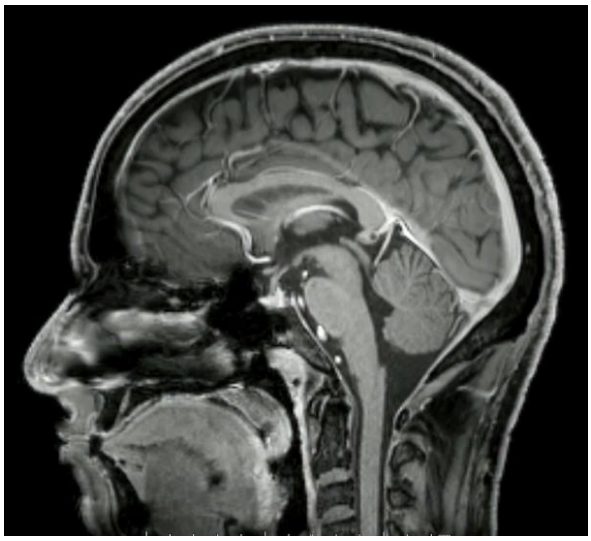
Brockville General Hospital

MRI:

A Practical Guide to the Use of Magnetic Resonance Imaging

As of May 2024



INTRODUCTION

This guide has been prepared to assist physicians and referring clinicians with understanding Magnetic Resonance Imaging (MRI) and using this modality in their practice. While no guide can address all concerns for every possible clinical situation, the information in this guide will help referring physicians navigate diagnostic imaging options at Brockville General Hospital (BGH).

The MRI unit at BGH is a 1.5 Tesla Siemens unit, which includes state-of-the-art hardware capabilities and supporting software. Since Siemens MRI units are standard at the Kingston Health Sciences Center (KHSC), where possible, imaging protocols will be aligned to ensure that Brockville patients receiving care at KHSC have comparable imaging to facilitate continuity of care.

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FREQUENTLY ASKED QUESTIONS

What is MRI?

MRI stands for Magnetic Resonance Imaging. Unlike other radiology procedures that use x-rays, MRI uses magnetism, radio waves, coils and a computer to produce images of the body. As the patient is moved into the magnetic field, hydrogen protons in the body align themselves with the field. A radiofrequency pulse is then transmitted through the body that tilts the hydrogen protons. When the pulse is turned off, the protons realign with the field producing a signal which is detected by the antenna (coil) surrounding the part of the body being scanned. This signal is measured by the computer and transformed into an image.

MRI is a painless procedure that has the advantage of not using any x-rays, and therefore no radiation. There are no known side effects of MR imaging to date.

What are the risks of MRI?

The MRI scanner generates a strong magnetic field, which can pose a risk to some patients. Anyone going into the magnet room is subject to the same risk.

The most common safety concerns for scanning are when patients have the following:

- cardiac pacemaker, implanted defibrillator
- brain aneurysm clips, wires in the brain or spine
- metal in the eyes
- implanted devices, such as electronics, insulin pumps, stents, filters, shrapnel
- certain types of eye and ear implants
- new procedures or implants done within 6 weeks: colonoscopy

A safety screening form **MUST** be completed before scanning a patient. In some cases, the exam cannot be performed due to a recent colonoscopy, a new stent with conditional wait times, staples, or clips on blood vessels. Some exams cannot be performed if a patient cannot remain immobile for a suitable time.

Surgical reports with implant details (make and model) provided with the requisition help prevent scheduling delays. The technologist can answer any questions that patient may have prior to the scan. The MR exam may require an injection of contrast material containing gadolinium, which is detailed below.

Is Preparation required for an MRI scan?

The first step is to be certain that it is SAFE for the patient to have an MRI scan. There is no specific preparation required. Patients may take their medication as usual. There are no food or drink restrictions unless the patient is having an abdominal or pelvic scan, which require a minimum of 4 hours of fasting. All removable metallic objects will be left outside the scanning room. These include jewelry, keys, watches, coins, eyeglasses, removable hearing aids, dentures, and prosthetic devices. A secure locker will be provided for these items.

How Long Does MRI Take?

That depends on the part of the body being scanned, and whether any special or additional scans are needed. Normally, the entire exam takes between 20 minutes and 1 hour.

What Happens During the Scan?

First, the patient will be re-screened by the MRI technologist to ensure that the scan is appropriate and safe for the patient. The procedure will then be explained in detail, and the technologist will answer any questions the patient may have. The patient will change into a gown and store all personal and metallic items in a secure locker. No metal or foreign bodies can enter the magnet room.

Depending on which part of the body is being scanned, the patient will lie on the table and advance into the scanner either head or feet first. Although alone in the room, the patient is always within sight of the technologist through a large window and can communicate with the technologist between scans through the intercom system. The patient is given a call bell to contact the technologist at any time.

The scanning process, although painless, can be loud. Earplugs or a headset are provided for all patients, and a patient entertainment system is available. While images are being obtained, the patient must lie as still as possible and follow the technologist's instructions. Most MRI exams last about 30 minutes, although complex cases may approach 1 hour in length.

What is Contrast Material?

During an MRI examination, there may be a need for contrast (dye) containing gadolinium to be administered to the patient. Gadolinium changes the way that tissues react to magnetism and radio waves, allowing certain tissues and blood vessels to become more visible. Although rare, possible contrast reactions and side effects include redness or itching around the injection site, flushing, and nausea. In the unlikely event of a more serious or allergic reaction, protocols and medications are in place for appropriate therapy.

In the past decade, a rare entity termed *Nephrogenic Systemic Fibrosis* (NSF) has been linked to gadolinium administration in patients with severe renal disease, usually if they are on dialysis. The newest generation of contrasts has nearly eliminated this complication, and eGFR values are no longer required.

Can Claustrophobic Patients be Scanned?

With the guidance and support of the technologist, many claustrophobic patients can tolerate an MRI examination without sedation. For lower extremity scans, patients enter the MRI unit feet first, with their head outside the gantry, and rarely require sedation.

BGH does not provide sedation for patients.

It is advisable to prescribe a mild sedative (i.e. Ativan) for claustrophobic patients. Please ensure they have it in hand on the day of their exam should they require it. For any patient taking sedatives, it is important that they are escorted to the exam by a friend or family member as the patient will need a driver. The patient must arrive 1 hour prior to the MRI appointment for screening, so the technologist can inform the patient when to administer the sedation.

Why do Patients Sometimes Need X-rays Prior to an MRI Procedure?

Occasionally, x-rays may be necessary prior to the MRI to screen for metal that might be in the body. By far, the most common x-ray required is screening for metallic foreign bodies in the eyes. If the patient has ever had metal in their eyes, they will require x-rays. If the patient has worked with metal, such as grinding or welding, but has **always** worn safety glasses, they will likely not require x-rays. **These screening x-rays are required before your patient's scheduled MRI.** Ideally, a report of the x-rays would be forwarded at the same time as the MRI requisition.

REQUESTING MRI EXAMINATIONS

Out-patients

- You can send a request for MRI to BGH as soon as the electronic and fax options are made available. An MRI request form from another facility is acceptable if it includes standard MRI safety screening questions. MRI requests on all other forms will not be accepted.
- It is imperative the MRI requisition be filled out COMPLETELY. Each section of the requisition has been prepared to help ensure a safe and thorough examination. Please provide as much clinical information as possible and ensure that the safety questions are answered accurately. Incomplete requisitions will be returned.

In-patients

- Please ensure a complete requisition is sent to the Diagnostic Imaging Department. An appointment time will be made after patient safety, clinical appropriateness, and scanning protocols are determined.

- **Please Note:** MRI examinations take considerably longer to complete than CT for technical reasons. MRI facilities can only accommodate a limited number of inpatient requests in any given week (considerably fewer than CT). Please consider the need for an inpatient MRI carefully.
- In-patients need to be co-operative and stable to undergo an MRI procedure. They must be able to follow commands or be sedated enough to remain still. The patient must be still for at least 1 hour. MRI studies may be postponed or prematurely terminated in case of agitated or uncooperative patients.

MRI AND THE PREGNANT PATIENT

Can a Pregnant Patient Undergo MRI?

There are no documented negative effects of magnetic field exposure on the developing fetus.

It is prudent to screen women of reproductive age for pregnancy prior to permitting them access to the MR imaging environment. If pregnancy is established, consideration should be given in determining whether performance of the requested MR examination could safely wait until the end of the pregnancy.

Pregnant patients may be accepted to undergo MR scans at any stage of pregnancy if the risk/benefit ratio to the patient warrants that the study be performed. Criteria include:

1. The information requested from the MR study cannot be acquired via other non-ionizing means (i.e. ultrasound).
2. The study is needed to potentially affect the care of the patient or the fetus during the pregnancy.
3. The referring physician does not feel it is prudent to wait until the patient is no longer pregnant to obtain the study and will provide written documented medical consent for the procedure in the patient's file.
4. The Radiologist is informed, has reviewed the clinical history and requisitions, and given documentation for the exam. The radiologist will give final risk/benefit analysis and deem if MRI is necessary for patient.

MR Contrast Material and the Pregnant Patient

MR contrast agents are not routinely given to pregnant patients. The decision is one that must be made on a case-by-case basis by the radiologist.

Studies have demonstrated that gadolinium-based MR contrast agents pass through the placental barrier and enter fetal circulation. From there, they are filtered in the fetal kidneys and then excreted into the amniotic fluid where they may remain indefinitely. The risk to the fetus with administration of gadolinium-based MR contrast agents remains unknown.

It is recommended that pregnant patients undergoing an MR examination provide written informed consent documenting that they understand the potential risks and benefits of the MR procedure to be performed, are aware of the alternative diagnostic options available to them (if any), and they wish to proceed.

HOW TO AVOID DELAYS IN OBTAINING AN MRI

1. If your patient has had **metal in their eyes** or an injury to their eyes, they require orbital x-rays prior to the MRI appointment date. If the images are done outside the hospital, the study report must be available prior to MR imaging.

2. Always use an MRI requisition when requesting an MRI and ensure it is filled out COMPLETELY. Delays may occur if the exam requested and clinical information areas are not completed. The MRI safety questions must be answered. All incomplete requisitions will be returned without an appointment.

TYPICAL CLINICAL APPLICATIONS

BRAIN

Stroke

- Acute stroke protocols depend on rapid access CT, which may include contrast-enhanced perfusion and CTA. MRI is useful if the CT is negative, especially if brainstem or cerebellar infarction is suspected. MRI is preferred in young patients with neurologic deficits, when non-ischemic etiologies must also be considered. (i.e. MS)
- MRI detected stroke can be followed with CT, in an outpatient setting.
- DWI scanning is a specialized neuroimaging sequence useful to characterize acute ischemic stroke, abscess, epidermoid cysts, highly cellular tumors including lymphoma and medulloblastoma, as well as active demyelination.

Tumor (including primary, metastatic, and lymphoma)

- MRI is more sensitive and specific than CT for the presence of primary and metastatic neoplasm, including leptomeningeal disease, and provides useful information for treatment planning.

- Perfusion imaging can be used for the evaluation of brain tumors, providing indirect measures of malignancy, grade, and prognosis, particularly in gliomas. Perfusion imaging is also helpful to differentiate between recurrent tumors and radiation necrosis in post therapy follow-up.
- MR Spectroscopy can be used to evaluate tissue metabolites such as N-acetyl aspartate, creatine, and lactate (visible as the result of anaerobic metabolism). MRS has a variety of uses but is mostly used for brain tumors.

Multiple Sclerosis

- MR is the preferred imaging modality for diagnosis and follow-up, including response to therapy.

Seizure

- Patients presenting with seizures through the Emergency Department (ED) will usually be assessed initially with CT to exclude a significant acute finding. Outpatient MR can follow if necessary, on an elective outpatient basis.
- MRI is the preferred examination for mesial temporal sclerosis (history of possible temporal lobe seizures).
- MR is also preferred for patients with chronic epilepsy, who generally do not require contrast.
- Patients with a known history of CVA and elderly patients with new unexplained seizures can be assessed with CT initially. MR can be useful on an elective basis if there are no acute findings on CT.

Infection (including meningitis, encephalitis, and abscess)

- CT is preferable in the urgent setting and can rule out a bleed or mass lesion prior to lumbar puncture.
- If the patient is clinically stable, MR is more sensitive and can better assess extent, necrosis, or secondary complications including abscess or ischemia.

Pituitary Assessment, Sella (hormonal disturbance)

- MR is preferred to evaluate for a pituitary tumor or parasellar mass.
- CT is indicated in patients where temporal bone anatomy is questioned, or cannot have an MRI

Dementia

- CT is an excellent screening exam in elderly patients with dementia. CT will identify atrophy, hydrocephalus, most mass lesions, and advanced small vessel disease. MRI is more sensitive, but CT is generally adequate. Dementia patients will find MRI difficult because of long scan time times and noise.

Headache

- CT is preferred if: low clinical suspicion, no neurological findings, possible subarachnoid bleed.

- MRI if moderate to high suspicion, or neurological findings
- PLEASE NOTE: Very low positivity rate of CT or MRI in uncomplicated, chronic headache.

Congenital Malformations

- MR is superior in anatomic detail, resolution, and tissue characterization.
- Typically young patients, where lack of ionizing radiation is preferred

Dizziness

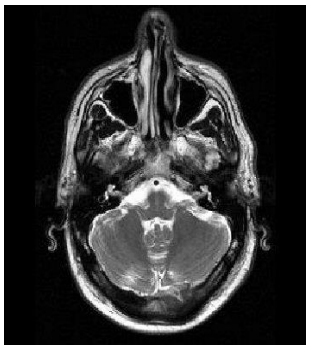
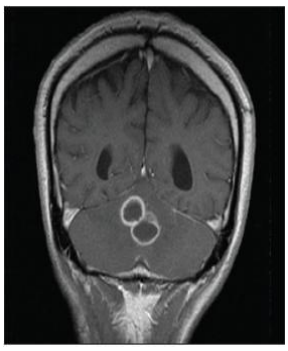
- MR is preferred if cerebellar or brain stem pathology is suspected.
- If clinical suspicion of vestibular schwannoma/acoustic neuroma, dedicated internal auditory canal MR examination can be performed.

Facial Pain Syndromes (Trigeminal Neuralgia, Cranial Nerve Symptoms)

- MR is the preferred imaging modality for cranial nerve evaluation.

Tinnitus/Hearing Loss

- CT and MRI are complimentary.
- CT better assesses the petrous bone for tumor and vascular variants, and is recommended in cases where a middle ear mass is visualized otoscopically. CT is preferred in cases of conductive hearing loss.
- MR is superior in screening for a posterior fossa vascular malformation or mass.
- MR is advised in patients with neurosensory hearing loss.
- MR is preferred for clinical suspicion of vestibular schwannoma (acoustic neuroma).
- MR is the preferred imaging modality for vascular malformations and venous sinus thrombosis.
- Both CT and MR can screen for aneurysms.


HEAD AND NECK, ORBITS AND TMJS

Head and Neck

- CT and MR are complimentary in assessment of pathology in the region. Mass lesions and lymphadenopathy can be assessed by either modality.
- CT is first line imaging, preferred for assessment of larynx, petrous bone structures, bony skull base for tumor invasion and mandible.
- MR is preferred for detailed cancer staging of the head and neck tumors (typically after CT). More sensitive to perineural extension, notably at the skull base.

Sinuses

- For assessment of common sinus problems such as chronic sinusitis and OMU disease, CT is preferred.
- MR is preferred for the assessment and staging of sinus tumors.

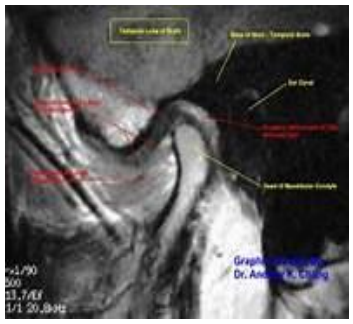
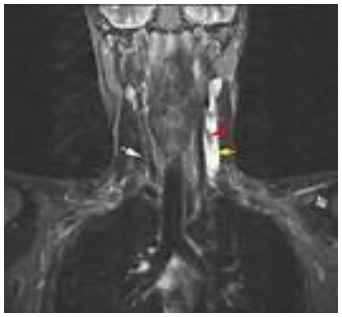
Orbits

- MR is preferred for orbital masses, optic neuritis, vascular abnormalities, and sudden blindness.
- CT is preferred for trauma, foreign body, and thyroid related orbital disease.
- Both modalities can be used to evaluate orbital pseudotumor, orbital cellulitis or abscess.

TMJ

- MR is preferred for evaluation of the articular disc (internal derangement of the TMJ).
- PLEASE NOTE: Perforations of the disc are often not well demonstrated by MR.
- CT is preferred for evaluating bony structures for degenerative changes, although MR can also assess for this.



SPINE

Assess for “red flag” findings:

1. Age less than 18 years or greater than 50.
2. Pain not resolved by analgesia.
3. History of trauma or recent spinal interventions (surgery, injections).
4. History of coagulopathy or abdominal aortic aneurysm.
5. Symptoms or history of malignancy (night sweats, weight loss, etc.).
6. History of immunodeficiency (diabetes mellitus, IVDU), recent infection, or fever.

7. Cord compression/cauda equina symptoms (bowel/bladder/erectile dysfunction, saddle anesthesia, progressive bilateral leg weakness).

For the vast majority of patients with a chief complaint of back pain, imaging is not typically indicated. For uncomplicated low back pain, there is often poor correlation between clinical and imaging findings, and imaging often does not alter clinical management.

In patients where you suspect a potential serious pathology, imaging can provide the diagnosis and guide management strategies. In general:

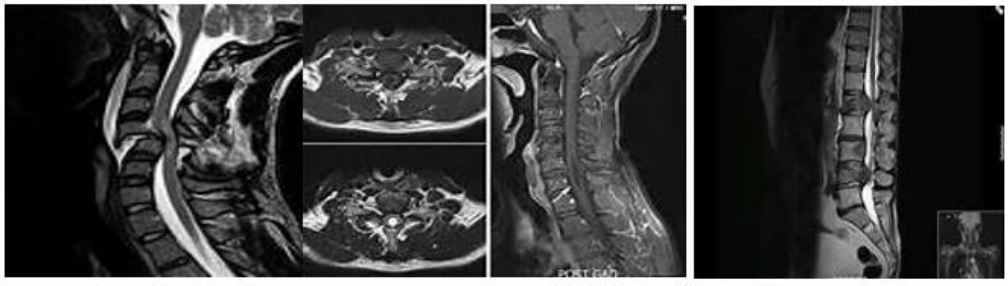
Plain radiographs: Typically not indicated or necessary in mechanical presentations. Can consider if fractures are suspected, minor trauma, or in patients with longstanding back pain.

CT: Consider in patients with a history of trauma. Can be helpful in the evaluation of spinal ligamentous injury and canal compromise in patients with fractures.

MRI: Gold standard diagnostic modality in most cases of serious pathology including cord compression, cauda equina/conus medullaris syndrome, spinal epidural hematoma/abscess, and osteomyelitis.

Ultrasound: Screen for a post-void residual in patients with suspected cord compression, assess for vascular lesions such as AAA.

- Degenerative disease with suspected radiculopathy (no prior surgery) – Either CT or MR can be used to evaluate disc disease and central canal stenosis. Nerve roots, CSF and dural surfaces can be delineated with MRI.
- Spinal MR for radiculopathy is indicated for for troubleshooting unexpected CT findings (vascular anomaly, meningiona, dural sheath tumour, Tarlov cyst, or other mass) and for specific treatment planning e.g. surgery.
- Previous back surgery – Contrast enhanced MR is the preferred modality. MR is far more accurate in the assessment of postoperative scar vs. recurrent disc, arachnoiditis.
- Trauma – CT and MR are complimentary. Bony injuries are better demonstrated by CT. Central canal content including spinal cord are better examined by MR. MR is sometimes useful in helping to differentiate osteoporotic compression fractures from pathologic fractures.
- Neoplastic disease – CT can demonstrate bony metastases but overall MR provides a more comprehensive exam as epidural space and cord are also assessed.
- Spinal Cord abnormalities (demyelination, tumours, infection, ischemia, syrinx) – MR.
- Suspected congenital anomaly (split cord, low conus, tethered cord) in any region – MR.
- CT may provide complementally information to spinal MRI on recommendations by a radiologist.



MUSCULOSKELETAL

Apart from acute fractures which are characterized by CT, MR is useful for suspected undisplaced, insufficiency, avulsion, or stress fractures, and bone marrow edema.

MR is the preferred modality for most soft tissue MSK pathology, including soft tissue injury, neoplastic and non-neoplastic masses, and infection, inflammation or ischemia. Most routine studies do not require contrast injection. Orthopedic surgeons are best positioned to determine the appropriate type and timing of MSK MRI studies.

Specific indications for some joints include:

Shoulder - Many rotator cuff tears of the shoulder are easily demonstrated by US. Shoulder US is non-invasive, fast initial examination for patients with painful shoulders, and can be performed dynamically to assess for impingement. MR is more sensitive to soft tissue pathology and associated intraarticular derangement including glenolabral pathology.

Knee - MR is the preferred imaging modality for soft tissue assessment and internal derangement. Advanced knee osteoarthritis typically is NOT an indication for MRI, unless requested by an orthopedic surgeon for targeted problem solving or treatment planning.

Hip - Specific indications include osteonecrosis, transient bone marrow edema syndrome, and various forms of hip impingement.

Ankle and Wrists - MR is typically requested by orthopedic surgeon for treatment planning, including extent of injury, associated findings, and bone marrow assessment such as AVN in scaphoid injury.

MRI is more sensitive to erosive arthropathy, typically requested by rheumatology specialists.

Soft Tissue Masses

- US is first line imaging for any superficial or palpable mass.
- CT is useful for lipomatous, calcified, and vascular lesions, and for associated bony changes.
- MR is complimentary and may be useful in both tissue characterization and extend of disease, particularly for biopsy or treatment planning, as well as post therapy follow up.

Bone Pathology

- Cortical bone is well assessed by CT, while bone marrow is better assessed with MRI, including evaluation of osteonecrosis, osteomyelitis, as well as occult and stress fractures,
- Although abnormal marrow findings on MR are generally non-specific, a normal MR exam can virtually exclude osteomyelitis and bony injury. Abnormal bone marrow edema can guide the clinician to a region suitable for marrow biopsy.
- MRI, CT and bone scintigraphy are often complimentary in the assessment of bone pathology. Physicians are encouraged to discuss their diagnostic requirements with a radiologist to determine the most appropriate imaging strategy.

VASCULAR SYSTEM

MR Angiography (MRA)

CT and MR angiography (CTA, MRA) techniques produce high quality images of vascular structures in a non-invasive fashion. Each has its advantages and disadvantages. As BGH develops diagnostic imaging strategies, vascular imaging recommendations and protocols will be communicated to the physician community.

CT Angiography

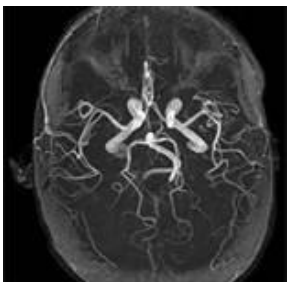
PROS	CONS
• Short exam times compared to MRA • Claustrophobia less problematic • Safety issues of MR are not a problem • Allows plaque characteristic analysis • More post-processing options • CTA are more sensitive and better spatial resolution	• Iodinated contrast can affect renal function • Radiation exposure • More Radiologist time intensive

MRA Pros and Cons

PROS	CONS
• No radiation • Some exams do not require contrast	• Long exam times compared with CTA • Claustrophobia may be a problem

Applications for MRA/CTA Include:

- Circle of Willis studies aneurysm screening
- Peripheral circulation (run off) studies for Peripheral Vascular Disease (CT preferred)
- Carotid stenosis, dissection (CT)
- Renal artery stenosis studies; renal vein (CT preferred)
- IVC tumor invasion (CT initially then follow up MR)
- Intestinal angina assessment (CT preferred)
- Aorta for aneurysm, dissection, occlusion (CTA)
- Cranial venous sinus thrombosis (MRA)
- Pulmonary arteries for PE (CTA)





BODY (CHEST)

Heart

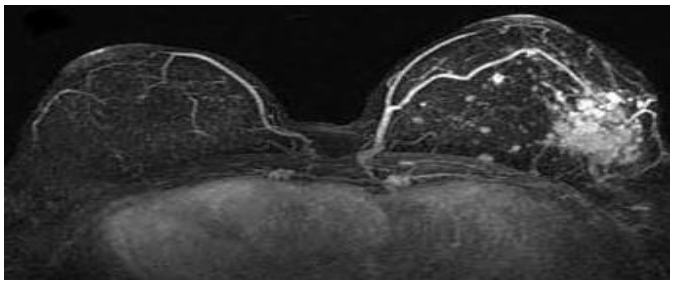
- The uses of MR for assessment of cardiac disease is increasing. BGH will not be offering cardiac MR upon initial startup.

Lungs/Mediastinum

- CT is the preferred modality overall for the assessment of thoracic pathology. MR has no practical application in the assessment of lung pathology. MR does not generally offer any advantage over CT in lung cancer staging except in assessing for chest wall, spinal or brachial plexus invasion. Mediastinal lymph node enlargement is seen equally well with either modality (see Lymph Nodes below).

Breast

- The MRI service will not offer breast MR initially, but may be made available in the future once our core MR services are established. The scope of the program has yet to be determined.



BODY (ABDOMEN)

Multi-slice CT is often the preferred initial modality for imaging of the abdomen. MRI often plays a supportive or complementary role, often used to help clarify the nature of equivocal findings found on CT. As such, MR of the abdomen is used in a targeted fashion to answer specific questions, typically regarding solid organs, rather than investigating non-specific pain. Bowel imaging by MR is useful for some limited indications, but will not be offered initially at BGH.

MR is sometimes used for patients with impaired renal function who cannot safely receive CT contrast. Gadolinium contrast for MR is has a significantly lower incidence of complications, as well as adverse and allergical reaction than iodinated contrast used for CT (see Contrast section above)

Liver

- Enhancement characteristics of liver masses are similar for MR and CT. While atypical lesions on CT are often atypical on MR, MR may be useful for some specific diagnoses, such as FNH, fatty infiltration, iron deposition disorders and hemangioma MR. can often detect more metastatic lesions than CT, and offer improved detection of HCC in cirrhotic livers.
- The absence of ionising radiation is useful in young patients, assessment of congenital abnormalities, potential liver donor, and repeat post treatment imaging to assess response.

Kidneys

- MR can help clarify the nature of equivocal findings on CT or US. Although MR findings are often non-specific, enhancing renal lesions on MR are generally considered malignant unless proven otherwise.

Adrenals

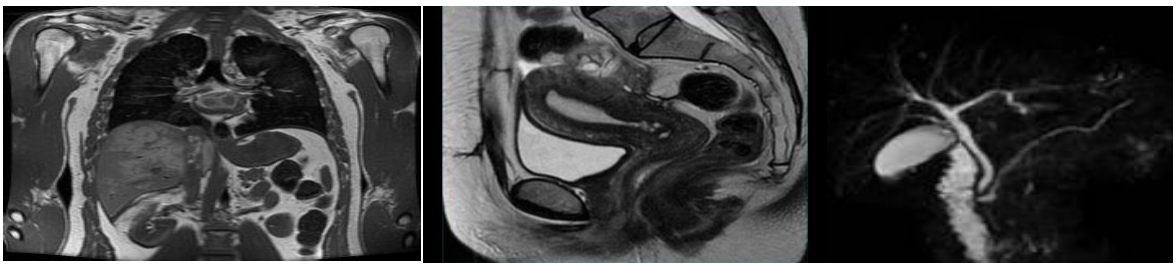
- MR can help to identify some equivocal adrenal nodules as adenomas, although many atypical nodules cannot be characterized by either CT or MRI, and require follow up or biopsy depending on the level of clinical suspicion.

Spleen

- Many lesions non-specific on CT are similarly non-specific on MR

Pancreas

- MR can be used to characterize pancreatic pathology detected by CT. Additional information might discriminate solid/cystic lesions, ductal obstruction, fluid collections, and surgical planning
- Acute pancreatitis is best assessed with CT. MR is less sensitive to the presence of calcifications and ductal stones than CT in chronic pancreatitis.



Biliary System

- MRCP (Magnetic Resonance Cholangio Pancreatography) offers a non-invasive, accurate method to evaluate the biliary ductal system. It can be very useful in assessing for ductal stones and strictures. The gallbladder is best initially assessed with US.

Lymph Nodes

- MR and CT are equal in their ability to detect enlarged lymph nodes. Neither can identify malignancy in normal sized nodes, nor differentiate between malignant or benign enlarged nodes. MRI is more time consuming, with a longer wait list for the exam to be performed.
- MR readily identifies peritoneal seeding of malignancy, providing the exam is tailored to this.

PELVIS

Pelvis (Gyne)

- Ultrasound remains the preferred imaging modality for the initial evaluation of gynecological problems. It is reasonably non-invasive and readily available. CT is rarely of use in assessing the ovaries and uterus, but has a role in abdominopelvic cancer staging and treatment follow-up.
- MR offers significant advantages over CT and Gyne applications such as:
  - Fibroids (size, number, location), Adenomyosis, Endometriosis
  - Local staging of endometrial and cervical carcinoma
  - Characterization of some adnexal massess
  - Differentiating ovarion vs. uterine origin of adnexal massess
  - Uterine morphology (septate, bicornate etc.)

Pelvis (Other)

- MR can be useful in the local staging of rectal carcinoma, prostatic carcinoma and bladder neoplasms.
- MR can help to identify the course of complex pelvic fistulas.

This is a living document and will be periodically updated.