Introduction to MS3 Students Starting Clerkships
Choosing Imaging Procedures

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Process

- Please read this handout. We will not present this content in the lecture.
- Twenty cases are provided to you. Your task is to select the appropriate imaging procedure for each case based on the knowledge that you acquired by reading the handout. You will make the choice of the procedure using ARS in the lecture session. In the session on 6/27/13 we will review your decisions and provide clarification.
- **ARS is anonymous and individual student will not be identified.**

Objectives

After the session you will be able to:

- Choose the appropriate imaging procedure for a given clinical problem.
- Explain the principles involved with each imaging study.
- Recognize common indications and contraindications for each imaging procedure.
- Describe how each procedure is done.
- Recognize limitations and safety of each imaging study.
- Recognize cost associated with each imaging procedure.

PS: The session will not cover image findings of each case.

Plain Radiographs

How Plain Radiographs Are Done

- Plain radiographs are images produced using x-rays, which are high energy radiation waves that can penetrate body parts.
- Patient is positioned so that the body part to be evaluated is between the x-ray source and a device (cassette) that records the image.
- The patient must remain still (for a couple seconds) when the x-ray is taken.
- Most plain x-ray examinations consist of at least two views of a body part at right angles to one another (i.e. PA and lateral CXR).

Example Indications

- Chest radiograph
  - Most commonly used imaging procedure
  - For evaluation of pulmonary or cardiac symptoms
- Abdominal radiograph, sometimes called KUB (kidney, ureters and bladder area)
  - Acute pain
- Bones and Joints
  - Injuries
  - Pain

Limitation

- Significant pathology can be missed
- Radiation exposure is low = approximately 0.1 mSv (miliSievert). Equivalent to 10 days of background exposure from naturally occurring radiation on earth

Useful For

- It can be diagnostic with no additional imaging required.
- Can be performed portably, e.g. x-ray machine can go to patient in ICU to perform exam and patient does not need to leave their room and travel to the radiology department.
- It serves as preliminary image to plan for more specific imaging studies like CT or MRI.
- Required for interpretation of other imaging procedures like V/Q lung scan.

Cost: $

Computed Axial Tomography (CT) Scan

Principle

- CT scanning combines x-rays and computer to produce precisely detailed cross-sectional images of the organs.
    - A thin x-ray beam rotates around the patient.
    - Detectors measure the amount of x-rays that make it through a particular area of interest.
- CT scans are enhanced by using intravenous iodinated contrast material to delineate vascular structure, focal lesions in solid organs like liver and kidney, and function of certain organs, e.g. kidneys.
    - Normal enhancement of solid organ parenchyma can be compared to increased enhancement of the tumor.
- When necessary, reconstructed images can create three-dimensional models of organs.

How CT Is Done

- The patient lies on a narrow table that slides into the center of the scanner.
- IV access will be required if contrast media needs to be administered.
- For abdominal and pelvic CT's, oral contrast may also need to be swallowed or given by NG tube.(To outline bowel loops)
- Patient will be required to hold their breath for approximately 5-10 seconds and not move, as motion causes blurred images.
- Scan time varies depending on the type of scanner and required studies.
    - The newest multi detector (also known as spiral scanners) scanners can image from head to toe, in less than 30 seconds.

Useful For

- CT scan is helpful in delineating the precise anatomy and location of pathology.
- Three-dimensional reconstructions studies add information about blood supply and provide "road maps" for planning surgeries.

Example Indications

- CT is often utilized in the trauma setting to evaluate the brain, chest, and abdomen as the first diagnostic procedure.

- CT is done routinely in patients with cancer to evaluate the mass its extension and metastatic disease for staging.
- CT can be used to guide interventional procedures, such as biopsies and placement of drainage tubes.

Limitation / Safety

- Table cannot fit very obese patients > 450 lbs.
- Some patients cannot lie supine or remain still.
- Patient is required to travel from room to the radiology department. This study cannot be performed portably in the patient's room.
- Radiation exposure is moderate to high, 10-20 mSv. This is equivalent to radiations exposure from 100 plain chest radiographs.
- Requires IV access to inject contrast.
- IV contrast may be contraindicated in patients in renal failure or with renal insufficiency and in patient with history of contrast allergy in some patients. Patients with renal failure can be dialyzed after IV contrast administration. There is protocols to follow using steroid and antihistamines prior to exam to limit a reaction if the IV contrast is absolutely necessary.
- .Medications may need to be held prior to CT (i.e., metformin).

Cost: $$

Magnetic Resonance Imaging (MRI)

Principle

- MRI uses a strong magnet, radio waves and computers to create detailed images of the body.
- It does not use ionizing radiation, unlike conventional radiography and computed tomographic (CT) imaging.
- MRI imaging is based on the magnetic properties of hydrogen atoms.

How MRI Is Done

- Patient lies inside a massive hollow magnet and is exposed to short bursts of powerful non-ionizing radio wave energy directed at protons of the nuclei of hydrogen or water atoms in the body.
- Radio signals that are generated by first "exciting" and then "relaxing" those protons are computer-processed to form digital images, reflecting different types of tissue.
- Scanner must be located within a specially shielded room to avoid outside interference.
- The patient will be asked to lie on a narrow table which slides into a large tunnel-like tube within the scanner.
- Special body coils are placed around the areas to be studied, e.g. knee, shoulders, etc. These coils can add to the feeling of claustrophobia.
- These special body coils send and receive the radio wave pulses, and improve the quality of the images.
- Hydrogen proton imaging.
- Observe behavior of protons in magnet after application of radiofrequency signal.

Advantages

- An MRI provides superior tissue contrast resolution.
- Because of its ability to show soft tissues in exquisite detail, MRI can detect soft tissue disease and evaluate vasculature.
- An MRA, or magnetic resonance angiogram, is a special type of MR that creates three-dimensional reconstructions of vessels containing flowing blood. It is often utilized when

conventional angiography cannot be performed due to renal failure or other contraindications. Gadolinium IV contrast is needed for this study. Flowing blood appears dark in the arteries.
- MRI can delineate a cyst from a solid mass.
- It can identify the spread of cancer into the vessels and soft tissue (staging).
- When contrast CT cannot be done due to an allergy, MRI is useful to evaluate vascular lesions. Patients are very rarely allergic to the gadolinium contrast given for MRI, as opposed to the more common allergy to iodinated contrast given for CT.
- Radiation exposure is 0 because no ionizing radiation is used.
- Many MRI's are done with IV gadolinium contrast which also requires good renal function.

Example Indications

- Spinal cord compression: MRI is the procedure of choice. It has replaced myelogram.
- Brain lesions: Post traumatic (follow-up of subdural, no IV contrast), acute CVA (CT first to r/o blood, functional MRI for acute CVA), tumors, mets, etc.
- Joint disease.
- Soft tissue tumors.

Limitation

- Procedure is expensive.
- It has limited availability.
- A complete scan, depending on the sequences performed, may take up to one hour or longer.
    - It is difficult for patients to remain still.
    - Newer scanners may complete the process in less time.
- Patients with certain types of metals (heart valves, pacemaker. etc.) cannot undergo MR studies since the clips can be dislodged by the magnetic field. Hip prosthesis is OK as long as it is not immediate post op period.
- If the patient is claustrophobic, the study cannot be done without sedation.
- Warn the patient that the scan involves loud noises so they can anticipate this.
- Gadolinium contrast in a patient with compromised renal function can cause nephrogenic systemic fibrosis.
- Weight limit.

Cost: $$$$

Ultrasound (US) (Sonogram)

Principle

- The use of high-frequency sound waves to produce real-time images provides a simple and painless way to examine structures.
- An ultrasound machine sends out high-frequency sound waves which reflect off body structures.
- A computer receives these reflected waves and uses them to create a picture.

How US Is Done

- A clear, water-based conducting gel is applied to the skin over the area being examined to help with the transmission of the sound waves.
- A hand held transducer is then moved over the area being examined.
- Transducer sends high frequency sound waves into the body.
- The waves are reflected back by various tissues they go through.
- The reflected waves, with a help of a computer, form an image on the screen.

- Doppler examination is done using US waves aimed at a moving object - arteries or veins or cardiac valves.
- In color Doppler ultrasound, coding of the various reflected echoes provides color images which can tell you the direction of flow movement.
- In waveform or spectral Doppler, the reflected waves, with computer aid, give us the velocity of blood in various vessels.

Example Indications

- Pregnancy evaluation
- Ectopic pregnancy
- Torsion testis
- Echocardiography
- Localization of loculated pleural effusion or ascites for thoracentesis or paracentesis and biopsy of organs (kidney) or masses close to the chest or abdominal wall.

Advantages

- Non-invasive test.
- Involves no pain
- Provides accurate anatomic information, including dimensions.
- Radiation risk is zero because no ionizing radiation is used. Useful to study reproductive organs and evaluation of pregnancy.
- Avoids the potential allergic and toxic complications of contrast media.
- Can be used on individuals with poor kidney function, in whom contrast cannot be given.
- No complications.
- Can be done at bedside and provides real-time information.
- Relatively economical exam.
- No IV needed.

Limitation

- Operator dependant.
- Gas in the GI tract and lungs prevent the sound waves from passing; thus not useful in portions of abdomen and lungs.

Cost: $$

Nuclear Medicine Studies

Principle

- Uses radioactive substances in diagnosis and therapy.
- Based on function of organs.

How It Is Done

- Most of the studies start with by injecting or inhaling or ingesting a radioisotope.
- The type of isotope used varies with each study.
- The isotope concentrates in the organ that is being tested.
- Scanning of body or organ follows.
- When to start and end scanning, varies with each study.
- Majority of diagnostic tests involve formation of an image using a gamma camera.
- Most diagnostic radionuclides emit gamma rays.

Useful For

- Primarily useful to evaluate the function of the organ studied.

Commonly Used Radionuclides

- technetium-99m
- iodine-123 and 131
- thallium-201
- gallium-67
- PET scan

Example Indications

- Renal scan: To evaluate renal function.
- Bone scan: To evaluate bone metastasis and occult fractures.
- Perfusion lung scan (VQ scan): Patients suspected of having pulmonary embolism.
- Myoview (Thallium): Patients suspected of having coronary artery disease.
- Testicular scan: To evaluate testicular torsion, mass etc.
- PET scan: Tissue functions such as blood flow, oxygen use and sugar metabolism, i.e., to detect increased metabolic rate as is seen with cancer.
- MUGA scan: To document LVEF (left ventricular ejection fraction) and track over time in patients receiving cardio toxic chemo, such as like Adriamycin.

Advantages

- Radionuclide imaging is safe since it does not carry the risk of allergic reaction encountered with contrast.

Limitation

- No anatomical details provided.
- Isotope availability is sometimes limited or restricted.
- Radiation exposure varies with the isotope but is low to moderate, ranging from approximately 1-10 mSv. (Equivalent to 10-100 times radiation exposure of one CXR).

Cost: $$

Fluoroscopy

Principle

- Contrast is instilled into the tubular organ that is being studied and images are taken with fluoroscopy, which means real time x-rays .

Example Procedures

- GI studies
- Voiding cystourethrogram
- Retrograde pyelogram
- Fistulogram

How It Is Done

- Upper GI: Patient swallows contrast and x-rays of the esophagus, stomach and duodenum are taken to follow the course of the contrast in the GI tract.
- Small bowel exam (small bowel follow through): Radiographs of abdomen taken to follow progression of contrast through small bowel.
- Lower GI: Contrast is instilled into the colon, via an enema, and x-rays are taken.
- Voiding Cystourethrogram: Contrast is instilled into the bladder and x-rays taken during micturition.
- Contrast injected into the fistula to see the course of the tract.

Example Indications

- Upper GI: Peptic ulcer.
- Lower GI: Cancer colon.
- Voiding Cystourethrogram: Pyelonephritis in children, ureteral reflux, urethral stricture or rupture (trauma).

Limitation

- Fiberoptic endoscopy has replaced many of the GI studies.
- Endoscopy has the advantage of direct visualization of the lesion, ability to biopsy and the ability to take therapeutic action, e.g. removal of a suspicious polyp.
- A lower GI study requires proper cleansing of the bowel.
- Since fluoroscopy uses x-rays, there is radiation dose from ionizing radiation. Dose is low-moderate, approximately 1-5 mSv (equivalent to 10-50 chest x-rays).

Cost: $$

Mammogram

Mammography is a specific type of imaging that uses a low-dose x-ray system for the examination of breasts.

Example Indications

- Palpable breast mass
- Screening for breast cancer
- Follow up

Limitation

- Fear of radiation in young patients. MR of breast is becoming an alternative study.
- Radiation dose is very low, approximately .5 mSv (equivalent to one CXR)

Cost: $

Arteriogram

Principle

- Arteriography is a procedure in which a contrast material is injected into an artery to evaluate the vasculature.
- An arteriogram can be used to examine almost any artery.
- CT and MRI have replaced the need for angiograms. It is rarely done nowadays for diagnostic purposes.

- However, the therapeutic applications of angiography have expanded considerably.

How it is done

- A catheter is placed into the blood vessel of interest, contrast material is injected and x-rays are taken.

Example Indications

- Cerebral angiography: Aneurysms, Tumors
- Renal angiography: Reno vascular hypertension
- Pulmonary angiography: Pulmonary embolism
- Right or left heart ventriculography
- Coronary angiography: Angina or Myocardial infarction
- Aortic angiography: Dissecting aneurysm
- Eye angiography: Diabetic

Advantages

- Arteriograms give the best pictures of the arteries.
- Arteriograms are used to make specific diagnoses and to help determine what the best treatment is in a particular case.
- Often, the treatment itself can be performed using the same type of catheters used in the arteriogram.

Safety

- Invasive procedure
- Bleeding and injury to the artery
- Contrast complications
- Plaques may be dislodged distal to the catheter producing CVA, arterial occlusion, etc.

Cost: $$$$

CT Angiogram: CTA

- After contrast is injected in a peripheral vein, multiple scans of neck are obtained during the arterial phase (i.e., delay for contrast to reach RV-Pulmonary artery-Pulmonary vein-Left ventricle-Aorta-Carotids-Head.
- Smaller amount of contrast is used than an arteriogram and can be repeated if needed.
- The arteries below the knee or elbow are not well imaged and will require catheter angiography.

MR Angiogram: MRA

- Contrast enhanced MRA is usually done for visualization of arteries of head, neck, aorta and lower extremities.
- Advantage: MRA contrast is less toxic to the Kidneys than iodinated contrast used in CTA. It can diagnose stenosis, aneurysm and abnormal anatomy of vessels etc. It is not useful for coronary artery disease.
- Disadvantage: The cots and the long time for the examination for the patient to remain still.

Past Procedures

Many of the procedures of the past have been replaced with new procedures or endoscopies.

Procedure	Replaced by	Advantage
IVP	CT with contrast	CT is much more sensitive and provides additional information.
Skull x-rays	CT	CT is much more sensitive and provides additional information.
Sinus x-rays	CT	CT is much more sensitive and provides additional information.
Cholecystogram	Ultrasound and Hida nuclear scan	Simpler procedures.
Myelogram	MRI	MRI is much more sensitive and easier to perform. Non invasive. No contrast allergy.
Bronchogram	CT	Much simpler procedure.
Upper and Lower GI	Endoscopy	Ability to biopsy and remove or cauterize the lesion.

Procedure Limitations

	Plain film	**US**	**CT**	**MRI**	**Nuc Med**
Radiation	Insignificant	No	Significant	No	Significant
If Pregnant / Reproductive organs	Shield pelvis	No problem	Shield pelvis	No problem	Usually not done
Holidays weekend / Ease of Scheduling	Available 24 hours per day	Available 24 hours per day	Relatively Available 24 hours per day	Available 24 hours per day	Available 24 hours per day
Test duration	Short	Medium	Short	Long	Long
IV Access			Required	Required	Required
Patient Cooperation				Orthopnoea / Claustrophobia	
Weight Limit			450 lbs	450 lbs	
Limitation		Operator dependant			
Bed side	Yes	Yes	Cannot be done	Cannot be done	Cannot be done
Anatomic details	++	++	+++ Great	++++ Exquisite details	No / Function based
Renal function	No problem	No problem	Needed	Needed	No problem
Cost	$	$$	$$$	$$$$	$$$

Radiation induced Cancer risk is for doses above 100 mSv

Comparison of Radiation Doses From Medical Imaging Tests and Background Radiation

Examination	Radiation dose (mSv)*
Computed tomography	
Sinuses	0.6
Head	2.0
Chest	7.0
Chest (pulmonary embolism)	10.0
Abdomen and pelvis	10.0
Multiphase abdomen and pelvis	31.0
Radiography	
Extremity	0.001
Chest	0.1
Lumbar spine	0.7
Abdomen	1.2
Other	
Mammography	0.7
Bone densitometry (DEXA)	0.001
Nuclear medicine	
Lung ventilation/perfusion	2.0
Bone scan	4.2
Cardiac perfusion (sestamibi)	12.5
Fluoroscopy	
Barium swallow	1.5
Coronary angiography	5-15

DEXA=dual-energy x-ray absorptiometry.

*These doses are effective doses, which are theoretical quantities proposed by the International Commission on Radiation Protection to assess the health risks of low doses of ionizing radiation.

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