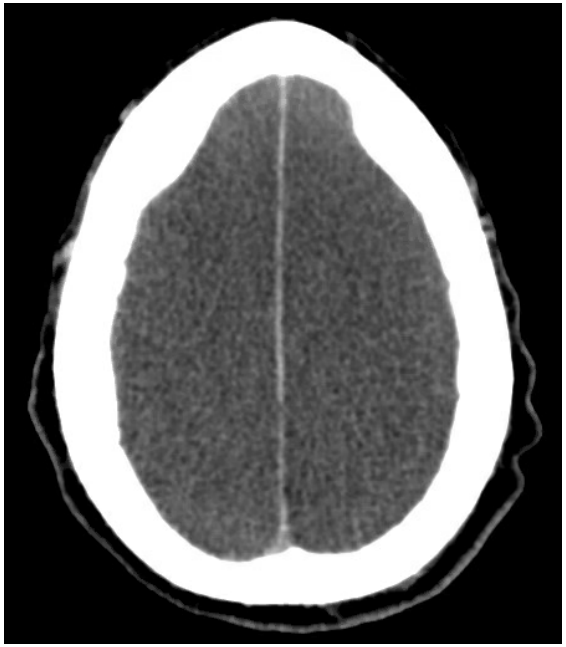
- Often initially normal
- Valuable
  - Can rule out a cerebral cause of the arrest (ICH, SAH, etc.)
  - Can rule out head trauma
    - Unwitnessed (SDH, contusions, etc.)
    - Witnessed from hitting head as a result of the arrest
- Can change treatment
  - Presence of hemorrhage often precludes therapeutic hypothermia, anticoagulation, antiplatelets, etc.

CT Findings in Anoxic Brain Injury

- Sulcal effacement and crowding of the cisterns
- Decrease in hyperdensity of the gray matter
- Loss of gray-white differentiation
- American Heart Association. "…presence of marked reduction in gray-white ratio on the on brain CT obtained within 2 hours after CA to predict poor outcome (Class IIb, LOE B-NR)" (for survivors of CA without TTM)

CT Findings in Anoxic Brain Injury

- Why get a CT head in cardiac arrest patients?
  - When severe anoxic brain injury is identified on head CT it essentially excludes all other pathologies and no further diagnostic imaging is needed



MRI use in Anoxic Brain Injury

- "consider extensive restriction of diffusion on brain MRI at 2 to 6 days after CA…to predict a poor neurological outcome" (Class IIb, LOE B-NR)

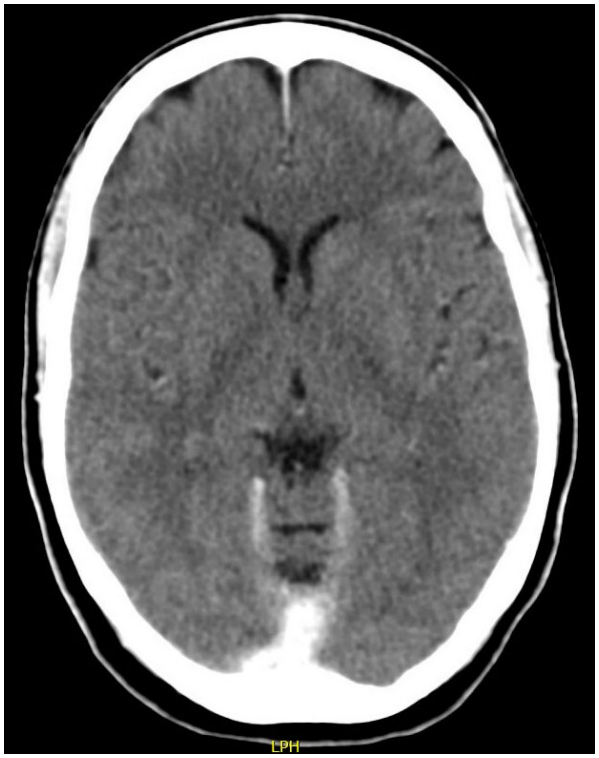
- MRI may be normal, especially if obtained within 24 hours
- Days 3-5 post CA:changes involving the cortex, basal ganglia, and cerebellum
- Late subacute: White matter changes
- DWI changes followed by FLAIR changes

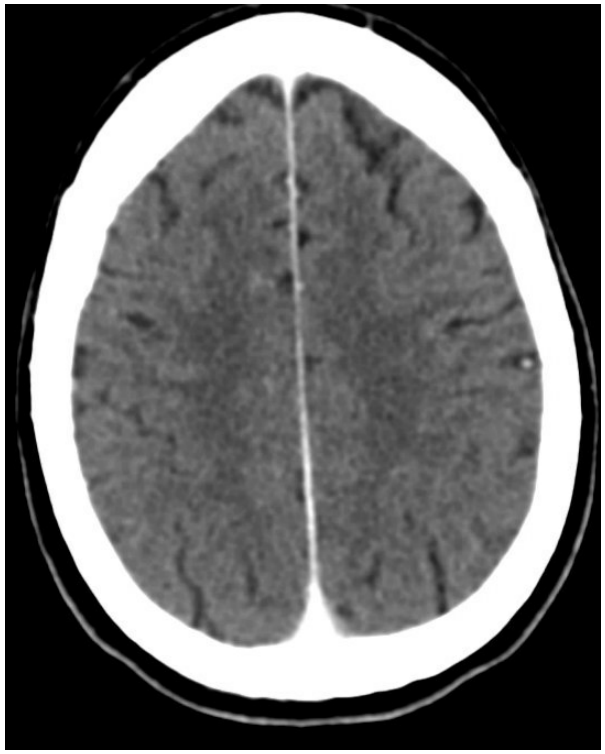
Illustrative Case 1

- 56 year-old female had witnessed cardiac arrest while having an argument outside of church
- She was shocked for V-fib arrest and taken for PCI, +methamphetamines
- Developed immediate myoclonic status epilepticus (confirmed by EEG)

Illustrative Case 1 (cont.)

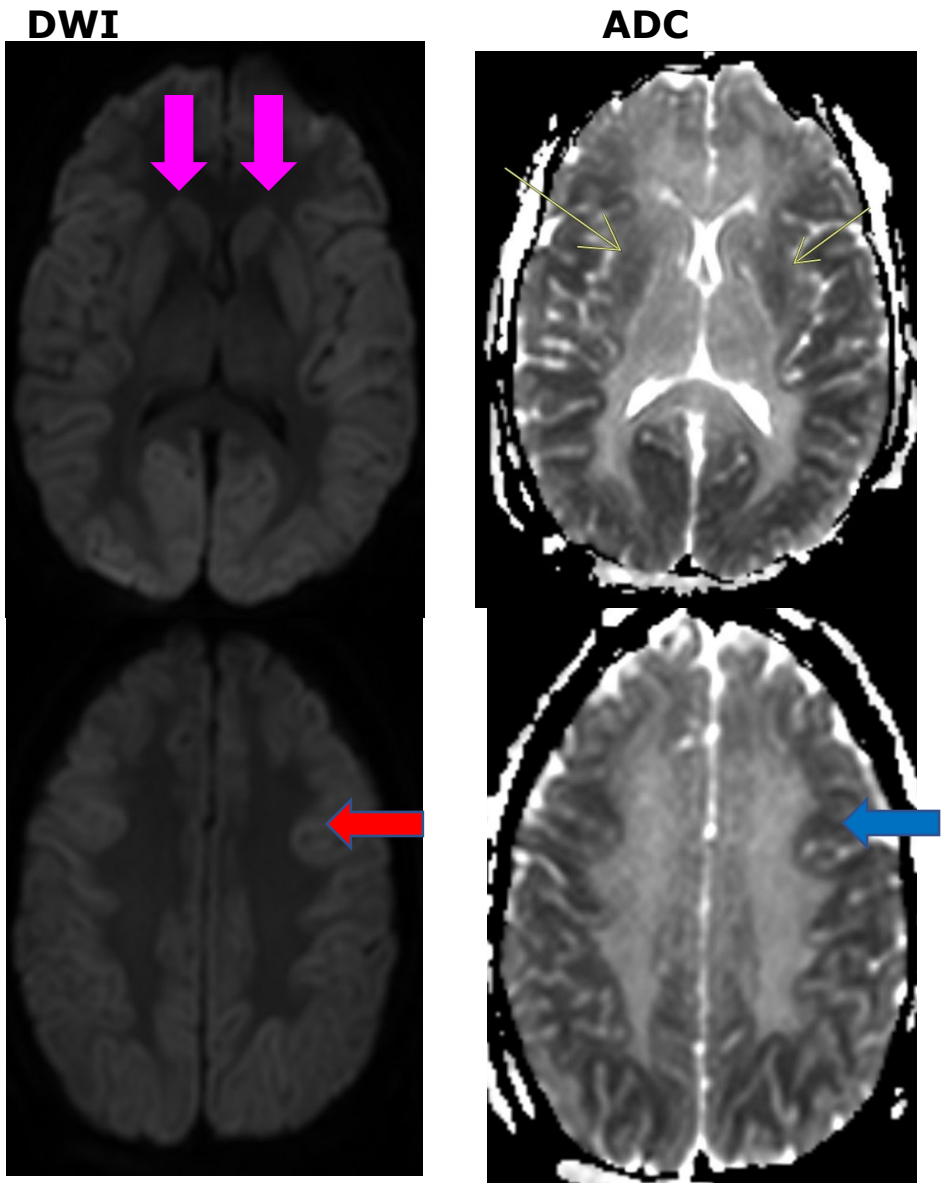
- Post-cath head CT(normal)





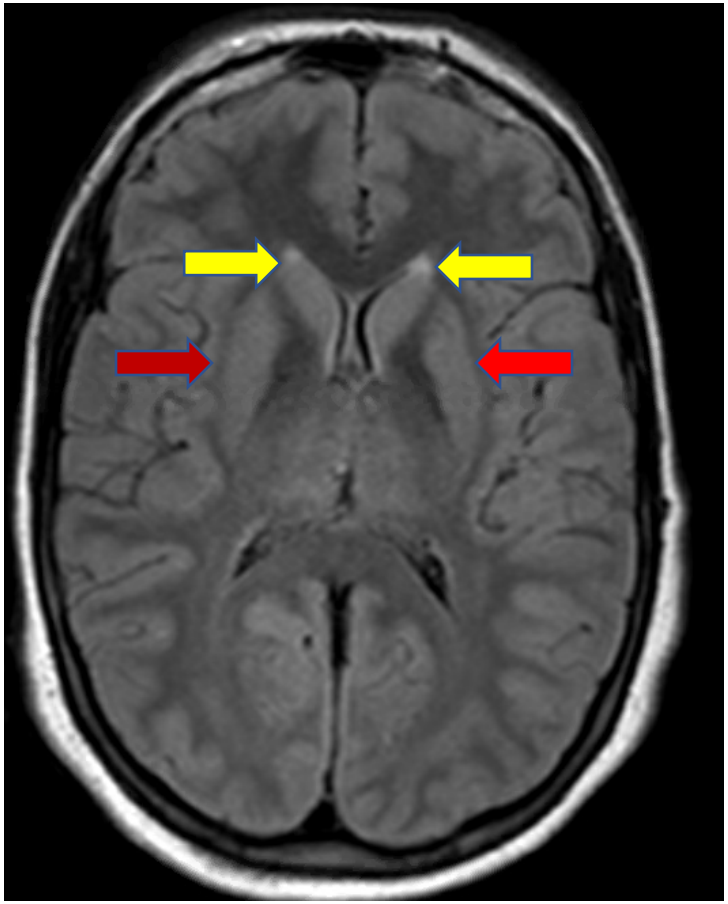
Illustrative Case 1 (cont.)

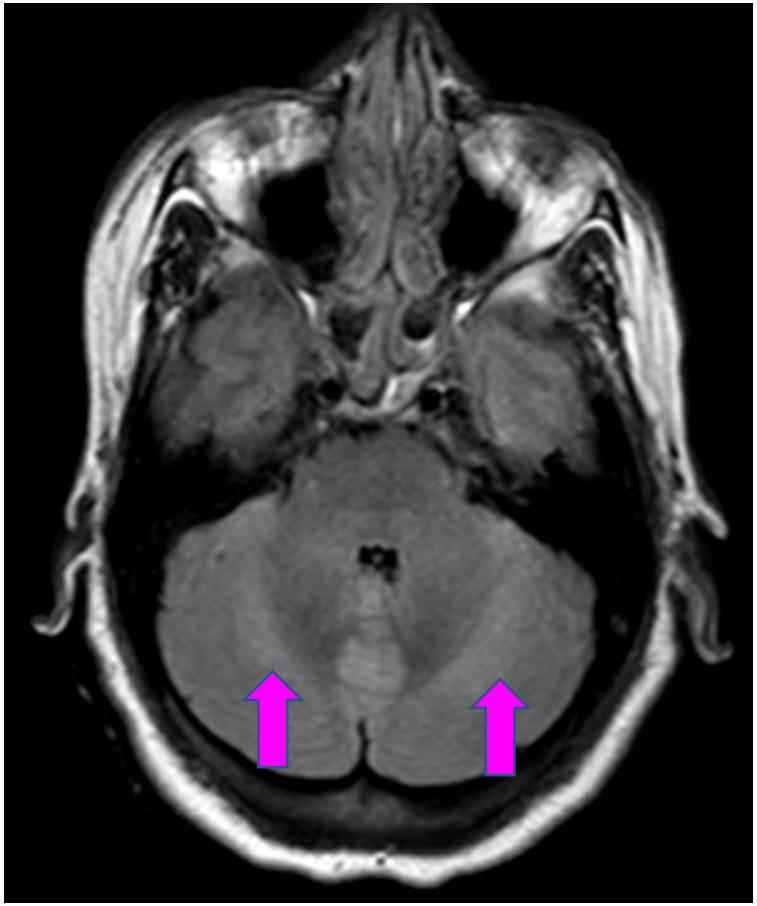
- Day 4 MRI brain (diffuse anoxic brain injury)
- Caudate injury (pink)
- Putamenal injury (yellow)
- Cortical ribboning pattern
  - Cortical layers 3,5,6 (red and blue)



Illustrative Case 1 (cont)

FLAIR Imaging with B/L putamenal (red), caudate (yellow) and cerebellar (pink) hyperintensities

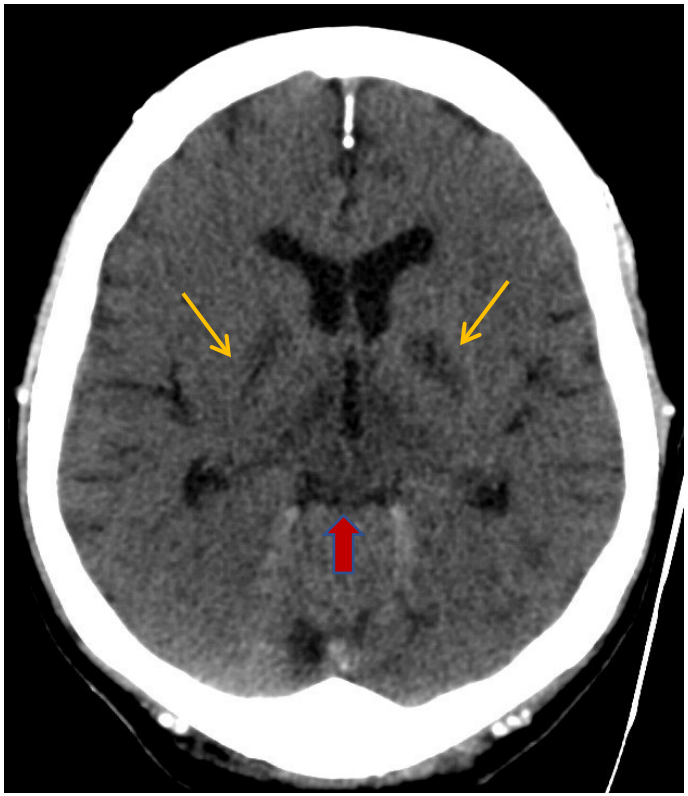




Illustrative Case 2

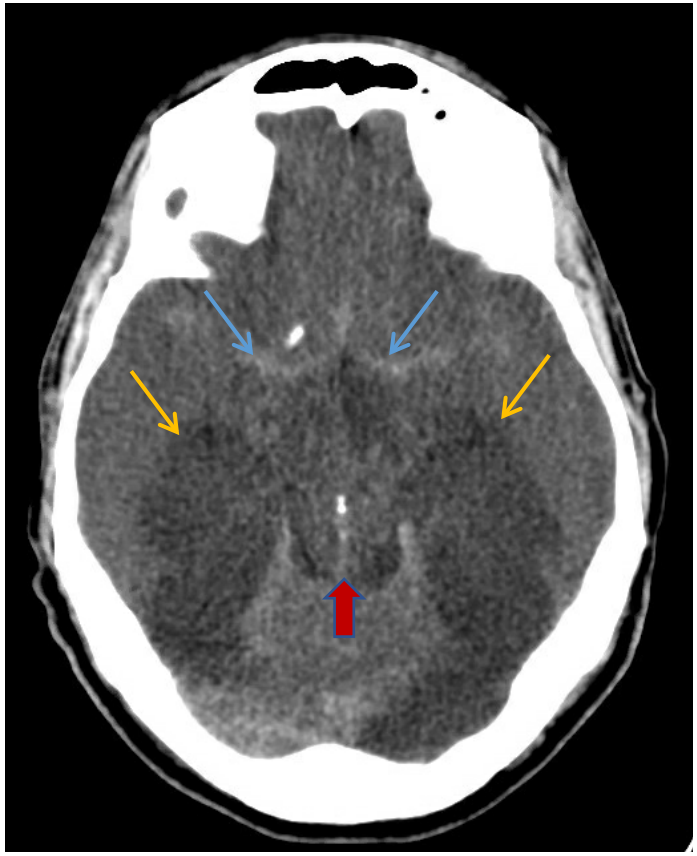
- 75 yo male with PMH of ESRD on dialysis, DM, heart failure, CAD, MI, melanoma, HTN, and anemia presented after PEA arrest during dialysis

CT head on Day 2 with
Bilateral basal ganglia injury
Pontine ischemic injury



Illustrative Case 3

- 52-year-old male with attempted suicide by hanging leading to cardiac arrest
- Vertebrobasilar artery infarction
  - pons (red)
  - PCA distribution (yellow)
- Note pseudo-SAH in non-contrast study (blue)
  - "agonal subarachnoid hemorrhage"
  - Venous engorgement with adjacent hypodensity



Brain Death Determination

- Requires that the patient have neuroimaging findings that explain the state of the patient

Four steps to diagnosis of death by neurologic criteria

1. Establish irreversible and proximate cause of brain death
   - History, physical exam, neuroimaging, laboratory studies
   - Exclude CNS depressants as contributor by waiting 5 half-lives (assuming normal renal and hepatic function) or by checking plasma levels (ex: EtOH less than 0.08%)
   - Exclude neuromuscular blockade with 4/4 Train-Of-Four
   - Exclude severe acid-base, electrolyte, or endocrine abnormalities

AAN Practice Parameter: Determining Brain Death in Adults. 2010.

Four steps to diagnosis of death by neurologic criteria

2. Achieve normal core body temperature (>36 °C)
   - Hypothermia may depress pCO2 levels
   - May effect results of apnea test

AAN Practice Parameter: Determining Brain Death in Adults. 2010.

Four steps to diagnosis of death by neurologic criteria

3. Achieve normal systolic blood pressure (SBP> 100 mm Hg)
   - May require pressors

AAN Practice Parameter: Determining Brain Death in Adults. 2010.

Four steps to diagnosis of death by neurologic criteria

4. Neurological exam
   - Coma
   - Absence of eye opening
   - Absence of motor movement other than spinal cord mediated movement (ex: Babinski response)
   - Absence of brainstem reflexes
   - Absence of pupillary reactivity
   - Absence of occulocephalic and occulovestibular response
   - Absence of corneal response
   - Absence of facial muscle movement
   - Absence of pharyngeal and tracheal reflexes

AAN Practice Parameter: Determining Brain Death in Adults. 2010.

Four steps to diagnosis of death by neurologic criteria

4. Neurological exam (continued)

- Apnea testing
- Prerequisites of normothermia, normotension, euvolemia, eucapnea, absence of hypoxia, no prior evidence of hypercapnea
- Preoxygenate with 100% FIO2 for at least 10 minutes such that PaO2 is greater than 200 mm Hg
- Reduce ventilator frequency to 10 breaths per minute for eucapnea
- Decrease PEEP to 5 cm H20
- If pulse ox > 95%, obtain an ABG
- Disconnect patient from ventilator
- Place oxygen catheter into ET tube at level of carina with 6L/min oxygen
- Observe for respiratory movements (abdominal or chest excursions) for 8-10 minutes
- Abort if SBP < 90 mm Hg or if O2 sat < 85% for 30 seconds
- Retry procedure with T-piece and CPAP setting of 10 cm H20 pressure support and 12L/min O2
- In absence of respiratory movements, recheck ABG after 8 minutes, look for PCO2 > 60 or 20 mm Hg increase from baseline normal PCO2 (supports brain death)
- If test is inconclusive and patient is hemodynamically stable repeat the process and wait 10-15 minutes for ABG

AAN Practice Parameter: Determining Brain Death in Adults. 2010.

AAN recommendations on use of ancillary testing

Cerebral Angiography

The contrast medium should be injected in the aortic arch under high pressure and reach both anterior and posterior circulations.

No intracerebral filling should be detected at the level of entry of the carotid or vertebral artery to the skull.

The external carotid circulation should be patent.

The filling of the superior longitudinal sinus may be delayed.

AAN Clinician Guideline Supplement: Ancillary Testing; Update: Determining Brain Death in Adults. 2010.

AAN recommendations on use of ancillary testing

Electroencephalography

A minimum of eight scalp electrodes should be used.

Interelectrode impedance should be between 100 and 10,000 Ω.

The integrity of the entire recording system should be tested.

The distance between electrodes should be at least 10 cm.

The sensitivity should be increased to at least 2 μV for 30 minutes, with inclusion of appropriate calibrations.

The high-frequency filter setting should not be set below 30 Hz, and the low-frequency setting should not be above 1 Hz.

Electroencephalography should demonstrate a lack of reactivity to intense somatosensory or audiovisual stimuli.

AAN Clinician Guideline Supplement: Ancillary Testing; Update: Determining Brain Death in Adults. 2010.

AAN recommendations on use of ancillary testing

Transcranial Doppler Ultrasonography

Transcranial Doppler (TCD) is only useful if a reliable signal is found. The abnormalities should include either reverberating flow or small systolic peaks in early systole. A finding of a complete absence of flow may not be reliable owing to inadequate transtemporal windows for insonation. There should be bilateral insonation and anterior and posterior insonation. The probe should be placed at the temporal bone, above the zygomatic arch and the vertebrobasilar arteries, through the suboccipital transcranial window.

Insonation through the orbital window can be considered to obtain a reliable signal. TCD may be less reliable in patients with a prior craniotomy.

AAN Clinician Guideline Supplement: Ancillary Testing; Update: Determining Brain Death in Adults. 2010.

Take Home Messages

- Obtain a head CT following ROSC in CA patients to exclude non-cardiac etiologies of CA
- Hold off on obtaining ultra-early MRI as it may be falsely normal
- Do not use neuroimaging in isolation for prognostication
- Consider head CT 2-3 days post CA, when initial head CT was normal
- MRI brain (if needed) day 3-5 post CA (later if TTM was provided)
- Neuroimaging superior to EEG as ancillary test for brain death determination

References

- Greer, D and Wu, O. Neuroimaging in Cardiac Arrest Prognostication. *Semin Neurol* 2017;37:66–74.
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Questions
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