Ordering Appropriate Imaging for Traumatic Brain Injury (TBI):
Everything You Always Wanted to Know, But Didn’t Have Time to Ask!

October 21st, 2015 – 2pm ET

www.HeadInjuryInstitute.org
www.ACR.org
Today’s Presenters

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Disclosures

- Dr. Wintermark
  - Member of GE NFL Advisory Board
- Dr. Sanelli
  - No financial disclosures
- Dr. Le
  - No financial disclosures
Audience and Goals for This Video

Intended audience

- This educational webinar is designed for professionals involved in treating traumatic brain injury (TBI), including emergency physicians, internists, pediatricians, physiatrists, neuropsychologists, and radiologists.
- In addition, TBI patients, caregivers or TBI case coordinators may be interested in this information.

The goals of this webinar are to teach you how to:

- Identify appropriate, evidence-based imaging for patients presenting with TBI.
- Explain to patients the medical reasoning behind the selection of the most appropriate procedure.
- Describe (at the highest level) the most promising directions for TBI imaging research.
ACR Overview

- Founded 1923
- 30,000+ Members are radiologists, radiation oncologists, interventional radiologists, nuclear medicine physicians and medical physicists
- 400+ staff in Reston, VA, Washington, DC, Philadelphia, PA, and Silver Spring, MD
What is the HII?

- The Head Injury Institute (HII) is a group of neuroradiologists and other professionals convened by the ACR to advance the understanding, diagnosis, and treatment of head injuries.

www.headinjuryinstitute.org
Why Should YOU Care About Traumatic Brain Injury?

- In 2010, there were 2.5 million ED visits, hospitalizations, and deaths in U.S. due to traumatic brain injury (TBI).
- TBI kills 138 Americans each day.
- TBI-related ED visits increased by 70% over the past decade.

TBI in the News...

SOCCER

Brain Trauma Extends to the Soccer Field

By JOHN BRANCH

Chronic traumatic encephalopathy, the degenerative brain disease linked to repeated blows to the head, has been found posthumously in a 29-year-old former soccer player, the strongest indication yet that the condition is not limited to athletes who played sports known for violent collisions, like football and boxing.

PRO FOOTBALL

Brain Trauma to Affect One in Three Players, N.F.L. Agrees

By KEN BELSON

The National Football League, which for years disputed evidence that its players had a high rate of severe brain damage, has stated in federal court documents that it expects nearly a third of retired players to develop long-term cognitive problems and that the conditions are likely to emerge at “notably

U.S.

Brain Ailments in Veterans Likened to Those in Athletes

By JAMES DAO

Scientists who have studied a degenerative brain disease in athletes have found the same condition in combat veterans exposed to roadside bombs in Iraq and Afghanistan, concluding that such explosions injure the brain in ways strikingly similar to tackles and punches.
How is TBI Diagnosed and Graded?

- A multidisciplinary approach including:
  - a detailed history
  - physical exam
  - neurologic exam
  - neurocognitive/neuropsychological testing
  - imaging

- Lab tests (e.g., blood S100B levels) are not yet in wide use

- Tissue sampling is not, and may never be, feasible
What Imaging Studies do Clinicians Order to Assess TBI?

- There is **enormous variability**

- While decision rule sets have been established, they are neither well known nor widely used

- In one study, the rates at which different ED attendings at one institution ordered head CTs for TBI ranged from 7.2% to 41.7%
  

- In another study, non-trauma centers were **9% less likely** to order head CTs for pediatric TBI patients; non-teaching hospitals were **8% more likely** to order them
  
  (Reference: Marin JR et al. Variation in emergency department head computed tomography use for pediatric head trauma. Acad Emerg Med. 2014 Sep;21(9):987-95.)
There is a Lot of Variability in Imaging Utilization… So What?

- Variability in imaging utilization hurts patients and payers, and is a waste of our professional talents

- Inappropriate use of imaging can lead to misdiagnosis or delayed diagnosis, which in turn can lead to worse outcomes and higher costs

- Inappropriate use of imaging can also lead to unnecessary/excessive radiation exposure for patients

- The U.S. could save $120 million yearly in imaging costs alone if imaging utilization for mild TBI adhered to guidelines

In Other Words…

*Presence of a head* is not a sufficient indicator of the need for a head CT!

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What Causes the Variability in Imaging Utilization?

• No one has synthesized the current research on TBI imaging in a form that can be accessed and used with ease by:
  • Emergency Department (ED) Physicians
  • Internists
  • Pediatricians
  • Psychiatrists
  • Neuropsychologists
  • Radiologists
  • Other TBI Professionals
Current Recommendations for TBI imaging: Two Papers You Need to Know

Imaging Evidence and Recommendations for Traumatic Brain Injury: Conventional Neuroimaging Techniques

Max Wintemark, MD, MAS\textsuperscript{a,*}, Pina C. Sanelli, MD, MPH\textsuperscript{b,*}, Yoshimi Anzai, MD\textsuperscript{c}, A. John Tsiouris, MD\textsuperscript{d,e}, Christopher T. Whitlow, MD, PhD\textsuperscript{f}, on Behalf of the ACR Head Injury Institute

http://tinyurl.com/TBI-Whitepaper

Imaging Evidence and Recommendations for Traumatic Brain Injury: Advanced Neuro- and Neurovascular Imaging Techniques

M. Wintemark, P.C. Sanelli, Y. Anzai, A.J. Tsiouris, and C.T. Whitlow, on behalf of the American College of Radiology Head Injury Institute

http://tinyurl.com/TBI-Whitepaper-Advanced
Definitions

• Severity
  • **Mild TBI**: Glasgow Coma Scale (GCS) score of 13 to 15
  • **Moderate TBI**: GCS score of 9 to 12
  • **Severe TBI**: GCS score of 3 to 8

• Acuity
  • **Acute TBI**: the injury occurred within the past 7 days
  • **Subacute TBI**: the injury occurred within the past 8 to 89 days
  • **Chronic TBI**: the injury occurred 90 or more days ago

• Patient age
  • **Child**: under 18 years old
  • **Adult**: 18 years old or older
Glasgow Coma Scale (GCS)

- Scores range from 3 to 15; a low score indicates severe injury

- To determine the GCS score, start at zero and:
  - Add 1 pt. if the **eyes** do not open, 2 pts. if they open in response to a painful stimulus, 3 pts. if they open in response to a verbal command, or 4 pts. if they open spontaneously
  - Add 1 pt. if the patient does not **speak**, 2 pts. if he makes non-word noises, 3 pts. if he says inappropriate words, 4 pts. if he speaks in confused sentences, or 5 pts. if he speaks normally
  - Add 1 pt. if the patient does not **move**, 2 pts. if he extends his limbs in response to a painful stimulus, 3 pts. if he flexes his limbs in response to a painful stimulus, 4 pts. if he withdraws from a painful stimulus, 5 pts. if he localizes a painful stimulus, and 6 pts. if he moves in obedience to commands
How are Approaches to TBI Imaging Classified?

- A classification system adapted by the National Institute for Health and Care Excellence from the Oxford Centre for Evidence-Based Medicine:
  - **Class I**: There is evidence and/or consensus that this imaging approach is beneficial
  - **Class IIa**: There is conflicting evidence and/or disagreement in opinion, with weight of evidence/opinion favoring this approach
  - **Class IIb**: There is conflicting evidence and/or disagreement in opinion, with the usefulness of this approach being less well-established
  - **Class III**: There is evidence and/or consensus that this approach is not beneficial and may even be harmful
The ACR Appropriateness Criteria® Rates the Appropriateness of Different Approaches to Imaging

- Approaches are rated on a scale of 1 to 9: 1-3 means “usually not appropriate,” 4-6 “may be appropriate,” 7-9 “usually appropriate”
- The Criteria should be used in conjunction with clinical information
- The Criteria for TBI can be accessed here: https://acsearch.acr.org/docs/69481/Narrative/

Example:
- A patient presents with head trauma…
  - The ED physician suspects vascular injury. She wonders, “Which test is more appropriate: CTA of the head and neck with contrast, or CT of the head with and without contrast?”
  - The Appropriateness Criteria state that CTA of the head and neck with contrast has a rating of 8 for this scenario, whereas CT of the head with and without contrast only has a rating of 6.
  - Question answered
What are the Main Objectives in TBI Imaging?

1. Identify patients who need emergent intervention (surgical or other)
2. Identify patients who would benefit from early medical therapy or intensive surveillance
3. Determine the prognosis in order to optimize management and appropriately counsel the patient and his/her family
Moderate to Severe TBI in Adults, Acute

- Acute phase
  - **Noncontrast head CT is the first-line imaging test** (Class I; ACR Appropriateness Criteria rating 9)
    - Sensitive for hemorrhage, foreign body, and skull fracture
    - Highly predictive of mortality
  - **Noncontrast brain MRI may be indicated** if CT is normal and symptoms persist (Class I)
    - MRI is more sensitive for diffuse axonal injury (DAI), but it is uncertain that MRI findings of DAI correlate with disease severity or prognosis (Class IIb)
Moderate to Severe TBI, Acute

- Follow-up
  - These patients should be followed-up with repeat noncontrast head CT (Class I)
  - Follow-up noncontrast brain MRI may be indicated if the CT is normal and symptoms persist (Class I)
Mild TBI in Adults, Acute

- Acute phase

- **Some patients can safely forgo having any imaging**
  - Such patients can be identified with rules like the Canadian CT Head Rule (CCHR) and Nat’l Emergency X-Ray Utilization Study (NEXUS-II) (Class I)
  - The CCHR states an adult with blunt head trauma, GCS >12, and no bleeding diathesis can safely forgo imaging if he has none of the following:
    - age 65 years or older
    - a dangerous mechanism of injury (e.g., fall down >5 stairs, or struck by vehicle)
    - GCS score <15 at 2 hours post-trauma
    - retrograde amnesia for 30 minutes or more
    - 2 or more episodes of vomiting
    - open skull fracture
    - clinical signs of skull base fracture (e.g., raccoon eyes, hemotympanum, clear rhinorrhea/otorrhea, Battle’s sign)
Mild TBI in Adults, Acute

- Acute phase, continued:
  - **If imaging is indicated, noncontrast head CT is the first-line imaging examination** (Class I; ACR Appropriateness Criteria rating 7), as it has a high negative predictive value for the need for surgical intervention
  - Routine use of MRI is not recommended (Class IIb)
  - **Noncontrast brain MRI may be indicated** if there are new, persistent, or worsening symptoms (Class I; ACR Appropriateness Criteria rating 6)
Mild TBI in Adults, Acute

• Follow-up
  • **Routine use of follow-up imaging is not recommended** for mild TBI patients whose initial CT scan was normal (Class III)
  • Follow-up with repeat noncontrast head CT should be obtained if patients have worsening symptoms or are on anticoagulation and had an abnormality on initial CT scan (Class I)
  • Follow-up noncontrast brain MRI may be indicated if CT is normal and there are persistent unexplained symptoms (Class I)
Mild TBI in Children, Acute

- CT should be used cautiously due to radiation risks (Class I)
- Clinical observation is increasingly being used instead of routine CT in this population (Class IIa)

- If imaging is indicated, noncontrast head CT is the first-line imaging examination
- MRI is more sensitive than CT, does not expose patients to radiation, and may be useful for problem-solving in suspected child abuse cases, but there is not yet adequate evidence to know which children would benefit from it.
TBI of All Severities, Subacute or Chronic

- **Noncontrast brain MRI may be indicated** if the patient has new, persistent, or worsening symptoms (Class I; ACR Appropriateness Criteria rating 8)

- Persistent symptoms that might warrant MRI include:
  - cognitive symptoms (e.g., difficulties with attention, executive function, working memory, language, or information processing speed)
  - neuropsychological symptoms (e.g., depression, anxiety)
  - somatic symptoms (e.g., headache, generalized pain)
What About Cases of Suspected Vascular Injury?

• Suspect vascular injury if there is a basilar skull fracture, mandible fracture, complex skull fracture, cervical spine injury, or penetrating neck injury (Class I)

• Obtain one of the following:
  • *Contrast-enhanced CTA of the head and neck* (Class IIa; ACR Appropriateness Criteria rating 8)
  • *Non-contrast MRA of the head and neck* (ACR Appropriateness Criteria rating 8)
  • *Contrast-enhanced MRA of the head and neck* (ACR Appropriateness Criteria rating 8)
Advanced Imaging Techniques for Mild TBI

- Conventional CT and MRI can underestimate the extent of mild TBI
- Advanced imaging techniques currently being investigated include:
  - Diffusion tensor imaging (DTI)
  - Quantitative volumetric imaging
  - Quantitative susceptibility mapping
  - Functional connectivity imaging
  - MR spectroscopy (MRS)
  - Perfusion imaging
  - Functional MRI (fMRI)
  - Positron Emission Tomography (PET)
  - Magnetoencephalography (MEG)
While these advanced techniques may someday benefit persistently symptomatic patients without abnormalities on conventional imaging, there is currently insufficient evidence to support their routine use in individual patient care. (Class IIb)
• **What is DTI?**
  • A special MRI technique that can potentially identify axonal injury too subtle to be detected by other techniques

• **How does DTI work?**
  • When a nerve axon is intact, water particles tend to move in a straight line from one end of the axon to the other.
  • When an axon gets injured, water particles stop moving in this coordinated way and start moving in all directions.
  • DTI detects these differences in water particle motion, quantifying them using a metric called “fractional anisotropy” (FA)
DTI - Recent Research Findings

• In chronic mild TBI, *FA is decreased* in the corticospinal tracts, sagittal stratum, and superior longitudinal fasciculus; these changes, which are correlated with worsened cognitive function, appear to be due to axonal damage and not necessarily irreversible myelin damage.


• In chronic mild TBI, there are not only areas of decreased FA but also *areas of increased FA*, which may reflect plasticity in response to injury.

Future Directions in Research: Positron Emission Tomography (PET)

- A radioactive imaging agent is injected, and then pictures are taken with a special camera
- 18F-FDG is an imaging agent that preferentially accumulates in highly metabolic tissue
- Newer agents preferentially accumulate in brain areas where there is:
  - *neuroinflammation* (e.g., TSPO, PK11195, cFLFLF-PEG-64Cu)
  - *neurodegeneration* (e.g., amyloid beta, paired helical filament tau)
  - *apoptosis/caspase activity* (e.g., CP18)
PET- Recent Research Findings

• In acute TBI, even apparently uninjured brain tissue at a distance from the site of contusion demonstrates *decreased hexokinase activity* that can be detected using 18F-FDG PET

• In chronic TBI, there is *decreased cholinergic system activity* throughout the neocortex that can be detected using the PET agent [methyl-(11)C]N-methylpiperidyl-4-acetate
Questions & Answers

Thank you for attending the webinar!

Please submit your Questions via the GoToWebinar interface and our panelists will answer as many as they can, time permitting.

For more information, please contact us at: info@headinjuryinstitute.org

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