

# WELCOME

## Overview of Imaging for Traumatic Brain Injury from Current Standards to Advanced Techniques

Moderator



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Co-site Director, DVBIC  
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Fort Sam Houston, Texas

# Continuing Education

This webinar has been approved for the following:

- **1.5 AMA PRA Category 1 Credits™**
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- **1.5 Nursing Contact Hours**
- **1.75 CE Contact Hours for Physical and Occupational Therapists and Assistants**
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To receive CE credits, you are REQUIRED to pre-register for this webinar. If you have not yet registered and received an email confirmation, please register at <http://dcoe.adobeconnect.com/dvbicfebruarywebinar/event/registration.html>

Registration will remain open until 1:15 p.m. EST.

# Continuing Education

## **PRE-REGISTERED**

**ON or BEFORE February 14, 2013**

Visit <http://conf.swankhealth.com/dvbic> and complete the online evaluation in order to receive a continuing education certificate.

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The above website will be available starting February 22, 2013.

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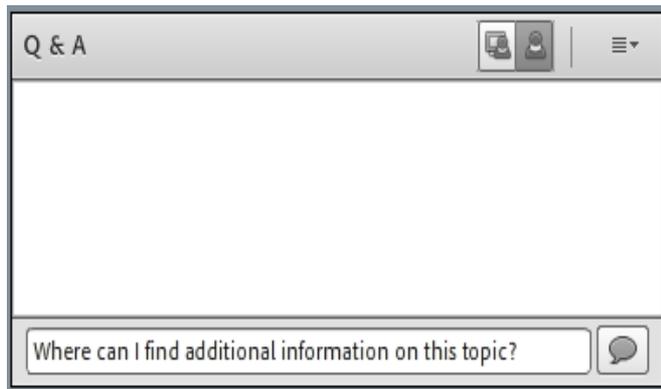
**Website will close on March 13, 2013.**

For full accreditation information, visit [www.DVBIC.org](http://www.DVBIC.org) and click on “Medical Providers” to access the Winter Webinar Series. It is the responsibility of the participant to understand his or her board’s continuing education requirements.

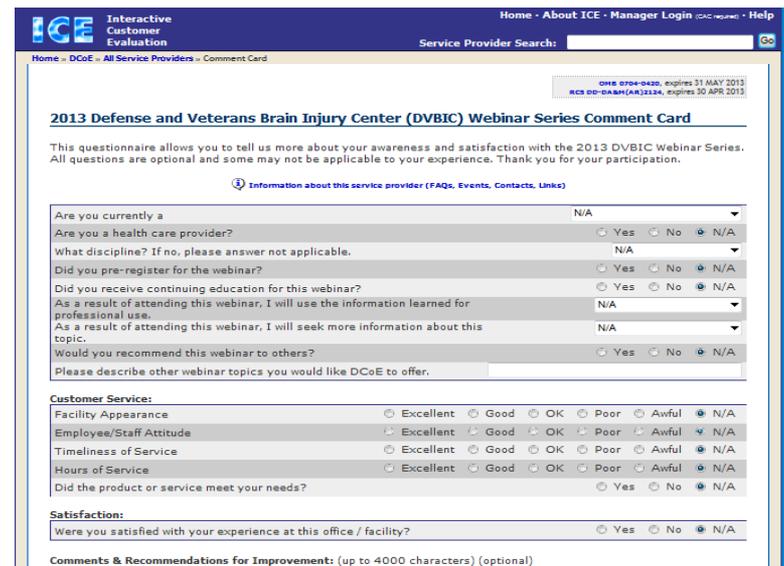
# Additional Webinar Details

This presentation with audio will be available online beginning March 1, 2013 at <http://www.dvbic.org/online-education>

Please submit your questions using the **Q&A** box located on your screen.



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# Topic Overview



# Gerald York, LTC, MC



Director of Research, Radiology  
Co-site Director, DVBIC  
San Antonio Military Medical Center  
Fort Sam Houston, Texas

Dr. York has expertise in the interpretation of MRI of the brain, spinal cord and head-neck disorders. He reads about 12,000 neuroradiology cases per year, including many acute, sub-acute and chronic TBI cases. His research focuses on imaging of changes in cognitive rehabilitation in TBI patients and chronic changes in brain function and structure. He also oversees projects involving MRI and PET imaging in TBI.

He has lectured nationally on combat-related TBI and neuroimaging. He participates on imaging working groups with the Defense Centers of Excellence for Psychological Health and Traumatic Brain Injury, as well with the National Intrepid Center of Excellence. He also works with the Polytrauma Center to study chronic sequelae of TBI in veterans of Operation Iraqi Freedom, Operation Enduring Freedom and Operation New Dawn.

# **Overview of Imaging for Traumatic Brain Injury from Current Standards to Advanced Techniques**

**Gerald York, LTC, MC**

**Director of Radiology Research and Co-Site  
Director of DVBIC, SAMMC**

# Disclaimer

- The following presentation does not represent the opinions or views of San Antonio Military Medical Center, Army Medical Department, U.S. Army, or Federal Government.
- I have no financial disclosures to report.

# Overview

- Standard Imaging, basis and application
  - CT
  - MRI
  - Nucs: SPECT/PET
  - TCD
- Advanced Imaging/Research
  - CT
  - MRI
  - Nucs: PET ligands

# Computed Tomography (CT)

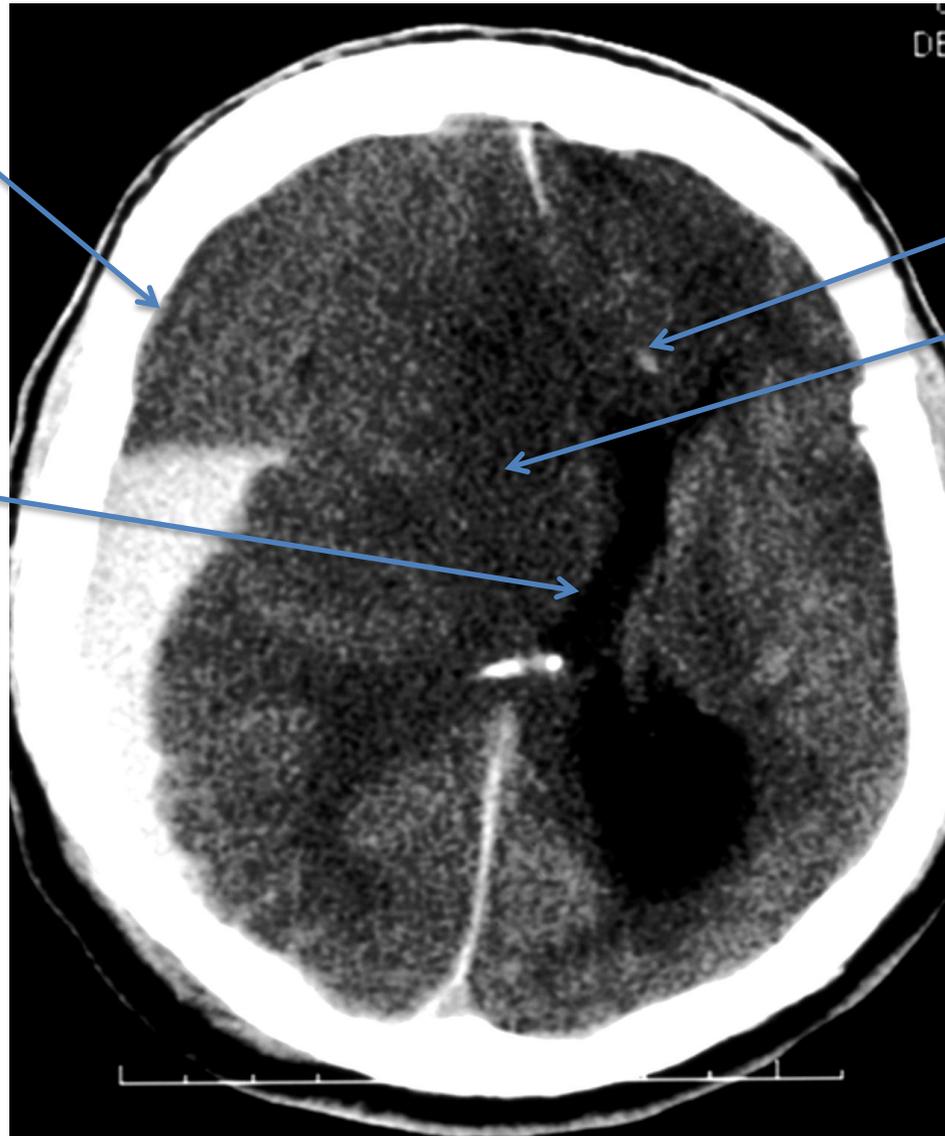
- Uses ionizing radiation (x-rays)
- Thin, overlapping slices allow reformations into multiple planes (multislice >16)
- Standard initial evaluation in civilian and military practice
- Allows anatomic localization
  - Detection of hemorrhage
  - Loss of gray-white matter for stroke/secondary edema

# CT Quickly Localizes Hemorrhage

- Surgical vs. Non-surgical?
- Subdural
- Epidural
  - Arterial
  - Venous (middle cranial fossa; peds)
- Subarachnoid
- Ventricular

Subdural

Subfalcine  
Herniation



DAI

Edema

Image courtesy of  
LTC Gerald York

# Acute SDH

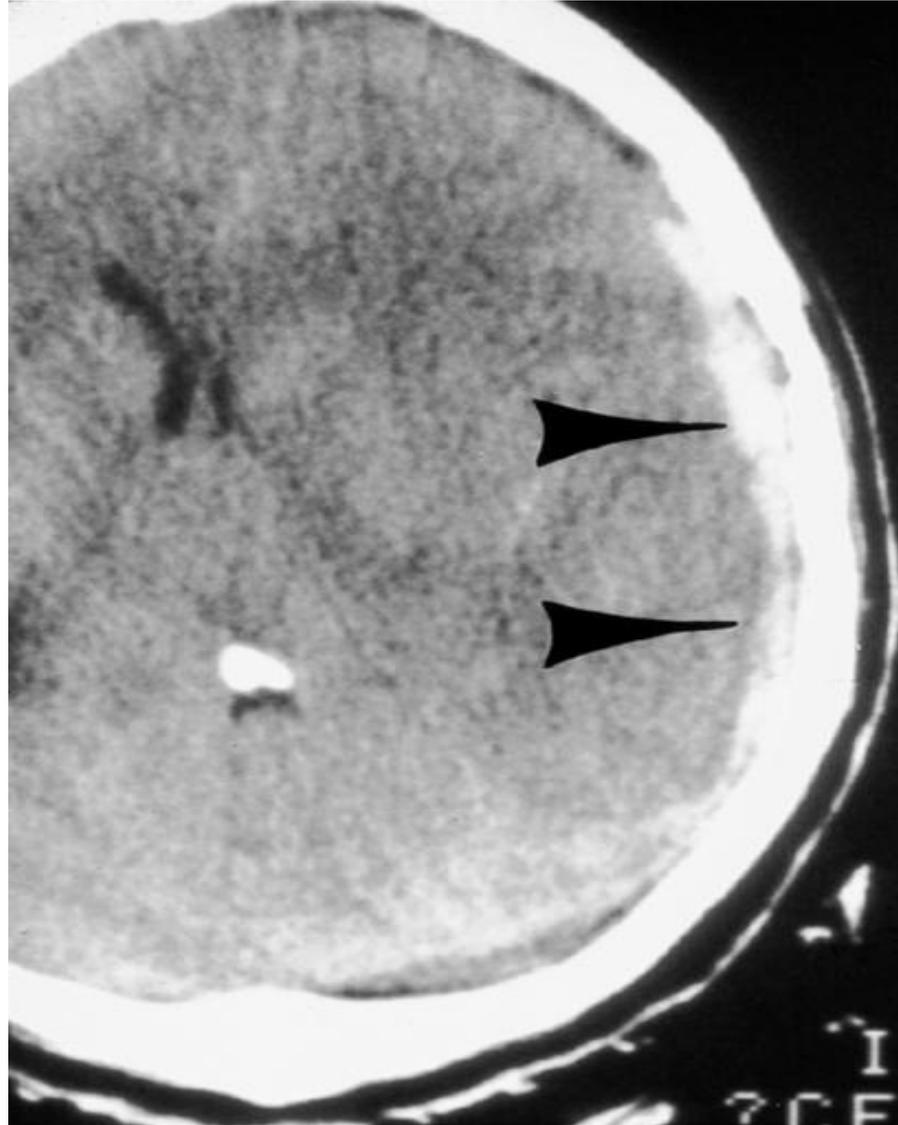


Image courtesy of  
LTC Gerald York

# Epidural Hematoma

- Lucid Interval in 50%
- Delayed enlargement in 10%-30%, usually in first 24-48 hours



Image courtesy of LTC Gerald York

**Venous EDH**

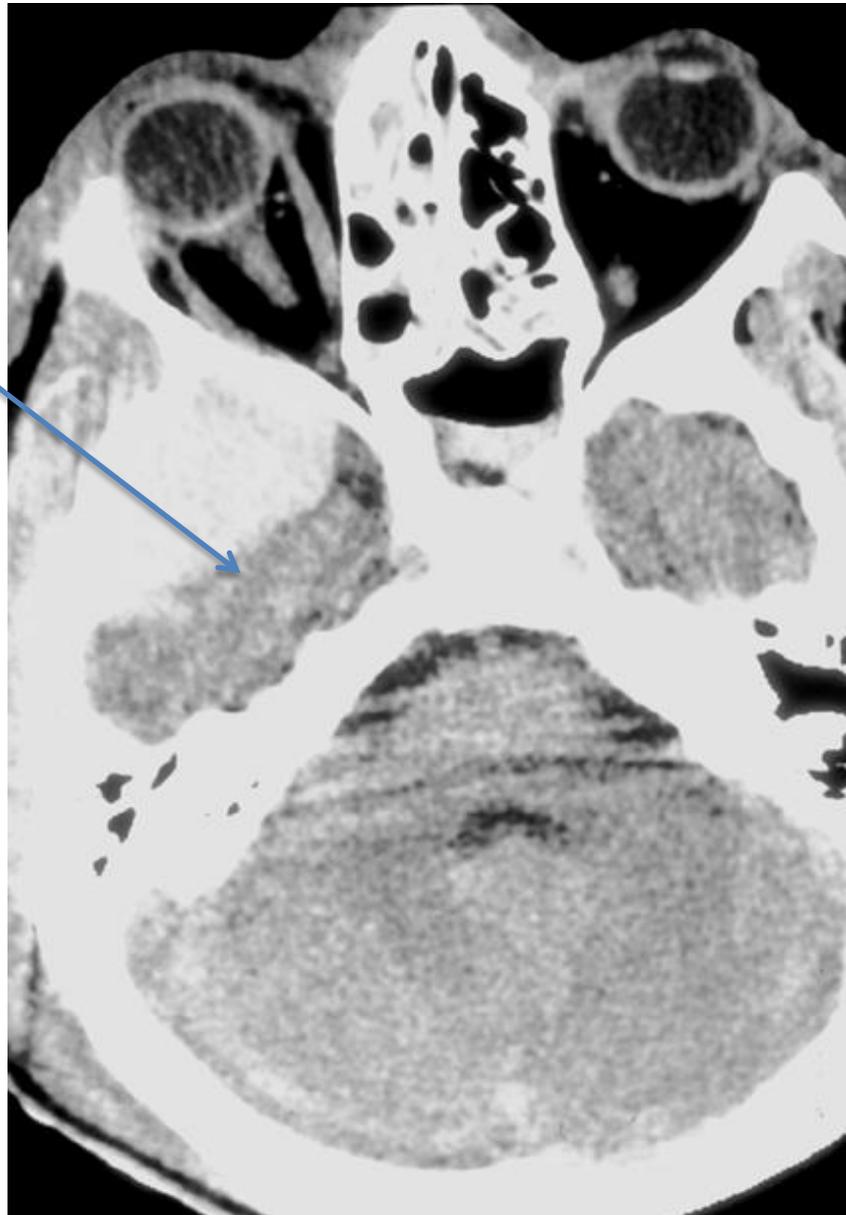
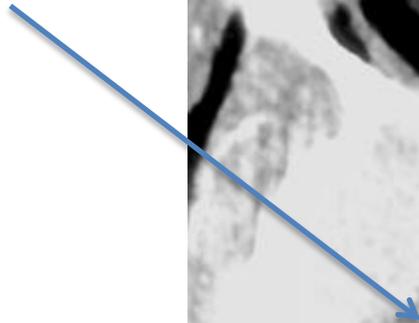


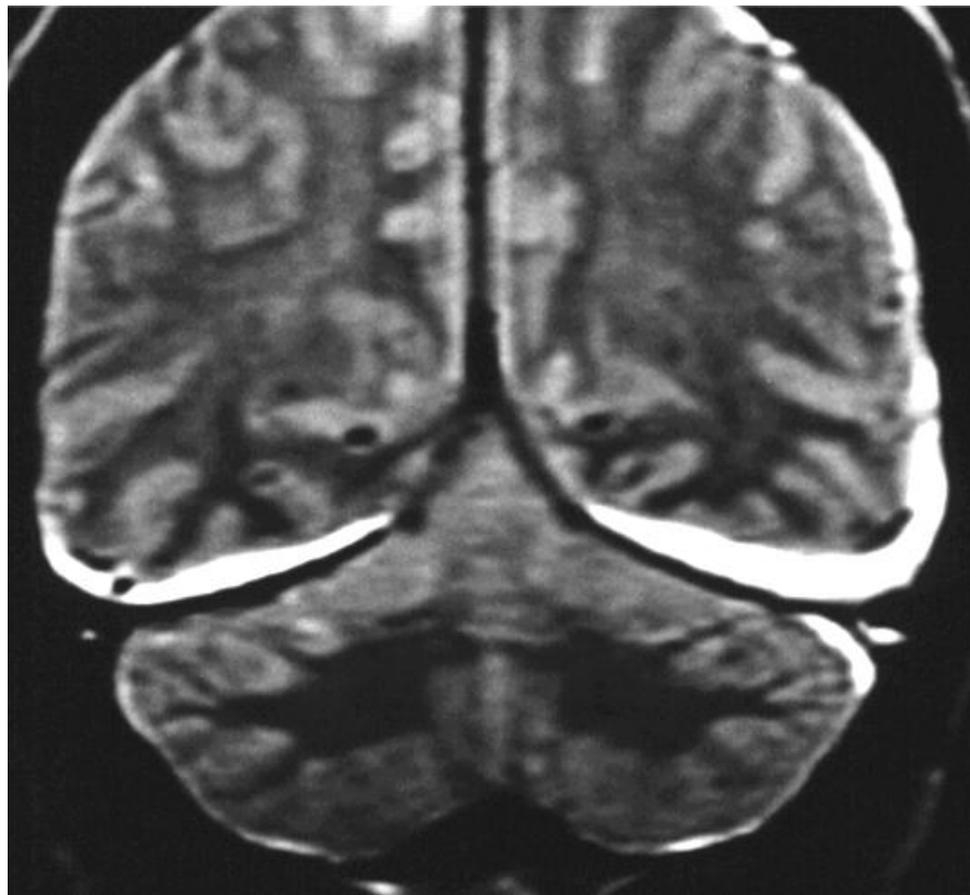
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# Bilateral Chronic SDH



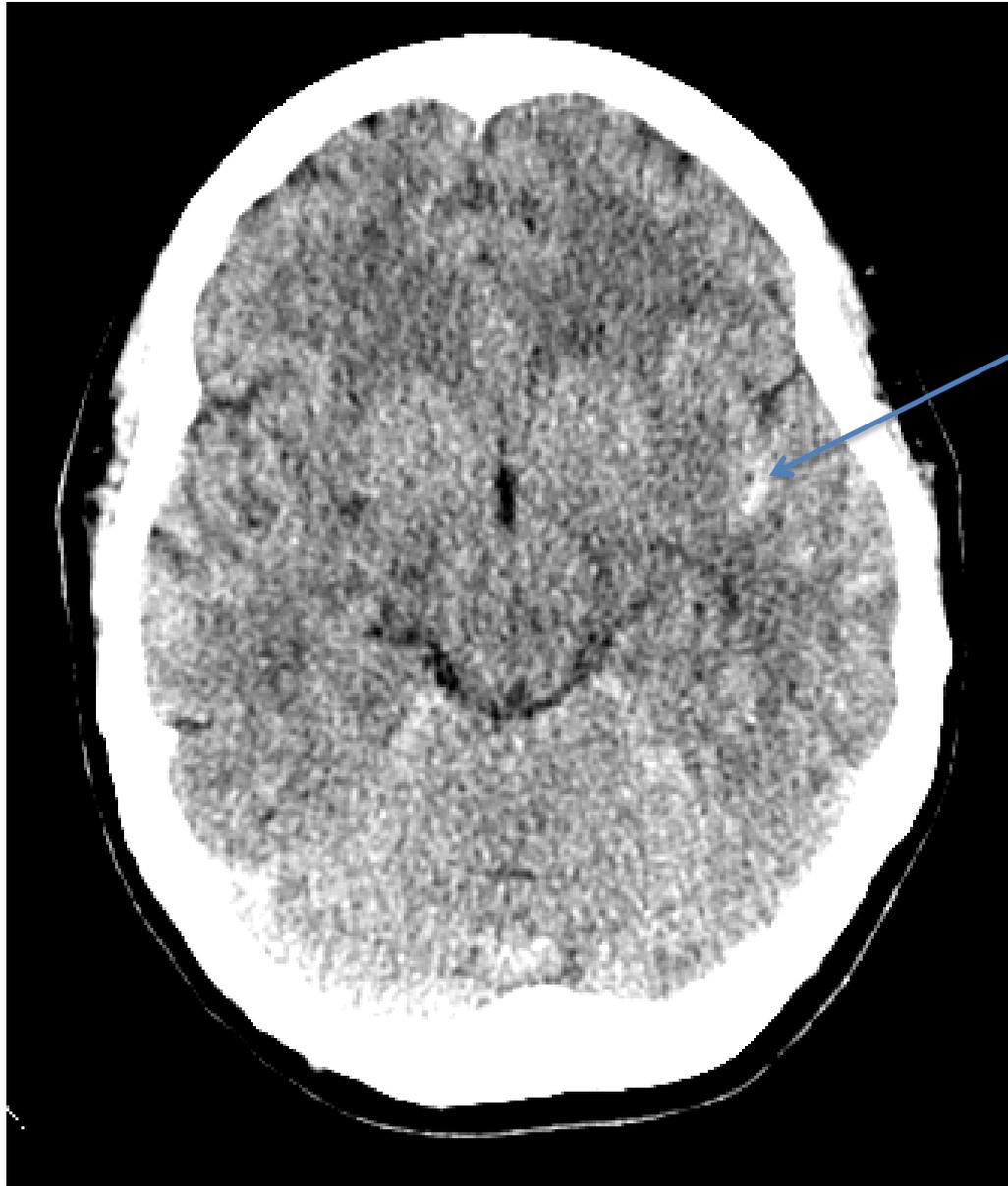
Image courtesy of  
LTC Gerald York

# Tentorial SDH



T2 Weighted MRI, Coronal

Images courtesy of LTC Gerald York



## SAH

- trauma
- aneurysm
- stroke

Image courtesy of  
LTC Gerald York

# SDH + SAH

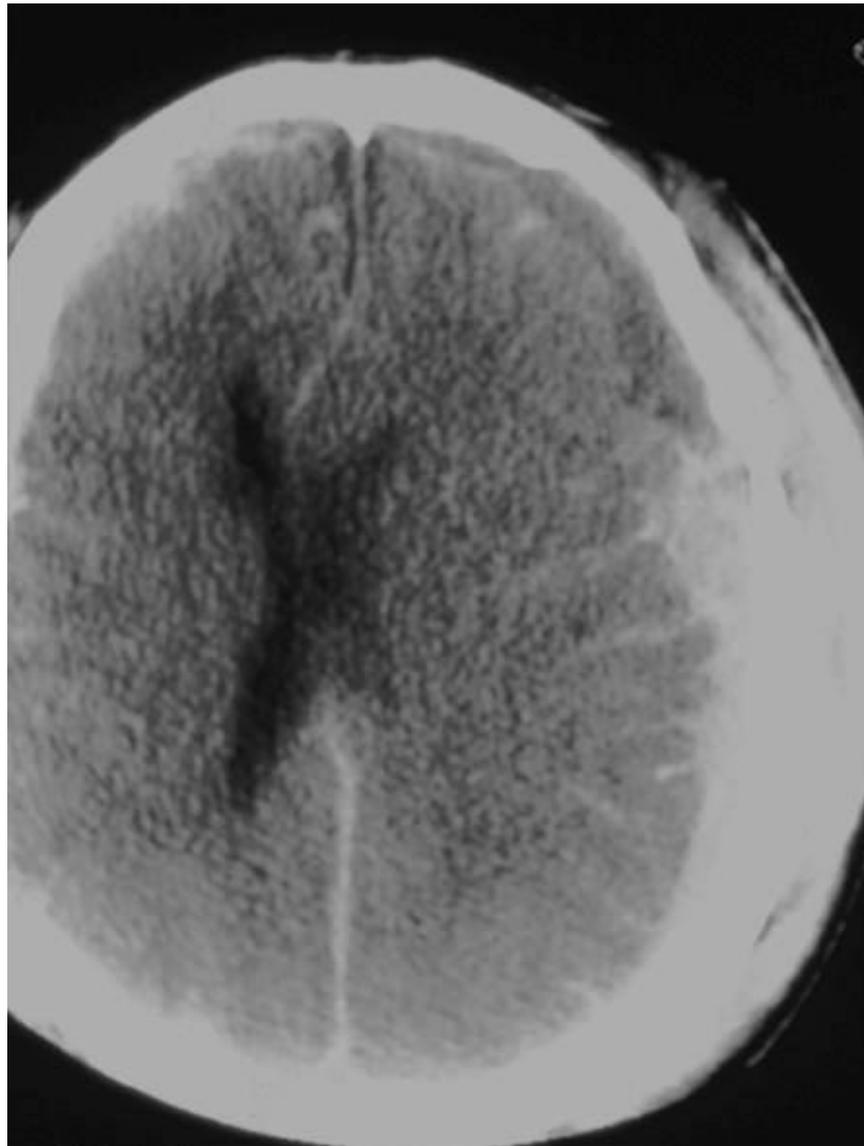


Image courtesy of  
LTC Gerald York

# DAI



Image courtesy of  
LTC Gerald York

# CT

## Advantages

- Fast
- Readily available; Deployed in CSH since 90's
- High linear resolution
  - Helpful for evaluation of fractures (skull base, etc.)

## Disadvantages

- Ionizing radiation
- Limited functional information
- Lower sensitivity than MRI for DAI/TAI

# Current Guidelines for CT Use

- New Orleans Criteria (NOC): GCS 15
  - Headache, vomiting, age>60, EtOH/Drug Intoxication
  - Persistent anterograde amnesia, visible trauma above clavicles, seizure
- Canadian CT Head Rule (CCHR): GCS 13-15
  - High Neurosurg Intervention: GCS <15 after 2hrs, suspect open or depressed skull fx
  - Any sign of basal skull fx (hemotympanum, raccoon eyes, csf otorrhea or rhinorrhea, Battle's sign)
  - 2 or more episodes of vomiting, age > 65 years.
  - Medium risk for brain injury: amnesia before impact of greater than 30 minutes, "dangerous mechanism"
- American College of Radiology (ACR)
  - Combination of these studies; best practice guideline

# Comparison of CCHR and NOC

- Equivalent high sensitivities for:
  - Detecting any traumatic intracranial injury
  - Determining need for neurosurgical intervention
- CCHR higher specificity and showed greater potential to lower neuroimaging rates

Papa L, Stiell I, Clement C, et. al., "Performance of the Canadian CT Head Rule and the New Orleans Criteria in Predicting Any Traumatic Intracranial Injury on Computed Tomography in a United States Level I Trauma Center." Academic Emergency Medicine, Jan 2012, 19:1-10.

# CT and Secondary Injury

- Ischemia/Infarct due to vascular injury
- Swelling due to ischemia vs. reaction to contusion
- Herniation patterns:
  - Subfalcine
  - Transtentorial
    - Ascending/Descending
  - Tonsillar

# Hematoma Infarct Descending Transtentorial and Uncal Herniation

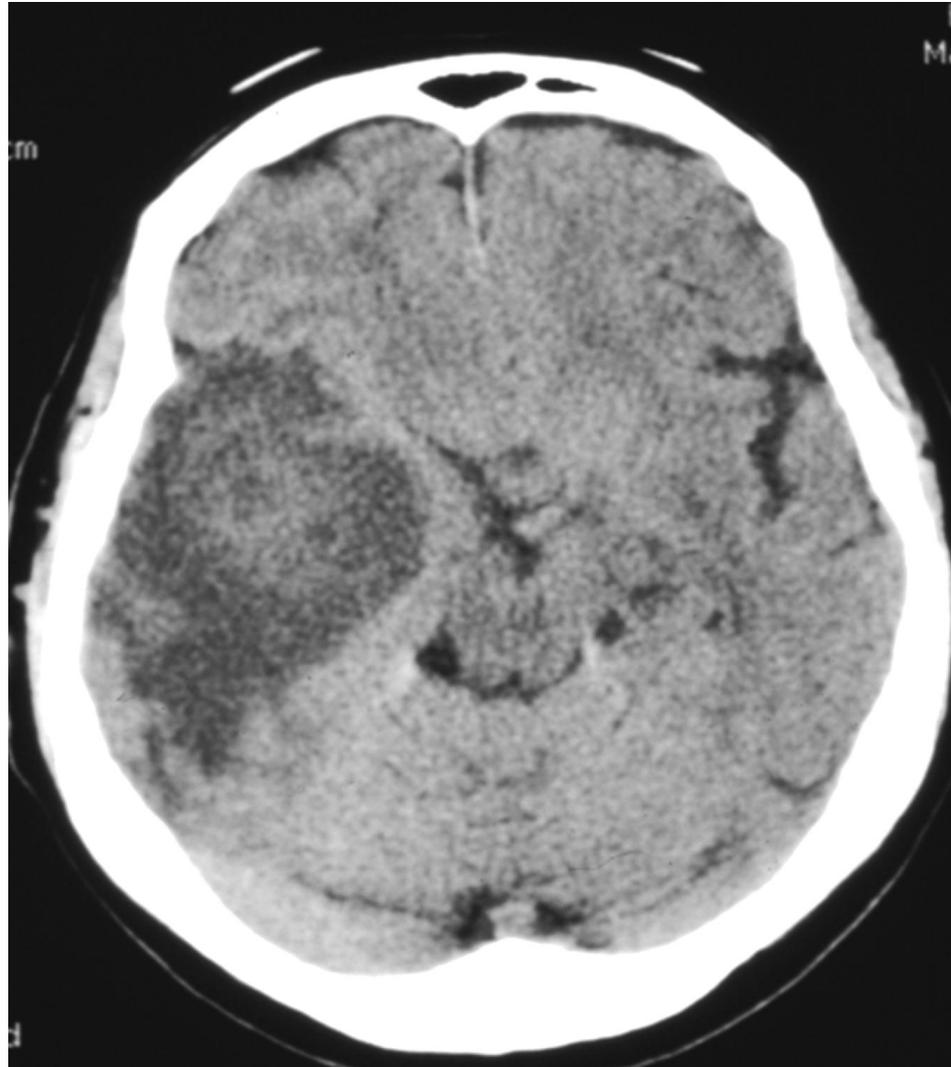


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# Encephalomalacia

-Chronic effect of prior trauma

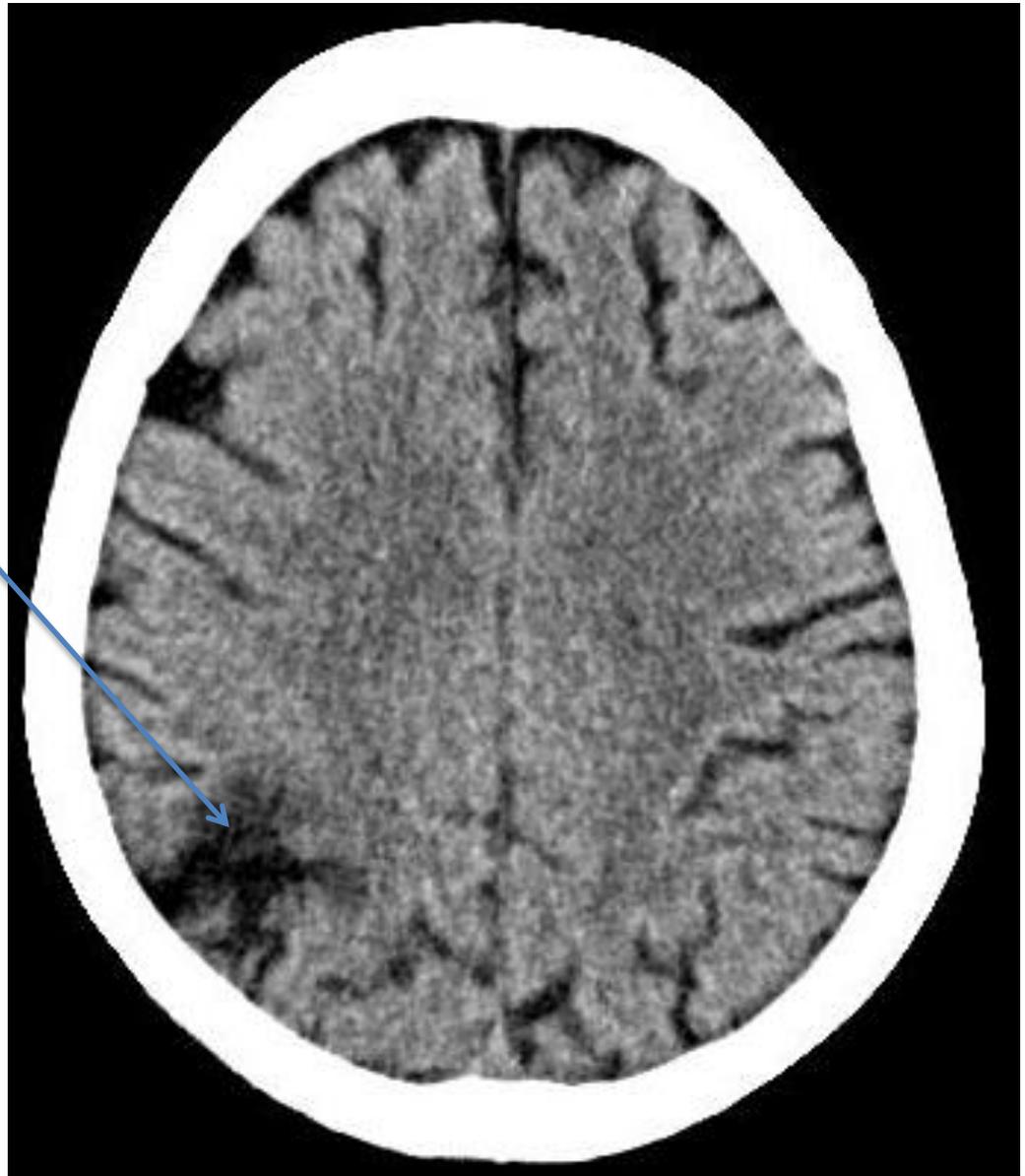


Image courtesy of  
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# CT Perfusion

- Increased mean transit time (MTT) in regions affected by vascular injury
  - Measured in seconds
  - Normal MTT is <6 seconds
- Decreased cerebral blood flow (CBF) in regions affected by trauma
  - Normal CBF is >70 cc/100g/min
- Decreased blood flow in occipital and frontal lobes post-trauma, reported even in mTBI
  - May worsen secondary to vascular injury and edema

# MTT: Mean Transit Time

Right MCA dissection  
and stenosis  
-Significant increase of  
MTT on the right  
(green to red = 9-12  
sec)

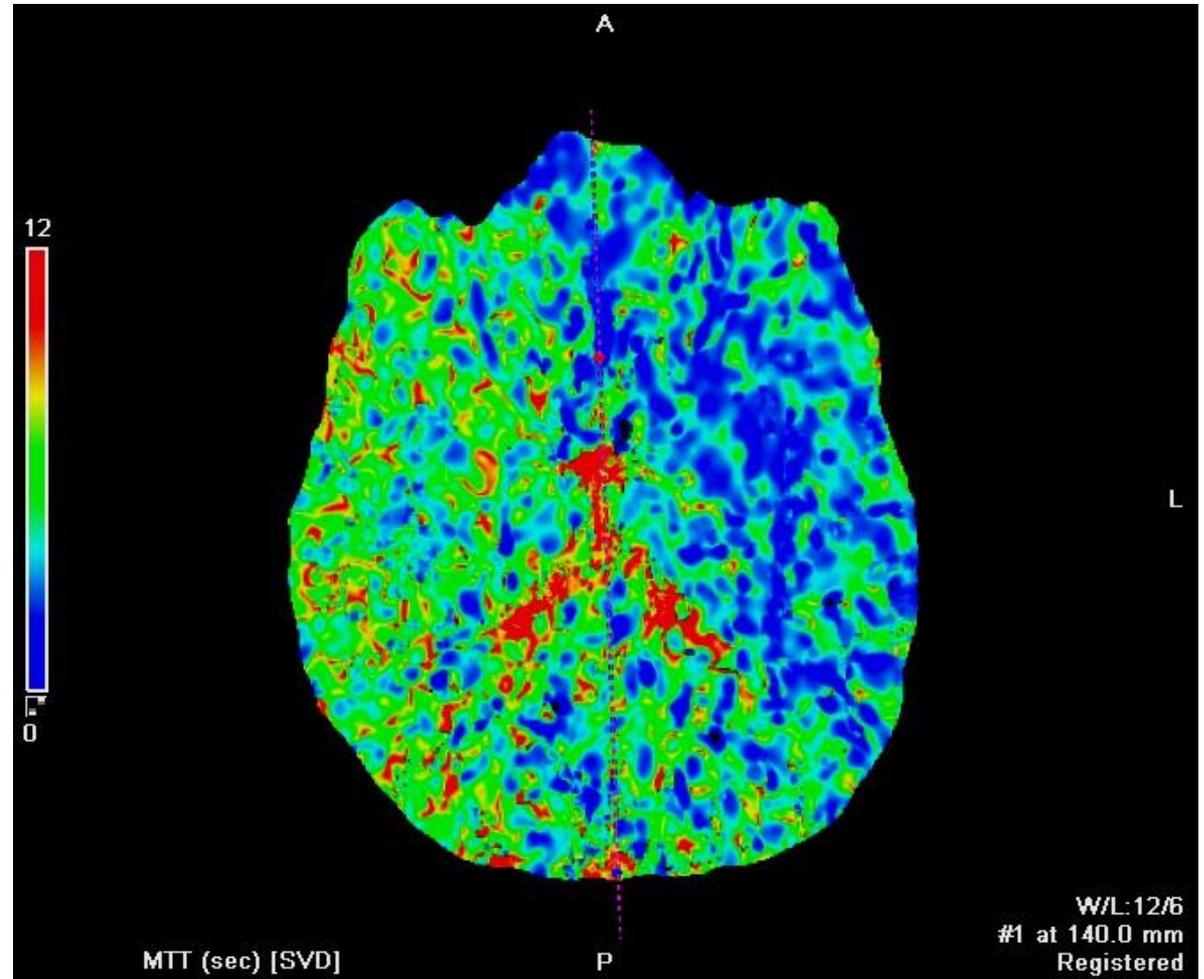
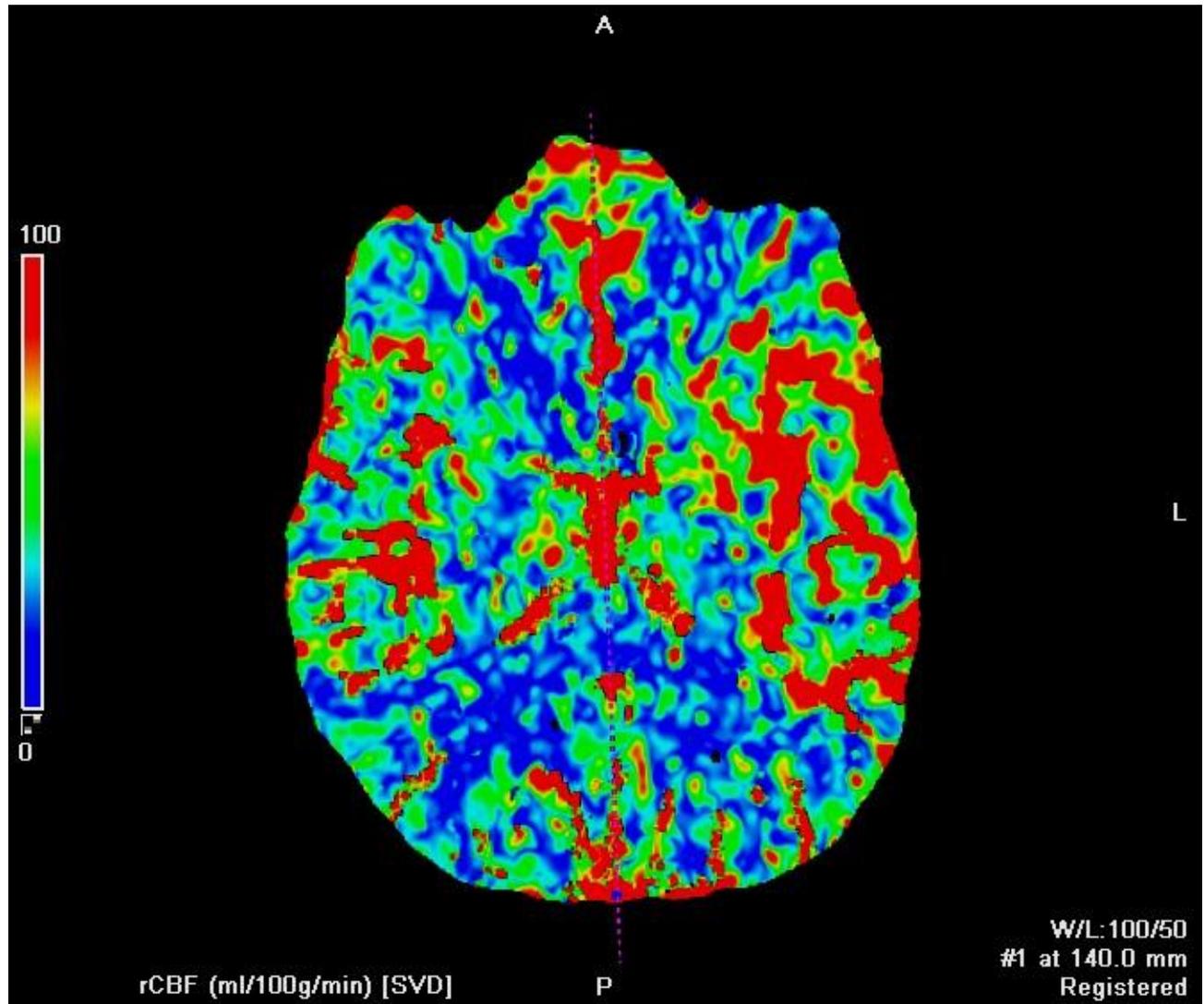


Image courtesy of LTC Gerald York

# CBF: Cerebral Blood Flow

Decreased CBF  
<70 mL/100g/min  
on the right



Audience Participation: Please submit your answer via the polling box on your screen.

## What is an advantage of CT?

- A) It uses ionizing radiation.
- B) It allows for better characterization of brain function.
- C) It has excellent linear resolution compared to MRI.
- D) There is no advantage of CT compared to MRI.

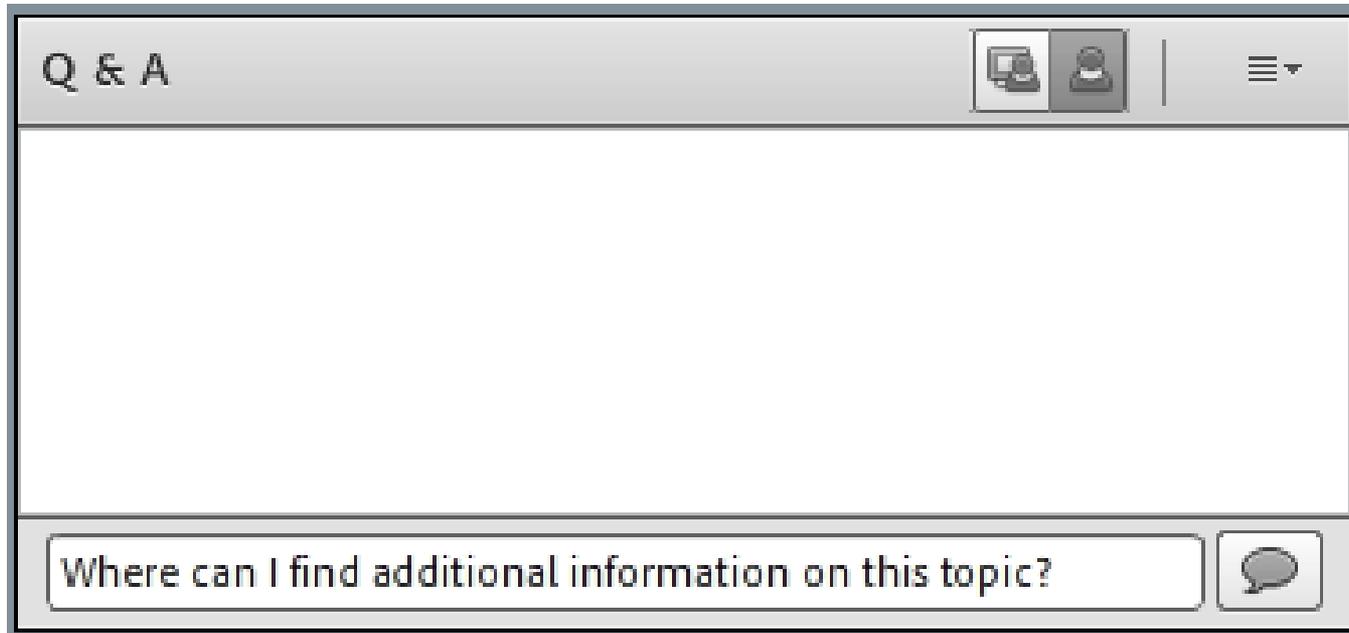
Audience Participation: Please submit your answer via the polling box on your screen.

## How is CT perfusion helpful in the acute TBI evaluation?

- A) Allows definitive diagnosis of mild TBI.
- B) Does not involve ionizing radiation.
- C) Provides accurate assessment of final injury status.
- D) Gives important information regarding possible vascular injury.

# Questions about CT?

Please submit your CT-related questions to Dr. York via the Q&A box located on your screen.



The image shows a screenshot of a Q&A interface box. The box has a grey header with the text "Q & A" on the left, a small icon of a person and a computer on the right, and a vertical line separator. Below the header is a large white text area. At the bottom of the box is a text input field containing the text "Where can I find additional information on this topic?" and a speech bubble icon to its right.

# MRI in TBI

# MRI: Overview

- Magnetic Resonance Imaging
  - NON-ionizing radiation (radiofrequency)
- True multi-planar imaging
- Relies on contrast of tissues to image
  - Water, fat....hydrogen imaging
- Physiologic and metabolic imaging
  - Flow (blood, csf)
  - Spectroscopy

# MRI: Routine imaging

- Anatomic data
  - Hemorrhage on FLAIR/SWI/T1
    - SWI = Susceptibility Weighted Imaging
  - Stroke on DWI (diffusion trace)
  - Thin T2/FLAIR for baseline in trauma
- Volumetric changes
  - Semi-automated (FreeSurfer, research)
  - Automated (NeuroQuant, clinical)
- MRA if concern for vascular compromise

## FLAIR

- Post-trauma
- T2 bright spots (UBO)

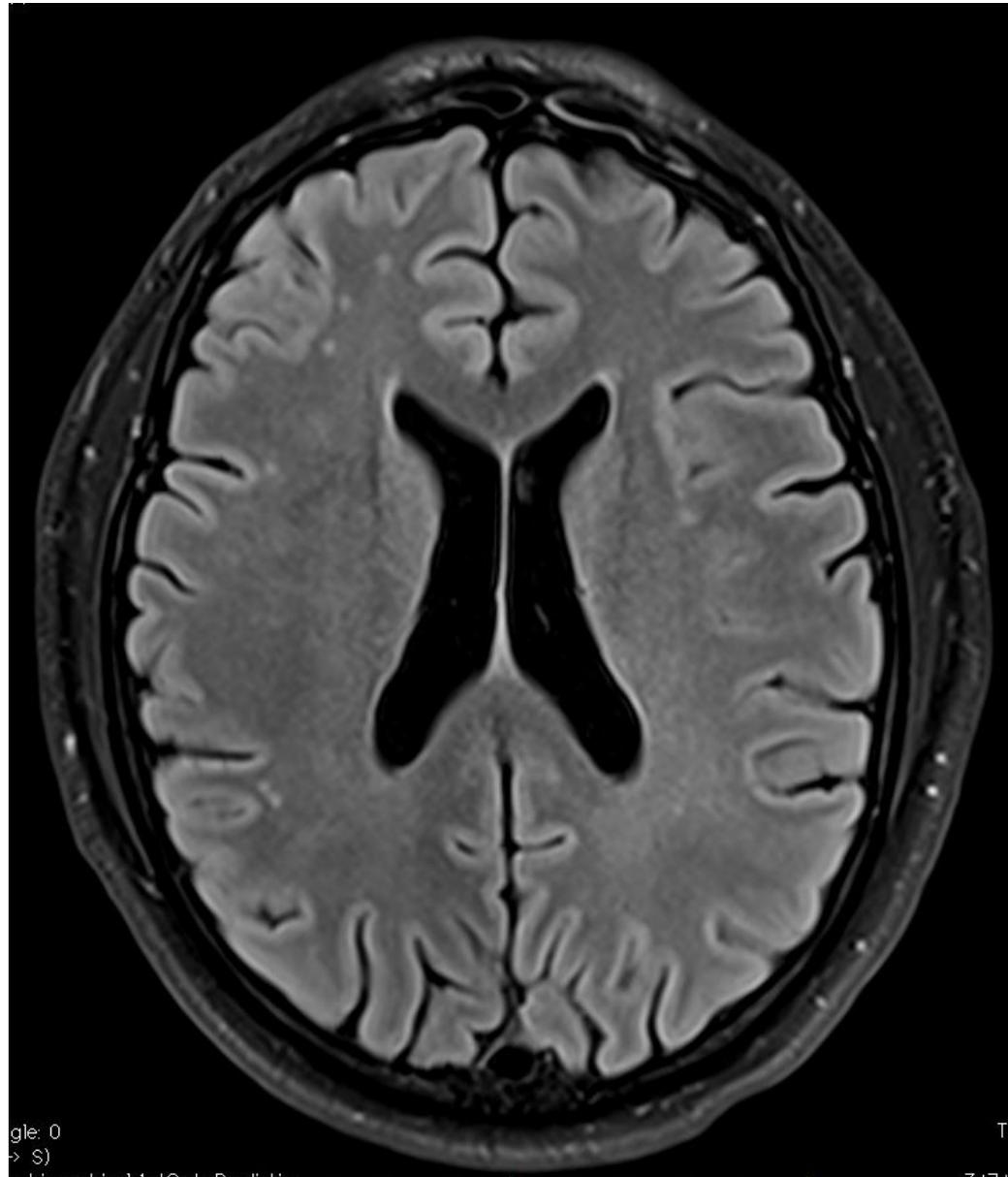
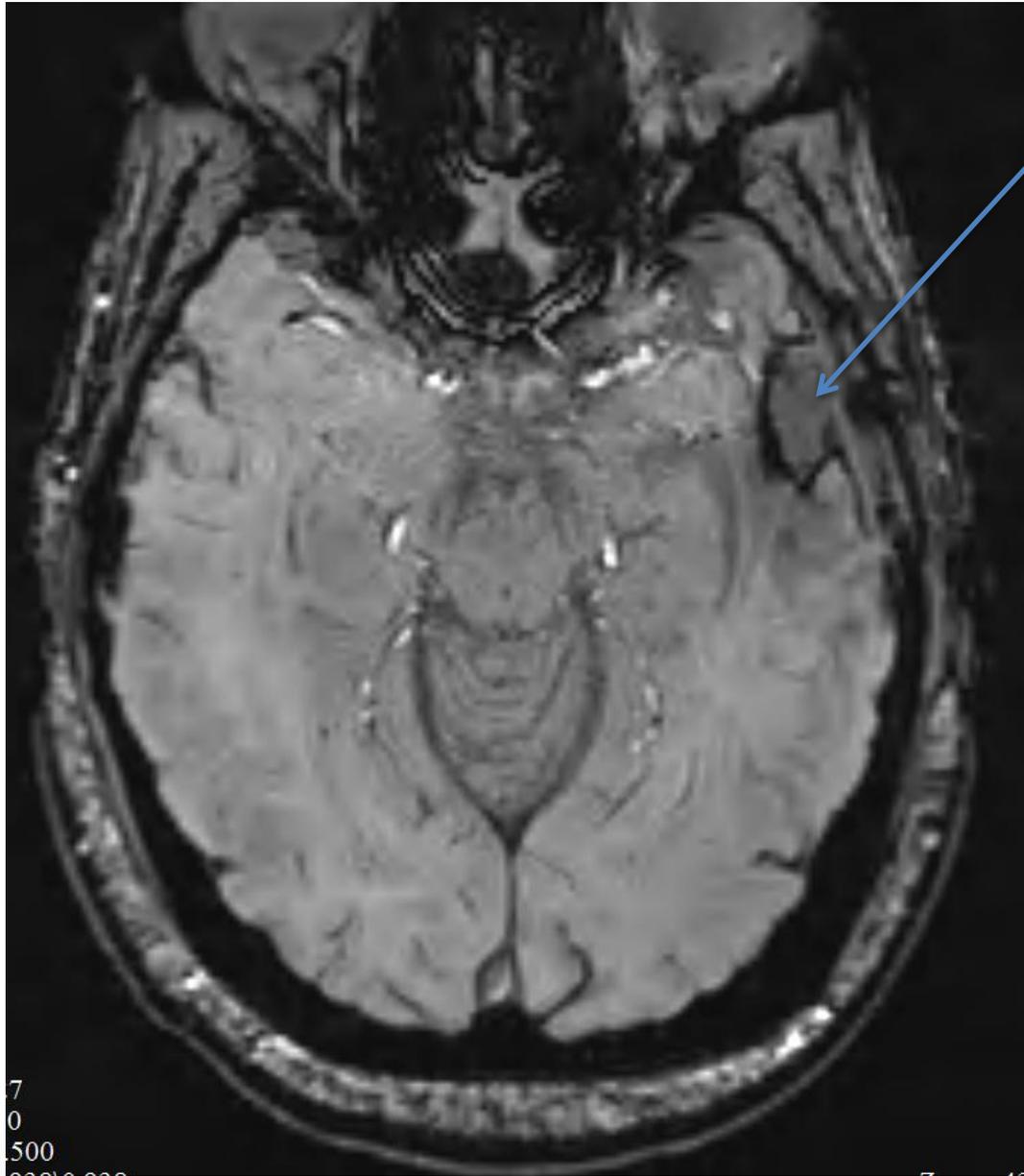


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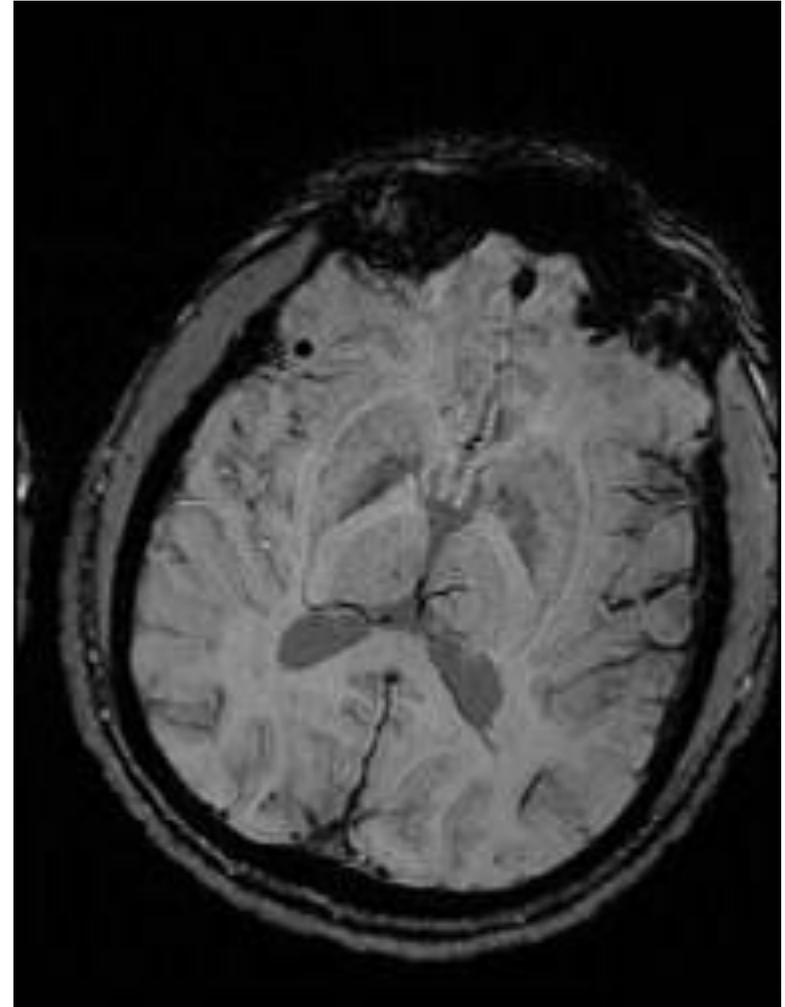
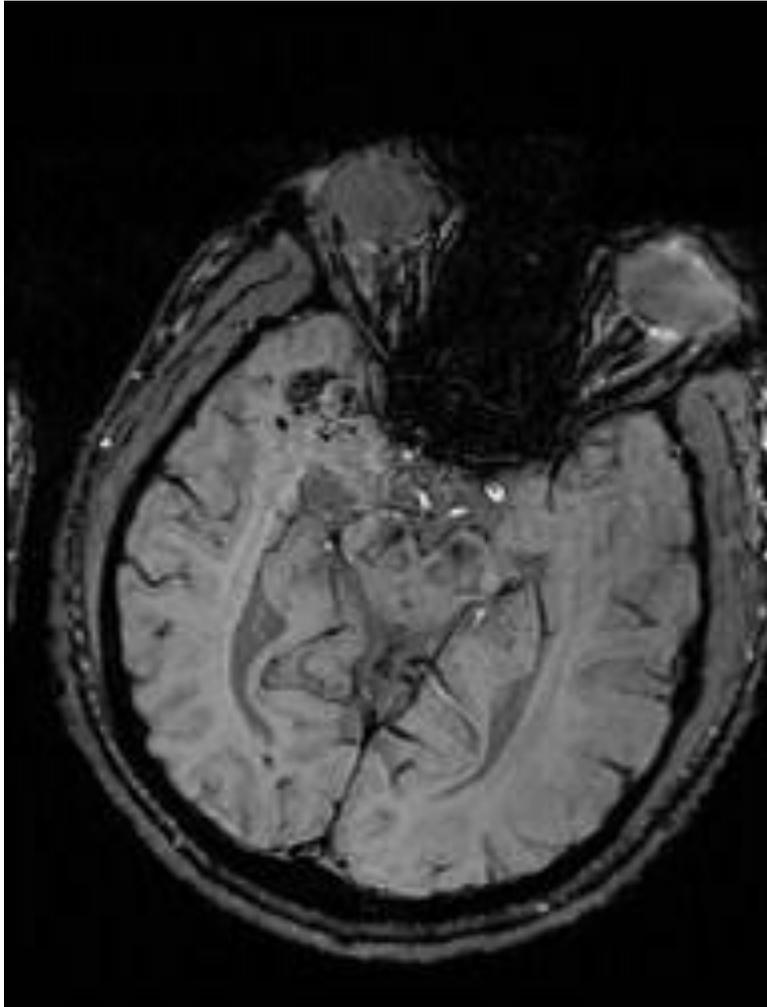


SWI

Hemosiderin in post-surgical  
cavity

Image courtesy of  
LTC Gerald York

# SWI



Images courtesy of LTC Gerald York

# Volumetrics: Segmentation Analysis

Segmentation

-Gray-White Matter  
(BrainVISA)

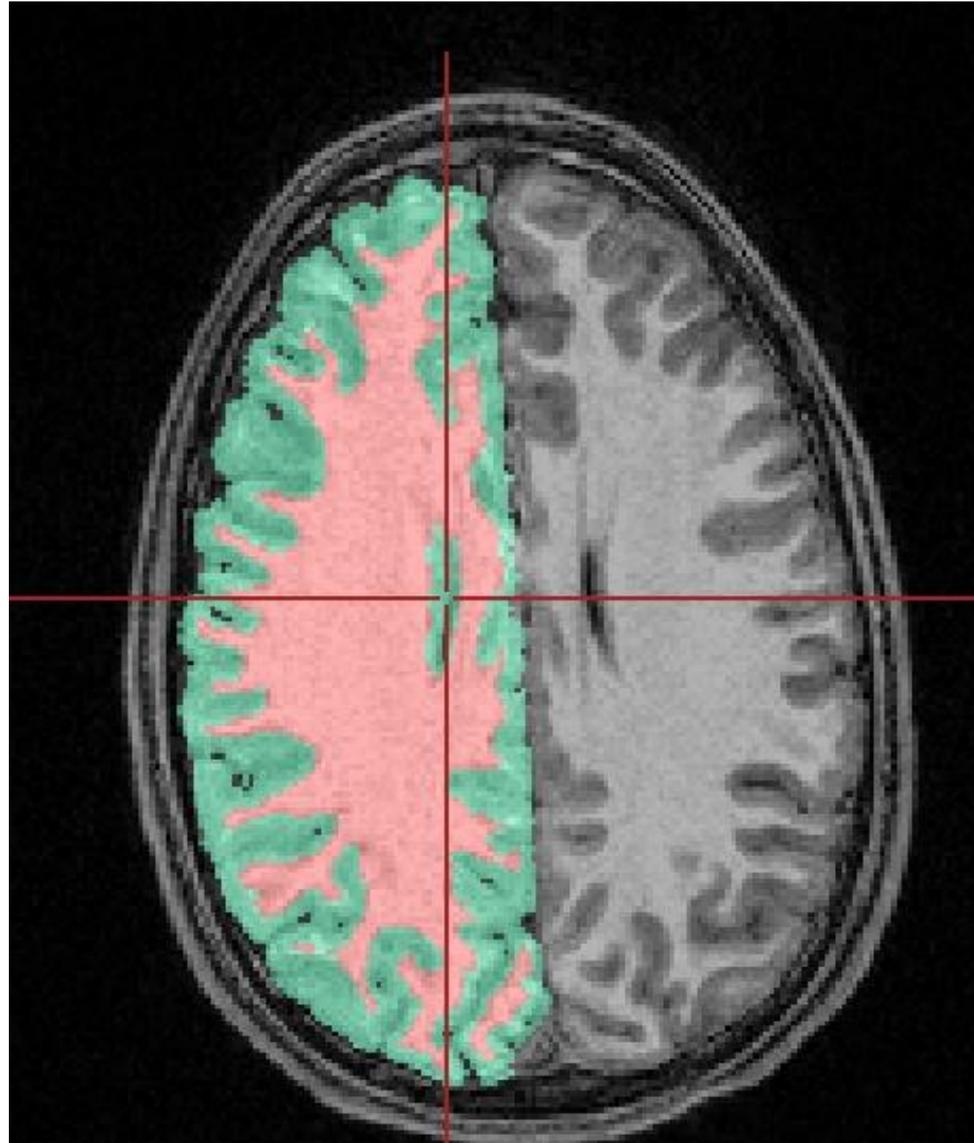


Image courtesy of  
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## White Matter Mesh -based on segmentation

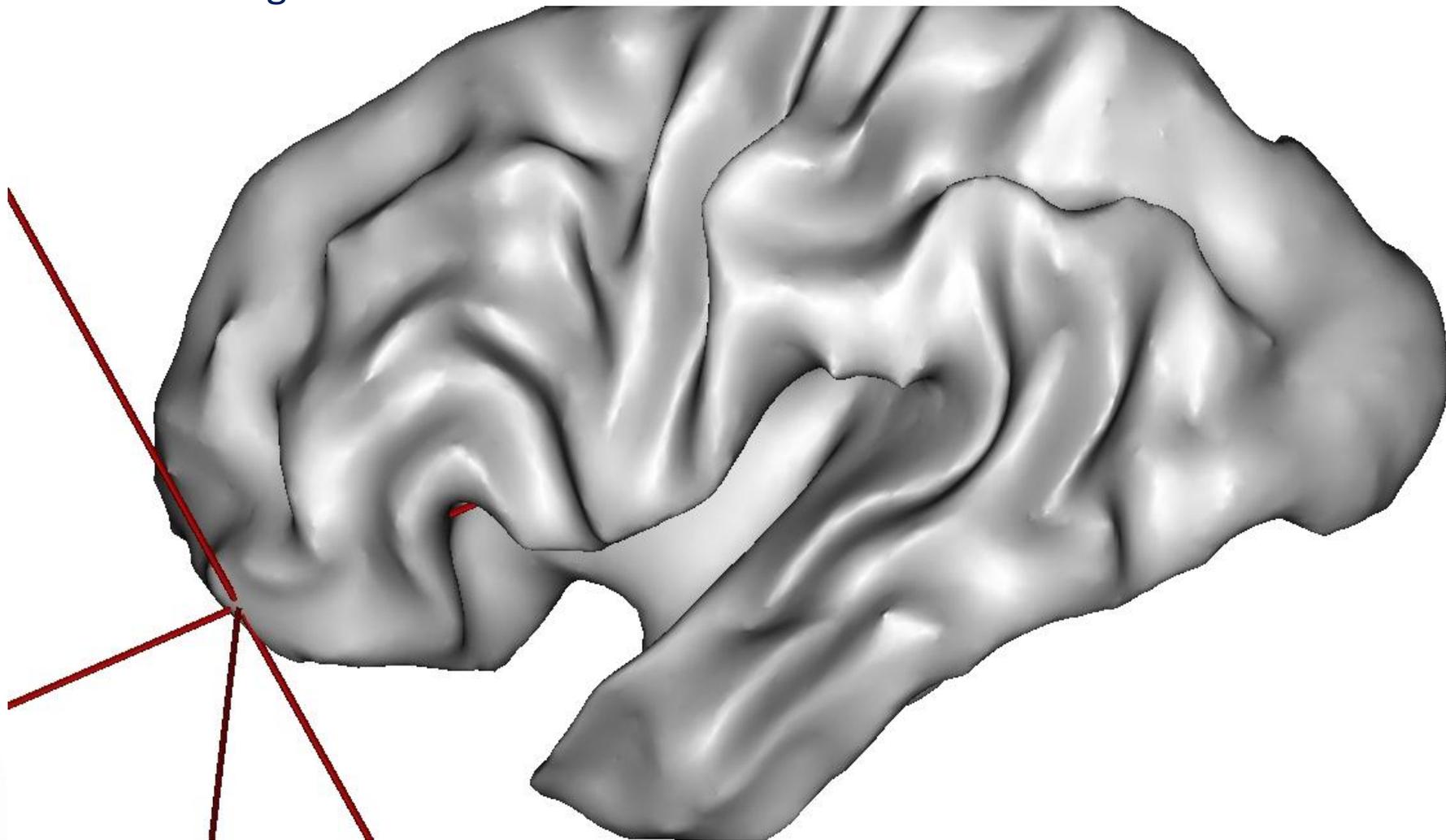


Image courtesy of LTC Gerald York

# Sulcal Volumes processed with BrainVISA

-TBI patient: baseline

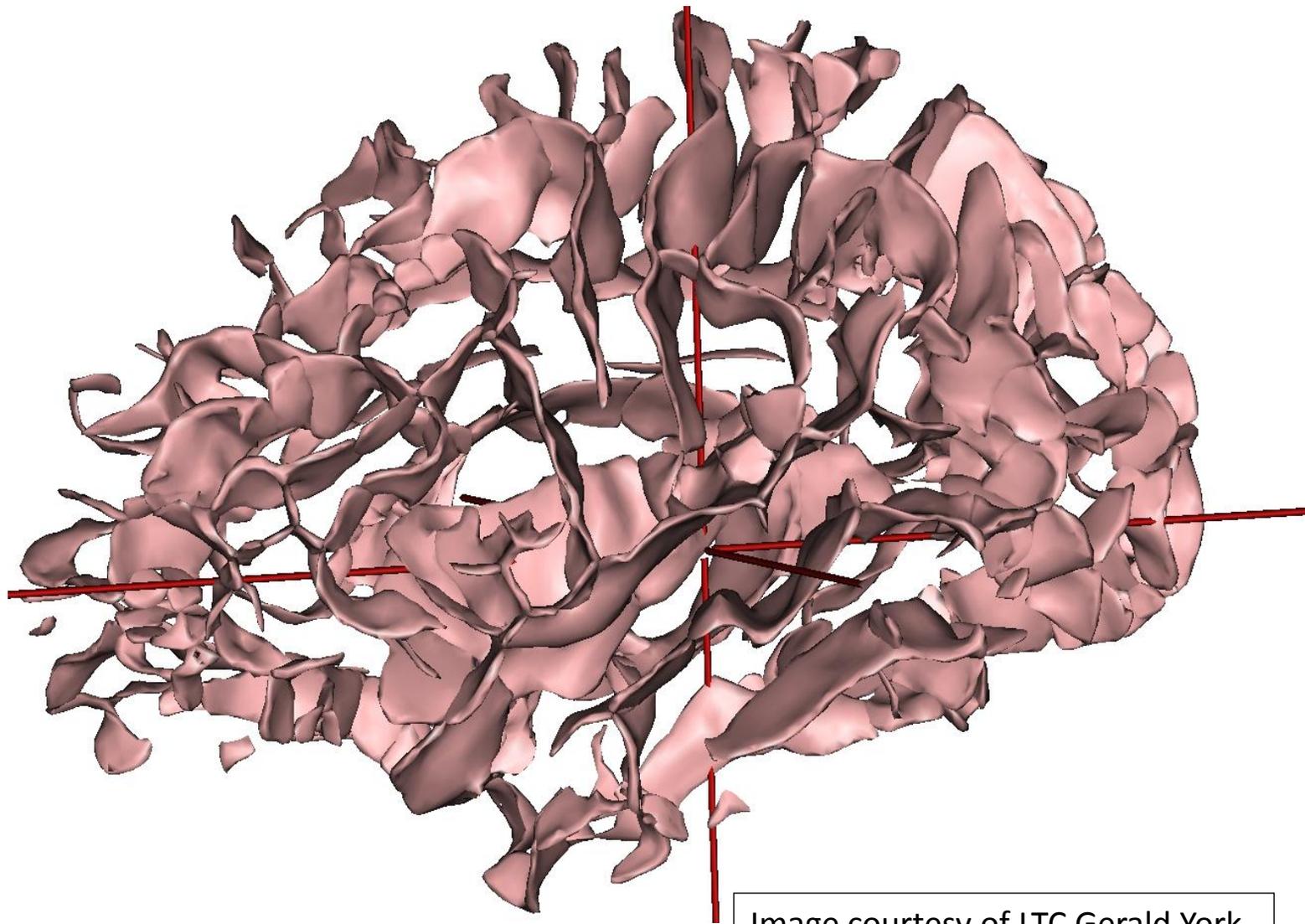


Image courtesy of LTC Gerald York

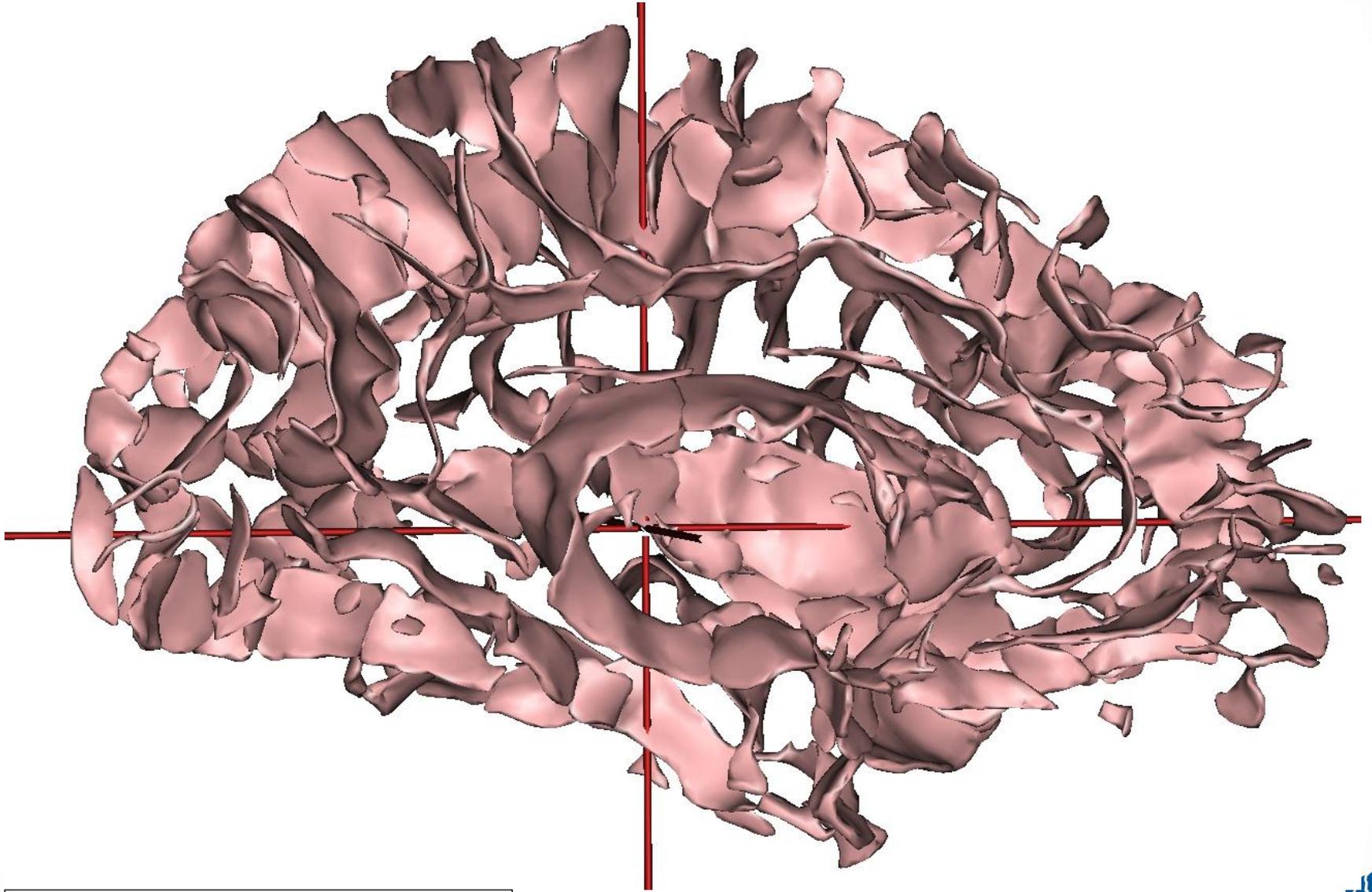


Image courtesy of LTC Gerald York

# Automated Segmentation, NQ

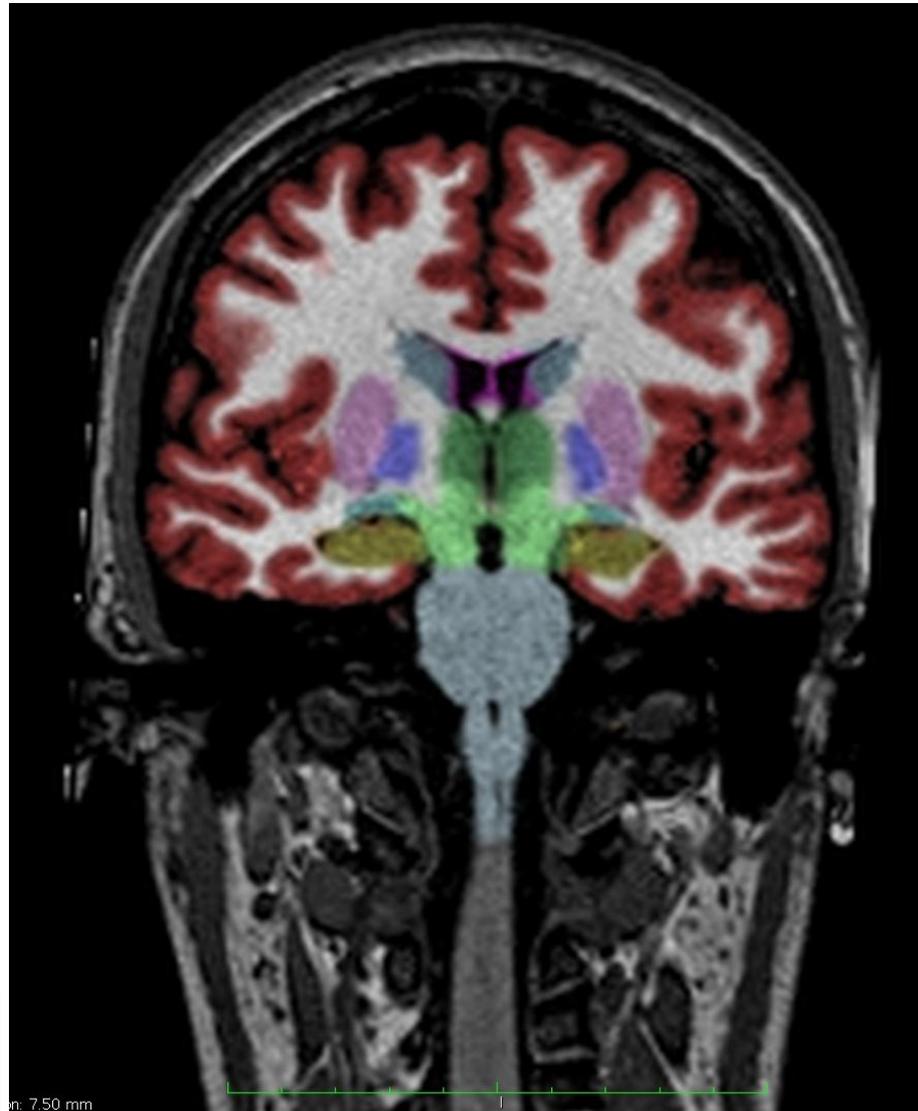
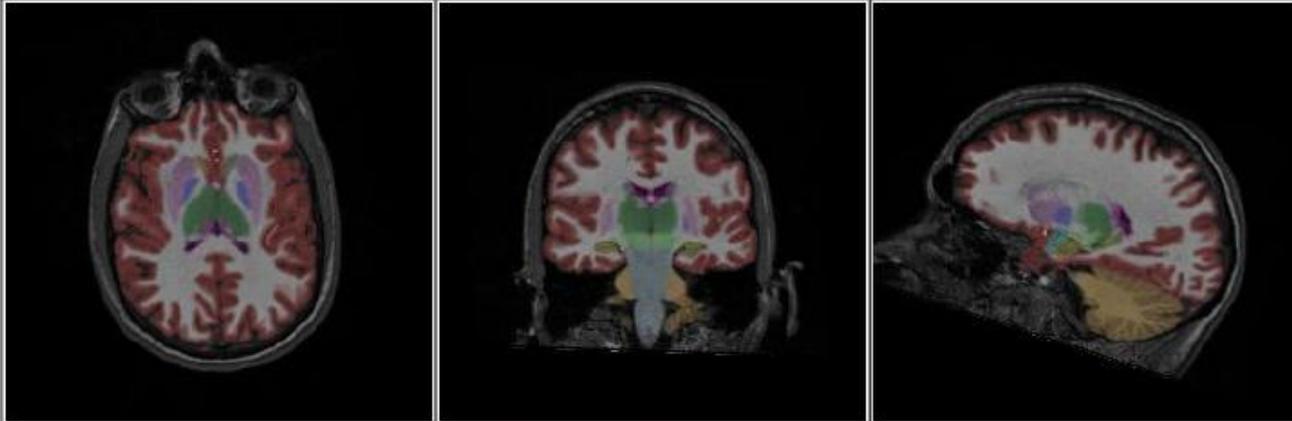


Image courtesy of  
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7.50 mm

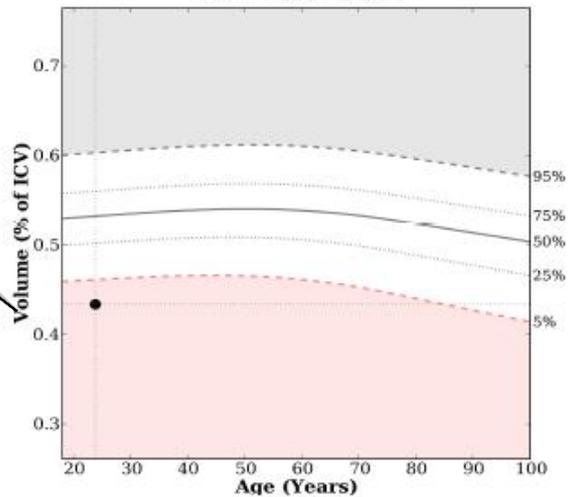
## MORPHOMETRY RESULTS



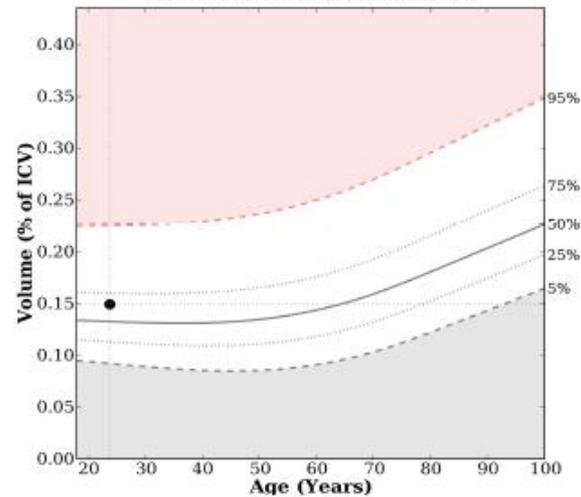
Brain Structure	Volume (cm <sup>3</sup> )	% of ICV (5%-95% Normative Percentile*)	Normative Percentile*
Hippocampi	7.16	0.43 (0.46-0.60)	< 1
Lateral Ventricles	11.89	0.72 (0.07-1.62)	56
Inferior Lateral Ventricles	2.46	0.15 (0.09-0.23)	65

### AGE-MATCHED REFERENCE CHARTS\*

**L & R Hippocampus**



**L & R Inferior Lateral Ventricle**



\*Charts and normative values are provided for reference purposes only. The FDA has not approved their use for diagnostic purposes.

Image courtesy of LTC Gerald York

# MRA: Distal Vert Dissection



Image courtesy  
of  
LTC Gerald York

MRA: neck

# MRA: Normal Intracranial Circulation

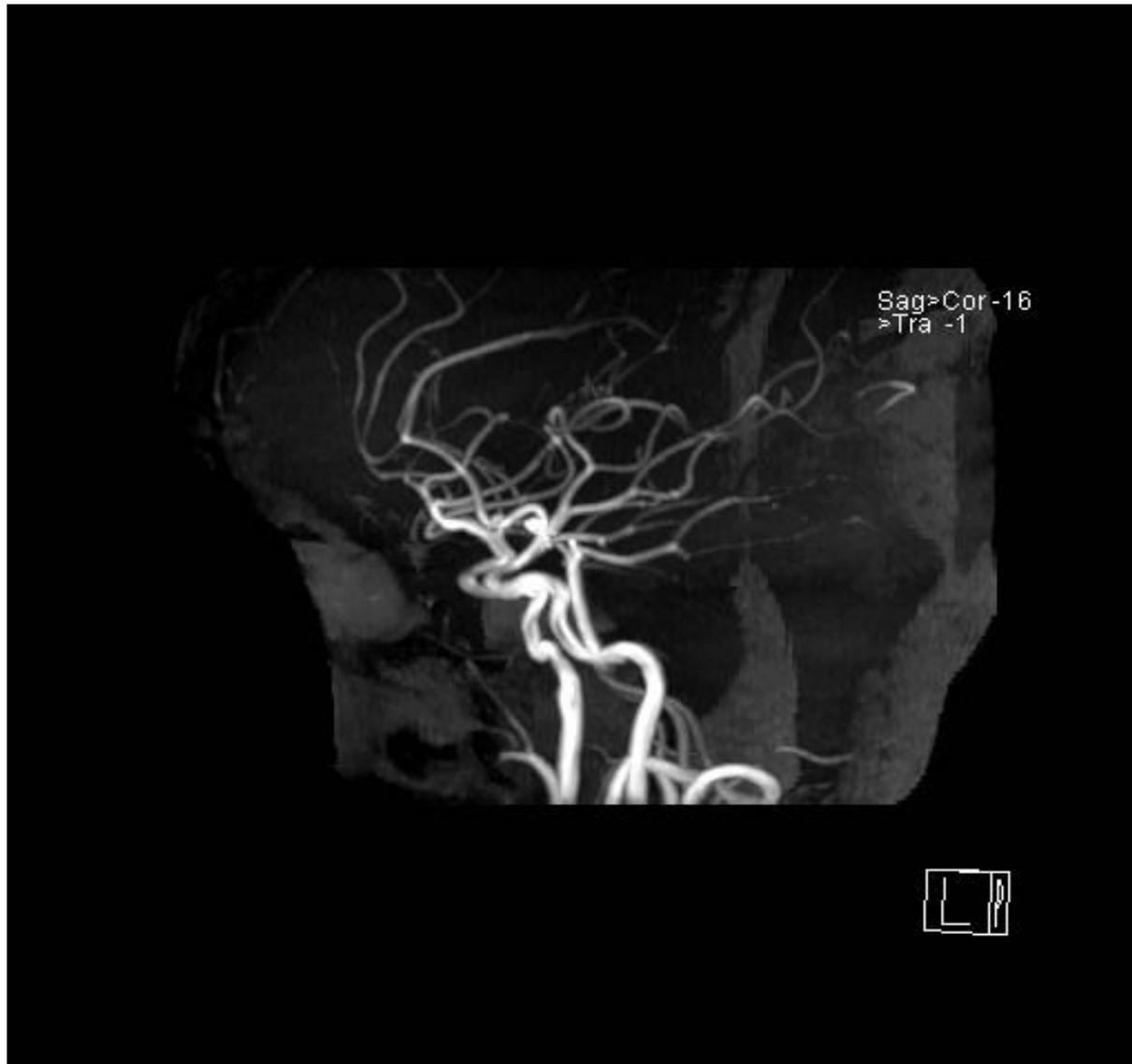


Image courtesy  
of  
LTC Gerald York

# MRI: DTI

- DTI = Diffusion Tensor Imaging
- Scalar values:
  - Measure of MAGNITUDE of diffusion of water is ADC (Apparent Diffusion Coefficient) also known as MD (Mean Diffusivity)
  - Measure of limit of DIRECTION of diffusion of water is FA (Fractional Anisotropy), values 0 to 1

# MD or ADC

- Decreased in restricted diffusion for stroke, relative to normal white matter
  - ADC <400 in infarct; >2000 in CSF
- Decreased in central portion of abscess
- May be increased or decreased in trauma
  - Depends on timing and location of measurement
  - Correlation to inflammation? WM integrity?

**MRI: FA**

Fractional Anisotropy

**ZERO**

# **MRI: FA**

## Fractional Anisotropy



**ONE**  
(almost)

# FA Map: Color is directional

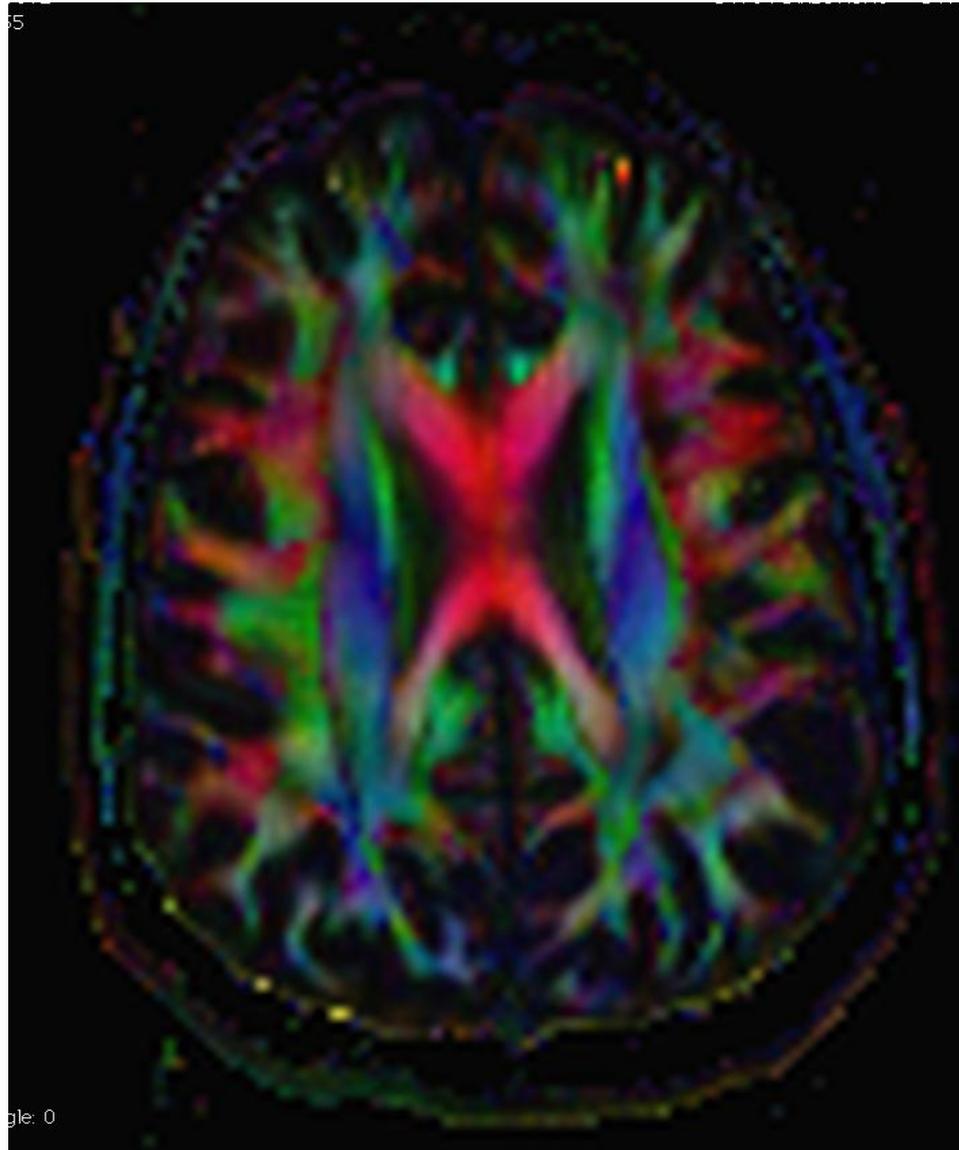


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# Limits of DTI

- Assumption that we are measuring values associated with tract “integrity”
- Is water ‘free’ in the extracellular space?
- Areas around SWI foci, artifact
- Crossing fibers
- Need for longer scan times to improve resolution raises issues with patient motion (and IRB)
  - HDFT DTI scan times of 20-40 minutes

# Tractography

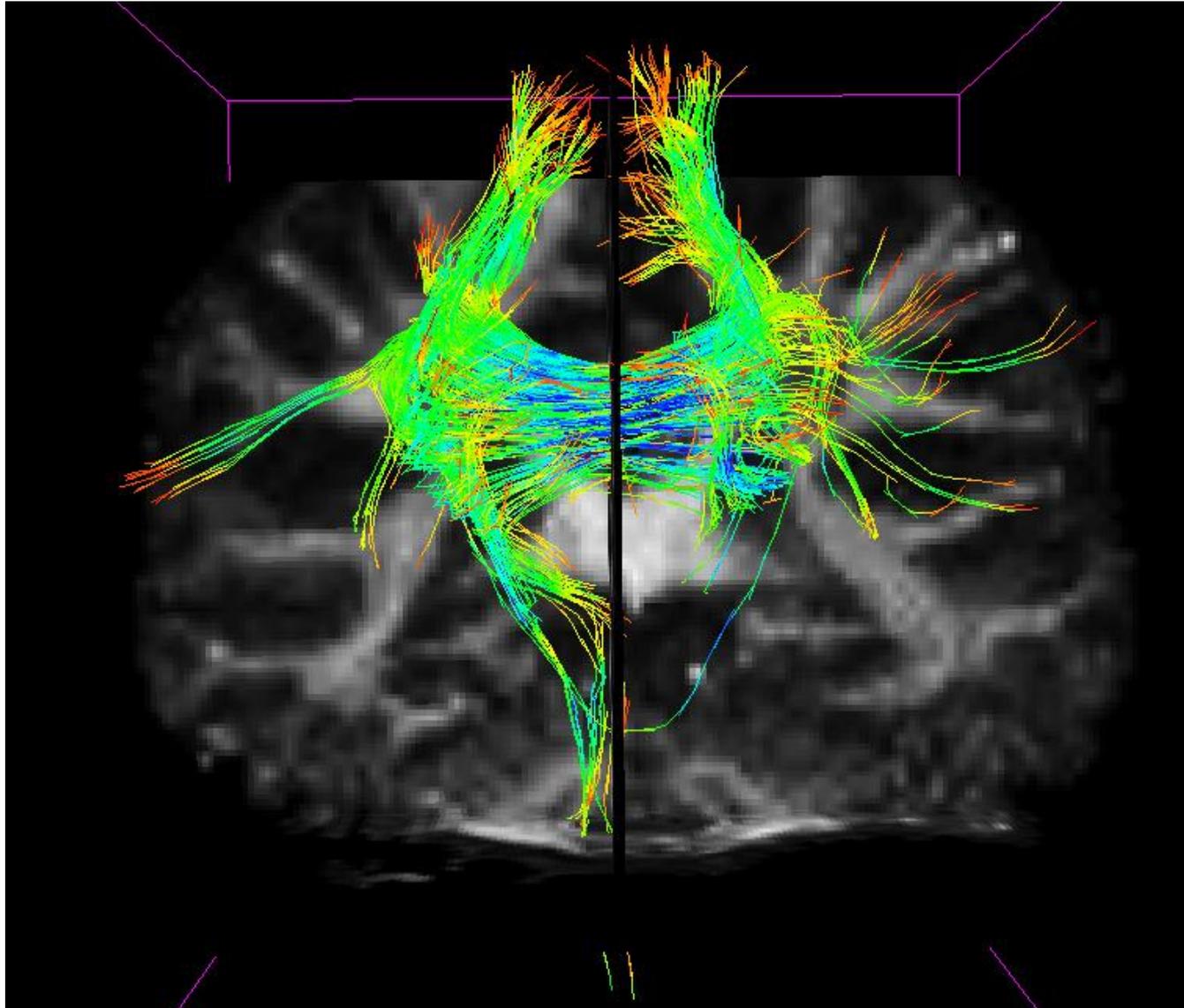


Image courtesy of LTC Gerald York

# DTI in Trauma Evaluation

- Reduced FA in the CC in acute phase
- Thalamic FA changes associated with variance in executive function, attention, and memory
- Acutely higher FA and reduced ADC/MD in mesencephalon in symptomatic vs. asymptomatic patients
- Axial and Radial Diffusivity (AD v. RD) changes
  - Axonal integrity correlation?

# Functional MRI: task or resting state

Multiple paradigms for task-oriented fMRI

[http://www.asfnr.org/docs/ASFNR\\_BOLD-Paradigms.PDF](http://www.asfnr.org/docs/ASFNR_BOLD-Paradigms.PDF)

Resting state **BOLD** imaging:

- Requires only patient to hold still (no task)
- Analysis of these is complex: Measuring noise?
- Need for longitudinal and control comparison data

# Resting State fMRI (rfMRI) in TBI

- “Postconcussive symptom severity linked to abnormal regional connectivity within nearly every brain network”\*
  - Functional deficits and enhancements
  - Compared to demographically-matched controls
- Enhancement of rfMRI may be related to secondary recruitment
  - Supplement damaged primary regions

\*Stevens MC, Lovejoy D, et. al., “Multiple resting state network functional connectivity abnormalities in mild traumatic brain injury.” Brain Imaging and Behavior (2012) 6:293-318.

# MRS: Spectroscopy

- Single voxel (SVS)
- Multi-voxel (CSI)
  - Additional phase encoding step allows larger volume localization
  - Post-processing of large volume into smaller voxels for metabolite evaluation
- 2D spectroscopy COSY

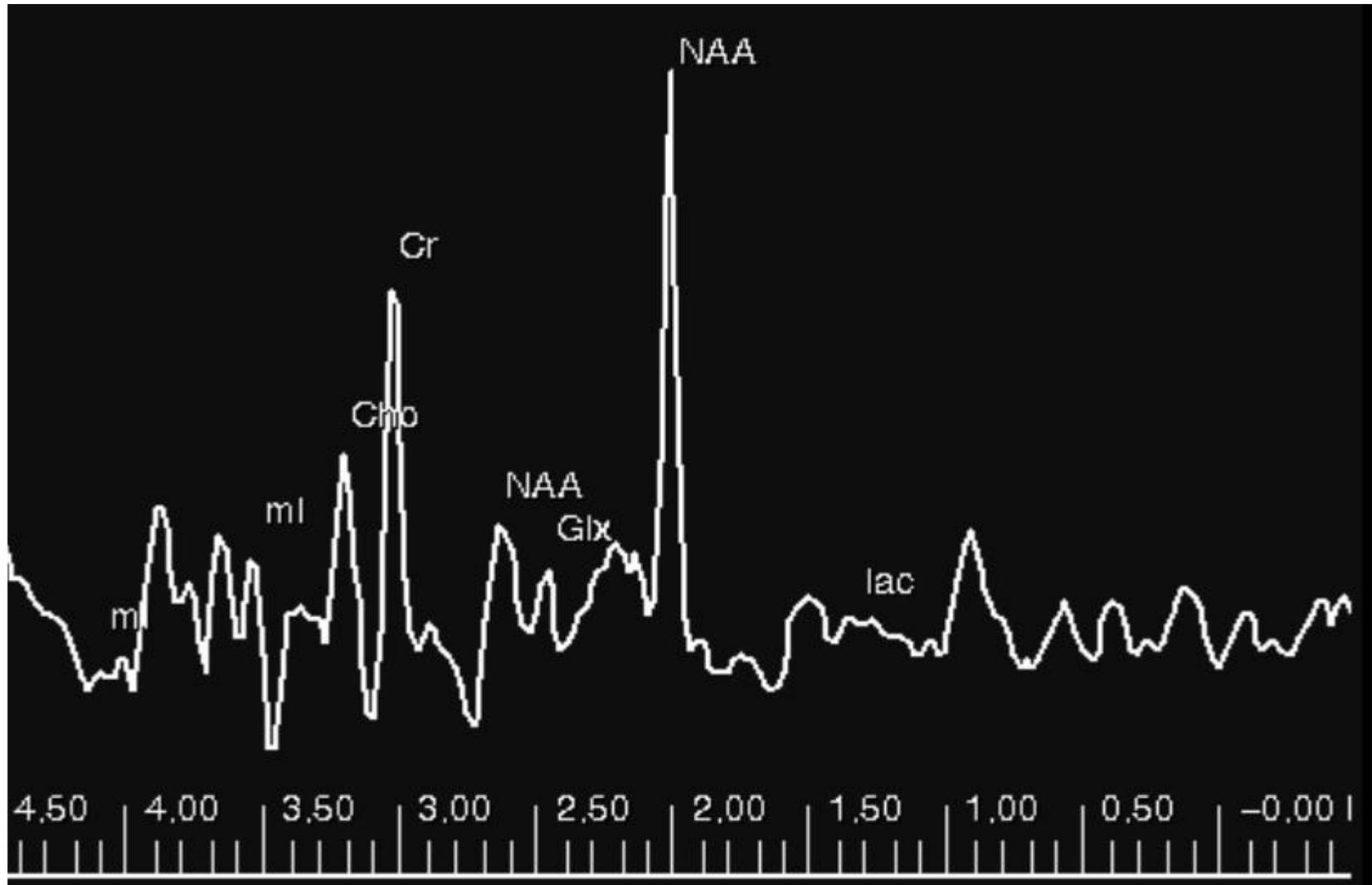


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# NORMAL – LOW TE

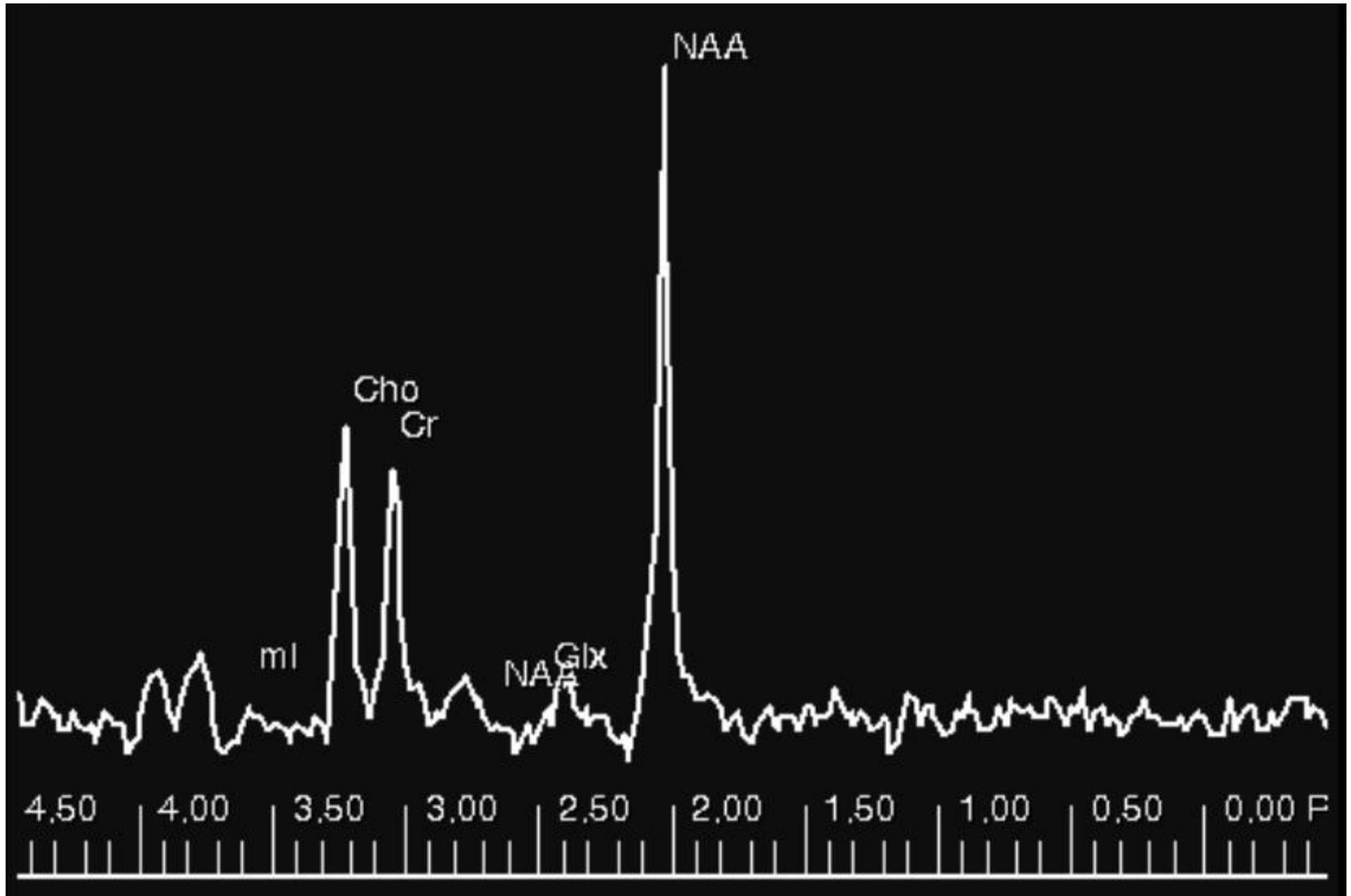


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**NORMAL – HIGH TE**

# MRS: NAA

- NAA (N-acetyl aspartate) is found in normal brain tissue with normal neuronal density
- Decreased in TBI
  - When neurons are displaced or destroyed by malignancy, trauma, stroke, NAA levels fall

# MRS: Creatine

- Creatine (Cr) is the second largest peak in normal spectrum
- Other chemicals in this peak: GABA, creatine phosphate, lysine, and glutathione
- Tends to be low in all brain tumor spectra
- Marker of metabolism

# MRS: Choline

- Choline is at 3.2ppm, one of most important to look at with brain tumors
- Peak is from glycerophosphocholine, phosphocholine, and phosphatidylcholine
- Reflects metabolism and cellular membrane turnover (signaling also)
- Cho is increased in primary and secondary tumors, Cho/Cr ratio elevated in highly malignant tumors

# MRS: Lactate

- Doublet at 1.32 ppm
- Lactate is NOT found in the brain normally--
  - the brain is an oxidative organ, lactate is produced only in nonoxidative pathways
- Seen in tumors outgrowing their blood supply, stroke, and predictor of poor outcome in TBI
- Changing TE to 135ms inverts Lac peak

# Astrocytoma

No NAA

Incr Cho

Lactate

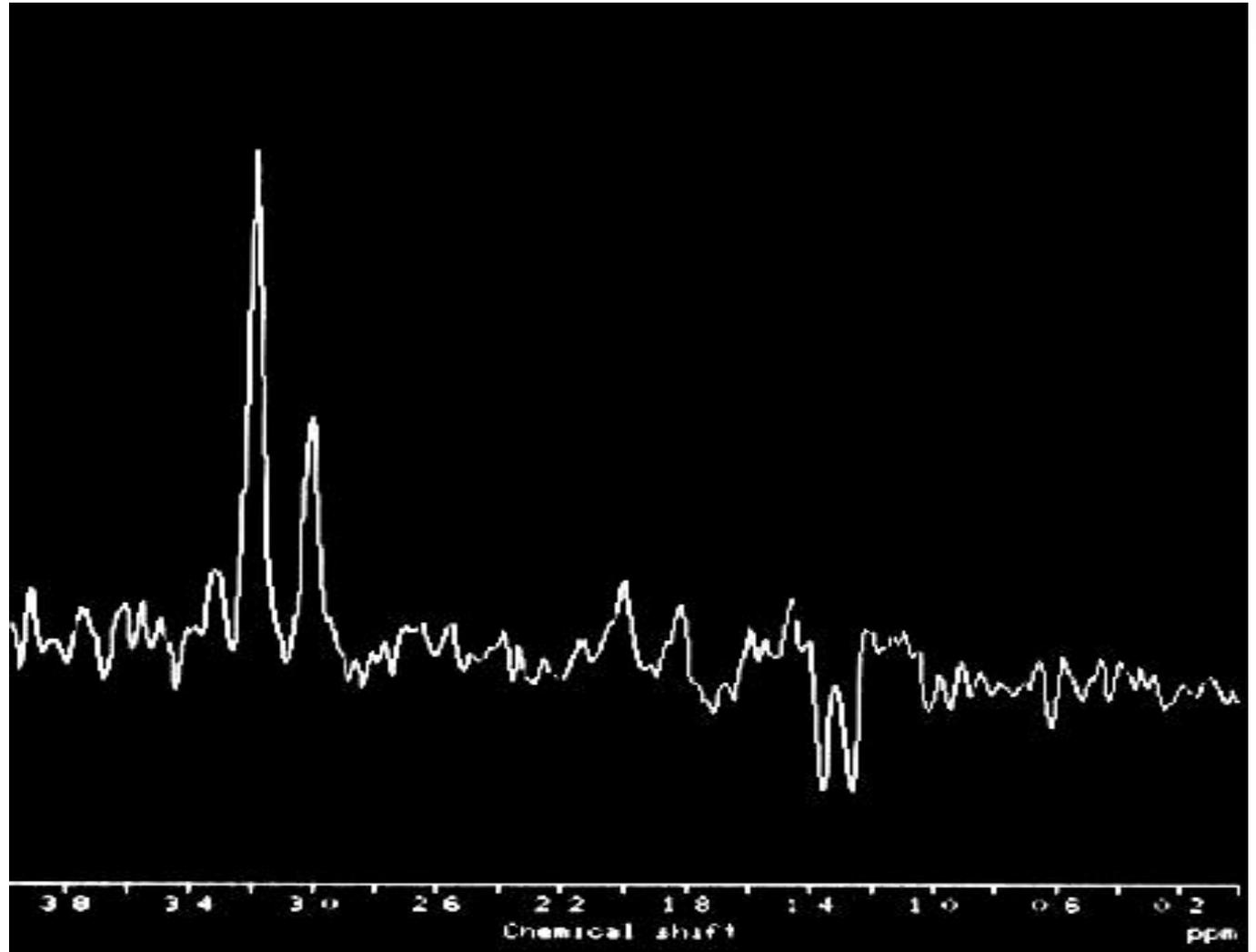
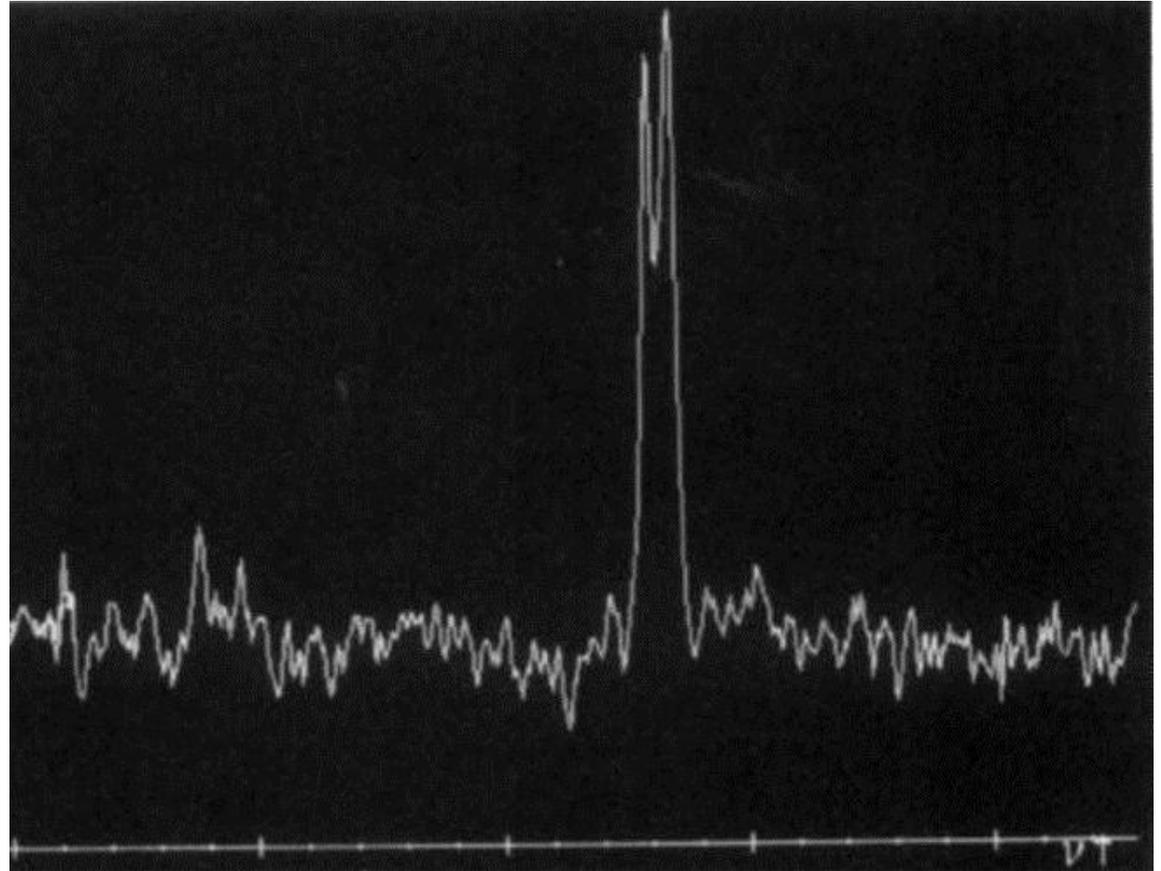
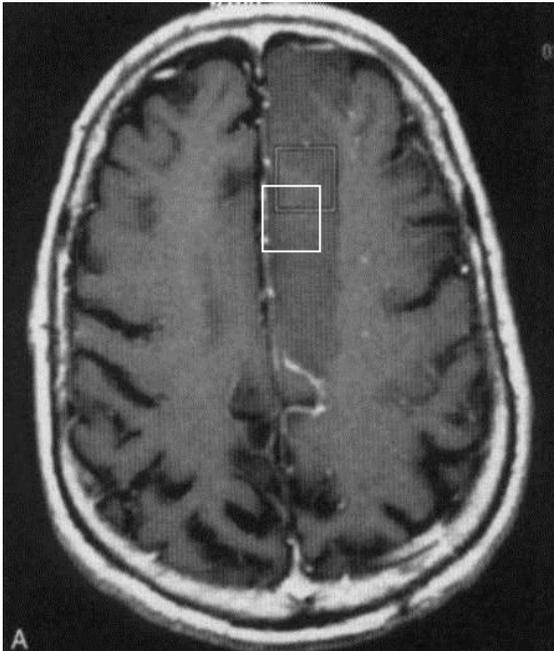


Image courtesy of LTC Gerald York

# Stroke: No NAA, Lact



Images courtesy of LTC Gerald York

## Fungal Abscess:

- Decr NAA
- Glx peak
- Lactate
- Choline

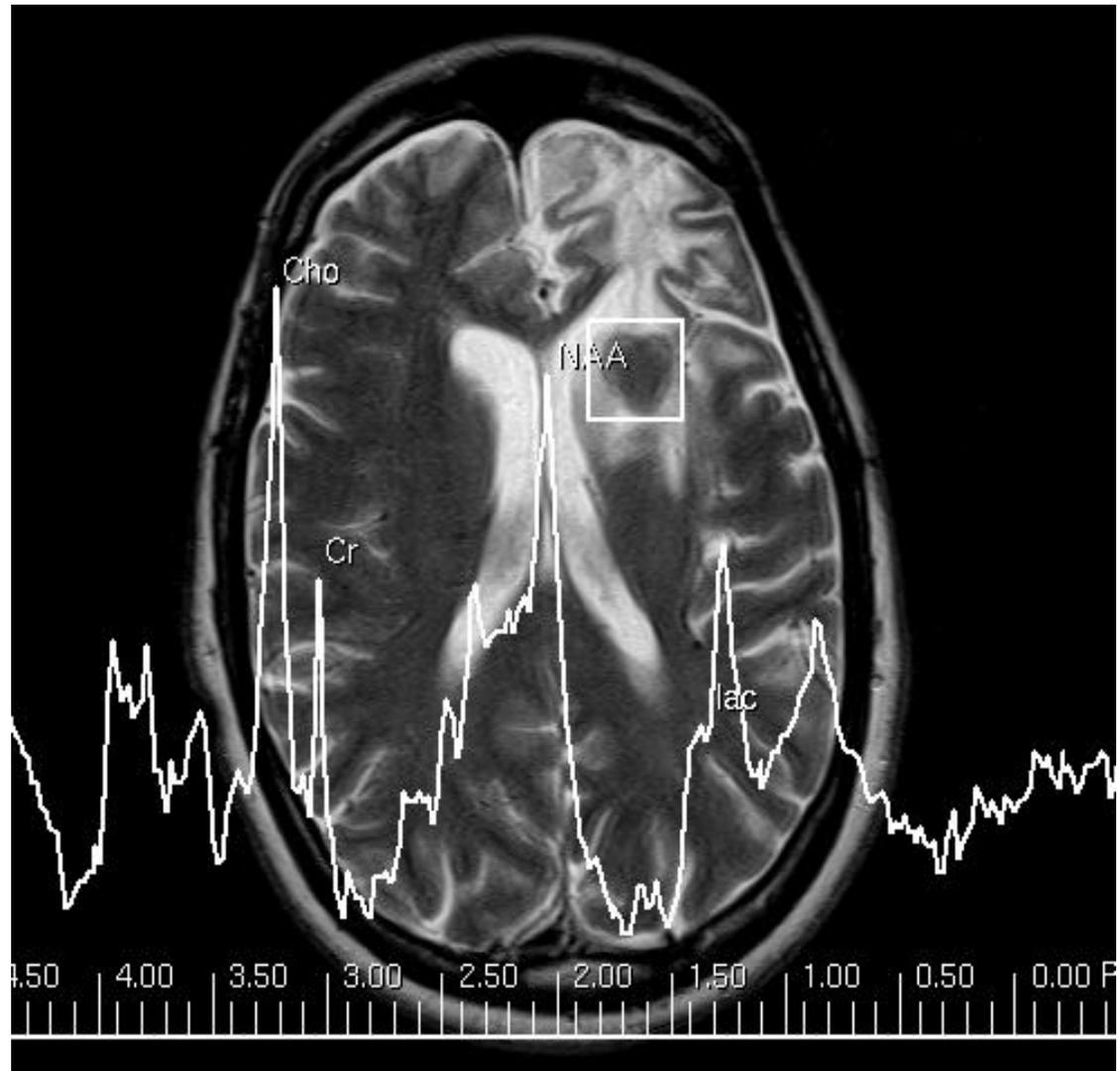
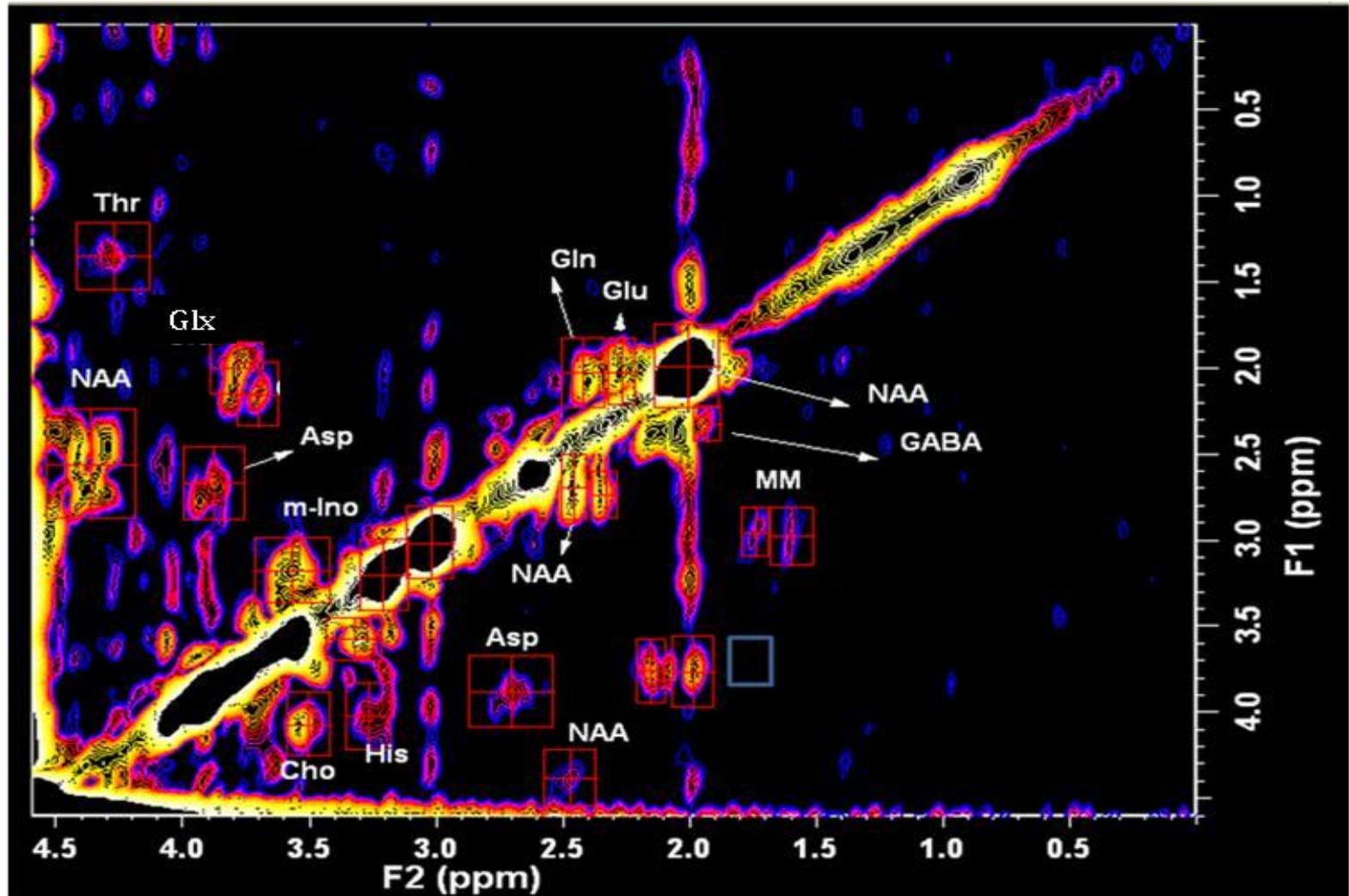


Image courtesy of LTC Gerald York

# 2D COSY



Courtesy Alex Lin, PhD. Psychiatry Neuroimaging Lab, Brigham and Women's Hospital

Audience Participation: Please submit your answer via the polling box on your screen.

## What can SWI/GRE help demonstrate?

- A) Calcification
- B) Hemosiderin deposition
- C) Iron
- D) All of the above

Audience Participation: Please submit your answer via the polling box on your screen.

## What is the role of DTI in assessment of TBI?

- A) Measure white matter “integrity”
- B) Measure inflammatory changes
- C) Evaluate presence and location of water
- D) All of the above

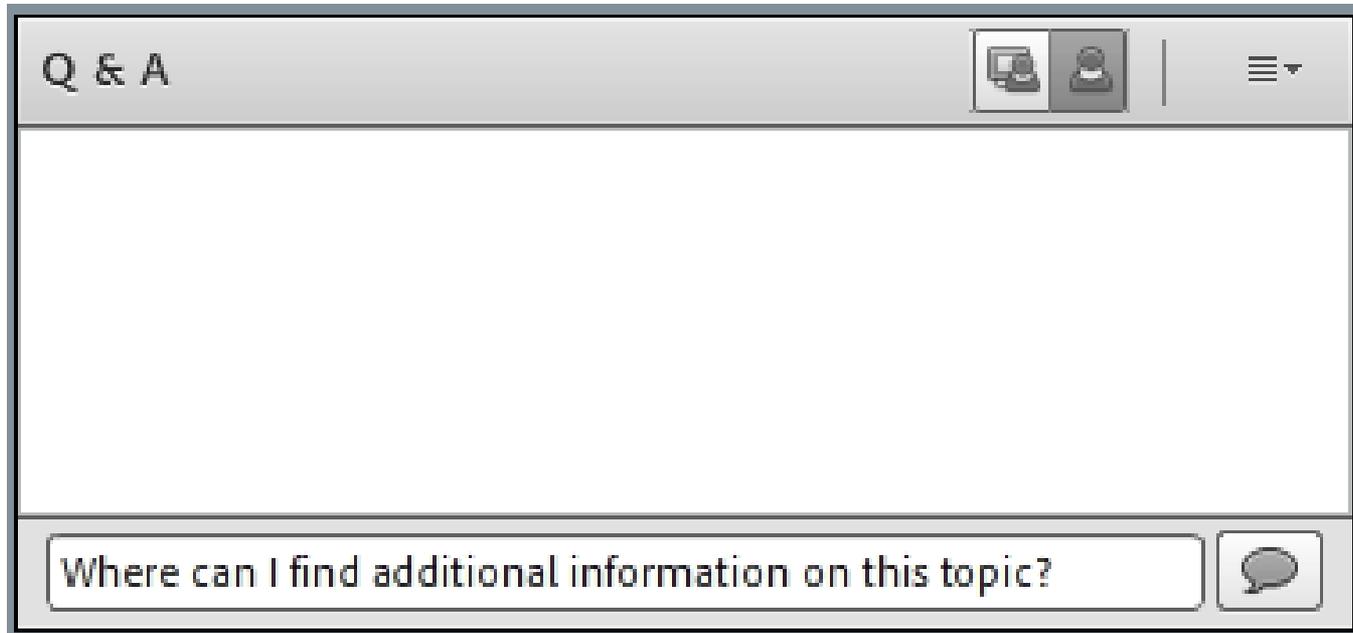
Audience Participation: Please submit your answer via the polling box on your screen.

## Which of the following are true?

- A) Lactate is normally present in measurable quantities in the brain.
- B) NAA (N-acetyl aspartate) is a normal neuronal marker
- C) Elevated Creatine is seen in tumors.
- D) Elevated NAA is seen in TBI.

# Questions about MRI?

Please submit your MRI-related questions to Dr. York via the Q&A box located on your screen.

A screenshot of a Q&A interface. The top bar is grey and contains the text "Q & A" on the left, a camera icon and a person icon in the center, and a hamburger menu icon on the right. Below the top bar is a large white rectangular area for questions. At the bottom, there is a text input field containing the text "Where can I find additional information on this topic?" and a speech bubble icon to its right.

Q & A

Where can I find additional information on this topic?

# Nuclear Medicine Imaging

# NUCS

- SPECT

- Perfusion, Tc-HMPAO

- Decreased CBF in Frontal/Occipital

- PET

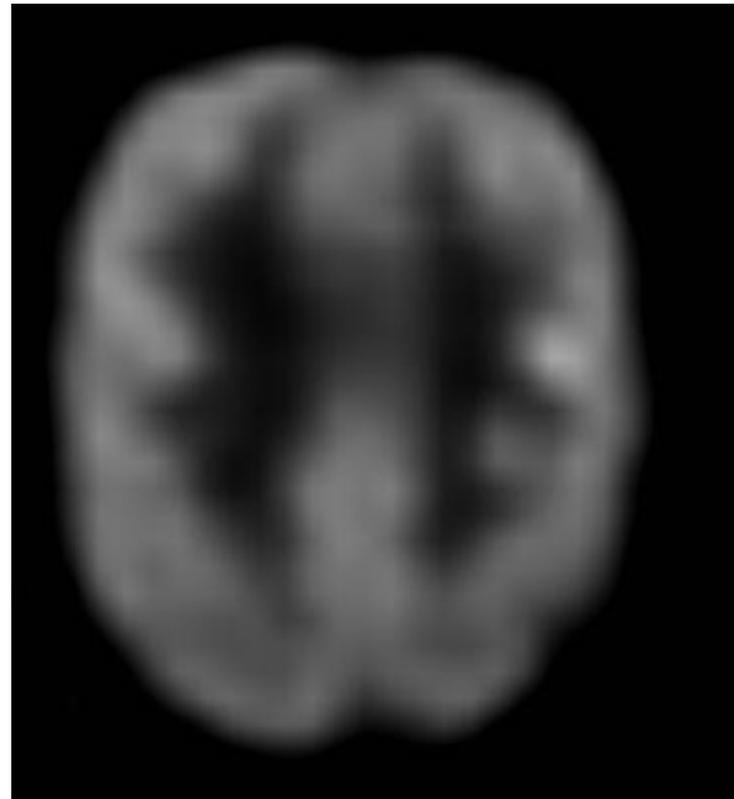
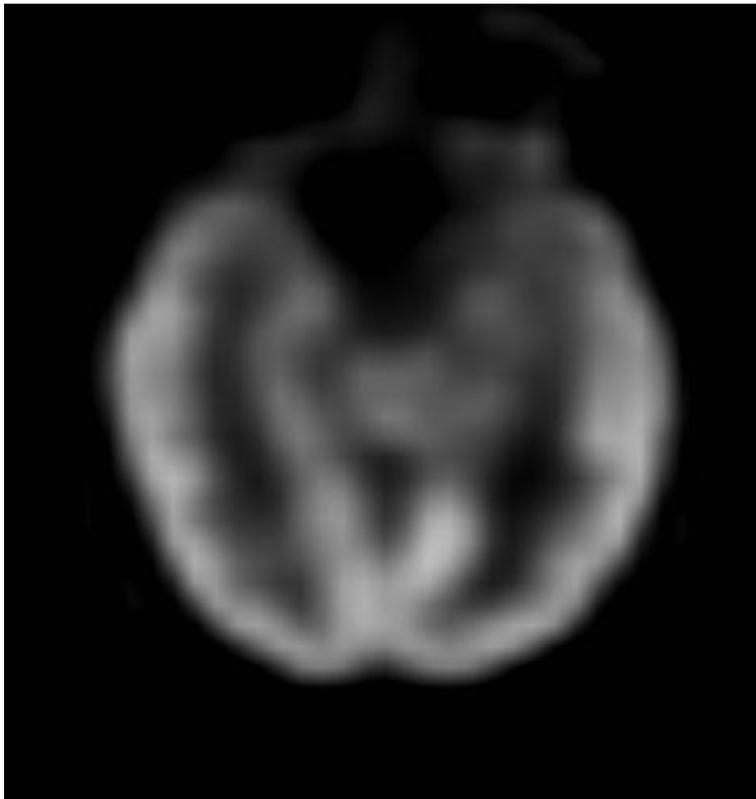
- FDG: Decr metabolism in frontal and parietal lobes

- Inflammatory/Excitotoxic markers

- Molecular imaging

# Alzheimer's on FDG

Decreased FDG activity in the temporal and parietal lobes.

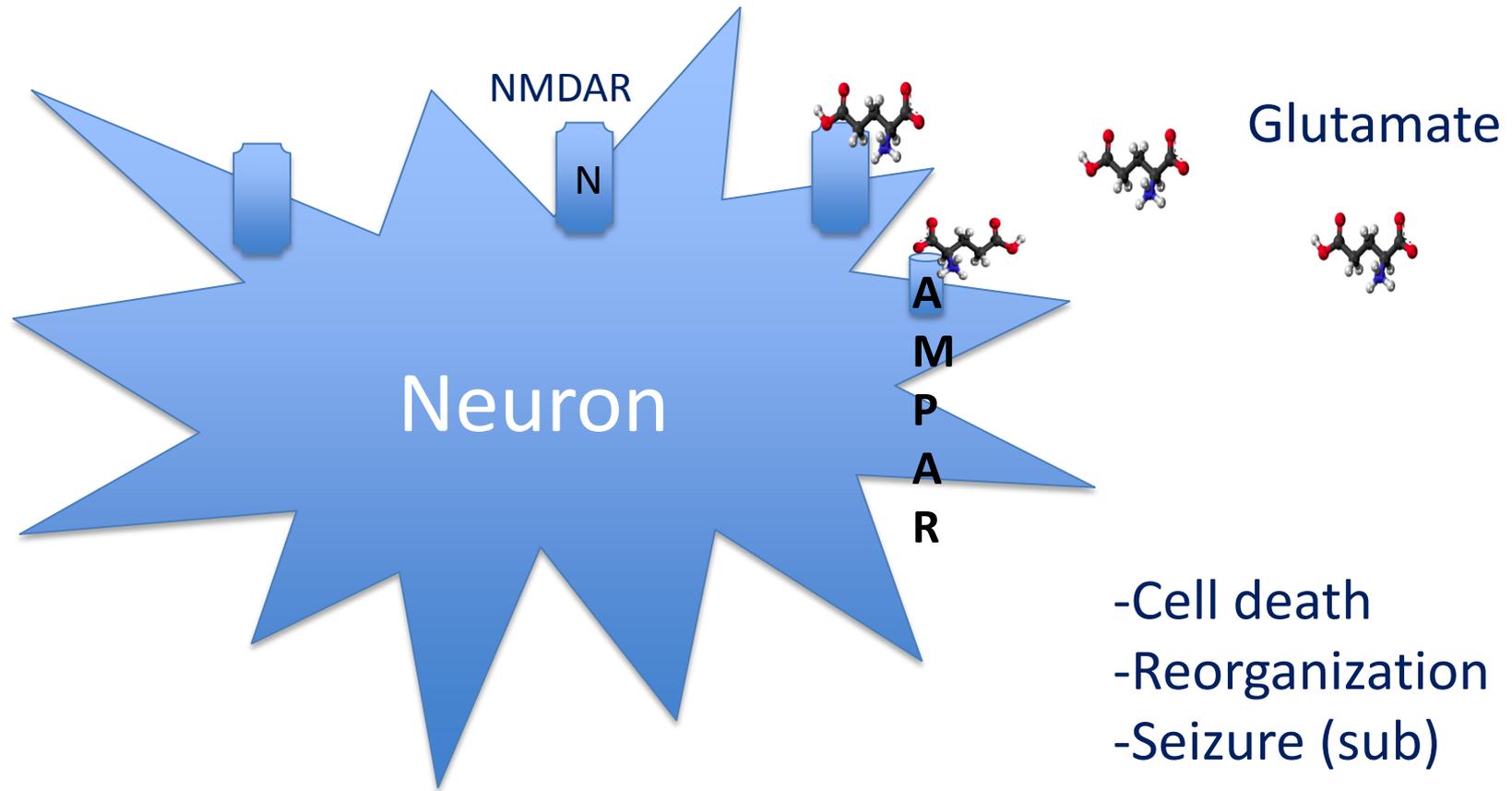


Images courtesy of LTC Gerald York

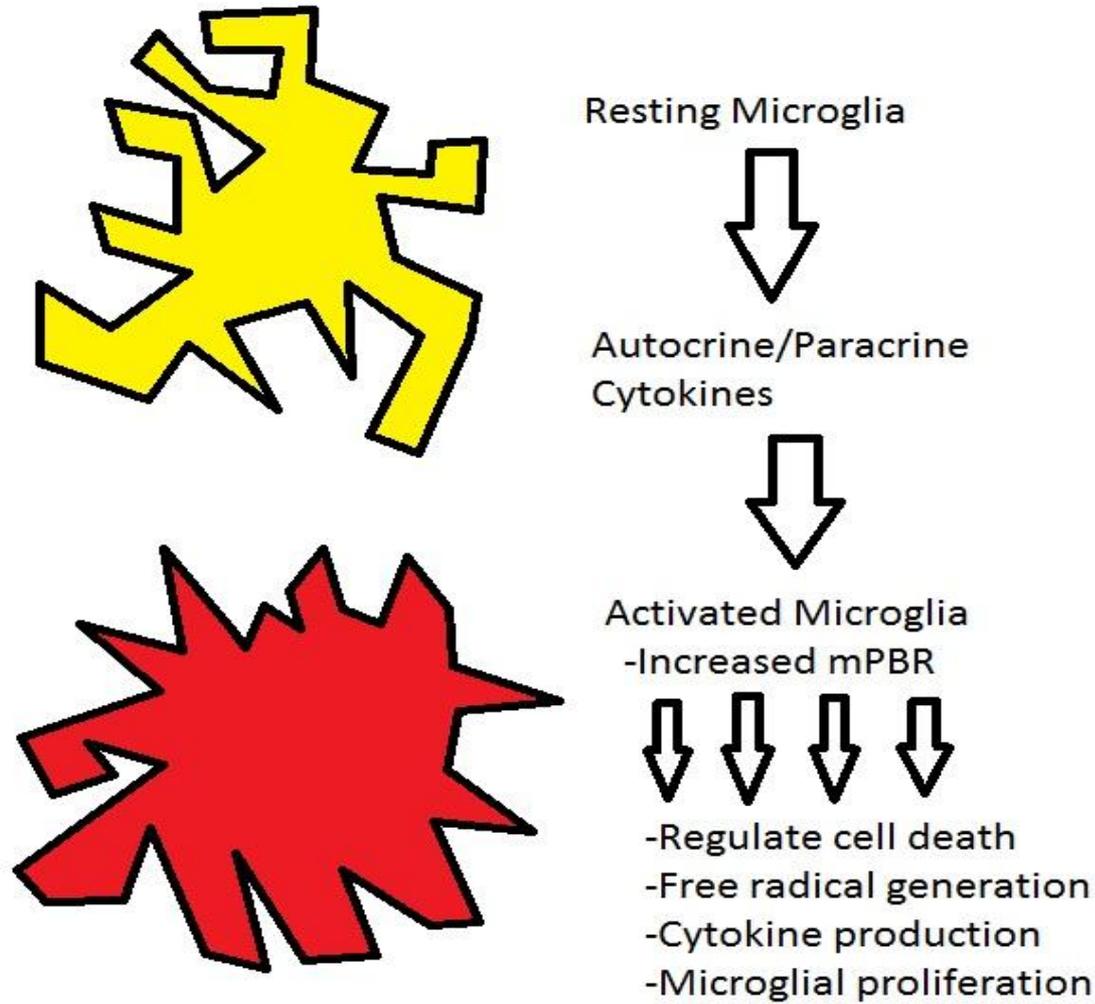
# Nucs: Molecular Imaging

- Targets for imaging from:
  - Neurotransmitters and Receptors
  - Inflammatory markers
  - Breakdown of neurons, free radicals
- NMDA(R)
- Glutamate (excitatory) and GABA (inhibitory)
- Tau (hyperphosphorylated tau), amyloid
  - FDDNP, [18F]-T808 (Siemens)

# Excitotoxicity



# Inflammation Post Injury

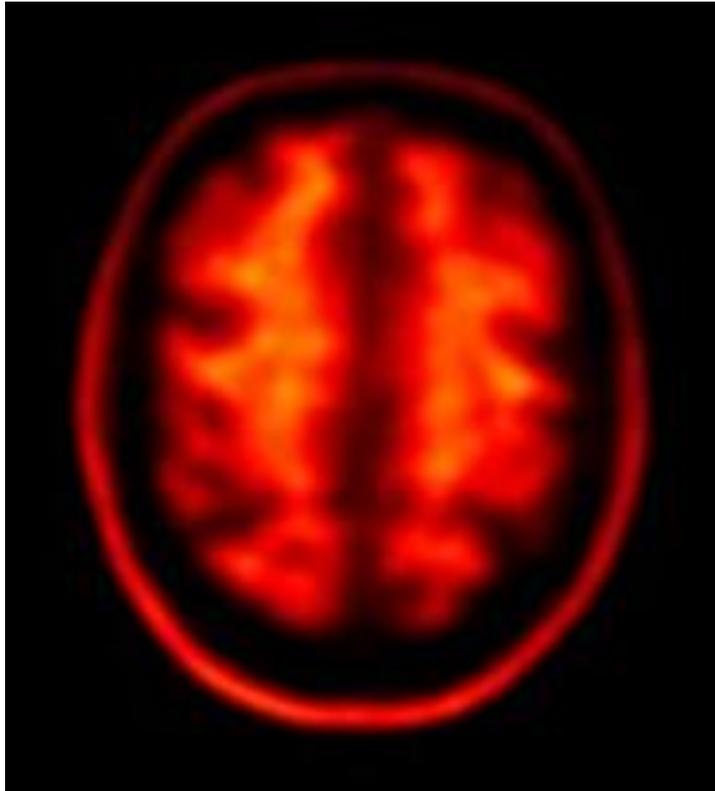


# Amyvid: Florbetapir 18F

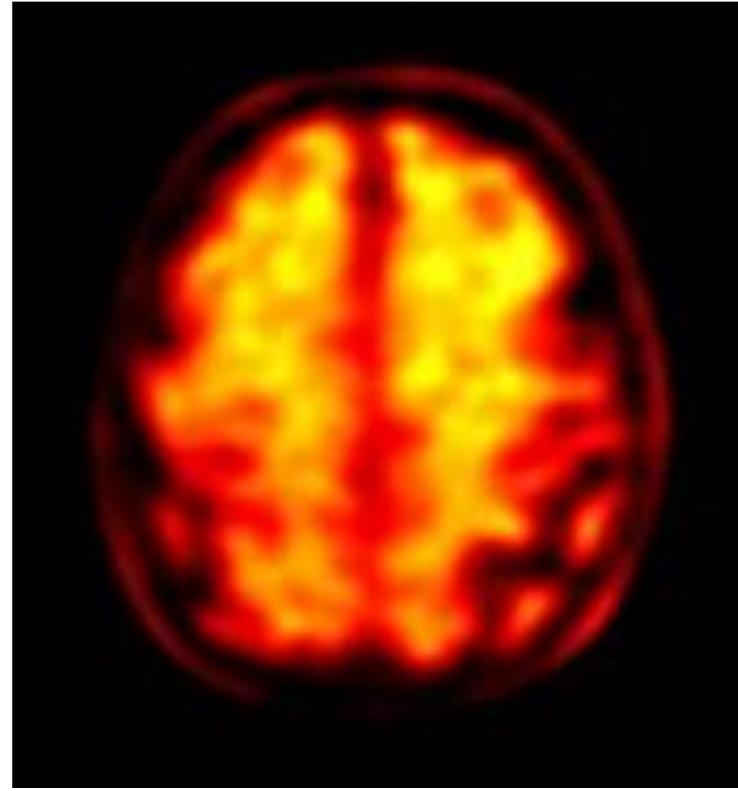
- PET imaging to estimate beta-amyloid plaque
- Negative Amyvid indicates sparse to no plaque
  - Inconsistent with a neuropath diagnosis of AD at time of scan
- Positive Amyvid indicates moderate to frequent amyloid neuritic plaque
  - Path correlation shows this is present in patients with AD
  - Does NOT establish a diagnosis of AD or cog disorder

# Amyvid

68 y/o with cognitive decline  
- No Amyvid activity



56 y/o with memory difficulty  
- Positive Amyvid



Images courtesy of LTC Gerald York

# TCD

## Advantages

- Portable
- Flow evaluation in trauma
- Vasospasm post injury
- Occlusion in stroke/dissection

## Disadvantages

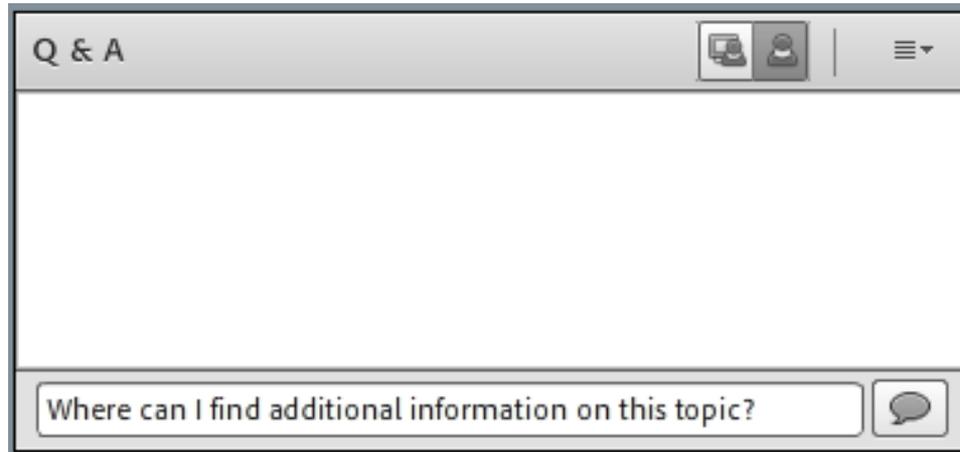
- Not widely available
- Expertise in acquisition/interpretation

# Conclusions

- CT is standard first-line imaging for acute TBI
  - NOC, CCHR: high sensitivity
- MRI helpful for detection of injury
  - DAI
  - DTI—still work in progress for FA/MD other measures
  - Volumetrics—proven changes, baseline imaging crucial
- Nucs: Indicated for subacute/chronic if MRI not obtainable
  - Future Research with specific tau ligands or other markers of inflammation/degeneration

# Questions?

Please submit your questions to Dr. York via the Q&A box located on your screen.



A screenshot of a Q&A interface window. The window has a title bar with the text "Q & A" on the left and icons for a printer, a person, and a menu on the right. The main area is a large empty white box. At the bottom, there is a text input field containing the text "Where can I find additional information on this topic?" and a speech bubble icon to its right.



# For additional TBI information and resources, visit

The screenshot shows the DVBIC website with a navigation bar containing links for Service Members & Veterans, Family & Friends, Medical Providers, About DVBIC & TBI, Educational Materials, Research, and DVBIC Locations. A search bar is in the top right. The main content area features a 'Free Webinar with CE/CME credit' titled 'Post-traumatic Headaches: Initial Management & Alternate Approaches' on Jan 16, 2013, featuring Dr. Marc S. Husid and Dr. John L. Rigg. A 'Find a DVBIC location near you' button with a map is on the right. Below the webinar is a 'Download and order materials' button with an image of a book titled 'PROTECT Your Head: Your Headaches Weigh In'.

[dvbic.org](http://dvbic.org)

The screenshot shows the DCoE website with a navigation bar for About DCoE, Psychological Health, Traumatic Brain Injury, Service Members & Families, Media Center, Training & Conferences, and 24/7 Help. The main content area features a video titled 'Interview with T2 Leadership' with a description of T2 director Gregory Gahn and deputy director Mark Reger. Below the video are three center logos: DHCC (Deployment Health Clinical Center), National Center for Telehealth and Technology, and DVBIC (Defense and Veterans Brain Injury Center).

[dcoe.health.mil](http://dcoe.health.mil)

# Presentation & Audio

This presentation with audio will be  
available online at

<http://www.dvbic.org/online-education>

**Beginning March 1, 2013**

# Continuing Education

## **PRE-REGISTERED**

**ON or BEFORE February 14, 2013**

Visit <http://conf.swankhealth.com/dvbic> and complete the online evaluation in order to receive a continuing education certificate.

## **PRE-REGISTERED**

**AFTER February 15, 2013 (but before 1:15 p.m. EST today)**

The above website will be available starting February 22, 2013.

**If you did not pre-register, you will not be able to receive continuing education credit for this event.**

**Website will close on March 13, 2013.**

# Neuroimaging after mTBI/Concussion

Clinical Recommendation  
will be published summer 2013

# Webinar Evaluation/Feedback

We want your feedback!

Please take the Interactive Customer Evaluation found on the DVBIC website: [www.dvbic.org/winter-webinar-series-hot-topics-traumatic-brain-injury](http://www.dvbic.org/winter-webinar-series-hot-topics-traumatic-brain-injury)

# DVBIC Winter Webinar Series

**March 20, 2013**

Intimacy: Sex, Drugs and TBI

**Archived at [www.dvbic.org](http://www.dvbic.org)**

The Battle Within:  
TBI, PTSD and Violence Risk

Post-traumatic Headaches in the  
Military Population: Initial Management  
and Alternate Approaches

