Pediatric Imaging – What test do I order?

Graham Buirski, MBBS, MRCP, FRCR, FRANZCR, MD
Section Head MSK Imaging, Sidra Medical and Research Center
Assoc Professor of Radiology, WCMC-Q

Co-Contributors:
Deepak Kaura, MD, FRCPC, DABR
Pediatric Radiologist

Ioannis Delakis PhD
Medical Physicist

DISCLOSURE

None of the presenters for this session have any relevant financial relationship with commercial interest to disclose.

Objectives

- Describe the key facts and physics for different diagnostic imaging modalities
- Understand their imaging capabilities
- Describe differences in risk for different types of diagnostic tests
- Understand the principle of justification
- Consider a diagnostic paradigm for imaging
- Appreciate the importance of collaboration/ communication between referrer, radiologist, patient and family.

So Why do I need to chose?

- Not all tests are free of risk.
- Ionising Radiation
- MRI contraindications and safety

Electro-magnetic spectrum

Energy (eV) **N.B 1eV = 1.6 x 10^{-19} J**

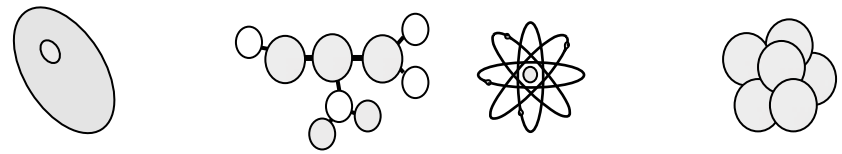
Frequency (Hz)

10^{6} 10^{8} 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{8} 10^{12}

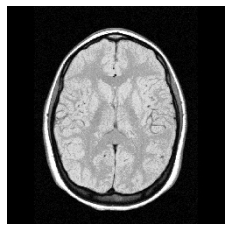
Radio | Microwave | mm | Infrared | Ultraviolet | X-ray | Gamma ray

Wavelength (m)

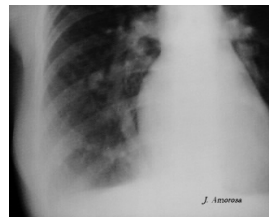
10^{2} 1 10^{-2} 10^{-4} 10^{-6} 10^{-8} 10^{-10} 10^{-12} 10^{-14}



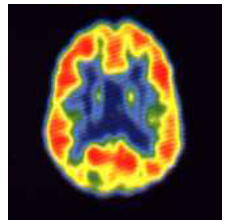
Cell Molecule Atom Nucleus



MRI



X-ray



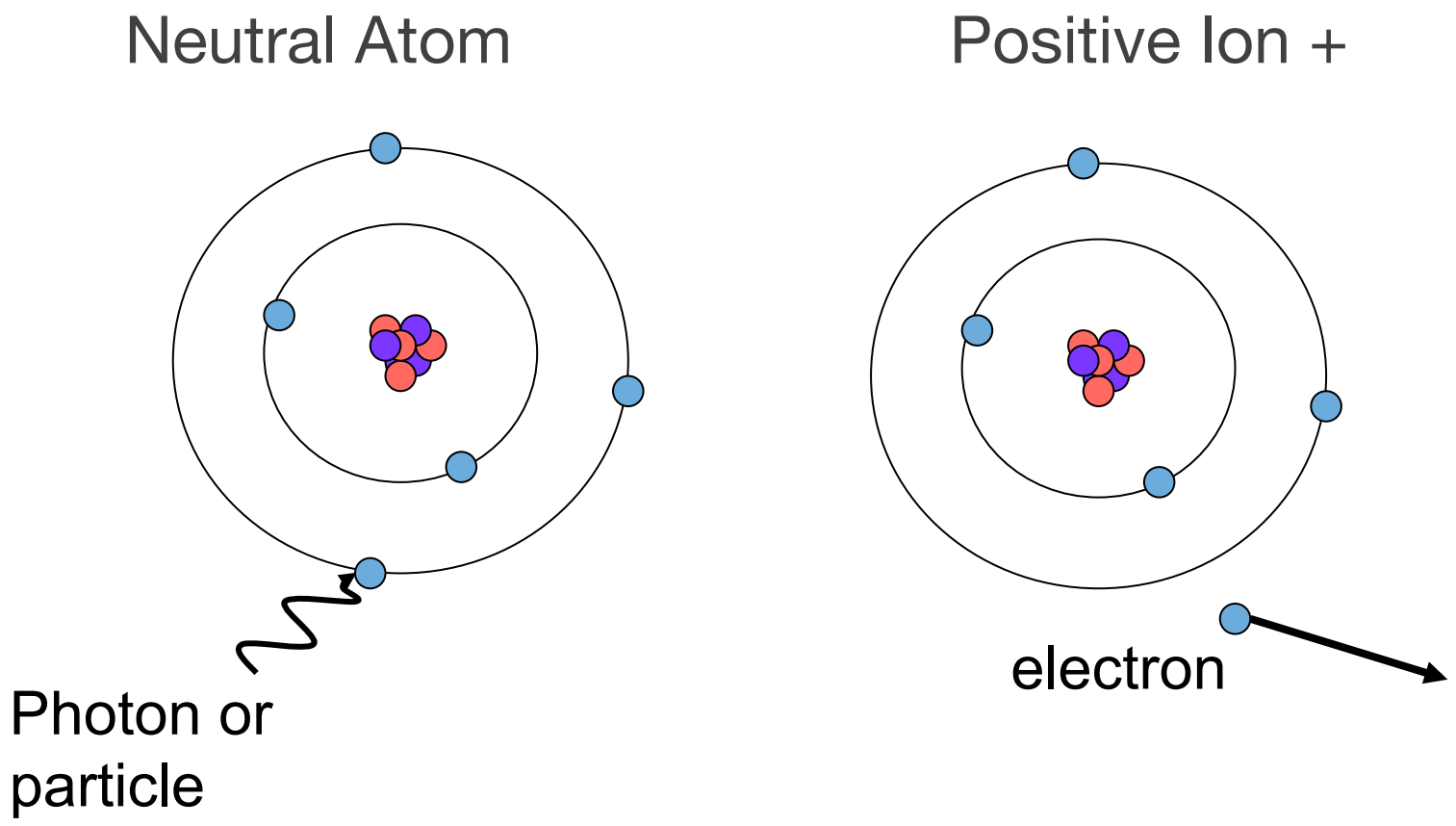
PET

X Ray penetration and attenuation in human tissues

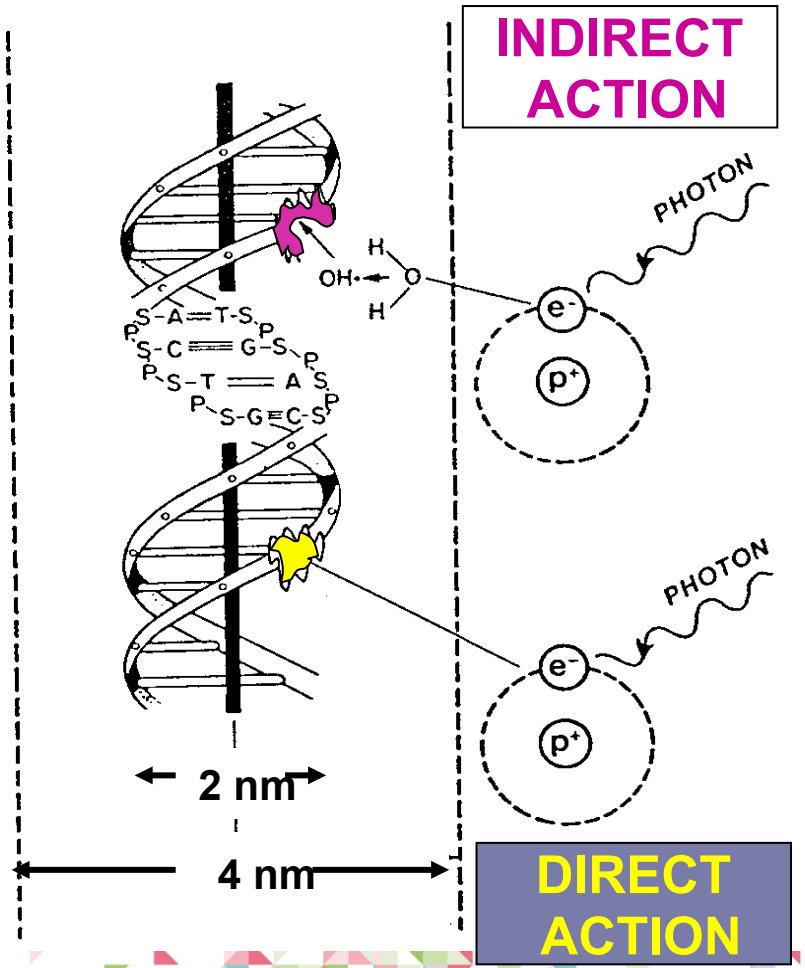
Attenuation of an X Ray beam:

- air: **negligible**
- lungs: **weak** due to density
- bone: **significant** due to relatively high density (atom mass number of Ca)
- soft tissue (e.g. muscle,..): **similar** to water
- fat tissue: **less than water**

Ionisation



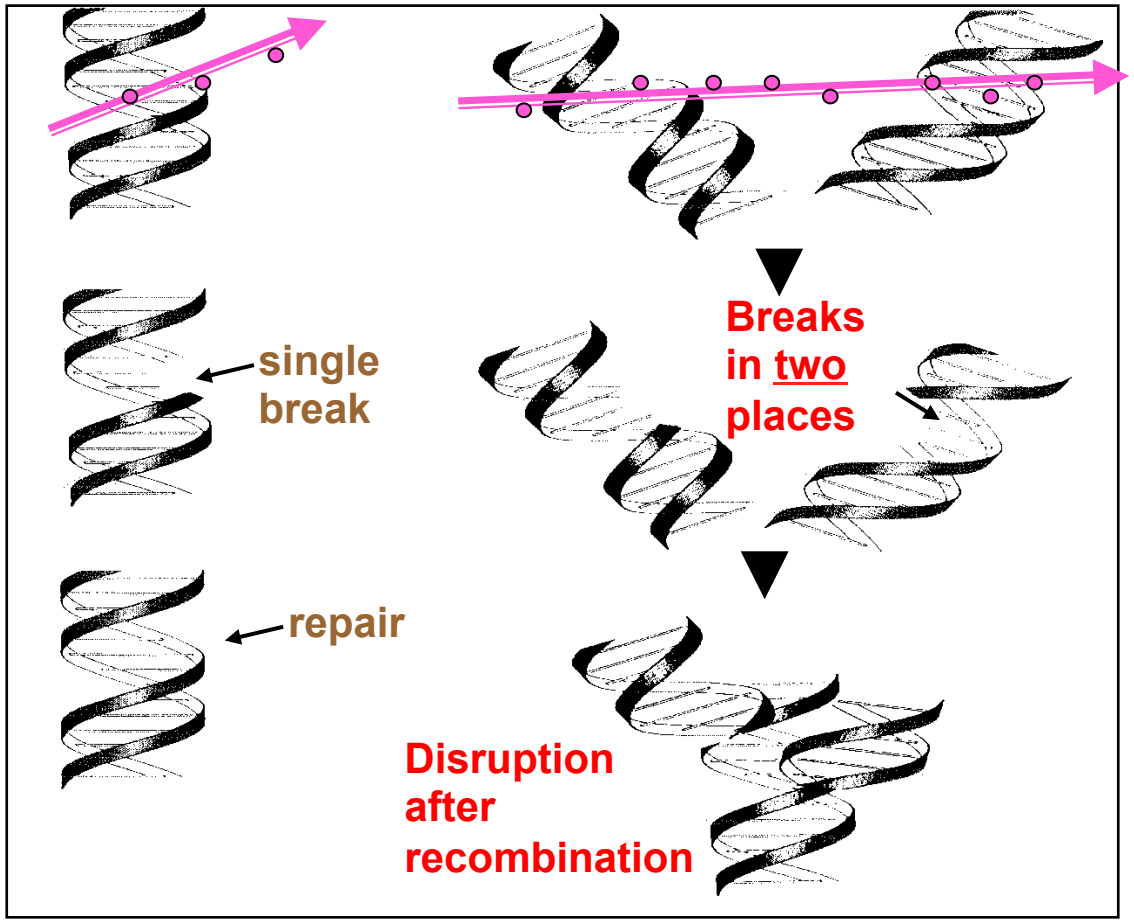
Radiation Damage



- Free radicals diffuse to damage critical targets
- More likely to occur due to water in cells

- High energy radiation hits critical targets in cells

Radiation Damage



Radiation Damage - summary

- Radiation Exposure

↓

- Ionisation

↓

- Free Radicals (Chemical Change)

↓

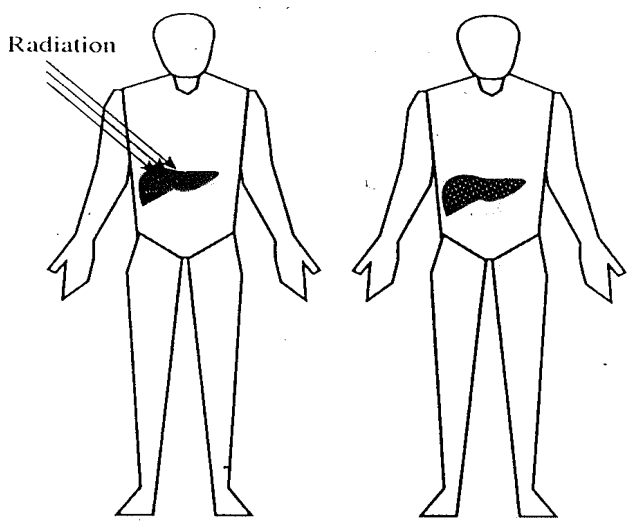
- Molecular Changes (DNA – trigger)

↓

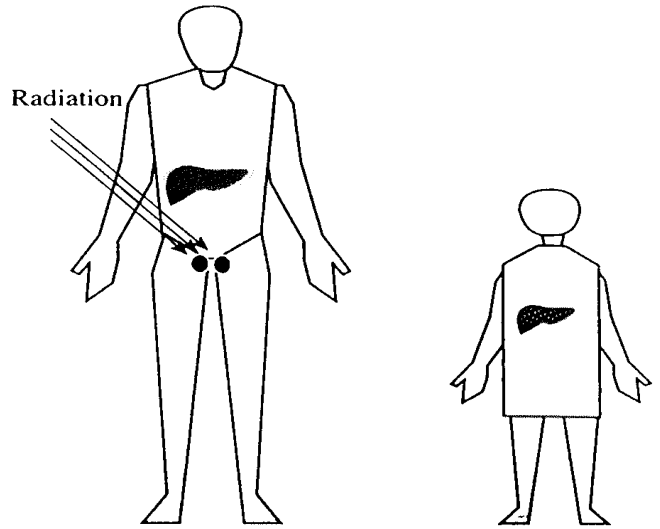
- Biological Effects

Somatic & Genetic Effects

Somatic



Genetic



Deterministic & Stochastic Effects

- Deterministic effects are those which, above a certain threshold, will happen.
  - E.g. erythema, cataracts

- Stochastic effects are those which may happen, i.e. are based on probability
  - A single photon could cause a mutation

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

BMJ 2013 ; 346 doi: https://doi.org/10.1136/bmj.f2360 (Published 21 May 2013)
Cite this as: *BMJ* 2013;346:f2360

Lancet. 2012 Aug 4; 380(9840): 499–505. PMCID: PMC3418594
doi: 10.1016/S0140-6736(12)60815-0

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce,[a,*] Jane A Salotti,[a] Mark P Little,[c] Kieran McHugh,[d] Choonsik Lee,[c] Kwang Pyo Kim,[e] Nicola L Howe,[a] Cecile M Ronckers,[c,f] Preetha Rajaraman,[c] Alan W Craft,[b] Louise Parker,[g] and Amy Berrington de González[c]

Effective Dose from typical Exams

Remember: Background radiation in Qatar is 2.5-3 mSv per annum

Category	Examination	Effective Dose (mSv)
Simple x-ray	Chest	0.02
Simple x-ray	Skull	0.05
Simple x-ray	Abdomen or pelvis	1
Simple x-ray	Lumbar spine	1.5
Complex x-ray	Barium meal	3
CT	Head	2
CT	CT abdomen/pelvis	14
Nuclear Medicine	Tc-99m Bone scan	3
Nuclear Medicine	F-18 FDG PET-CT scan	10

At Sidra:

CT head = 1.4mSv

CT CAP = 7mSv

CT c-spine = 4mSv

Risk Factors for typical Exams

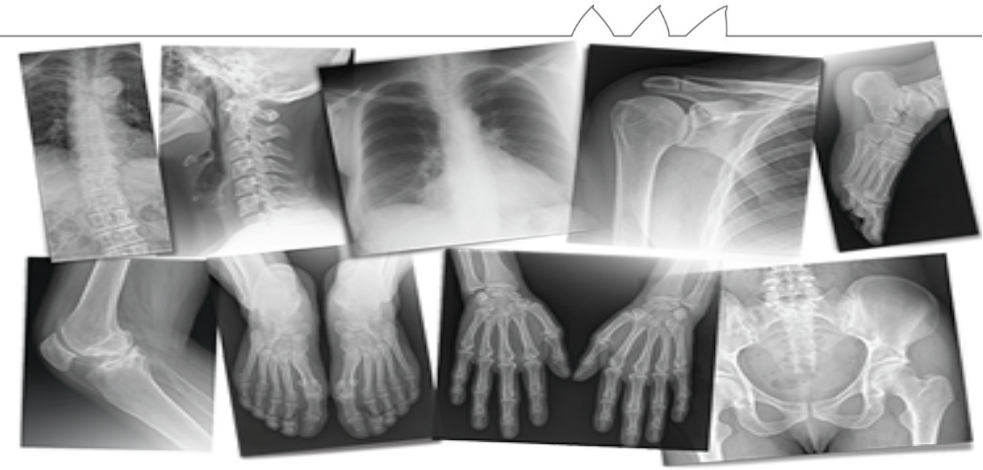
Examination	Effective Dose (mSv)	Deaths (fatal cancer)
X-ray of pelvis	1	1 in 20000
CT Head	2	2 in 20000
Tc-99m bone scan	3	3 in 20000
FDG PET/CT scan	10	10 in 20000

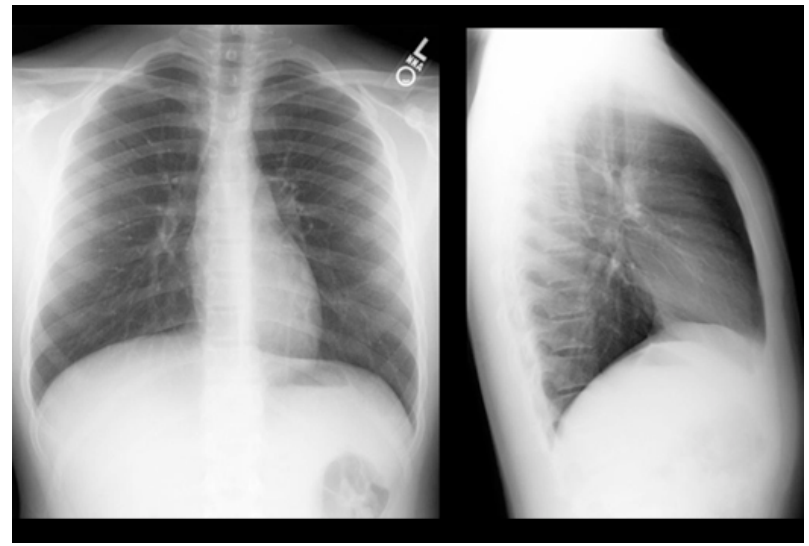
Risk of Death

- **Smoking 150 cigarettes**
  - smoking 20 cigarettes a day for 20 years, a total of 150,000, gives a 1 in 10 chance of dying
- **Travelling 25,000 miles by passenger aircraft**
  - 10 transatlantic journeys give a 1 in 5,000 chance of dying through crashing, fire etc
- **Whole body exposure to 2 mSv of ionising radiation**
  - 1 in 10,000

Quick facts- General X-ray and CT

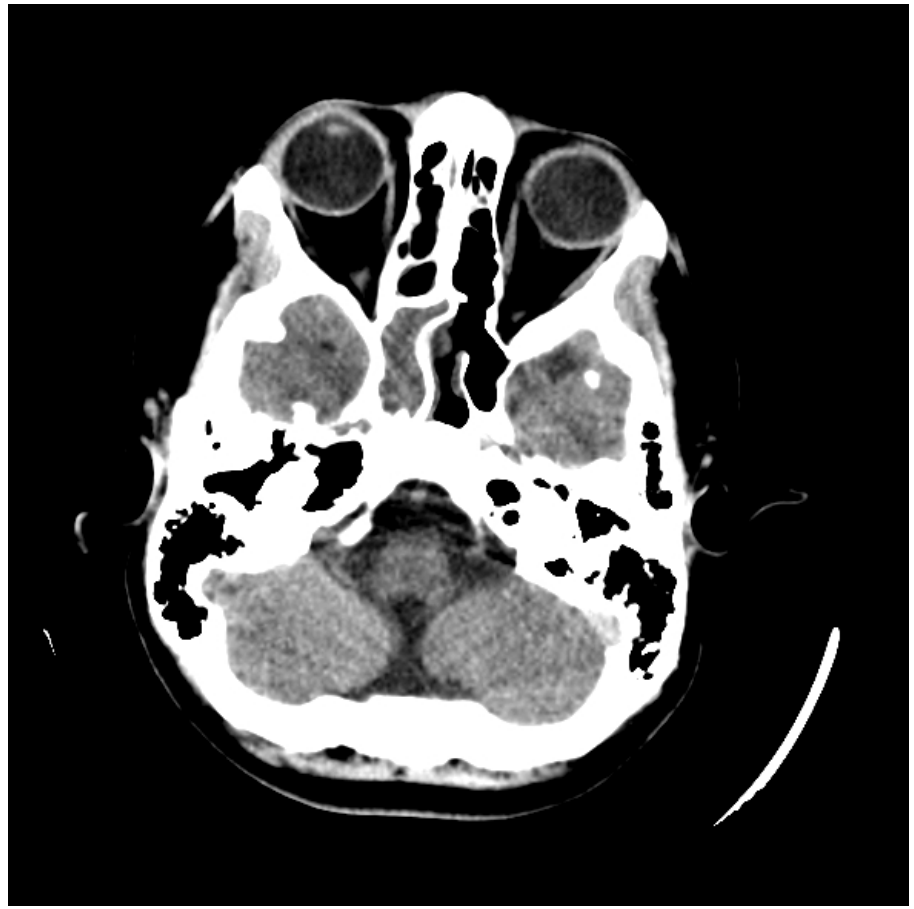
- General X-ray is used for projection images
- CT is used for slices through the patient's body
- General X-ray and CT are widely used because they are fast (e.g. single breath CT) and have high resolution.
- General X-ray and CT expose the patient to radiation.
- Radiation risk is cumulative so careful consideration needs to be given to pediatric and pregnant patients

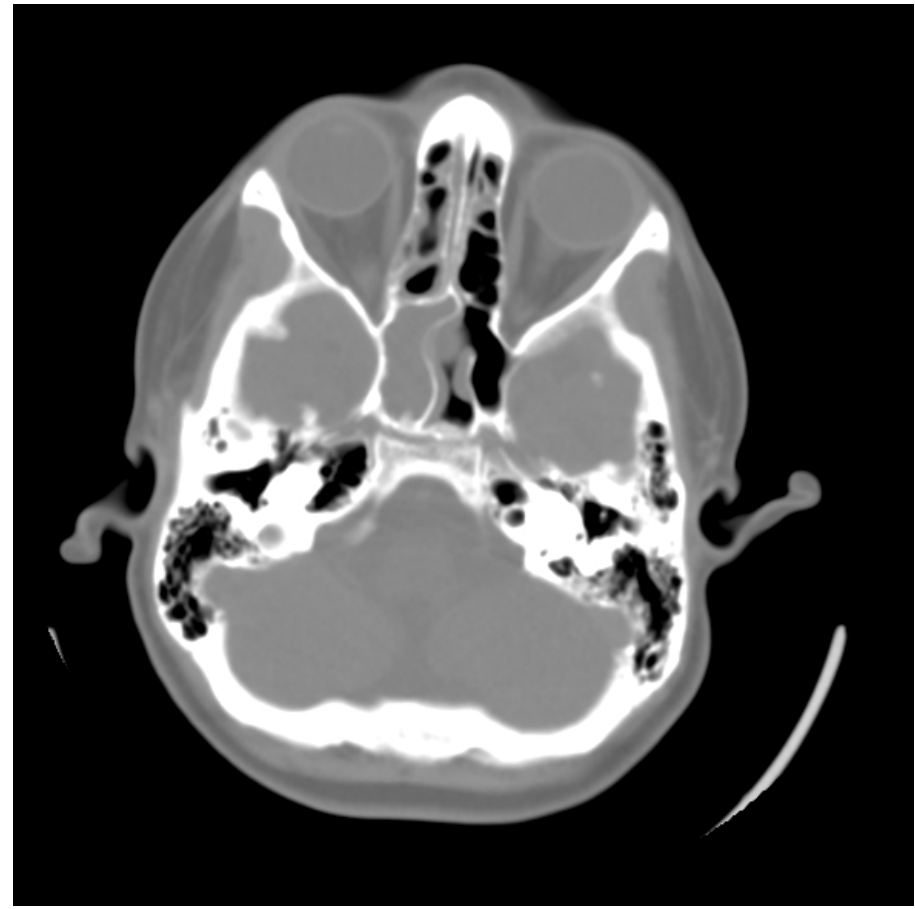


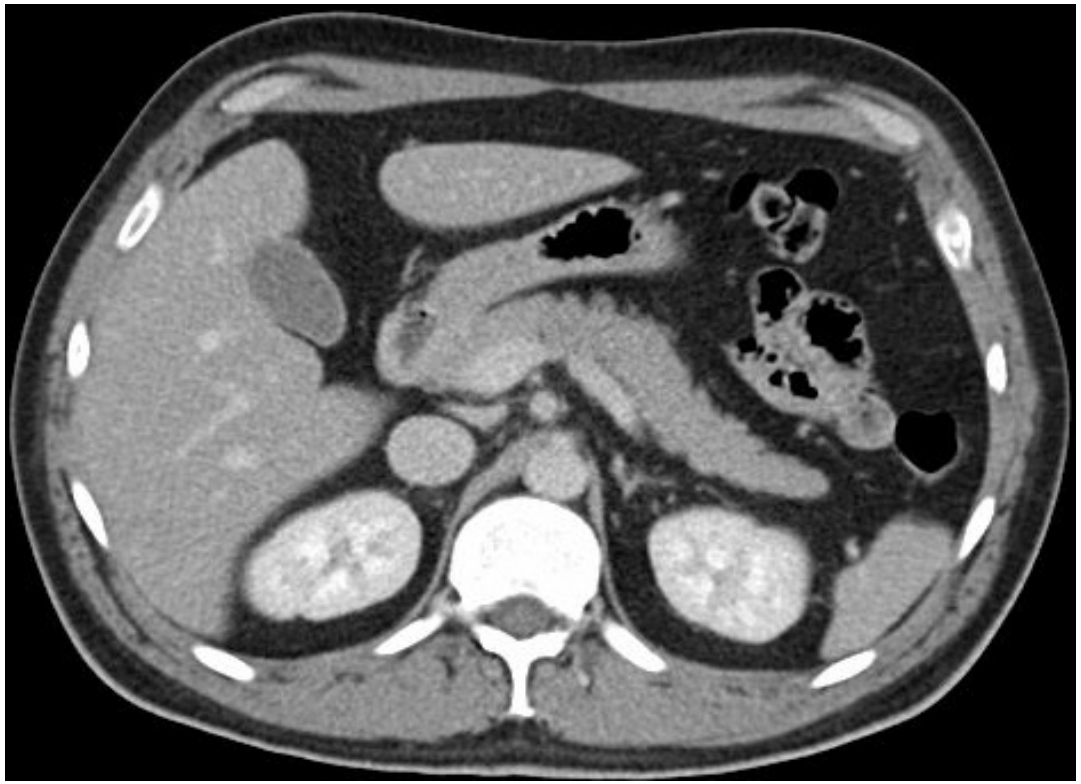


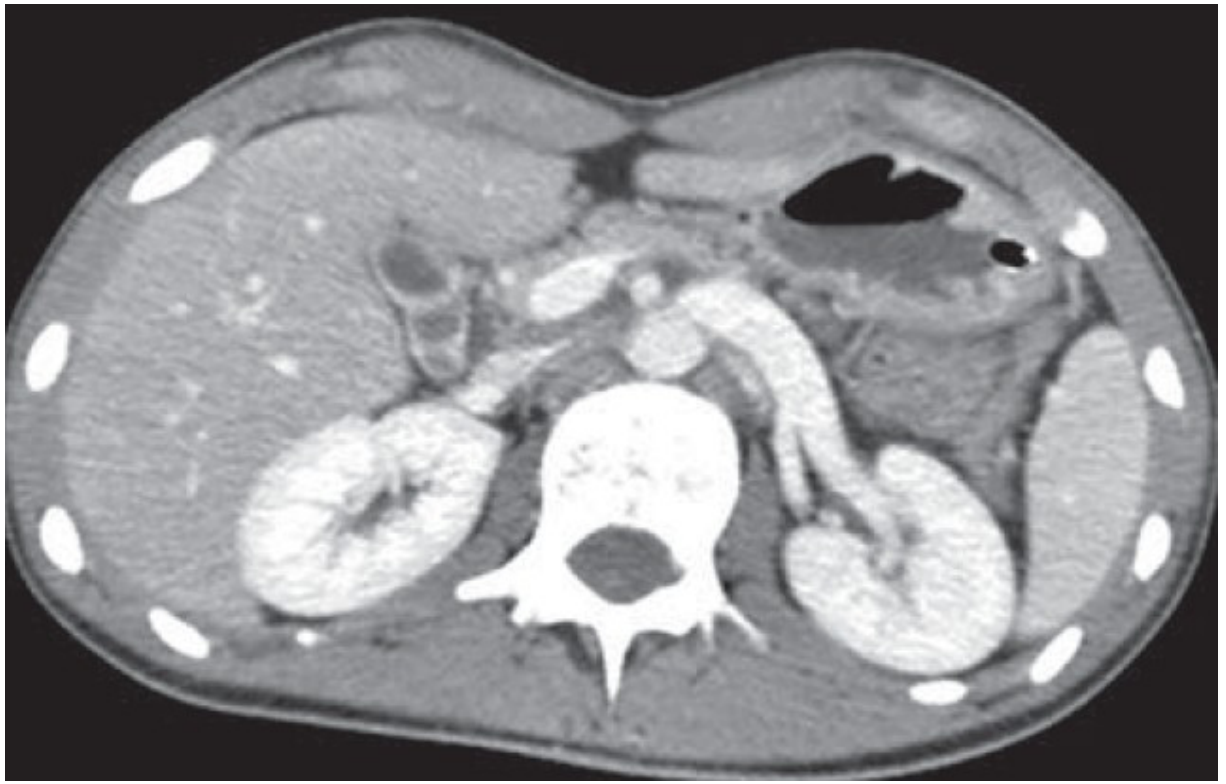
CT

- 4 densities
  - Bone
  - Soft tissue
  - Fat
  - Air
  - [Contrast]
  - [Metal]

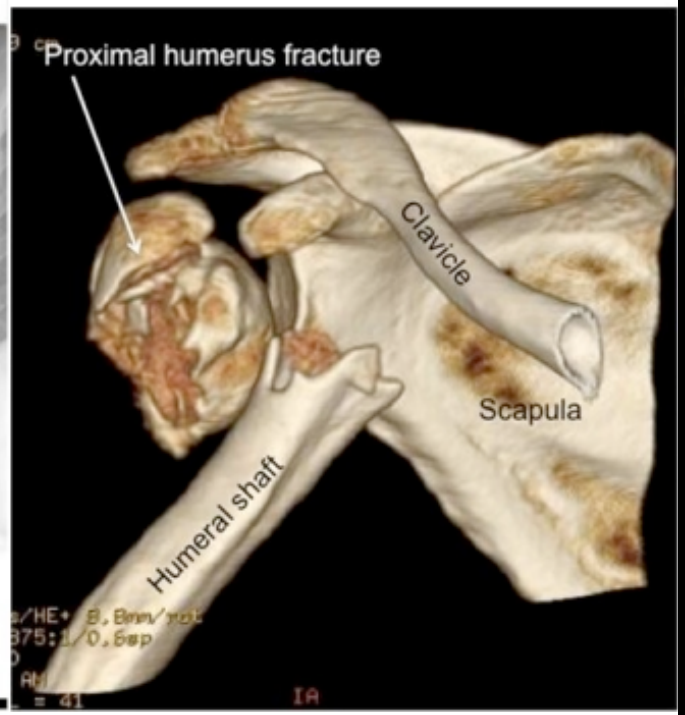


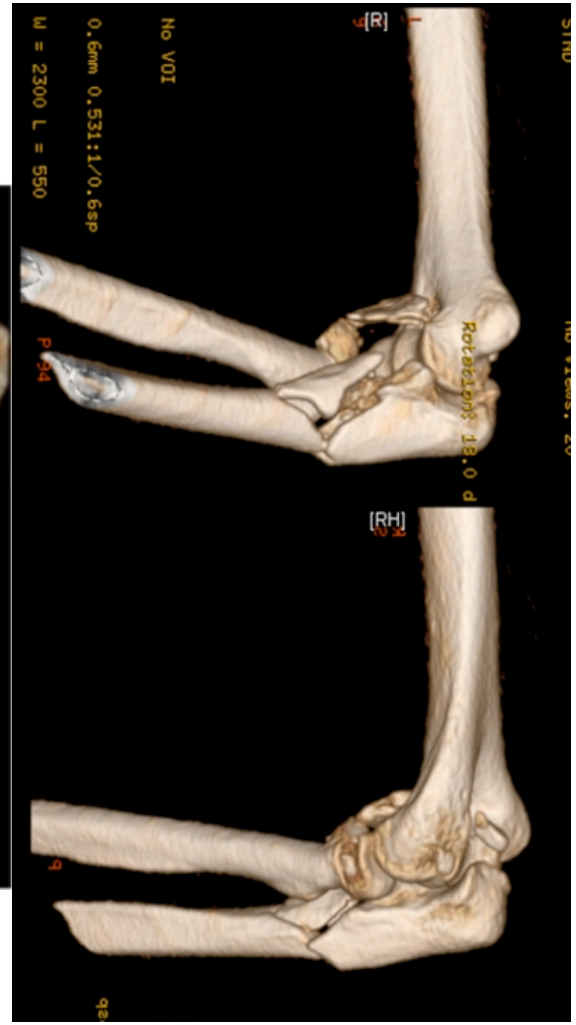


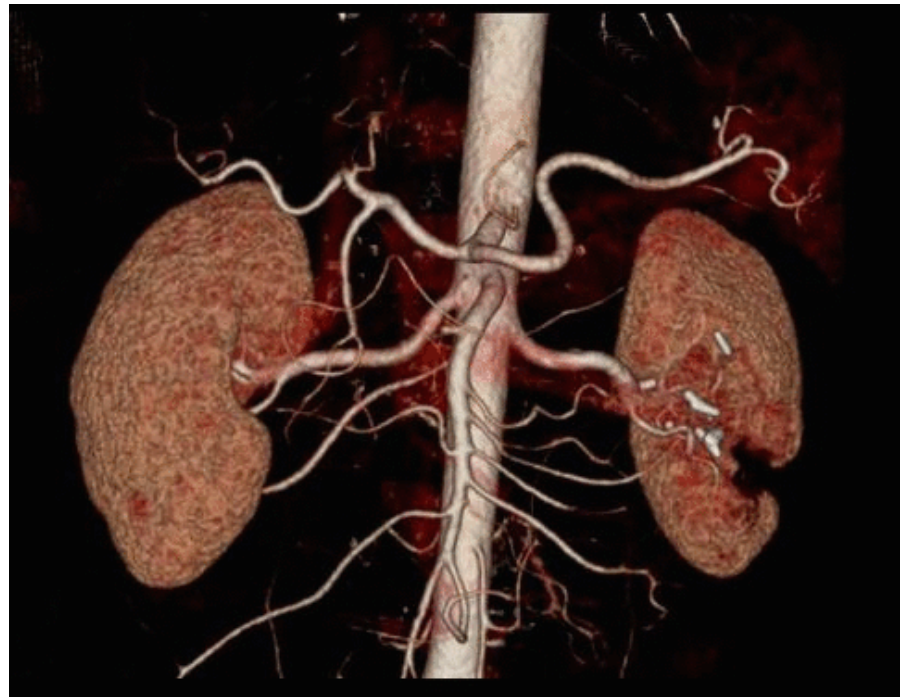




CT Reformatting





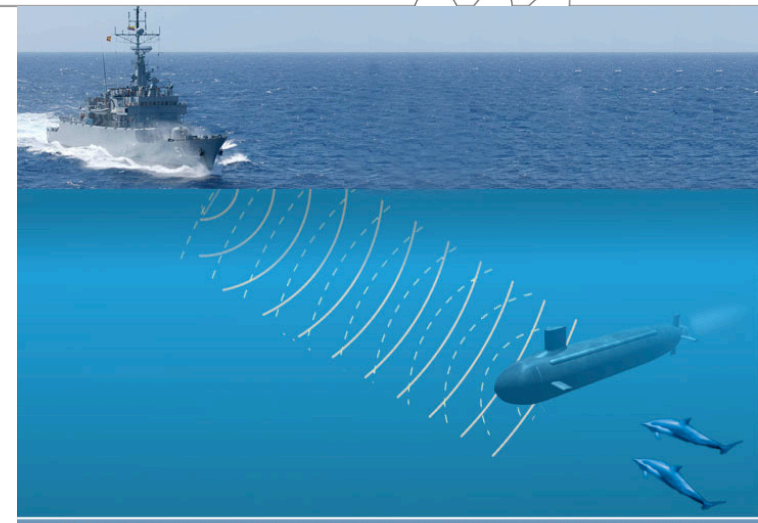


Risk vs. Benefit

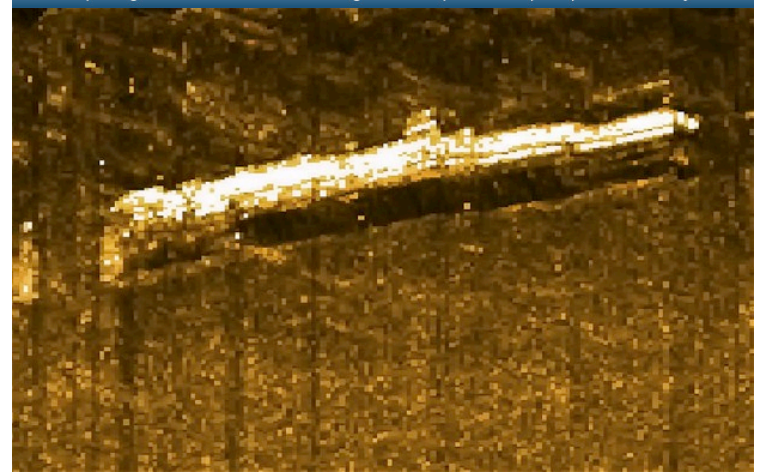
- Radiation clearly has damaging properties
- Why use it at all?
- Excellent imaging capabilities.
- More harm may come from not obtaining the information (diagnosis) than the radiation dose itself
- ALARA Principle: As Low As Reasonably Achievable
- Industry Challenge: reducing dose but maintaining imaging quality
- **What other options are there?**

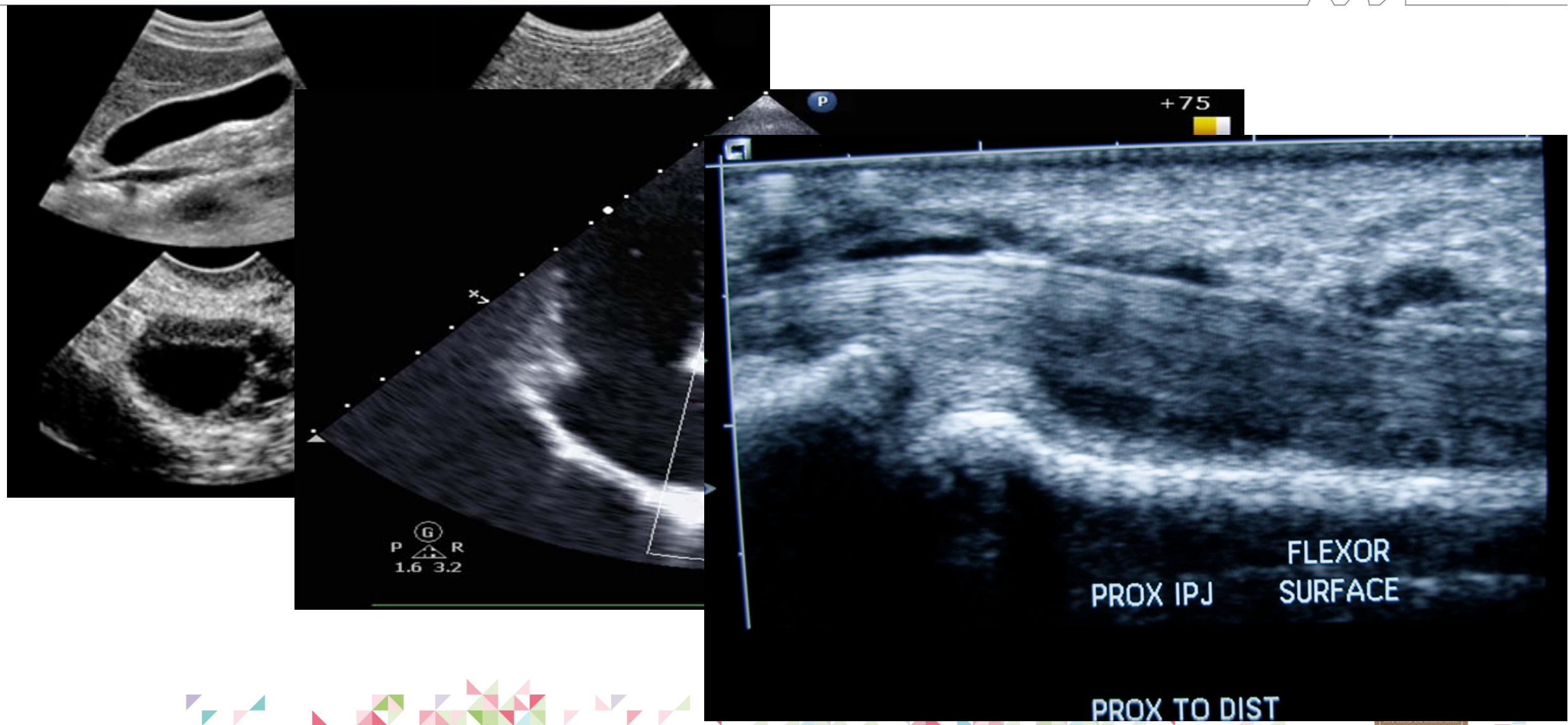
Quick facts- ultrasound

- Ultrasound uses high frequency sound waves.
- Ultrasound can be brought to the patients' bedside (POCUS).
- Ultrasound offers real-time imaging in multiple variations/planes.
- Ultrasound does not expose the patient to any radiation.
- Ultrasound field-of-view is usually smaller than other imaging techniques. Ultrasound is also constrained by not being able to image through bone or gasses.
- Obese patients are poor ultrasound candidates



Warships using sonar to find submarines. It's thought the war ships sonar disrupts dolphins ultrasound system.

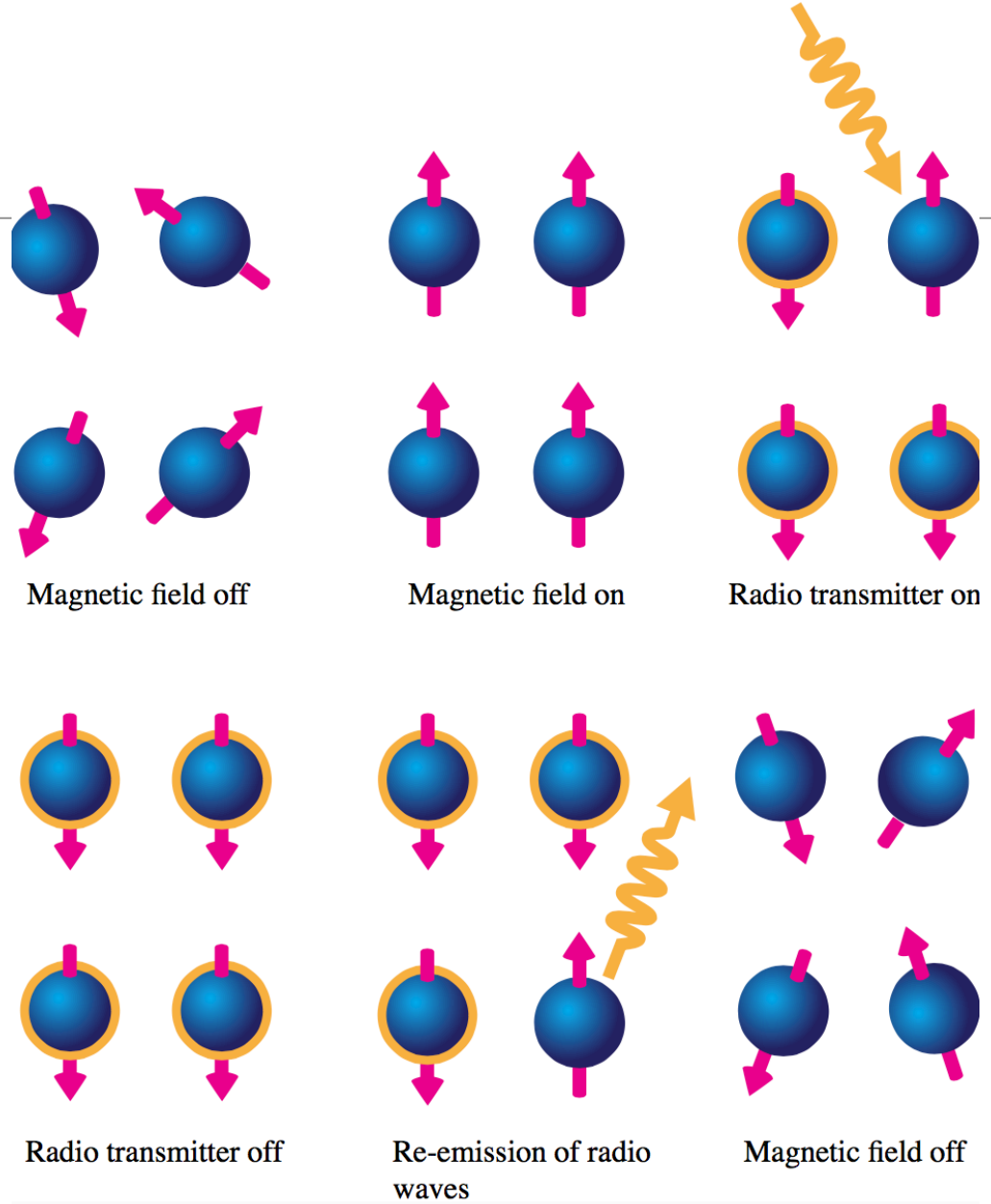


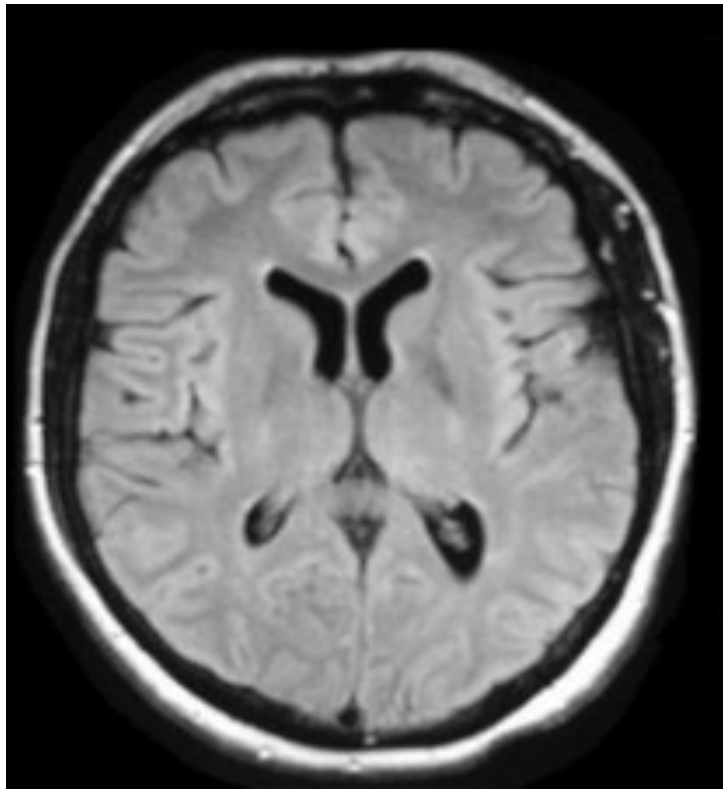

P
+75
G
P R
1.6 3.2
FLEXOR
PROX IPJ
SURFACE
PROX TO DIST

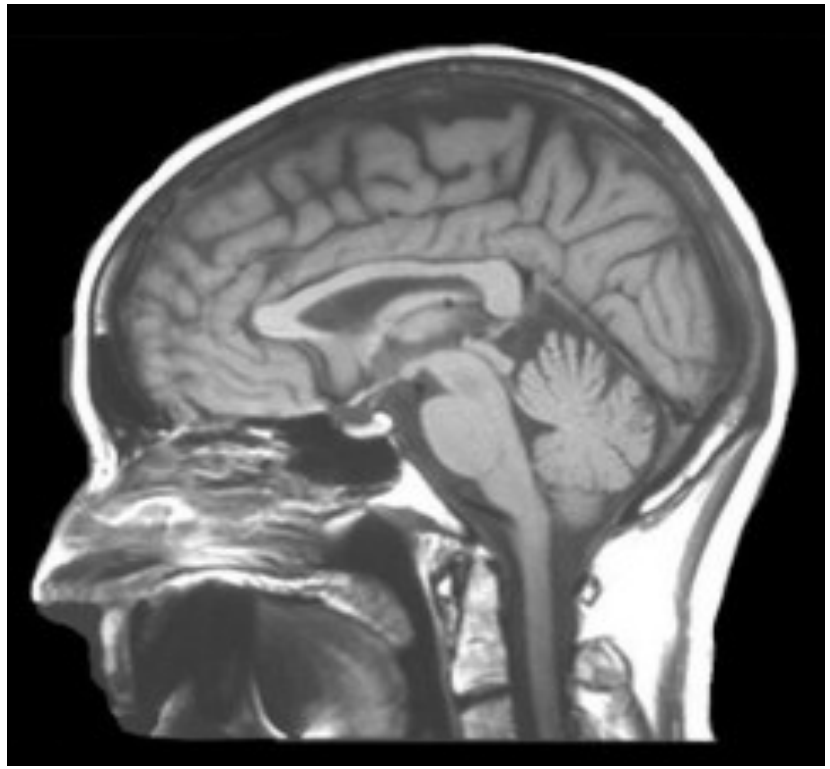
Quick facts- MRI

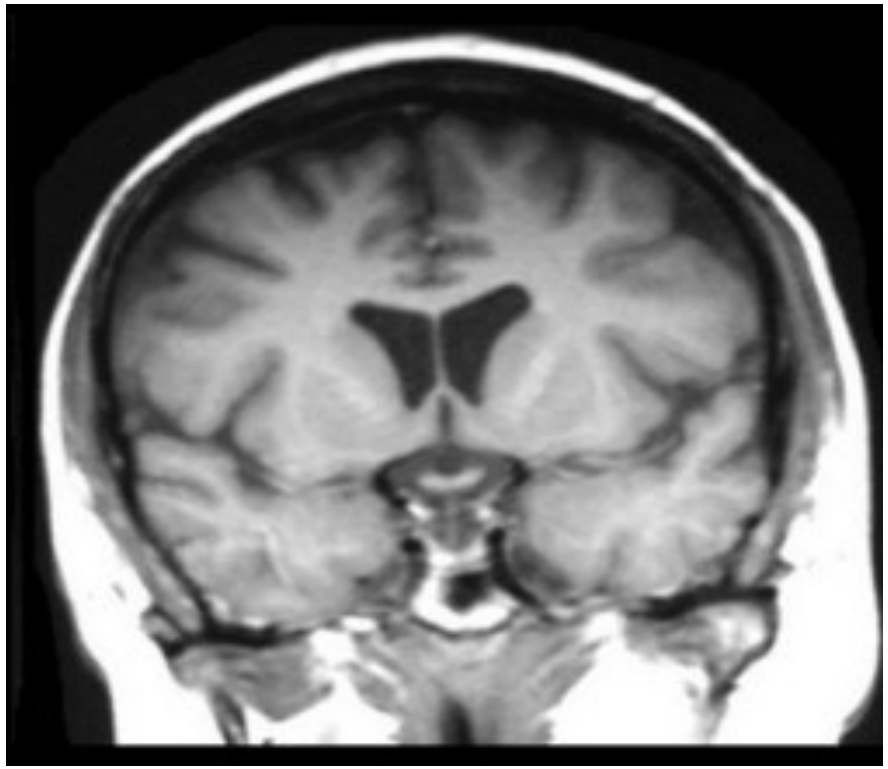
- MRI uses a magnetic field and radio waves to generate images of the inside of the body.
- MRI requires the patient to be extremely still for long periods of time in order to obtain the images (Sedation / GA)
- MRI images can be viewed with multiple variations/planes.
- MRI does not expose the patient to any radiation.
- **Some patients are not candidates for MRI, such as those with pacemakers or metal implants, some pregnant women (1st trimester), or people unable to remain still for long periods of time.**

HYDROGEN PROTONS OF WATER









MRI risks

- Implants may be displaced or malfunction in the environment of the MRI scanner (strong magnetic field)
- In some cases patients may suffer burns because of the RF fields
- Long studies- claustrophobic environment

The Telegraph

Home Video News World Sport Finance Comment Culture Tr

Politics | Investigations | Obits | Education | Science | Earth | Weather |

HOME » NEWS » UK NEWS

Pacemaker death after error in hospital

By Paul Stokes
12:01AM BST 03 Apr 2004

A former mayor died after hospital staff failed to note that she had a pacemaker when they sent her for a magnetic scan, an inquest was told.

FDA U.S. Food and Drug Administration
Protecting and Promoting *Your* Health

A to Z Index | Follow FDA | En Español

Search FDA

Home | Food | Drugs | Medical Devices | Radiation-Emitting Products | Vaccines, Blood & Biologics | Animal & Veterinary | Cosmetics | Tobacco Products

Archived Content

The content on this page is provided for reference purposes only. This content has not been altered or updated since it was archived.

Search Archive

Medical Devices

Home > Medical Devices > Medical Device Safety > Safety Communications > Public Health Notifications (Medical Devices)

Public Health Notifications (Medical Devices)

MRI-Related Death of Patient With Aneurysm Clip

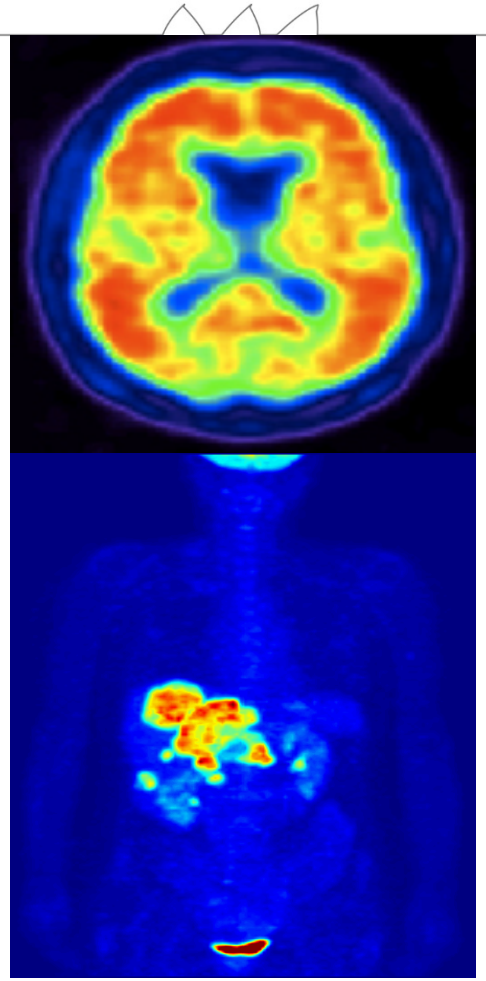
SHARE | TWEET | LINKEDIN | PIN IT | EMAIL | PRINT

November 25, 1992

MRI Safety

Quick facts- Molecular Imaging (NM and PET)

- Molecular Imaging involves the introduction of a radiotracer into the body of the patient (usually injection)
- The signal of the radiotracer is detected and used to create an image
- Molecular imaging exposes the patient to ionizing radiation.
- Molecular imaging exams can take very long and the resolution may not be as high as in other techniques.



Imaging Pearls

- X RAY — **Bone detail**. Limited Soft tissue
- CT — **Bone** and **Soft Tissue**
- MRI — **Soft Tissue** and **Bone**
- US — **Soft Tissue** in range of probe.

So consider what anatomical structure you are interested in.

Justification of medical imaging

- Do I need it?
- Do I need it now?
- Is this the best examination?
- Have I explained the problem (to the radiological practitioner and **patient/family**)
- Are too many investigations being performed?

Justification of medical imaging

The Principle of justification:

- Examination for an individual patient should be justified
- Responsibility lies jointly with the referring medical practitioner and the radiological practitioner
- Consultation between the radiological practitioner and the referring medical practitioner unless it is part of an approved health screening program (e.g. breast screening)

Over-investigating

Potential reasons for over-investigation:

- Patient wishes.
- Financial.
- Defensive medicine.
- Role of media.
- Role of industry.
- Convenience.

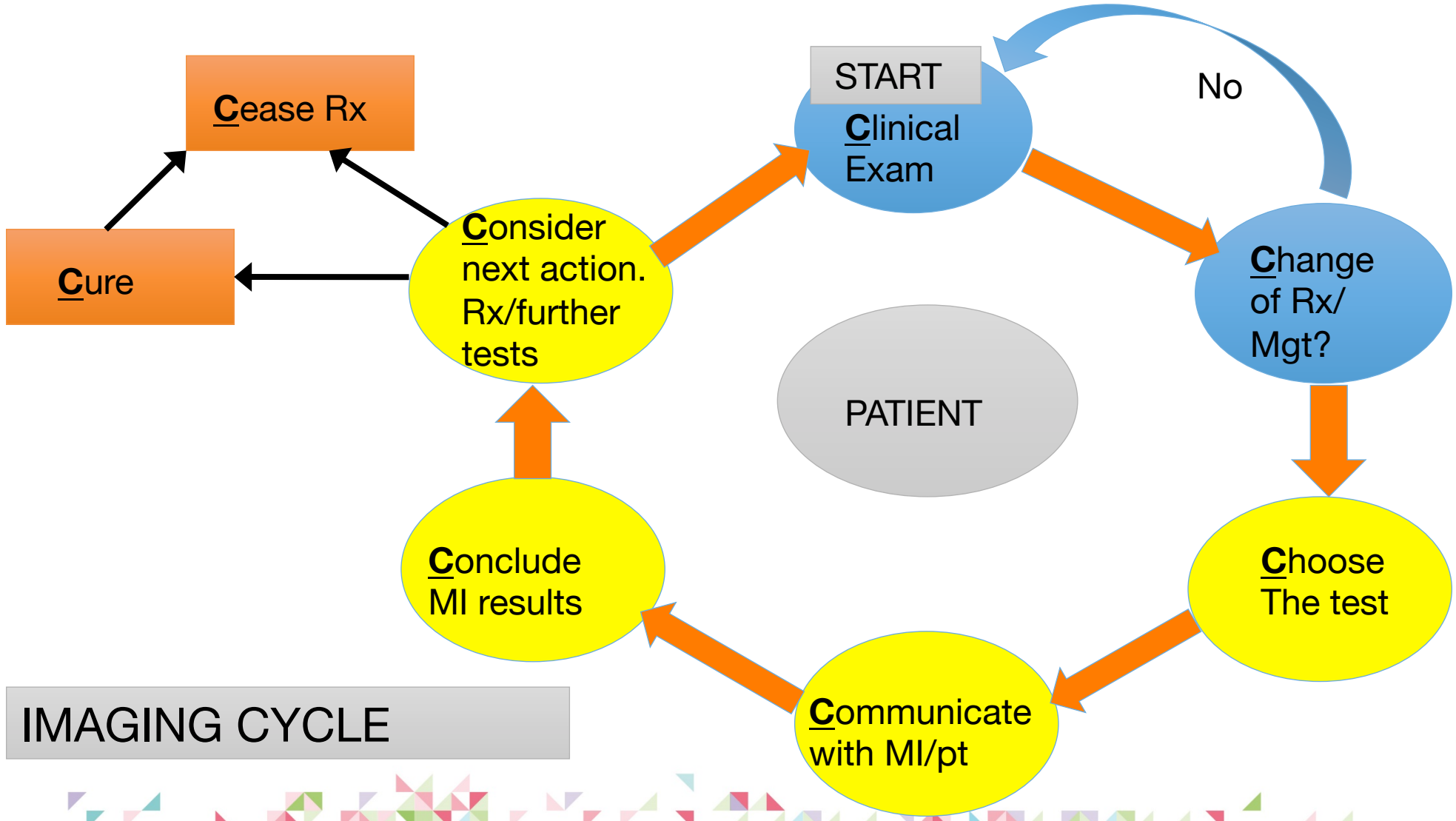
Decision Tools

- KISS principle:

KEEP
IT
SIMPLE
SAFE

+

Decision Tools: The 8 “C” Imaging Cycle



Decision Tools: Referral guidelines

- Help referrer determine the most appropriate imaging investigation or intervention
- Provide practical guidance based on best available evidence
- Examples (all available as apps):
  - ACR appropriateness criteria (USA)
  - iRefer (UK)
  - Diagnostic Imaging pathways (Australia)

ACR

RCR iRefer
Making the best use of clinical radiology

dip

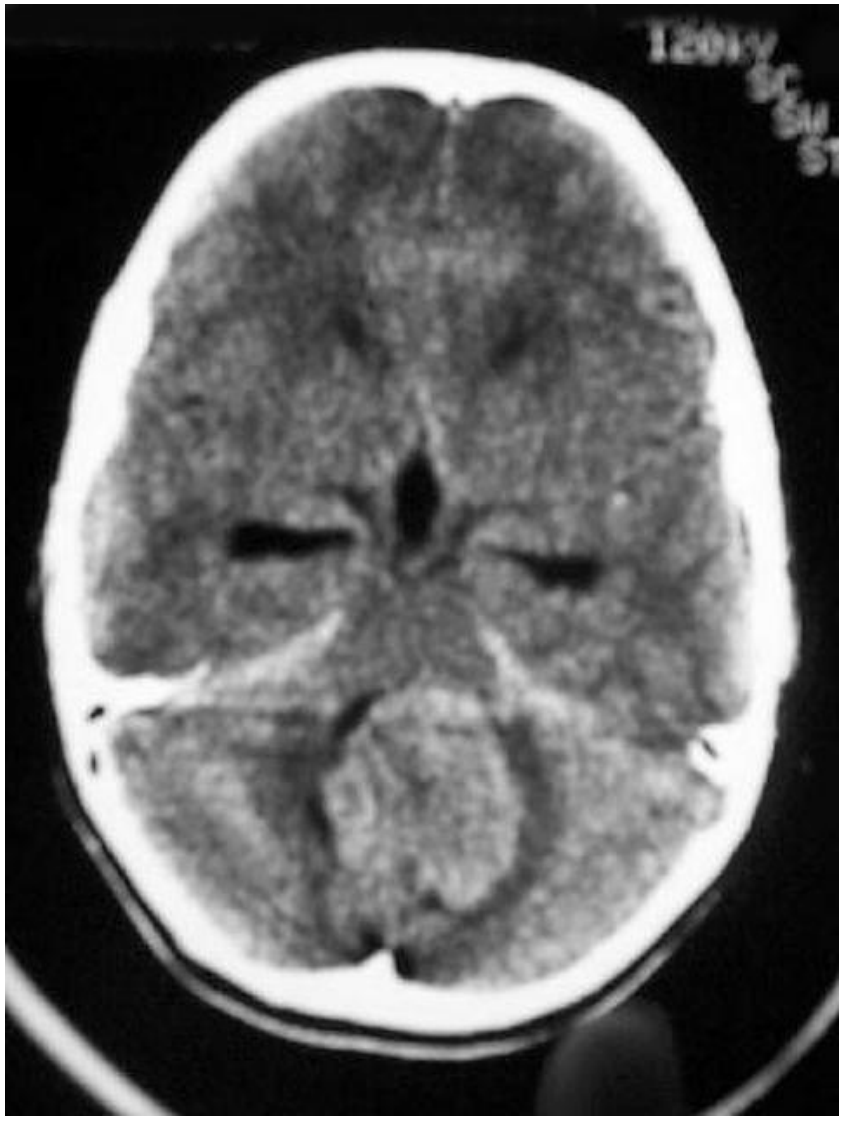
Decision Tools: Consumer information for patient/family

- Help referrer explain the chosen test to the patient or family
- Provide practical information to the patient/family as to what the test involves
- Help allay concerns of safety and possible patient discomfort from the imaging test
- Examples (all available as apps):
  - InsideRadiology: RANZCR Australia
  - RadiologyInfo.org: ACR

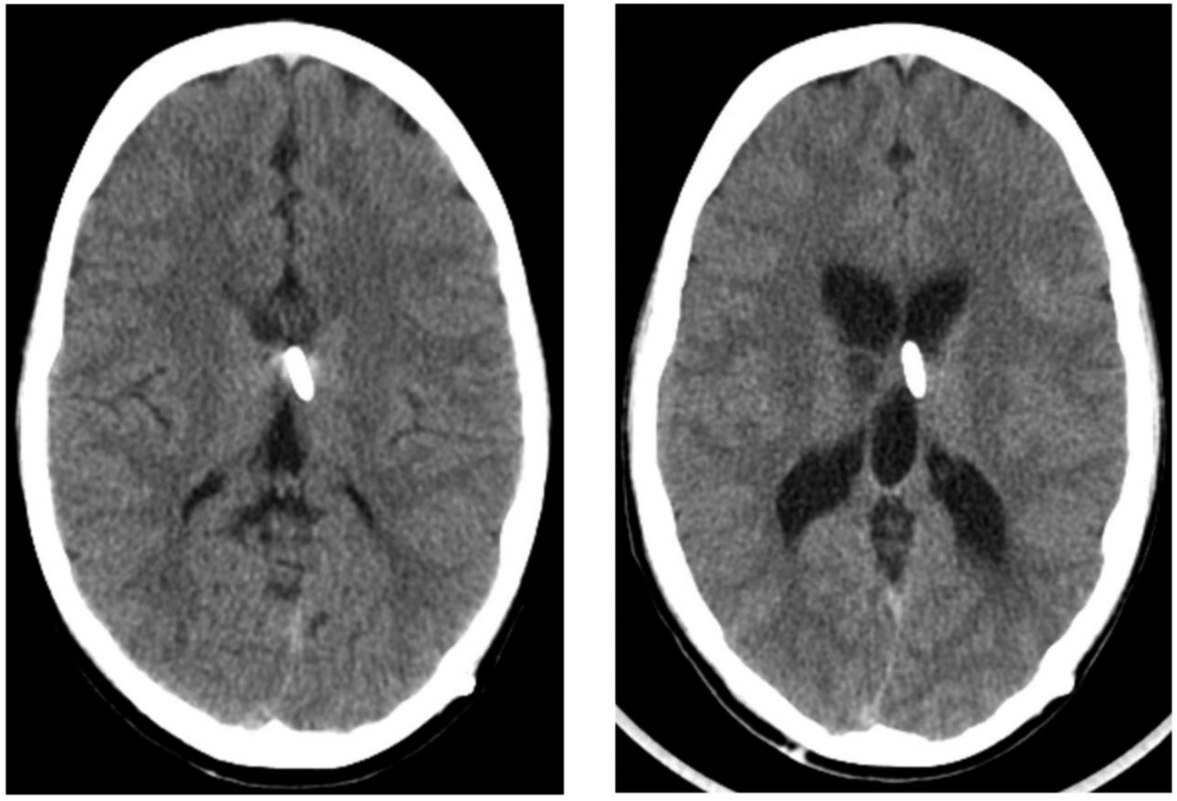
Inside Radiology

RadiologyInfo.org
For patients

Headaches



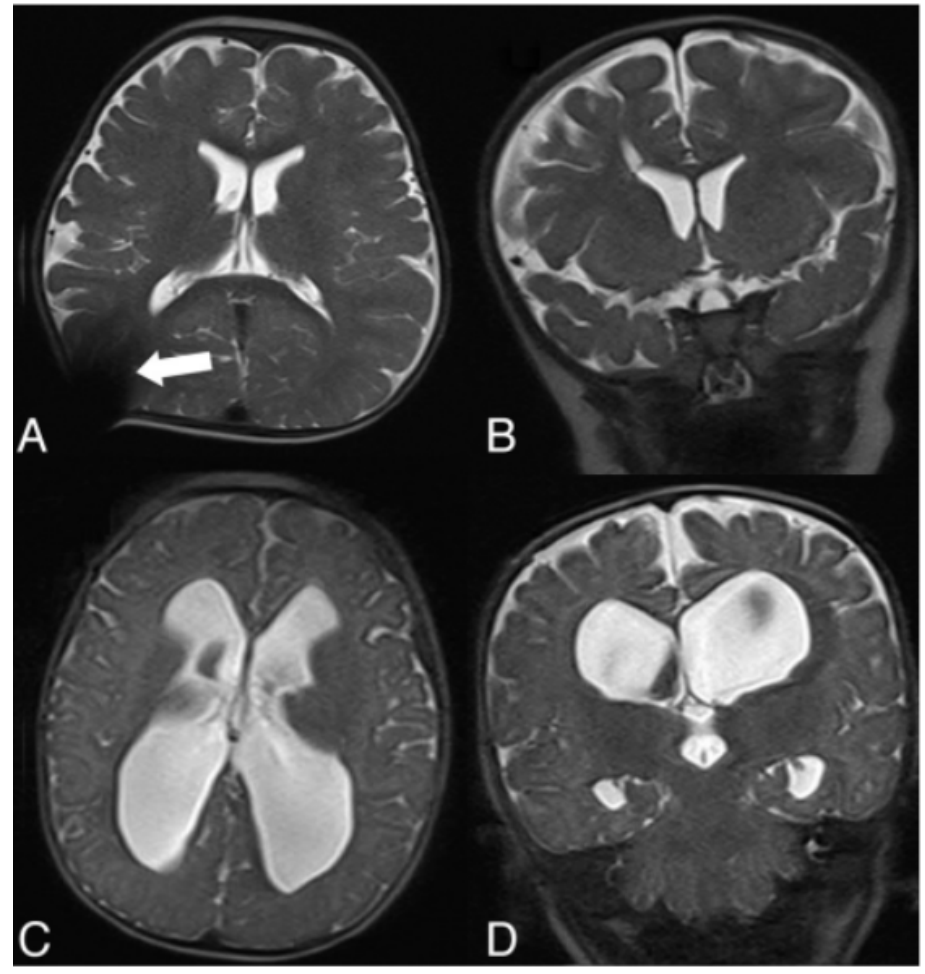
VP shunt malfunction



Pediatr Emerg Care. 2015 Apr;31(4):239-42. doi: 10.1097/PEC.0000000000000248.

Benefits of brain magnetic resonance imaging over computed tomography in children requiring emergency evaluation of ventriculoperitoneal shunt malfunction: reducing lifetime attributable risk of cancer.

Kim I[1], Torrey SB, Milla SS, Torch MC, Tunik MG, Foltin JC.



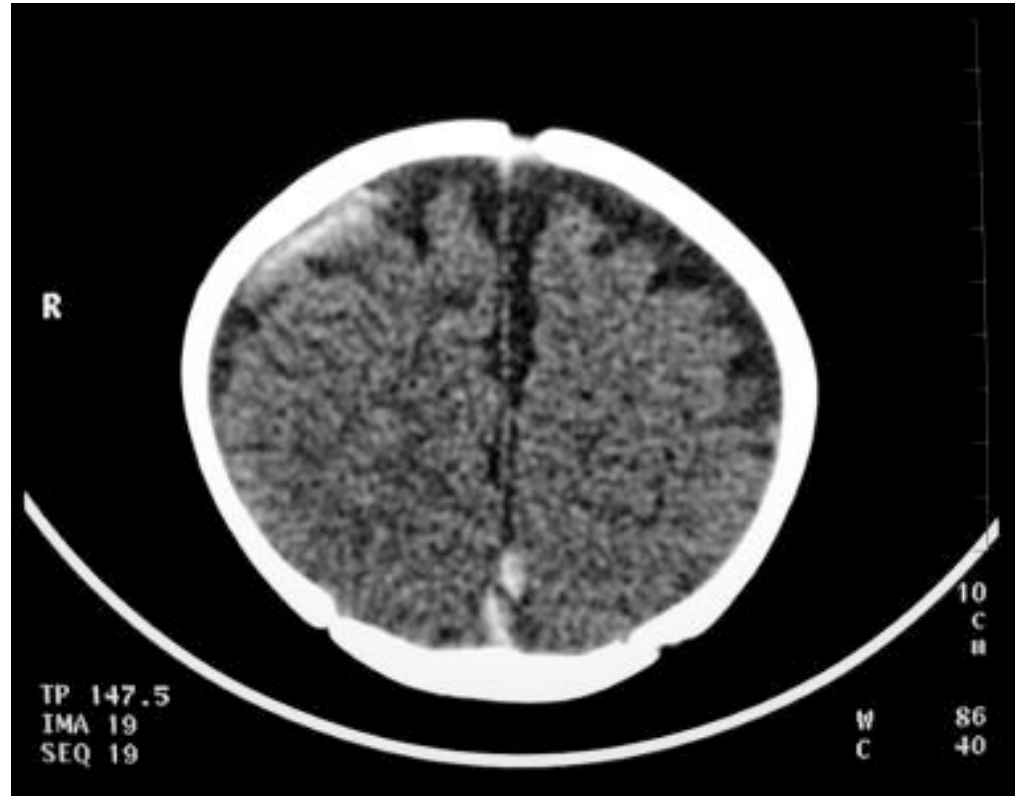
Published April 4, 2013 as 10.3174/ajnr.A3510

ORIGINAL RESEARCH
PEDIATRICS

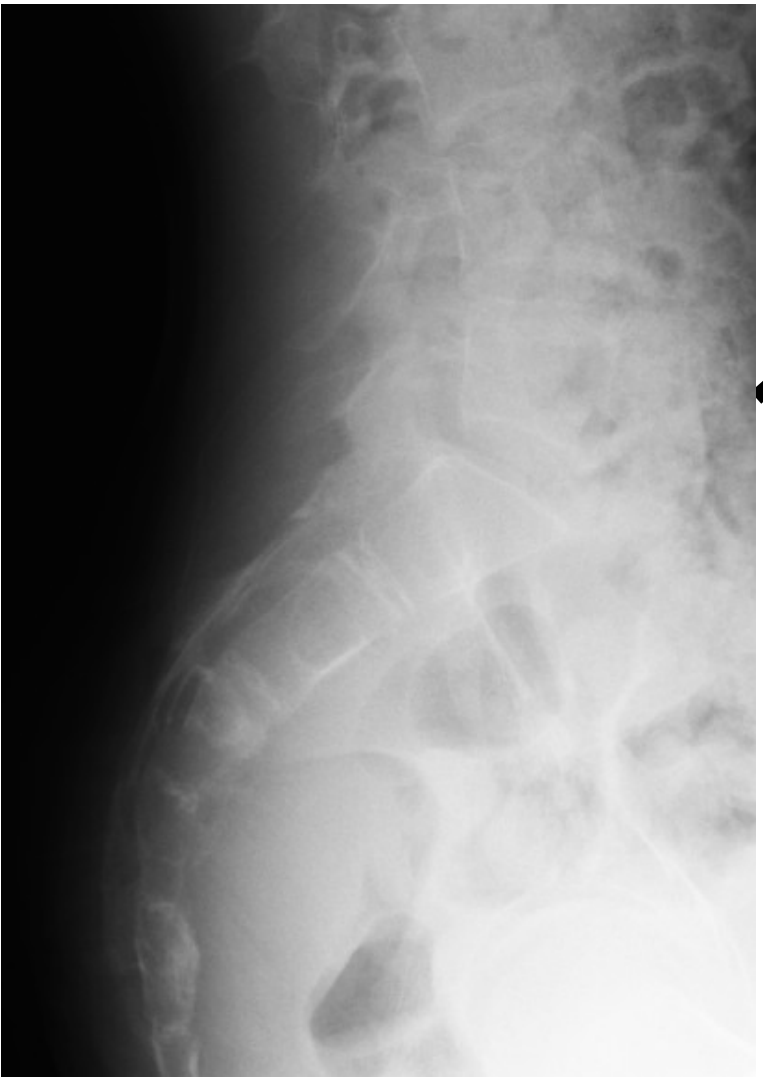
Retrospective Review of Rapid Pediatric Brain MR Imaging at an Academic Institution Including Practice Trends and Factors Affecting Scan Times

B.D. Niederhauser, R.J. McDonald, L.J. Eckel, G.F. Keating, E.M. Broomall, N.M. Wetjen, F.E. Diehn, K.M. Schwartz, C.H. Hunt, K.M. Welker, and D.F. Kallmes

Non Accidental Injury



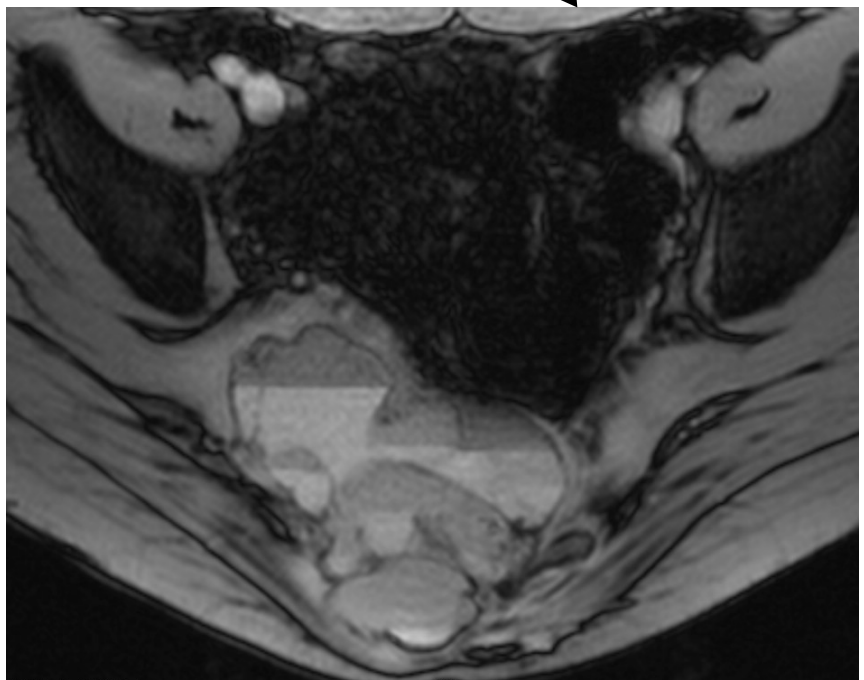
Painful back.



XR

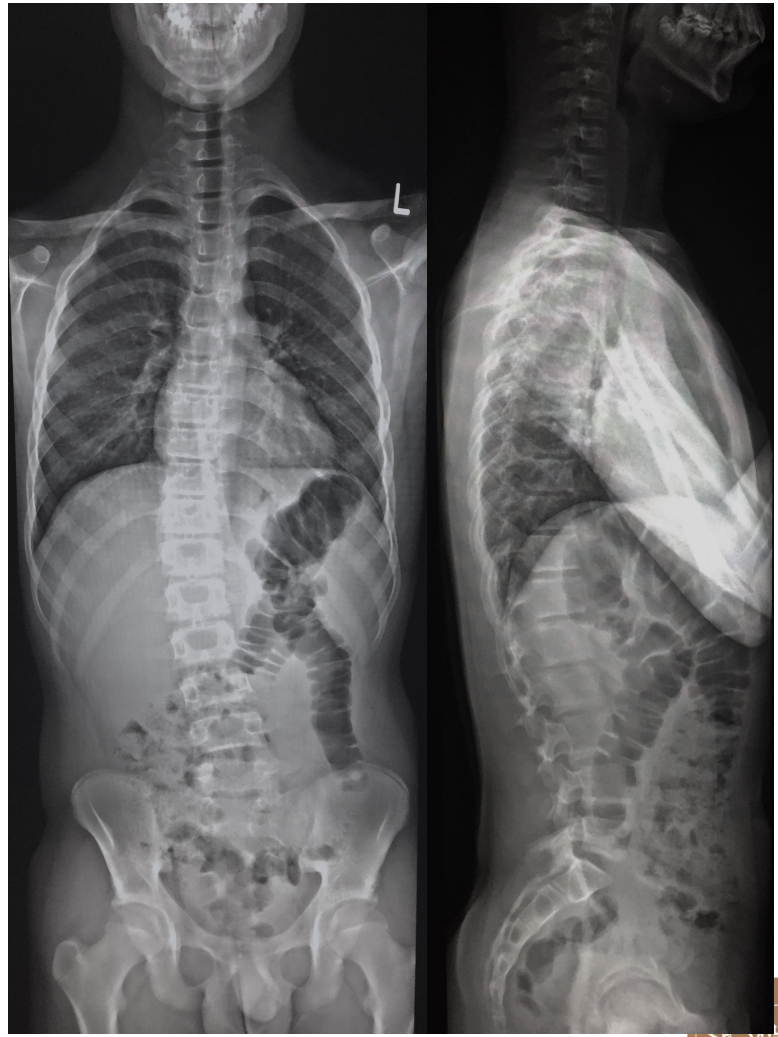
CT

MRI



Scoliosis

- EOS Imaging. 10 x reduction in dose c.f Plain xray (1 mSv v. 0.08 mSv EOS)



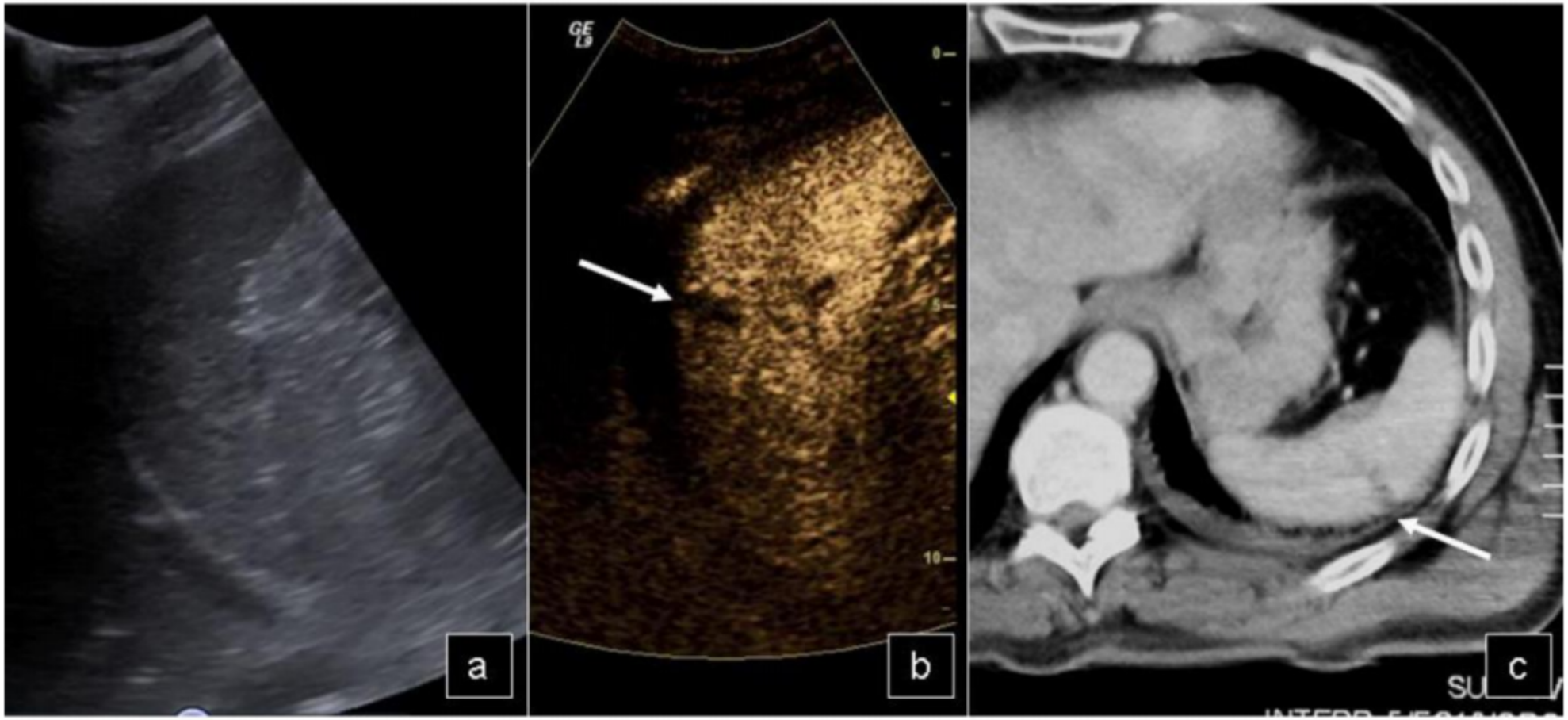
Trauma

- Trauma patients have significantly higher exposure to radiation
  - Upto 18 mSV *
- Abdominal trauma: Ultrasound should be the “default” way of practicing, especially in children
- Point of Care US: FAST scans

*Baker KS et al. Evaluation of radiation dose among patients admitted through a university hospital emergency department. Emerg Radiol. 2012 Dec;19(6):505-12.

Blunt, low-energy abdominal trauma

- Contrast enhanced ultrasound



Br J Radiol. 2016;89(1061):20150823. doi: 10.1259/bjr.20150823. Epub 2016 Jan 8.

Contrast-enhanced ultrasound (CEUS) in blunt abdominal trauma.

Miele V[1], Piccolo CL[1], Galluzzo M[1], Ianniello S[1], Sessa B[1], Trinci M[1].

Neck trauma

- Plain film radiography highly sensitive for detection of injury in children
- Flex-ext views best to document instability

Emerg Radiol. 2016 Oct;23(5):443-8. doi: 10.1007/s10140-016-1417-y. Epub 2016 Jun 20.

Sensitivity of plain radiography for pediatric cervical spine injury.

Cui LW[1], Probst MA[2], Hoffman JR[3], Mower WR[4].

Pediatr Emerg Care. 2012 May;28(5):426-32. doi: 10.1097/PEC.0b013e3182531911.

Utility of plain radiographs in detecting traumatic injuries of the cervical spine in children.

Nigrovic LE[1], Rogers AJ, Adelgais KM, Olsen CS, Leonard JR, Jaffe DM, Leonard JC; Pediatric Emergency Care Applied Research Network (PECARN) Cervical Spine Study Group.

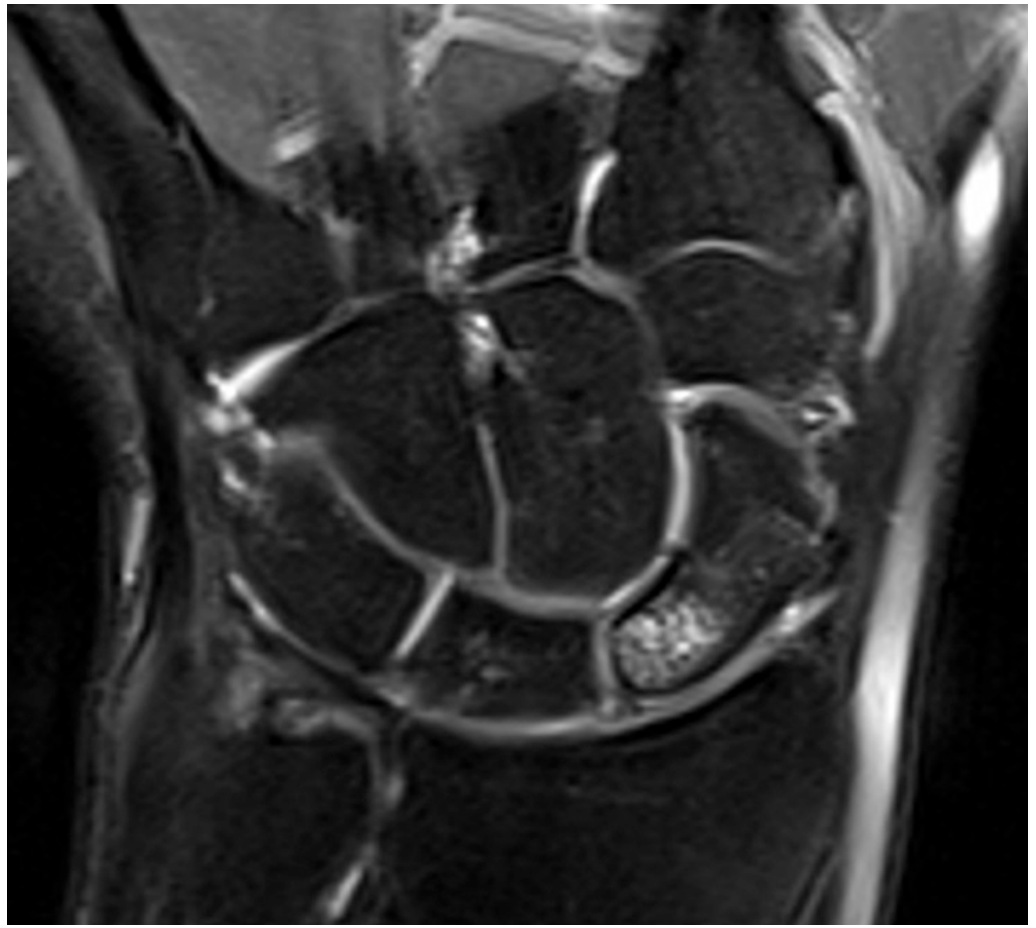
Childs Nerv Syst. 2012 May;28(5):699-705. doi: 10.1007/s00381-012-1696-x.

The pediatric cervical spine instability study. A pilot study assessing the prognostic value of four imaging modalities in clearing the cervical spine for children with severe traumatic injuries.

Brockmeyer DL[1], Ragel BT, Kestle JR.

Occult fractures

- Non visualisation of fracture on X ray
- Option 1. Immobilise for pain relief and repeat X ray in 10 days
- Option 2. Further investigation: MRI
- MRI is definitive for diagnosis of scaphoid fractures
- 3T is superior to 1.5T
- Complications better seen
- Other fractures identified



Acta Orthop. 2015 Jun; 86(3): 303–309. PMCID: PMC4443450
Published online 2015 May 13. doi: 10.3109/17453674.2014.986627

Costs analysis and comparison of usefulness of acute MRI and 2 weeks of cast immobilization for clinically suspected scaphoid fractures

Torbjørn H Bergh,[1,2] Knut Steen,[1,3] Tommy Lindau,[2,4] Lars Atle Soldal,[1] Soosaipillai V Bernardshaw,[1] Lene Lunde,[5] Stein Atle Lie,[6] and Christina Brudvik[1,2]

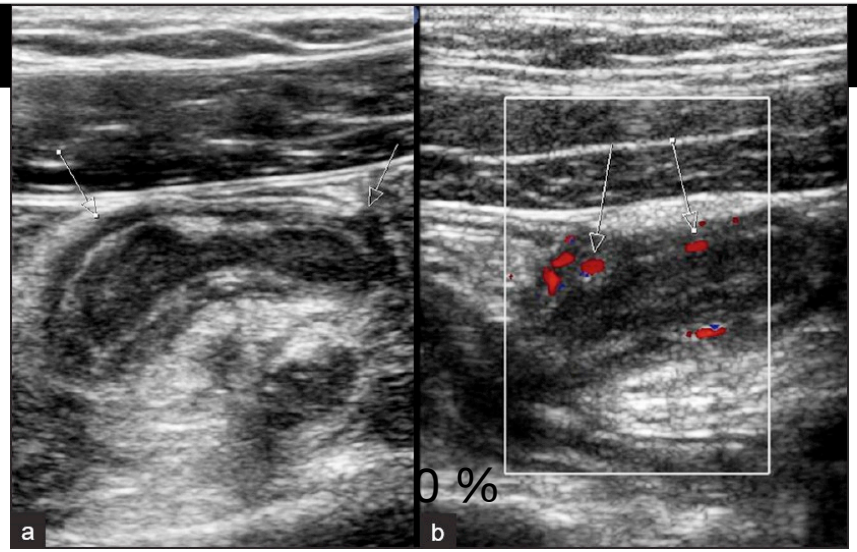
In Vivo. 2016 Jul-Aug;30(4):495-9.

Short MRI Protocol for Excluding Traumatic Lesions of the Scaphoid Bone in Children.

Kanavaki A[1], Draenert C[2], Ceroni D[3], Hanquinet S[4].

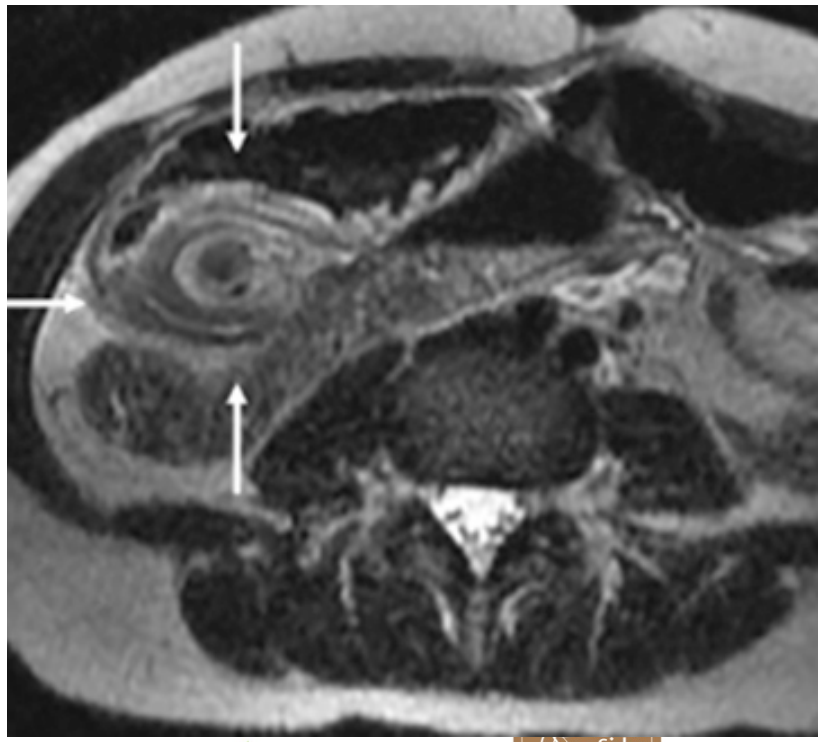
Appendicitis?

CT



US

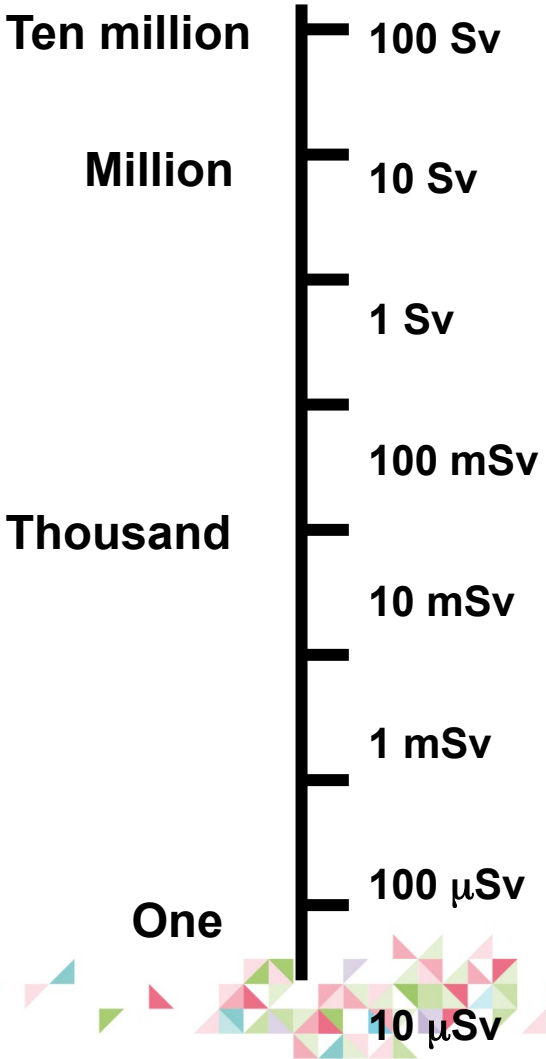
MRI



Summary

- Any Ionizing radiation has the potential to damage DNA
- Where possible, default to non-ionizing forms of imaging:
  - Ultrasound
  - MRI
- KISS principle
- Imaging cycle:
  - Choose best modality optimal for the region of clinical concern
  - Communicate with Radiology, patient and parents
- Not sure? Phone your friendly Radiology department!

Radiation doses and Effects



Death within 2 days @ 50 Sv (CNS radiation sickness)

50% fatalities in 60 days @ 4 Sv (Damage to lens of eye; GI radiation sickness; skin burns; bone marrow radiation sickness)

Temporary blood count depression

Temporary sterility

Annual Dose limit to worker: 20 mSv

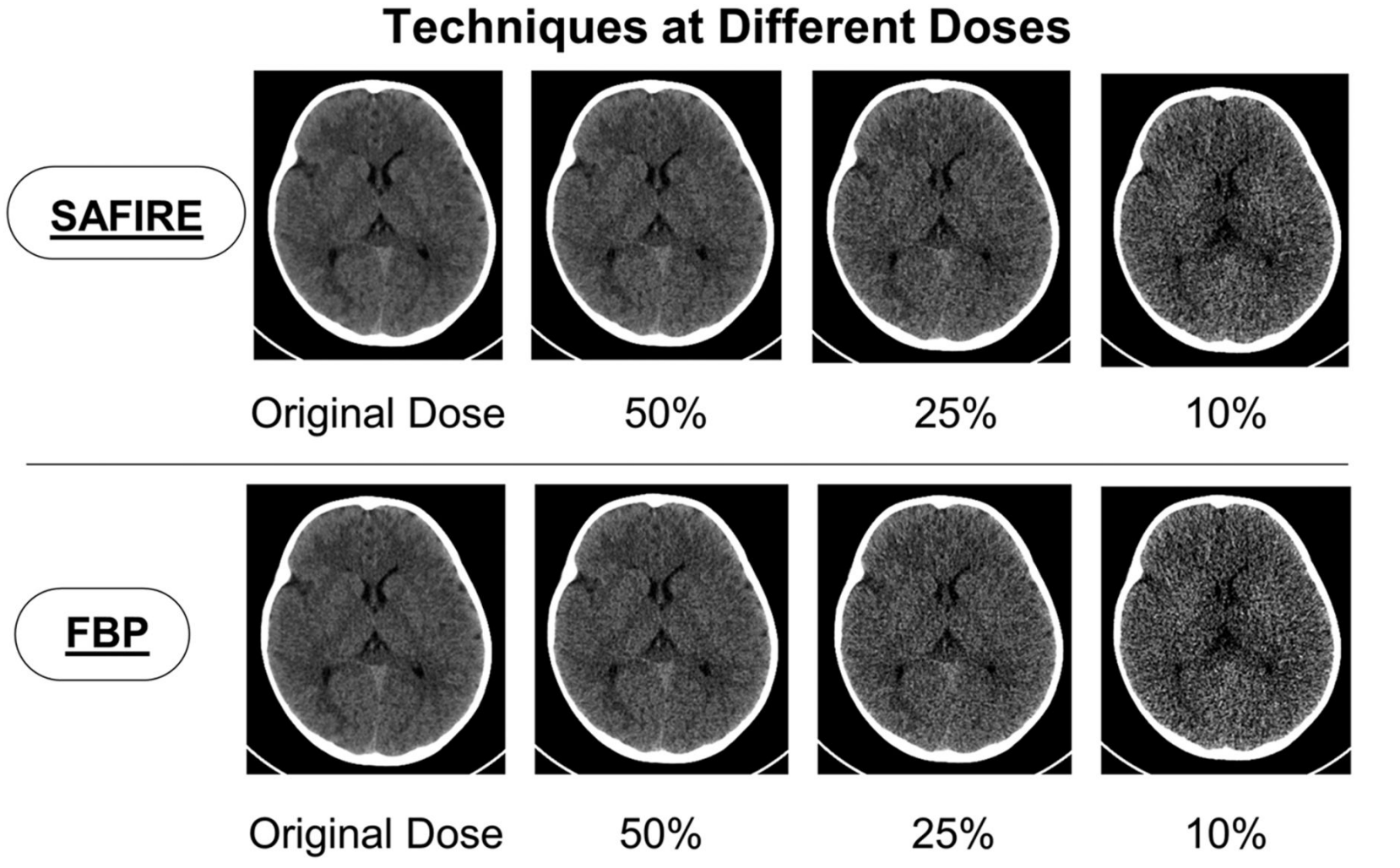
Barium Enema: 8 mSv

Average annual background: 2.5 mSv

- CT first
- Then MRI, depending upon the differential diagnosis
- Not much role for Ultrasound acutely

Case courtesy of A.Prof Frank Gaillard, Radiopaedia.org, rID: 10678

An actual subject from our study showing the full dose, 50% dose, 25% dose, and 10% dose using sinogram-affirmed iterative reconstruction and filtered back-projection reconstructions.



S. Gabriel et al. AJNR Am J Neuroradiol 2014;35:2237-2242

Instability

- Flex-ex views best to document instability
- False positives with MRI

Childs Nerv Syst. 2012 May;28(5):699-705. doi: 10.1007/s00381-012-1696-x.

The pediatric cervical spine instability study. A pilot study assessing the prognostic value of four imaging modalities in clearing the cervical spine for children with severe traumatic injuries.

Brockmeyer DL[1], Ragel BT, Kestle JR.

Low dose CT

- The corresponding estimated effective dose was reduced from 1.8 to roughly 0.18 mSv,
- Negligible relative to the annual background radiation in the United States from naturally occurring sources (mean, 3.0 mSv; range, 1–10 mSv)
- Improved location of VP shunt tip

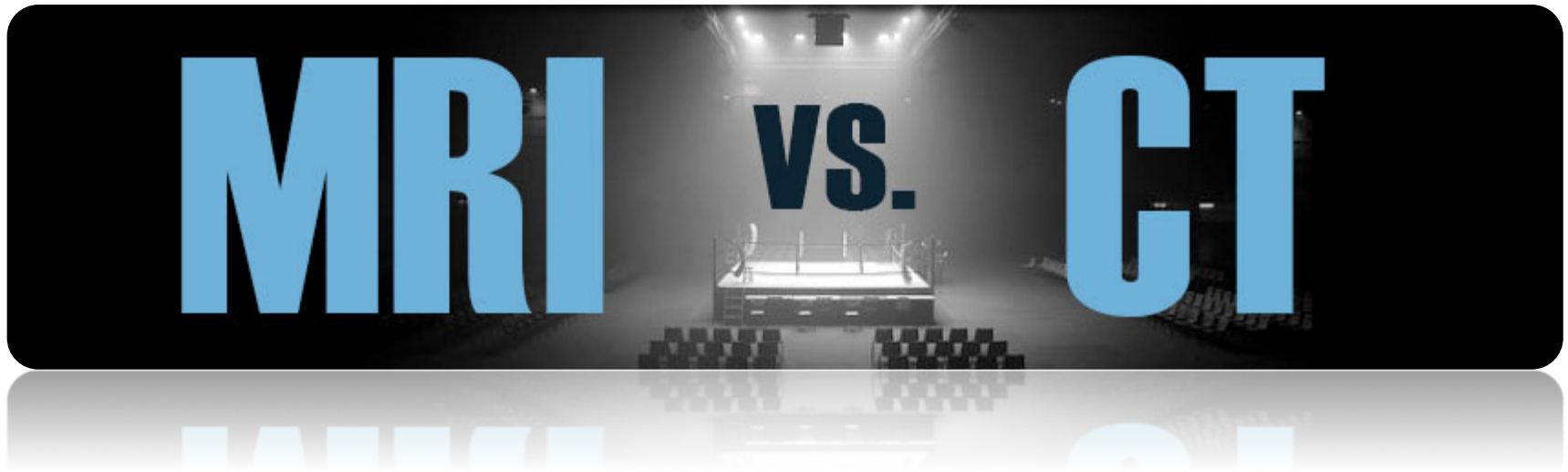


Image source - http://www.two-views.com/article_ct_vs_mri.html