1 Radiation and Contrast Concerns

General Considerations

- The risks of iatrogenic injury from radiation exposure and contrast administration (in any route) should always be seriously considered prior to the request for an imaging study. Remember, *primum no nocere* . . . "first do no harm."
- Almost every imaging investigation carries with it risks, some of which are yet unknown for newer modalities.
- Risks include radiation-induced malignancy (a cumulative risk over the lifetime of a patient), contrast reaction, contrast-induced nephropathy (CIN), and nephrogenic systemic fibrosis (NSF). These entities are considered in this chapter.

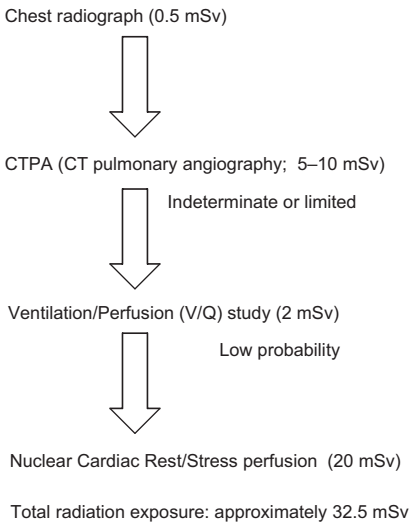
Radiation Risks

- Every human is exposed to radiation on a daily basis, in the form of solar radiation. Individuals living in areas where there is loss of the protective ozone layer have increased exposure to this ionizing radiation. Individuals also receive increased exposure to background radiation when they fly in airplanes.
- The highest single exposure to ionizing radiation on record occurred in the fallout from the atomic bombs dropped on Hiroshima and Nagasaki. This fallout totaled a radiation dose of 5–200 mSv.
- Medical radiation is the highest exposure to ionizing radiation that most individuals receive, putting them at increased risk of radiation-induced malignancy.
- The following is a rough estimate of the amount of radiation involved with most imaging exposures; these and other values

are available online. The total effective radiation dose is dependent upon the equipment used and varies from center to center.

Background Radiation	0.3 mSv
Chest Radiograph	0.5 mSv
Abdominal Radiograph	1.2 mSv
Chest CT	5–8 mSv
Routine Abdominopelvic CT	10–20 mSv
Hematuria Protocol CT	30–40 mSv
Flank Pain Protocol CT	6–10
Head CT	2 mSv
Cervical Spine CT	2 mSv
Cardiac Nuclear SPECT	10–20 mSv
Coronary CT Angiography (CTA)	7–15 mSv
HIDA Scan	2–3 mSv
PET	14 mSv
Coronary Angiography	5–20 mSv (diagnostic catheter)

- The risk of malignancy is approximately 1 in 2,000 if a patient receives 10 mSv of radiation, according to FDA data.
- Many patients undergo repeated examinations that require ionizing radiation. The total radiation exposure can far exceed that received from the fallout in Hiroshima. For example, a patient may present with chest pain to the ER. A hypothetical (but plausible) evaluation of this patient may include the following:



- If alternative imaging modalities that do not involve radiation are available and they can provide adequate information to confirm a suspected diagnosis or direct appropriate treatment, they should be seriously and carefully considered. An example would be use of a retroperitoneal ultrasound to evaluate for hydronephrosis in a patient with known renal stones who is presenting with classic flank pain. Use of retroperitoneal ultrasound would obviate the need for a flank pain protocol CT (6–10 mSv) and would direct therapy because percutaneous or transureteral stenting would only be required if renal obstruction was present. The treatment, otherwise, would be medical with hydration and pain control.

Contrast Agents and Administration

- *Oral contrast:* For studies in which bowel opacification is necessary (e.g. appendicitis) or useful (e.g. mesenteric metastases), oral contrast is administered. Oral contrast allows the bowel wall to be visualized, and it allows the presence and location of bowel obstruction, extrinsic compression, inflammation, and so on to be determined. Three main oral contrast agents are routinely used: barium, Hypaque, and water. Water is a "negative" contrast agent, which makes the bowel low in density (attenuation). Barium and Hypaque are "positive" contrast agents, which make the bowel dense (or white appearing). Barium is used for routine outpatient imaging and is an inert substance. Its drawback is that if it leaks from the bowel into the peritoneum (e.g. in bowel perforation), it becomes thickly adherent to the peritoneal surfaces, which can complicate surgery. Hypaque does not have this property, thus it is used for inpatient and ER patients who may require surgical treatment. Hypaque, however, can cause pulmonary edema if aspirated into the lung.
- *IV contrast:* There are two main types still used in routine clinical practice: ionic and non-ionic. There are a variety of preparations of each, with various viscosities and different risks to the kidneys, particularly in the diabetic population. Non-ionic contrast is less nephrotoxic and has a reported lower risk of contrast reaction than ionic contrast; however, non-ionic contrast material is slightly more expensive than ionic.
  - IV contrast can be nephrotoxic; therefore, it should not be administered to patients with chronic renal insufficiency or acute or chronic renal failure. The level of renal

dysfunction at which individuals still receive IV contrast varies by institution. At our institution, contrast is not administered if the creatinine (Cr) is >1.5 mg/dL. Patients with elevated Cr may be hydrated and given acetylcysteine (Mucormyst) prior to a study in an effort to be renoprotective. The radiologist should be consulted at the time of the study request for these patients in order to determine if IV contrast should be administered or if an alternative imaging study should be considered.

- ☐ Patients taking oral hypoglycemic agents (e.g. metformin) are at risk for lactic acidosis when IV contrast is administered. To decrease this risk, the patient is advised to discontinue the metformin on the day of and for 48 hours following the examination. They are also advised to have Cr redrawn 48 hours following the contrast administration to evaluate for CIN.
- ☐ Patients with IV contrast allergies should be premedicated where appropriate (see the following).
- ☐ IV contrast may be administered by hand injection; however, this technique has limitations. Although it may be the only manner in which IV contrast can be administered to small children or to patients with small caliber or tenuous IVs (in whom "power injection" with a machine is not safe), hand injection means that the bolus of contrast material is spread out over time. This leads to delayed scanning of the patient, often minutes after contrast administration, at which time contrast may have already left the arterial vascular bed and may be in later phases of organ enhancement (e.g. portal venous phase in the liver). This delay may significantly compromise an examination, particularly if the study must be timed to a specific vascular bed such as the pulmonary arteries for evaluation of pulmonary embolism. CT pulmonary angiography (CTPA) cannot be performed if the patient must be hand injected.
- ☐ Most studies are performed with the use of a power injector; this is a machine that holds contrast material to inject intravenously, which is controlled from the scanner console. These injectors have pressure safety monitoring devices such that if the pressure exceeds a certain amount, the injection is stopped. Because of this, large bore IVs are required for rapid contrast administration

under pressure (usually required for vascular studies such as pulmonary embolism aortic dissection, and CT coronary angiography). If routine chest, abdomen, pelvis, or neuro CTs are performed, a slower rate of contrast administration is sufficient, which can be performed through a smaller IV. It is advisable to check with your department to determine the required IV size for study indication (e.g. 20-gauge IV is required for CTA and CTPA).

- ☐ PICC lines and central lines cannot be injected by power injector or by hand (unless a special "power PICC" specifically designed for this indication is used). The reasoning behind this is that there is a risk of shearing off the tip of the catheter with the pressure from the contrast injection or showering thromboemboli from around the catheter tip.

- *Angiography (intra-arterial contrast administration):* The risks of performing contrast tests are the same as for IV administration, although the risks surrounding contrast may be more severe and immediate.
  - ☐ For enteric contrast (i.e. bowel), barium is the agent of choice over Hypaque unless there is concern about bowel perforation. Barium is an inert substance (a member of the periodic table), which is very dense and thus is well visualized on x-ray (fluoroscopic) studies. Barium has the advantage over Hypaque in that it is easily seen with fluoroscopy and thus outlines bowel pathology well.
    - There are differences in the preparations/suspensions of barium for different imaging modalities. The barium used for fluoroscopic studies is an extremely dense suspension that is not appropriate for CT as it causes the CT x-ray beam to be deflected in various directions and causes so-called streak artifact, which can render the CT uninterpretable. Therefore, if a CT is considered for a patient already scheduled for a fluoroscopic barium study, the CT should be performed first. The x-rays in fluoroscopy can "see through" the CT barium, if necessary.

Premedication for Intravascular Contrast

- Experts differ in their opinions about what constitutes an increased risk of contrast reaction; it is best to discuss the local policies for premedication with your radiology department.

- There is a theoretic increased risk of contrast reaction in patients with multiple allergies, atopy, and shellfish allergy.
- Patients with previously documented contrast allergy should be premedicated for a contrast-enhanced examination unless an anaphylactic reaction to contrast was previously documented. In these patients, intravascular contrast SHOULD NOT be administered.
- Contrast reaction includes minor and major reactions and may present as any of the following:
  - ☐ Sneezing
  - ☐ Vomiting
  - ☐ Hypo/hypertension
  - ☐ Cutaneous reactions (e.g. itching or hives)
  - ☐ Throat tightness
  - ☐ Wheezing
  - ☐ Chest tightness/shortness of breath
  - ☐ Anaphylaxis
- The following are normal side effects of contrast administration that some patients experience and are not contrast reactions:
  - ☐ Metallic taste
  - ☐ Flushing
  - ☐ Nausea
  - ☐ Warm feeling
- Premedication regimens:
  - ☐ A variety of regimens are in clinical use for the premedication of patients with known or suspected contrast reaction.
  - ☐ The need for premedication must be communicated to the scheduler at the time of the imaging request so that the examination may be scheduled for a time when the premedication regimen has been completed. For inpatients requiring premedication, it is suggested that the housestaff stay in communication with the technologists/schedulers to ensure completion of the regimen.
  - ☐ The following regimens are suggested:
  - ☐ Regimen 1:
    - Medication: Prednisone
    - Route: Oral
    - Dose: 50 mg
    - Schedule: 13, 7, and 1 hour prior to contrast-enhanced CT (CECT)

- Diphenhydramine (Benadryl) 50 mg oral or IV is also administered 1 hour prior to CECT
- Cimetidine may also be administered for its H_2 antagonist effects

□ Regimen 2:
- Medication: Methylprednisolone sodium succinate (Solu-Medrol)
- Route: IV
- Dose: 125 mg
- Schedule: 4–6 and 1 hour prior to CECT
- Benadryl 50 mg oral or IV is also administered 1 hour prior to CECT
- IV cimetidine may also be administered for its H_2 antagonist effects

Nephrogenic Systemic Fibrosis

- NSF is a recently recognized disease that has been linked to the IV administration of gadolinium contrast agents for MR examinations.
- NSF is a scleroderma-like disease that progresses over the course of several years and may result in death.
- NSF is associated with the administration of gadolinium in patients with impaired renal function. Currently, there are no national guidelines as to the precise level of renal dysfunction at which it is safe to administer gadolinium. Institutional policies vary and are based on the estimated glomerular filtration rate (eGFR), which is more accurate than serum Cr for evaluation of nephron function.
- At our institution, patients at risk for or with known renal impairment must have an eGFR calculated within 1 month prior to the study. Patients with severe liver disease must have labs within 24 hours before the study. For patients with renal disease, gadolinium may be administered if the eGFR is > 30; it must be > 40 for patients with severe liver disease due to the partial hepatic excretion of gadolinium.
- It is recommended that the local policy be determined prior to request for a contrast-enhanced MR examination.

2 Chest Imaging

Conventional Radiographs

- A CXR is the initial step in imaging acute cardiopulmonary disease.
- A CXR may be performed using a stationary or portable radiography unit.
- Indications for portable CXR include unstable patients in acute distress, intubated patients in ICUs, and intraoperative/recovery room radiographs.
- Optimal CXR includes frontal and lateral projections. It may only be possible to obtain frontal views due to a patient's clinical status, body habitus, or pregnancy. Pregnant patients are required to give verbal consent after discussion of the risks of radiation to the fetus, and these patients are double or triple lead shielded for the study. The risk to the fetus is low, particularly in later pregnancy when the fetus has developed beyond the stage of organogenesis. The patient (mother) is "triple shielded," meaning that lead aprons are placed over the abdomen and pelvis to protect the fetus from the x-ray beam. The actual scatter radiation from a single x-ray is quite low and typically of no significant risk to the fetus.
- CXR findings often lag behind clinical findings by up to 48 hours.
- In certain disease processes, the CXR may be normal.
- CXR findings may be non-specific and can be seen in a variety of diseases; for example, it may not be possible to differentiate pulmonary edema from multilobar pneumonia. The clinical history is often key to interpreting radiographic findings.

Decubitus Radiographs

- This is the radiographic imaging study of choice to evaluate layering versus loculated pleural effusions; however, ultrasound is becoming the overall study of choice. Ultrasound allows quantification and characterization of pleural fluid (e.g. loculations), which radiographs cannot.
- Bilateral decubitus images are obtained to evaluate right and left pleural abnormalities.
- Decubitus radiographs may allow for evaluation of underlying pulmonary parenchymal abnormalities.
- Decubitus radiographs may occasionally be useful to evaluate for subtle pneumothorax, particularly in premature infants.
- They may be used to evaluate for air-trapping in patients suspected of aspirating foreign bodies.
- CT should be performed to evaluate for loculated pleural effusions only if the patient is too unstable or immobile for decubitus positioning; ultrasound may be performed to evaluate for complicated pleural effusions or loculation and does not require a radiation exposure. Ultrasound has the added advantage of performance at the bedside if the patient is too unstable to be transported to the CT scanner.

INDICATIONS

- ☐ Assessment of layering pleural effusion
- ☐ Assessment of underlying pulmonary parenchymal abnormality
- ☐ Assessment of air trapping from aspirated foreign body (usually pediatric population)
- ☐ Assessment of pneumothorax (usually pediatric population)

CONTRAINDICATIONS: None

LIMITATIONS

- ☐ Patients may be difficult to position due to clinical condition, contractures, or body habitus.
- ☐ Obese patients may have suboptimal films due to the increased soft tissue penetration required in the decubitus position.
- ☐ Patients should be maintained in the decubitus position for several minutes before imaging to allow for changes in location of fluid or air that occur with change in position. If patients are imaged too quickly after repositioning, there may be insufficient time for relocation of fluid or air.

Inspiration/Expiration Radiography

- Expiratory CXR (i.e. taken with patient in full expiration) is useful to evaluate for subtle pneumothoraces. The change in intrathoracic pressure draws the lung away from the pleural space and accentuates the pneumothorax.
- Inspiratory CXR (i.e. taken with the patient in full inspiration) should always be attempted. This allows for full expansion of the lungs, thus allowing for the optimal evaluation of the lung parenchyma. Full inspiration also allows for optimal assessment of cardiac size.

  INDICATIONS:
  - ☐ Inspiratory films should be obtained in all patients to optimize evaluation of cardiopulmonary disease.
  - ☐ Expiratory films should be obtained if there is clinical or radiographic suspicion of subtle pneumothorax.

  CONTRAINDICATIONS
  - ☐ If patients cannot comprehend or comply with verbal commands, the study cannot be performed adequately.

  LIMITATIONS
  - ☐ Poor patient cooperation may make it difficult or impossible to obtain inspiratory or expiratory images.

Apical Lordotic Imaging

- Apical lordotic imaging is obtained with the patient in the AP/PA projection. The x-ray beam is angled toward the patient's head.
- It is useful when evaluating the lung apices, particularly for suspected nodules or masses overlying the first costochondral articulations.
- This type of imaging should not be performed as routine practice but rather as a problem-solving tool.

  INDICATIONS
  - ☐ Evaluation of the lung apices in patients with abnormal AP/PA chest film in which there is a suspicion of mass or nodule overlying the first costochondral articulation

  CONTRAINDICATIONS: None

  LIMITATIONS
  - ☐ Patient positioning may be difficult, particularly in older or immobile patients.