Neuroimaging Fundamentals: A Case Study Approach

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January 30th , 2021

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DISCLOSURES

- FINANCIAL DISCLOSURE
  - Nothing to disclose
- UNLABELED/UNAPPROVED USES DISCLOSURE
  - Nothing to disclose
- Some of the slides have been adapted from teaching materials used at the University of Oklahoma Health Sciences Center

Schedule- Mountain Time

- 9:00 - 9:05 am : Welcome and Program Overview - Emma Fields
- 9:05 - 9:30 am :Fundamentals of neuroimaging modalities - Emma Fields
- 9:30- 10:00 am : How to calculate an ASPECTS score and its clinical implication - Doug Mayson
- 10:00 -10:30 am : Multi-modality acute stroke neuroimaging - Jorge Ortiz-Garcia
- 10:30 - 11:00 am : Break
- 11:00 - 11:45 am : Incorporating neuroimaging in prognostication post-cardiac arrest - Ryan Hakimi
- 11:45 am -12:30 pm : Using optic nerve sheath diameter and TCD for ICP assessment - Venkatakrishna Rajajee
- 12:30 - 1:00 pm : Break
- 1:00-1:40 pm : Introduction to neuromuscular ultrasound - Eduardo Cortez- Garcia
- 1:40-2:10 pm : A case-based approach to demyelinating diseases - Keith Dombrowksi
- 2:10 -2:30 pm :Q& A

LEARNING OBJECTIVES

- Discuss CT imaging basics, advantages and limitations of CT imaging
- Review MR imaging basics, advantages and limitations of MR imaging
- Contrast CTA vs MRA imaging techniques
- Review Transcranial Doppler (TCD) basics
- Discuss Optic nerve sheath diameter (ONSD) basics

Outline

- Computed Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Transcranial Doppler (TCD)
- Optic nerve sheath diameter (ONSD)

Fundamentals of Neuroimaging

- Neuroimaging: use of various techniques to image the brain for structure or function
  - Structural neuroimaging :structure of the brain (cerebrospinal fluid, grey matter, white matter).
    - CT, MRI, transcranial color coded Duplex, Optic nerve sheath diameter
  - Functional neuroimaging: indirectly measure brain functions (e.g. neural activity)
    - fMRI

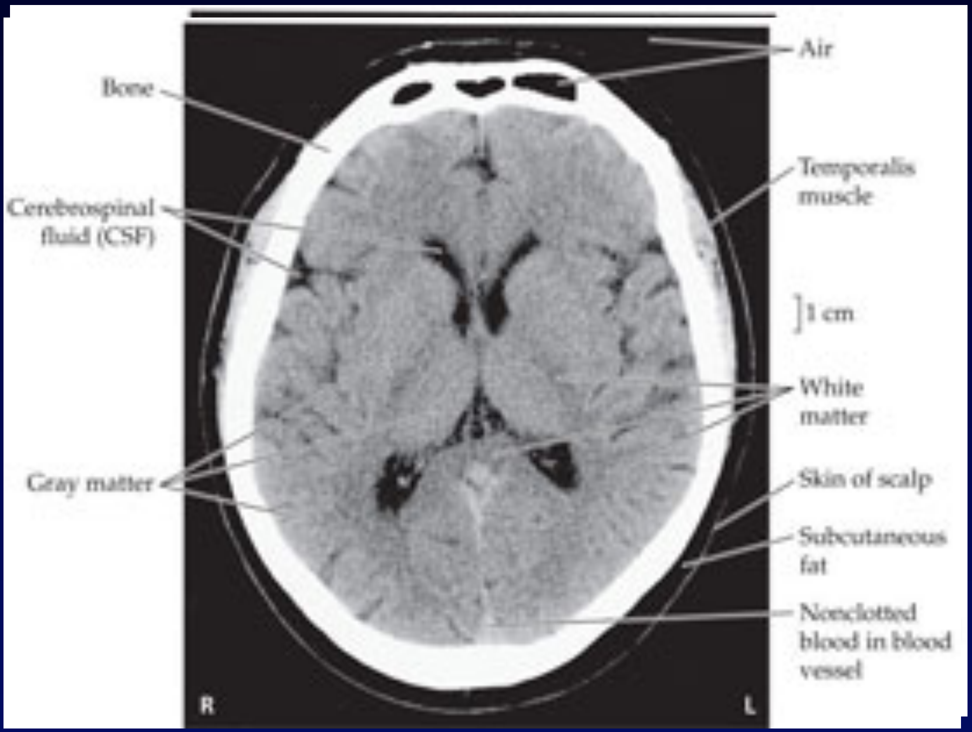
CT basics, advantages and limitations

- **Basics:** CT uses x-rays to make cross-sectional axial images, Right is on left and vice-versa.
- **Advantages**: fast, quickly accessible, cost-effective, less claustrophobia limitations, good for bone/fracture & fresh hemorrhage imaging.
- **Limitations**: radiation exposure, fair tissue imaging cannot detect blood flow, iodinated contrast, brainstem, poor posterior fossa imaging (artifact).

CT density

- Black

Structure/ Tissue	Hounsfield units
Air	-1000 to -600
Fat	-100 to -60
Water	0
CSF	+8 to 18
White matter	+30 to 41
Gray matter	+37 to 41
Acute blood	+50 to 100
Calcification	+140 to 200
Bone	+600 to 2000



White

Blumenfeld, 2010

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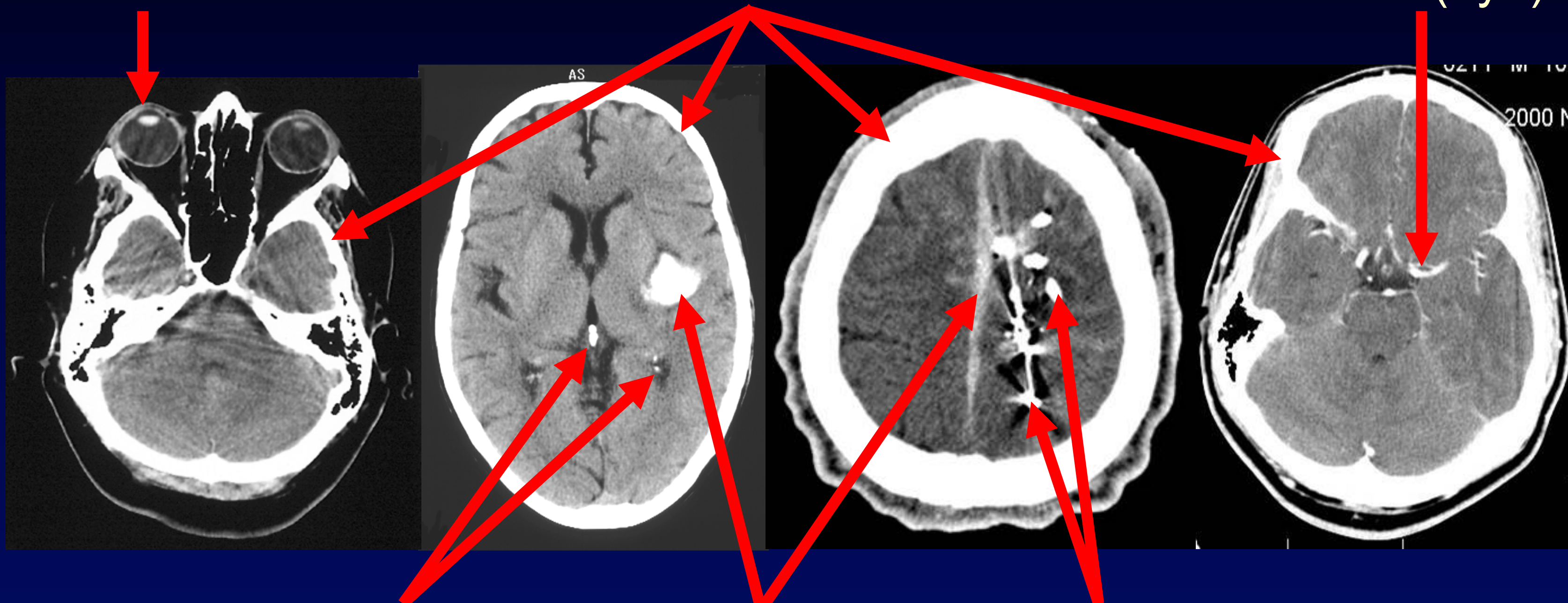
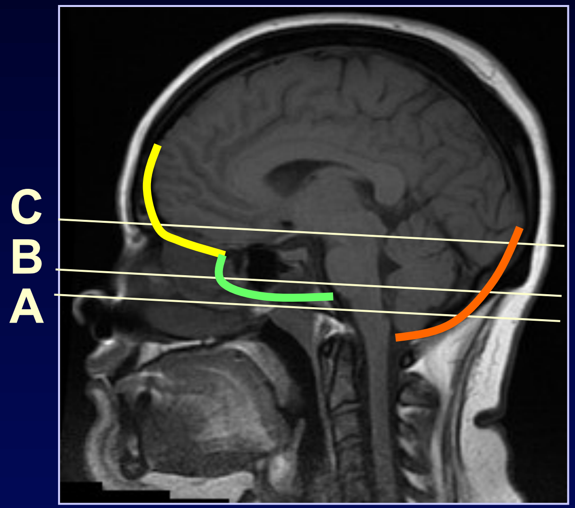
Hypodensity(black): Air, Fat, Cerebral spinal fluid (CSF)
Hyperdense(white): 3 B's (bone, bullets, blood), Contrast, calcifications, Ocular lens
Isodense (gray): Brain tissue (Gray and White matter

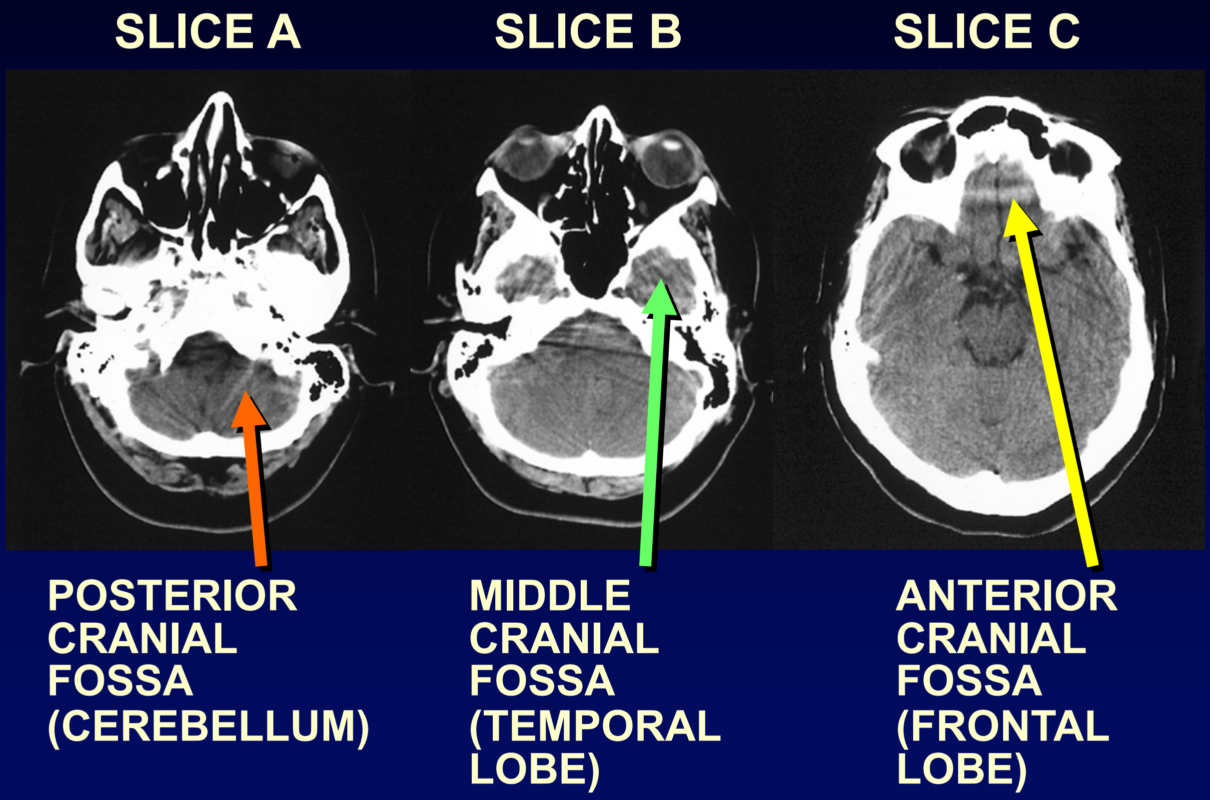
Hyperdense things on CT

- Bone, calcium, acute hemorrhage & contrast



CT Brain: Cranial Fossae





Progressing from inferior to superior, axial slices first visualize posterior fossa, then middle fossa, then anterior fossa of skull

CT BASICS-Windowing

- Windowing allows the CT reader to evaluate the CT with subtle differences in tissue densities.
  - Acute ischemic window : gray and white matter differentiation
  - Blood window : acute hemorrhage
  - Brain window : evaluation of soft tissue, CSF spaces.
  - Bone window : detailed evaluation for fractures

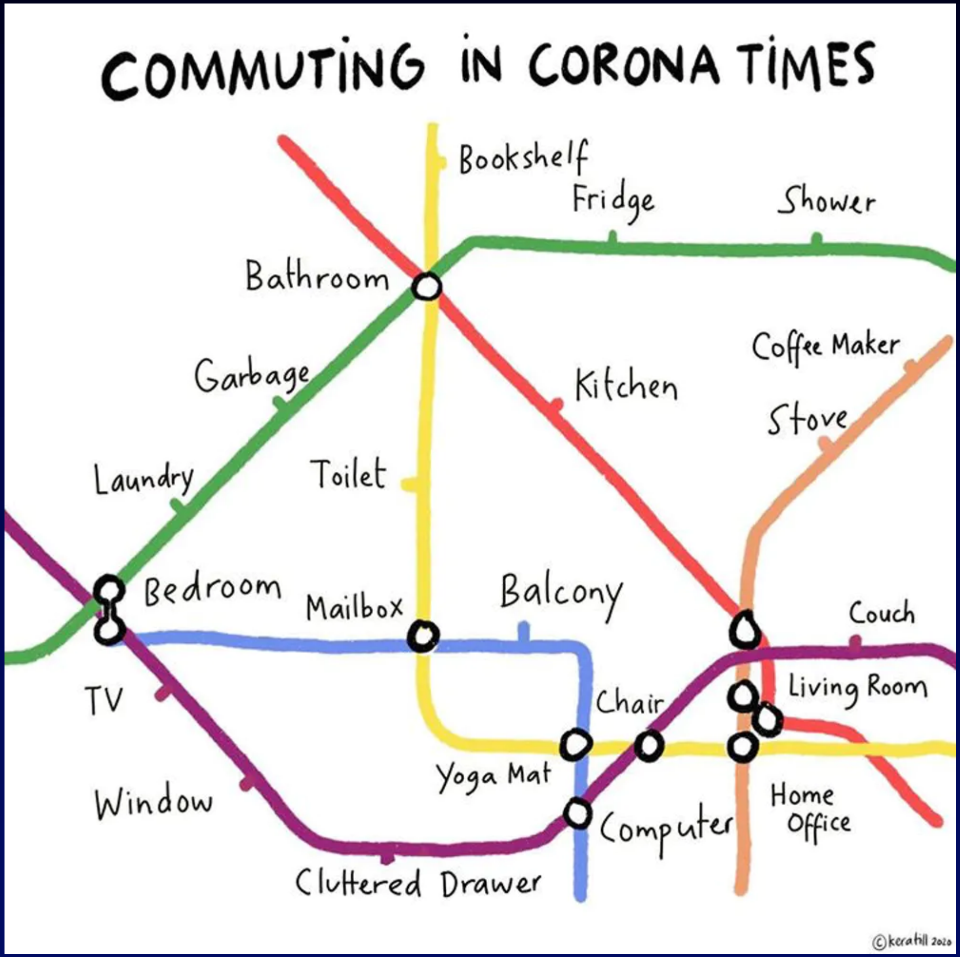
Approach to reading a CT scan- ABBBC

- A- Air-filled structures (nasal cavity, sinuses, mastoid air cells)
- B- Bones (fractures)
- B- Blood (subarachnoid, intracerebral, subdural, epidural hematoma)
- B- Brain tissue (infarction, edema, masses, brain shift
- C- CSF spaces (sulci, ventricles, cisterns, hydrocephalus, atrophy)

Neuroimaging techniques:

- ~~Computed Tomography (CT)~~
- Magnetic Resonance Imaging (MRI)
- Transcranial Doppler (TCD)
- Optic nerve sheath diameter (ONSD)

Tips & Tricks for Telecommuting Right in COVID-19 Times March 31 2020 By Karen Hallisey



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MRI BASICS

LEARNING OBJECTIVES

Upon completion of this course, participants will be able to:

- Understand the basics of MR imaging
- Establish an approach to MR interpretation

MRI basics

- MRI uses a magnet and radio-wave pulses to create cross-sectional pictures between external magnetic fields and tissues within the patient
- MRI is an intensity based study vs CT scan which is density (hyperintense vs hyperdense lesion, respectively)
  - Hyperintense = increased signal = white
  - Hypointense = decreased signal = black

MRI -advantages

- Provides multiple brain views easily without moving the patient, including axial, sagittal, and coronal
- Quick detection of ischemic changes w/in minutes (diffusion-weighted MRI sequence)
- MRI is more sensitive for parenchymal lesions, including infarcts & older blood
- Superior visualization of posterior fossa

MRI -disadvantages

- Claustrophobia limitations
- Difficult for the very young to be still for imaging may require sedation
- Weight limitations
- Critical patients on multiple infusions
- Slower, less accessible
- Fair bone imaging
- Presence of metallic objects

MRI sequences

- DWI
- T1
- T2
- FLAIR
- GRE
- ADC

DWI- diffusion weighted imaging

- Dark-CSF
- Bright-cytotoxic edema, necrosis,abscess
- Ischemic lesions
  - New infarctions are white 30 min to few weeks
  - Old lesions not seen
- Compare to T2 or FLAIR to distinguish new & old lesions
- Compare to ADC to ensure infarction is real
  - *DWI may show lesions due to other conditions such as seizure or "T2-shine-through" phenomenon*

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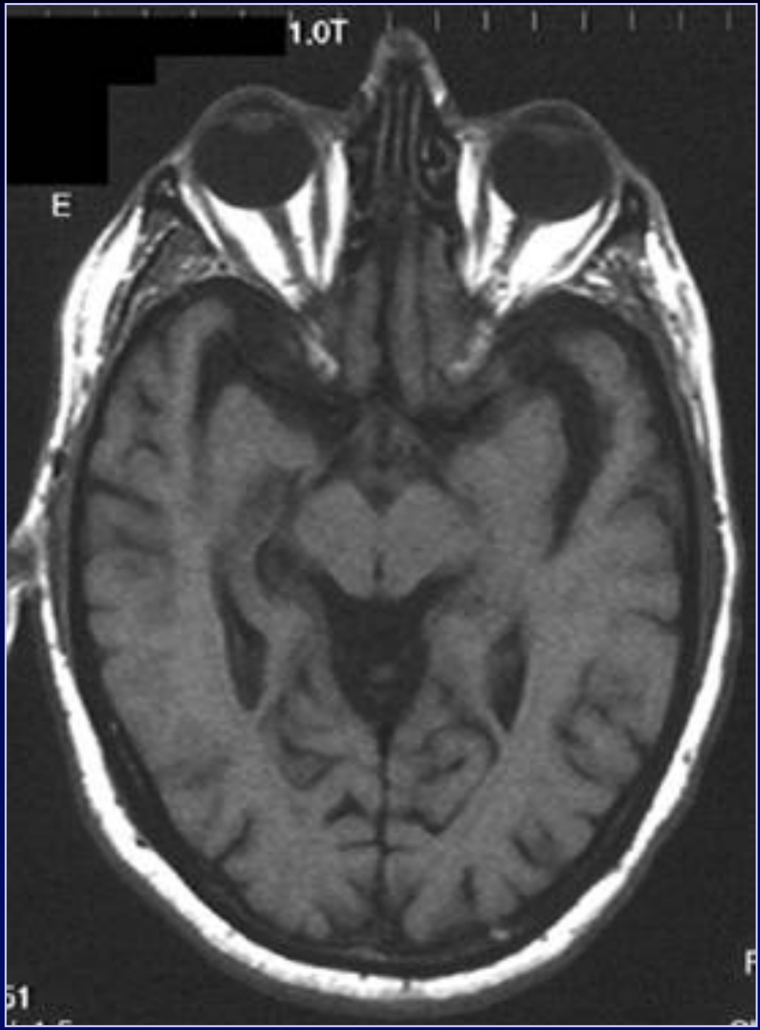
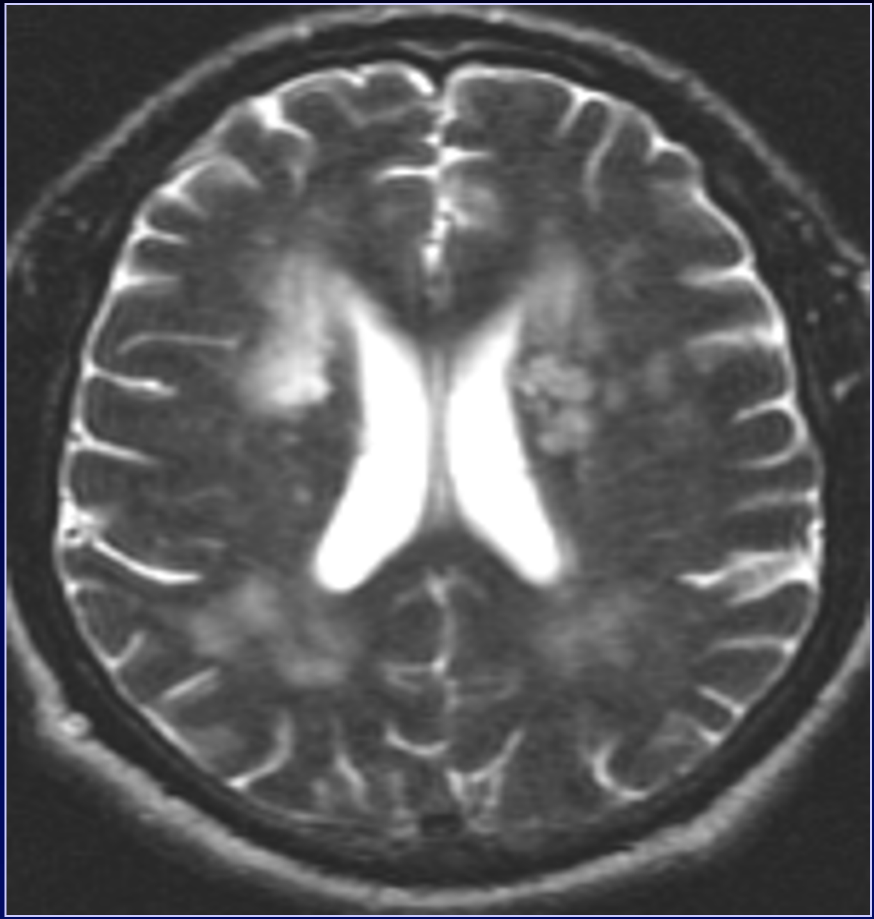
T1-Good for anatomy evaluation

- Dark-CSF, edema, water, acute infarction ,gliosis
- Bright- fat, metals,
- Lesions poorly seen without IV contrast (gadolinium)
- Best used for pre- & post-gadolinium comparisons
- Ca++ & bone black



T2-good for pathology

- CSF is white
- Lesions are white
  - Edema
  - Water
  - Acute infarction
  - Gliosis
- Lesions very well seen, but…
  - May be difficult to distinguish lesion and CSF
  - Does not visualize very new infarctions
  - Cannot distinguish new and old lesions
- Ca++ & bone black



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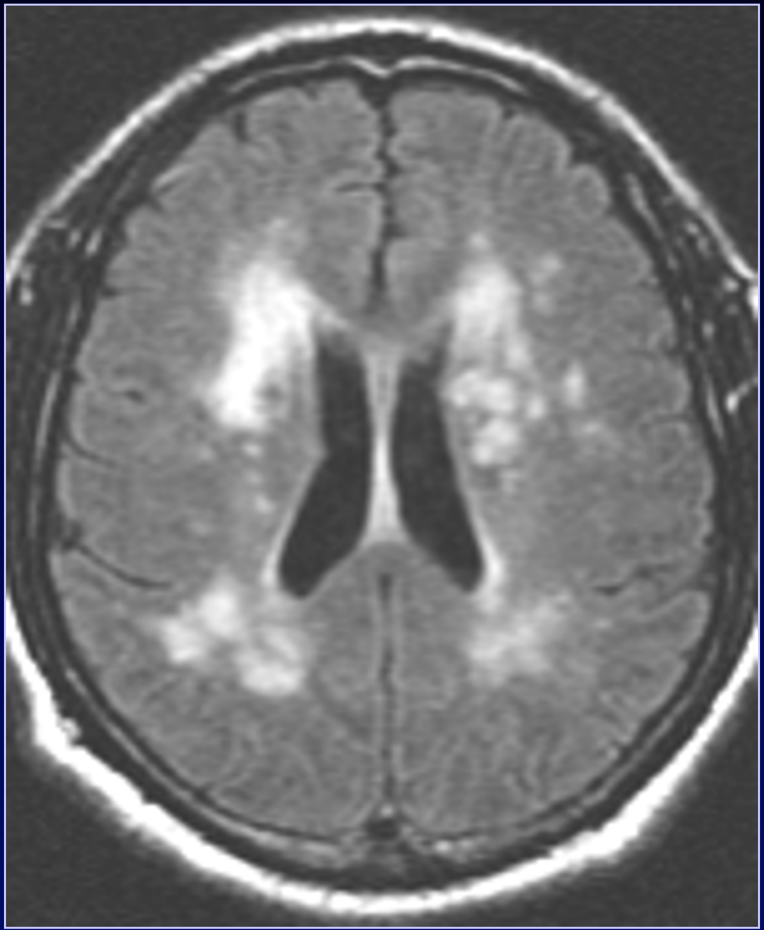
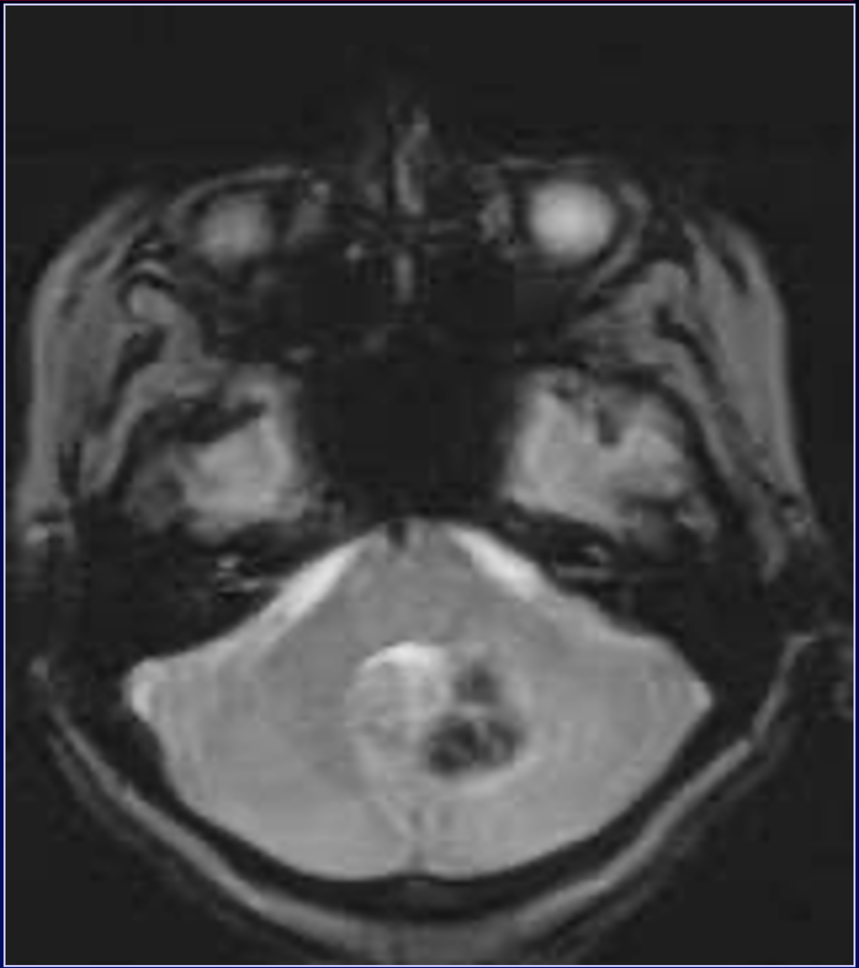
FLAIR- *Fluid-attenuated inversion recovery)- basically like T2 but CSF is dark*

- T2-weighted image with standing water turned black, therefore:
  - CSF & old lacunes black
- Lesions are white
  - Edema
  - Acute infarction
  - Gliosis
- Lesions <u>very well</u> seen, but…
  - Does not visualize very new infarctions
  - Cannot distinguish new & old lesions
  - Lesions may be inadvertently erased—compare to T2
- Ca++ & bone black



GRE-Gradient Echo

- Good for looking at brain tissue
- Most sensitive MR technique for detecting intraparenchymal blood (black)
- Parenchyma and nonblood lesions fuzzy



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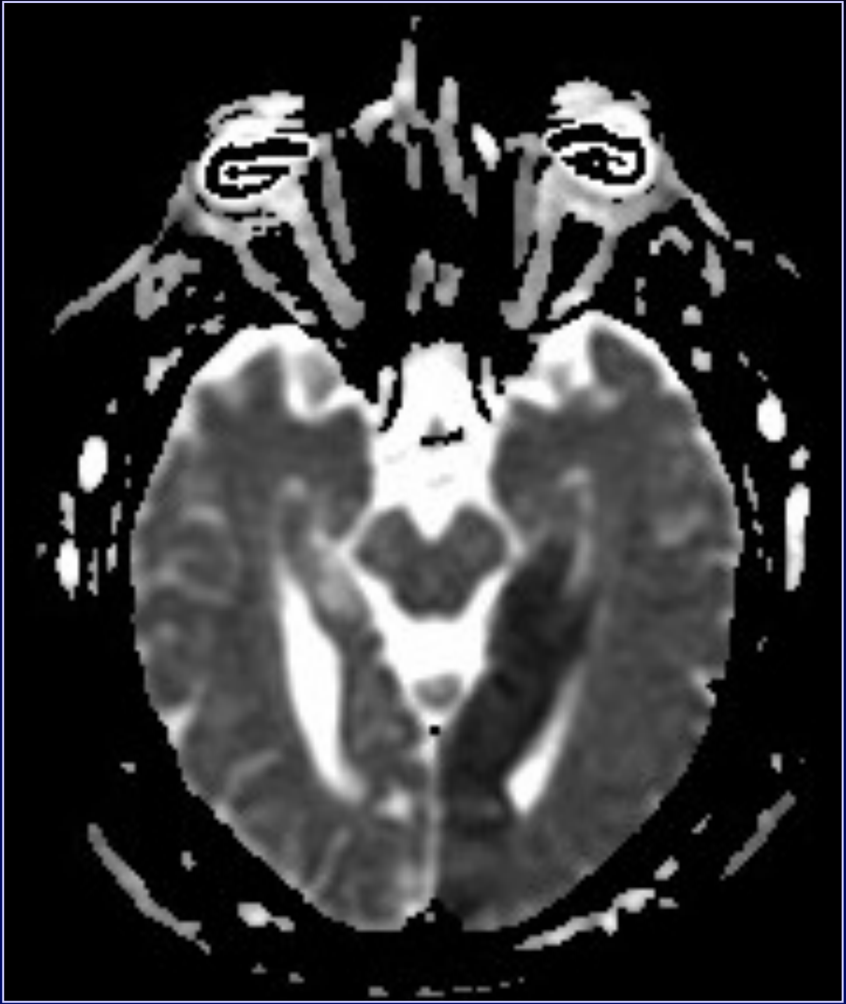
ADC-Apparent diffusion coefficient

- Bright-CSF, gliosis
- Dark-Infarcts
  - New infarctions are black, confirm that white DWI lesion is truly infarction
- Hemorrhage may also be black, so must compare to other MR sequences



VISUALIZING PARENCYMAL EDEMA & BLOOD ON DIFFERENT MRI SEQUENCES

	T1	T2	FLAIR	DWI
VASOGENIC EDEMA		WM	WM	
CYTOTOXIC EDEMA		WM GM	WM GM	x 14d
ACUTE HEME *(deoxyHb)*				
SUBACUTE HEME *(metHb)*				
CHRONIC HEME *(hemosiderin)*				

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CTA VS MRA

CTA

- CT angiography (CTA) is performed by combining the intravenous administration of iodinated contrast material and CT scanning to evaluate vascular related conditions, such as aneurysms or stenoses.
- Disadvantages of CTA include radiation exposure and contrast administration with subsequent risk of contrast induced nephropathy and serious allergic reaction.

MRA

- MR angiography (MRA) of the head does not require contrast administration as it uses time-of-flight imaging that eliminates the risk of a serious allergic reaction and contrast induced nephropathy. In addition, radiation exposure is avoided.
- The sensitivity and specificity of 1.5 Tesla MRA is lower the than that of modern multi-slice CTA studies

Neuroimaging in acute stroke

CT

- Non contrast CTH usually the first study done widely given it is quickly accessible, cheap and fast.
- Accurately demonstrates intracranial hemorrhage
- Demonstrates the extent of infarction with limitations of posterior circulation
- Contrast enhancement can provide CT angiographic and perfusion information
- CTA/MRA to identify vascular lesion responsible for diagnosis

MRI

- MRI if CT contraindicated such as with pregnancy
- DWI identifies ischemic lesions within minutes, distinguish recent (within 2 weeks) infracts from chronic infarcts.
- MRA detects vascular abnormalities that led to the stroke (stenosis/occlussion, aneurysm, vascular malformation)
- DWI and MRA are well-established techniques, perfusion MRI is still largely investigational but promising.

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CT VS MRI

CT

Air	Dark
Fat	Dark
Water	Dark
Brain tissue	gray
Bone, cortical brain tissue,	Bright

MRI

	MR-t1	MR-T2
Air	Dark	Dark
Fat	Bright	Bright
water	Dark	Bright
Brain tissue		
Bone , cortical brain tissue	Dark	Dark

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Transcranial Doppler (TCD)

- Non invasive bedside monitoring
- Regional = cerebral arterial blood flow
- Mean velocities--→ proportional to blood flow
- Changes in TCD often precede clinical manifestations
- Advantages: immediate around-the-clock availability, reproducible, noninvasive.
- Disadvantages: Operator-dependent technology, lack of sonographic window (5-20%), expensive, training.

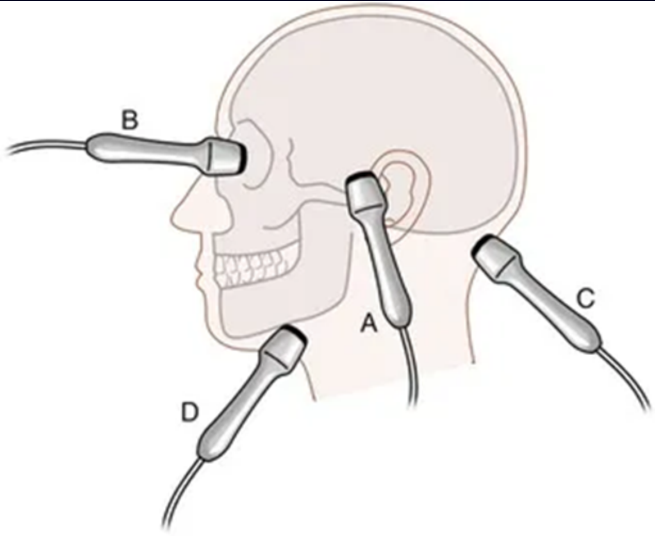
Lau et al . 2020 Better With Ultrasound.
Chest, ISSN: 0012-3692, Vol: 157, Issue: 1, Page: 142-150

Critical Care TCD application

- Midline shift
- Cerebral vasospasm
- ICP evaluation
- Cerebrocirculatory arrest/ brain death
- Sickle cell disease stroke prevention- flow velocities
- Emboli detection (systemic thrombolysis & detection of the right to left shunt).

TCD: Acoustic windows

- Temporal: MCA, ACA, PCA, midline shift.
- Orbital: Ophthalmic, ICA siphon & optic sheath nerve diameter.
- Sub occipital: Vertebral & basilar
- Submandibular: extracranial & intracranial or extradural segment of the ICA.



Transducer positions for the four TCDI windows.
(A) Transtemporal
(B) Transorbital
(C) Suboccipital
(D) submandibular

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Kreiza (2000), Bode (1988)

AIUM guideline (Coley 2012)

Drawing by Blankvisual, Thun, Switzerland

TCD measurements

Transcranial Doppler Grading Criteria for Middle Cerebral Artery Vasospasm

MFV, cm/s	MCA/EC ICA MFV (Lindegaard) Ratio	Interpretation
<120	≤3	Hyperemia
>80	3–4	Hyperemia + possible mild spasm
≥120	3–4	Mild spasm + hyperemia
≥120	4–5	Moderate spasm + hyperemia
>120	5–6	Moderate spasm
≥180	6	Moderate-to-severe spasm
≥200	≥6	Severe spasm
>200	4–6	Moderate spasm + hyperemia
>200	3–4	Hyperemia + mild/residual spasm
>200	<3	Hyperemia

EC indicates extracranial; ICA, internal carotid artery; and MCA, middle cerebral artery.

Transcranial Doppler Grading Criteria for Basilar Artery Vasospasm

MFV, cm/s	BA/EC VA MFV (Sviri) Ratio	Interpretation
>70	>2	Vasospasm
>85	>2.5	Moderate or severe vasospasm
>85	>3	Severe vasospasm

BA indicates basilar artery; EC, extracranial; and VA, vertebral artery

PSV-Peak systolic velocity
EDV- End diastolic velocity
MFV-Mean flow velocities : Systolic +2 Diastolic/3
PI: PSV-EDV/MFV

Kumar V & Alexandrov A (2015). Journal of ultrasound in medicine.

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Optic Nerve Sheath Diameter-ONSD

- Use of ONSD for ICP dates back to 1987, ocular US 1957
- Good surrogate measurement for ICP
- Optic nerve directly comes from (CNS) surrounded by meningeal sheaths and cerebrospinal fluid
- Advantages: immediate around-the-clock availability, reproducible, noninvasive and low cost.
- Disadvantages: Small margin of error, retinal artery artifact(hypoechoic as well- Use color Doppler to distinguish)

Clinical application ONSD

- Linear probe transverse over the closed eyelid of the patient, optimize (globe in the center), locate optic nerve 3mm behind the globe perpendicularly.
- 2 readings on each eye
- Increase in ICP → moves CSF into the optic space → increases in diameter.
- ONSD normal values vary with age
  - Adult < 5mm
- Greater than 6mm correlates with >ICP 20, 5-6 unsure
  - Sensitivity > 95
  - Specificity > 92
- >0.5 cm correlate well with an ICP >20 mmHg

Summary

- Discussed CT basics, advantages, densities and windowing
- Reviewed MRI basics and sequencing
- Briefly discussed TCD basics and applications
- Briefly discussed ONSD basics and applications

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