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Section I – Low back pain

Plain film radiography

There is no condition that is more synonymous with chiropractic care than low back pain. Low back pain is the fifth most common reason for seeing any physician in the United States and affects about seventy-five percent of all US citizens. “Twenty-five percent of adults in the US population report low back pain lasting at least one day in the previous three months.” Most chiropractors have plain film radiography available in their offices or nearby establishments. In the wake of continuing advances in computed tomography (CT) and magnetic resonance imaging (MRI), is plain film still appropriate for diagnosing patients suffering from low back pain? The answer in the most current of literature is absolutely; plain film radiography still has an important role in low back pain diagnosis. Of course, it goes without saying that diagnostic imaging, of any variety, does not supplant the need for a comprehensive physical examination. An in-depth examination of low back pain should include evaluations of neurological, musculoskeletal and vascular systems. Remember that many diagnostic imaging procedures expose the patient to ionizing radiation and the law for radiation exposure is ALARA (as low as reasonably achievable). In many cases, diagnostic imaging is not needed and should be restricted to those patients that need dangerous pathology ruled out, have red flags, or has failed the initial treatment plan.

One such serious pathology where plain film imaging is appropriate would be degenerative lumbar spinal stenosis, a common condition presenting in a chiropractic office. Stenosis is a narrowing of the vertebral canal, lateral recess or intervertebral foramen. Stenosis can be congenital or acquired, due to degeneration of the spine.
Whether congenital or acquired, symptoms usually do not arise until the patient reaches middle age and men are more likely to suffer from the condition in a ratio of 2:1 compared with women. In degenerative induced stenosis, hypertrophy due to degeneration of the facet joints can cause medial encroachment on the spinal canal (figure 1).

![Figure 1. Arrows denote extensive facet joint hypertrophy from degeneration at the L5 level on this plain film lumbar radiograph. (Contrast is found in the kidney and an aneurysm exists anterior to L1/2.)](image)

If the stenosis is congenital, even mild degeneration, ligamentum flavum hypertrophy or herniated disc can bring on symptoms; thus, a patient can have stenosis from both congenital and acquired causes. The doctor is suspicious of degenerative lumbar spinal stenosis if the patient reports having pain, numbness, and paresthesias in the thighs and legs. The lower extremity may feel heavy or weak. If the symptoms are aggravated by prolonged walking or standing, the patient has corresponding neurogenic claudication. Differentiating neurogenic claudication from vascular claudication is important. Vascular claudication patients present with cramping calf pain that radiates proximally. Patients with neurogenic claudication tolerate flexion activities best such as walking uphill, leaning forward as on a shopping cart or walker, and riding bicycles. In these patients, the first most appropriate imaging would be weight-bearing plain film radiographs. Being chiropractors, we are one of the few doctors that will have readily
available weight-bearing imaging. The radiographic series should include an anteroposterior (AP) view, flexion, extension, and lateral radiographs for initial screening. While radiographs are not diagnostic for spinal stenosis, radiographs will typically show the degenerative changes in the intervertebral disk and facet joints. Facet arthrosis will show subchondral sclerosis, hypertrophy, and/or loss in joint space. The intervertebral disk will typically show loss in disk space, subchondral sclerosis, subchondral cysts, and/or osteophyte formation. Other pathology can be ruled out such as spondylolisthesis or scoliosis, commonly seen in degenerative lumbar spine patients. Degenerative spondylolisthesis usually occurs at L4/5 and may result in L5 radiculopathy because of nerve root compression. Surgical conditions can also be ruled out with plain film such as compression fracture, tumor, or infection.

Key points:
- Diagnostic imaging is not a substitution for a thorough physical examination
- For degenerative lumbar spinal stenosis, weight-bearing AP, flexion, extension, and lateral plain film radiographs are most appropriate

**Magnetic Resonance Imaging (MRI)**

Although MRI is not a source of ionizing radiation and has no known detriment to the patient, it is still one of the more expensive diagnostic imaging test procedures and therefore should only be used when patients show significant red flags. Some of these red flags associated with low back pain include: cauda equina syndrome, malignancy, underlying systemic disease, spinal infection. With patient history and physical examination, cauda equina is suspected when the patient suffers bowel or bladder change, sexual dysfunction, bilateral perineal numbness, or sciatica-type pain. Malignancy is suspected when the patient suffers night pain that arouses the patient from sleep, previous history of cancer, or weight loss of unknown reason. Systemic disease is suspected when pain is not relieved by bed rest and spinal infection is suspected when there is associated febrile illness. MRI is the main imaging modality used for patients with significant neurological findings. MRI is preferred over CT because it has better soft tissue resolution, and better visibility of vertebral narrowing and the spinal canal.

In general, here is the rule for ordering MRI with low back pain. An MRI should be ordered in patients with significant neurological findings. MRI can clarify unknown abnormal radiographic findings. MRI is the gold standard for nerve root impingement imaging and has excellent sensitivity in diagnosing lumbar disk herniation (figure 2).
Figure 2. The arrow denotes a posterolateral disc herniation on this axial MRI
Even with degenerative lumbar spine stenosis, MRI can be beneficial. T2-weighted sagittal and axial images show superior visualization of the central canal and lateral recess stenosis. T1-weighted parasagittal images are ordered to view neuroforaminal stenosis. Use MRI prior to invasive procedures such as epidural injections or spine surgery.

Key point:
- MRI is best to assess patients with significant neurological findings.

**Diskography**
The downside to using MRI is that MRI is great at identifying lumbar disk herniations but does not identify if that herniation is the patient’s source of pain. Previous studies have shown that many patients have asymptomatic disk herniations. This is where discography steps in. This can be a brutal test but clearly identifies the source of patient pain. Diskography entails injecting a radiopaque contrast medium into the disk. A positive test is a reproduction of the patient’s pain. It’s kind of like saying, “does it hurt here” and poking it. Diskography is appropriate in nonradicular low back pain and ruptured disks, especially within the first three months of treatment. This test is often performed prior to surgical fusion.
Besides eliciting pain in the patient, discography is known to result in accelerated disk degeneration, disk herniation, decrease in disk height and signal, and the development of reactive endplate changes. In addition, the safety and diagnostic accuracy of the test is currently being debated in the literature.

Key points:
- Diskography is valuable for correlating a ruptured intervertebral disk with symptoms.
- Many complications are known to result from diskography

**Bone scans (figure 3)**
This test is rarely appropriate for the low back pain patient. Bone scans have poor spatial resolution and should only be used in cases of suspicious infection, tumor and perhaps, fracture. Bone scans are still usually followed by an imaging modality that shows the anatomy more clearly, such as MRI or CT.

![Bone scans](image)

*Figure 3. The arrows denote biopsy proven sites of multiple myeloma.*

Key point:
- Bone scan is rarely needed in low back pain patients
Computed Tomography (CT) (Figure 4a,b)

Figure 4a and b show a posterior disc herniation on CT with bone window and soft tissue window respectively.
CT is mainly used to look at bony architecture. It also has good disk resolution when used with myelography and therefore would be appropriate to assess for disk herniation in patients where MRI is contraindicated. Remember MRI uses strong magnets and thus patients with ferromagnetic materials imbedded in the body cannot receive MRI. For example, some orthopedic hardware, bullet fragments, and metal workers should not receive MRI.

Key points:
- CT provides excellent osseous detail
- CT is used when MRI is contraindicated

References:

Section II – Pediatrics and diagnostic imaging

Children are trouble
Children are not just small adults when it comes to imaging. They have growth plates, not found in adults, their body proportions are different, and their ratio of red to yellow marrow is greater. Not only is the imaging different, but the traumatic injuries are different, making what you expect to find on diagnostic imaging different from adults sustaining the same trauma. Pediatric trauma and diagnostic imaging is DIFFICULT!

Let us first look at the differences found in the growing skeleton. Bone growth occurs at the growth plate which is the junction between the metaphysis and epiphysis. In the limbs, there are two types of epiphyses. First, the pressure epiphyses, found at the ends of long bones, when traumatized, can result in vertical growth arrest of that bone (figure 5). Unfortunately, the growth cartilage in this area is more vulnerable to damage than either neighboring bone or adult cartilage. Given the same trauma, in an adult, ligaments are likely to rupture; whereas, in a child, the epiphyseal plate is most likely to sustain the injury.
Figure 5 shows a pressure epiphysis at the end of this ulna and radius (black arrows). There is also a fracture in the distal radius (white arrow).

The second type of epiphysis is known as traction epiphysis (or apophysis) and this is found at the insertion point of muscles and tendons (figure 6). The apophyses are responsible for giving the bone its shape. Like the pressure epiphyses, the traction epiphyses are more likely to sustain injury than the attached muscle or tendon. In an adult, repetitive trauma would likely cause tendonopathies. In a child, repetitive trauma would likely result in traction apophysitis leading to avulsion. Adding to the weakness of the apophyses is the disproportionate growth. Often the muscle and tendons will lag bone growth, resulting in tight and inflexible joints. This imbalance puts the child at higher risk of injury.
Issues may also arise when viewing irregularities in bone mineralization and ossification. This occurs normally in many epiphyses, apophyses and bone junctions near growth plates. I own one and I believe everyone who reads radiographs of children should own a normal variants textbook. Personally, I own Keats’s *Atlas of normal Roentgen variants that may simulate disease*. Some variants are insignificant and some are significant. For example, fragmentation of the tibial tuberosity can be indicative of Osgood-Schlatter disease which is an overuse injury at the insertion of the patellar ligament. This is significant because it causes tenderness and pain. Other pain producing findings that need to be differentiated from asymptomatic variants include: Sever disease (calcaneal apophysis), os trigonum, os tibiale externum, dorsal defect of the patella, and bipartite patella. How do I know if these are just normal variants or are they the source of patient pain? A bone scan can be ordered and would show increased radionuclide uptake if it is significant. On MRI, T1-weighted is low signal and T2-weighted is high signal indicating edema when the finding is significant. When MRI contrast is utilized, symptomatic findings will show increased contrast enhancement of bone marrow and adjacent soft tissue, indicating edema.

While MRI can demonstrate the difference between significant and insignificant developmental variants, MRI can also confuse the issue. For example, the ischiopubic synchondrosis usually closes asymmetrically between four and twelve years of age. Unilateral swelling and irregular mineralization may be evident on plain film, with edema.
signal change being seen on MRI and increased radionuclide uptake evident on bone scan. This appearance seems significant when in actuality, this is a normal ossification pattern and produces no symptoms for the patient.

Some developmental lesions in children can mimic severe pathology. For example, cortical irregularity in the femur due to avulsion can be misdiagnosed as osteomyelitis or malignant lesion. How do you differentiate the avulsion from significant pathology? On plain film, the avulsion should be seen at the insertion of the medial head of the gastrocnemius or adductor magnus muscle. A sharp sclerotic margin should indicate a non-aggressive finding. With MRI, the surrounding soft tissue is usually normal in signal with the avulsion. Another easily misdiagnosed lesion is the fibrous cortical defect or non-ossifying fibroma. This lesion is an incidental finding on plain film. The fibrous cortical defect is the most common benign bone tumor found in pediatrics and requires no intervention. It can be differentiated from significant tumors or infection because it has well-defined sclerotic borders, and is found in the long bones of lower extremities in a predictable location, the metadiaphysis.

Another issue is knowing the normal bone marrow changes that occur with age and are visible on MRI. Bone marrow is either red or yellow. Red marrow is hematopoietic, which means that blood cells are being produced in that location. Yellow marrow is fatty and the ratio of yellow to red marrow increases with age. When one is a child, bone has red marrow because more blood cells are needed to meet the demands of a growing skeleton. With age and increased height, less red marrow is required as demand diminishes. Red marrow is replaced with yellow marrow. In a neonate, the entire bone marrow is red which is low signal on T1-weighted images and is intermediate signal on sequences such as STIR (short inversion time inversion recovery) or fat-saturated T2-weighted images. With contrast utilization, the marrow will enhance due to the hypervascularity of the marrow. Starting in the first year of life, red marrow starts to convert to yellow marrow beginning in the appendicular skeleton and progressing centrally until skeletal maturity. Yellow marrow will be high signal on T1-weighted images and lower signal on T2-weighted images (figure 7). By a child’s second birthday, the hands and feet are entirely yellow marrow. The epiphyses and apophyses will initially contain red marrow upon their appearance and will convert to yellow marrows in just a few months. The vertebrae also show this conversion where the vertebrae are hypointense on T1-weighted images in year one of life, are isointense up until age five and then hyperintense thereafter.
Figure 7. Note the bright marrow in the vertebrae of this normal adult cervical spine. There is also a disc herniation at C5/6 but does not impact the vertebral marrow signal.

If one knows the marrow patterns, what is the difficulty? The problem comes when islands of red marrow persist and can resemble bone marrow edema. Sometimes the red marrow persists in the metaphyses forming flame-shaped, geographic, ill-defined foci.

Key points:
- There are two types of epiphyses: traction and pressure
  - A doctor needs to know when they ossify to understand if this is normal growth or fracture
- Irregularities in bone mineralization and ossification occur
  - A doctor needs to know what anatomical variants or developmental lesions are significant
    - A doctor needs to differentiate these variants and lesions from diseases of high morbidity and mortality such as malignancy or infection
- Bone marrow changes from red to yellow with age
  - Red marrow is low on T1-weighted MRI and isointense on STIR and fat-saturated T2-weighted images
    - Yellow marrow is high on T1-weighted MRI images and lower signal on T2-weighted images
  - A doctor needs to know that islands of red marrow can persist in yellow marrow and not be mistaken for bone marrow edema

References:

Section III – Pediatrics continued

**Pediatric pathology on MRI**
The greatest concern on any imaging is missing cancer. Pediatrics is no exception. Because this has a chiropractic focus, I will only address bone tumors in children. Topping the list for pediatric bone cancers would be leukemia, lymphoma and sarcomas. With any of these cancers, the affected bone will have low signal intensity in the marrow on T1-weighted MRI images and high signal intensity on T2-weighted images. When severe anemia ensues, which could be primary or secondary to any of these space occupying cancers, the yellow marrow can reconvert to red marrow. Anemia is tissue oxygen deprivation and one way anemia can occur is through the marrow being utilized for tumor instead of blood production. Anemia can also occur in these patients due to the toxic effects of chemotherapy. When the body senses this severe anemia, it amazingly has the ability to convert the non-blood producing yellow marrow into the hematopoietic red marrow. The reconversion begins in the axial skeleton and extends to the appendicular skeleton.

Whether plain film or MRI, another difficulty is with differentiating bone cancer versus osteomyelitis. They both can feature osseous destruction with trabecular and cortical disruption, periosteal reaction, edema, and soft tissue mass. In reality, from an imaging standpoint, many times osteomyelitis cannot be differentiated from bone cancer. Biopsy may be necessary.

Some benign lesions of bone can also mimic osteomyelitis or malignant tumor. For example, osteoid osteoma can appear aggressive. To avoid a misdiagnosis, look for the osteolytic nidus surrounded by bone proliferation which is indicative of the benign osteoid osteoma. The nidus on MRI will show central low signal with rim enhancement. Fracture can also mimic osteomyelitis or bone cancer. Fracture is evident if a hypointense line is seen on MRI, indicating the fracture line, or a larger zone of sclerosis in an area of edema on MRI, also indicating a fracture.
Key points:
- Difficulties can arise when trying to differentiate osteomyelitis, bone cancer, fracture or benign tumors

Pediatric trauma
Pediatric traumatic injuries are on the rise, especially those involving sports. There is greater pressure on children to perform athletically and many pediatric programs have coaches that lack training, thus leading to higher risks of childhood injury. In light of this bad parenting, I first want to discuss overuse injuries to these immature skeletons, not physically ready for such intense athletic competitions.

Little leaguer’s shoulder is an overuse injury due to throwing. The result is microtears and widening of the physis at the proximal humerus. This widening can be seen on plain film along with demineralization, sclerosis, cystic change, and fragmentation of the lateral aspect of the proximal metaphysis. Little leaguer’s elbow is traction apophysitis of the medial epicondyle seen in children ages nine to fourteen. This is due to repetitive valgus stress placed on the elbow. If plain film is negative in either case, order an MRI which will show low T1-weighted signal intensity and high T2-weighted signal intensity due to edema. With little leaguer’s elbow, proton density T2-weighted images with fat saturation show bone marrow edema in the medial epicondyle of the humerus and edema in the flexor tendons. One consequence at the elbow is possible osteochondral changes in the capitellum and premature closure of the radial epiphysis. Other consequences of pitchers at the elbow can be osteochondritis dissecans which is subchondral infarction followed by chondral lesions and dehiscence of bony fragments, mainly seen in the capitellum or trochlea. If MRI fails to adequately show the condition, CT arthrography would be appropriate.

For gymnasts with repetitive axial loading and hyperextension, the distal radius physis undergoes microtears and leads to growth disturbance and chondral damage. Plain film is appropriate to show ulnar plus deformation, widening and irregularity of the physis, narrowing of the epiphysis and sclerosis and cystic change in the metaphysis. If plain film is inconclusive, MRI would be most appropriate.

In most sports, the lower extremity takes the most load and is thus more prone to overuse injuries. In descending order, stress fractures most commonly occur in the following locations: superior tibia, femur diaphysis, fibula, calcaneus, second and third metatarsal and inferior pubic ramus. Women are at higher risk, especially those with amenorrhea or eating disorders, commonly seen in runners. Plain film has a low sensitivity for stress fracture. When evident, plain film will show a linear lucency or signs of bone sclerosis and periosteal reaction if detected later in the process. The most sensitive imaging for stress fracture is bone scintigraphy, with one hundred percent sensitivity, showing the band of increased uptake in the injured area. Technetium-99m-methylenediphosphonate is considered the gold standard test.

Runners are prone to overuse injuries such as shin splints, which is periostitis of the anterior tibial spine due to chronic pull by the muscle contractions. MRI is the best
modality for confirmation of this disorder, showing the periosteal edema.
Chondromalacia is the most common cause of anterior knee pain in runners.
Chondromalacia is a softening of the patella cartilage causing pain with repetitive knee flexion. MRI shows the swelling and thinning cartilage. Sinding-Larsen-Johansson syndrome is a calcified tendinopathy in the avulsed distal apophysis of the patella apex. It is self-limiting. Osgood-Schlatter syndrome is tendinopathy on the ossification center at the tibial tuberosity. In either Sinding-Larsen-Johansson or Osgood-Schlatter syndrome, plain film should be ordered to note the fragmentation of the patella and tibial tuberosity respectively.

Figure 8. Note the unilateral pars interarticularis fracture on this lumbar CT.

Stress fractures can also occur in the spine. Spondylolysis, or pars interarticularis fracture, occurs more frequently in children than in adults (figure 8). Either L4/5 or L5/S1 are fractured due to repetitive hyperextension such as in gymnastics and football. If spondylolysis is bilateral, spondylolisthesis is likely, which is separation of the vertebral body from the posterior elements of the corresponding vertebra.
Figure 9. This lateral lumbar radiograph shows L4 spondylolisthesis.

Lateral lumbar radiographs show the break and the slippage (figure 9). Plain film may also show sclerosis after healing with enlargement of the contralateral pedicle. Staging of the spondylolisthesis is important because slippage of less than fifty percent is considered
stable while greater than fifty percent is considered unstable. Contributing to symptoms may be secondary vertebral deformation, disc protrusion, or disc degeneration. Repetitive hyperextension can also result in anterior apophyseal injury which can be detected with MRI. With posterior ring apophyseal fracture, CT is considered the gold standard for showing the fractured fragment displaced into the spinal canal. The athlete is also more prone to Scheuermann’s disease than non-athletes. This disease shows disc degeneration, reduced disc height, Schmorl nodes, flattening of the vertebral bodies and kyphotic deformation. Plain film can easily confirm Scheuermann’s disease.

If a child is hit during athletics such as with a thrown baseball, myositis ossificans traumatica (MOT) can result (figure 10). Initially, MRI will not be able to differentiate MOT from infection or tumor but with maturation of the injury, the soft tissue edema resolves leaving a well-defined mass with decreased rim signal intensity on all MRI sequences. Plain film and CT can show the peripheral mineralization in a few weeks and clearly differentiate MOT from the more concerning osteosarcoma.

Figure 10. Post-traumatic heterotopic ossification has occurred inferior to the femur head.

The point of this section was to help the doctor determine what imaging is most appropriate for common pediatric trauma. However, it behooves the doctor to educate the parent about what is realistic for a growing skeleton to endure. Perhaps, working on the
child’s college athletic scholarship when they are six years old may be detrimental to this goal if significant trauma occurs due to these overuse injuries.

Key point:
- MRI is best for looking at edema and will show low signal on T1-weighted images and high signal on T2-weighted images
  - Edema is not specific for trauma so the diagnosis must be made in light of the history
- Plain film is adequate for most of these osseous traumas and MRI may not be necessary.
- CT is considered the gold standard for showing the fractured vertebra fragment displaced into the spinal canal
- Bone scintigraphy has one hundred percent sensitivity for showing stress fractures due to the increased uptake in the fractured region.

References:
SECTION IV- Plain film for extremities

Plain film radiographs for extremities-knee
With the advent of MRI, many practitioners are advocating for the use of MRI and forgoing the once popular plain film radiograph. In some instances, this may be a mistake (figure 11).

Figure 11. This MRI shows loss in medial compartment joint space and osteophyte formation, both features that could have been seen on plain film at a fraction of the cost.

When determining proper imaging, perform a cost/benefit analysis and in this case, I literally mean COST. A 2008 article found that Medicare paid $25.33 for the technical fee and $10.37 for the professional fee of a three view plain film knee series. For the same region of interest, Medicare paid $478.67 for the technical fee and $72.12 for the professional fee for an MRI. Therefore, you would expect a higher diagnostic yield from MRI in order to warrant its use. This article showed that plain film knee x-rays had a higher initial diagnostic yield than the corresponding MRI. The gold standard for screening the knee for pathology was the weight-bearing radiograph in patients over sixty years of age complaining of knee pain. MRI frequently gives false positive results. For example, MRI often shows degenerative meniscal tears that are asymptomatic and are irrelevant to the patient’s presenting complaint of knee pain. In this population, MRI
should only be ordered with persistent knee pain with normal weight bearing x-rays. MRI can rule out stress fractures, meniscus pathology, and malignancies not seen on plain film.

Knee pain is extremely common in patients of advanced age. Up to thirty percent of older patients report persistent knee pain lasting greater than three months. The most common cause of the pain is osteoarthritis that can be clearly detected with plain film. As the baby boomers age, there will likely be more and more cases of chronic knee pain so think of all the wasted money if doctors keep ordering MRI when plain film is most appropriate. Another negative about ordering MRI without first investigating with plain film is delay in diagnosis and treatment. Many doctors have x-ray machines in the office but few have an MRI machine. The patients are inconvenienced by having to drive to an MRI location and they will need to make an appointment which could take days. Whereas, with plain film, the patients will likely not have to travel and can have diagnosis and treatment commence on the same day due to the convenience of imaging.

More than seventy-five percent of patients over the age of sixty-five have imaging evidence of osteoarthritis. The plain film will show the joint space narrowing, subchondral cysts, subchondral sclerosis, and osteophyte formation. Osteophytes and subchondral sclerosis are the two features most associated with pain severity. In the knee, the medical compartment is lost to a greater extent than the lateral giving the patient a genu varus appearance.

When is plain film warranted for an acute knee complaint? X-ray should be ordered in patients with acute knee trauma or pain if the patient is unable to bear weight or flex the knee more than ninety degrees. Plain film is also warranted if there is tenderness in the patella or fibular head. This algorithm has shown one-hundred percent sensitivity for identifying fracture which means that the radiograph will always detect the fracture.

Key points:
- MRI is drastically more expensive than plain film
- Plain film is the imaging modality of choice when screening for knee pathology

**Plain film radiographs for extremities- ankle**

Just like with knee, MRI is frequently over ordered for the ankle as well, but in this case, even plain film is often over ordered. For most simple ankle sprains, physical examination is all that is needed – NO IMAGING! Often times, imaging is ordered because of insecurity of the doctor with making a proper diagnosis from history and physical examination. Insecurity is not an adequate reason for ordering imaging, especially expensive imaging like MRI or unnecessarily exposing patients to ionizing radiation like in plain film.

Twenty-one percent of sports injuries are ankle sprains, typically an inversion sprain. This sprain results in lateral ligament tears which include: anterior talofibular ligament (ATFL), calcaneofibular ligament (GFL) and posterior talofibular ligament. Palpate over the fibular origin of the ATFL and the calcaneal insertion of the GFL. Extensive
knowledge of the anatomy is expected. Swelling anterior or inferior of the malleolus is consistent with sprain while swelling supramalleolar is consistent with fracture or syndesmotic injury. The anterior drawer test is used to assess the integrity of the ATFL. The talar tilt test assesses the integrity of the GFL. In these cases, no imaging is necessary.

When should imaging be ordered? Plain film is warranted if the tenderness is perceived at the tip of either malleolus, the patient cannot walk four steps, or pain is felt at the base of the fifth metatarsal. Both foot and ankle xrays should be ordered. MRI is only necessary with medial ecchymosis and chronic sprains that do not resolve after four months post-injury.

If a syndesmotic injury (high ankle sprain) is suspected, perform the squeeze test. Apply pressure to the midcalf pressing the patient’s fibula and tibia together and this should incite pain. Pain is also elicited with external rotation of the foot. The ligaments involved are the anterior inferior tibiofibular ligament, posterior inferior tibiofibular ligament and the interosseous ligaments. With syndesmotic injuries, order AP, mortise, external rotation stress, and lateral ankle xrays.

Key points:
- Most ankle sprains do not require imaging
- MRI is rarely necessary; most imaging should be plain film

**Plain film radiographs for extremities-foot**
Lisfranc or midfoot sprains are due to rotation on a planted foot, commonly occurring in football where axial load is added by having one player falling on the foot of another. Physical examination will show swelling and the inability to single heel rise or run. Pain is over the metatarsal bases, especially the first and second metatarsal. Plain film is most appropriate. AP, lateral, and oblique weight bearing foot images are indicated. Plain film will show an avulsed flake of bone at the second metatarsal base or diastasis between the first cuneiform and the second metatarsal. Compression fractures of the cuboid and cuneiforms are also common.
The Jones fracture is fracture of the proximal fifth metatarsal (figure 12). This fracture occurs from “lateral tensile stresses from forced forefoot adduction”. The plain film radiograph is again the most appropriate imaging modality. AP, oblique and lateral x-rays of the foot are warranted.

Stress fractures occur when the demand placed on the foot exceeds the bone’s ability to withstand this demand. Unfortunately, plain film often lags symptoms and may not show evidence of this fracture for up to four weeks. In this case, bone scan or MRI would be most appropriate.

Key points:
- Plain film is good at detecting Lisfranc sprains and Jones fractures but not so good at early detection of stress fractures
  - MRI and bone scan are better tests to determine stress fractures.

Plain film radiographs for extremities-shoulder
The rotator cuff includes the supraspinatus, infraspinatus, teres minor, and subscapularis muscles and their tendons. Most rotator cuff tears involve the supraspinatus tendon because the articular surface is most vulnerable to tearing. The initial work-up should always include a plain film shoulder series which should include AP, axially and scapular Y views. Rotator cuff tears are common in older patients with fifty percent of people over the age of sixty having at least a partial thickness rotator cuff tear. Complaints will include shoulder pain, stiffness, weakness, or loss of active range of motion. Pain is
worst at night and with over the head activities. Greater pain is more indicative of a partial thickness tear while weakness and loss of range of motion is more indicative of a full-thickness tear. On plain film, the doctor is looking for subacromial spurs and elevation of the humeral head in relation to the glenoid cavity. MRI may still be warranted because it can show the soft tissues that plain film cannot. MRI will clearly determine whether the damage is partial or full-thickness and whether biceps brachii pathology exists. Young patients may even require MRI arthrography.

Key points:
- Plain film should always be ordered in the initial work-up of the shoulder

References:
Section V- Extremities and advanced imaging

**Ultrasonography (figure 13)**

![Ultrasonography of a medial cruciate ligament tear](image)

While ultrasonography is inexpensive, has no known detrimental effects on the patient, is a dynamic real-time examination, has focus on the exact site of pain, has easy access of opposite side comparisons, and is somewhat readily available, it is still an underutilized apparatus.

One of the main reasons for this underutilization is because it is such a difficult examination to learn. Reading ultrasound is challenging and is very operator dependent for getting the best view of the pathology. For example, if the probe is not perpendicular to the tendon surface, the tendon appears hypoechoic which may be misinterpreted as torn. Overlying deltoid muscles can cause a misdiagnosis of rotator cuff tear.

The most common usage of ultrasound in the musculoskeletal system is for the assessment of rotator cuff tears. When assessing the rotator cuff, obtain views of the acromio-clavicular joint. If the rotator cuff tear is long standing, the Geyser sign may be evident. This is when fluid leaks into the acromio-clavicular joint and demonstrates a large soft tissue mass. Finding fluid in the subacromial-subdeltoid bursa and joint space, known as the double-effusion sign, is associated with rotator cuff tears in ninety percent of patients. Ultrasound has a ninety-three percent sensitivity at detecting rotator cuff damage and a ninety percent specificity and accuracy in determining full thickness and partial rotator cuff tears. This is in comparison to MRI with only eighty-four percent sensitivity.

Tendinosis, degeneration of the tendon due to atrophy, can be differentiated from partial thickness tears on ultrasound. Tendinosis will show an ill-defined hypoechoic area, focal
swelling, and the adjacent bone is normal. Partial thickness rotator cuff tears will be well defined with clear margins and will have bony cortical changes.

Ultrasound is also beneficial to assess for muscle tears, such as in the pectoralis muscle or deltoid muscle. Other shoulder tendons can also be viewed, such as the biceps brachii tendon in the bicipital groove. If the groove is shallow, the biceps brachii tendon has a tendency to dislocate medially. Dislocation of the biceps brachii tendon has been seen in twenty percent of patients with associated rotator cuff tears. The bursa above the supraspinatus tendon is usually not visualized but when bursitis is evident, the region will show echo changes. Occult fractures of the greater tuberosity in skeletally immature patients can be detected on ultrasound when commonly missed on plain film.

Beyond the shoulder, musculoskeletal ultrasound is also very appropriate for the rheumatoid arthritis patient. Ultrasound detects subclinical inflammation in joints and is at least as sensitive as MRI in detecting synovitis and erosions. Ultrasound is accessible and is less expensive and not as time-consuming as MRI. The most commonly scanned location for the rheumatoid arthritis patient is the hand and wrist. Not only is ultrasound used to make the diagnosis of rheumatoid arthritis, in eighty percent of patients, it was used for follow-up assessment of the patient’s disease. Ultrasound can be used to develop a management plan for the patient and because it can be done in-house, unlike most MRIs and CTs, there is no delay in diagnosis or treatment.

Key points:
- Ultrasound is valuable in assessing the rotator cuff and for corresponding shoulder muscles, tendons, and bursa.
- Ultrasound has been crucial in proper diagnosis and management of patients with rheumatoid arthritis
In musculoskeletal radiology, the buzz word is always MRI but CT has not been replaced by MRI. For example, CT is the gold standard for investigating tarsal coalition (figure 14). CT has very few absolute contra-indications unlike MRI due to the magnet affecting ferromagnetic metals. CT has advanced, with the most recent advances including 128-slice, 256-slice, and dual-source technology with arrays of 64 detectors for each source (figure 15).
One downside however is ionizing radiation and another is the spatial resolution decreases with greater distances from the center. The area of interest must be in the center of the CT gantry. Both CT and MRI have significant artifacts when prostheses are present. With CT, the artifact is proportional to the density of the hardware metal. For example, titanium produces no artifact but cobalt-chrome creates severe artifact.

CT is most appropriate when looking for fractures (figure 16). Beyond spine fractures, scaphoid fractures are well seen on CT and is the most common wrist bone to fracture. This is an important diagnosis, since the scaphoid is known to undergo non-union and avascular necrosis. Failure to diagnose can result in long-term disability. For other extremity locations, CT has an eighty percent sensitivity and ninety-eight percent specificity for detecting torn collateral ligaments in tibial plateau fractures. The most common tarsal bone to fracture is the calcaneus. Multi-detector CT allows the foot to be examined comfortably in non-anatomical positions, essential for trauma patients. Multi-detector CT is more reliable than plain film at detecting trplane tibial fractures. This fracture is a coronal, sagittal, and axial fracture involving the closing epiphysis of the distal tibia in adolescents. The fracture occurs when the foot is externally rotated with the foot in plantar flexion.
CT arthrography is often superior to MRI. CT arthrography (CTA) has a ninety-three percent sensitivity and eighty-nine percent specificity at detecting recurrent meniscus tears following meniscectomy. CTA is better than MRI for detecting tears in the ligaments and cartilage of the wrist. CTA is better than MR arthrography (MRA) at detecting sclerosis and enthesophytes in the shoulder. CTA is better than MRA for detecting cartilage lesions in the ankle. Sometimes the technology is combined. CTA-MRA is best for seeing intra-articular lesions of the shoulder.

Multi-detector CT (MDCT) is commonly used to evaluate unexplained findings on MRI. For example, osteoid osteomas commonly require MDCT for proper diagnosis. CT can be used to determine a stress fracture, while on MRI; stress fracture cannot be separated from many other sources of bone marrow edema.

Key points:
- MRI has not replaced CT
  - CT is the gold standard for assessing tarsal coalition
  - CT is most appropriate for fracture assessment and general trauma
  - CTA is superior to MRI in many areas and can even be combined with MRA for most accurate diagnosis.

**MRI and the extremities**
We will conclude with the most common advanced imaging ordered for musculoskeletal complaints: MRI. This section will be brief since most doctors make ordering MRI a common practice. MRI is great for assessing soft tissue, such as muscle and tendon. It is
great at showing fluids like inflammation and edema. Fluids will typically show a low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. In tendinopathy, MRI will commonly show increased signal intensity on both T1 and T2-weighted images with corresponding tendon thickening. This suggests a degeneration of the tendon due to long-standing tendinitis and not an acute inflammatory response. Inflammation would be low on T1 and high on T2-weighted images. MRI has the advantage over plain film and CT by not utilizing ionizing radiation, but MRI is a more expensive exam than the other two modalities.

Key points:
- MRI is commonly ordered for musculoskeletal complaints due to the excellent view of soft tissue and fluids.

References: