IMAGING OF TRAUMATIC BRAIN INJURY

Introduction

Personal injury cases often rely on objective radiological evidence of fractures, bleeding, disc herniations, infections, or tumors shown on radiographs, sonograms, computed axial tomography, magnetic resonance imaging, or nuclear medicine studies. But sometimes, the evidence needed to show injury or harm is not visible on the images that the client has already had done. Such evidence may be there and missed by the first radiologist or may not be there at all. If there is an abnormality in the client that evaded detection on routine images, new advanced imaging methods are useful to detect and show abnormalities not otherwise visible. This is especially true in traumatic brain injury (TBI).

Learning Objectives

1. Recognize vague terms in radiology reports that may be related to TBI but are often misattributed to other disease processes.
2. Evaluate and understand the relative advantages and disadvantages of advanced imaging techniques for TBI
3. Understand the steps to "prove" a brain imaging with imaging
4. Determine whether advanced imaging techniques will be helpful for clients/patients.
5. Review examples of available brain imaging techniques
6. Identify effective resources for diagnostic criteria to overcome defense objections to appropriate diagnostic testing

The Pieces of the TBI Puzzle

Medical imaging is only one piece of the puzzle when it comes to a TBI case. The pieces do not always fit together at first. Medical professionals consider diagnostic efforts to require three parts, like three legs of a stool: they are all needed for stability. *These are history, physical exam, and laboratory test results.* This last one includes radiology results. For example, to diagnose traumatic injury, one needs a history of trauma, medical records that indicate the examiner suspected trauma, like TBI, and radiology reports, neuropsychology test reports, EEG, MEG, or other positive tests that confirm the diagnosis of TBI.

Appropriateness Criteria Resource

https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria

The American College of Radiology website offers a free service at the above link that chronicles their suggestions for the best diagnostic tests for nearly any clinical situation, including TBI.

The ACR admits in the Appropriateness Criteria that diffusion-weighted images and ADC maps, SPECT scans and PET scans are all helpful in TBI, despite the efforts of defendants to devalue these methods as "experimental."

Imaging Examples Presented

- skull fractures,
- epidural and subdural hematomas,
- brain contusions,
- intraparenchymal hemorrhage,
- brain edema,
- subarachnoid hemorrhage, and
- pneumocephalus

Linear Skull Fracture

The most common type of skull fracture. Plain films may show a line or band of decreased or increased density. CT scans show some fractures better than plain films, and some not as well. One can often see soft tissue swelling next to a skull fracture on CT. Skull base fractures are difficult to detect, especially if they are in the complex temporal bones. Sometimes, a radiologist might mistake a normal variant for a fracture. Accessory suture lines look like fractures in a child, but are not, and recognition of this normal variant can save a parent from false accusations of child abuse.

Brain Contusions

Brain contusions appear as dense (whiter) areas near the surface of the brain on CT scans. Parts of the brain are more susceptible to such injury, but they can occur anywhere. When the brain is injured by a blow that pushes the skull into it, and then another injury occurs on the opposite side of the head when the brain rebounds and slams into the opposite side of the inner part of the skull, the pattern is said to be one of a "coup-contrecoup" injury. This just means hit-opposite hit.

Intracranial Bleeding

Bleeding inside the skull is never normal, and you will be shown an example of a subarachnoid bleed to show how different it looks from the other kinds of bleeding already covered.

Gas or Air Inside the Skull

Likewise, gas or air inside the skull is never normal. It commonly occurs when a fracture passes through a sinus or other part of the skull that contains air. This is called pneumocephalus. Vary examples will be shown.

Traumatic Axonal Injury

Traumatic axonal injury (TAI), also sometimes called diffuse axonal injury (DAI) or shear injury occurs when the axon of a nerve cell is damaged or severed near its origin from the cell body of the nerve cell, or neuron. Attendees will be shown the steps that occur as a brain is impacted by a blow and the axon is sheared or injured at or near the gray-white junction. This is the location of shear injury because that is the location near where the cell bodies of the neurons give rise to the axons or nerves that go elsewhere from the brain. TAI can be seen on CT, routine MR, and with advanced MR like DWI. Examples will be shown.

"Proving" Brain Injury Through Imaging

1. Obtain and review ALL previous brain studies (hard to get if the patient/client is under 7 years old).
    a. Are old studies normal or read as normal?
    b. Was anything missed on the first scans after the trauma?
2. Obtain and review ALL follow-up scans
    a. Check the report for appropriate history (headache vs. headache following MVA)
    b. Look for "non-specific findings" in reports
3. Consider Advanced Imaging →

Advanced Imaging

Newer methods exist for showing abnormalities in the brains of injured persons, including:

- gradient echo imaging (GE or GRE)
- susceptibility-weighted imaging (SWI) to find microhemorrhages.
- SWI is about 5-6 times more sensitive than GE, but this method also shows veins very well, and that makes it a little harder to see the hemorrhages. All MR machines can do GE, but only a few can do SWI.
- SPECT imaging is a nuclear medicine method that looks at the blood flow to the parts of the brain. Any damaged brain will show decreased blood flow to that area.
- PET scan imaging is a different type of nuclear medicine method, one that employs a dual-photon method. We give the patient a radioactive sugar molecule that is taken up by brain tissue. Abnormal brain takes up less than normal sugar, relative to the whole brain, and other normal areas that are working harder to compensate for the other abnormal areas show up as taking up more than the normal proportion of sugar. Thus, we can see normal, abnormal, and compensatory brain activity using PET.
- There are some very effective computer software packages that can measure the size of the brain or parts of it and compare it to normal brains. Since brain trauma can result in brain atrophy, this method is good for detecting that kind of outcome.

Evaluating Diffusion Tensor Imaging

Diffusion Tensor imaging or DTI uses the magnetic properties of water to create a map of the white matter in the brain. There are four ways to evaluate diffusion tensor imaging results that come from an advanced application using MRI:

1. Inspection –a visual inspection (can be time consuming) of the datasets gathered during DTI
2. Region-of-interest Measurements – Using an anatomically defined region (can be based on anatomical areas or simply a specified geometric shape) to extract DTI measures. Those measurements can be analyzed by manual delineation or by aligning all subjects to a template.
3. Tractography -- a 3D modeling technique used to visually represent nerve tracts using data collected by diffusion MRI by using special techniques and computer-based diffusion tensor imaging.
4. Voxel Based Statistics -- a computational approach to neuroanatomy that measures differences in local concentrations of brain tissue, through a voxel-wise comparison of multiple brain images. Voxel-wise analysis of DTI is characterized by spatial normalization of DTI, statistical analysis including hypothesis test at each voxel and multiple comparison correction.

Role of Imaging in Brain Trauma Cases Summary

1. History and physical examinations are used by doctors along with “laboratory results” that include radiology to arrive at diagnoses. Doctors can make diagnoses based on any one of these or by using a combination of these.
2. Radiology findings can provide a high level or a low level of evidence of brain trauma, or no evidence at all. However, the absence of evidence of brain trauma is not the same as evidence of the absence of brain trauma.
3. The strongest radiological evidence of brain trauma comes from the earliest and most basic studies, like the finding of blood in or around the brain immediately after a trauma. If you have that, you may not need advanced imaging, especially if you have a good history and positive physical exam findings.
4. Milder brain injuries may have no positive findings on what I call routine imaging techniques, like CT and routine MRI. But, if the patient has a good history and positive symptoms, advanced imaging methods may provide objective evidence to support a claim of brain injury.
5. Confounding factors, such as prior atrophy, ageing changes, migraine headaches, or previous head traumas from sports, military service, or prior single violent events make it harder to argue that any positive findings found after a particular injury are related to that injury.

GLOSSARY OF TERMS

Apparent diffusion coefficient map (ADC) -- a measure of the magnitude of diffusion (of water molecules) within tissue, and is commonly clinically calculated using MRI with diffusion weighted imaging (DWI)

Brain Contusion – a bruise of the brain tissue. Also known as cerebral contusion

Brain Edema – fluid collection around the brain, causing an increase in intracranial pressure. Also known as cerebral edema

Computed Axial Tomography -- pictures of structures within the body created by a computer that takes the data from multiple X-ray images and turns them in pictures (CAT scan/ CT scan)

Coup Injury – an injury on the impact side of the brain

Contrecoup Injury – an injury on the opposite side of the brain from the impact

Coup-Contrecoup Injury – injuries on both the impact and opposite sides of the brain

GLOSSARY OF TERMS CONTINUED

Dura Mater - a tough, thick layer of fibrous tissue between the brain and the skull

Diffuse Axonal Injury (DAI) -see also Shear Injury and Traumatic Azonal Injury -- occurs when the axon of a nerve cell is damaged or severed near its origin from the cell body of the nerve cell, or neuron

Diffusion Tensor Imaging -- the use of specific MRI sequences as well as software that generates images from the resulting data using the diffusion of water molecules to generate contrast in MR images

Epidural Hematoma -- bleeding just under the skull and above the dura

Gradient Echo Imaging -- an alternative technique to spin echo sequences, differing from it in two principal points: utilization of gradient fields to generate transverse magnetization, and flip angles of less than 90° (GR or GRE) [all MRI scanners can do this]

Hematoma – an abnormal collection of blood outside the blood vessels

Hemorrhage – bleeding from a ruptured blood vessel, especially when profuse

Intraparenchymal Hemorrhage -- bleeding in which there is bleeding within brain parenchyma

Magnetic Resonance Imaging -- measures the response of the atomic nuclei of body tissues to high-frequency radio waves when placed in a strong magnetic field, and that produces images of the internal organs. (MRI)

Nuclear Medicine Studies -- a branch of medical imaging that uses small amounts of radioactive material to diagnose and determine the severity of or treat a variety of diseases

Parenchyma -- the functional tissue of an organ as distinguished from the connective and supporting tissue.

Pneumocephalus -- gas or air inside the skull (never normal)

Radiographs -- an image produced on a sensitive plate or film by X-rays, gamma rays, or similar radiation

Shear Injury – See also Diffuse Axonal Injury (DAI) and Traumatic Axonal Injury (TAI) -- occurs when the axon of a nerve cell is damaged or severed near its origin from the cell body of the nerve cell, or neuron

Sonogram -- a visual image produced from an ultrasound examination

SPECT scan -- A single-photon emission computerized tomography is a nuclear imaging scan that integrates computed tomography (CT) and a radioactive tracer. The tracer is what allows doctors to see how blood flows to tissues and organs.

Subarachnoid Hemorrhage - bleeding into the space surrounding the brain within the sulci.

Subdural Hematomas – bleeding between the dura mater and the brain

Sulci – the furrows or grooves on the surface of the brain

Susceptibility-Weighted Imaging -- originally called BOLD venographic imaging, is an MRI sequence that is exquisitely sensitive to venous blood, hemorrhage and iron storage. SWI uses a fully flow compensated, long echo, gradient recalled echo (GRE) pulse sequence to acquire images. (SWI) [only some MRI scanners can do this]

Traumatic Axonal Injury (TAI) – see also Diffuse Axonal Injury (DAI) and Shear Injury -- occurs when the axon of a nerve cell is damaged or severed near its origin from the cell body of the nerve cell, or neuron