Neuroradiology: Nuts and Bolts, Do's and Don'ts. Part 1: BRAIN

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Disclosure

I have no relevant relationships with ineligible companies to disclose within the past 24 months.

Learning Objectives

At the conclusion of this session, participants should be able to:

1. Compare and contrast the risks, benefits, alternatives, indications, contraindications, advantages and costs of different imaging modalities used to evaluate patients with neurologic complaints involving the brain
2. Select the most appropriate imaging modality to evaluate a patient with neurologic complaint
3. Apply fundamentals of image interpretation in reviewing Magnetic Resonance Imaging and Computed Tomography

Neuroimaging

Ordering tests comes with responsibility:

- Ordering the correct test
- Noting the indications for the test
- Communication with the radiologist
- Communication with the patient
- Communication with consultants

Recent Malpractice Award:

- $75 million
- Spilt between ER doctor and radiologist

Problems in the case focused on *miscommunication*

Resulted in a 32 year old patient being "Locked-In"

Overview of Imaging Modalities

Radiograph (X-ray)

Computed Tomography (CT, CAT scan)

Magnetic Resonance Imaging (MRI)

Skull Radiographs

Low utility in neuroradiology

- Very low sensitivity for detecting skull fractures or predicting hemorrhage
- Not recommended in trauma

Possible uses:

- Excluding metallic material before an MRI
- Evaluating a ventricular shunt
- Extracranial radiopaque foreign body

Computed Tomography

Very commonly used, particularly in acute settings

Fast, relatively inexpensive

- MC pays about $120, patient pays about $30 (medicare.gov)

Reliable in identifying surgical pathology

- Bones, blood, midline shift

Lots of ionizing radiation: 1.6mSv = 7 months background radiation (radiologyinfo.org)

Poor sensitivity for acute stroke and tumor, risk of missed diagnosis

Iodinated Contrast and Kidney Function

Recommendations have changed recently

Simultaneous joint publication in *Radiology* and *Kidney Medicine* by Davenport et al. in 2020

- "*The putative risk of administering modern intravenous iodinated contrast media in patients with reduced kidney function has been overstated*"
- Recommends prophylactic NS for appropriate patients with decreased renal function before contrast administration

Magnetic Resonance Imaging

Lower utility in emergency departments, but use is increasing sharply

- 100% increase in MRI brain and 220% increase MRI C-spine over 8 years in recent study (Poyiadi, 2023)

Slow, and relatively expensive

- MC pays about $380, patient pays about $94 (medicare.gov)

Lots of absolute and relative contraindications

Case Study #1

Setting: ED

Hx: 19 year old male, hit by a grounder while playing 3rd base.

Was acting ‘off’ for a few mins per trainer, now back to normal

- No relevant medical history, takes no meds

PE: No neurologic deficits, baseball shaped bruise over left eyebrow

- No signs of basal skull fracture

Clinical Decision Tools

No tool is 100% sensitive, application of any tool results in a non-zero missed injury rate.

New Orleans Criteria and **Canadian CT Head Rule** are the most common

Canadian Head CT Rule

For use with ’minor head injury’

Two outcomes in the study:

1. *Need for neurosurgical intervention*
2. *‘Clinically Important’ injury on CT*

Canadian CT Head Rule

CT Head Rule is only required for patients with minor head injuries with any one of the following:

High risk (for neurological intervention)

- GCS score <15 at 2 h after injury
- Suspected open or depressed skull fracture
- Any sign of basal skull fracture (haemotympanum, ‘racoon’ eyes, cerebrospinal fluid otorrhoea/rhinorrhoea, Battle’s sign)
- Vomiting ≥two episodes
- Age ≥65 years

Medium risk (for brain injury on CT)

- Amnesia before impact >30 min
- Dangerous mechanism (pedestrian struck by motor vehicle, occupant ejected from motor vehicle, fall from height >3 feet or five stairs)

Minor head injury is defined as witnessed loss of consciousness, definite amnesia, or witnessed disorientation in a patients with a GCS score of 13–15

Stiell IG, Wells GA, Vandemheen K, et al. The Canadian CT Head Rule for patients with minor head injury. *The Lancet (British edition)*. 2001;357(9266):1391-1396. doi:10.1016/S0140-6736(00)04561-X

New Orleans Head CT Criteria

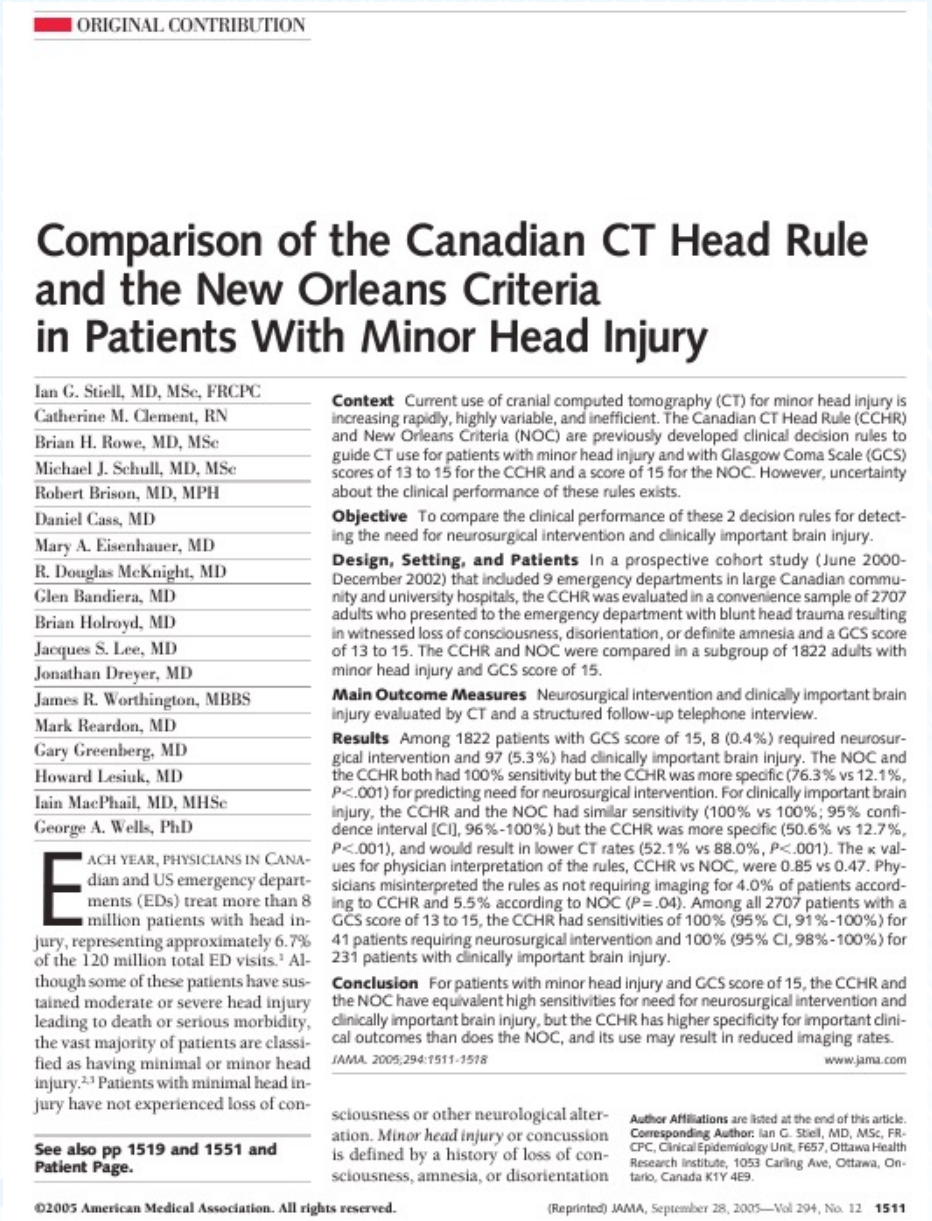
For use with ’minor head injury’

- ❑ *GCS of 15*
- ❑ *Normal CN exam*
- ❑ *Normal Motor and Sensory exam*

CT is required for any of the following findings:

1. Headache
2. Vomiting
3. Older than 60 years
4. Intoxication
5. Anterograde amnesia
6. Visible trauma above clavicle
7. Seizure

Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PMC. Indications for Computed Tomography in Patients with Minor Head Injury. The New England journal of medicine. 2000;343(2):100-105. doi:10.1056/NEJM200007133430204



ORIGINAL CONTRIBUTION

Comparison of the Canadian CT Head Rule and the New Orleans Criteria in Patients With Minor Head Injury

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Context Current use of cranial computed tomography (CT) for minor head injury is increasing rapidly, highly variable, and inefficient. The Canadian CT Head Rule (CCHR) and New Orleans Criteria (NOC) are previously developed clinical decision rules to guide CT use for patients with minor head injury and with Glasgow Coma Scale (GCS) scores of 13 to 15 for the CCHR and a score of 15 for the NOC. However, uncertainty about the clinical performance of these rules exists.

Objective To compare the clinical performance of these 2 decision rules for detecting the need for neurosurgical intervention and clinically important brain injury.

Design, Setting, and Patients In a prospective cohort study (June 2000-December 2002) that included 9 emergency departments in large Canadian community and university hospitals, the CCHR was evaluated in a convenience sample of 2707 adults who presented to the emergency department with blunt head trauma resulting in witnessed loss of consciousness, disorientation, or definite amnesia and a GCS score of 13 to 15. The CCHR and NOC were compared in a subgroup of 1822 adults with minor head injury and GCS score of 15.

Main Outcome Measures Neurosurgical intervention and clinically important brain injury evaluated by CT and a structured follow-up telephone interview.

Results Among 1822 patients with GCS score of 15, 8 (0.4%) required neurosurgical intervention and 97 (5.3%) had clinically important brain injury. The NOC and the CCHR both had 100% sensitivity but the CCHR was more specific (76.3% vs 12.1%, $P<.001$) for predicting need for neurosurgical intervention. For clinically important brain injury, the CCHR and the NOC had similar sensitivity (100% vs 100%; 95% confidence interval [CI], 96%-100%) but the CCHR was more specific (50.6% vs 12.7%, $P<.001$), and would result in lower CT rates (52.1% vs 88.0%, $P<.001$). The κ values for physician interpretation of the rules, CCHR vs NOC, were 0.85 vs 0.47. Physicians misinterpreted the rules as not requiring imaging for 4.0% of patients according to CCHR and 5.5% according to NOC ($P=.04$). Among all 2707 patients with a GCS score of 13 to 15, the CCHR had sensitivities of 100% (95% CI, 91%-100%) for 41 patients requiring neurosurgical intervention and 100% (95% CI, 98%-100%) for 231 patients with clinically important brain injury.

Conclusion For patients with minor head injury and GCS score of 15, the CCHR and the NOC have equivalent high sensitivities for need for neurosurgical intervention and clinically important brain injury, but the CCHR has higher specificity for important clinical outcomes than does the NOC, and its use may result in reduced imaging rates.

JAMA. 2005;294:1511-1518 www.jama.com

EACH YEAR, PHYSICIANS IN Canadian and US emergency departments (EDs) treat more than 8 million patients with head injury, representing approximately 6.7% of the 120 million total ED visits.[1] Although some of these patients have sustained moderate or severe head injury leading to death or serious morbidity, the vast majority of patients are classified as having minimal or minor head injury.[2,3] Patients with minimal head injury have not experienced loss of consciousness or other neurological alteration. *Minor head injury* or concussion is defined by a history of loss of consciousness, amnesia, or disorientation

See also pp 1519 and 1551 and Patient Page.

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Sooooo.....

Both tools have similar High sensitivity

Canadian HCT Rule, more *Specific*, would lower use of CT imaging

Stiell I, Clement C, Rowe B, et al. Comparison of the Canadian CT Head Rule and the New Orleans Criteria in patients with minor head injury. *JAMA : the journal of the American Medical Association*. 2005;294(12):1511-1518. doi:10.1001/jama.294.12.1511

Organization	Recommendation for CT scan in Minor Head Injury
ATLS®	Use tool adapted from Canadian CT Head Rule
ACEP mTBI policy 2023	**Level A:** Use the Canadian CT Head Rule (CCHR) to provide decision support and improve head CT utilization in adults with a minor head injury. **Level B:** Use New Orleans Criteria or NEXUS
ACR Appropriateness Criteria	Apply a clinical Decision Making tool
EAST	**Level 2:** Clinicians should perform brain CT scan on patients that present with suspected brain injury in the acute setting if it is available. If CT resources are limited, consideration may be given to the use of a set of standardized criteria (e.g., the Canadian CT Head Rule [CCHR], New Orleans Criteria [NOC]) to determine which patients with MTBI receive a brain CT scan.

Case Study #1- Review

Setting: ED

Hx: 19 year old male, hit by a grounder while playing 3rd base.

Was acting ‘off’ for a few mins per trainer, now back to normal

- No relevant medical history, takes no meds

PE: No neurologic deficits, baseball shaped bruise over left eyebrow

- No signs of basal skull fracture

An approach to Reviewing Head CT (trauma)

Evaluate for findings immediately dangerous to life and health and may require surgery or admission

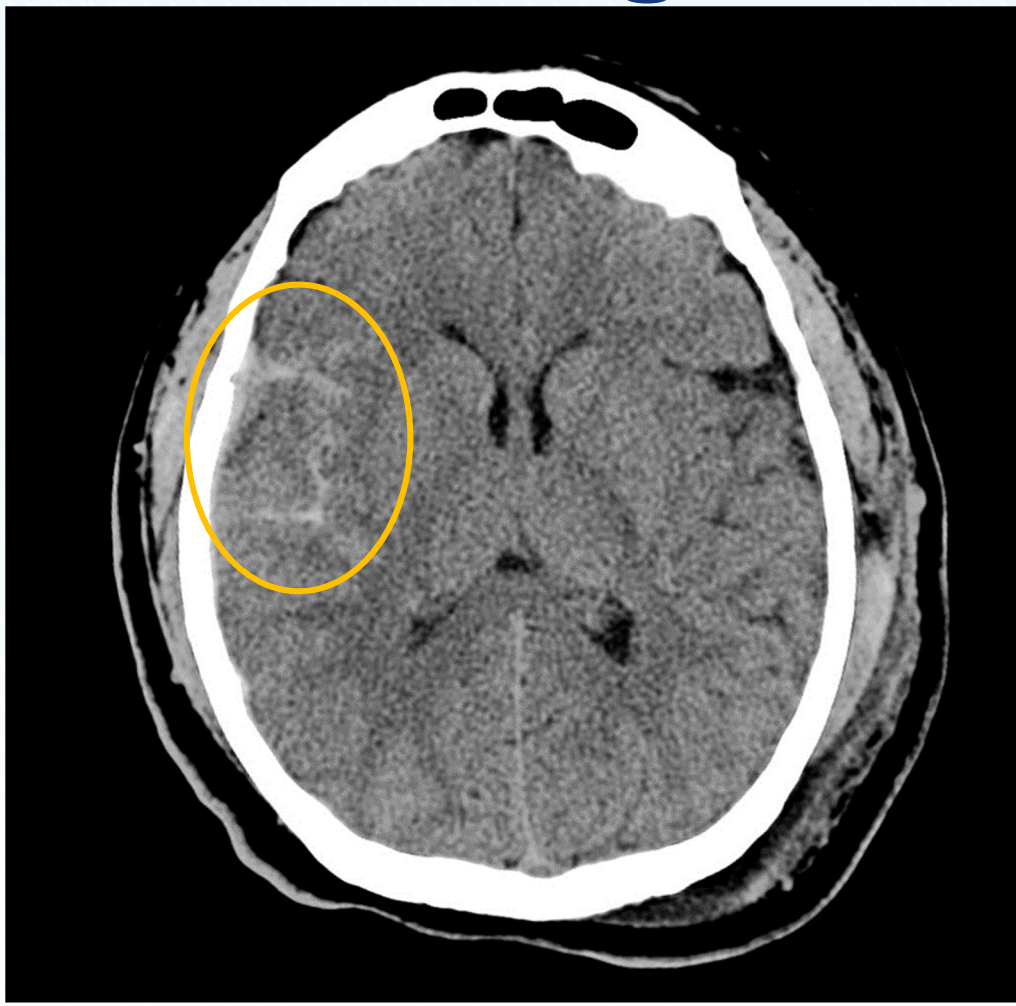
- Hemorrhage
- Fracture
- Edema and herniation
- Foreign bodies

Traumatic Subarachnoid Hemorrhage

Most common CT finding in head injury

Bleeding into the subarachnoid layer from damage to vessels

- Acute blood into sulci (*not around the Circle of Willis*)
- Distribution varies with the mechanism



Gaillard F, Traumatic subarachnoid hemorrhage with contusion. Case study, Radiopaedia.org (Accessed on 21 Feb 2024) https://doi.org/10.53347/rID-4852

Acute Subdural Hematoma

Bleeding into layer under the dura

Can be acute, subacute or chronic

Crescent shaped/ concave

Important Measurements:

Max thickness
Midline Shift

Epidural Hematoma

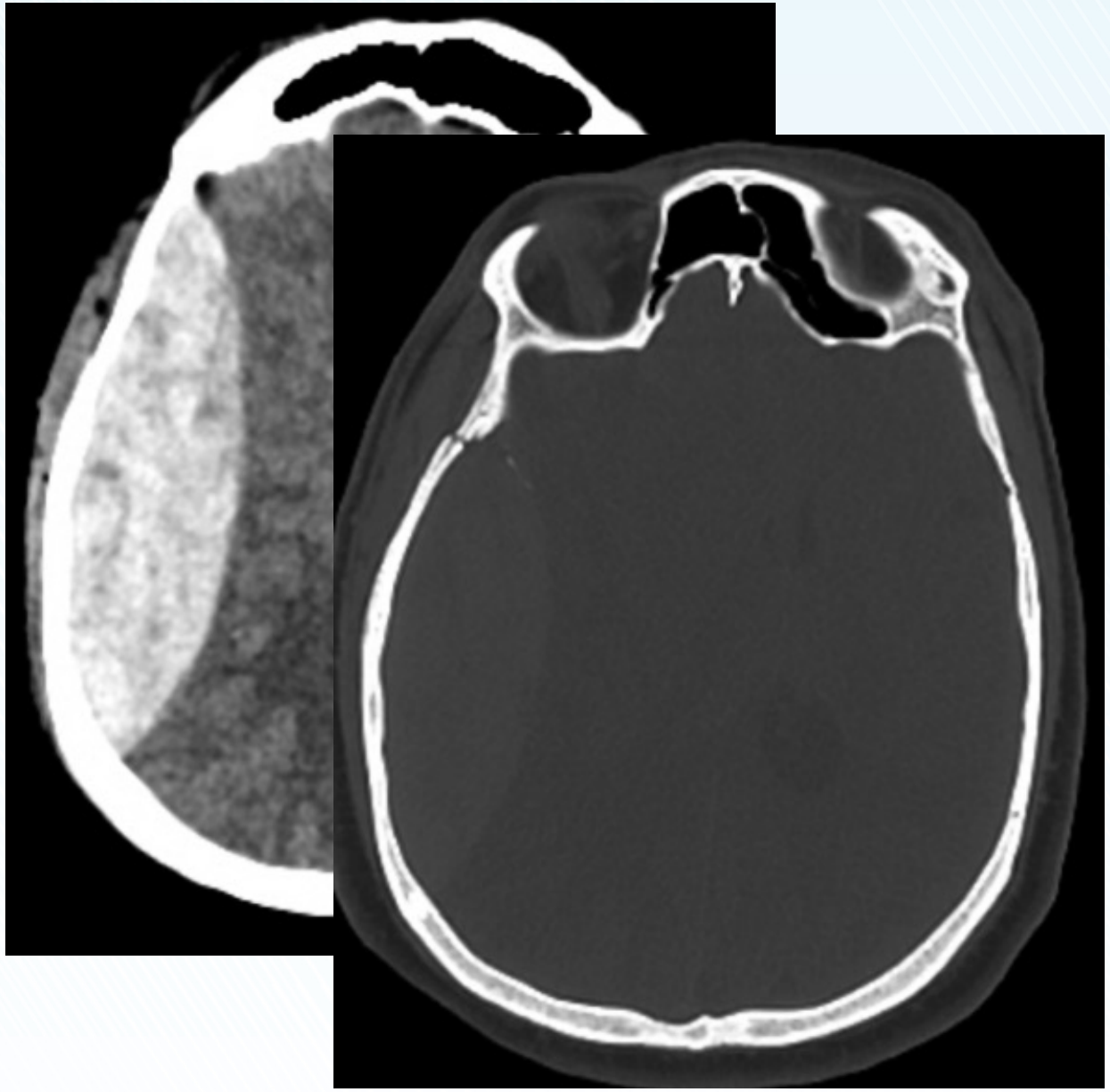
Bleeding between skull and dura

Don’t Cross suture lines

Biconvex shape

- *Lens shaped, egg shaped*

Skull fracture overlying the hematoma (75% of the time there is an overlying fracture)



Kumar K, Epidural hematoma. Case study, Radiopaedia.org (Accessed on 21 Feb 2024) https://doi.org/10.53347/rID-165693

Case Study #2

68-year-old Right-handed patient brought to ER by ambulance

- Acute onset Right sided weakness and slurred speech
- Last known well 38 mins prior
- NIHSS 21
- Code Stroke is called

Imaging for Acute Ischemic Stroke

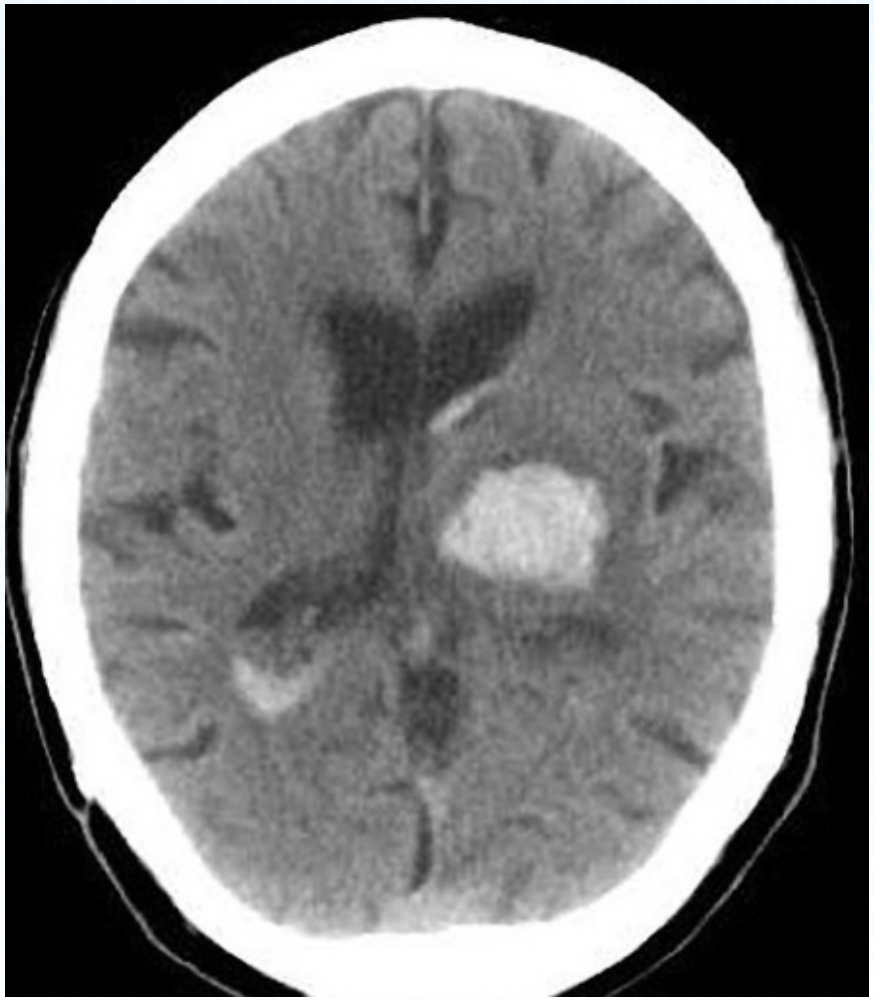
Non-contrast Head CT is generally first line

High sensitivity to exclude hemorrhage
- guides treatment with TPA

Should be ordered, completed and interpreted as fast as possible

Some centers have STAT MRI capabilities

Imaging for Acute Ischemic Stroke



Radiology U, Hemorrhagic stroke - basal ganglia. Case study, Radiopaedia.org (Accessed on 21 Feb 2024) https://doi.org/10.53347/rID-34156

Non-Con CT Stroke Findings

Obscuration of the Lentiform Nucleus

May be seen on CT images within 2 hours after the onset of a stroke

Batta N, Disappearing basal ganglia sign. Case study, Radiopaedia.org (Accessed on 21 Feb 2024) https://doi.org/10.53347/rID-24702

Non-Con CT Stroke Findings

Hyperdense Vessel Sign

Acute thrombus has high attenuation

Highly specific but sensitivity is poor

Don’t forget the Basilar Artery

Di Muzio B, Hyperdense MCA sign. Case study, Radiopaedia.org (Accessed on 21 Feb 2024) https://doi.org/10.53347/rID-28154

Vascular Imaging

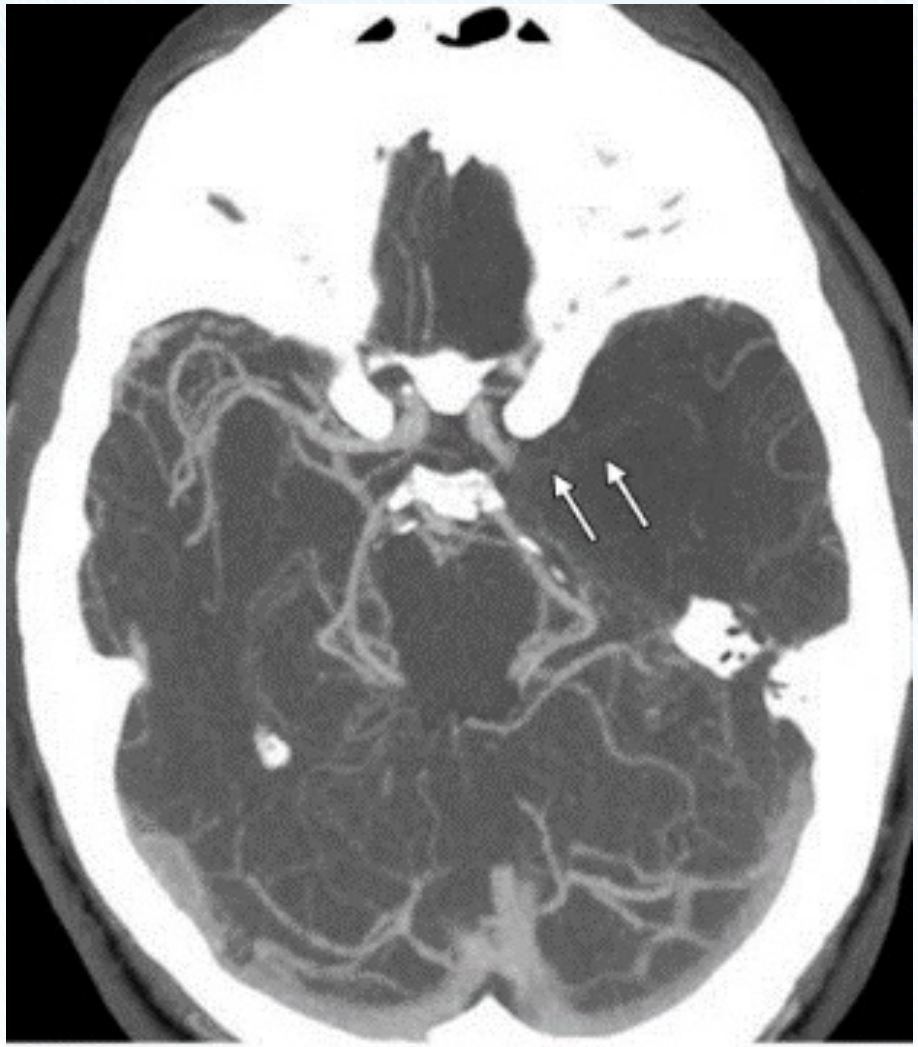
CTA/ MRA to assess for large vessel occlusion

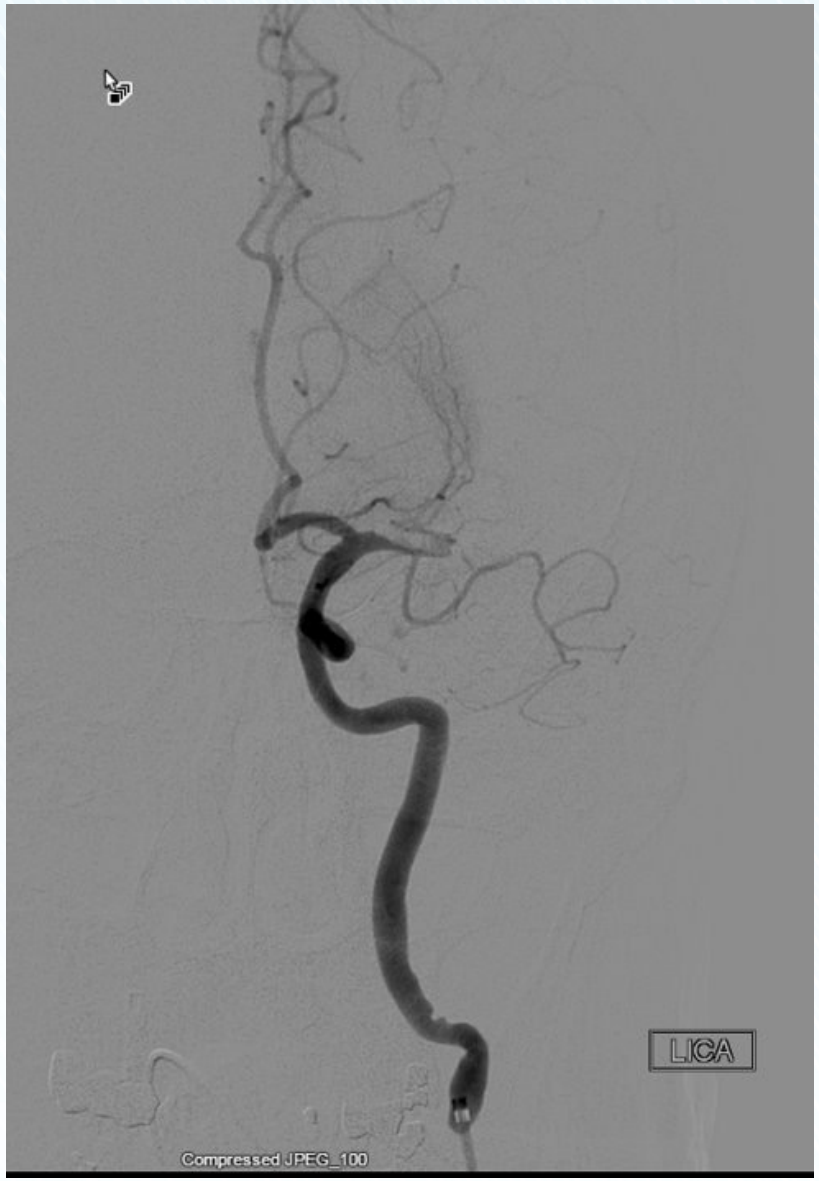
- guides treatment for mechanical thrombectomy

- Contrast and renal function?

CT perfusion can be added

- further guides candidacy for mechanical thrombectomy

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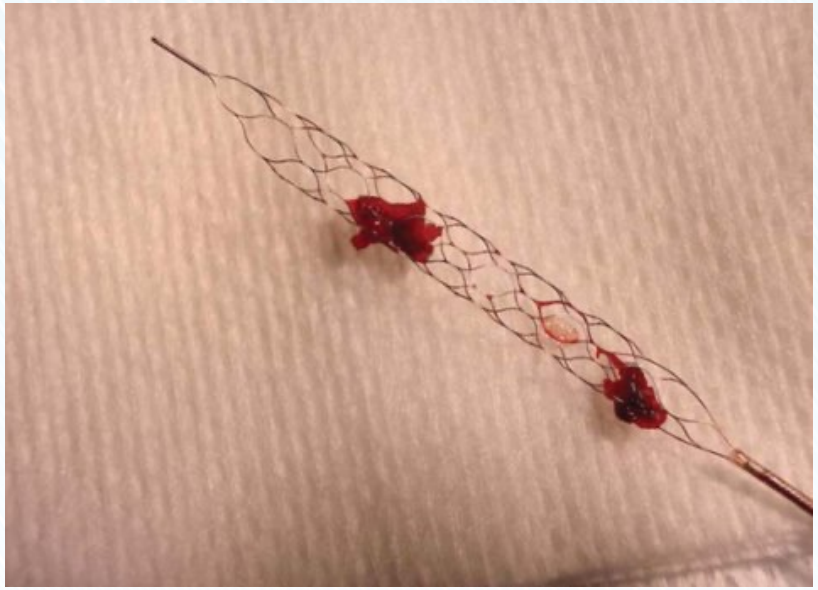

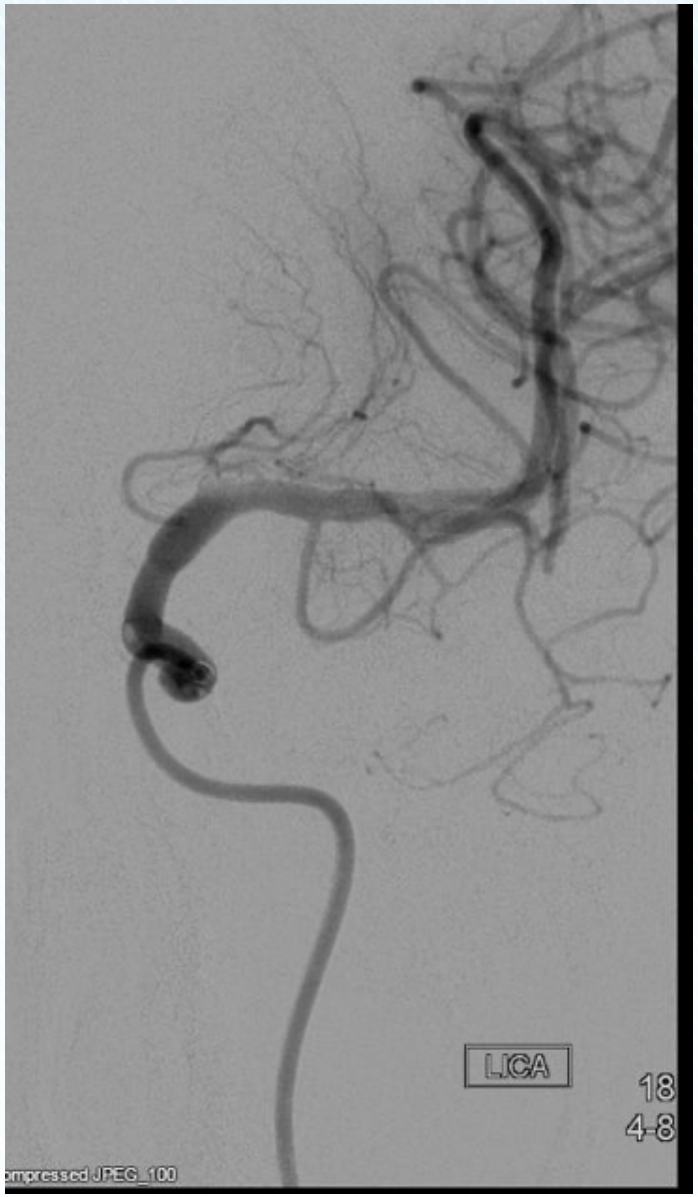
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Case Study #3

36 year old reports to the ED with an unusual and severe headache that started very suddenly about 3 hours ago

- No significant medical history or meds
- No trauma
- One episode of vomiting

Exam:

Uncomfortable, but no neurologic deficits

Aneurysmal Subarachnoid Hemorrhage

CT Head without contrast is the initial test of choice

- Sensitivity near 100% in first 3 days (Cortnum, 2010)
- Will show hydrocephalus or hematoma

Indication for LP is increasingly debatable (Lawton, 2017)

MRI may be of value in a negative CT

CT angiography timing is center dependent

Approach to the CT in SAH

Acute blood is hyperdense, becomes less dense over time

Look for blood:

- Basal cisterns
- Sylvian fissure
- Occipital horns of lateral ventricles

Look for hydrocephalus

Approach to the CT in SAH

Suprasellar Cistern

Sylvian Fissure

Occipital Horns

Jones J, Subarachnoid hemorrhage. Case study, Radiopaedia.org (Accessed on 22 Feb 2024) https://doi.org/10.53347/rID-8808

Approach to the CT in SAH

Temporal Horns (tips)

Fourth Ventricle

Jones J, Subarachnoid hemorrhage. Case study, Radiopaedia.org (Accessed on 22 Feb 2024) https://doi.org/10.53347/rID-8808

Case Study #4

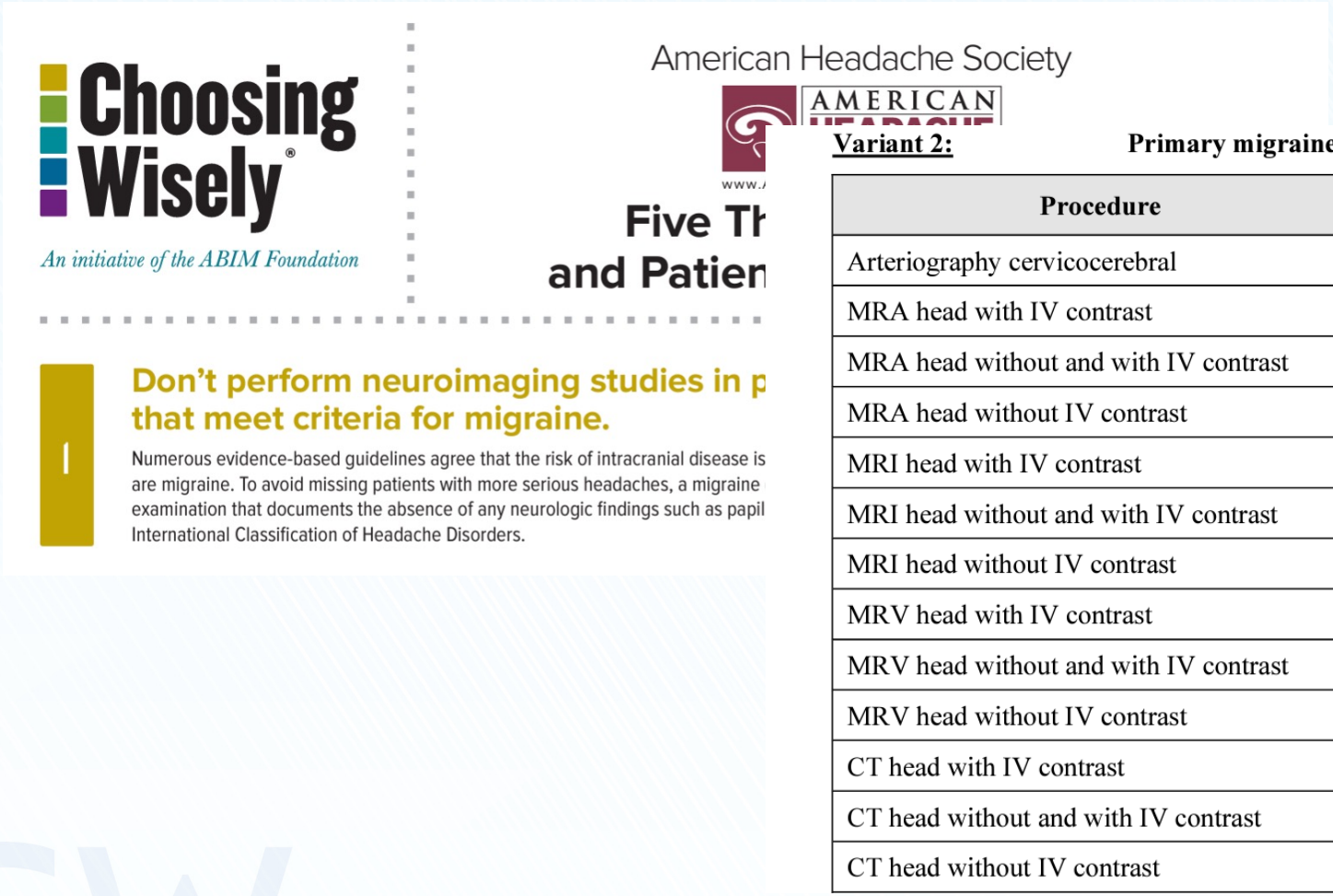
28-year-old patient, presents to family practice clinic for migraine maintenance

- long history of migraines
- no change in frequency or severity, but not at treatment goal

Exam

- no focal neurologic deficits

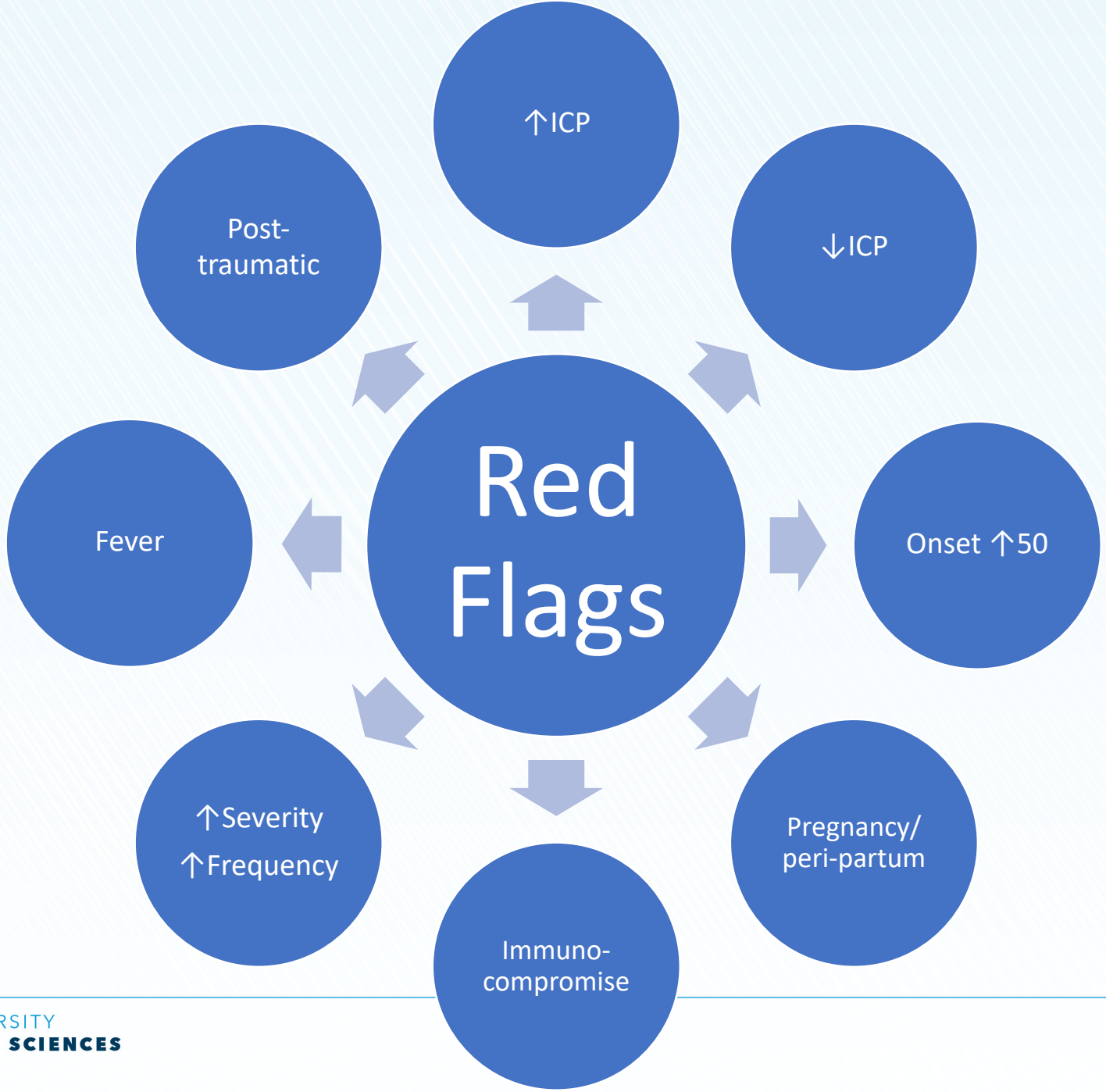
Imaging for Migraines



Variant 2: **Primary migraine or tension-type headache. Normal neurologic examination. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRV head with IV contrast	Usually Not Appropriate	O
MRV head without and with IV contrast	Usually Not Appropriate	O
MRV head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢

Whitehead MT, Cardenas AM, Corey AS, et al. ACR Appropriateness Criteria® Headache. *Journal of the American College of Radiology*. 2019;16(11):S364-S377. doi:10.1016/j.jacr.2019.05.030


↑ICP
↓ICP
Onset ↑50
Pregnancy/
peri-partum
Immuno-
compromise
↑Severity
↑Frequency
Fever
Post-
traumatic
Red
Flags

Variant 7: **Headache with one or more of the following "red flags": increasing frequency or severity, fever or neurologic deficit, history of cancer or immunocompromise, older age (>50 years) of onset, or posttraumatic onset. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without and with IV contrast	Usually Appropriate	O
MRI head without IV contrast	Usually Appropriate	O
CT head without IV contrast	Usually Appropriate	☢☢☢
Arteriography cervicocerebral		
MRA head with IV contrast		
MRA head without and with IV contrast		
MRA head without IV contrast		
MRI head with IV contrast		
MRV head with IV contrast		

Variant 6: **Headache with new onset or pattern during pregnancy or peripartum period. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
CT head without IV contrast	Usually Appropriate	☢☢☢
MRV head without IV contrast	May Be Appropriate	O
CTV head with IV contrast	May Be Appropriate	☢☢☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O

Whitehead MT, Cardenas AM, Corey AS, et al. ACR Appropriateness Criteria® Headache. *Journal of the American College of Radiology*. 2019;16(11):S364-S377. doi:10.1016/j.jacr.2019.05.030

Case Study #5

44 year old patient presents to the ER in a postictal state after a witnessed generalized seizure this morning at work

- No personal history of seizure or recent trauma

Exam

- Airway is patent
- GCS 14 (eyes open to command)
- Participates in exam, no focal deficits

New Onset Seizure – CT Head

Initial imaging of choice

Assesses for structural issues like hemorrhage, stroke, AVM, hydrocephalus and tumor (contrast may help)

If history of trauma- assesses for hematoma, fracture, hydrocephalus (no role for contrast in trauma)

New Onset Seizure - MRI

Study of choice in non-emergent setting

Identifies and characterizes structural epileptogenic lesions

- hippocampal sclerosis, focal cortical dysplasia, tumor

New Onset Seizure - MRI

Tumor is a common presentation of brain tumor (26%)

Tumor should be aggressively sought in any first-time unprovoked seizure in an adult. The patient should have extensive evaluation and if the initial MRI is negative, patient should have serial imaging for a period of time.

- Greenberg Handbook of Neurosurgery

Take Home Points

Application of Clinical Decision Making Tools can be helpful in deciding when to order imaging

Providers must understand indications and limitations of different radiologic modalities

Communication is key

Look at all of your imaging, ask questions, use resources

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Questions?

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Thank you

- images courtesy of Michael Johnson unless otherwise stated.

Case study questions

Case Study #1- Which of the following is the most appropriate in the management of this patient?

E- No imaging is indicated

This is probably the most correct answer though it could be argued that application of the NO criteria would view the bruise over the eyebrow to be ‘trauma above the clavicle’ and need CT imaging.

Case study questions

Case Study #2: Which of the following is the most appropriate next step?

C- CT head without contrast.

This is the most appropriate study, though some stroke centers have the capability to perform MRI instead of CT as the initial study.

Case study questions

Case Study #3 What is the initial imaging modality that should be performed for this patient?

B- CT head without contrast

This is the initial study of choice to assess for subarachnoid hemorrhage. Some centers my add CTA at the same time, but it is not helpful to the diagnosis of the bleed, but may show a cause like aneurysm or AVM

Case study questions

Case Study #4- What imaging is the most appropriate for this patient with migraines?

A- No imaging is indicated

No imaging is indicated for stable migraines.