

# **MCG Basic Radiology Primer: An Introduction to Problem-Oriented Imaging Algorithms Version 6-23-04**

**General Introduction:** this manual is designed to assist medical students, health-care providers, and interested parties in selecting the right imaging test for the right patient in the right order. The goal is to improve the efficiency and utilization of radiology and nuclear medicine. This text is organized as a series of brief suggested algorithms based on the anatomical part of the body being imaged or a specific clinical problem. This is not a comprehensive presentation, but rather is designed as an educational aid to address common situations in imaging in a general manner. Of necessity, this is not an authoritative document, and all suggested algorithms serve as an overview designed for the clinical realities present at MCG. Patterns of practice may differ in other circumstances at other locations. Please feel free to contact an imager in any section of the department and discuss complex or atypical clinical scenarios in order to customize your imaging requirements as clinically indicated.

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## **General Modality Considerations**

**Ultrasound (US)** is cheap, generally non-invasive, relatively easily available, and has essentially no mortality or morbidity. Endovaginal, transesophageal, and endocavitary US carry procedural risks related to introduction of the US probe. Please note that there is no in-house US capability after 10PM. Patients should be NPO X 4 hours for gall bladder (GB), liver, pancreas, and biliary ductal examinations. MCG US can be reached at 1-4071. Vascular US is available at 1-5201. No obstetric US is performed in the imaging department except emergency examinations for potential ectopic pregnancy after normal business hours.

**Computed Tomography (CT)** is expensive, available 24 hours per day in-house, and carries mortality and morbidity related to radiation exposure (especially children, breast tissue, and ovaries/testes) as well as risk related to IV contrast use (death approximately 1 case per 40,000 – 100,000 uses). All patients must be assessed for ability to receive IV contrast, even in “non-contrast” situations since changing circumstances may necessitate the use of IV contrast. All use of IV contrast requires IV access; of specific importance is that high-pressure contrast injections require at least an 18-gauge access with a catheter rated to accept high pressures! PICC lines and catheters of 20 gauge or less don’t meet these requirements. This has particular importance for PE and other CT angiogram procedures (aorta, renal arteries etc.) and may render these CT procedures unable to be performed if suitable IV access isn’t available. The requesting healthcare provider should request a specific CPT code-based CT procedure on the radiology requisition form that fits the required

clinical scenario; this will be reviewed and assigned a formal protocol by a radiologist. Ideally patients should be NPO X 4 hours before administration of IV contrast, in case of contrast-induced vomiting, but this is optional if there is any urgency to the examination. MCG CT can be reached at 1-4586 and CMC CT can be reached at 1-5210.

CT IV contrast contraindications include Creatinine of 2.0+, allergy to iodine or contrast, renal failure, or lack of consent. Informed consent or emergency consent signed by the referring provider is required in all cases. Minors, incapacitated patients, or incompetent patients require consent from a guardian or emergency consent as above. MRI contrast also requires specific informed consent. Please note that MRI and CT IV contrast are both quite expensive!

Magnetic Resonance Imaging (MRI) is very expensive, less easily available, and carries little mortality or morbidity due to electromagnetic exposure or IV contrast. Small gauge IV access for IV contrast use is acceptable. The patient doesn't need to be NPO, but must be able to lay still. In cases of claustrophobia or a non-cooperative patient elective sedation may be required; this is arranged and ordered by the referring healthcare provider. MCG MRI can be reached at 1-3566. A mobile unit is also present on Fridays and can be reached at 1-3566. The mobile unit will be discontinued when a new 3 Tesla MRI unit becomes operational in 2004-2005.

Nuclear Medicine (NM) is moderately expensive, less available, and carries minimal mortality and morbidity from the radiation and associated labeled radiopharmaceuticals. Small gauge IV access for IV radiopharmaceutical use is acceptable. The patient should be NPO X 4 hours for gall bladder (GB), GB ejection fraction, and cardiac NM examinations. Please note that a cooperative patient who isn't artificially ventilated is required for the ventilation part of a lung V/Q scan; if these conditions aren't present then an alternative PE examination should be selected. MCG NM can be reached at 1-2867. PET/CT is considered as a NM procedure and scheduled via the nuclear medicine department. Note that a whole-body PET/CT scan costs slightly less than a CT scan of the chest, abdomen, and pelvis.

Fluoroscopic procedures (upper gastrointestinal =UGI, small bowel follow-through = SBFT, barium enema =BE) are relatively inexpensive, less available after regular business hours, and carry mortality and morbidity related to radiation exposure. There is also a procedural risk of perforation (BE) and aspiration of oral contrast media (UGI & SBFT), as well as potential anaphylaxis due to allergic reaction to the latex balloon (BE). Specific informed consent is not required. Patients scheduled for UGI, SBFT, and BE examinations should be on restricted diet and/or bowel prep before their procedures. Details are available in the radiology department. MCG fluoroscopy can be reached at 1-4948 and CMC fluoroscopy at 1-5201.

Biopsy and angio/interventional procedures are expensive and carry potentially significant procedural risks as well as any associated mortality and morbidity from

radiation exposure and contrast use (IV, intra-arterial, or intracavitary). Availability is by consult to the angio/interventional service. Specific informed consent by the patient or guardian is required in all cases, unless the referring healthcare provider gives emergency consent. There will be formal pre-op and post-op evaluation and monitoring of the patient to ensure maximum safety during and after the procedure. Angio/interventional procedures are “mini surgeries”. The MCG contact number for angio/interventional is 1-8220.

Plain films are cheap, widely available, and carry mortality and morbidity related to exposure to radiation. Mammography is inexpensive and available during business hours at 1-3260.

## **Emergency Room Imaging – A Few Words**

### **The Ramifications of Ordering an Examination as “Urgent” when the Designation of “Routine” is More Appropriate**

This situation pertains frequently to exams ordered in the emergency room. It is important for scheduling and reimbursement purposes to distinguish between real emergency situations and elective outpatient diagnostic evaluations, since insurance coverage may be denied for non-emergency care delivered in an emergent situation. Emergency room examinations are always more costly and likely to be ordered in a less efficient manner. This may well have the unfortunate effect of leaving the patient with a large non-reimbursed expense, necessitating further more applicable examinations, and denying the institution revenue. It also delays the performance and interpretation of true emergency examinations, thus impeding the care of patients who actually require urgent care, such as traumas. Please carefully triage patients and schedule elective exams as outpatient procedures with appropriate referrals for follow up care.

For example, a patient with “weight loss for six months”, or “painless hematuria” is an outpatient case, not an emergency. A carefully designed elective workup may also result in less expensive care by utilizing appropriate screening tests such as PSA, fecal occult blood, mammography, and chest x-ray (CXR) to direct the evaluation, instead of immediately utilizing expensive imaging such as CT of the chest, abdomen, and pelvis, which has expense, mortality, and morbidity and may miss important diseases like colon cancer.

## **Part A: Imaging Solutions by Body Part.**

- **Imaging the Brain:** the first step is a CT of the brain without IV contrast for trauma, CVA (stroke), TIA (transient ischemic attack), dementia, atrophy, hemorrhage, alcohol-induced seizures, acute seizure disorder, or in the case of a patient who is unable to consent for the use of IV contrast. Alternatively, the first step is a CT of the brain with and without IV contrast for the evaluation of tumor,

metastases, aneurysm, AVM (arteriovenous malformation), infection, or the complete elective evaluation of seizure disorder (new onset or non-alcoholic seizures). Occasionally a contrast study will be required for the evaluation of a subacute subdural hematoma. For patients being screened for brain metastases (lung, breast etc.), but without symptoms, CT of the brain with and without contrast is suggested. However, in patients with suspected metastases to the brain who are symptomatic, MRI is a better first step in evaluation. In many cases when brain tumor is clinically felt to be likely, the first examination will be MRI with and without IV contrast. MRI is otherwise generally reserved for complex problem solving such as MS, subtle infection, complete tumor evaluation, MRA (magnetic resonance angiography) for vascular disorders or other indications. Please consult with a neuroradiologist (phone 1-3681) as needed.

- **Imaging the Neck:** ultrasound should be utilized to image the thyroid gland, with nuclear medicine reserved for follow-up evaluation of the thyroid if necessary. Most other evaluations of the neck require a CT scan of the neck, usually with IV contrast. MRI isn't typically utilized as a first-line examination, except for evaluation of the great vessels of the neck.
- **Imaging the Cervical Spine:** plain films of the cervical spine are virtually always the first step. Many evaluations end here with the discovery of significant degenerative change but no radicular symptoms. MRI should be reserved for significant neurological symptoms or for persistent symptoms that do not respond to conservative therapy. When deciding whether or not to employ advanced imaging applications please consider whether or not the patient is a potential surgical candidate. If subsequent surgical intervention is not feasible there may be no need to proceed with further imaging evaluation. MRI without contrast is indicated for cervical disc disease. MRI with contrast is only indicated for evaluation of potential tumor, infection, MS, or other uncommon disease processes.
- **Imaging the Thoracic Spine:** plain films of the thoracic spine are usually the first and final step. No further imaging is usually required to diagnose chronic appearing compression fracture or degenerative changes. CT or MRI should be reserved for unusual indications such as tumor. If there is clinical reason to suspect metastatic disease a NM bone scan may be helpful to evaluate the entire skeleton. Compression fractures are common in patients with osteoporosis.
- **Imaging the Lumbar Spine:** the first step is plain films. Many disease processes can be tentatively diagnosed with regular x-rays. Many evaluations end here with the discovery of significant degenerative change but no radicular symptoms. Please note that MRI and CT also require plain films for correlation. MRI or CT should be reserved for significant neurological symptoms or for persistent symptoms that do not respond to conservative therapy. Most patients with lower back pain improve spontaneously. When deciding whether or not to employ advanced imaging applications please consider whether or not the patient is a potential surgical candidate. If subsequent surgical intervention is not feasible there may be no need to proceed with further imaging evaluation. If further evaluation is clinically warranted, MRI without contrast is the examination of choice for disc disease. If evaluation of post surgical disc disease or scar is

required, MRI of the lumbar spine with and without IV contrast is indicated. Other indications for MRI with and without IV contrast include tumor & metastatic disease.

- **Imaging the Sinuses:** plain films of the sinuses are relatively unrevealing and should not be routinely ordered. CT without contrast is the preferred modality for sinusitis evaluation, with contrasted CT or MRI reserved for tumor and other complex situations.

- **Imaging the Chest:** the first examination is a PA and lateral chest x-ray (CXR). In many cases, the examination process can end here. Subsequent CXR findings or unresolved clinical issues may ultimately require the use of chest CT as a second step. MRI of the chest is unusual and primarily relates to vascular or cardiac disorders.

- **Imaging the Shoulder:** the first examination is plain films of the shoulder. Films of the cervical spine should also be considered since shoulder pain is often radicular pain. MRI of the shoulder without contrast should be reserved for clear evidence of rotator cuff injury or other clinical applications that require advanced imaging. When deciding whether or not to employ advanced imaging applications please consider whether or not the patient is a potential surgical candidate. If subsequent surgical intervention is not feasible there may be no need to proceed with further imaging evaluation. CT is rarely used except for fracture or contrasted arthrography.

- **Imaging the Knee:** the first examination is plain films of the knee. The presence of severe degenerative change may answer the clinical question. MRI of the knee without contrast should be reserved for evaluation of ligamentous or meniscal injury or other pertinent orthopedic issues. When deciding whether or not to employ advanced imaging applications please consider whether or not the patient is a potential surgical candidate. If subsequent surgical intervention is not feasible there may be no need to proceed with further imaging evaluation. CT is primarily required for complex fracture evaluation; MRI may also be utilized for fractures.

- **Imaging the Hip:** plain films of the hip are the first examination. In many cases, plain films of the lumbar spine may be useful since hip pain is frequently radicular pain. The presence of severe degenerative change at the hip on the plain films is frequently the conclusion of the imaging evaluation. CT or MRI without contrast may be quite helpful for the evaluation of suspected occult fracture. MRI is the most sensitive modality if avascular necrosis (AVN) is clinically suspected.

### **Part B-1: Imaging Solutions by Clinical Scenario-Adult or Child**

- **Right Upper Quadrant Pain:** the first test should be gallbladder ultrasound. This frequently diagnostic. If the patient has gallstones and the US isn't definitive regarding acute cholecystitis, a NM HIDA (hepatobiliary) scan is usually confirmatory. In a patient without gallstones who has diabetes, the HIDA scan is useful for detecting acalculous cholecystitis, which can produce a false negative US examination. If the patient has no cholelithiasis or other RUQ (or right kidney) abnormality defined by US, the next examination is an UGI to evaluate the

stomach and duodenum. If these two exams are unrevealing an abdominal CT (to specifically evaluate the pancreas) or a gallbladder ejection fraction NM exam (to evaluate biliary function) should be considered. Please note that if the patient has symptoms of pancreatitis CT is preferred instead of US.

- **Choledocholithiasis or Biliary Obstruction:** the first examination is US of the right upper quadrant to evaluate the liver, GB, bile ducts, and the pancreas. If biliary obstruction is identified then CT of the pancreas is suggested to define the exact site and cause of obstruction. To confirm patency of the common duct or to evaluate for bile leak, a NM HIDA scan is useful. It may or may not be clear at this point whether biliary obstruction is related to choledocholithiasis. Cholelithiasis can exist without choledocholithiasis and choledocholithiasis can occur without cholelithiasis. If further imaging is required this is usually accomplished via endoscopic retrograde cholangiopancreatography (ERCP) with cholangiographic data being obtained during the examination. Many times the evaluation is completed at this point. MRI is reserved for complex entities such as cholangiocarcinoma or incompletely defined pancreatic neoplasms. During ERCP a biliary stent may be placed to relieve biliary dilatation, and the pancreatic duct can also be evaluated if pertinent.

- **Sinusitis:** the preferred initial examination is a full non-contrasted sinus CT without contrast, which defines the anatomy of the paranasal sinuses. Plain films are not generally useful. Follow-up examinations for sinusitis may be performed utilizing a full sinus CT without contrast or the limited “mini sinus CT” protocol, depending on the complexity of the clinical situation and the requirements of the requesting physician. MRI is not indicated for the evaluation of routine sinus disease.

- **Cirrhosis, Hepatitis B or C, and Other Hepatic Metabolic Disorders:** abdominal ultrasound is the suggested first imaging examination for evaluation of liver and spleen size, anatomy, and parenchymal character as well as flow to the portal vein, hepatic veins, hepatic artery, and the splenic vein. CT is not typically required, but may be recommended by the radiologist to complete the evaluation of an abnormality seen by US or NM imaging. Serial liver function testing is a good manner in which to evaluate and follow hepatic metabolic function. Imaging may not be necessary. If specific hepatic metabolic information via imaging technology is required, the preferred examination is the NM liver-spleen scan. CT guided biopsy of the liver may be reserved for cases in which a tissue diagnosis is required to guide subsequent therapy.

- **“Dysphagia”:** not to be confused with swallowing dysmotility and aspiration, the first examination is the barium swallow. This diagnoses anatomical abnormalities of the esophagus and provides a very limited functional evaluation. Endoscopy may ultimately be required. If aspiration and swallowing dysmotility are suspected the Speech pathology department should be consulted. A formal “modified barium swallow” may ultimately be required to evaluate esophageal function. Please note that a modified barium swallow will not reliably detect anatomic abnormalities of the esophagus.

- **Appendicitis:** a plain film of the abdomen and pelvis should be performed first to survey the patient and potentially identify other causes of RLQ pain. If

appendicitis remains an important differential consideration the next step is a CT scan of the abdomen and pelvis with oral contrast and “appendix” protocol. This will target the appendix but also survey the entire abdomen and pelvis. US of the appendix is relatively ineffective compared to CT. Occasionally a female child may receive a pelvic US before CT to screen for a potential right adnexal mass that is presenting in a manner similar to appendicitis. BE, MRI, and NM bleeding or Meckels scanning are not routinely employed.

- **Flank Pain:** the initial examination is a plain film of the abdomen to evaluate for the presence or absence of visible stones. This also excludes gross bowel obstruction or other processes that may masquerade as “flank pain”. The next examination should be a CT of the abdomen & pelvis without oral or IV contrast i.e. “stone hunt” protocol. Some clinicians prefer an IVP instead of CT. The IVP provides detail evaluation of the ureters. The CT provides better visualization of the kidneys. If the patient is allergic to IV contrast, a good alternative is renal ultrasound. This is particularly sensitive to the presence of hydronephrosis, but will not visualize the ureters beyond the UPJ unless they are grossly dilated. Renal ultrasound is also a less expensive and less risky alternative than CT or IVP. CT with IV contrast is reserved for subsequent evaluation of renal mass or other incompletely defined abnormalities seen on the non-contrasted CT exam.

- **Peptic Acid Disease & Reflux:** the first examination is an UGI series. No other imaging is usually necessary. In cases where an active ulcer is identified, a follow-up UGI examination in 6 weeks is suggested to assure resolution in response to therapy and exclude a subtle malignant process. Endoscopy may be a part of the total patient evaluation if an atypical ulcer or a mass lesion is identified on the UGI.

- **Heme+ Stools or “Anemia”:** the first imaging examination is usually a double contrast barium enema. This provides a thorough evaluation of potential polyps, tumor, diverticulosis, or mucosal disease. In the absence of acute or rapidly progressive symptoms, the BE should be ordered routinely. Please note that there is only a 2% true positive rate for the stool guaiac test. Colonoscopy is an alternative to the barium enema. The next examination, if necessary, is the UGI to evaluate the proximal portions of the GI tract. If further imaging is required options include CT, the NM bleeding scan or Meckels scan, and small bowel enteroclysis (a somewhat uncomfortable dedicated fluoroscopic examination of the small bowel via an NG tube).

- **Lower Abdominal Pain:** the initial examination is a plain film of the abdomen. In most cases, the next test should be a barium enema since diverticulosis is very common. Please note that ultrasound is a poor modality in the lower abdomen. If the clinical problem remains unresolved, the third step would be a CT scan of the abdomen and pelvis with oral and IV contrast.

- **Upper Abdominal Pain:** the initial examination is a plain film of the abdomen. If pain is apparently related to a specific upper abdominal organ (liver, GB, kidney) the next step is an ultrasound of the abdomen. If pain is less specific or not apparently organ-specific, an UGI series is suggested for the evaluation of peptic acid disease. If these steps are inconclusive, then a CT scan of the abdomen with oral and IV contrast should also usually be requested. Please note that acute

evaluation of the pancreas is frequently more effectively accomplished by skipping US and going straight to CT with pancreatic protocol.

- **Abdominal or Thoracic Aortic Aneurysm:** if there are acute symptoms an urgent CT of the abdomen or thorax (or both) with IV contrast with aorta angiogram protocol without oral contrast is the first examination. This is a potential surgical emergency. In cases of suspected traumatic injury to the aorta angiography may be elected, since definitive evaluation of anatomy is required for potentially emergent surgery. If elective evaluation of a potential abdominal aortic aneurysm without acute symptoms is desired, the most cost-effective screening test is an ultrasound of the aorta. Ultrasound is safer than CT. MRI evaluation of the aorta is not a first-line examination.
- **Known or Suspected Renal Mass or Hematuria:** a renal ultrasound is a good first step. Many benign renal masses are simple cysts. In many cases the evaluation of the kidneys is finished at this point if there is no hematuria. If the renal mass is not a simple cyst or there is unexplained hematuria, the appropriate follow-up examination is a CT scan of the kidneys before and after IV contrast with renal protocol. Oral contrast is not required. CT reveals the characteristics of the renal mass as well as surrounding lymph node sites, the IVC, and the remainder of the abdomen. Cystoscopy or retrograde pyelography may ultimately be required in cases of unresolved hematuria in order to definitively evaluate the ureters and bladder. A NM renal scan may be a useful adjunct if nephrectomy is considered, since it can quantify overall renal function and determine how much function is present in the potentially resected kidney; this may occasionally indicate that partial nephrectomy or wedge resection is preferable to total nephrectomy.
- **Pancreatitis:** the first examination is usually a plain film of the abdomen, followed by a CT scan of the abdomen with oral and IV contrast, with specific pancreatic protocol. This provides a thorough evaluation of the pancreas and evaluates all surrounding structures for evidence of pseudocyst formation, phlegmon, pancreatic hemorrhage, abscess, or other complications. In addition, unsuspected retroperitoneal processes that can present as “back pain” like pancreatitis, such as abdominal aortic aneurysm (AAA), are also reliably detected. Ultrasound is less desirable due to the presence of bowel gas that frequently obscures the pancreas. For initial diagnosis and as part of the follow-up evaluation of pancreatitis, serial use of amylase & lipase may be quite useful. In uncomplicated cases of pancreatitis, serial enzyme measurements alone may be adequate to assess resolution. In more complex cases, serial enzyme measurements should be combined with follow-up CT of the abdomen with IV contrast to reassess the pancreas and determine if post-pancreatitis complications have resolved or improved.
- **Bowel Obstruction/Severe Acute Abdominal Pain:** the first test should be plain films (3 views) of the abdomen to include an upright chest for the detection of free air. A lateral decubitus view of the abdomen is an alternative to the chest x-ray if necessary. Frequently bowel obstruction will improve or resolve with NG suction, and only serial plain films are required to assess progress. If obstruction worsens or fails to resolve, an urgent small bowel series may be useful to evaluate the jejunum and ileum. A single contrast barium enema is the alternative examination

if the site of obstruction is felt to be in the colon. The plain films will frequently determine upper vs. lower obstruction and guide these imaging decisions. Other modalities such as CT may be useful as second line or follow-up examinations.

- **Renal Obstruction, Failure, or Infection:** a renal ultrasound with screening images of the bladder is the best overall initial examination. The kidneys, bladder, and prostate gland can all be quickly evaluated. It is essential to distinguish between obstructive uropathy, which is an emergency potentially requiring immediate urological intervention, and medical renal disease. A plain film of the abdomen may be helpful if renal lithiasis is suspected. CT and IVP examinations may also be useful in order to assess the ureters and evaluate potential neoplastic causes of obstruction. Renal US is less sensitive for the detection of stones but quite effective in detecting hydronephrosis; US will not detect ureteral abnormalities. Detailed evaluation of the bladder can be attempted with cystography, but cystoscopy is required for a truly comprehensive evaluation.

- **Scrotal Symptoms:** scrotal ultrasound is the examination of choice for tumor, torsion, epididymitis, and varicocele or hydrocele. Nuclear medicine testicular scanning should be reserved for the detection of suspected torsion in cases where US Doppler is not adequate.

- **Bone Metastases:** in most cases of the examination of choice is a nuclear medicine single-phase bone scan of the entire skeleton. Plain films of focally painful portions of the skeleton should also be ordered as correlation with the bone scan and since some purely lytic tumors (renal cell carcinoma, multiple myeloma, thyroid cancer etc.) may not be well seen by NM bone scan techniques. CT or MRI rarely has a role unless cord compression is clinically suspected.

- **Osteomyelitis:** the first examination is plain films of the affected area. In a substantial number of cases, these will effectively diagnose osteomyelitis and no further evaluation is required. If the plain films are negative and osteomyelitis is perceived to be significantly likely, the next examination is usually a three-phase nuclear medicine bone scan of the affected area. Most of the time this test is diagnostic. However, if there is a known history of significant degenerative joint disease (DJD), past fracture, or previous infection at the site of current clinical concern, then an indium labeled white blood cell (WBC) nuclear medicine study should be performed concurrently with the three-phase bone scan. The bone scan and the indium scan results are compared and utilized to evaluate for the presence of acute osteomyelitis superimposed on existing chronic changes. Please note that this same rationale also applies to the evaluation of a potentially infected joint prosthesis e.g. a total hip replacement, since the surgery will produce a positive bone scan and the indium study will more specifically address concurrent infection.

- **Deep Vein Thrombosis (DVT):** Duplex venous ultrasound of the affected leg or arm is the procedure of choice and should be ordered as an urgent examination, since DVT is life threatening due to the risk of pulmonary embolus (PE). Arterial ultrasound (segmental plethysmography) is not useful in this circumstance.

- **Pulmonary Embolus (PE):** the first examination should always be a chest x-ray (CXR)! The chest x-ray aids in the interpretation of the lung scan. It also identifies non-embolic conditions superficially mimicking those of pulmonary embolus such

as pneumonia, CHF, or pneumothorax. After the CXR is completed, diagnosis of PE is addressed specifically by either a NM lung V/Q (ventilation/perfusion) scan or a chest CT with pulmonary embolus protocol. Most of the time the imaging evaluation ends at this point. Pulmonary arteriography is suggested only when there is a medical contraindication to anticoagulation that makes absolute diagnosis of PE a necessity or it is technically impossible to perform an adequate V/Q scan or CT PE angiogram. An US of the legs (or occasionally an arm with a central line or other predisposing factor) may be considered concurrently to evaluate for DVT.

- **Breast Symptoms or Screening**: the first test should virtually always be a mammogram. The radiologist will add elective mammographic views as needed. Breast ultrasound should virtually never be ordered as an initial diagnostic modality, with the possible exception of pediatric age groups with breast symptoms. If a breast mass is identified by mammography, a breast ultrasound can assist in the determination whether the mass is a cyst (benign) or a true solid neoplasm (potentially malignant). Breast ultrasound can also be ordered in cases where the mammogram is negative but there is a specific palpable abnormality. CT and MRI are not usually necessary and should only be considered after consultation with a mammographer.
- **Renal Artery Stenosis (Hypertension)** : please recall that renal artery stenosis is rare! This should be a relatively unusual imaging evaluation. Routine renal US is relatively inaccurate, except for the detection of concurrent renal parenchymal disease or obstructive uropathy, which may (or may not) contribute to hypertension. Evaluation of the renal arteries requires a dedicated renal vascular US for careful evaluation of the flow characteristics of each renal artery, and is an entirely separate examination than the standard “renal US”, which doesn’t evaluate the renal arteries. Other options include arteriography for analysis of the renal arteries, which is substantially more invasive, but may be required when renal vascular US is inconclusive or technically unable to be performed or a NM renal scan with angiotensin-converting-enzyme (ACE) augmentation. A renal CT with arterial protocol is another way to screen for obvious renal artery stenosis. The clinical scenario of evaluation renal artery stenosis-mediated hypertension is a good circumstance to consult directly with a radiologist since there are multiple options available, all with advantages and limitations.
- **Evaluation of Left Ventricle Function**: the nuclear medicine MUGA examination is preferred when determination of left ventricle wall motion and left ventricle ejection fraction (LVEF) is desired. The MUGA examination is not good for the determination of myocardial ischemia vs. scar vs. normal variation. Global and segmental wall motion are analyzed and quantified. Echocardiography is also an excellent option, and produces superior evaluation of hemodynamics and valvular function.
- **Evaluation of Myocardial Ischemia**: the preferred examination is nuclear medicine perfusion imaging (“dip-thal”) performed with Sestamibi or Thallium. The patient undergoes the stress nuclear medicine part of the test following graded treadmill exercise or pharmacologic (Persantine = Dipyridole or Dobutamine or Adenosine) stress, which is utilized to induce myocardial ischemia. Then a resting

scan is performed and the results of both phases of the test are compared. Myocardial perfusion abnormalities that resolve with rest are considered ischemia, while perfusion abnormalities that don't resolve with rest ("fixed") are usually considered areas of infarction. Please note that this examination will also generate a calculated LVEF, but this is not the focus of the examination.

- **Imaging of CVA (stroke or cerebrovascular accident)**: The first test is an urgent CT of the head without contrast to exclude intracranial hemorrhage or other neurosurgical emergencies that are a contraindication to thrombolytic therapy. Please note that a CVA typically takes 24 hours or so to become manifest on CT, therefore a follow-up CT in several days may be useful to define stroke anatomy and extent if the patient goes on to a completed CVA. MRI is not generally needed to evaluate acute CVA, but may be requested by subspecialty clinicians. An excellent follow-up examination is a carotid ultrasound to attempt to define the cause of the patient's neurological symptoms and identify a potentially treatable lesion and avoid further episodes.

- **Ectopic Pregnancy**: the patient should have a confirmed +BHG (positive pregnancy test). The next examination is a pelvic US with transabdominal and endovaginal imaging. CT, MRI, NM, plain films aren't usually indicated.

- **Peripheral Vascular Disease (PVD) in the Lower Extremities**: the non-invasive test of choice is segmental plethysmography (SP), which gives a general idea of the amount and location of PVD as well as overall perfusion. This allows prognosis regarding DM ulcer healing and allows PVD to be excluded in patients with leg pain, who commonly have radiculopathy or neuropathy. This exam may allow selection of patients for medical management vs. intervention. If intervention is felt to be potentially appropriate then arteriography is elected, which allows angioplasty to be performed at the same time in selected patients. In patients who can't tolerate contrast administration alternatives include color Doppler US of the lower extremities for direct visualization of atherosclerosis or magnetic resonance angiography (MRA). Please note that SP is a cost-effective tool for PVD screening in diabetics, if clinically applicable. SP is CONTRAINDICATED for evaluation of acute arterial embolus; in these cases arteriography is the preferred examination. SP will not provide definitive evaluation of embolic arterial disease or allow accurate localization and treatment of emboli.

- **Cancer and PET/CT**: PET/CT is an examination that combines the anatomic detail of CT with the metabolic activity information of positron emission tomography (PET), thus providing a more sensitive (but not more specific) evaluation of cancer or potential cancer. The main indications for PET/CT are evaluation of an indeterminate mass (such as a lung mass or nodule), the evaluation of cancer of an unknown primary site, and staging/restaging of known cancer. PET/CT is becoming a standard of care in the complete evaluation of cancer, and is currently Medicare approved for lung, colorectal, esophageal, head & neck, lymphoma, melanoma, thyroid, and breast cancer. Please call the NM department for more information and consultation at 1-2867.

- **Stress Fracture, "Shin Splints" or Occult Fracture**: the first examination is always plain films of the affected site. If plain films are non-diagnostic and stress fracture, occult fracture, or shin splints are suspected clinically, the best

examination is a nuclear medicine 3-phase bone scan, possibly followed by CT or MRI of the affected site for further characterization of the fracture (if the bone scan is positive). In suspected hip fracture or fractures where relatively immediate diagnosis is required the CT or MRI examination should be ordered immediately following the plain films instead of the preliminary step of a bone scan.

- **Plantar Fasciitis:** plain films of the calcaneus may be diagnostic and demonstrate heel spurs. If no spur is demonstrated or more information regarding disease activity is required then a limited three-phase NM bone scan of both feet is recommended since this examination will demonstrate the presence or absence of active inflammation at the plantar fascia insertion at the calcaneus, and provide evidence of some otherwise unsuspected abnormality of the bones of the feet and ankles.

- **Pelvis Mass or Pain in a Female:** the examination of choice is a pelvic US with endovaginal imaging, since this defines subtle soft tissue characteristics of the adnexa and uterus more effectively than CT. Ovarian torsion and other vascular abnormalities can also be assessed utilizing the Doppler component of the examination. If a potential ovarian, endometrial, or cervical neoplasm is identified the next examination is a CT of the abdomen and pelvis with IV and oral contrast to assess the nodal sites and other potential locations of metastatic disease and stage the tumor preoperatively. MRI may have a role in endometrial and cervical cancer as a second line examination. PET/CT may also have a role; please discuss these situations with the NM physician for guidance.

- **Carotid Artery Disease:** the initial examination is Doppler US of the carotid arteries. This provides data concerning the amount and location of carotid atherosclerosis and allows an estimate of degree of stenosis. The Doppler part of the evaluation allows hemodynamics to be assessed in detail, unlike other modalities. Generally speaking, if stenosis >80% with or without symptoms or stenosis <80% with symptoms is present, surgical or stent intervention is considered. The next examination is typically magnetic resonance angiography (MRA) of the great vessels of the head and neck, since portions of the carotid arteries are not well seen by US and the circle of Willis can be assessed. If the carotid US and MRA are in agreement this is considered an adequate presurgical evaluation. If the MRA and US aren't in agreement then angiography of the carotid arteries is indicated for final presurgical evaluation. In cases where the patient isn't a surgical candidate or disease doesn't yet warrant intervention carotid US can be performed approximately every 6-12 months to monitor disease stability or progression.

- **GI Bleeding:** in many cases the gastroenterologist or surgeon will begin the evaluation with upper and/or lower endoscopy. If this is not diagnostic then next step is a labeled red blood cell (RBC) NM bleeding scan. This examination can detect bleeding as little as 0.1cc/min and usually will give an approximate location of the site of bleeding e.g. colon site vs. small bowel. If the bleeding scan is unsuccessful or if catheter-based treatment is desired, an angiogram of the abdomen and pelvis will be performed. Angiography can detect active bleeding at a rate of 1-2cc/min. Treatment options, if a specific site of bleeding is identified,

include vasopressin to provoke vasoconstriction. A last option is arterial or venous embolization.

- **Pulmonary Masses:** the first examination is the CXR. This is usually followed by chest CT with IV contrast if a mass or metastatic disease is suspected clinically or being excluded during the staging of another neoplastic entity. Many pulmonary masses or nodules are incidental findings on CT scans of the abdomen. But there are many benign pulmonary masses such as granulomas, hamartomas, and areas of rounded scar. Technically a lung mass is a density  $>3\text{cm}$  and a lung nodule is a density  $<1\text{cm}$ . The range between 1 – 3cm is undefined. Generally speaking, nodules  $<1\text{cm}$  are managed more conservatively, with serial examinations instead of immediate invasive diagnosis. Exceptions are nodules  $<1\text{cm}$  with radiographically “malignant” characteristics, enlarging nodules, and new lesions (multiplicity) during the surveillance period. PET/CT scanning is the most sensitive means of evaluating lung nodules for malignancy, with 95% negative predictive value for nodules  $\geq 7\text{mm}$ , and may be utilized for CT-indeterminate lung nodules  $\geq 1\text{cm}$ . “Benign” appearing nodules may, also, be managed by sequential chest CT exams without contrast for 2 years. Once 2 years of stability is demonstrated the nodule is essentially considered benign. Any significant change during the 2-year observation period warrants biopsy or resection. The goal is to avoid unnecessary dangerous interventions on benign lesions and yet detect and treat significant lesions in a timely manner.
- **Osteoporosis:** plain films are insensitive since they require up to 50% bone loss before they are positive. The correct examination is the DEXA evaluation, which provides a much more sensitive determination of bone mass and can be utilized to track response to treatment. Note that up to about 70% of women and 20% of all men will eventually have significant osteoporosis. Predisposing factors include use of steroids, DM, oophorectomy, alcohol, and malnutrition. MRI and NM examinations are not indicated.
- **Spinal Cord Compression-Acute:** this is an emergency that requires immediate diagnosis and treatment. Etiology is usually related to tumor (or trauma). Immediate imaging of the applicable spine segment (cervical, thoracic, or lumbar as determined by the neurological examination) by CT with and without IV contrast or MRI with and without IV contrast is indicated. MRI is usually preferred if available and the patient can tolerate the examination. Once the imaging has been completed the referring physician should be prepared for immediate consultation to the neurosurgery or radiation therapy (or both) services, depending on the etiology of spinal cord compression.

## Part B-2: Imaging Solutions by Clinical Scenario-Pediatric

- **UTI in a Child:** an US of the kidneys and bladder followed by a voiding cystourethrogram (VCUG) is the standard evaluation. CT, NM (renal NM scan), and MRI are second line tests indicated only in specific circumstances as determined by the initial imaging procedures. A male child is traditionally evaluated after the first UTI; many pediatricians don't evaluate a female child

until a second UTI has occurred since urinary tract infections of benign etiology are relatively common in girls.

- **Appendicitis-Child:** a plain film of the abdomen and pelvis should be performed first to survey the patient and potentially identify other causes of RLQ pain. If appendicitis remains an important differential consideration the next step is a CT scan of the abdomen and pelvis with rectal contrast instead of oral contrast and “appendix” protocol. This will target the appendix but also survey the entire abdomen and pelvis. US of the appendix is relatively ineffective compared to CT. Occasionally a female child may receive a pelvic US before CT to screen for a potential right adnexal mass that is presenting in a manner similar to appendicitis. BE, MRI, and NM bleeding or Meckels scanning are not routinely employed.
- **Non-bilious Vomiting in an Infant:** The clinical difference between bilious and non-bilious vomiting is critical because it distinguishes between life threatening surgical abnormalities such as malrotation and midgut volvulus and less urgent entities like duodenal atresia and pyloric stenosis. If true non-bilious vomiting is present the first examination is a plain film of the abdomen and pelvis to evaluate the bowel gas pattern and other structures. If the infant is <6-7 weeks of age this is followed by an US of the right upper quadrant to evaluate potential pyloric stenosis. If the infant is >6-7 weeks of age the next examination is typically an upper gastrointestinal fluoroscopy (UGI). Further imaging, if necessary, should be performed after consultation with the pediatric radiologist.
- **Bilious Vomiting in an Infant:** if true bilious vomiting is determined to be present the pediatric surgeon should be consulted immediately, since midgut volvulus and malrotation are imminently life threatening. The initial imaging examination is a plain film of the abdomen and pelvis followed by an UGI series. If both of these examinations are inconclusive a barium enema is performed to assist in the determination of bowel anatomy and position. Further imaging, if necessary, should be performed after consultation with the pediatric radiologist.
- **Wheezing/Inhaled FB in a Child:** Typically a child between the ages of 1-4 will have acute onset of wheezing and a clinical suspicion of potential inhaled FB. In children who are old enough to cooperate the first test is an inspiratory and expiratory CXR, which will demonstrate air trapping on the expiratory view in the lung containing the FB, if present. An alternative for younger or non-cooperative children is bilateral lateral decubitus chest x-rays. The chest side down will act like the expiratory view and demonstrate air trapping in the lung containing the FB, if present. When a FB is tentatively diagnosed or still felt clinically to be likely the patient will receive either a CT scan of the chest or go directly to bronchoscopy. Either course of action is reasonable. Bronchoscopy is more invasive but allows diagnosis and therapeutic intervention. CT involves the risk of radiation and allows diagnosis (and possible exclusion) of chest pathology but no therapeutic intervention. A final choice of modality may depend on the plain film images and clinical history.
- **Intussusception in a Child:** the pediatric surgeon should be consulted immediately since this is a life-threatening emergency. The initial imaging examination is plain films of the abdomen. If the patient clinically or radiographically is suspicious for intussusception, the next examination is an

enema study. Air or fluid (Hypaque) may be utilized as contrast, and the examination may be therapeutic as well as diagnostic if the hydrostatic pressure exerted by the enema procedure successfully reduces the visualized area of bowel intussusception. Successful reduction occurs up to 90% of the time. Further imaging, if necessary, should be performed after consultation with the pediatric radiologist.

- **Respiratory Stridor in a Child (Croup vs. Epiglottitis):** this is a potentially life-threatening medical emergency. The patient should have immediate upright frontal and lateral soft tissue views of the neck to evaluate the airway. Croup and epiglottitis have different patterns of pathology and can usually be distinguished radiographically. The patient should be accompanied at all times by medical personnel capable of intubating the child if necessary. Imaging should never be performed in the supine position since this will potentially compromise the airway. CT of the neck with IV contrast may be useful if abscess, foreign body or mass is suspected. A barium swallow is indicated if a vascular ring is suspected, with MRI confirmation if the barium swallow is positive. US & NM aren't usually indicated.
- **Abdominal or Pelvic Mass in a Child:** all pelvic masses in children require a plain film of the abdomen and pelvis first, followed by US of the pelvis. Many benign or cystic abnormalities can be identified at this level of imaging. If a solid or malignant appearing abnormality is identified by US, the next examination will typically be a CT of the abdomen & pelvis with oral & IV contrast. Genitourinary congenital anomalies and sacrococcygeal teratomas will probably require MRI for further characterization. Abdominal masses in children require a slightly different approach: the main determinant becomes age. In children <5 years of age the first step is a plain film of the abdomen followed by US. Many benign entities are defined at this point. Solid masses require CT of the abdomen & pelvis with oral & IV contrast; in patients <3 years of age with a likely diagnosis of neuroblastoma MRI is the next step directly after US. In patients >5 years of age the first step is a plain film of the abdomen followed by CT of the abdomen & pelvis with oral and IV contrast; US isn't routinely a first-line modality.
- **Vesicoureteral Reflux in a Child:** the first test is a fluoroscopic voiding cystourethrogram (F-VCUG). If no anatomic abnormalities are identified reflux can subsequently be followed by F-VCUG or a nuclear medicine voiding cystogram, which gives a much lower radiation exposure. If anatomic abnormalities are discovered then reflux should be followed by F-VCUG.
- **Congenital Hip Dislocation in a Child:** if the child is <5-6 months the preferred diagnostic test is ultrasound of the hip. If the child is >5-6 months the first test is plain films of the hips and pelvis with frog leg views. The role of CT is limited to post operative evaluation when the patient is in a Spica cast. MRI isn't normally indicated.
- **Child Abuse:** standard imaging protocol is plain films (2 views) of the skull, spine, ribs, pelvis, and all the bones of the arms and legs. This will screen for fractures or other injury patterns suggesting abuse. This group of films is ordered as a group entitled "bone survey" instead of ordered individually. An alternative examination is a whole body single-phase bone scan, with directed films only at areas of positivity on the nuclear medicine exam. Many pediatricians will also

order a head CT to screen for neurological sequelae of abuse. CT of the chest, abdomen, pelvis or elsewhere is directed by specific clinical indications if present. If significant evidence of abuse is discovered the child should be retained within the imaging department and immediate consultation with social services performed in order to protect the patient from further injury.

### **Part C: Sources of Error or Confusion in Ordering Imaging Examinations and How to Avoid These Mistakes**

#### **Type A: Not Assigning a Right or Left Modifier When Ordering Examinations**

Each request (and the accompanying history) should specify which arm, leg, hand etc. is to be examined. A request for an x-ray of the “foot” is incomplete without a modifier specifying right or left.

#### **Type B: Ordering an Examination Without an Appropriate Medical History.**

Each request should have a specific history that refers to the patient’s medical condition and justifies the examination ordered. An appropriate history assures a more directed and accurate interpretation by the radiologist and is necessary for regulatory compliance as well as billing and reimbursement purposes.

A specific application in CT is when a chest, abdomen, and pelvis study are ordered. It is necessary for reimbursement purposes to be able to justify each part of the exam. For example, an evaluation of lung cancer may not require a pelvis CT, since metastatic disease to the pelvis is relatively uncommon and the routine use of pelvic CT in these cases is probably not necessary. Expense is also increased.

#### **Type C: The Stated History Doesn’t Match the Examination Requested.**

The fundamental error is failure of the provided history to match the type of examination requested. This type of error reduces the sensitivity and specificity of our interpretation, makes billing difficult or impossible, has substantial medico-legal and regulatory risks, and introduces lack of clarity about the nature of the clinical problem being evaluated. It is essential to provide a clear and concise history that relates directly to the examination requested.

Examples include a CXR ordered with a history of “head pain”, a history of “decreased pulses” for a foot x-ray, a history of “right arm pain” for a CXR, and a history of “dementia work-up” for a CXR. The association of the clinical symptom complex and the exam ordered is tenuous in all these cases, and probably incorrect in many of them. It is helpful to make it clear what the relationship is between the exam requested and the history so “guessing” and inappropriate examinations are minimized.

Another common error is the “unnecessarily broad” or “imprecise” category. The basic error is that of “overkill”, in which too much imaging is being ordered to get the job done. This increases expense and may make CPT-code based billing difficult. Examples include ordering an US of the entire abdomen with a history of “evaluate AAA”, when an US of the aorta is the correct and less extensive exam to order. A similar error is to order an abdominal US with a history of “evaluate kidneys for hydronephrosis”, when a renal US is the correct test to order. Please be careful to order only as much imaging as you require.

Yet another example is when the right exam and body part are selected, but the wrong R & L modifiers are utilized. This would appear as a history of “left hip pain” associated with an order for a right hip x-ray. This introduces ambiguity about where the patient’s symptoms are. Sometimes we end up asking the patient! Needless to say this introduces a high risk of imaging the wrong body part or not being able to bill for an exam since the “wrong” exam was ordered.

In another variation the wrong exam modifier was selected such that the exam is difficult to perform or the exam ordered will not do the best job of imaging the patient. Examples include ordering a PA and lateral CXR for a patient in the MSCU on a ventilator (impossible to do) or ordering a “preop CXR” with a history of “LLL pneumonia”.

Lastly, there are cases in which the history does not describe the site of the patient’s symptoms. Typically these are NM bone scans, with a history of “evaluate osteomyelitis”, but no information was given as to WHERE the potential osteomyelitis was located. We end up asking the patient and/or calling the provider.

## **Part D: Imaging Modality Weight Limits and Alternative Bariatric Imaging Techniques**

Unfortunately not all patients are eligible for all imaging services due to body size or weight. In many cases exceeding the physical weight limit of the piece of equipment will void our warranty and/or damage the equipment. In other cases the patient will not be able to fit into the piece of imaging equipment or large patient size will result in a technically unsatisfactory examination that will not provide clinically useful information. Each modality is reviewed below to assist our providers in selecting the appropriate modality or choosing available alternatives.

- The fluoroscopy table has a weight limit of 350 pounds. Alternatives to fluoroscopy include EGD and Colonoscopy. Another option is that the patient can ingest barium and serial plain films taken in order to provide a “rough” examination and evaluate for post-operative anastamotic leak. This removes the necessity to utilize fluoroscopic equipment that may be limited by patient weight or size, both of which can be exam-limiting factors.

- The IVP table has a limit of 325 pounds. Alternatives to intravenous urography include CT, US, MRI, and cystoscopy/retrograde pyelography. Serial plain films following IV contrast injection can also be performed as noted above.
- The single head (camera) nuclear medicine table has a weight limit of 300 pounds, the dual head NM table has a weight limit of 350 pounds, and the PET/CT table has a weight limit of 420 pounds. There is progressive image degradation as weight increases due to soft tissue attenuation of the gamma rays being emitted by the radiopharmaceutical. Patients can be imaged in the anterior position while on a mobile hospital bed, removing the need for a stretcher.
- The CT scanners at CMC & MCG have a relative weight limit of 400 pounds and an absolute weight limit of 450 pounds. Patients with weight over 300 pounds or protuberant abdomens tend to have degraded image quality. PE studies in particular suffer degradation as weight increases, and a V/Q scan is a better exam in large patients. Patient size may also limit access to the CT gantry. One option is to refer the patient to University Hospital for open MRI. Contact the Imaging Department for details.
- US has no definite fixed weight limit, but image quality and penetration decline as weight and/or size increases. Portable exams can be provided if the patient can't be transported to the US suite or is unable to fit on the US stretcher. For DVT exams that are impaired by limb size, a nuclear venogram is an alternative. Limited CT angiogram images of the lower extremities may also yield some information regarding DVT if the patient can fit into the CT gantry.
- The MCG and mobile MRI (Friday only) have weight limits of 300 pounds. Larger patients may require referral to the open MRI at University Hospital, as noted above in the CT section.
- Plain films done with portable technique have no fixed weight limit, but image quality declines with increasing patient weight and/or size. A departmental examination is always of better quality than a portable study due to better quality equipment and higher obtainable radiation parameters. Departmental examination tables have a weight limit of 325 pounds.
- Mammography has no specific weight limit.
- Vascular US has no weight limit per se, but very large limbs will have poor quality results or not be able to be meaningfully examined. The cuffs may not be able to fit on very large limbs.

Brought to you by your colleagues in the Imaging Department. Please let us know of any suggested future topics, questions about this manual, or other ways in which we can serve you better and meet the imaging needs of your patients. **Feel free to email the editor of this manual at: [pkarmin@mail.mcg.edu](mailto:pkarmin@mail.mcg.edu)**

## **Part E: Evaluation of Trauma**

The evaluation of trauma in the adult or child is ultimately guided by the site of injury or suspected injury. The brain and associated bone structures of the head and face are imaged initially with non-contrasted CT; skull films are contraindicated since they are of low sensitivity and specificity and serve only to delay care of potentially life-threatening intracranial abnormality.

A lateral plain film of the neck initially evaluates the cervical spine, with a full cervical spine series as indicated. The cervical collar should only be removed once the applicable clinician has “cleared the neck”. If an abnormality or suspected abnormality is identified the neck is subsequently evaluated by CT without contrast for primary evaluation of the bones or MRI without contrast for primary evaluation of the spinal cord. Sometimes both modalities are required.

Trauma to the chest, abdomen, and pelvis is evaluated initially by plain films of the affected site, with contrasted CT afterwards to evaluate the soft tissues more completely. Plain films are particularly useful for detection of fracture and pneumothorax. Oral contrast is not usually given since time is of the essence. If injury to the aorta is suspected the patient may receive either a contrasted CT with angiographic protocol or immediate angiography; this decision may be influenced by the plain film of the chest and the degree of clinical suspicion for significant injury.

A contrast cystogram or CT cystogram may be required to complete the evaluation of the bladder and decide whether potential injury has resulted in extraperitoneal or intraperitoneal rupture.

Fractures of the extremities are usually diagnosed by plain films alone. Complex fractures of the pelvis or hips may require CT without contrast for further characterization.

Fractures of the thoracic and lumbar spine are initially identified by plain films with CT or MRI for further characterization, especially if the fracture is unstable or there are neurological signs and symptoms.

## **Part F: Resources in Imaging**

To schedule imaging examinations, you can call 721-9729 (721-XRAY) or submit your order directly to Radiology using the OrderCom system. If you do not have access to OrderCom or you are outside of the MCGHI Health System, you may send orders for imaging examinations via fax at 721-9329 (721-XFAX). Emergency examinations can be requested through the relevant section of the imaging department or through the on-call radiology resident (off-hours only), but still require an order to be written.

**Radiology resident on-call pager: 1-7396**

- **File room at MCG: 721-3305**
- **Fluoroscopy: 721-4948**
- **CT at MCG: 721-4586**
- **CT at CMC: 721-5210**
- **Mammography: 721-3260**
- **MRI: 721-3566**
- **Mobile MRI: (Friday only):  
721-3566**
- **Nuclear Medicine and  
PET/CT: 721-2867**
- **Neuroradiology: 721-3681**
- **Ultrasound at MCG: 721-4071**
- **GRTC: 721-2971**
- **Angio/interventional: 721-8220**
- **All pediatric imaging: 721-5201**
- **Vascular US: 721-5201**