20 General Radiology Imaging and Laboratory Testing
What to Order and When

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Imaging

1. What Are Some General Rules to Follow When Ordering X-rays?

- Conventional radiographs are sensitive and specific in detecting long bone fractures.
- They are indicated when there is a history of trauma (which may indicate that the patient needs immediate, further work-up), but in general x-rays should almost always be the initial imaging tool. Other indications for obtaining plain films can be found in Table 20-1.
- Because conventional x-rays compress images into two dimensions, it is essential to obtain a minimum of two views of the area of interest that are 90 degrees apart (eg, AP/lateral).
- X-ray interpretation becomes difficult when bones project upon one another and when they have irregular surfaces. This can be addressed by obtaining additional projections (eg, oblique) or special views.
- If there is a history of trauma, x-rays should include the joint above and the joint below the bone that is involved.

2. Should X-rays Be Ordered Before Asking for a More Advanced Imaging Modality?

Almost all imaging should begin with conventional radiography, especially if there is a history of trauma because x-rays are excellent in revealing long bone fractures. They also provide excellent contrast between bone and soft tissue. They are widely and readily available, inexpensive, and results can be known in a short period of time. Although advanced imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT) scan can provide more diagnostic details, abnormal findings can sometimes be nonspecific. Thus, correlation with plain films is crucial for the correct interpretation of musculoskeletal abnormalities on advanced imaging modalities.

3. When Do I Need to Order Comparison Views on Plain X-rays?

- Physeal injury—Salter-Harris type I fractures or chronic physeal stress injuries (such as seen in gymnast wrist or little league shoulder) may show the subtle widening of the physis

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Table 20-1. Indications for Obtaining Plain Films	
• Bone or joint pain, especially pain worsening at night* • Bone infection, especially accompanied by fever, weight loss* • Radiopaque foreign body • Evaluating structural/developmental abnormalities	• Injury at apophyseal sites to rule out avulsion fracture • Bone or soft-tissue mass • Assessing for anatomic or ossification variants • Follow-up radiographs 14 to 21 days postinjury to diagnostically confirm an occult fracture (Figures 20-1 and 20-2)
*Potential "red flags" that may need immediate, further work-up.	

Figure 20-1. X-ray of a normal tibia in a child who refused to bear weight after an injury.

Figure 20-2. X-ray of a healing midshaft tibia fracture taken 3 weeks after the 2-year-old patient was treated in a long leg cast for an occult fracture; x-ray shows periosteal reaction along the tibia shaft, suggesting fracture healing.

on radiographs, and it is not always apparent. Comparison views may be helpful in demonstrating the difference in the two sides (Figures 20-3 and 20-4).

- Accessory ossification center—Accessory ossicles can be incidental findings and are distinguished from fracture fragments by their smooth, round contours. A radiograph of the opposite side can sometimes be helpful, as there can be bilateral findings.
- Apophyseal or ossification center variations—Fusion of apophyses and ossification centers may be variable and appear abnormal on x-rays, especially if there is incomplete fusion (Figure 20-5). When in doubt, obtaining comparison views can be helpful to rule out avulsions or fractures, as often times the findings of apophyseal or ossification variants are bilateral. This is also true for apophyseal injuries and injuries to ossification centers with little displacement.

Figure 20-3. X-ray of a left distal radius physeal injury in a gymnast presenting with wrist pain; note the widening of the distal radius physis compared with the normal physis of the patient's right wrist (see Figure 20-4).

Figure 20-4. Normal x-ray of the same patient's right wrist shows no widening of the distal radial physis.

Figure 20-5. Normal x-ray findings showing a bipartite patella, which may commonly be mistaken for an acute fracture.

4. Ultrasonography Is Best Used to Evaluate What Conditions?

Ultrasonography has the advantages of avoiding radiation exposure, being inexpensive and easily available, and allowing for dynamic imaging in real time. It has been widely used in diagnosing pediatric hip disorders. However, with its excellent soft-tissue contrast and advances in high-resolution ultrasonography, it is now well suited to evaluate the pediatric musculoskeletal system. Although many applications for ultrasonography have been developed, it is most ideal for evaluation of traumatic, inflammatory, degenerative, and even infections or neoplastic conditions that affect the following:

- Tendons
- Muscles
- Joints (shoulder, knee, hip)
- Ligaments
- Peripheral nerves
- Soft-tissue foreign bodies

5. Computed Tomography Scan Is Best Used to Evaluate What Conditions?

CT provides the best imaging modality for investigation of bone. It provides clear details of fractures in terms of extent of the injury and the position of bony fragments, which may be necessary for decision making in terms of nonoperative management or surgical intervention. It can also assess for bony healing. CT is also the imaging modality of choice in trauma because it detects acute bleeding and can quickly provide details of bony anatomy in all dimensions. The following conditions are best evaluated with CT:

- Complex or intra-articular fractures
- Assessment of fracture and stress fracture healing, including the lumbar spine
- Acute head or abdominal/pelvic trauma

6. Bone Scan Is Best Used to Evaluate What Conditions?

Bone scan has an advantage over other imaging modalities in that it is highly sensitive to any bony pathology and can detect bone injury as early as 24 hours after a triggering event. The downfall is that it lacks specificity. Any abnormalities on bone scan will require further investigation with a more specific imaging modality to determine the etiology of the abnormality. Bone scan is best indicated as a screening tool for the evaluation of the following:

- Stress fractures
- Osteomyelitis; detecting occult infections or localizing the site of infection when an inflammatory process is present
- Generalized bone pain to detect presence of tumor
- Osseous metastases in neoplastic disease

7. Magnetic Resonance Imaging Is Best Used to Evaluate What Conditions?

MRI provides excellent soft-tissue contrast. It also has the ability to provide high-resolution images of the body in multiple planes. For these reasons, MRI is the ideal imaging modality for evaluating soft tissue, joints, and bones. The following conditions can be best assessed with MRI:

- Soft-tissue injury (muscle, ligament, tendon, meniscus, cartilage)
- Joint derangements
  - Shoulder (rotator cuff disease, glenoid labrum tear, acetabular labrum tear)
  - Knee (ligament injury, meniscal tear)
- Osteochondral injuries
- Occult fracture, especially physeal injuries
- Stress fractures
- Lower back pain
- Infection (osteomyelitis, abscess)
- Abnormalities of bone marrow
  - Infection (osteomyelitis)
  - Stress reaction or fracture
  - Bone contusion
  - Neoplasia
  - Devascularization (avascular necrosis)
- Bone and soft-tissue masses, tumors
- Spinal cord injury

8. Which Imaging Modalities Might Have Greater Radiation Exposure?

Radiation risk from diagnostic imaging is an area of concern, particularly in the pediatric population. These patients are more sensitive to radiation-induced cancer risk than adults. To this regard, MRI and ultrasonography are commonly being used because of their lack of ionizing radiation exposure. Of the remaining imaging modalities, CT has the greatest radiation exposure. Most epidemiologic studies on radiation exposure risk have been completed in cohorts who have been exposed to radiation treatment for benign diseases. Very few studies have looked at the cancer risk following diagnostic radiation exposure in children. In general, however, radiation doses are low for a single procedure unless the diagnostic procedure is performed multiple times. Studies have shown that high cumulative dose exposure over time can increase the risk of developing malignancies in a linear fashion, notably solid tumors and leukemia.[1]

Laboratory Testing

Laboratory considerations in ailing athletes are diverse and depend greatly on the working differential diagnosis of the physician. In general, labs are ordered in athletes when there is concern for an underlying medical condition such as infection, hematologic/oncologic disease, rheumatologic disease, endocrine abnormality, cardiac disease, metabolic disorders, or gastrointestinal disease. A large number of lab studies are available, so it is important to approach the sick athlete with considerations of his or her history, symptoms, and examination. More often than not, the history will indicate the direction of the work-up. For this reason, only order labs that are indicated after obtaining a thorough history and performing a thorough physical examination so as to minimize the risk of missing an ominous diagnosis. If the history and examination are normal, laboratory tests are usually unnecessary on the initial visit given their very low yield, but they can be considered if there is no improvement of symptoms over a 2- to 3-week period.[2]

9. What Tests Should Be Considered When Evaluating a Fatigued or Underperforming Athlete?

- Athletes may report symptoms of fatigue, a decline in training endurance or performance, or just feeling ill from training. Most of these athletes will be suffering from overtraining syndrome, which is associated with increased training intervals, intensity, duration, and decreased rest periods. Along with declining performance, a history of mood symptoms, muscle or joint pain, elevated resting heart rate, and sleep disturbance have been described.[3-5] For young athletes, fatigue and disinterest for competition are also common manifestations.[5] In overtraining syndrome, these symptoms typically persist beyond a 2-week period despite appropriate rest.[3,4] Although obtaining a thorough training history is essential to assess such athletes, overtraining must remain a diagnosis of exclusion until other medical conditions have been ruled out. If the patient's history does not seem to match up with overtraining alone, it is often warranted to evaluate for underlying medial conditions that may present with fatigue. Generalized laboratory tests may include complete blood count (CBC), ferritin levels, thyroid studies, and vitamin D levels. If the athlete is female, a pregnancy test may be warranted. Based on clinical history and physical examination, the following laboratory assessments can be considered, by system:
- Cardiovascular—Chest pain, syncope, or unusual dyspnea on exertion.
  - Evaluate for arrhythmias, valvular heart disease, and structural heart disease.[2,6,7]
    - Chest x-ray, EKG, echocardiogram.
- Female Athlete Triad—See Chapter 17, questions 1 to 3.
- Gastrointestinal—Nausea, vomiting, bloating, anorexia, and abnormal stooling patterns.
  - Consider food allergies, celiac disease, and inflammatory bowel disease.
    - Food allergy testing, fecal fat, stool cultures, celiac panel, and inflammatory bowel disease panel.
  - Consider infections.
  - CBC, comprehensive metabolic panel, lipase, hepatitis panel, stool culture, *Clostridium difficile* toxin, and stool O&P.
  - If gastrointestinal upset appears to be more gastric related, consider gastritis/ulcers.

- Infectious disease—Fever, malaise, and fatigue.
  - Chronic, indolent infections can present with vague symptoms of fatigue, fevers, and malaise.
  - Consider infectious mononucleosis. Obtain Epstein-Barr virus titers.
  - A thorough symptom history can guide specific laboratory testing for any suspected infection.
  - General labs include CBC, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and blood cultures.
  - Specific antibody titers and cultures based on history.
- Oncologic—Fevers, fatigue, anorexia, weight loss, night sweats, and night pain.
  - Consider leukemia, lymphoma, sarcoma, germ cell tumors, and central nervous system tumors.
  - Ask the patient about constitutional symptoms.
  - CBC, ESR, CRP, and often a peripheral blood smear or focused imaging of the symptomatic region can be useful.
- Rheumatologic—Fatigue, fever, weight loss, rash, and joint pain.
  - Fatigue may be the initial presenting symptom prior to clinical manifestation of other more specific symptoms such as rash or joint pain.
  - Consider rheumatoid arthritis, systemic lupus erythematosus, sarcoidosis, dermatomyositis, and scleroderma.
  - CBC, CRP, ESR, rheumatoid factor (RF), creatine phosphokinase, and antinuclear antibody (ANA) titer are helpful initial lab tests followed by rheumatologic referral and more specific antibody testing, if needed.[6]

10. What Lab Tests Should I Order if I Suspect an Infected Joint?

- Septic joint: effusion, erythema, warmth, tenderness, and +/– fever.
- Rheumatologic disease, trauma, bleeding disorders, and oncologic processes should also be considered.[8]
- Obtain CBC, CRP, ESR, RF, ANA titer, and blood culture.
- Joint aspirate should be sent for cell count, Gram stain, and culture.[8]

11. Can Young Athletes Have Normally Elevated Labs?

It is important to keep in mind that certain labs are expected to be mildly elevated in the young active athlete, especially after recent exercise, and they should not draw concern for work-up. In particular, the specific labs discussed in Table 20-2 may be transiently elevated after vigorous activity and would need to be repeated in the rested state to confirm normalization.[7,9] Also, due to their larger muscle mass, athletes often have elevated baseline levels of labs pertaining to muscle metabolism.[9,10]

References

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Table 20-2. Commonly Elevated Labs in Athletes			
LAB	*ACCEPTABLE ELEVATIONS*	*APPROPRIATE FOLLOW- UP*	*COMMENTS*
Alkaline phosphatase	2 to 3 times adult levels in children with high growth velocity 2 to 3 times adult levels during pregnancy	None necessary	Normal adult range: 30 to 120 U/L Children: up to 350 U/L
Proteinuria	1 to 2+ proteinuria up to 48 hours postexercise	Repeat supine morning sample 48 hours postexercise	If repeat sample abnormal: obtain 24 hours urine protein/creatinine
Hematuria	Microscopic hematuria (>3 red blood count/high power field) up to 48 hours postexercise	Repeat sample in 24 to 48 hours	If repeat sample abnormal: obtain urine culture, blood urea nitrogen, creatinine
Blood urea nitrogen	Up to 50% elevations with increased muscle mass	None necessary	
Creatine phosphokinase	10 to 20 times normal levels after vigorous exercise up to 3 to 5 days Up to 50% elevation with increased muscle mass	Repeat in 3 to 5 days Peak levels seen at 1 to 2 days post-exercise	Normal range: 38 to 275 U/L Consider expanded differential if levels >5000 U/L or not normalized after 5 days
Aspartate transaminase, alanine aminotransferase	1.5 times normal levels postexercise up to 10 to 12 days Up to 50% elevation with increased muscle mass	Repeat at rested levels in 2 weeks	Normal ranges: Aspartate transaminase (5 to 40 IU/L) Alanine aminotransferase (7 to 56 IU/L) Consider work-up for hepatitis, gall stones, liver disease if abnormal

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