THE RADIOLOGY GUIDE & Learning Application

2nd Edition

"Blue Book of Radiology" – 4 Week Radiology Course

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CHAPTER 1

Introduction to Imaging Technology & Safety

Introduction to Imaging Technology

The physics of diagnostic imaging is enormously complex and sophisticated. However, we will devote several paragraphs of grossly oversimplified descriptions of all these conventional imaging technologies.

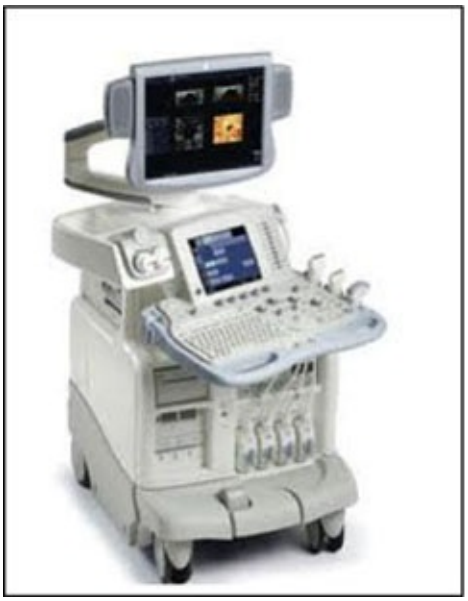
Xray producing technologies include the following.

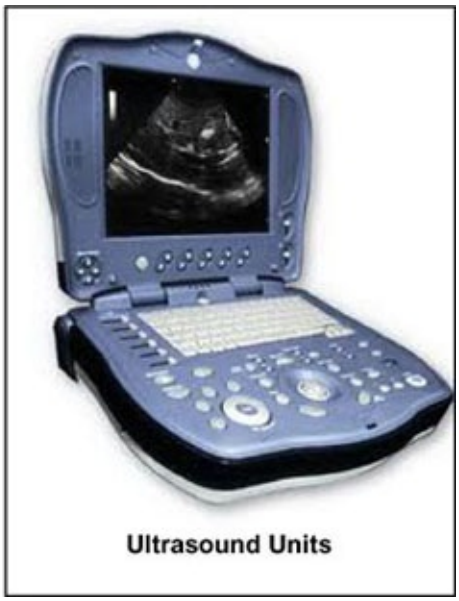
- **Xray & Fluoroscopy**
- **Mammography**
- **DEXA scan**
- **CT scan**

Typical xrays are produced using an xray tube, which can be thought of as much like a very powerful light bulb, except it emits high energy gamma rays instead of low energy photons. In fact, we have humorously grouped all of the xray emitting devices (xray, fluoroscopy, mammography, DEXA scan, and CT scan) as 'giant light bulb technologies.' Instead of emitting photons, the xray tube emits gamma radiation. The actual physics of xray production is more complicated than this, but essentially involves bending of a high energy electrical current, and in the process, producing a wave of gamma radiation. The degree of bending produces gamma radiation of different energy ranges. The radiation passes through the body, some of which is scattered, and then exposes a detection device, which could be film, digital recording device, or a fluorescent screen. Xray generators usually use high voltage, or three phase power. Smaller xray generators are plug-in or battery operated devices, which operate as single-phase electrical power. When films are

used as the recording device, they are usually contained in cassettes, or film holders. A Bucky is a moving grid device which eliminates scatter and allows better penetration of the xray beam. Diagnostic xray uses higher energy xrays (50 to 110 kV range), to penetrate thick body parts. Mammography uses lower energy xrays (25 kV range) specifically to examine breast or soft tissue density. DEXA scans for osteoporosis screening produce a very crude xray and are not designed for diagnostic images; the xray data is translated into bone mineral density data and compared normal subjects to determine the relative degree of bone loss. During fluoroscopy, another xray producing technology, the images are captured much like a digital camera or camcorder, which allows specific evaluation of physiologic function (like swallowing or bowel peristalsis) or for positioning of a needle or catheter.

The evolution of diagnostic imaging occurred in 1970's. Prior to the 1970's, radiology was limited to plain films and fluoroscopy. In 1972, Sir Godfrey Hounsfield introduced the first EMI CT scanner. A *CT scan*, a high powered xray producing technology, is a revolving xray with multiple detector sources, enabling a composite image of a large number of point sources, arbitrarily quantified into small boxes called pixels. The pixels are reconstructed into a detailed two dimensional image seen on the viewing screen. Three dimensional imaging involves using the 2D information and reprocessing these into other scan planes, which can be reconstructed in 3D. This task has more to do with computer software application rather than xray generation. Modern CT scan systems are typically of the 3rd or 4^{th} generation type; the former uses a revolving scan detector; in the latter, the scan detector is stationary. Spiral scans (same as helical) involve a continuous scan acquisition, instead of the traditional scan pause, scan another slice, then pause. Single slice spiral CT performs the scan one slice at a time in a continuous fashion; more expensive multi-slice helical CT scans obtain multiple slices at a time during the acquisition. The expense of the multi-slice helical CT scanners comes from the high capacity xray tube or tubes, some capable of generating xray output over the life of the scanner. CT scan is very helpful in determining density. A simple cyst, containing water or fluid, measures in the density range of 0 to 20 H.U. (H.U. stands for CT units.) Complex cysts have fluid contents which are greater than 20 H.U. Hemorrhage usually measures in the range of 70 H.U. A nodule that is at least 10% calcified will measure about 200 H.U. Fat measures in the minus range, typically at around –30 to –100 H.U. Air is very, very low, usually less than –1000 H.U. Bone is very, very high, usually greater than 1000 H.U. For a number of years, scans were acquired at 1 second per slice. Recently introduced slip ring technology and high heat capacity xray tubes have permitted sub-second per slice scanning capability, and extremely fast scans.





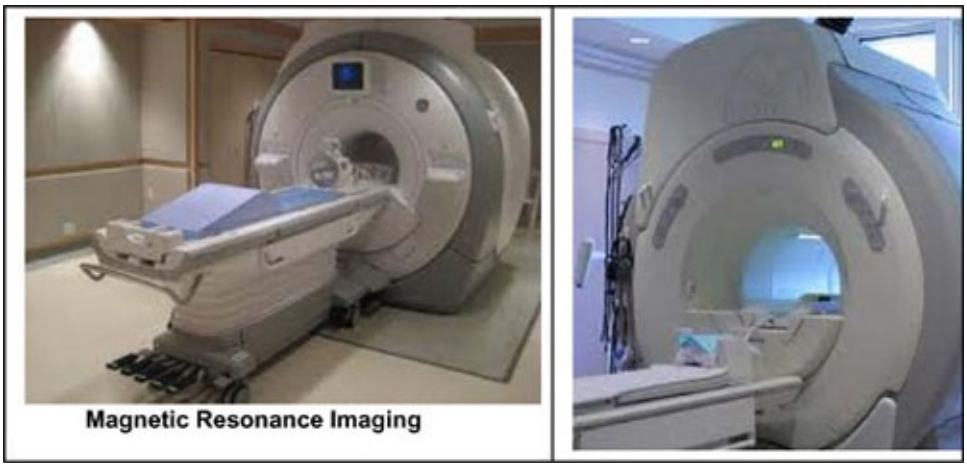
Ultrasound Units

Ultrasound (sound wave technology) uses sound waves to penetrate body organs and tissues. Frequencies of 2 MHz (megahertz) to 15 MHz emitted by handheld devices called transducers are typical for diagnostic ultrasound. Therapeutic ultrasound uses a different frequency range. Unlike xrays, which pass through the body and then recorded on a detection device, sound waves do not pass through the body. During an ultrasound examination, the sound waves penetrate to a certain depth and then are reflected back and recorded on a viewing screen as a two dimensional image. Typical depths are from millimeters thick to 20 cm. During the examination, the viewer sees the images as real-time, similar to a camcorder or motion picture. The examiner can obtain static images, or individual snap shots, or continuous pictures and send them to a storage media, archiving device, or printer. Also ultrasound does not use ionizing radiation, and therefore is safe to use in pregnant women. By ultrasound, *simple* cysts are defined by three criteria. [If they do not adhere to these criteria, then they are not simple cysts.]

- **Anechoic (completely black or devoid of signal)**
- **Smooth borders**
- **Very thin, imperceptible walls**

Other ultrasound properties are shown below.

- **Fat and blood - are echogenic, concentrate sound waves**
- **Calcium - densely echogenic with clean shadows below the calcification, because sound waves cannot penetrate calcium**
- **Air - creates 'dirty shadowing' and scattering, since sound waves cannot penetrate air**



Magnetic resonance imaging, or MRI, is the most complex of all imaging technologies. MRI is essentially a proton scan. The two most abundant protons in the body are water and fat, which are ideal as imaging media. The magnetic field is required to align the body's protons in the magnetic field at a specific frequency dictated by the strength of the magnet (the large doughnut or bore the patient goes through). Radio waves of a particular frequency are applied to the patient in the magnetic field so as to alter the spins of the protons. In effect, the protons absorb the applied radio waves, causing the protons to wobble or resonate, then realign back to the magnetic field, and in the process emit a low level (non-ionizing) energy which is recorded as a matrix of recorded data. Water protons and fat protons absorb and emit the radio waves slightly differently, so as to create the varying image contrast seen on the images. Essentially, MRI measures the slightest variations in the applied magnetic field of the human body determined by the relative proportions of fat and water. The presence of iron also affects this magnetic field.

The high field MRI allows more clarity and faster scans. The advantage of open MRI for patients is mainly more open bore, allowing more comfort for large patients and claustrophobic patients. For MRI owners, open MRI units are less expensive to purchase and operate. The open MRI compensates by taking longer scans to create more clarity. For example, the high field MRI samples the protons less than the open MRI. This sampling is known as NEX (number of excitations). Typical matrix arrangements are 256 × 256 for high field MRI and 256 × 192 for open MRI scanners. High field may operate at 3 NEX, while low field may operate at 6 NEX for the same anatomic part. The high field records 3 × 256 × 256, or 196608 points of data per image; while the low field records 6 × 256 × 192, or 147456 points of data for the same image. This relative difference in data is reflected in scan resolution but not contrast, which is determined by the homogeneity of the magnetic field. Open MRI scans produce excellent tissue contrast between fat and water, particularly on STIR (a type of T2) scans. Basic image properties on MRI are T1 and T2 scans. Fat is bright (or hyperintense) on T1 and dark (hypointense) on T2 scans; water is dark (hypointense) on T1 and bright (or hyperintense) on T2 scans. Water sequences are best for cysts and fluid (such as cerebrospinal fluid, joint effusions). Fat sequences are best for fatty tumors (like dermoids, teratomas, lipomas). Blood, containing heme or iron, is also seen on MRI scans. Acute blood is poorly seen on MRI. However subacute hemorrhage and old hemorrhage are well seen by MRI. This has to do with the oxidation state of iron (+2 for acute versus +3 for subacute/chronic blood). Subacute hemorrhage is typically bright on both T1 and T2 scans. Chronic or old blood (known as hemosiderin) is very dark on both T1 and T2 scans. Hemosiderin is similar to metallic

foreign body seen on MRI (dark on all MRI sequences).

- **MRI properties of cysts, or water - dark (hypointense) on T1 scans; bright (hyperintense) on T2 scans**
- **MRI properties of fat - bright (hyperintense) on T1 scans; dark (hypointense) on T2 scans**

Nuclear medicine is a technology where the energy sources for imaging come from radioactive materials which emit gamma radiation. The most common radioactive isotope used for diagnostic imaging is Technetium 99m, which is unstable and rapidly decomposes, with a half life of approximately 6 hours. During decomposition, the isotope emits a gamma wave at an energy of 159 keV. When radiopharmaceuticals are ingested or injected, this energy is emitted through the body tissues and recorded by a gamma ray detector which projects this information onto a viewing screen.

Medical diagnostic imaging is a highly regulated specialty. Any modality using an xray tube (such as diagnostic xray, fluoroscopy, mammography, and DEXA scan) requires state inspection and licensure. Radiation monitoring of technical employees is mandatory. Additionally, mammography must be further inspected and licensed by the FDA. Nuclear medicine requires an NRC license at the state level. The *American College of Radiology (ACR)* accredits the following modalities: MRI, CT scan, ultrasound (general, obstetrical, breast, and vascular sections separately), and mammography. Other accreditation bodies include the *Intersocietal Accreditation Commission (ICACTL)*, and *American Institute of Ultrasound in Medicine (AIUM)*. Most insurance plans now require facilities to be accredited in order to receive payment. Hospitals and most outpatient facilities are further required to be certified by the *Agency for Healthcare Administration*, at the state level, and *JACHO*, a federal agency. Outpatient radiology facilities are required also to have a Certificate *of Need (CON)* in order to operate, except in a select few states (such as Florida and California). Radiation limits are monitored on the state level with annual inspections. The annual radiation dose limits are also strictly regulated.

Radiation Dose by Examination Type

Examination Description	Radiation Dose (in millirems)	Equivalent Background Radiation	Maximum Lifetime Risk of Fatal Cancer
Xray, Extremity	0.1	3 hours	1 : 1,000,000
DEXA Scan	0.1	3 hours	1 : 1,000,000
Xray, Dental	0.5	1 day	1 : 1,000,000
Xray, Chest	10	10 days	1 : 100,000
Mammogram	40	7 weeks	1: 10,000
Xray, Spine	150	6 months	1: 10,000
CT Brain	400	16 months	1: 1,000
CT Spine	600	2 years	1 : 1,000
Upper GI	600	2 years	1 : 1,000

CT Chest	700	2 years	1 : 1,000
Barium Enema	800	3 years	1 : 1,000
CT Abdomen	1500	5 years	1 : 1,000
CT Pelvis	1500	5 years	1 : 1,000
CTA Chest	1600	5 years	1 : 1,000
CT A/P Combo	3000	10 years	1 : 500

Source: http://www.radiologyinfo.org/en/safety

Radiation Dose Limits

Body Exposure	Dose Limit
General Public	0.1 rad/year
Fetal	0.5 rad/gestation
Whole (Total) Body	5 rad/year
Blood-Forming Organs	5 rad/year
Gonads	5 rad/year
Lens of Eye	15 rad/year
Extremities & Skin	50 rad/year

Source: U.S. Nuclear Regulatory Commission. Title 10, Part 20, Code of Federal Regulations

Safety in Diagnostic Imaging

Pregnancy

- All female patients, ages 12 through 55, who require xray examinations must acknowledge if there is any possibility of pregnancy on the day of the examination), with a writtten signature, in the presence of a witness (preferably the technologist performing the examination).
- Examinations should be performed within 10 days of the last menstrual period.
- Alternatively, a pregnancy test can be performed if menstrual dates are inaccurate or unknown.

Iodinated Contrast Precautions

Patients should be screened for *high-risk* of potential iodinated contrast reaction or adverse event. Preferably, *non-ionic contrast* (containing organically bound iodine) should be used routinely if not cost-prohibitive. There is great controversy regarding the use of

iodinated contrast (ionic versus non-ionic), mainly a cost issue (non-ionics are more expensive).

The following is a list of *high-risk* patients and adverse effects - renal failure (RF), potentiation of cardiac disease (CD), pre-existing disease exacerbation (DA), and anaphylaxis (AF).

- **Allergy to iodine, seafood, or shellfish (AF)**
- **Prior contrast allergy (AF)**
- **Multiple myeloma (malignant bone tumor) (RF)**
- **Pheochromocytoma (adrenal tumor) (DA)**
- **Asthma and COPD (DA)**
- **Sickle cell anemia (DA, RF)**
- **Congestive heart failure (DA)**
- **Cardiomyopathy (enlarged heart) (DA)**
- **Angina pectoris (DA)**
- **High blood pressure (DA)**
- **Hyperthyroidism (overactive thyroid) (DA)**
- **Renal problem/failure – elevated creatinine of >1.4 (GFR <60) (RF)**
- **Diabetes mellitus (RF)**

The following is a list of *general precautions* to iodinated contrast administration.

- **High-risk allergic and asthmatic patients** need to be pre-treated with steroids prior to receiving non-ionic contrast. A sample prep is *prednisone*, 20 mg po (oral) tid (or 24hrs, 12 hrs, and 1 hr) prior to the study.
- **Diabetic patients** need to discontinue certain oral diabetes medications which are can potentiate renal toxicity and acute tubular acidosis, including *Metformin*, *Glucovance*, *Glucophage*, *Avandamet*, and *Metaglip*. These medications should be be discontinued the day of the examination and resumed 48 hours (2 days) later, provided that renal function is normal (GFR >60).
- **Breast feeding** should be discontinued the day of the examination and resumed 48 hours (2 days) later. Organically bound iodine is secreted in breast milk and can concentrate in the neonate.
- **Closed head trauma** should be considered a contraindication to IV iodinated contrast media, which *lowers the seizure threshold*.

CLINICAL PEARL: Acute tubular necrosis (or ATN)

ATN indicates a significant adverse contrast event. On imaging studies, a very dense nephrogram is seen, without excretion of contrast into the collecting systems because of tubular failure.

Recognizing and Treating a Contrast Reaction

Mild contrast reaction

- **Mild hives (urticaria), facial swelling or redness, erythema**

- **Treat with oral or intravenous diphenhydramine (Benadryl), 25 mg.**

Moderate contrast reaction

- **Severe urticaria, eyelid swelling, lip edema or swelling.**
- **Treat with diphenhydramine (25 mg, IV) and hydrocortisone (40 mg, IV)**

Serious/severe reaction

- **Wheezing, bronchospasm, cardiac arrest, and renal failure**
- **Severe bronchospasm – requires emergency treatment; epinephrine, 1:1000 (0.3 mg, IM) or 1:10,000 (0.3 mg, IV)**
- **Cardiac arrest – requires cardioeversion.**

Oral Contrast Media

Oral contrast is used to opacify and visualize the bowel and provide contrast between bowel and adjacent mesentery and solid abdominal viscera; comes in two types: *barium suspension* (1 or 2%) or water soluble *diatrizoate salts*. Barium suspension is preferred by radiologists; however, it should be used cautiously in the setting of acute abdomen or perforated viscus, leading to peritonitis when (barium) is free in the peritoneal cavity. Water soluble diatrizoate media is ideal in the acute abdomen but should be used cautiously in patients at risk for aspiration, since the media produces a severe form of aspiration pneumonitis.

CAUTION: Barium suspension should be used *cautiously* with bowel perforations.

Magnetic Resonance Imaging Safety

Metallic objects must be carefully screened in preparing patients for MRI examinations. There are some metallic objects which are not ferromagnetic in addition to a number of medical devices which are MRI compatible. If the status of a particular metallic object or medical device is not known, there is a comprehensive website available to cross check these on the following website: **www.mrisafety.com**.

The following is a list of *contraindications* to performing an MRI examination.

- **Pacemaker or implanted defibrillator**
- **Brain aneurysm clip**
- **Stapes implant, inner ear surgery using metal**
- **Implanted infusion devices, pumps, spinal TENS unit/stimulator**
- **Prosthetic heart valves (unless cleared by the manufacturer)**
- **Metallic stent (within 6 weeks of placement)**
- **Pregnancy**
- **Penile implant (unless cleared by manufacturer)**
- **Metallic foreign body or shrapnel, body piercings**
- **Tattoos (containing metal dyes), some permanent makeup (eyeliner, lip-liner, eye brow liner)**
- **Grinding metal wheel, metallic dust exposure to the eyes**

Other MRI safety concerns include *cryogens*, *magnetic field interference*, and *adverse contrast reactions*.

CAUTION: Cryogens, while generally safe, can present a significant danger when not properly contained.

In superconducting (high field) systems, liquid helium, a *cryogen*, is used to cool the magnetic head as part of the standard operation of the equipment. This enables the high magnetic fields used to produce detailed MRI images. A *quench* is a serious event involving rapid expansion of the liquid helium into gas, due to power loss and/or system malfunction. In the event of a system quench, it is imperative that all personnel and patients be evacuated from the MR scan room as quickly and as safely feasible and that the site access be immediately restricted to all individuals until the arrival of MR equipment service personnel. This is especially so if cryogenic gases are observed to have vented partially or completely into the scan room, as evidenced in part by the sudden appearance of white clouds or fog around or above the MR scanner. It also especially important to ensure that all police and fire response personnel are restricted from entering the MR scan room with equipment (such as axes, air tanks, guns, etc.) until it can be confirmed that the magnetic field has been successfully dissipated, because there may still be a considerable static magnetic field present despite a quench or partial quench of the magnet.

CAUTION: Be aware of the *5 Gauss* line.

Another significant safety concern is the *5 Gauss (magnetic field) line*. This line specifies the perimeter around a MR scanner within which the static magnetic fields are higher than 5 Gauss; where 5 Gauss and below are considered safe levels of static magnetic field exposure to the general public. Medical devices and portable electronic devices requiring a separation distance between the device and the MR magnet, should be considered *MR Safe*, *MR Compatible*, or intended for use in the MR environment. Typically the 5 Gauss line is the only location where the static magnetic field strength is specified around a MR scanner. Therefore, labeling specifying a separation distance between the MR magnet and the device to ensure safe or proper operation of the device should be avoided.

CAUTION: As a general precaution, *first trimester pregnancy* is contraindicated in all MRI examinations.

No MRI examinations should be performed on pregnant patients because the long term risks of magnetic fields and gradient fields on the fetus and mother are unknown.

The current guidelines of the FDA require labeling of MRI equipment to indicate that the safety of MRI with respect to the fetus "*has not been established*." Safety concerns arise with respect to both mother and fetus. Maternal safety concerns are the same as for a non-pregnant patient, and are addressed by pre-scan screening. Fetal concerns are twofold: first, for the possibility of teratogenic effects; and second, the possibility of acoustic damage. In general, it should be noted that most studies evaluating MRI safety during pregnancy showed no deleterious side effects.

CAUTION: As a general precaution, MRI contrast agents should not be administered in patients with *GFR <30*.

MRI contrast agents contain *gadolinium*, a paramagnetic metal ion useful for magnetic resonance imaging (MRI). Gadolinium-based contrast agents (GBCAs) are manufactured by a chelating process, reducing toxicity, via renal excretion of the stable chelate. The FDA has issued a boxed warning regarding reports of *nephrogenic systemic fibrosis (NSF*) in patients who received GBCAs. NSF was identified in 1997 and has been reported only in patients with severe kidney disease. NSF causes fibrosis of the skin and connective tissues throughout the body. Patients develop skin thickening that may prevent bending and extending joints, resulting in decreased mobility of joints. NSF usually starts in the lower extremities. Fibrosis can also develop in the diaphragm, muscles in the thigh and lower abdomen, and lung vessels, and can cause death.

Whether GBCAs are the only agents or conditions that may be associated with NSF in patients with renal disease is unknown. The conclusions that can be drawn from the NSF reports are limited. However, the reports the FDA has received are published reports of gadolinium deposits in the skin of patients with NSF/NFD. Other published reports suggest that GBCAs play a role in the development of NSF in patients with acute or chronic severe kidney insufficiency or kidney dysfunction due to the hepatorenal syndrome or in the perioperative liver transplantation period. At this time, only certain patients who receive GBCAs appear to be at an increased risk for developing a serious systemic fibrosing disease, NSF. The patients most at risk are those with acute or chronic severe renal insufficiency defined as glomerular filtration rate < 30 mL/min/1.73m^2; or renal dysfunction due to hepatorenal syndrome or in the perioperative liver transplantation period. In the hepatorenal syndrome or in the perioperative liver transplantation period, the risk applies to any severity of renal dysfunction.

Staff and physicians are advised to screen for any signs of NSF, including: swelling; skin tightening; reddened or darkened patches on the skin; burning or itching; yellow raised spots on the whites the eyes; joint stiffness; difficulty straightening arms, hands, legs, or feet; deep pain in the hip bones or ribs; and muscle weakness. Staff technologists and physicians should consider the risks and benefits of using GBCAs in patients with acute or chronic severe renal insufficiency (glomerular filtration rate <30 mL/min/1.73m^2); renal dysfunction of any severity due to the hepatorenal syndrome or in the perioperative liver transplantation period. In these patients, GBCA should be avoided unless the diagnostic information is essential and not available with non-contrast enhanced MRI. Additional risk factors that may increase the risk are repeated or higher than recommended doses of a GBCA and the degree of renal impairment at the time of exposure. For patients already receiving hemodialysis, physicians may consider the prompt initiation of hemodialysis following the administration of a GBCA in order to enhance elimination of GBCA. However, the usefulness of hemodialysis in the prevention of NSF is unknown.

Recognition & Treatment of Contrast Extravasation

Contrast extravasation is the accidental extravascular injection of intravascular contrast media caused by dislodgment of the cannula, contrast leakage from the vessel puncture site, or rupture of the vessel wall. Contrast extravasation is a well recognized complication, with reported frequencies of 0.25% to 0.9%. Extravasation usually causes some combination of immediate pain, erythema, and swelling, but fortunately these are

usually self-limiting and long-term major morbidity is rare. However, severe skin and subcutaneous ulceration can occur, and subfascial extravasation may cause compartment syndrome (neurovascular signs and symptoms due to increased volume in the confined spaces formed by the deep fascia). When extravasation does occur, complications are more severe in extremities with poor vascular or lymphatic circulation (e.g., on the side of a prior mastectomy with radiation or lymph node dissection) or when extravasation occurs on the dorsum of the hand of foot.

The following care guidelines are suggested in monitoring a contrast infusion.

- **Ensure the IV site is properly selected, placed, secured, and tested.**
- **Make sure the vein is not obstructed when repositioning the arm.**
- **Consider a lower flow rate in patients at particular risk (while high flow rates do not seem to increase the risk of extravasation, they result in a more rapid accumulation of extravasated contrast).**
- **Warn the patient to report any unusual sensations at the IV site immediately.**
- **Observe the IV site for the first 10-20 seconds of the injection and discontinue the injection if there is any concern or question of extravasation.**

Treatment of extravasation involves stopping the contrast infusion immediately, removing the catheter, and alerting the radiologist. The affected extremity should be elevated above the heart and cold compresses applied topically. The radiologist evaluating the patient will decide how the patient will be further managed. Referral to the Emergency Department is reserved in cases of skin blistering, altered tissue perfusion, increasing pain, or change in sensation distal to the site of extravasation. In all cases, it is critical that the responsible radiologist communicates directly with the patient, referring physician, and Emergency Department and appropriately documents these communications in the report or medical record.

General CT Scanning Planning Considerations

- **Protocol depends on body part selection.**
- **Need to decide the use of intravenous and/or oral contrast media.**
- **Always obtain consent form and creatinine level when applicable.**
- **Need to decide scan planes.**
- **Need to select scan slice thickness.**
- **Need to decide the rate and speed of contrast administration.**
- **Know what windowing levels need to be included in the image set.**
- **Know the capabilities of your scan CT (helical versus non-helical).**

CT Abdomen/Pelvis Scan Protocol

Use both oral and intravenous contrast unless otherwise contraindicated. Additional non-contrast scans through the kidneys to the bladder are necessary in the setting of excluding renal calculi or calcification. Scans typically at 7 mm thick at 7 mm increments, can be reconstructed to 3 or 5 mm scans when acquired helically. Thin section scans (3 or 5 mm) are required through the pancreas and adrenal glands also to evaluate for renal calculi, when indicated. The CT abdomen extends from the lung bases to the iliac crests; the CT pelvis examinations extend from the iliac crests to the perineum. Be aware that any

pathology relevant to bowel must include the CT pelvis order, which is sometimes inadvertently omitted in some house staff orders.

CT Brain Protocol

Use non-contrast scans in elderly, uncooperative patients, and closed head trauma. Optimally, scans should be performed without and with contrast. Angled/axial scans from the vertex to the skull base at 5 mm thick at 5 mm intervals are the norm; include bone windows in the setting of trauma or metastatic disease.

CT Neck Protocol

Use contrast unless otherwise contraindicated at 3 mm thickness at 3 mm intervals. Additional non-contrast scans should be performed in the upper neck to evaluate submandibular and parotid calculi.

CT Orbit/Facial Protocol

Bone windows are required at 3 mm scan thickness at 3 mm scan intervals; both axial/oblique and coronal/oblique scans. No contrast required. Scans can be reconstructed to thinner slices (e.g., 1.5 mm).

CT Sinuses Protocol

Coronal/oblique scans at 3 mm thickness at 3 mm scan intervals. No contrast required. Optional axial/oblique scans and sagittal reconstructed scans should be performed only if required by your referring otolaryngologist (ENT).

CT Chest Protocol

Use intravenous contrast unless otherwise contraindicated. Scans are generally performed at 7 mm thickness at 7 mm scan intervals from the clavicles (to assess for supraclavicular masses) to the adrenal glands (to assess for adrenal metastasis). When acquired helically, these scans can be reconstructed to thinner slices (3.5 or 5 mm scans). Pre-contrast scans without contrast are optional at some centers. A high resolution chest CT [HRCT] is performed non-contrast at 1 mm slice thickness at 5, 7, or 10 mm intervals, depending on individual preference. HRCT is obtained in the evaluation of interstitial lung disease.

CT Skeleton Protocol

These are angled/axial scans performed generally for patients in whom osseous pathology is seen or suspected (advanced spondylosis/ degeneration, pars defect, metastasis) or the patient has a contraindication to MRI. No intravenous contrast is used. Osteoarthritic spurs usually create susceptibility or streak type artifact which can often overestimate the degree of stenosis. Sometimes myelographic contrast containing water-soluble contrast (oil and *Pantopaque* are no longer used) is intraduced intrathecally under fluoroscopic guidance, to distinguish disk herniation, nerve root impingement, and osteoarthritic spurs. Cervical

spines are performed at 3 mm thick 3 mm scan intervals; lumbar spines can be performed at either 3 mm thick 3 mm scan intervals through the disk spaces or 5 mm as a continuous acquisition. Reformatted sagittal and coronal scans can be obtained (from 1.5 to 3 mm thickness) when scans are acquired helically.

Prescribing & Ordering Diagnostic Imaging Studies

Orders for radiologic tests should be written on valid scripts accepted within your state. At a minimum, scripts could contain the following pertinent information.

- **Ordering physician name and office address**
- **Ordering physician fax number – so that the radiologist can issue a report on an expedited basis**
- **The patient's name and date of birth**
- **Specific radiologic examination(s)**
- **Specify whether contrast is to be used (without, with, or both without and with)**
- **Specify the medical indications for the test recognized by the ICD-9 Procedure and Medical Terminology Manual**
- **The test must be medically necessary and also should match the primary care physician's office notes in the event the records are audited by an insurance company to document medical necessity (See chart – next page)**

Additional *legal considerations* when ordering diagnostic tests are as follows.

- **Changing the medical record or providing a diagnosis which the patient does not have is considered fraudulent, in most states.**
- **A valid diagnosis code does not start with the words '*rule-out*…' Be sure the chart record match the clinical signs/symptoms or diagnosis provided on the patient script.**
- **Check to see if a precertification or authorization from the insurance company is required for a diagnostic imaging test (particularly CT, MRI, and contrast examinations); this will affect the imaging center's ability to see a particular patient in an expedited manner.**
- **Prescribing/ordering physicians, under federal (U.S.) and state law, must have less than 5% financial interest in a diagnostic medical imaging venue to be considered legal (anti-kickback).**
- **Xrays and diagnostic imaging films, CD's, and reports are considered part of the medical record and require the patient's expressed written authorization to be released.**
- **Record retention policies – diagnostic xrays are no exception and must be retained by the facility for at least 5 years (or longer in some states).**

Signs & Symptoms Justifying Medical Necessity

Chest	Chest pain, shortness of breath (dyspnea), wheezing, fever, cough, blood in sputum (hemoptysis), asthma
Abdomen	Fever, weight loss, nausea, vomiting,, constipation, heartburn, epigastric pain, distention,, dysphagia (difficulty swallowing), RUQ/LUQ pain, epigastric pain, generalized abdominal pain
Breast	Breast lump, nipple discharge, personal or family history of breast cancer, swelling
Pelvis	Pain, tenderness, change in bowel habits, frequency, pain or burning in urination, vaginal/penile discharge, bloating, blood in stool, diarrhea, constipation, RLQ/LLQ pain
Spine	Spinal surgery, trauma, injury, pain, numbness, pain radiation (radiculopathy, myelopathy, weakness

Extremities	Swelling, edema, calf pain with or without exercise, arm pain, numbness, injury, or trauma
Feet & Toes	Pedal edema, swelling, discoloration, injury, or trauma
Hand & Fingers	Swelling, numbness, tingling, injury, trauma
Joints	Pain, swelling, trauma, injury, clicking, popping, dislocation, numbness/ tingling, burning, decreased mobility, decreased range of motion, prior surgery
Head & Neck	Headache, migraine, dizziness, vertigo, blurred vision, facial numbness, weakness, TIA, ataxia, neck lump or swelling, goiter, closed head injury
DEXA Scan	Menopause, estrogen deficiency, primary ovarian failure, hormone use (such as exogenous steroids), osteoporosis, compression fracture