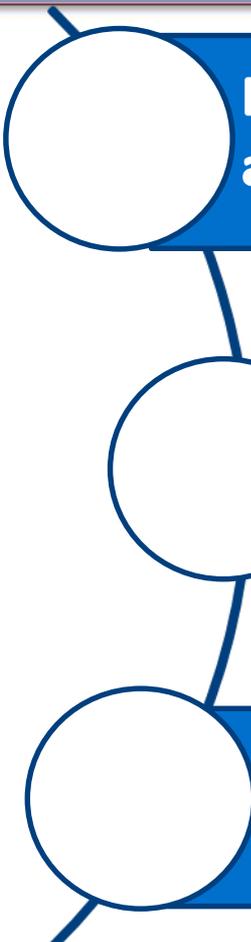


## Clinical Recommendation: **Neuroimaging** **Following Mild Traumatic Brain Injury** (Non-deployed Setting)



# Learning Objectives



**Describe clinical indications for neuroimaging in the acute, sub-acute, and chronic stages following mild TBI**

**Outline red flags, history of mild TBI, and special considerations for neuroimaging**

**Demonstrate understanding of neuroimaging recommendations for each stage**

# Scope of Clinical Recommendation



The *Neuroimaging following Mild Traumatic Brain Injury (mTBI)* clinical recommendation (CR) and companion clinical support tool (CST) offers guidance for the Military Health System (MHS) providers as a standard approach for imaging from the acute through chronic stages following mTBI in the non-deployed setting.

Guidance for Neuroimaging following mTBI in the deployed setting is addressed by the CENTCOM Joint Theater Trauma Systems (JTTS) Clinical Practice Guideline (CPG), the Department of Defense Instruction (DoDI) 6490.11 “Department of Defense Policy Guidance for the Management of mTBI/ Concussion in the Deployed Setting”, the VA/DoD CPG “Management of Concussion/ mTBI, and the Concussion Management Algorithms (CMA’s).



DoD Photo  
Source: [DefenseImagery.mil](http://DefenseImagery.mil)

# Closed TBI Classification



Severity	Mild	Moderate	Severe
Structural imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of consciousness (LOC)	0 to 30 Minutes	> 30 Minutes and < 24 hours	≥ 24 Hours
Alteration of consciousness (AOC)	A moment up to 24 hours	> 24 Hours severity based on other criteria	> 24 hours severity based on other criteria
Post traumatic amnesia (PTA)	24 Hours	> 24 Hours and < 7 days	≥ 7 Days

*Source: Assistant Secretary of Defense for Health Affairs. Health Affairs Memorandum (October 1, 2007). Traumatic Brain Injury: Definition and Reporting*

This classification refers to severity at the time of injury, not symptoms experienced

# Clinical Recommendation



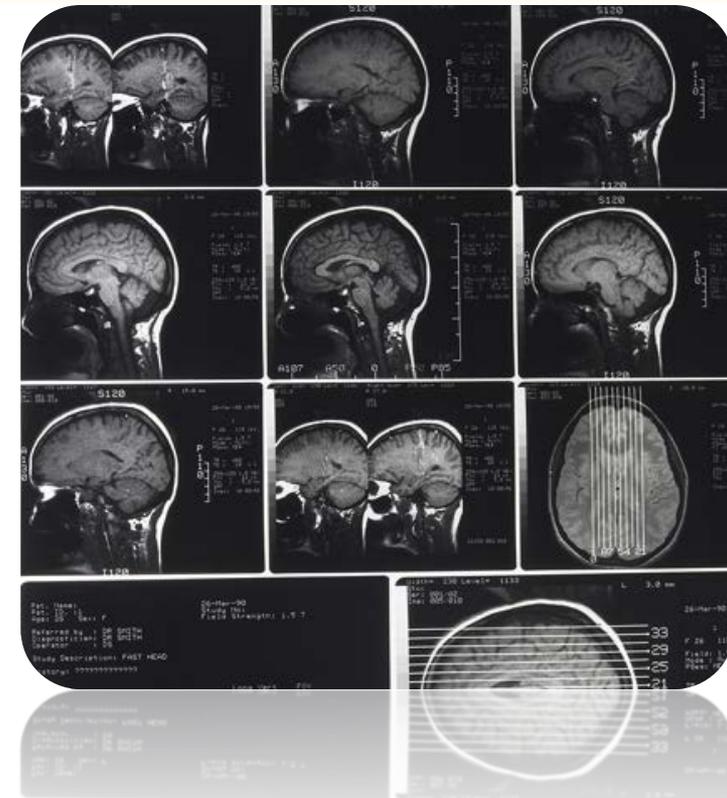
Neuroimaging is recommended for the evaluation of service members (SM) with clinical red flags\*, new onset or persistent or worsening symptoms and individuals whose recovery is not progressing as anticipated.

Red Flags and Indications for Neuroimaging			
Progressive declining level of consciousness (LOC)	Progressive declining, neurological exam	Focal neurological deficit: motor or sensory, slurred speech	Cannot recognize people or disoriented to place
Pupillary asymmetry	GCS < 15	Double vision	LOC > 5 minutes
Seizures	Worsening headache	Visible physical injury above clavicle	Repeated vomiting
Drug or alcohol intoxication	Coagulopathy	Unusual behavior	Age > 60

\*(CMA and New Orleans' Criteria apply for CT Scan)

# Discussed Neuroimaging Techniques

- Computerized Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Positron Emission Tomography (PET)
- Single Photon Emission Computed Tomography (SPECT)



DoD Photo  
Source: [Brainlinemilitary.org](http://Brainlinemilitary.org)

# Stages of mTBI



The specific neuroimaging recommendations are discussed related to the following three timeframes post mTBI:

- Acute – time of injury to 7 days post injury
- Sub-Acute – 8 to 89 days post injury
- Chronic – 90 days post injury and beyond

# Acute Stage



## Acute: Time of injury to 7 days

- Neuroimaging is not routinely recommended for evaluation following mTBI
- Goal: Identify risk for surgical mass or lesions via **clinical red flags**
- Key Point: Less than 1% of mTBI patients require surgical intervention

Computed Tomography (CT) scan is the recommended acute imaging modality when imaging is indicated

# Computed Tomography



The most common imaging test is computerized axial tomography (CT or CAT scan) and features:

- Use of ionizing radiation (x-rays)
- Produces thin, overlapping slices which allow reformations into multiple planes (multi slice >16) with slice thickness no greater than 5mm
- Allows anatomic localization of injury
  - Detection of size and location of hemorrhage
- May help determine therapeutic intervention
  - Surgical vs. Non-surgical
- Can help determine the anatomic area of damage

# Computed Tomography (continued)



## Advantages

- Fast, inexpensive, high linear resolution
- Helpful for evaluation of fractures (skull base, C-spine)
- Can be used in sub-acute and chronic patients if MRI is contraindicated

## Disadvantages

- Ionizing radiation
- Limited functional information
- Lower sensitivity than MRI for Diffuse Axonal Injury (DAI)

# MRI in Acute Stage



## Indications for MRI in Acute Stage include:

- Sustained a concussion with alteration of consciousness (AOC) to include any memory loss greater than 15 minutes and has persisting or worsening symptoms after 72 hours.
- Sustained concussion with loss of consciousness (LOC) less than (<) 30 minutes and has persisting or worsening symptoms after 72 hours despite a normal CT.
- Sustained three or more concussions in past 12 months.
- Has a documented diagnosis of concussion and has a Military Acute Concussion Evaluation (MACE) Cognitive Score of less than (<) 25 after 72 hours post-injury.

# Sub-acute Stage



## Sub-acute: 8 to 89 days after injury

- Goal : Evaluation of SM, enhance understanding of symptoms, provide education, and identify the need for specialist referral
- Key Points:
  - Treatment relies heavily on trajectory of symptoms
  - History of injury is critical to making right decision

Minimum requirements for MRI are outlined in the Preferred 1.5 T Protocol (Appendix A)

- MRI Should be complete before referral to specialty care
- If MRI is unavailable or contraindicated, CT is the modality of choice

# Sub-acute Stage Considerations



## Key Considerations

- Trajectory of symptoms
  - Is the SM seeing improvement or worsening of symptoms?
- Functional impact on the SM
  - Does SM have the ability to rest or is there a requirement to return to normal activities immediately?
- SM's history of concussions
  - Has the SM experienced more than one concussion? If so, how many and over what period of time?

# Sub-acute Considerations (continued)



- SM's history of examination and assessments
  - How many visits to medical care has the SM had since time of injury?
- Symptom tracking and documentation
  - How symptoms being documented and what is being used to track symptoms? Example: Neurobehavioral Symptom Inventory
- SM's history of imaging after injury
  - If indicated, has cervical spine imaging been completed?

# Magnetic Resonance Imaging

## Features of Magnetic Resonance Imaging (MRI):

- Higher contrast resolution image
  - Can detect subtle intracranial pathology
- NO ionizing radiation (radiofrequency)
- True multi-planar imaging
- Relies on contrast of tissues to image
  - Example: water, fat molecules
- Physiologic and metabolic imaging
  - Flow (blood, cerebrospinal fluid)
  - Can perform spectroscopy



DoD Photo  
[Defenselmagery.mil](http://Defenselmagery.mil)

MRI at 1.5 Tesla has been reported to detect different markers of cerebral injury in 30% of individuals that have a normal head CT <sup>23</sup>

## Sub-acute Stage:

If there are no structural abnormalities identified on the MRI or CT, and/or abnormalities do not explain persistent symptoms, following advanced neuroimaging techniques may offer additional information in the understanding of sequelae following mTBI :

- Positron Emission Tomography (PET) or
- Single-photon Emission Computed Tomography (SPECT)

# Nuclear Medicine Modalities



## Positron Emission Tomography (PET)

- Uses metabolic function to determine cerebral blood flow
  - 2-deoxy-2-(18F) fluoro-D-glucose
- Can detect decreased or increased metabolism in frontal and parietal lobes
  - Molecular imaging of inflammatory/excitotoxic markers using a glutamate isotope

## Single Photon Emission Computed Tomography (SPECT)

- Uses short-lived radio active particles to determine blood flow
  - Technetium 99m-hexamethylpropylene amine oxime (99mTc-HMPAO)

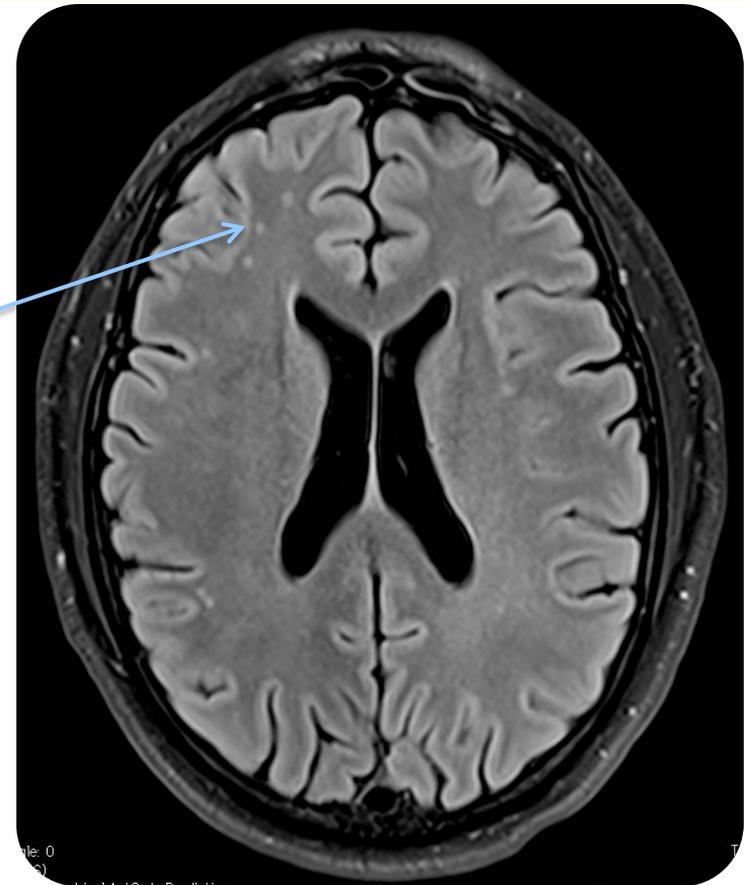
# Relationship Between Neuroimaging Techniques and mTBI Pathology



Mild TBI Pathophysiology	Recommended Imaging Technique
Axonal Injury/White Matter Injury	<ul style="list-style-type: none"> <li>▪ Fluid Attenuated Inversion Recovery (FLAIR)</li> <li>▪ Diffusion Weighted Imaging (DWI)</li> <li>▪ 2-Dimensional/ 3-Dimensional (2D/3D) T2</li> </ul>
Traumatic Sub-Arachnoid Hemorrhage (tSAH)	<ul style="list-style-type: none"> <li>▪ FLAIR</li> <li>▪ 3D T1</li> <li>▪ Susceptibility Weighted Imaging (SWI)/Gradient Echo (GRE)</li> </ul>
Cortical Contusions	<ul style="list-style-type: none"> <li>▪ FLAIR</li> <li>▪ 3D T1</li> <li>▪ SWI/GRE</li> </ul>
Vascular Injury	<ul style="list-style-type: none"> <li>▪ SWI/GRE</li> </ul>
Volume Loss	<ul style="list-style-type: none"> <li>▪ 3D T1</li> </ul>

# MRI: Fluid Attenuated Inversion Recovery (FLAIR)

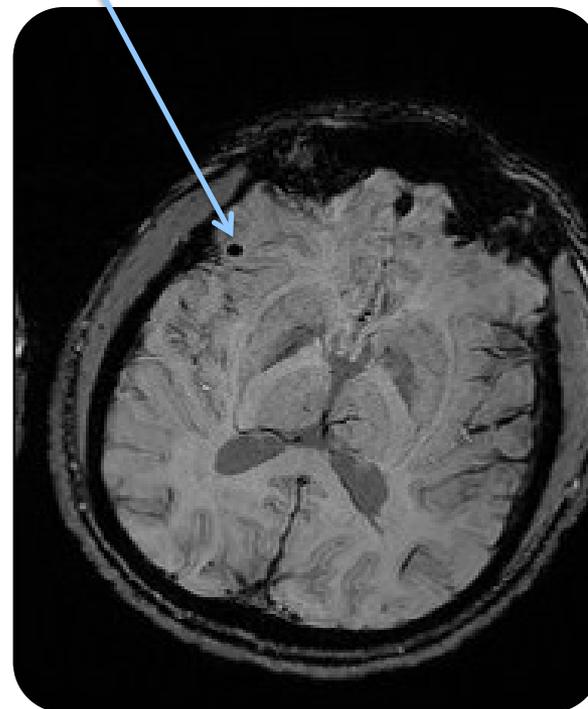
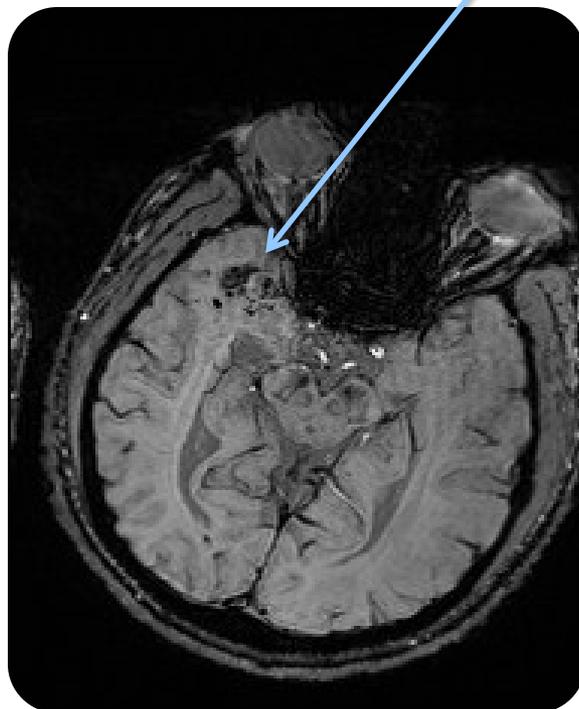
Axonal Injury / White Matter Injury



*DoD Photo  
Source: LTC Gerald York*

# MRI: Susceptibility Weighted Imaging (SWI)

Micro hemorrhages



DoD Photo  
Source: LTC Gerald York

# Chronic Stage



## Chronic: 90 days after injury and beyond

- Goal: Further evaluate SM's injury, enhance understanding of persistent symptoms, provide counseling/education, identify need for specialty referral
- Key Points:
  - Repeat subsequent imaging if the previous exam was a CT
  - Repeat is also suggested if a previous MRI indicates need for follow-up, or if it did not meet the minimum recommendations sufficient for exam
  - If there are no structural abnormalities identified on the MRI or CT and/or abnormalities do not explain symptoms, PET or SPECT may offer additional information in the understanding of sequelae following mTBI

Following recommendations must be considered when educating patients on the need for neuroimaging after a mTBI:

- Neuroimaging is not routinely recommended for all individuals who have sustained a mTBI
  - Patients may have expectations of imaging that cannot be met or may not change therapy
  - Unnecessary testing can be harmful

Most patients with mTBI recover fully within 5 to 7 days and do not require additional interventions.

# Special Considerations



## Pregnancy

- Women of reproductive age should be screened for pregnancy
  - Documentation and risk-benefit analysis required
- Head CT exposure is <math><0.01</math> rad of ionizing radiation
  - Very low fetal risk
- No harmful fetal effects from MRI currently known
- Contrast agents, i.e. gadolinium, should NOT be administered during pregnancy
  - Consult radiology for possible alternatives

## Knowledge Check Questions

# Knowledge Check 1



What is true about neuroimaging following mTBI?

- a) Neuroimaging should be considered for all patients who have sustained a mTBI
- b) It is not the role of primary care provider to order neuroimaging for patients with mTBI diagnosis
- c) MRI is the modality of choice for patient in the acute stage following a mTBI
- d) Neuroimaging is not routinely recommended for the evaluation of all SM following mTBI

Answer:

- d) Neuroimaging is not routinely recommended for the evaluation of all SM following mTBI**

# Knowledge Check 2



Which of the following signs/ symptoms are indications for CT scan in the acute stage for a patient who sustained a mTBI?

- a) Repeated vomiting
- b) Progressively declining neurological status
- c) Brief LOC
- d) Answer A and B
- e) All of the above

Answer:

- d) Answer A and B**

*Repeated vomiting and declining neurological status are indications for CT.*

# Knowledge Check 3



What is the primary role of neuroimaging during the sub-acute stage?

- a) Evaluate symptoms and identify the need for specialist referral
- b) Identify risk for surgical mass or lesions via clinical red flags
- c) Avoid unnecessary testing
- d) Repeat Computerized Tomography (CT) if mTBI symptoms persist

Answer:

- a) Evaluate symptoms and identify the need for specialist referral

*Primary role of neuroimaging during the sub-acute stage is to evaluate symptoms and identify need for specialist referral*

# Knowledge Check 4



Which of the following are recommended clinical indications for conducting a MRI in the acute stage following a CT scan?

- a) If symptoms are persistent or worsening after 72 hours or clinical red flags are present
- b) History the patient has sustained 3 more concussions in the past 12 months
- c) Sustained a concussion with >15 minutes LOC
- d) All of the above

Answer:

- d) All of the above**

*All are indications for conducting MRI during acute stage following a CT scan*

# Case Study



Maj James Smith, 46 year male, was taken to a civilian ER following a motor vehicle accident. He was diagnosed with a mTBI/concussion, contusion to the right clavicle, and shoulder dislocation. The CT of his head was negative for a bleed/fracture. His physical exam was normal except for right shoulder dislocation, and contusion of the clavicle. He complained of a headache and dizziness, and received the appropriate treatment. He was admitted for observation and subsequently discharged after all of his symptoms subsided.

He presents at the base clinic 9 days post injury for a follow up visit with his primary care provider with symptoms of reoccurring headache and dizziness. He is also complaining of a new onset of confusion and sensitivity to light.

The provider evaluates the patient's symptoms, determines that there are no red flags present, and determines the course of treatment.

# Case Study Knowledge Check



What should be the best course of action that provider should take given Maj Smith's symptoms?

- a) Order a repeat CT
- b) Order a MRI
- c) Refer patient to specialty care
- d) Educate that patient on symptoms of concussion, and reaffirm that neuroimaging is not necessary in his case

Answer:

- b) Order a MRI

*MRI is the neuroimaging modality of choice during the sub-acute stage when there are new, persistent, or worsening symptoms. MRI should be conducted prior to specialist referral*



# Conclusion



- Neuroimaging is not routinely recommended for evaluation of all SM following mTBI
- The role of this clinical recommendation is to provide an evidence based standard approach to neuroimaging following mTBI
- CT and MRI can be ordered by primary care providers
- The possible need for more complex imaging (PET or SPECT) or nuclear imaging should involve consultation with subspecialty providers
- Unnecessary imaging increases patient risk and cost without sufficient benefit

# References 1



1. Defense Veterans Brain Injury Center, 2012, DoD worldwide numbers for TBI worldwide totals. Retrieved from: <http://www.dvbic.org/sites/default/files/uploads/dod-tbi-2000-2012.pdf>
2. Armed Forces Health Surveillance Center. (2013). Deployment-Related Conditions of Special Surveillance Interest, U.S. Armed Forces, by Month and Service, January 2003-December 2012 (data as of 22 January 2013) Traumatic Brain Injury. Retrieved from: [http://www.afhsc.mil/viewMSMR?file=2013/v20\\_n01.pdf#Page=17](http://www.afhsc.mil/viewMSMR?file=2013/v20_n01.pdf#Page=17)
3. Joint Theater Trauma System Clinical Practice Guideline (2011). Use of magnetic resonance imaging (MRI) in the management of mild traumatic brain injury (mTBI) concussion in the deployed setting. Retrieved from: [http://www.usaisr.amedd.army.mil/assets/cpgs/Use\\_of\\_MRI\\_in\\_Mgmt\\_of\\_mTBI\\_in\\_the\\_Deployed\\_Setting\\_1\\_1\\_Jun\\_12.pdf](http://www.usaisr.amedd.army.mil/assets/cpgs/Use_of_MRI_in_Mgmt_of_mTBI_in_the_Deployed_Setting_1_1_Jun_12.pdf)
4. Department of Defense Instruction 6490.11: DoD Policy Guidance for Management of Mild Traumatic Brain Injury/Concussion in the De-ployed Setting, September 18, 2012. Retrieved from: <https://www.hsdl.org/?search&collection=public&fct&so=date&submitted=Search&offset=0&tabsection=US+Depts%2C+Agencies+%26+Offices&page=1&publisher=United+States.+Dept.+of+Defense>

# References 2



5. Concussion Management in Deployed Settings version 4.0 (2012). Retrieved from: [http://www.dcoe.health.mil/Content/Navigation/Documents/DCoE\\_Concussion\\_Management\\_Algorithm\\_Cards.pdf](http://www.dcoe.health.mil/Content/Navigation/Documents/DCoE_Concussion_Management_Algorithm_Cards.pdf)[http://www.dcoe.health.mil/Content/Navigation/Documents/DCoE\\_Concussion\\_Management\\_Algorithm\\_Cards.pdf](http://www.dcoe.health.mil/Content/Navigation/Documents/DCoE_Concussion_Management_Algorithm_Cards.pdf)
6. Management of Concussion/mTBI Working Group. (2009). VA/DoD clinical practice guideline for management of concussion/mild traumatic brain injury. *Journal of Rehabilitation Research and Development*, 46(6), CP1–68.
7. Levine, Z., (2010). Mild traumatic brain injury. *Canadian Family Physician*, 56(4), 346-349.
8. Hayel, M., Preston, C., Mills, T., Luber, S., Blaudeau, E., & DeBlieux, P., (2000). Indications for computed tomography in patients with minor head injury. *New England Journal of Medicine*, 343(2), 100-105
9. Shenton, M., Hamoda, H., Schneiderman, J., Bouix, S., Pasternak, O., Rathi, Y., ... & Zafonte, R. (2012). A review of magnetic resonance imaging and diffusion tensor imaging findings in mild traumatic brain injury. *Brain Imaging and Behavior*, 6, 137-192.
10. Haacke, E.M., Duhaime, A.C., Gean, A.D., Riedy, G., Wintermark, M., Mukherjee, P.,... Smith, D.H. (2010). Common Data Elements in Radiologic Imaging of Traumatic Brain Injury. *Journal of Magnetic Resonance Imaging*, 32(3), 516-43.

# References 3



11. Jagoda, A.S., Bazarian, J.J., Bruns, J.J. Jr, Cantrill, S.V., Gean, A.D., Howard, P.K., ... Whitson, R.R. (2009). Clinical policy: neuroimaging and decision making in adult mild traumatic brain injury in the acute setting. *Annals of Emergency Medicine*, 52(6), 714-748.
12. McAllister, T.W., Sparling, M.B., Flashman, L.A., & Saykin, A.J. (2001). Neuroimaging findings in mild traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, 23(6), 775-791.
13. American College of Radiology–American Society of NeuroRadiology. (2010). Practice guideline for the performance of computed tomography (CT) of the brain. Retrieved from: [http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/CT\\_Brain.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/CT_Brain.pdf)[http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/CT\\_Brain.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/CT_Brain.pdf)
14. Le, T.H., & Gean, A.D. (2009). Neuroimaging of traumatic brain injury. *Mt Sinai J Med*, 76(2),145-62
15. Duhaime, A.C., Gean, A.D., Haacke, E.M., Hicks, R., Wintermark, M., Mukherjee, P., ... Riedy, G. (2010). Common Data Elements Neuro-imaging Working Group Members, Pediatric Working Group Members. Common data elements in radiologic imaging of traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, 91(11), 1661-6.
16. Toth, A., Kovacs, N., Perlaki, G., Orsi, G., Aradi, M., Komaromy, H.,... Schwarcz, A. (2012). Multi-modal magnetic resonance imaging in the acute and sub-acute phase of mild traumatic brain injury: Can we see the difference? *Journal of Neurotrauma*, 30(1), 2-10.

# References 4



17. Yuh, E., Mukherjee, P., Lingsma, H., Yue, J., Ferguson, A., Gordon, W. et al., (2013). Magnetic resonance imaging improves 3-month outcome prediction in mild traumatic brain injury. *Annals of Neurology*, 73(2), 224-35.
18. Benzinger, T., Brody, D., Cardin, S., Curley, K., Mintun, M., Mun, S., Wong, K., & Wrathall, J. (2009). Blast related brain injury: Imaging for clinical and research applications: report of the 2008 St. Louis workshop. *Journal of Neurotrauma*, 26 (12), 2127-2144
19. Lin A., Liao, H., Merugumala, S., Prabhu, S., Meehan, W., & Ross, B. (2012). Metabolic imaging of mild traumatic brain injury. *Brain Imaging and Behavior*, 6, 208-223.
20. Bigler, E., & Maxwell, W., (2012). Neuropathology of mild traumatic brain injury: Relationship to neuroimaging findings. . *Brain Imaging and Behavior*, 6, 108-136..
21. American College of Radiology (2008) ACR Practice guideline for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation. Retrieved from:  
[http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant\\_Patients.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf)
22. Wang, P., Chong, S., Kelly, A., Knoepp, U., Mazza, M., & Goo, M. (2012). Imaging of the Pregnant and Lactating Patients: Part I, evidence –based review and recommendations. *American Journal of Radiology*, 198, 778-784.

# References 5



23. Mittl, R., Grossman, R., Hiehl, J., Hurst, R., Kauder, D., Gennarelli, T., & Alburger, G., (1994). Prevalence of MR evidence of diffuse axonal injury in patients with mild head injury and normal CT findings. *American Journal of Neuroradiology*, 15(8), 1583-1589.