Back to Basics: Radiography of the Lower Extremities

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ABSTRACT

Conventional radiography remains the imaging modality of choice for most applications in the lower extremities. The most common indication for X-rays of the lower extremity is acute trauma. The hip, femur, knee, lower leg (tibia/fibula), ankle, foot, calcaneus, and toes are common radiographic series that are useful in diagnosing an acute fracture, dislocation, or other traumatic injuries a patient may sustain to the lower body. The preferred modality for initial evaluation and diagnosing other bony pathologies in the lower extremity is radiography. Other imaging modalities such as computed tomography, sonography, and magnetic resonance imaging play important supplementary roles in helping to diagnose patients with soft tissue injuries. It is essential that radiologic technologists understand all the components of the imaging chain that lead to the production of high-quality diagnostic radiographs. To this end, this course will provide detailed reviews of the anatomy and bones of the lower body as well as ideal patient positioning for both standard and nonstandard projections of the toes (phalanges), the foot (metatarsals), the calcaneus, the ankle, the lower leg (tibia/fibula), the knee, the femur, and the hip joint. The imaging chain consisting of radiographic exposure factors, proper use of digital capture devices, accessory items, and radiation safety practices will also be addressed.

Introduction

Despite the evolution of new medical imaging technologies and cross-sectional techniques over the last several decades, diagnostic radiography remains the most frequently performed medical imaging examination in the United States (US) and around the world. Radiography is useful for a wide range of medical applications due to the widespread availability of X-ray imaging devices, relatively low cost, ease of use, low radiation exposure profile, favorable safety profile, and excellent spatial resolution and contrast.[1-3] It has been estimated that radiography examinations make up about 74% of all radiology imaging procedures performed in the US.[4-5] Perhaps the most important role of radiographs in a clinical setting is its role in musculoskeletal imaging for both acute trauma or evaluation of bony pathology. Radiologic technologists (RTs) need to be aware of the anatomy, various positions, and imaging techniques required to provide the clearest view of the anatomy in question. Correct positioning is essential to achieve proper radiographic exposure settings to provide diagnostic quality radiographs at the lowest patient radiation dose possible. The first step to achieving a successful X-ray imaging study of the lower extremities is to understand the basics of the anatomy being imaged.

Skeletal Anatomy of the Lower Extremities: An Overview

Bones of the Skeletal System

The skeletal system is made up of bones and joints, which work in unison with the muscles, tendons, and ligaments to provide the foundation and support structure for the body.[6] The skeletal system is divided into 2 parts (Figure 1)[7]:

- Axial skeleton – Comprised of bones of the head (skull), neck (hyoid bone) and cervical vertebrae, spine, and trunk (ribs, sternum, vertebrae, sacrum)
- Appendicular skeleton – Comprised of bones of the upper (shoulder, pectoral girdles, arms, wrist, and hands) and lower limbs (hip, pelvic girdles, legs, ankles, and feet)

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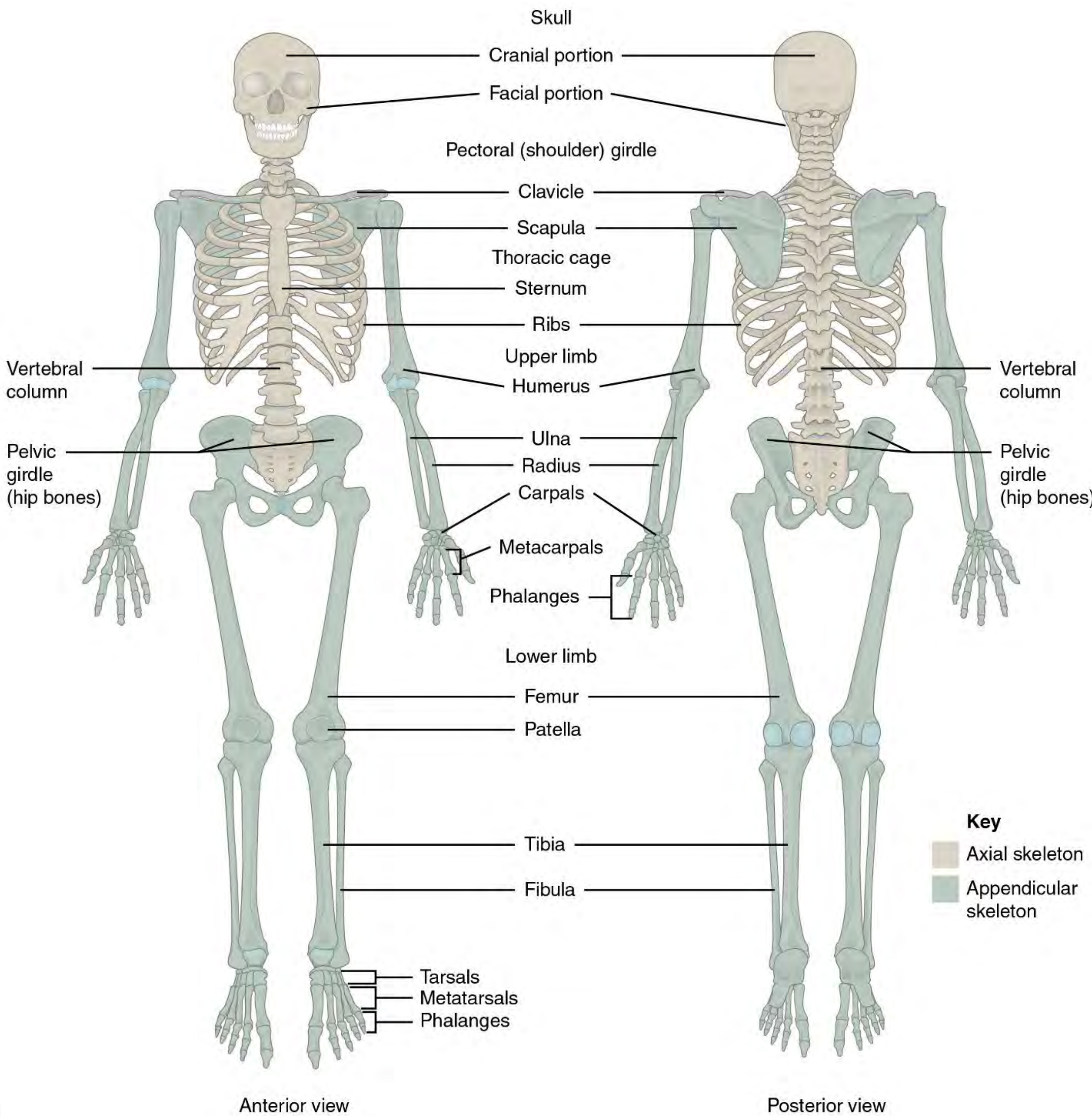
Figure 1. Axial and Appendicular Skeleton



Betts et al. Divisions of the skeletal system. In: *Anatomy and Physiology*. Houston, TX: OpenStax; 2021.[7] For educational purposes only.

The skeletal system is made up of 2 major types of connective tissue: bone and cartilage.[8] Bone is a living tissue and represents the hardest of all connective tissue in the human body; it is comprised of compact bone or spongy (trabecular or cancellous bone). The outer layer that covers bone is called the periosteum, which is made up of fibrous connective tissue and blood vessels.[9] Skeletal short bones (eg, hands, wrists, feet, and ankles) and long bones (eg, arms and legs) of the upper and lower extremities undergo a process called endochondral ossification, where glass-like cartilage (hyaline cartilage) is converted to bone. Endochondral ossification begins early in the gestation process, continues through puberty, and into early adulthood until skeletal maturity is reached (at about 18–25 years of age) when all the cartilage is replaced by bone.[10] A typical long bone consists of the following structures (Figure 2)[11]:

- The diaphysis is the shaft of the bone, which is hollow and made up of hard compact bone.
- The epiphyses are the distal and proximal ends of the bone.
- The metaphysis is the section of bone that lies between the diaphysis and epiphysis once the bone has reached maturity.
- The articular cartilage is a thin layer of cartilage that covers the epiphysis. The function of articular cartilage is to act like a shock absorber.
- The periosteum is a thick, fibrous membrane covering the entire surface of the long bones.
- The medullary cavity is the central, hollow area inside the diaphysis that contains the soft, yellow bone marrow.
- The endosteum is the lining of the medullary cavity.

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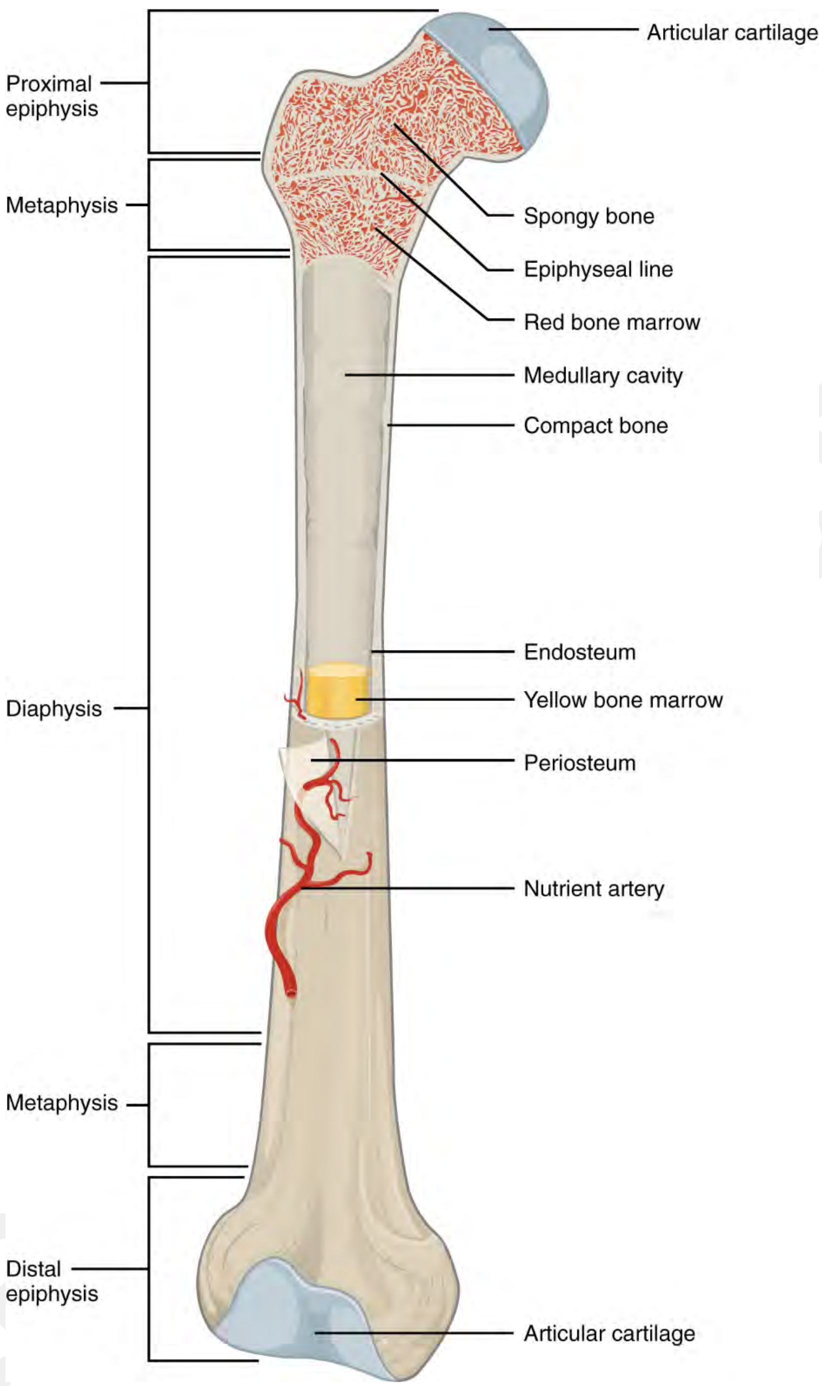
Figure 2. Anatomy of a Long Bone



A typical long bone with various anatomical features.

Biga et al. Bone structure. In: *Anatomy & Physiology*. Corvallis, OR: Open Oregon State; 2021.[11] For educational purposes only.

Bone surface markings appear wherever tendons, ligaments, and fasciae are attached. It is important that RTs be familiar with them, because in some situations, they can be used as topographic positioning landmarks. The most common bone markings include[12]:

- Angles: Sharp bony angulations that may function as attachment sites for soft tissue or other bones; examples include the superior, inferior, and acromial angles of the scapula.
- Body: Usually refers to the largest part of bone such as the shaft of the humerus.
- Condyle: Refers to a large prominence in the bone that commonly provides support for hyaline cartilage and has a knuckle-like appearance.
- Crest: A ridge or prominent part of a bone where muscle and bone are attached by connective tissue. A key topographic landmark is the iliac crest of the ilium bone of the pelvis.
- Diaphysis: Refers to the main part of a long bone shaft
- Epicondyle: A prominence on top of a condyle that attaches muscle and connective tissue to bone and provides support to the musculoskeletal system. Examples include the femoral medial and lateral epicondyles and humeral medial and lateral epicondyles.
- Epiphysis: Articulating segment of a bone; it is usually located at the bone's proximal and distal portions and is essential for bone growth.
- Facet: A smooth, flat, surface where bone articulates with another bone. When connected to another flat bone or another facet, they create a gliding joint.
- Fissure: An open region in a bone that usually contains nerves and blood vessels.
- Foramen: An opening or passage through a bone where blood vessels, nerves, and ligaments can pass through.
- Fossa: A depression or hollow area within a bone.
- Groove: A furrow in the bone surface that runs along the length of a vessel or nerve.
- Head: A rounded, prominent extension of bone that forms part of a joint. It is the main articulating surface with the adjacent bone, forming a ball-and-socket joint.
- Malleolus: An expanded projection/rounded process usually located at the distal end of the fibula or tibia at the level of the ankle.
- Margin: The edge of any flat bone
- Meatus: A tube-like channel extending within a bone

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- Neck: The segment between the head and the shaft of a bone. In the humerus, the anatomical neck runs obliquely from the greater tuberosity to just inferior to the humeral head.
- Notch: An indentation at the edge of any structure or bone
- Ramus: The curved part of a bone that gives structural support to the rest of the bone.
- Spinous Process: A raised, sharp elevation of bone where muscles and connective tissue attach. It is different than a normal process in that a spinous process is more pronounced.
- Trochanter: A large prominence on the side of the bone where many of the larger muscle groups and most dense bundles of connective tissue attach.
- Tubercle: A small, rounded prominence to which connective tissues attach. Examples include the greater and lesser tubercle of the humerus.
- Tuberosity: A large, rounded elevation, where connective tissues attach, especially from the surface of a bone.

Joints

The definition of a joint is a point where 2 bones come together. The main function of a joint is to enable movement between the bones. Functionally, the 3 types of joints are synarthrosis (immovable), amphiarthrosis (slightly moveable), and diarthrosis (freely moveable); the majority of joints in the body are freely movable (diarthroses). Joints are classified as follows[13-15]:

- Fibrous joints are united by fibrous tissue; there is almost no range of motion.
- Cartilaginous joints are joints where the bones attach by hyaline cartilage or fibrocartilage to the opposed bony surfaces.
  - Primary cartilaginous joints, also known as synchondroses, only involve hyaline cartilage, and may be slightly mobile (amphiarthroses) or immobile (synarthroses).
  - The secondary cartilaginous joints, also known as symphyses, may involve either hyaline or fibrocartilage and are only slightly mobile (amphiarthroses).
- Synovial joints are the most common type of joint in the human body. They are found between bones that move against each other (eg, joints of limbs, such as the shoulder, the hip, and/or the elbow), are freely mobile (diarthroses or diarthrodial), and are considered to be the main functional joints of the body. They are further classified by the type of movement they allow (Figure 3)[13-15]:
  - Ball-and-socket joint: An articulation between the rounded head of one bone (ball) and the concavity of another (socket). This type of joint provides the greatest range

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of-motion as it allows movement in multiple planes (eg, the shoulder joint or hip joint).

- Condyloid joint: This type of joint is an articulation between the shallow depression of one bone and the rounded structure of another bone or bones; an example is the metacarpophalangeal.
- Hinge joint: An articulation between the convex end of one bone and the concave end of another (eg, the knee joint).
- Pivot joint: Allows for the rotation around a central axis (eg, the proximal radioulnar joint).
- Planar joint: Also called a gliding joint; it is an articulation between bones that is both flat and of similar size (eg, the acromioclavicular joint [AC joint] between the acromion of the scapula and the clavicle).
- Saddle joint: A biaxial joint that allows movement in 2 planes (abduction and adduction as well as flexion and extension). The thumb is an example of a saddle joint.
- Syndesmosis joint: An immovable fibrous joint that maintains the integrity between long bones and resists forces that attempt to separate the 2 bones (eg, the joint between the fibula and tibia at the ankle).
- Uniaxial joint**:** A joint that only allows motion in a single axis or plane.

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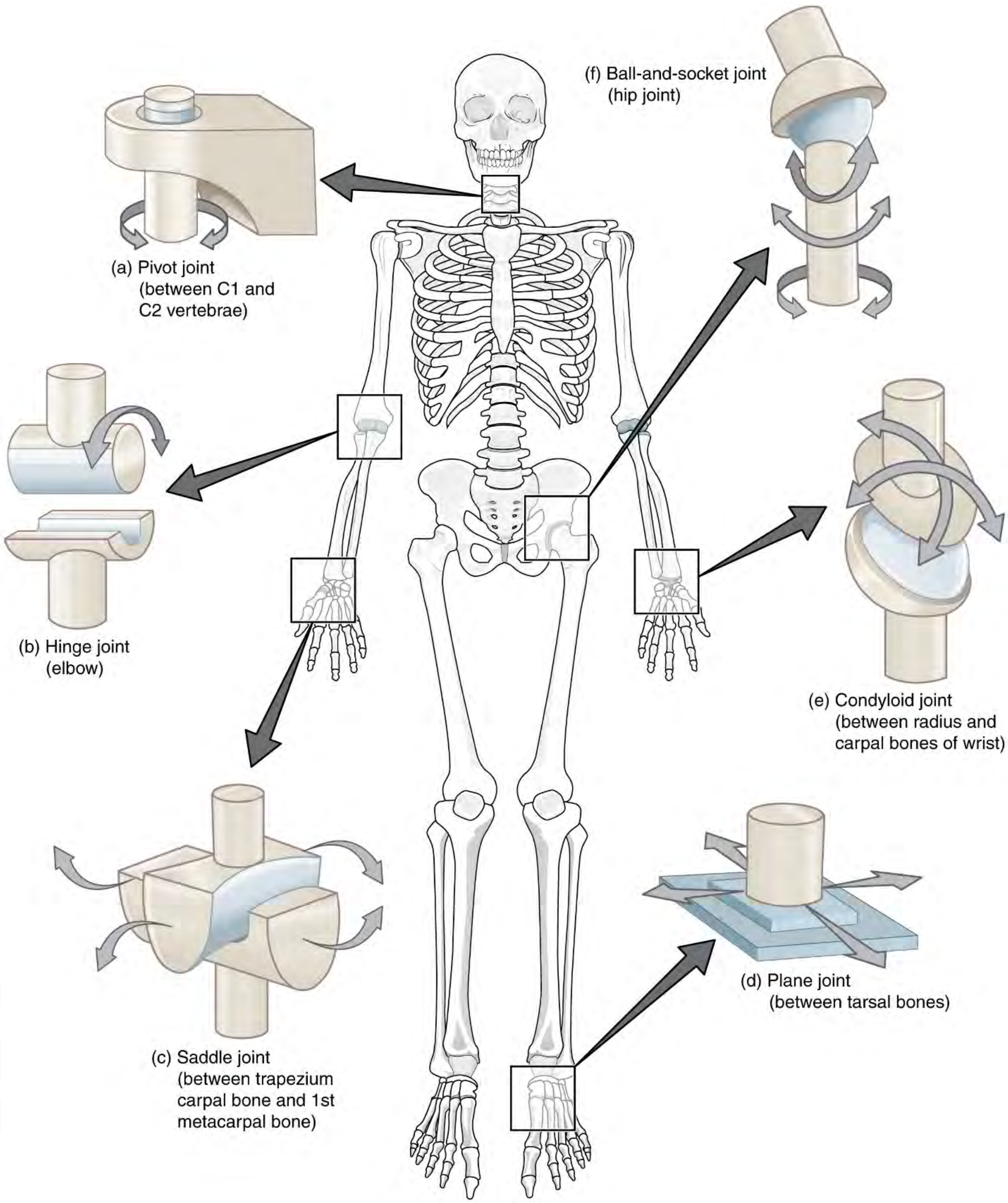
Figure 3. Examples of Synovial Joints



Biga et al. Synovial joints: Types of synovial joints. In: *Anatomy & Physiology*. Corvallis, OR: Open Oregon State; 2021.[14] For educational purposes only.

Bones and Joints of the Lower Extremities

Bones and Joints of the Foot

The foot is a complex combination of anatomical structures that is made up of numerous bones, joints, ligaments, muscles, and tendons and lies distal to the ankle joint. This combination is responsible for the complex coordinated movements of gait and our ability to stand and hold ourselves up in an upright position.[16] The bones of the foot are arranged in longitudinal and transverse arches, providing a strong, shock-absorbing foundation support the body.[17] Twenty-six bones (tarsal, metatarsal, and phalanges) make up the foot, which are subdivided into groups known as the hindfoot (talus and calcaneus), the midfoot (cuboid, navicular, and 3 cuneiforms) and the forefoot (metatarsals and phalanges) (Figure 4).[16,18] There are 5 metatarsal bones; each one is composed of a head, body, and base. The second metatarsal is the longest, while the first is the shortest.[19]

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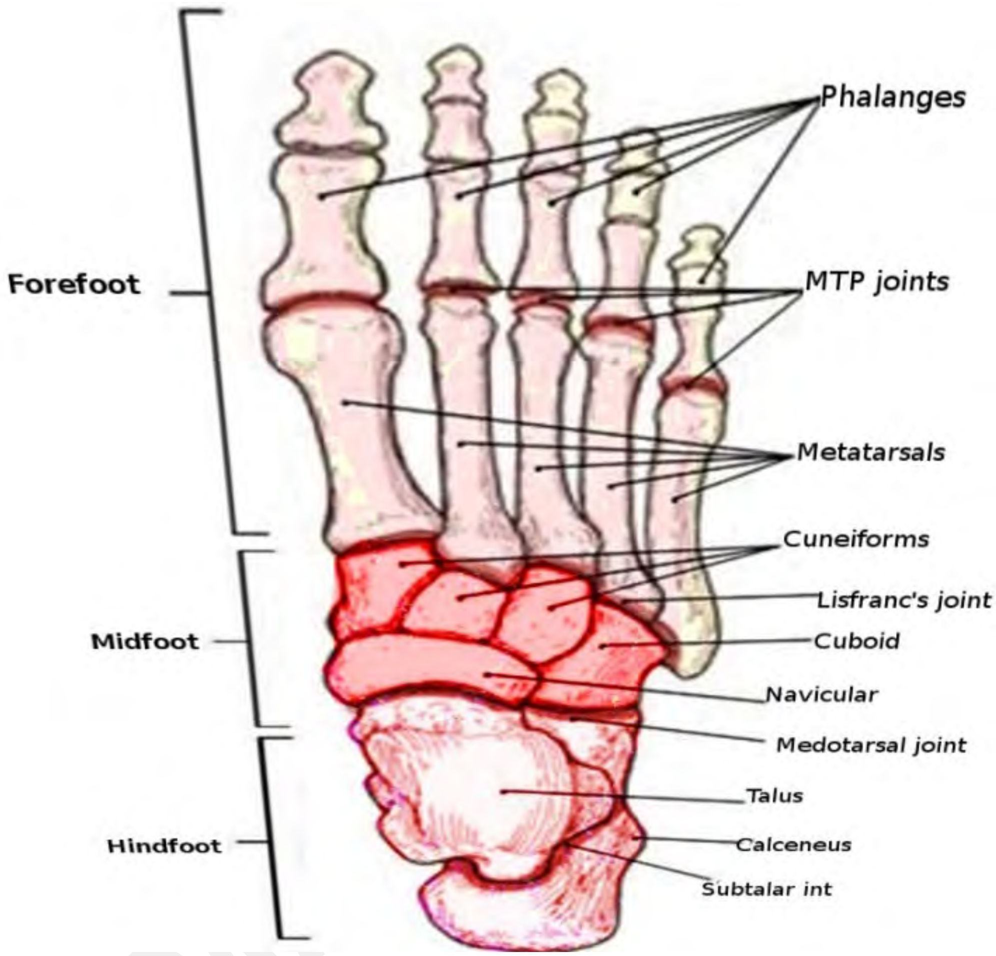
Figure 4. Bones and Joints of the Foot



Manganaro et al. Anatomy, bony pelvis and lower limb, foot joints. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2022.[18] Image courtesy of S Bhimji. For educational purposes only.

The articular surfaces of the bones have a covering of articular cartilage. There is also subcutaneous fat, fascia, and skin that make up the full anatomy of the foot and ankle.[16,20]

The joints between the tarsal bones of the foot are known as the intertarsal joints and are outlined in Table 1.[20]

Table 1. Joints of the Foot

Joint Name	Bones Included	Joint Type
Subtalar	Talus and calcaneus	Uniaxial
Transverse tarsal	Talus, navicular, calcaneus, and cuboid	Compound
Tarsometatarsal	Metatarsals, cuneiforms, and cuboid	Synovial
Metatarsophalangeal	Metacarpal and proximal phalanx	Condyloid; synovial
Interphalangeal	Adjacent phalanges	Synovial; hinge

Data from Betts et al. Synovial joints. In: *Anatomy and Physiology*. Vancouver, BC, Canada: BCcampus Open Publishing; 2021. Accessed August 21, 2021.[20] For educational purposes only.

Sesamoids of the foot are osseous structures that are partially or completely embedded in a tendon. Their function is to protect the tendon from injury by reducing the forces of friction. In contrast, accessory ossicles are supernumerary bones that commonly arise from unfused primary or secondary ossification centers (Figure 5).[21] They are thought to be normal variants with no definite known function. However, both sesamoids and accessory ossicles may be present with certain pathological conditions.[21]

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Figure 5. Sesamoids of the Foot

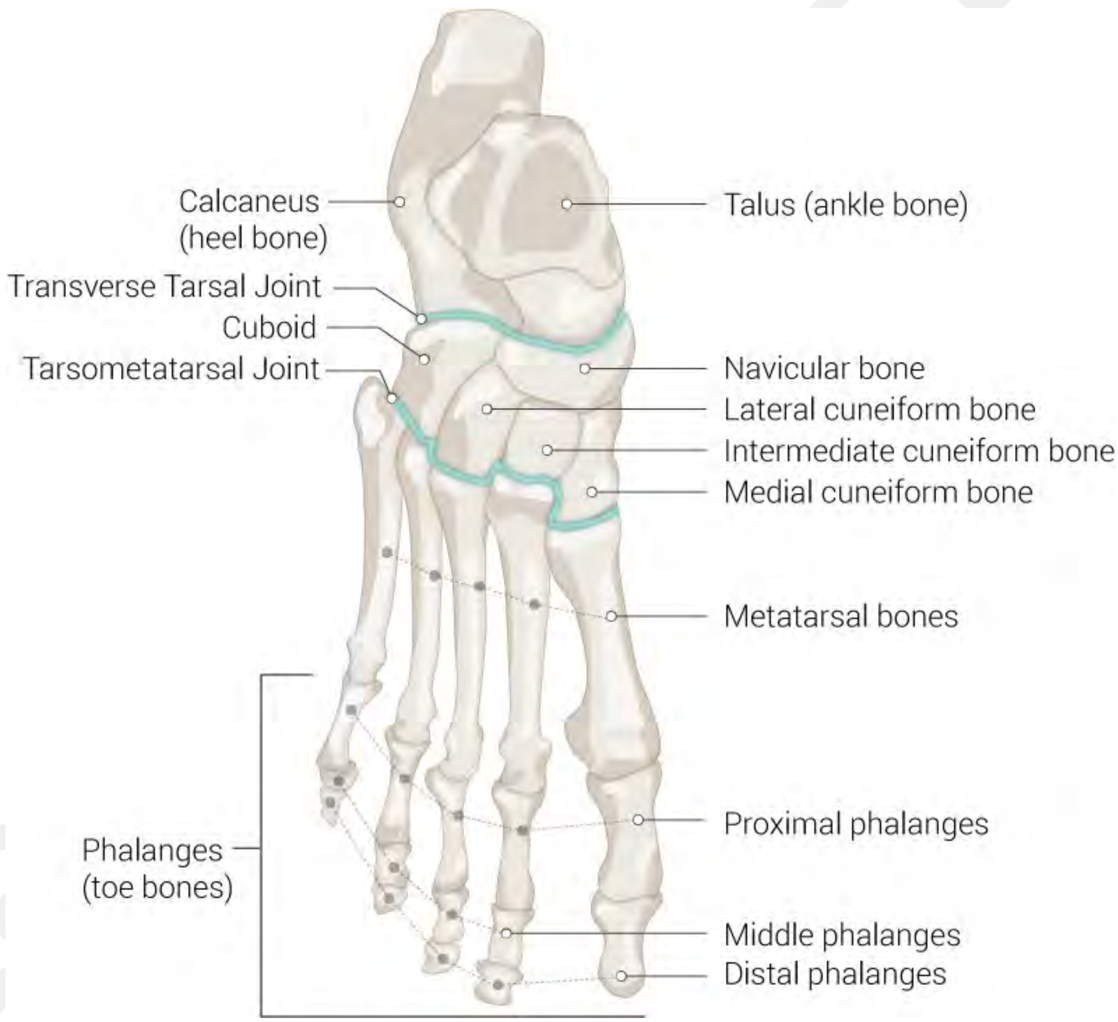
An anteroposterior radiograph of the foot depicting the anatomical sites of the hallucal (1), interphalangeal joint (2), and lesser metatarsal (3) sesamoids.

Nwawka et al. *Insights Imaging*. 2013.[21] For educational purposes only.

Bones and Joints of the Toes (Phalanges)

Fourteen small, long bones make up the phalanges on each foot. Each phalanx is composed of a base, body, and head. The phalanges articulate with the metatarsals proximally and with each other distally to form the toes.[22] All the toes of the foot, except the big toe, have 3 joints, which include the metatarsophalangeal joint (MTP) found at the base of the toe, the proximal interphalangeal (PIP) joint found in the middle of the toe, and the distal phalangeal joint found near the tip of the toe.[18] The big toe is made up of the MTP joint and 1 interphalangeal joint (Figure 6).[17-18,23]

Figure 6. Phalanges of the Foot

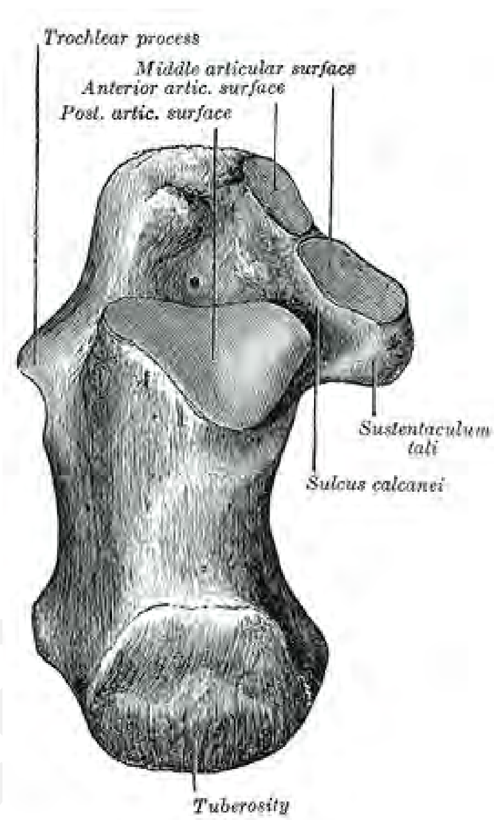


Gupton et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[23] For educational purposes only.

Bones and Joints of the Heel (Calcaneus)

Often referred to as the heel, the calcaneus is a large strong bone that forms the back of the foot and transfers most of a person's body weight from the lower extremity to the ground (Figure 7).[23] The calcaneus is the largest of the 7 articulating bones that make up the tarsus. It is positioned in the hindfoot and articulates with the talus and cuboid bones.[23] The subtalar joint, also called the talocalcaneal joint, is made up of 3 articulating surfaces: the posterior facet, the middle facet, and the anterior facet.[24] The middle facet (the attachment site for the calcaneal tendon commonly known as the Achilles' tendon) is a common site for many injuries.[23] The talocalcaneal joint allows essential foot movements, including inversion, eversion, dorsiflexion, and plantarflexion.[25] Many pathologies, such as congenital, infectious, traumatic, neoplastic, and inflammatory, can affect the calcaneus.[23]

Figure 7. An Illustration of the Calcaneus



Gupton et al. *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[23] Contributed by *Gray's Anatomy* Plates. For educational purposes only.

Bones and Joints of the Ankle

The ankle joint (sometimes referred to as the tibiotalar or talocrural joint) is made up of the talus and the recess formed by the distal tibia and fibula bones.[26] It is classified as a hinge synovial joint that moves in one plane to produce dorsiflexion and plantar flexion. Combined, the distal tibia and fibula articular form the ankle mortise, which contains the body of the talus bone. The ankle joint is composed of 3 malleoli: the lateral malleolus (distal end of the fibula), medial malleolus (medial lower end of the tibia), and the posterior malleolus.[27] Although frequently referred to as the "ankle joint," there are a number of articulations that facilitate motion of the foot. The *ankle joint complex* is made up of the talocalcaneal (subtalar), tibiotalar (talocrural) and transverse-tarsal (talocalcaneonavicular) joints (Table 2).[28-29]

Table 2. Joints of the Ankle Joint Complex

Joint Name	Bones Included	Joint Type
Talocrural (ankle)	Talus, tibia, and fibula	Synovial, Hinge
Proximal tibiofibular	Proximal tibia and fibula	Synovial
Distal tibiofibular	Distal tibia and fibula	Syndesmosis
Subtalar	Talus and calcaneus	Uniaxial

Data from Frank et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2022.[29] For educational purposes only.

Bones and Joints of the Tibia and Fibula

The fibula is one of the 2 long bones in the lower leg, and it is different from the tibia, which is a nonweight-bearing bone. The fibula is located posterolaterally to the tibia, and it is much smaller and thinner.[30] At its most proximal part, the fibula reaches the knee joint and lies just posterior to the proximal tibia. It runs distally on the lateral side of the leg, where it becomes the lateral malleolus at the anatomically region of the ankle.[30] The tibia shaft is a long bone that articulates with the talus, fibula, and the distal femur (Figure 8).[31-32] The fibula and tibia connect via an interosseous membrane, which attaches to a ridge on the medial surface of the fibula.[30] The proximal portion of the tibia consists of a medial and lateral condyle, which together form the

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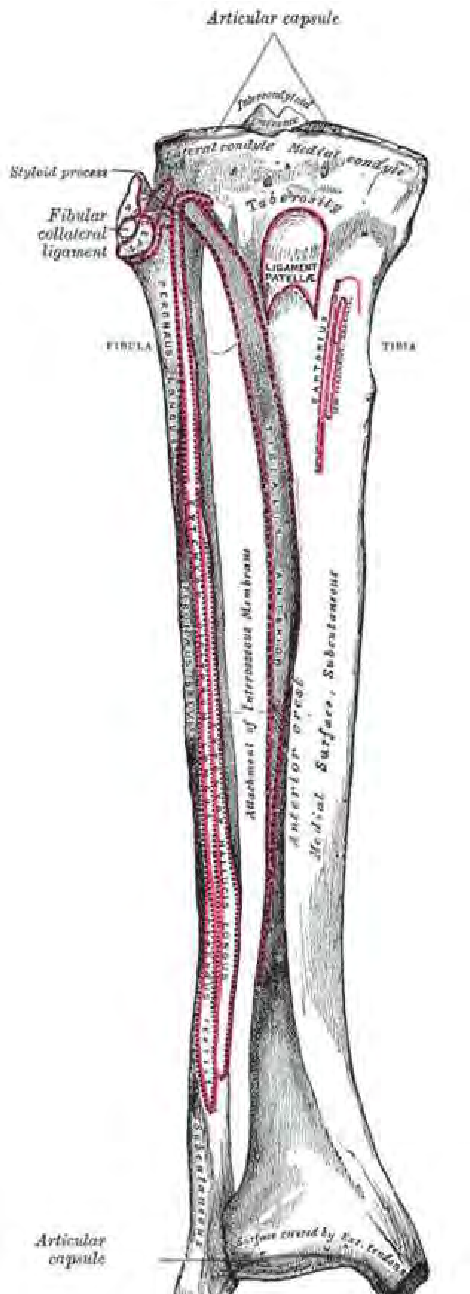
inferior portion of the knee joint. Between the 2 condyles lies the intercondylar area, where the anterior collateral ligament, posterior collateral ligament, and menisci all have attachments.[32]

Figure 8. An Illustration of the Tibia and Fibula

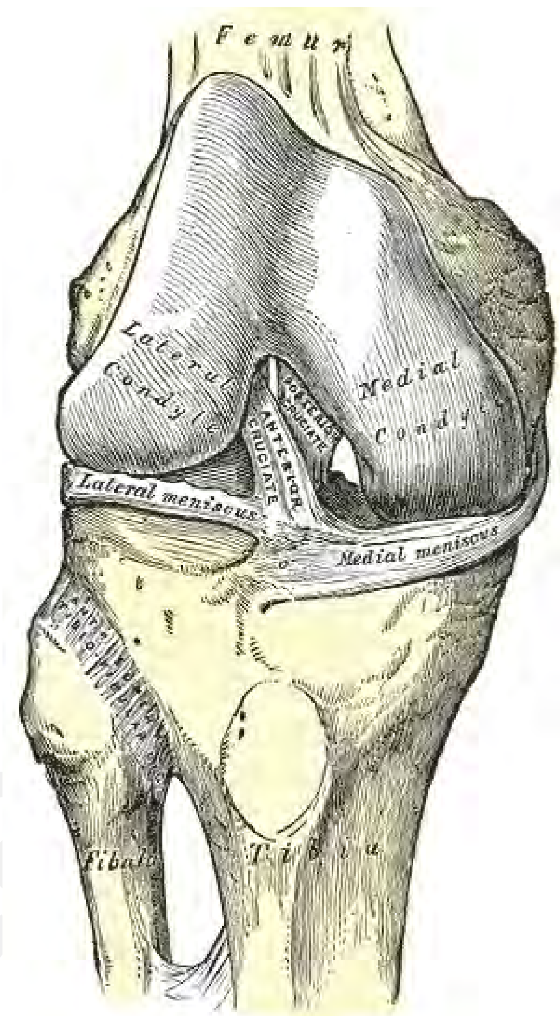


Bourne et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[32] Contributed by *Gray's Anatomy* Plates. For educational purposes only.

Bones and Joints of the Knee

The knee is the largest joint in the body and is a compound synovial joint, which allows weight-bearing function, flexion, and extension of the lower leg around a transverse axis in a sagittal plane. It is made up of the tibiofemoral and the patellofemoral joints. The functionality and strength of a person's knee depends on muscles, bones, ligaments, cartilage, synovial tissue, synovial fluid, and other connective tissues that surround it (Figure 9).[33] The 4 main stabilizing ligaments of the knee are the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), the medial collateral ligament (MCL), and the lateral collateral ligament (LCL).[33]

Figure 9. An Illustration of the Knee



Gupton et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[33]
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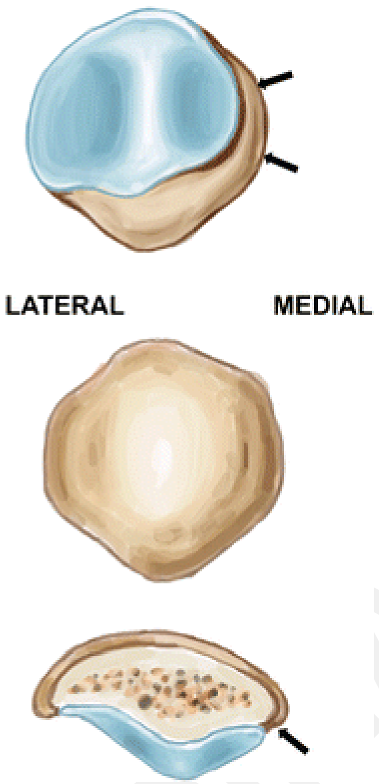
There are 2 menisci in the knee: the medial and the lateral. They function as shock absorbers for the knee joint and contribute to knee stability, protect underlying bone, and provide lubrication and nutrition to the joint.[34-35] The patella is the largest sesamoid bone in the body.[36] Despite many variations in shape, the patella is typically ovoid and flat on its anterior nonarticular surface (Figure 10).[37]

Figure 10. Multiple Views of the Patella



A drawing showing, from top to bottom, the anterior, posterior, and axial views of the patella. The proximal part is termed the basis, and the distal part, the apex. The distal pole is entirely devoid of articular cartilage. A longitudinal ridge divides the cartilaginous surface into medial and lateral facets. The odd facet (arrows) is located at the peripheral aspect of the medial facet and is devoid of cartilage.

Jarraya et al. *Insights Imaging*. 2017.[37] For educational purposes only.

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Bones and Joints of the Femur (Hip/Thigh)

The femur, or thigh bone, is the longest, heaviest, and strongest bone in the body. At the proximal end, the neck of the femur connects the spherical head at the apex and the cylindrical shaft at the base (Figure 11).[38] There are 2 prominent bony protrusions at the proximal end of the femur: the greater trochanter and lesser trochanter. These bony protrusions are attached to muscles that move the hip and knee. The femoral head is the most proximal portion of the femur and is supported by the femoral neck.[39] The femoral head serves as the "ball" of the hip joint, which articulates with the acetabulum of the pelvis (Figure 12).[39] Numerous muscles cross the hip joint to allow flexion, extension, abduction, adduction, internal rotation, and external rotation of the thigh, but none of them attach directly to the femoral head.[40] The hip joint connects the lower extremities with the axial skeleton and facilitates movement and weight-bearing (Figure 13).[40]

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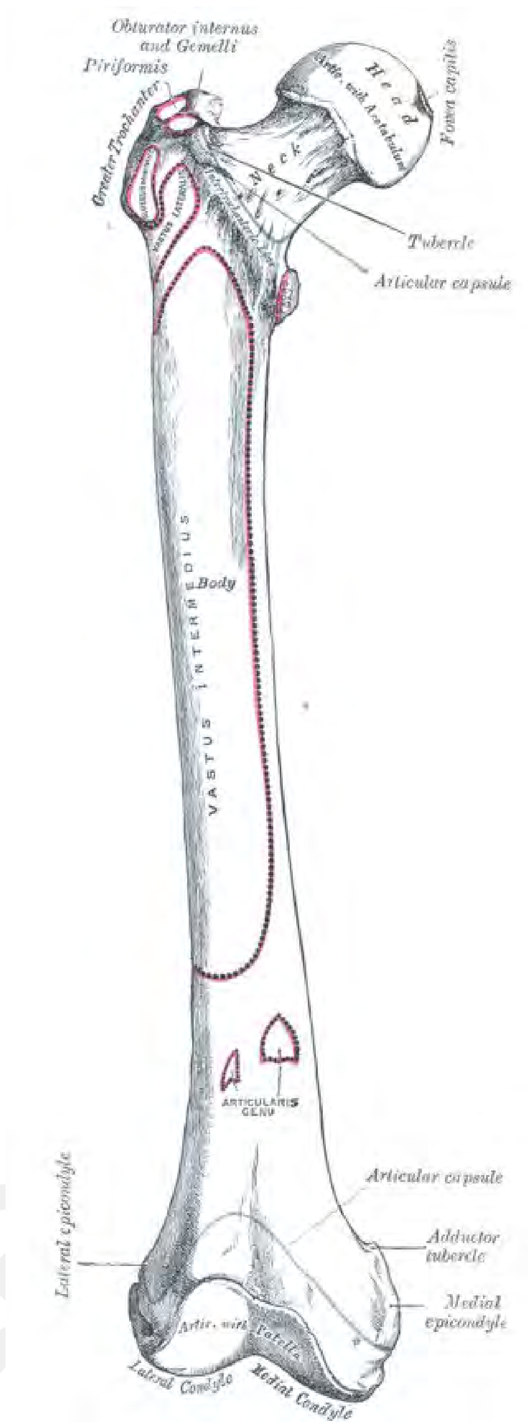
Figure 11. Illustration of the Femur



Chang et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[38]
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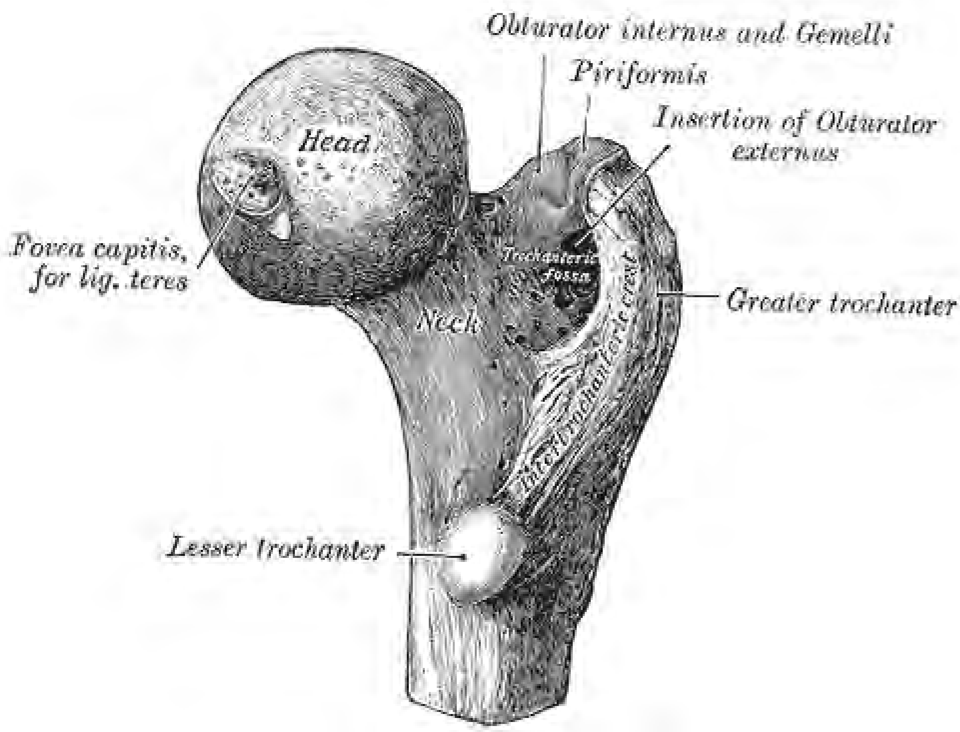
Figure 12. Illustration of the Proximal Femur



Lo et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[39]
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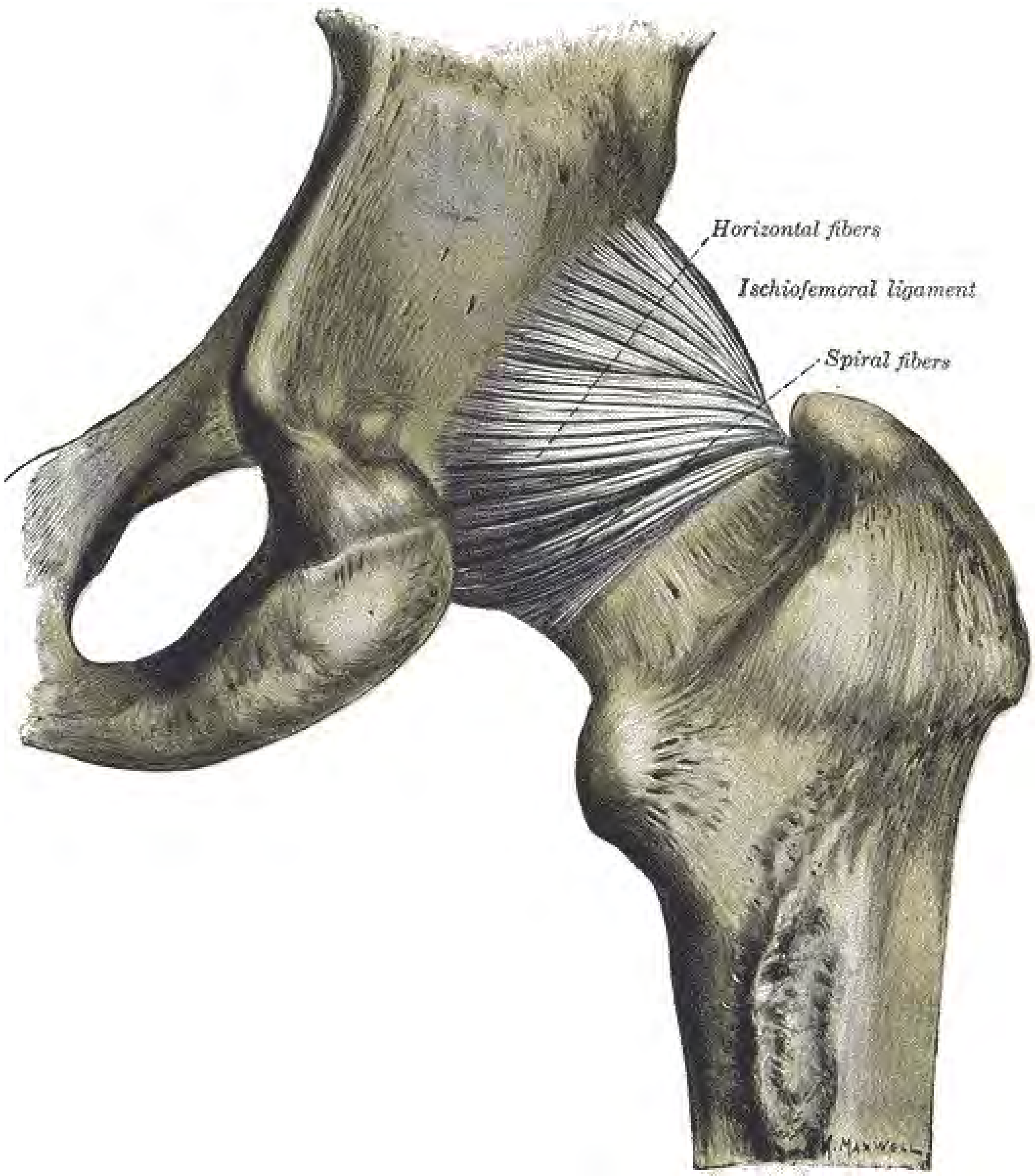
Figure 13. Illustration of the Hip Joint



Gold et al. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[40]
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Radiographic Equipment, Digital Imaging Capture Devices, and Imaging Parameters

Radiographic Equipment

Radiography imaging units are available in a wide array of sizes and capabilities including those specialized for extremity imaging. All diagnostic X-ray equipment used in a radiographic extremity imaging environment have the following key components[1,41-42]:

- X-ray tube
- Collimator (X-ray beam limiting device)
- Operation console for RTs to set exposure settings and protective barriers
- High-voltage X-ray generator available in various types (single-phase, high frequency, 3-phase, and both 6- and 12-pulse), and power ratings (32 Kw, 40 Kw, 50Kw, 64 Kw, and 80 Kw) depending on the clinical setting and types of imaging to be performed.
- Patient table with built-in grid (most have 4-way floating and elevating table options)
- Wall stand (newer wall stands offer options such as the ability to tilt or be positioned at an angle)
- Digital capture device (computed radiography [CR] or digital radiography [DR]-flat panel type system)
- Picture and archiving communication system for imaging viewing, transmission, and data storage

Other critical components of the radiographic imaging chain include the following:

- Automatic exposure control (AEC): AEC was developed for the purpose of achieving more consistent exposures, reducing repeated exposures, and ultimately reducing unnecessary radiation exposure to patients.[1,42-43] The difference in AEC systems lies in the type of device that is used to convert radiation into electricity.[44] There are 2 types of AEC systems that are primarily used: phototimers and ionization chambers. Phototiming specifically refers to the use of an AEC device that uses photomultiplier tubes or photodiodes, even though these systems are uncommon today.[45] The more common type of AEC system uses ionization chambers (Figure 14).[46]

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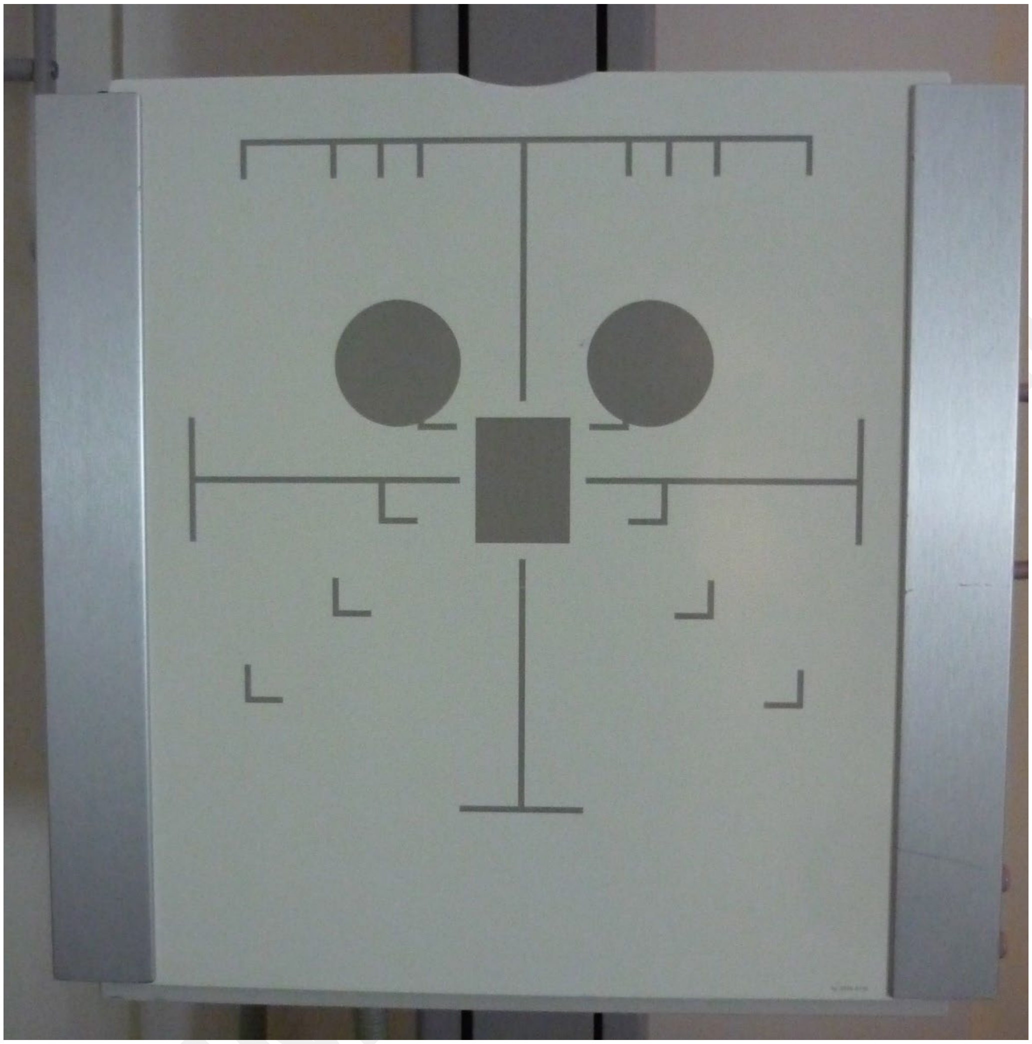
Figure 14. Ionization Chambers



Positions of ionization chambers of an AEC detector on an upright wall stand.

Basic Physics of Digital Radiography/The Source. WikiBooks.org. Updated 2021.[46] For educational purposes only.

Regardless of the specific type of AEC system used, almost all systems use a set of 3 radiation-measuring detectors arranged in a specific manner. These are referred to as the AEC cells. Density settings with AEC adjusts mAs up or down in increments of 25% to 30% per step on most commercial systems (X-ray currents are measured in milliamperes [mAs] while X-ray voltages are measured in kilovoltage peak [kVp]). The RT must still select optimum exposure parameters in both kVp and mAs. *It is important that the manufacturer* *sets up the appropriate "back-up time" of the AEC component to make sure the exposure terminates in case of system malfunction*.[46-49]

- Anatomically programmed radiography (APR): Some AEC systems are designed in the form of APR operating consoles.[5,43,45] With an APR system, RTs can select a part of the anatomy to be imaged, position it on the control panel, and the optimum mAs and kVp exposure factors are preset in the unit's generator by the manufacturer. Once displayed on the control panel, RTs may be able to further adjust the settings and exposures based on the imaging study being performed. Most units are preprogrammed by anatomical region, based on the size of the region being imaged, as well as a combination of other manual and AEC settings. [5,43,45] Many of the commercial units now available can store hundreds of preprogrammed settings as well as the ability to store previous exposure settings in memory.[47-49] RTs always have the option to override the APR and use manual techniques when appropriate. AEC and APR *should not* be used in the following scenarios[1,47-48,50]:
    - When the anatomical region being imaged is too small, especially when performing lower extremity orthopedic radiography in pediatric patients.
    - When there is a large metal artifact, such as orthopedic hardware or prosthesis in the imaging field.
    - If there is no well-collimated X-ray field of exposure; if not, the AEC will terminate the exposure too early causing excess scatter radiation from the table and patient, making it necessary to repeat the view, leading to an overall increase in patient dose.

- Built-in AEC Assistance Technology for DR: Conventional AEC control is through the circuitry of the X-ray generator. This cutting-edge and evolving technology allows the image sensor in the DR image capturing device (detector) to simultaneously generate images and analyze the pixel value corresponding to emitted X-rays in real time (Figure 15).[51] This new technology allows operators to specify a pixel value and then automatically send a notification to the X-ray generator. When that value is reached, the X-ray emissions from the X-ray generator stop automatically.[51]

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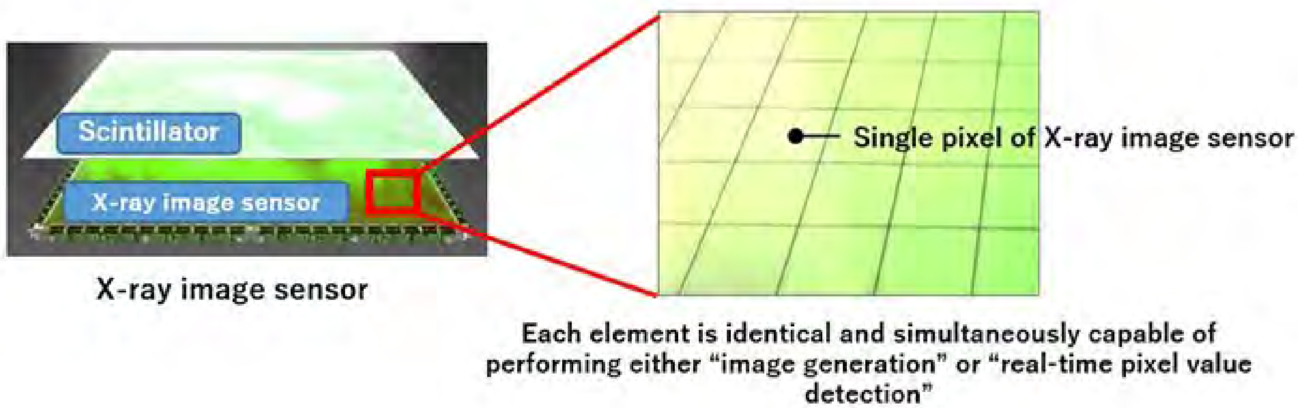
Figure 15. Built-In AEC Assistance



A conceptual illustration of pixels comprising an X-ray image sensor.

AEC = automatic exposure control.

Canon announces new built-in AEC assistance technology for X-ray image sensors [press release]. Tokyo, Japan: Canon Inc; March 25, 2021.[51] Image courtesy of Canon. For educational purposes only.

DR Image Capture Devices

Digital radiography/imaging is defined as, "…any image acquisition process that produces an electronic image that can be viewed and manipulated on a computer."[52] The general term digital radiography may be used to refer to several digital techniques, which are often subdivided into 2 general types of digital imaging: CR and direct DR (DDR).[53-54] CR uses a cassette-based system that is like conventional screen-film cassettes with a separate laser scanning process to extract X-ray intensity data.[1] In contrast, DDR refers to direct digital registration of the image at the detector with no intermediate processing step required to obtain the digital signals as opposed to CR's requirement of processing the plate in a reader. DDR uses several approaches to directly convert X-ray energy to digital data without the need for a separate scanning step.[1] There are 2 main types of DDR configurations: those that use a detector that's connected to the radiographic unit (eg, a U- or C-arm and built-in table or upright or table unit) or those that use a mobile DR flat panel, which are the most common.

Flat-panel DR detectors, or mobile detectors, are typically associated with digital detectors.[43] They may be further classified according to the type of X-ray detector that's included (eg, storage phosphor, scintillator, or photoconductor) and by the method that the X-ray signal is converted to an electric charge for image processing (direct or indirect conversion).[54] There are 2 main types of indirect capture DR flat-panel detectors: those that use a cesium iodide (CsI) or gadolinium oxysulfide (GOS) scintillator and those that use light-sensitive photodiodes.[52-54] Direct capture digital detectors use a direct conversion method where X-rays are absorbed and the electronic image is formed in 1 step. Direct capture systems generally utilize amorphous selenium as the photoconductor.[53]

The key characteristics of a DR system are defined by its spatial resolution (sharpness, modulation transfer function [MTF]), signal-to-noise ratio [SNR], and contrast-to-noise ratio [CNR]).[52-55] MTF defines border characteristics or how clearly and sharply edges can be distinguished.[53] It is one thing to be able to discern individual line pairs, but MTF is an indication of how sharp the line pairs appear.[53,56] MTF measures spatial resolution, which is critical when looking for finite detail in bone radiography to reveal either pathology or subtle fractures.[53] Detective quantum efficiency (DQE) is the measure of a receptor's ability to create an output signal that accurately represents the input signal. The actual radiographic exposure required to produce diagnostically acceptable images for a given digital receptor is the function of the receptor's DQE. DQE is important, because systems with higher DQE can use less radiation to achieve the same output image quality that a system with lower DQE achieves with a correspondingly higher radiation dose.[57] Table 3 outlines a comparison between CR and flat-panel DDR systems.[39,53-62]

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Table 3. Comparison of CR and DDR

	CR	DDR

Image Receptor Technology	• The most common type of CR phosphor plate composition is barium fluorohalide doped with europium.
	• There are also CR plates composed of fine needle phosphor made of cesium bromide.
	• The CR reader scans the phosphor plate with a helium-neon laser scanner. The emitted light is then sent to 1 or more photomultiplier tubes to measure its intensity and process the image data within the plate.
		• Flat-panel DDR receptors are classified as either *indirect* or *direct* X-ray conversion detectors; this classification is based on the physics of the X-ray charge conversion within the detector.
		  o *Indirect conversion detectors* are made by adding a-Si photodiode circuitry and a scintillator to form the top layers in the thin film transistor layer.
		  o *Direct conversion systems* use semiconductor materials made of a-Se instead of a-Si. This is a consequence of the X-ray absorption properties and the excessively high spatial resolution of a-Se.

Image Readout Processing Timeline	Image review generally takes 25–40 seconds.	Image review generally takes less than 10 seconds.

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Technological Benefits	• Low initial cost investment • Compatible with a wide range of traditionalradiographic systems • Effective workflow for smaller or low-volume clinics • Multiple CR plate sizes allow for greaterflexibility. • Available in more sizes than DDR	• Faster image acquisition and processing times • Higher spatial resolution • High volume workflow capacity • Both GOS and CsI-based DR detectors have higher dose efficiency than CR. When DR with CsI is used, DDR systems are 2–3 times more efficient at converting dose to signal than CR. This increased dose utilization means that CsI and GOS DR can produce the same image quality as CR at a lower dose. DDR can also produce images with higher contrast resolution than CR using the same dose.
Technological Limitations	• Longer time to image acquisition andviewing • High maintenance cost plus qualityassurance • CR involves more steps because cassette processing takes longer, which causes gaps in workflow. • CR plates need to be replaced every few years due to degradation.	• More expensive initial costs • Requires receptor protection/insurance for accidental dropping or mishandling • Image acquisition is at the point of exposure with portable imaging. • Protection or a cover is recommended if the panel is or can be removed from the bucky

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		tray or table and if weight bearing studies are being performed.

a-Se = amorphous selenium; a-Si = amorphous silicon; CR = computed radiography; CsI = cesium-iodide; DDR = direct digital radiography; GOS = gadolinium oxysulfide.

Data from Bowes. The Benefits of Digital Radiography. *e*RADIMAGING.com. Published August 1, 2015. Accessed August, 2021; Tsoukatos. Mobile Computed Radiography. *e*RADIMAGING.com. Published September 25, 2010. Accessed March 25, 2021; Image Gently. Image Gently – Back to Basics: Ten Steps to Help Manage Radiation Dose in Pediatric Digital Radiography. ImageGently.org. Published 2012; Giering. Pediatric Digital Radiography: Minimizing Exposure. *e*RADIMAGING.com. Published April 1, 2016. Accessed September 5, 2021; Don et al. *AJR Am J Roentgenol*. 2013; JPI Healthcare Solutions. Computed Radiography (CR) vs Digital Radiography (DR). Which Should You Choose? JPI Healthcare.com. Accessed September 5, 2021; Rowlands. *Phys Med Biol*. 2002.[1,56,58-62.] For educational purposes only.

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Imaging Parameters

<u>Exposure Factors and Extremity Technique Charts</u>

RTs must consider the following concepts and exposure and technique considerations when performing lower extremity bone radiography[63-65]:

- Making sure to follow the principles of ALARA (As Low As Reasonably Achievable) in regard to radiation dose.
- X-ray tube potential (kVps) settings for proper penetration of the bone but being careful to not overexpose the surrounding soft tissue
- Setting the proper tube current (mAs), exposure time (sec), source-to-image distance (SID), focal spot size, and other associated parameters
- If using a wall bucky to perform upright extremity imaging, make sure the reciprocating virtual grid suppression software has been properly set.
- If using AEC or APR settings, make sure the proper density settings and cell selection has been chosen as well as back up exposure time.
- Remembering that using electronic cropping is never an option versus the option of tight collimation.

Radiologic technologists should choose the highest possible kVp level consistent with image quality and the part of the body being imaged.[49] Techniques using a higher kVp along with a lower mA notably reduces patient dose, regardless of the image receptor type.[49,65] This is the best way to use exposure factors to reduce patient dose while obtaining a high-quality diagnostic image. When calculating the ideal manual radiographic exposure techniques for extremity radiography, values should be set for adequate penetration of the bone while not overexposing the surrounding soft tissue region.[41,48,65] The radiologist will look for radiographic signs within the soft tissue, such as hemorrhage or joint effusion, to determine the presence of trauma.

An up-to-date properly calibrated technique chart for each radiographic suite is required and mandated by many states' regulatory guidelines as well as a standard of care set forth by The Joint Commission.[48-49] Any technique chart should be based on all the associated technical nuances (X-ray generator, CR, DR, etc.) that make up a particular radiographic suite. Factors should be calculated using phantom testing with support from the facility's consulting radiation physicist and equipment manufacturer. Proper documentation is required in order to make changes and adjustments as required for image optimization. Using measuring calipers is the most accurate way to determine the size of the body part being radiographed in order to identify which imaging

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technique to select from the chart.[48] Using the optimal kVp technique indicated for the anatomy being imaged from a fixed-variable kVp chart is the preferred method for imaging using DR applications.[47] It is important to note that if a particular radiographic suite uses a combination of digital imaging receptors, such as CR and DDR, detector-specific technique charts need to be posted for each imaging receptor.[59]

<u>Exposure Techniques for Orthopedic Casts (Post-reduction)</u>

Radiographs taken after a broken bone of the extremity is orthopedically set and casted are known as post-reduction radiographs. Splints and casts immobilize musculoskeletal-related injuries while providing limb support, decreasing pain, and promoting healing. Orthopedic casts are typically made of either plaster or fiberglass.[43] They differ in their construction, indications, benefits, and risks.[66-67]

The appropriate radiographic exposure settings to image extremities with casts are based on the type of material the cast is made of, its thickness, and whether it is still wet or completely dry. The general rule of thumb is that most large, full plaster casts require a doubling of the mAs or a 12% to 15% increase in kVps.[43] If the plaster cast is still wet, it may require an increase of 3 times the mAs to obtain a proper post-reduction radiograph. Casts made of pure fiberglass mesh are extremely radiolucent, and normal radiographic exposure factors may be utilized. If the cast is composed of a 50% equal mix of fiberglass and plaster, then there needs to be a 50% increase in exposure technique.[43,57] These factors are important not only to obtain high-quality diagnostic post-reduction X-rays but to minimize repeat studies that increase overall patient dose.[43,68]

<u>Digital Exposure Indicators and Deviation Index</u>

Manufacturers of DR equipment, regardless of the type of receptor (DDR or CR), use different values and terminology to indicate overexposure and underexposure. This may be confusing because with some devices, the number should be low for less exposure, and with other devices, lower values should be used for higher exposure. RTs should check with the manufacturer to verify how their system's exposure index (EI) works and how it relates to dose and classic "speed setting" while remaining within the recommended parameters for each anatomical region being radiographed.[48,59-60] In recent years, the American Association of Physicists has collaborated with vendors, manufacturers, physicists, and quality assurance specialist to eventually standardize EIs among the many digital receptor products that are available on the market today.[48,59,69] This collaboration yielded a follow-up report in 2018 that provided additional updates on changes with manufacturers' EIs.[68-69] It is important to note that the EI is not representative of an individual

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patient dose metric.[48,53,59] Table 4 outlines the standardized terminology when referring to the various EIs used in DR.[59,70]

Table 4. IEC Standardized Terminology

Terminology	Definition
Exposure index (EI)	Amount of exposure received by the image receptor. EI is dependent upon the type of examination, imaging processing, and exposure
Target exposure index (EI_T)	Reference exposure when image is optimally exposed. Dependent on body part, view, procedure, and imaging receptor
Deviation index (DI)	Quantifies how much the actual EI varies from EI_T. It provides immediate feedback about the adequacy of the exposure

IEC = International Electrotechnical Commission

Data from Giering Pediatric Digital Radiography: Minimizing Exposure. *e*RADIMAGING.com. Available at: http://www.eradimaging.com/course/853. Published April 1, 2016; International Electrotechnical Commission. Medical Electrical Equipment-Exposure Index of Digital X-Ray Imaging Systems-Part 1. Geneva, Switzerland: IEC; 2008.[59,70] For educational purposes only.

Radiographic Grids (Conventional and Virtual Suppression Software)

The goal of any radiographic antiscatter grid is to minimize the amount of scatter radiation that reaches the image receptor, while allowing the primary radiation to pass through it. Current DR best practices indicate that grids should be used when radiographic exposure exceeds 70 kVp or when the anatomy being imaged is more than 10 cm thick. In pediatric DR applications where the body measurements are less than 12 cm thick, grids are not recommended due to the increase in exposure factors that are required.[70-72] Conventional grid specifications and choices are based on the parameters below[56,71-75]:

- Grid Ratio: A ratio of the height of the lead strip to the distance between them by the interspace material. A grid ratio of 8:1 is recommended when filming below 90 kVp, and a grid ratio of 10 or 12:1 is recommended for examinations requiring kVp ranges greater than 90 kVp.
- Grid Frequency: The number of lead strips or line pairs per inch or line pairs per millimeter (lp/m).

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- Grid Patterns: The most common grid pattern is the parallel linear format. There are 2 linear arrangements:
    - Short dimension: Lead strips are parallel to short dimension; also known as a “decubitus” grid
    - Long dimension: Lead strips are parallel to long dimension, which is the standard configuration
- Contrast Improvement Factor: Ratio of the contrast of a finished radiograph taken with the grid when compared to the contrast of a radiograph taken without the grid.
- Grid Cutoff: Uneven density or loss of density on the resultant image due to undesirable absorption of the primary X-ray beam by the grid.

Embedding an antiscatter radiographic grid into the CR plate offers RTs the full flexibility of having a grid within a digital capture device at the ready.[71-72] An example of an imaging procedure that would benefit from this configuration is cross-table shoulder radiography.[74] Recently, commercial software packages (referred to as virtual grid suppression software) have been developed by various X-ray equipment manufacturers that eliminates the need for antiscatter grids.[71,73] Radiographic grid suppression software removes the stationary grid patterns, thus preventing moiré artifacts (summation artifacts caused by the scanning laser beam overlapping with the grid line structure) from being generated on the resultant image.[53,56] The moiré pattern occurs when the laser scan lines that read the digital image run parallel to the gridlines with a frequency approximately equal to the laser scanning frequency.[53-54] Grid suppression algorithms can help eliminate the visibility of grid lines when utilizing a stationary grid (eg, performing a cross-table lateral projection of the skull for trauma). Otherwise, radiographic grid suppression software can remove the moiré lines from an image.[52-53,73] When the software is in place, a standard 103 lines-per-inch (lpi) grid is sufficient and customary. In the absence of this software, a 152-lpi grid or higher is required.[62] When performing lower extremity radiography, it may be beneficial to use an antiscatter grid when imaging large body parts such as the hip or pelvis.[74-75]

Imaging Various Fracture Types

Lower extremity bone radiography is used to diagnose bony fractures, acute injuries due to trauma, and gross destruction of bone, as well as suspected pathological conditions of the musculoskeletal system.[76] Even though most minor bony injuries are difficult to detect on conventional DR, X-ray may be more specific than magnetic resonance imaging (MRI) in being able to determine possible causes of injury due to its ability to visualize calcification patterns and periosteal reactions of the

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bony tissue.[77] Injuries (eg, fractures, dislocations, and sprains) are broken down to 2 major classifications: acute and chronic.[78] Lower extremity radiography can be used to diagnose potential acute bone fractures or dislocations due to trauma by a variety of causes (eg, falls, motor vehicle accidents, sports injuries, etc). Fractures are classified by their complexity, location, and other features (Table 5).[78]

Table 5. Types of Fractures

Type of Fracture	Description
Transverse	Occurs straight across the bone's axis
Oblique	Occurs at an angle to the bone's axis
Spiral	A fracture around the axis of the bone
Comminuted	Several breaks and small fragments pieces between 2 large segments of bone
Impacted	One fragment is driven into the other, usually because of extreme compression
Greenstick	A partial fracture or incomplete fracture in which only one side of the bone is broken
Open (or Compound)	A fracture in which at least one end of the broken bone tears through the skin
Closed (or Simple)	A fracture in which the skin remains intact with no penetration

Data from Betts et al. Fractures: Bone Repair. In: *Anatomy & Physiology*. Houston, TX: OpenStax; 2021.[78] For educational purposes only.

Radiographically occult and subtle fractures are difficult to diagnose with conventional imaging techniques. They may be categorized as: (1) high-energy trauma fractures, (2) fatigue fractures from cyclical and sustained mechanical stress, and/or (3) insufficiency fractures that occur in weakened bone (eg, in patients with osteoporosis and those who are postradiotherapy). Fractures, dislocations, foreign bodies, and tumors, although numerous in type, are usually easily visualized on standard radiography.[79] But, the differences in inflammatory and noninflammatory joint disease

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may be more difficult to image, recognize, and classify.[80] Additional imaging may be required such as 3D-computerized tomography or MRI for soft tissue detail and evaluation.

Proper Patient Positioning Concepts

It is important that RTs communicate well with and provide good direction to the patient to produce quality diagnostic radiographs. Prior to initiating the imaging study, a careful and tactful physical examination of the area of interest should be performed to locate and remove as many artifacts as possible without causing the patient discomfort or concern. It is usually possible to carry out this examination during positioning, which also presents an opportunity to ask the patient if there anything on their person that must be removed in a private changing booth if necessary. If the patient is a woman of childbearing age, RTs should ask if there is any possibility that the patient is pregnant. The RT should note the date of the patient's last menstrual period in her medical record.[81] These techniques go hand-in-hand with setting up the proper SID and utilization of accessories such as grids, cassette holders, and other devices.[56]

Understanding patient positioning requires the RT to know the basic terminology relating to patient positioning, which includes[82-86]:

- *Anterior* is towards the front of the body or anatomy.
- *Posterior* is towards the back of the body or anatomy.
- *Superior* is towards the top of the body or anatomy.
- *Inferior* is the bottom of the body or anatomy.
- *Medial* denotes the direction towards the midline of the body or anatomy.
- *Lateral* specifies a region away from the midline of the body or anatomy.
- *Proximal* is towards the center of the body or the point of origin of a body part.
- *Distal* indicates being away from the body's center or the farthest point from the anatomy's point of origin.
- *Superior or cranial* is towards the patient's head.
- *Inferior or caudal* is towards the patient's feet.
- *Erect* is the patient in the sitting or standing position for the projection.

- The *sagittal plane (lateral plane)* is a vertical plane that goes from front-to-back (parallel) to the median plane.
- The *coronal plane (frontal plane)* is the vertical plane that is perpendicular to the median plane and goes from side-to-side.
- *Pronation* corresponds to the movement of the hand is when the palm is face down.
- *Supination* corresponds to the movement of the hand when the palm is face up (the opposite of pronation).
- *Prone* corresponds to the patient lying face down.
- *Supine* corresponds to the patient lying face up, on their back.
- *Median sagittal plane* divides the body into right and left halves. Any plane parallel to this that divides the body into unequal right and left portions is simply known as the *sagittal plane* or *parasagittal plane*.
- *Transverse* or *axial plane* divides the body into a superior part and an inferior part (upper and lower parts).
- *Ipsilateral* denotes the same side of the body.
- *Contralateral* denotes the opposite side of the body.
- The *recumbent* position is the patient lying down on their back.
- *Projection* is the direction of the X-ray's central ray projecting from the tube that is relative to the planes of the body.
- *Dorsiflexion* refers to flexion at the ankle, so that the foot points more superiorly.
- *Plantarflexion* refers to the extension at the ankle, so that the foot points inferiorly.
- *Eversion* is an outward stress movement of the foot at the ankle joint.
- *Inversion* is inward stress movement of the foot as applied to the foot without rotation of the leg.

- *Valgus* describes the bending of the anatomy outward or away from the body's midline. When pertaining to the foot, *valgus* is sometimes used to describe eversion stress of the ankle joint; the mid-calcaneal line is deviated away from the midline.
- *Varus,* meaning "knock-kneed," describes the bending of a part of the body inward or towards the midline. When pertaining to the foot, *varus stress* is sometimes used to describe inversion stress applied at the ankle joint; the mid-calcaneal line is deviated towards the midline of the body.
- *Adduction,* when pertaining to the foot, is the movement of the metatarsals as a unit toward the midline, pivoting at the base.
- *Abduction,* when pertaining to the foot, is the movement of the metatarsals as a unit away from the midline, pivoting at the base.

When RTs join a new radiological imaging department, whether it be inpatient or outpatient, they should be given a copy of the departmental positioning protocols and guidelines as well as the radiation safety manual. These guidelines and protocols are made up of a variety of factors including, but not limited to, the following[82-84]:

- The radiologist on staff and both on and off-site subspecialists
- The patient's age
- Radiation dose factors for each body part in consideration of radiosensitive regions
- Input from the specialty physician on staff including orthopedics, rheumatology, as well as hand and trauma surgeons
- Potential regional nuances and prevalence of disease or trauma or surgical procedures common to that particular geographic area

With that noted, this course is a summary of what most facilities in the US consider to be part of the standard protocol. There are also sub-views that are considered supplemental that may be requested by the radiologist or ordering clinician. If the patient sustains an acute injury or was involved in a trauma, it's important for the RT to confirm with either the radiologist or emergency clinician whether there are certain positions in which the patient should not be placed based on the type and injury location. Any potential alternate views should also be discussed with the clinician if they may benefit the patient and lead to less pain based on the type of injury that was sustained.

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Radiographic positioning pertains to the way the RT positions the patient's body to make sure that the anatomy being imaged is in the proper plane of view to the image receptor. Part of any positioning protocol is also making sure that the proper source-to-image detector distance and object-to-image receptor distance (OID) are set as per the department protocols.[81] The SID is the distance of the X-ray tube from the image receptor, affecting magnification and other geometric distortion factors. The OID is the distance between the anatomical part being imaged to the image receptor.[82] For X-ray imaging of the lower extremities, the standard SID is 40 inches (102 cm).[87]

When an RT X-rays anatomical regions like the fingers, hand, wrist, forearm, and elbow, many times the patient is sitting in a chair at the edge of the table, and the positioning is done on a CR cassette or DDR receptor plate also on the table; this method is commonly referred to as "tabletop."[83] The table should be in a locked position and not free-floating. RTs should make sure the chair is both comfortable, properly sanitized, and depending on the patient's size, weight appropriate, if need be, to guarantee patient safety and a successful radiographic study. RTs should also make sure that any items that could attenuate the X-ray beam such as rings, bracelets, etc, are removed and secured. It is equally important that RTs use the appropriate side markers to note that the anatomy being imaged is either the "right" or "left." Best practice parameters from the American College of Radiology (ACR) indicate that RTs should use lead anatomic side markers placed on the image receptor. The guidelines also state that electronic annotations of the right or left side during digital postprocessing are not acceptable substitutes for using physical markers on the receptor.[48,50,70,88]

Below is a summary of key radiographic positioning concepts when performing lower extremity bone radiography[89-93]:

- RTs should use the proper digital image receptor size for the anatomical region being imaged in line with the proper SID.
- The basics of any radiographic positioning protocol are to always obtain a minimum of 2 projections 90° from each other as a starting point.
- Regardless of which digital imaging capture device is being used, tight collimation to the body part being imaged is critical for a quality imaging study.
- Any anatomical region being imaged requires proper labeling with a right or left side marker on the digital capturing device.
- RTs should ensure that all ALARA principles, including shielding, are being followed as per the current ACR Practice Parameters and any other local, state, or federal guidelines pertaining to radiation safety.

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- Verification of pregnancy status should follow ACR and departmental preset guidelines and protocols.
- RTs should use radiolucent positioning devices to keep the patient both immobile and comfortable.
- When placing multiple exposures on one CR cassette or DDR receptor, the side of the unexposed cassette should always be covered with lead.
- If there is any doubt about putting patients in certain positions due to trauma or discomfort, RTs should consult with either the radiologist, referring clinician, or emergency department (ED) physician.
- If any studies require "weight holding" or "stress views," doing so should first be cleared with either the radiologist, referring clinician, or ED physician. A specific weight amount that's considered safe for the patient and the projection should also be confirmed.
- Similar caution should be taken when using positioning sandbags to minimize movement of a patient's limb if necessary. RTs should ensure that using a sandbag to stabilize the patient's limb will not lead to further injury or that the sandbag itself, as a radiopaque device in in the field-of-view (FOV), will not interfere radiographically. Any sponges or other positioning assistance devices should be radiolucent.
- The RT is responsible for setting the proper SID, radiographic exposure factors (AEC, APR, or technique chart consultation), the choice of using a conventional or virtual antiscatter grid based on the anatomy being imaged, and whether or not to perform the study on a tabletop, using a wall bucky, or using a table grid.
- When performing extremity radiography with the patient in a standing position against a wall holder or bucky, RTs should ensure that the patient is stable so that there is no risk of falling due to their clinical condition or because of any acute trauma or injury they may have sustained.
- In general, when a trauma patient is sent from the ED with a splint, the splint should not be removed during imaging due to possible acute trauma. For most patients with fractures, the X-rays obtained are more than adequate to define the injury and determine a treatment plan. If the fracture pattern is complex, it may be helpful to temporarily remove the splint. However, this should *only* be performed by a physician who can ensure that the patient and fracture site are handled properly, with the utmost safety in mind.

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- When using DR imaging systems, the upright wall bucky can be angled in different positions. This should be taken into consideration when performing projections that in the past may have required more patient discomfort or movement.

Imaging Concepts and Techniques

Foot, Toes (Phalanges) Calcaneal, and Sesamoid

Foot fractures are among the most common injuries evaluated by primary care and ED physicians as 10% of all bone fractures occur in the foot.[94] If there is clinical concern for a midfoot and/or Lisfranc injury then, at a minimum, a weightbearing anteroposterior (AP) view is recommended in addition to routine projections (Figure 16).[21,94-95] Non-weightbearing views of the foot are not adequate for the assessment of alignment as the bones of the feet are not in their truly functional state; weightbearing imaging of the foot and ankle is essential for accurately evaluating patients for conditions such as flat foot, ankle arthritis, and hallux valgus.[94-95]

When evaluating X-rays of the feet and toes, the terms valgus and varus may be used to describe the way the bone or joint appears to bow or angulate in the coronal plane. When the distal part appears to be more lateral, it is called valgus. When the distal part appears to be more medial, it is called varus. So, for example, if the apex of a joint points medially, any potential condition would be called valgus, since the distal part points laterally.[96] These descriptors are important for accurately examining and diagnosing foot injuries as hindfoot malalignment is a recognized cause of foot and ankle disability and may result in degenerative joint disease.[97-100]

Figure 16. Sesamoids of the Foot

An AP radiograph depicting the sites of hallucal (1), interphalangeal joint (2) and lesser metatarsal (3) sesamoids of the foot.

AP = anteroposterior.

Nwawka et al. *Insights Imaging*. 2013.[21] For educational purposes only.

Metatarsal shaft fractures of the foot are a common injury and usually occur as a result of twisting injuries to the foot due to a static forefoot, or by excessive axial loading, falls from a high point, or direct trauma. A standard foot X-ray series that includes AP, lateral, and oblique views is appropriate in order to diagnose most metatarsal shaft fractures.[101] Sesamoid bone fractures of the foot are uncommon but are usually a result of direct injury to the foot from jumping or landing (Figure 16).[21,101-102] The most common sesamoid bone to be injured is the medial sesamoid of the big toe.

<u>Imaging the Sesamoid Bones</u>

In order to properly image the sesamoid bones, RTs will need to obtain an axial view of the fibular and tibial sesamoids under the first metatarsal head. There are 2 techniques for performing this scan: one with the patient lying supine and the other with the patient lying prone. The positioning goal for the RT is to have the patient's toes extended to bring the phalanges out of view and bring the sesamoids into view. The first position should have the patient lying prone on the table with their toes on the imaging receptor (IR) in a flexed position, with the central ray of the X-ray beam directed parallel to the bottom of the foot. The second positioning option is to put the patient in a supine position, with their knees extended, and ankle plantar flexed approximately 10°, with a sheet or string positioned under the patient's toes holding them in the extended position. The IR is then placed under the heel with the X-ray beam 90° from the IR. RTs can also obtain a weight-bearing radiograph of the sesamoids by placing the IR 90° to the floor and the X-ray beam horizontal to the ground. The patient's foot and toes should be positioned directly behind the IR, with a roll or towels positioned underneath the toes to hold them in the extended position. The patient's knee should be flexed and plantar surface of the midfoot and hindfoot should be 45° off the floor. The tangential or axial view of the sesamoids can be different based on the great toe's dorsiflexion.[102]

<u>Foreign Body Imaging</u>

Performing imaging studies of the foot and ankle may be needed in order to detect or rule out the presence of foreign bodies as a potential source of pain or injury. When it comes to foreign body detection, radiography is considered to be the imaging modality of choice because of its ability to detect most foreign bodies, its wide availability, low cost to the patient, and relatively low radiation exposure. Objects denser than soft tissue will attenuate and absorb more X-rays, and therefore, are visualized in greater contrast to the surrounding areas. Due to increased density, objects such as metal, glass, and gravel are considered to be radiopaque (dense structures that resist the passage of

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X-rays). Using DR imaging receptors to take multiview projections when imaging the foot for potential foreign bodies and examining soft tissues provides very specific and ideal imaging. However, foreign objects such as gravel and graphite in or near bony structures may be difficult to identify, because these objects have a similar density to bone. Radiography is also less effective for identifying radiolucent objects such as wood, plastic, and organics (such as thorns or spines) in soft tissue due to similar densities.[103]

<u>Imaging the Hindfoot</u>

Hindfoot malalignment is a well-known cause of foot and ankle disability. For preoperative planning and clinical follow-up, reliable radiographic assessment of hindfoot alignment is important. In addition to AP and lateral weight-bearing radiographs of the ankle, routine foot radiographic protocols are not diagnostically accurate because of superimposition of the foot and ankle bones. However, the hindfoot alignment view and the long axial view are 2 specialty projections that can assist in imaging the hindfoot.[97]

<u>Common Injuries and Conditions</u>

Common injuries and pathology to the foot, toes, and calcaneus include[103-115]:

- <u>General fractures</u>: Involves the various bones of the foot: talus, cuboid, navicular, and cuneiform.
- <u>Avulsion fracture</u>: A fracture of the fifth metatarsal styloid, which is also known as a pseudo-Jones fracture or a dancer fracture. This is a common injury which is usually associated with a related ankle sprain.
- <u>Turf toe</u>: Caused by a bending upward of the toe, which causes damage to the ligaments of the metatarsal head. Turf toe refers to a sprain, partial tear, or complete tear of the first MTP plantar plate.
- <u>Bony pathologies</u>: Diseases and conditions of the bone, some of which include osteoporosis, osteoarthritis, osteomyelitis, rheumatoid arthritis, and gout.
- <u>Foreign bodies</u>: Foreign objects in or around the foot, calcaneus, or toes causing pain or injury. As noted above, these may be evaluated radiographically or with soft tissue exposure techniques.
- <u>Chopart injury</u>: A fracture/dislocation of the midtarsal joint (Chopart joint) of the foot (ie, talonavicular and calcaneocuboid joints). The foot is usually dislocated medially and superiorly as it is plantar flexed and inverted. This type of injury is usually due to a high-energy impact type of trauma (Figure 17).[107]

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- Snowboarder's fracture: Formally known as a lateral talar process fracture, this is a talus fracture that can mimic a lateral ankle sprain. It may be isolated or part of a more complex ankle fracture.
- Jones fracture: A fracture of the base of the fifth metatarsal bone that involves fourth and fifth metatarsal articulation.
- March fracture: Also known as a fatigue or a stress fracture of the metatarsal due to repetitive stress or impact to the area.
- Stress fracture: A fracture that occurs when bone is subjected to repeated mechanical stress that results in a microscopic fracture. It often occurs when the frequency or degree of physical activity is significantly increased, and as a result, it is common among military recruits, athletes, and runners. This type of fracture commonly affects the second and third metatarsal shafts.
- Lisfranc joint fracture-dislocation: The most common type of fracture-dislocation involving the foot. It corresponds to the fracture-dislocation of the articulation of the tarsus with the metatarsal bases. This type of fracture-dislocation can be further categorized as:
    - HOMOLATERAL: A lateral displacement of the first to fifth metatarsals or of the second to fifth metatarsals where the first MTP joint remains congruent.
    - DIVERGENT: A lateral dislocation of the second to fifth metatarsals with medial dislocation of the first metatarsal.
    - ISOLATED: A fracture that involves 1 or 2 metatarsals that dislocate dorsally in isolation.
- Calcaneal fracture: Most commonly occurs during high-energy events leading to axial loading of the bone, but it can occur with any injury to the foot and ankle. Falls from a high point and car accidents are the most common causes of this type of fracture. Jumping onto hard surfaces, blunt or penetrating trauma, and twisting/shearing events may also cause this type of fracture, which causes the bone to flatten, widen, and shorten. A calcaneal fracture can be further classified as:
    - EXTRA-ARTICULAR: An avulsion injury of either the calcaneal tuberosity from the Achilles tendon, the anterior process from the bifurcate ligament, or the sustentaculum tali.
    - INTRA-ARTICULAR: A fracture where the talus acts as a hammer or wedge that compresses the calcaneus at the angle of Gissane.

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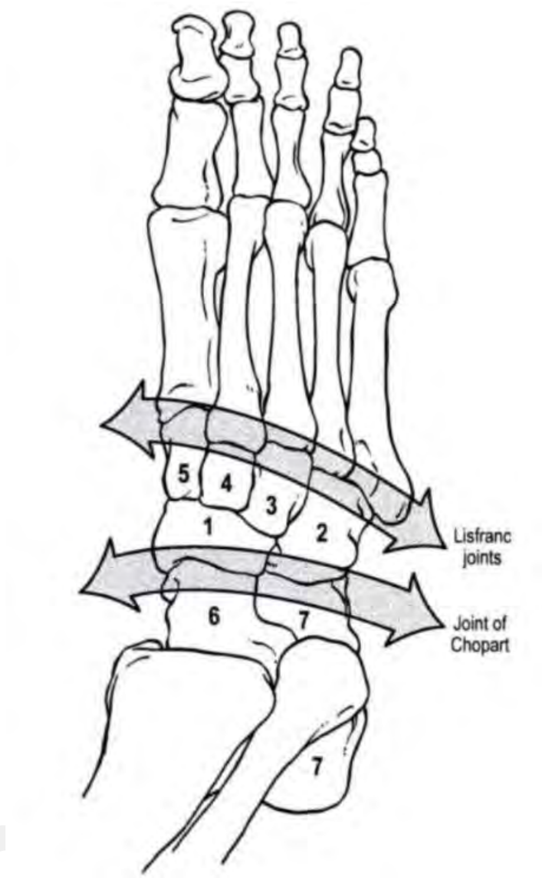
- Calcaneal fractures may also be further categorized as *displaced* or *non-displaced.*
- *Tongue-type* calcaneal fractures are longitudinal fractures that involve the calcaneal tuberosity.

- Sesamoid bone abnormalities: May include fracture/dislocation, infection, and osteochondritis/avascular necrosis (AVN).

Figure 17. Illustration of the Lisfranc Joint and the Joint of Chopart



An illustration of the Listfranc joints and the Joint of Chopart (grey arrows) as they relate to other bones in the foot, notably the navicular (1), cuboid (2), lateral cuneiform (3), intermediate cuneiform (4), medial cuneiform (5), talus (6), and calcaneus (7).

Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005.[107] For educational purposes only.

- Phalangeal fractures: The most common type of foot fracture seen in pediatric patients. The most common mechanisms of injury include[115]:
    - Axial loading (stubbing toe)
    - Abduction injury, often involving the fifth digit
    - A crush injury caused by a heavy object falling or running over the foot (ie, a motor vehicle tire running over the foot)
- Less common mechanisms of injury include joint hyperextension or hyperflexion, which can lead to spiral or avulsion fractures.[115]

Demonstrations and specific positioning instructions are essential for achieving high-quality X-ray imaging studies for the toes, sesamoid bones of the foot, and for the foot in general. Table 6 outlines the techniques for optimal imaging of the toes.[90,107,116-119] Table 7 outlines the proper techniques for optimal imagine of the sesamoid bones of the foot.[107,120-124] Table 8 delineates the proper positioning techniques and X-ray imaging information for successful projections of the foot.[97,125-137] Table 9 offers specific information for imaging the calcaneus.[90,102,107,136-143]

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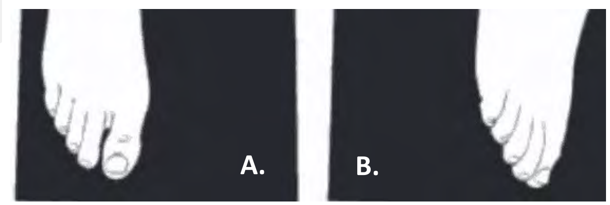
Table 6. Projections and Positioning Techniques for the Toes

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP and DP	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should be instructed to flex the knee of the affected side so the plantar surface of the toe being imaged can be in place on the IR (Figure 18).[107] • The central ray of the X-ray beam should be centered on the MTP joint	• This projection is part of a standard radiographic protocol. It is used for evaluating the digit in question for a disease process, trauma, lesions, foreign bodies, or other pathology, such as gout or osteoarthritis. • No rotation should be present; the shafts of the phalanges and metatarsals should appear equal on either side. The bases of the metatarsals are the most	**Figure 18. AP and Medial Oblique Positioning of the Toes (Phalanges)**  Positioning of the feet and toes for AP (A) and medial oblique (B) radiographs together without collimation. Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005.[107] For educational purposes only.

	in question and perpendicular to the IR. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required (Figure 19).[116-117]	reliable rotation indicator on the AP view.[118]	**Figure 19. Radiographs of the Toes (Phalanges)** 

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			  Standard X-rays of the foot in AP (A), medial oblique (B), and lateral (C) views.

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			Di Muzio. Osteomyelitis - middle toe distal phalanx. Case study. Radiopaedia.org. Published September 12, 2016. Accessed September 2021; Ho. First distal phalanx (toe) fracture. Case study. Radiopaedia.org. Published May 2, 2016. Accessed September 2021.[116-117] For educational purposes only.
Mediolateral	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should be placed in a lateral recumbent position with the affected toe extended. • Depending on the toe of interest and to reduce magnification, the affected	• This projection is part of a standard radiographic protocol. It is used for evaluating the digit in question for a disease process, trauma, lesions, foreign bodies, or other pathology, such as gout or osteoarthritis. • To prevent superimposition with the other toes, use radiolucent tape or rolled up gauze to separate the unaffected toes.[119] • If there is inadequate rotation, there will be equal	

	leg may be rotated medially (for the first to third toes) or laterally (for the fourth and fifth toes).[119] • To better evaluate each toe, RTs may need the assistance of various positioning devices or aids, such as radiolucent tape or a tongue depressor. When using these types of restraint, both patient comfort and safety are key to avoid further injury or motion artifacts.[119] • The central ray of the X-ray beam should be centered on the MTP joint in question and perpendicular to the IR**.**	concavity on the plantar and dorsal surfaces of the proximal phalanx, and the condyles will not be superimposed.[119]	

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	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Medial Oblique	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should be instructed to flex the knee of the affected side so that the plantar surface of the toe being radiographed can be place on the IR. • Gently oblique the foot 30°–45° towards the fifth metacarpal (Figure 18).[107]	• This projection is part of a standard radiographic protocol. It is used for evaluating the digit in question for a disease process, trauma, lesions, foreign bodies, or other pathology, such as gout or osteoarthritis.	

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	• The central ray of the X-ray beam should be perpendicular to the PIP joint of the digit being radiographed. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

Radiographic projections and positioning techniques for imaging the toes (phalanges). The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DP = dorsoplantar; DDR = direct digital radiography; IR = image receptor; MTP = metatarsophalangeal; PIP = proximal interphalangeal; SID = source-to-image distance.

Data from Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Clifton Park, NY: Thomson-Delmar; 2006; Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Di Muzio. Osteomyelitis - middle toe distal phalanx. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/47634. Published September 12, 2016; Ho. First distal phalanx (toe) fracture. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/44688. Published May 2, 2016; Gorton et al. Toes (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/47986. Published September 12, 2016; Er et

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al. Toes (lateral view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/78651. Published June 8, 2020.[90,107,116-119] For educational purposes only.

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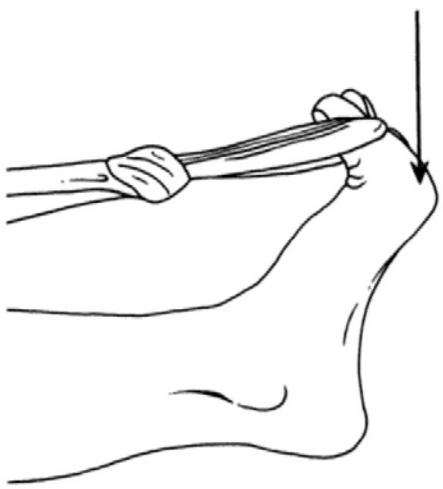
Table 7. Projections and Positioning Techniques for the Sesamoid Bones of the Foot

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
Tangential Projection, Holly Method	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The affected leg should be extended; the foot should be at an angle of 75° dorsiflexion with the plane of the IR. The toes should be secured in a flexed position by the patient (using a strip of a radiolucent positioning band if needed). The	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This specialty view of the sesamoid bone can be used in the evaluation of both sesamoid bones and accessory ossicles that can be affected by trauma, infection, degenerative disease, and osteonecrosis.[21] • This projection will reveal the sesamoids and sagittal	**Figure 20. Tangential (Holly Method) Positioning of the Sesamoid Bones** 

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	patient should be instructed to gently pull back on the band prior to the exposure (Figure 20).[107,120] • The central ray of the X-ray beam needs to be perpendicular and tangential to the first MTP joint.[120] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	plane relationship of metatarsal heads. • Although the Holly Method is usually more comfortable for the patient, the increased OID is greater. This distance will cause an increase in distortion and magnification, so the sesamoid bones will appear more magnified, with some accompanying loss of bony definition.[121]	 Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Er. Normal toe series. Case study. Radiopaedia.org. Published April 12, 2020. Accessed September 2021.[107,120] For educational purposes only.
Tangential Projection, Lewis Method	• The patient should be safely positioned on the table in the prone position and accessible to the proper SID for the X-ray tube (40 in or 102 cm).	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist.	

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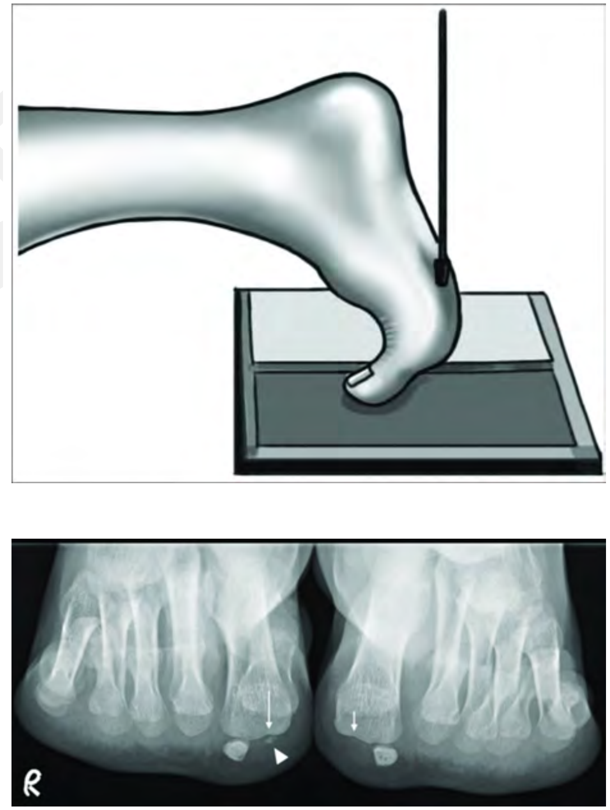
	• The toes should be in a dorsiflexion position, with the ball of the foot resting perpendicular to the IR (Figure 21).[122] • The foot should be placed in a dorsiflexion position until the plantar surface forms a 15°–20° angle to the vertical. The X-ray beam should be directed skyline and collimated closely to the metatarsal heads.[122] • Ensure that the long axis of foot is not rotated; place immobilization devices or other support mechanisms on both sides of the foot to prevent movement. • The central ray of the X-ray beam should be perpendicular to the	• This specialty view of the sesamoid bone can be utilized in the evaluation of both sesamoid bones and accessory ossicles that can be affected by trauma, infection, degenerative disease, and osteonecrosis. • When performed correctly, the projection demonstrates the sesamoid bones free of the heads of the metatarsal bones.	**Figure 21. Tangential (Lewis Method) Positioning of the Sesamoid Bones**  Batta et al. *Indian J Musculoskelet Radiol*. 2019.[122] For educational purposes only.

	posterior aspect of the first MTP joint. Depending on the amount of dorsiflexion of the foot, the central ray may need to be slightly angled for a true tangential projection.[123] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

Radiographic projections and positioning techniques for imaging the sesamoid bones of the foot. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

CR = computed radiography; DDR = direct digital radiography; IR = image receptor; MTP = metatarsophalangeal; OID = object-to-image receptor distance; SID = source-to-image distance.

Data from Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Er. Normal toe series. Case study. Radiopaedia.org. Published April 12, 2020. Accessed September 2021; Nwawka et al. *Insights Imaging*. 2013; Radiographic Positioning: Sesamoids - Axial. Wikiradiography.net. Accessed September 2021; Batta et al. *Indian J Musculoskelet Radiol*. 2019; Tangential

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Projection: Toes-Sesamoids. RADTECHONDUTY.com. Published June 9, 2012. Accessed September 2021.[107,120-123] For educational purposes only.

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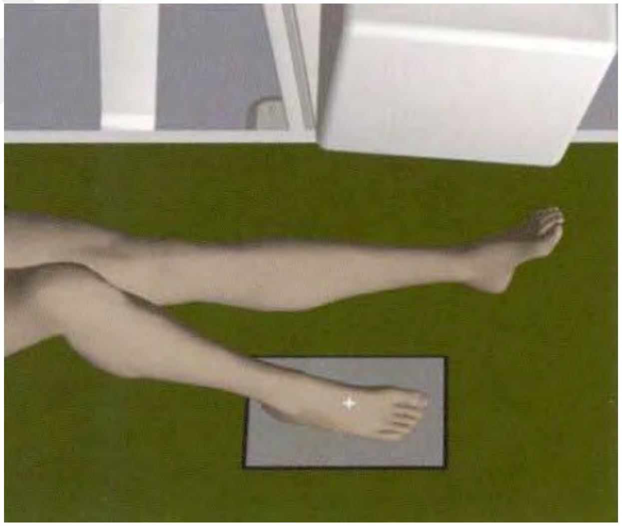
Table 8. Projections and Positioning Techniques for the Foot

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP and DP	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should be instructed to flex the knee of the affected side so that the plantar surface of the foot being imaged can be placed on the IR (Figure 22).[124] • The central ray of the X-ray beam should be angled 10° towards the heel and	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot for a disease processes, trauma, lesions, foreign bodies, or other pathology. • The AP-DP view demonstrates the metatarsals in their natural anatomical position. • This projection can be improved with the use of a wedge-type compensating filter, which may be needed due to the differences in thickness and attenuation	**Figure 22. AP-DP Positioning of the Foot** 

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	centered to the base of the third metatarsal. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	of the X-ray beam between the toe area and the much thicker tarsal area of the foot.	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

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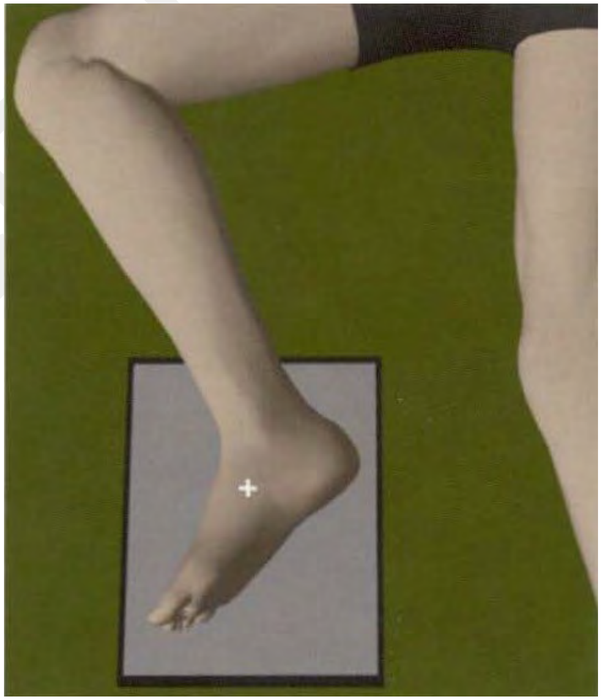
Mediolateral	• The patient should be safely positioned on the table in either a supine or sitting position accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should flex the knee of the affected side so that the plantar surface of the foot is placed on the IR. The affected leg should be rotated externally until the distal limb is parallel to the table (the patient may have to half-roll onto the affected side). The lateral aspect of the foot should be in contact with the IR (Figure 23).[124-126] • The nonaffected side should be kept posterior to prevent over-rotation. If	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot for a disease process, trauma, lesions, foreign bodies, or other pathology. • This view provides a critical overview of the anatomy of the foot and is also used to assess the plantar soft tissues for possible foreign bodies and/or plantar fasciitis.[127] • This view demonstrates the foot in profile from the distal phalanges, to the skin margins of the posterior calcaneus, and extending superiorly to the talocrural joint.[127]	**Figure 23. Mediolateral Positioning of the Foot** 

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	able, the patient should position the affected foot slightly dorsiflexion. The planter surface should be perpendicular to the IR.[125] • The central ray of the X-ray beam should be directed to the base of the fifth metatarsal. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Dixon. Normal foot X-rays. Case study. Radiopaedia.org. Published May 4, 2015. Accessed October 5, 2021.[124,126] For educational purposes only.
Medial Oblique	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot for a disease process, trauma, lesions, foreign bodies, or	

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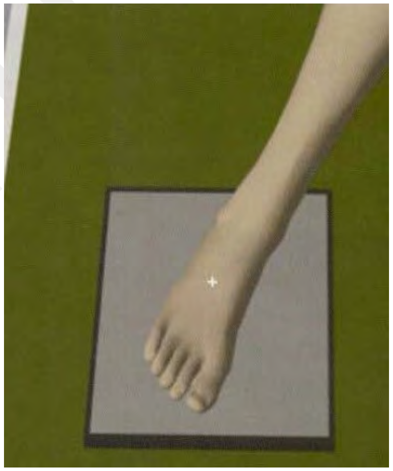
	102 cm). • The patient should flex the knee of the affected side so that the plantar surface of the foot being imaged can be placed on the IR. • Gently oblique the affected foot 30°–40° medially. (Figure 24).[102,124] • The central ray of the X-ray beam should be directed to the base of the fifth metatarsal. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	other pathology. • The medial oblique projection is the most important projection for evaluating the tarsal bones that form the midfoot and forefoot structures.[128]	**Figure 24. Medial Oblique Positioning of the Foot**  

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			Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Walt, Haynie. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021. Radiograph image courtesy of Steven Kautz, MD.[102,124] For educational purposes only.
Weight-Bearing AP-DP	• The patient should stand erect (normal and base of • gait) on a specially designed weight-bearing device that is customized for this study; there should be a slot for the IR to be placed either in or on. • The IR should also have a protective cover; RTs should check the weight capacity to ensure it can properly handle the	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is useful for demonstrating the condition of the patient's longitudinal arches underneath their full body weight. This projection is also used to evaluate the Lisfranc joint for potential	**Figure 25. Bilateral AP-DP Positioning for Weight-Bearing Imaging of the Feet** 

	patient's weight. • The patient's foot should be planted on the detector with the lower leg perpendicular to the floor (weightbearing surface). It is important to make sure the patient can safely stand and maintain their balance without assistance prior to the imaging study.[129-130] • The proper SID for the X-ray tube is 40 in or 102 cm. • The device should be configured so that the central ray of the X-ray beam is angled 10°–15° towards the heel directed to the base of the third metatarsal of the foot (Figure 25).[131-132]	injuries missed on routine imaging studies. If ordered by the treating physician, AP imaging of both feet can help detect subtle malalignment of the injured side.[133]	 Podiatry X-Ray Positioning. WikiRadiography.net. Available at: http://www.wikiradiography.net/page/Podiatry_X-ray_Positioning. Accessed September 30, 2021; O'Donnell. Missed Lisfranc fracture. Case study. Radiopaedia.org. Published March 28, 2012. Accessed October 2021.[131-132] For educational purposes only.

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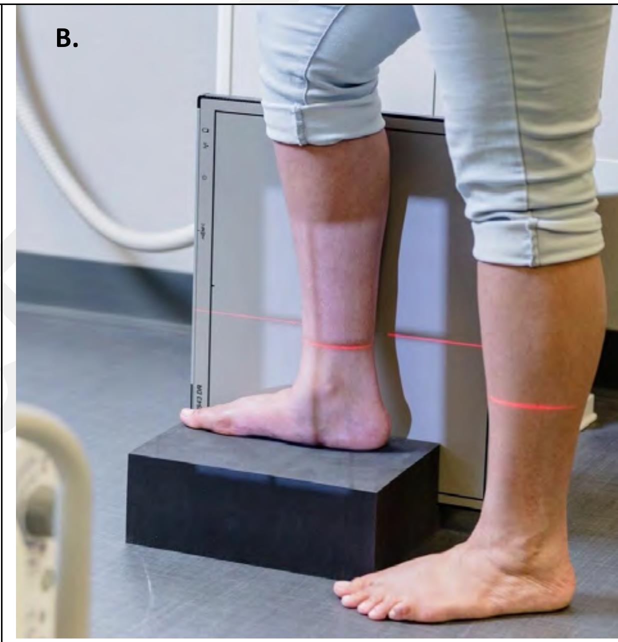
	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Weight-Bearing Lateral	• The patient should stand erect (normal and base of gait) on a specially designed weight-bearing device that is customized for this study; there should be a slot for the IR to be placed either in or on. • The IR should also have a protective cover; RTs should check the weight capacity to ensure it can properly handle the patient's weight.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is useful for demonstrating the patient's longitudinal arches under their full body weight. It is also used to evaluate the Lisfranc joint for potential injuries missed on routine imaging studies.[133]	**Figure 27. Positioning for Weight-Bearing Lateral Views of the Foot** **A.** 

	• The patient's foot should be planted on the detector with the lower leg perpendicular to the floor (weightbearing surface). It is important to make sure the patient can safely stand and maintain their balance without assistance prior to the imaging study.[129-130] • The proper SID for the X-ray tube should be 40 in or 102 cm. • The IR should be placed vertically between the feet and high enough for a horizontal central ray to be properly positioned (Figure 27).[131-133] • The device should be configured so that the		  Examples of patient positioning using a 2-step weight-bearing cassette (A) and a high-density foam block (B) for obtaining lateral weight-bearing images of the foot. The resultant

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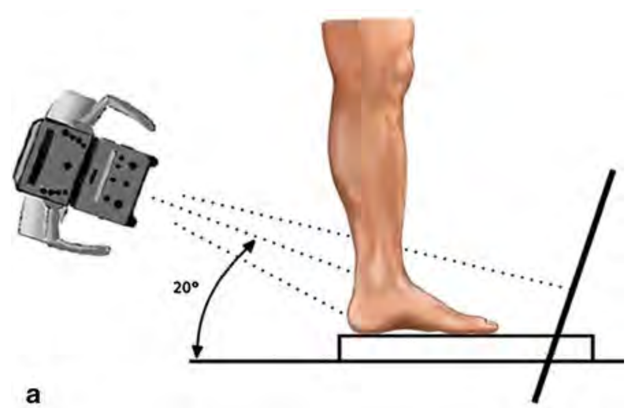
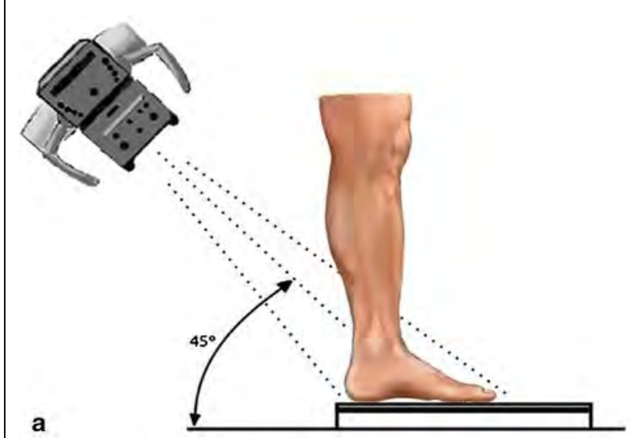
	central ray of the X-ray beam is angled 10°–15° towards the heel directed to the base of the third metatarsal of the foot. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		weight-bearing X-ray image of the right foot (C) also depicts the "C" sign. Figures 27A and 27B courtesy of Z&Z Medical, Inc. Figure 27C: Zhou et al. *J Orthop Surg Res*. 2014.[133] For educational purposes only.
Hindfoot Alignment	• The patient should stand erect (normal and base of gait) on a specially designed weight-bearing device that is customized for this study; there should be a slot for the IR to be placed either in or on. • The IR should also have a protective cover; RTs	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is used to evaluate the hindfoot for varus or valgus	**Figure 28. Hindfoot Alignment Positioning of the Foot and Ankle** 

	should check the weight capacity to ensure it can properly handle the patient’s weight. • The patient’s foot should be planted on the detector with the lower leg perpendicular to the floor (weightbearing surface). It is important to make sure the patient can safely stand and maintain their balance without assistance prior to the imaging study.[129-130] • The proper SID for the X-ray tube should be 40 in or 102 cm. • The angle of the central ray of the X-ray beam should be 20° to the floor. The IR should be perpendicular to	malalignment of the foot and ankle.	 The hindfoot alignment view. The inclination angle of the beam should be 20° to the floor, and the film cassette should be perpendicular to the central beam of the radiation source (A). The resulting radiograph is shown in B. Reilingh et al. *Skeletal Radiol*. 2010.[97] For educational purposes only.

	the central beam of the radiation source (Figure 28).[97] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Long-Axial	• The patient should stand erect (normal and base of gait) on a specially designed weight-bearing device that is customized for this study; there should be a slot for the IR to be placed either in or on. • The IR should also have a protective cover; RTs should check the weight capacity to ensure it can	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is used to evaluate the hindfoot for varus or valgus malalignment of the foot and ankle.	**Figure 29. Long-Axial View Positioning of the Foot and Ankle** 

	properly handle the patient's weight. • The patient's foot should be planted on the detector with the lower leg perpendicular to the floor (weightbearing surface). It is important to make sure the patient can safely stand and maintain their balance without assistance prior to the imaging study.[129-130] • The proper SID for the X-ray tube should be 40 in or 102 cm. • The angle of the central ray of the X-ray beam is 45° to the floor. The IR is perpendicular to the central beam of the		 The long axial view. The film cassette should be lying on the floor, and the patient should be standing on the film cassette (A). The inclination angle of the beam is 45° to the floor. The resulting radiograph is shown in B. Reilingh et al. *Skeletal Radiol*. 2010.[97] For educational purposes only.

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	radiation source (Figure 29).[97] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

Radiographic projections and positioning techniques for imaging the sesamoid bones of the foot. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DP = dorsoplantar; DDR = direct digital radiography; IR = image receptor; MTP = metatarsophalangeal; OID = object-to-image receptor distance; SID = source-to-image distance.

Data from Reilingh et al. *Skeletal Radiol*. 2010; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Murphy. Foot (lateral view). Radiopaedia.org; Published May 4, 2016. Accessed October 5, 2021 Dixon. Normal foot X-rays. Case study. Radiopaedia.org. Published May 4, 2015. Accessed October 5, 2021; Linklater et al. Imaging of the foot and ankle. In: *Mann's Surgery of the Foot and Ankle*. 8th ed. Philadelphia, PA: Elsevier Saunders; 2014: 61-120; Walt et al. Fluoroscopy Podiatric Assessment, Protocols, and Interpretation. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021; Murphy. Foot (medial oblique view). Radiopaedia.org. Published May 4, 2016. Accessed October 2021; Jones et al. Foot (weight-bearing dorsoplantar view). Radiopaedia.org. July 29, 2013. Updated February 3, 2022; Jones et al. Foot (weight-bearing lateral view). Radiopaedia.org. Published July 29, 2013. Updated February 3, 2022; Podiatry X-Ray Positioning. WikiRadiography.net. Available at: http://www.wikiradiography.net/page/Podiatry_X-ray_Positioning. Accessed September 30, 2021; O'Donnell. Missed Lisfranc fracture.

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Case study. Radiopaedia.org. Published March 28, 2012. Accessed October 2021; Zhou et al. *J Orthop Surg Res*. 2014; AP Weight-Bearing Projection. RADTECHONDUTY.COM. Available at: http://www.radtechonduty.com/2012/09/ap-weight-bearing-projection-foot.html. Published September 17, 2012. Accessed October 2021; Shoener. *Rad Notes: A Pocket Guide to Radiographic Procedures*. Philadelphia, PA: FA Davis; 2011; Ballinger et al. M*errill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. New York, NY: Mosby; 1999.[97,124-136] For educational purposes only.

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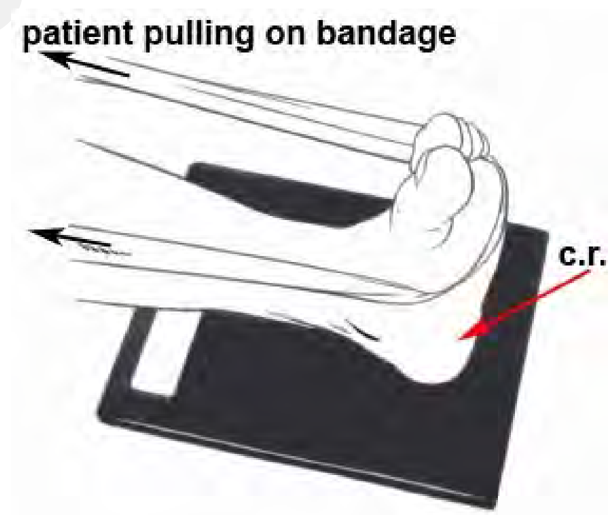
Table 9. Projections and Positioning Techniques for the Calcaneus

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
Axial Plantodorsal	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The IR should be placed under the patient's calcaneus. Instruct the patient to pull back on their toes with a radiolucent positioning band as much as is safely possible to properly visualize the talocalcaneal joint (Figure 30).[102,107]	• This projection is part of a standard radiographic protocol. It is used for evaluating for a disease process, trauma, lesions, foreign bodies, or other pathology of the calcaneus. • When performed properly, this projection provides visualization of the plantar-posterior aspect of the calcaneus and the subtalar joint. The entire calcaneus should be visible from the posterior tuberosity to the talocalcaneal joint.[137]	**Figure 30. Axial Plantodorsal Positioning of the Calcaneus** 

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	• The central ray of the X-ray beam is then angled 45° cephalad toward the base of the third metatarsal. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Walt et al. Fluoroscopy podiatric assessment, protocols, and interpretation. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2022; Adapted from Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005.[102,107] For educational purposes only.

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Mediolateral	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should flex the knee of the affected side so that the plantar surface of the foot is placed on the IR. The affected leg should be rotated externally until the distal limb is parallel to the table (the patient may have to half-roll onto the affected side). The lateral aspect of the foot should be in contact with the IR (Figure 31).[138-139] • The nonaffected side should be kept posterior to	• This projection is part of a standard radiographic protocol. It is used for evaluating for a disease process, trauma, lesions, foreign bodies, or other pathology of the calcaneus. The radiologist or referring clinical clinician may also request that a lateromedial projection be taken. • When performed properly, the talar domes should be superimposed allowing for adequate inspection of the superior articular surface of the talus. The joint space between the distal tibia and the talus should appear open and uniform.[141]	**Figure 31. Mediolateral View Positioning of the Calcaneus**   Smithuis. Fracture Mechanism and Radiography. RadiologyAssistant.nl. Available at:

	prevent over-rotation. If able, the patient should position the affected foot slightly dorsiflexion. The planter surface should be perpendicular to the IR. • The central ray of the X-ray beam should directed to a point 1 inch (2.5 cm) inferior to medial malleolus.[140] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		https://radiologyassistant.nl/musculoskeletal/ankle/fracture-mechanism-and-radiography. Accessed October 10, 2021; Hacking. Normal calcaneum radiographs. Case study. Radiopaedia.org. Published June 27, 2019. Accessed October 2021.[138-139] For educational purposes only.

Axial Calcaneal Weight-Bearing Harris and Beath View (Coalition View)	• The patient should stand erect (normal and base of gait) on a specially designed weight-bearing device that is customized for this study; there should be a slot for the IR to be placed either in or on. • The IR should also have a protective cover; RTs should check the weight capacity to ensure it can properly handle the patient's weight. • The patient's foot should be planted on the detector with the lower leg perpendicular to the floor (weightbearing surface). It is important to make sure the patient can safely stand	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is used to evaluate the body of the calcaneus, and the middle and posterior facets of the subtalar joint. It may also be helpful in diagnosing tarsal coalition and calcaneal stress fractures, as well as talus fractures, and subtalar dislocations.[137]	**Figure 32. Axial Calcaneal Weight-Bearing Positioning of the Calcaneus** 

	and maintain their balance without assistance prior to the imaging study. • The proper SID for the X-ray tube should be 40 in or 102 cm. • The central ray of the X-ray beam should be angled 45° toward the midline of the calcaneus (Figure 32).[131,142] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 An example of patient positioning for an axial calcaneal weight-bearing X-ray also known as the Harris and Beath View or the Coalition View. Podiatry X-Ray Positioning. WikiRadiography.net. Available at: http://www.wikiradiography.net/page/Podiatry_X-ray_Positioning. Accessed September 30, 2021; Knipe. Harris Beath projection. Radiopaedia.org. Published March 29, 2021. Accessed October 2021.[131,142] For educational purposes only.

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Radiographic projections and positioning techniques for imaging the sesamoid bones of the foot. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

CR = computed radiography; DDR = direct digital radiography; IR = image receptor; MTP = metatarsophalangeal; OID = object-to-image receptor distance; SID = source-to-image distance.

Data from Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Thomson-Delmar; 2006; Walt et al. Fluoroscopy podiatric assessment, protocols, and interpretation. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2022; Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Shoener. *Rad Notes: A Pocket Guide to Radiographic Procedures*. FA Davis; 2011; Ballinger et al. M*errill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. New York, NY: Mosby; 1999; Murphy. Calcaneus (axial view). Radiopaedia.org. Published May 5, 2016. Accessed October 2021; Smithuis. Fracture Mechanism and Radiography. RadiologyAssistant.nl. Available at: https://radiologyassistant.nl/musculoskeletal/ankle/fracture-mechanism-and-radiography. Accessed October 10, 2021; Hacking. Normal calcaneum radiographs. Case study. Radiopaedia.org. Published June 27, 2019. Accessed October 2021; Murphy. Calcaneus (lateral view). Radiopaedia.org. Published May 5, 2016. Accessed October 10, 2021; Gorton et al. Ankle (lateral view). Radiopaedia.org. Published November 5, 2015. Accessed October 10, 2021; Knipe. Harris Beath projection. Radiopaedia.org. Published March 29, 2021. Accessed October 2021.[90,102,107,135-142] For educational purposes only.

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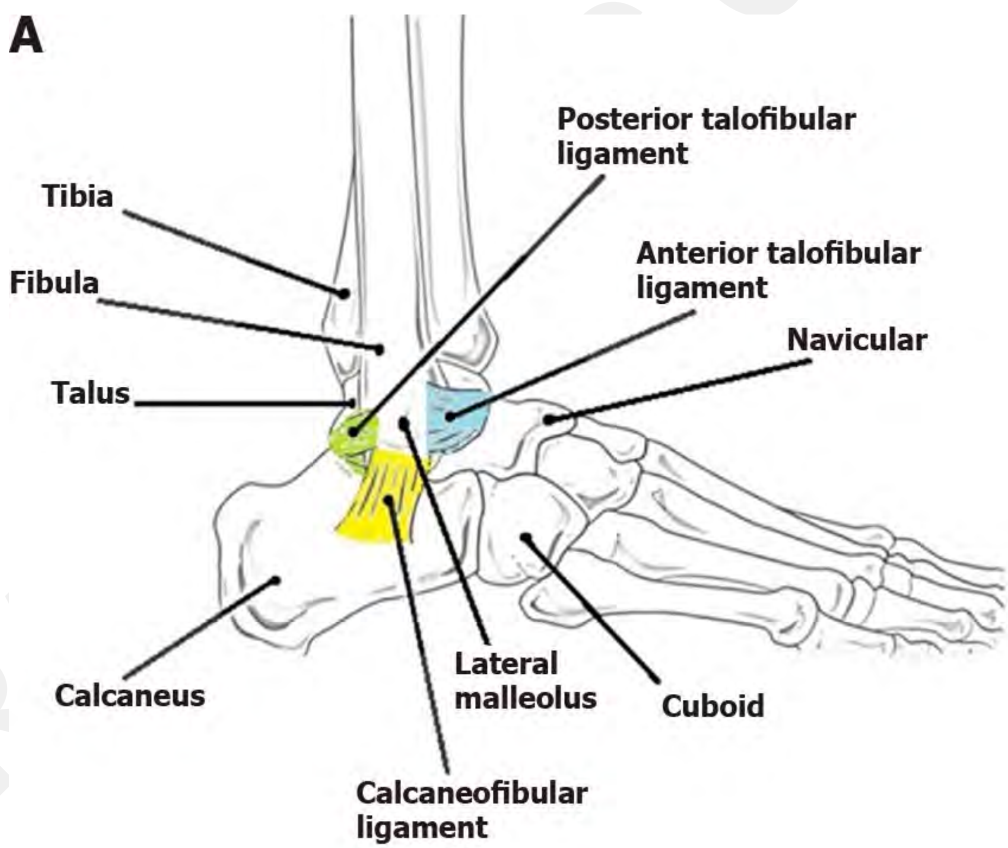
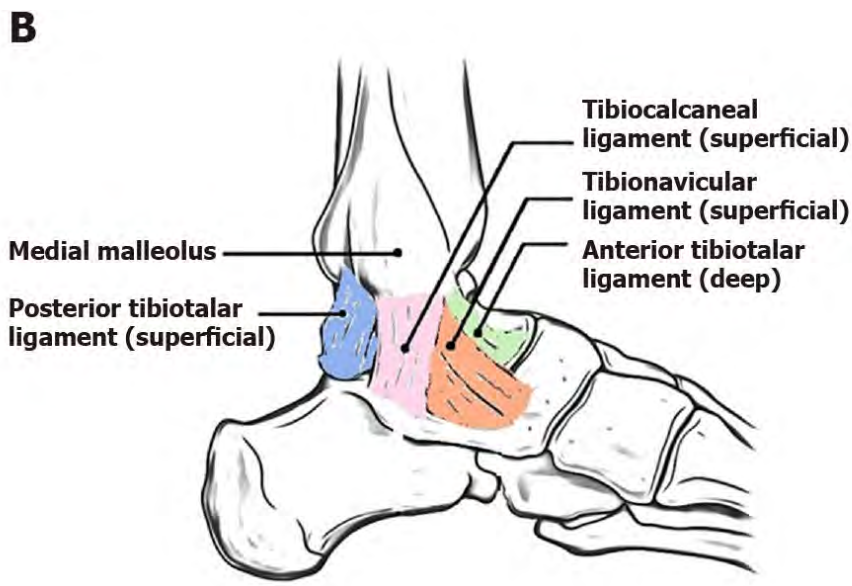
Ankle

The unique pattern of the ankle's anatomy and the anatomical-functional interaction with the foot make the ankle and ankle joint highly susceptible to injuries (Figure 33).[143-144] The ankle joint is a complex hinge that is composed of 3 main articulations: the talocalcaneal (subtalar), the transverse-tarsal (talocalaneonavicular), and the tibiotalar (talocrural) joints.[29] Ankle fractures are one of the most common injuries seen in the ED and is one of the most often treated injuries by orthopedic surgeons; they account for 9% of all fractures and 36% of all lower extremity fractures in the US.[143] Ankle dislocations are a relatively common type of dislocation encountered in the ED and are usually either a true dislocation without fracture or a fracture-dislocation, which is the most common.[29]

Figure 33. Lateral and Medial Views of the Ankle





A lateral view of the ankle (A) showing anatomy of the ankle joint and the lateral collateral ligaments and a medial view of the ankle (B) showing the medial collateral ligaments.

James et al. *World J Meta-Anal.* 2021.[144] For educational purposes only.

Ankle fractures were initially classified as unimalleolar, bimalleolar or trimalleolar. However, this classification was found to be limited, because it was unable to distinguish unstable and stable injuries. Most ankle injuries are clinically and diagnostically determined to be ligamentous injuries.[145] There are some patients that present clinically with a suspected ankle sprain, but imaging studies determine that it is actually a subtle fracture.[146-147] Ankle joint effusions may be identified by the presence of a soft tissue density in the region of the normal fat lucency anterior or posterior to the ankle joint. Many of the ligaments and tendons of the ankle and foot are not well-evaluated on radiography and will require additional imaging with MRI.[147]

Ankle fractures are categorized and classified in various ways, which may include[27]:

- Anatomical Classification: This system classifies ankle fractures based on the anatomical location of the fracture.
- Danis-Weber Classification: This system categorizes ankle fractures based on the distal fibula fracture line localization relative to the syndesmosis.
- The Lauge-Hansen Classification: This classification depends on the foot position and the direction of the force causing the injury.

Some of the most common ankle fractures include[27,147-148]:

- Lateral malleolus fracture: This is the most common type of ankle fracture and is a break of the lateral malleolus bone on the lower portion of the fibula.
- Bimalleolar ankle fracture: This is the second-most common type of ankle fracture and involves breaks of both the lateral and the medial malleolus bones.
- Trimalleolar ankle fracture: This fracture involves 3 sides of the ankle: the medial malleolus of the tibia, the lateral malleolus, and posterior malleolus bones.
- Pilon fracture: This fracture is also known as a plafond fracture and is a fracture of the weightbearing part of the ankle (the central portion of the lower tibia). This type of fracture occurs usually after falling from a great height.
- Maisonneuve injury: This fracture is an unstable injury caused by pronation external rotation injury. A Maisonneuve injury combines a proximal fibular fracture with tibiofibular syndesmosis and deltoid ligament injury with or without medial malleolus fracture.
- Bosworth fracture-dislocation: This is a rare type of ankle fracture dislocation where the fibula is posteriorly dislocated.
- Tillaux fracture: This fracture is an avulsion fracture of the anterior tibial tubercle, which occurs with external rotation and abduction of the foot.
- "Snowboarder's fracture": A fracture of the lateral process of the talus that occurs either due to ankle eversion or dorsiflexion and is typically only visualized on an AP ankle view.

Table 10 outlines ideal patient positioning and protocols to effectively image a variety of ankle fractures.[27,82,124,135-136,147,150-152]

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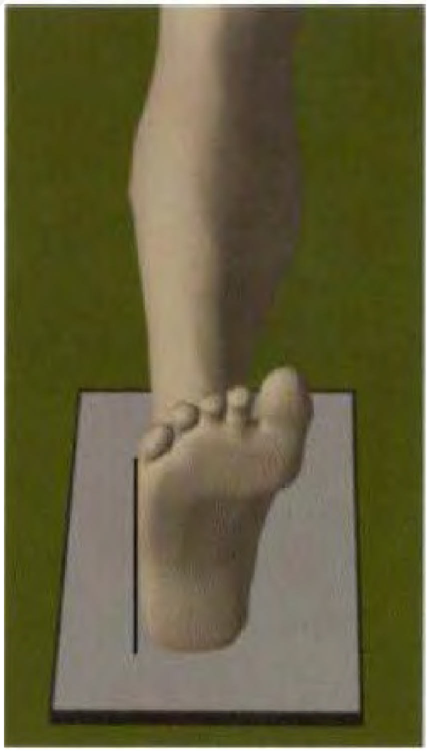
Table 10. Projections and Positioning Techniques for the Ankle

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient's foot should be positioned so that the long axis is about perpendicular to the long axis of the lower extremity (Figure 34).[124,149] • The central ray of the X-ray beam should be centered between the malleoli at the tibiotalar joint.	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot and ankle for a disease process, trauma, lesions, foreign bodies, or other pathologies. • The AP ankle view is best for assessing the ankle for soft tissue swelling around the medial or lateral malleolus that may lead to the discovery of other more subtle fractures.[27] • The talar dome can be seen in profile. There is mild	**Figure 34. AP Positioning of the Ankle** 

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	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	overlap of the lateral malleolus and the lateral talus whereas the medial tibiotalar joint is open.[150]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

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Mortise (Internal Oblique)	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • RTs should instruct the patient to flex the knee of the affected side so that the plantar surface of the foot being imaged can be placed on the IR. • Gently oblique the patient's ankle-leg 15°–20° of internal rotation (Figure 35).[124] • The ankle should also be dorsiflexed, which prevents overlap of the posterior calcaneus and	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot and ankle for a disease process, trauma, lesions, foreign bodies, or other pathologies. • The mortise view is important for assessing the ankle mortise (tibial plafond, medial malleus, lateral malleolus and talar dome). Radiographically, talar dome fractures are best visualized on the mortise view.[27,82] • If the radiologist or treating physician requests an internal oblique projection, the degree of internal	**Figure 35. Positioning for the Mortise View of the Ankle** 

	lateral malleolus. Dorsiflexion positioning should only be performed if the patient is physically able to.[151-152] • The central ray of the X-ray beam should be centered between the malleoli at the tibiotalar joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	rotation of the foot-ankle should be 45°.[82]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

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Lateral	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The lateral margin of the foot should be positioned against the IR, with the long axis of the IR parallel to the long axis of the lower extremity (Figure 36).[124,150] • As with the AP view, the patient's foot should be positioned so that the long axis is about perpendicular to the long axis of the lower extremity.[150]	• This projection is part of a standard radiographic protocol. It is used for evaluating the foot and ankle for a disease process, trauma, lesions, foreign bodies, or other pathologies. • The lateral view is best for assessing the posterior malleolus, the talus dome relative to the distal mortise, and the lateral column of foot, cuboid, and fourth and fifth metatarsals. • The fibula should project over the posterior half of the tibia. The medial malleolus should be slightly anterior to the lateral malleolus. The base of the fifth metatarsal should be	**Figure 36. Positioning for the Lateral View of the Ankle** 

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	• The central ray of the X-ray beam should be centered about 2 cm above the inferior tip of the lateral malleolus.[150] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	visible as patients with fractures in this area sometimes present with ankle pain.[150]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

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External Oblique	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should flex the knee of the affected side so that the plantar surface of the foot being imaged can be placed on the IR. • Gently oblique the patient's ankle-leg 30° of external rotation positioning (Figure 37).[124] • The central ray of the X-ray beam should be centered between the malleoli at the tibiotalar joint.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • The externally rotated oblique view is less common, but it may be useful in assessing the anterior tibial tubercle and the lateral malleolus.[149]	**Figure 37. Positioning for the External Oblique View of the Ankle** 

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	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

Radiographic projections and positioning techniques for imaging the sesamoid bones of the foot. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

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AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; RT = radiologic technologist; SID = source-to-image distance.

Data from Wire et al. Ankle fractures. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2022; Tafti et al. X-ray Radiographic Patient Positioning. In: *StatPearls* [Internet]; 2021; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Shoener. *Rad Notes: A Pocket Guide to Radiographic Procedures*. FA Davis; 2011; Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. Mosby; 1999; Judd et al. *Am Fam Physician*. 2002; Omar. Diagnostic imaging techniques of the foot and ankle. In: Kelikian AS, ed. *Sarrafian's Anatomy of the Foot and Ankle: Descriptive, Topographic, Functional*. Lippincott Williams & Wilkins; 1993; AP Mortise Projection - 15 TO 20 Degree Medial Rotation: Ankle. RadTechOnDuty.com. Available at: http://www.radtechonduty.com/2012/09/ap-mortise-projection-15-to-20-degree.html. Published September 19, 2012. Accessed October 20, 2021; Gorton et al. Ankle (mortise view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/40730. Published November 1, 2015. Accessed October 2021.[27,82,124,135-136,147,150-152] For educational purposes only.

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The Lower Leg (Tibia and Fibula)

The tibia is the second largest bone in the body and is located on the medial side of the leg. On the lateral side of the leg, slightly posterior to the tibia, is the fibula (Figure 8).[32] The tibia is a weight-bearing bone, but the fibula is not.[153] Fractures of the tibial and fibular shafts are some of the most common long bone fractures diagnosed in adult patients. Causes of these types of fractures are primarily direct force, such as those caused by falling, car accidents, and/or indirect or rotational forces. Fractures that result from overuse are primarily due to exercise or sports and are usually stress fractures of the tibia and fibula.[154] Fractures of the tibia/fibula are classified as[155]:

- Simple: (spiral, oblique, transverse, and green stick): Defined as a 1-line fracture.
- Wedge (spiral, intact, comminuted): Defined as 3 or more fragments, where the main fragment has contact after reduction.
- Complex: (spiral, segmental): Defined as 3 or more fragments where the main fragment has *no contact* after reduction.

Table 11 outlines ideal patient positioning techniques and views for imaging the tibia and fibula.[82,124,136,156-158]

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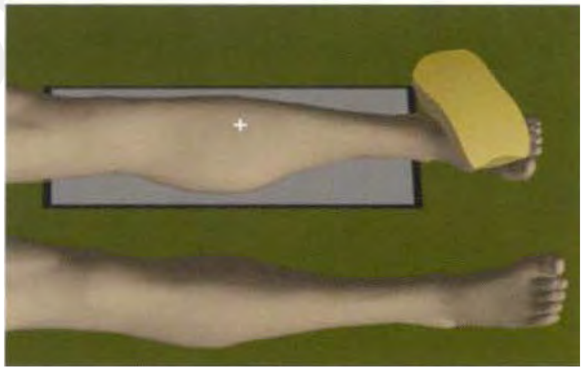
Table 11. Projections and Positioning Techniques for the Lower Leg (Tibia and Fibula)

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should place the posterior surface of the affected leg against the IR (Figure 38).[125,156] • The foot should be angled 90° to the lower leg. There should be no rotation of the knee or ankle. The foot should be flexed with toes pointing up.[82]	• This projection is part of a standard radiographic protocol. It is used for evaluating the lower leg for a disease process, trauma, lesions, foreign bodies, or other pathologies. • The entire tibia and fibula should be included in the AP view, with both the ankle and knee joints demonstrated. The lateral and medial malleoli of the distal fibula and tibia should be in profile. The tibiotalar joint space and	**Figure 38. AP Positioning of the Lower Leg** 

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	• The central ray of the X-ray beam should be perpendicular to the midpoint of the leg. Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	the knee joint space should be open.[157]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Murphy. Tibia and fibula series. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/68580.

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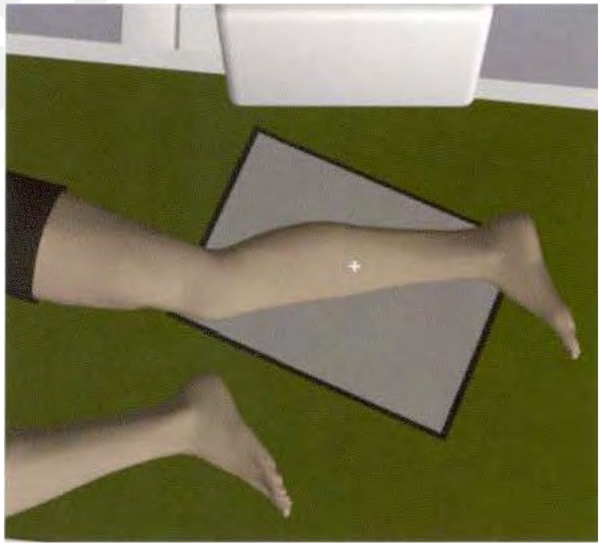
			Published June 6, 2019. Accessed October 20, 2021.[124,156] For educational purposes only.
Lateral	• The patient should be safely positioned on the table and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should place the lateral surface of the affected leg against the IR (Figure 39).[124,156] • The patient should be in the lateral recumbent position, with the injured limb facing down, with the opposite leg placed behind it. Sandbags or pillows can be used for support. The patient's knee should be flexed 45° to the affected	• This projection is part of a standard radiographic protocol. It is used for evaluating of the lower leg for a disease process, trauma, lesions, foreign bodies, or other pathologies. • When performed correctly, the fibula should be projected well posterior to the tibia with superimposition at both the proximal and distal ends. This view should also demonstrate the ankle joint without superimposition of calcaneus.[158]	**Figure 39. Lateral Positioning of the Lower Leg** 

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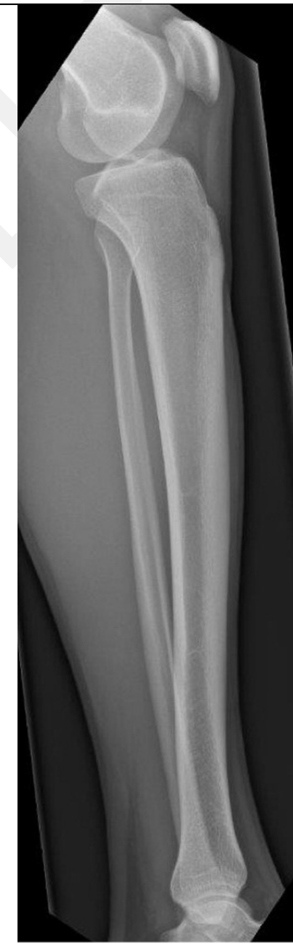
	leg, in the true lateral position (the plane of patella should be 90° to the IR).[157] • The foot of the affected leg should be positioned at a 90° angle to the lower leg. The knee should be in a slightly flexed position.[157] • The central ray of the X-ray beam should be perpendicular to the midpoint of the leg. Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Murphy. Tibia and fibula

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			series. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/68580. Published June 6, 2019. Accessed October 20, 2021.[124,156] For educational purposes only.

Radiographic projections and positioning techniques for imaging the sesamoid bones of the foot. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; RT = radiologic technologist; SID = source-to-image distance.

Data from Tafti et al. X-ray Radiographic Patient Positioning. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. Mosby; 1999; Murphy. Tibia and fibula series. Case study. Radiopaedia.org. Published June 6, 2019. Accessed October 20, 2021; Gorton et al. Tibia fibula (AP view). Radiopaedia.org. Published November 30, 2015. Accessed October 25, 2021; Radiographic technique of femur, knee joint, patella and leg. Slideplayer.com Available at: https://slideplayer.com/slide/7782586/. Updated September 8, 2014. Accessed November 7, 2021.[82,124,136,156-158] For educational purposes only.

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The Knee

The knee is the largest joint in the body and is a compound synovial joint, which is comprised of the tibiofemoral joint and the patellofemoral joints. It is formed by the proximal tibia, patella, and distal femur bones. The knee is a weight-bearing joint that allows flexion and extension of the lower leg around a transverse axis in a sagittal plane (Figure 9).[33]

The stability of the knee depends on the functionality and health of the surrounding muscles, bones, ligaments, cartilage, synovial tissue, synovial fluid, and other connective tissues. As discussed, the 4 main stabilizing ligaments of the knee are the ACL, PCL, MCL, and LCL.[33] Meniscal tears can be classified as horizontal, radial, vertical longitudinal, horizontal flap, vertical flap, or complex.[159] ACL tears are one of the most common causes for an acute large hemarthrosis (bleeding in the knee joint) in the sports/athletic population. Radiographs obtained early following an ACL injury most often demonstrate distention of the joint capsule.[159]

The patella is the largest sesamoid bone in the body and functions as an attachment point for the quadriceps tendon and patellar ligament. The patella can come in many different shapes, and the Wiberg classification is used to describe the shape of the patella based primarily on the asymmetry between the patellar medial and lateral facets on axial views of the patella, which include[36,160]:

- Type I: Characterized by concave, nearly symmetrical facets.
- Type II: Characterized by a medial facet that is flat or slightly convex and much smaller than the lateral facet.
- Type III: Characterized by a smaller medial facet similar to Type II, but the medial facet in a Type III patella is *always* convex.

Common conditions affecting the knee and surrounding soft tissue structures include:

Arcuate Complex Avulsion Fracture: The arcuate complex is the group of muscles and ligaments responsible for the stability of posterolateral knee, which includes: the FCL, biceps femoris, popliteus muscle and tendon, popliteofibular ligaments, fabellofibular, and arcuate ligaments, and the lateral gastrocnemius muscle. An arcuate complex avulsion fracture involves an avulsion of the insertion of the popliteofibular, arcuate, and fabellofibular ligaments from the fibular styloid process. On X-ray, this type of fracture is indicated by the “arcuate sign,” because the avulsed bone fragment has an elliptical shape. This fracture occurs when a varus force is applied to the externally rotated tibia or pushes on the anteromedial aspect of tibia in an extended knee or sudden hyperextension of the knee.[161-162]

Bursitis: Inflammation of the bursa sacs, which are small, fluid-filled sacs that act as cushions between bone and other moving parts, such as muscles, tendons, or skin. Patients are often diagnosed with bursitis after overusing a joint or sustaining an injury.[163]

Knee Dislocation**:** This injury occurs when the 3 primary bones of the knee are out of place and/or misaligned. A knee dislocation may also injure or disrupt one, several, or all of the 4 major ligaments that stabilize the knee joint (the anterior cruciate, posterior cruciate, medial collateral, and lateral collateral ligaments). Several major arteries are also at risk for injury with this condition.[164]

Patellar Dislocation: A misalignment of the patella, usually due to trauma. It is often caused by a noncontact twisting injury to the knee or from a direct blow to the medial aspect of the knee. Patellar dislocations are usually lateral, inferior, or superior (vertical), but medial displacement may also occur. Osteochondral and chondral fractures occur frequently in relation to the patellofemoral joint as a result of lateral patellar dislocations.[165]

Joint Effusion: Also known as a swollen joint, it is a relatively common condition. While nonspecific, its presence may be indicative of trauma, internal derangement, or inflammatory arthritis.[166]

Patellar Fracture: One of the most common knee injuries, which is usually a result of direct trauma to the patella. The most common type is a transverse fracture; also included are comminuted and vertical patellar fractures.[167]

Popliteal or Baker's Cyst: A swelling or fluid-filled mass protruding from the back of the knee (the popliteal fossa) that when palpated feels like a hard lump. High-resolution sonography is the modality of choice for confirming the presence of a Baker's cyst.[168]

Osgood-Schlatter Disease: A condition that occurs when the quadricep muscles (patellar tendon) that attaches to the tubercle of the tibia and pulls the tubercle away from the tibia. This condition is most often seen in adolescents who are involved in sports.[169]

Osteoarthritis**:** Also known as degenerative joint disease; this occurs when the cushioning of the knee (the cartilage) deteriorates due to aging and wear and tear. Joint space width should be evaluated on specialty weight-bearing views, also called Rosenberg views.[170]

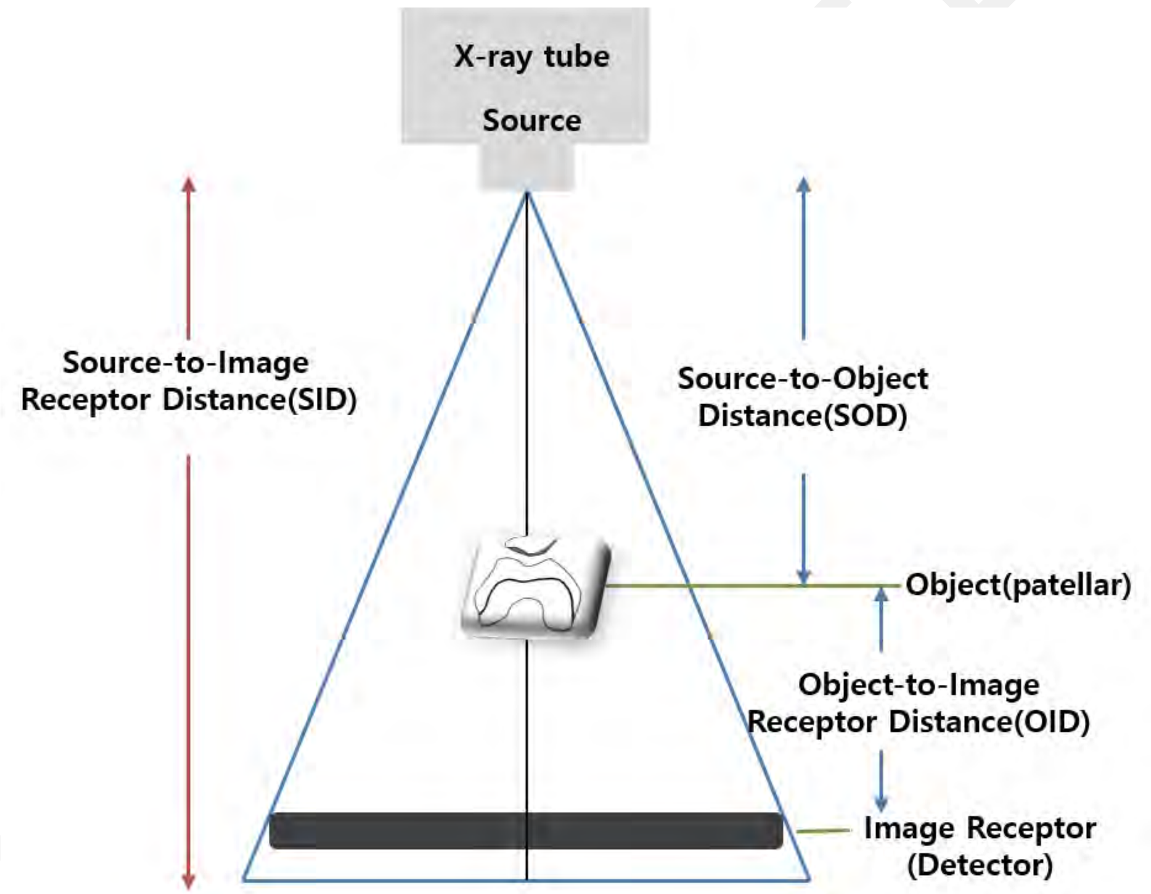
Segond Fracture: An avulsion fracture to the lateral proximal tibia at the attachment of the anterolateral ligament. This type of fracture suggests that there may also be an injury, which is typically a ruptured ACL. A reverse Segond fracture is typically located on the opposite side of the knee, arising from the medial aspect of the proximal tibia.[161,171]

Imaging Possible Osteoarthritis

If a patient is being evaluated for knee pain and osteoarthritis is suspected, then the protocol is usually performing a weight-bearing AP, lateral, and Merchant/skyline views of the knee. AP views should be taken with the patient bearing weight in full extension, and the lateral views should be midflexion views. If employing the skyline view in diagnosis, the patient's knee should be flexed to 45°.[172] Additional projections may include the skyline view performed as a Laurin projection, which is an inferior-superior projection of the patella.[173] A weight-bearing Rosenberg view may also play a role in diagnosing osteoarthritis. As first described in 1988, the Rosenberg method is a weight-bearing bilateral PA radiograph taken with the knees in 45° flexion.[174] Weight-bearing views of the knee have been shown to more accurately assess joint space narrowing than standard supine radiographs and can also better demonstrate malalignment, such as varus or valgus. If there is concern for the presence of osteophytes (an early sign of osteoarthritis of the knee), or loose bodies in the intercondylar fossa of the femur, the referring physician should consider ordering specialty views of the area, using the Holmblad (posteroanterior [PA]) or Camp Coventry (PA) method.[175] The Béclere (AP) method, commonly known as the "notch view," is another projection of the knee that's often used to better view the tibial plateau and femoral intercondylar spaces.[176] The Holmblad, Camp-Coventry, and Béclere projections are also used to evaluate the presence of split and displaced cartilage due to osteochondritis and under-development of the lateral femoral condyle as a result of a congenital slipped patella. If the treating physician wants to rule out subluxation as a diagnosis and wants to evaluate the shape of the patella, there are specialty projections that would be appropriate, including the Merchant view, and various tangential projections (also known as skyline projection, sunrise view, sunset view, patellofemoral joint view, or the Settegast's view).[177-178] MRI is the most comprehensive imaging assessment of the knee when performed early after injury.[179] Conventional diagnostic radiography often reveals acute fractures, however, it is commonly either negative or shows indirect signs of an acute soft-tissue injury.[159]

As with performing any imaging study, particularly of the knee and specialty views of the patella, it is essential that all imaging professionals be well versed in the concepts of SID, source to object distance (SOD), and OID.[180] Some specialty projections of the knee and patella require unique and very specific angulation of the X-ray tube and IR placement near or against the region. Key concepts that assist in minimizing image distortion and loss of bony detail are illustrated below (Figure 40).[180]

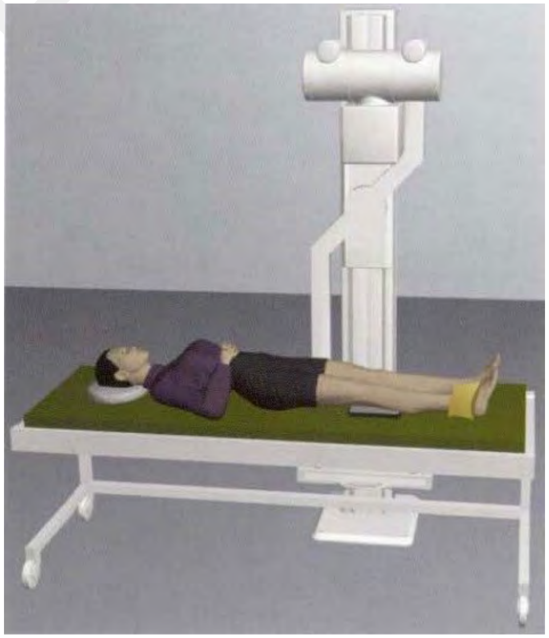
Figure 40. Fundamentals of X-Ray Tube Angulation and Distance



Rhee et al. Research Square.com. Available at: https://www.researchsquare.com/article/rs-869658/v1. Published September 13, 2021. Accessed November 2021.[180] For educational purposes only.

Table 12 details ideal patient positioning techniques and views for imaging the knee/patella.[83,107,124,158,173,178,181-198]

Table 12. Projections and Positioning Techniques for the Knee

Radiographic Projection	Radiographer to Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should be instructed to extend their leg so that the epicondyles of the affected knee are parallel to the IR (Figure 41).[124] • The central ray of the X-ray beam should be perpendicular to the affected knee's joint space.	• This projection is part of a standard radiographic protocol. It is used for evaluating the knee for disease process, trauma, lesions, foreign bodies, or other pathologies. • This projection may also be performed in the PA position. Many patients find it more comfortable in the AP position because direct pressure is not placed on the knee joint or against the table or the IR. • The AP view demonstrates the femorotibial joint space	**Figure 41. AP Positioning of the Knee** 

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	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	and adequately shows the intercondylar eminence. The patella should be superimposed over the femur.[181]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.
Lateral (Mediolateral)	• The patient should be safely placed in a recumbent position and turned on their affected	• This projection is part of a standard radiographic protocol. It is used for evaluating the knee for a	

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	side, with the lateral surface of knee on the table. The affected knee should be abducted with the unaffected limb positioned behind it. Positioning should be in line with an accessible SID for the X-ray tube (40 in or 102 cm).[182] • The affected knee should be in a lateral position with the tibial condyles perpendicular to IR. The affected knee should be flexed 20° to 30° if the patient can be positioned safely.[182] • The central ray of the X-ray beam should be angled 5° to 7° and should enter the knee joint 1 in (2.5 cm)	disease process, trauma, lesions, foreign bodies, or other pathologies. • When performing this view, **the patient's knee should not be flexed more than 30°**. If flexion of the knee is more than 30°, the patella may be forced down into the trochlear groove of the femur, which can distort/compress the suprapatellar pouch and its adjacent soft tissue structures.[183] • When performed correctly, the proximal fibula should be superimposed by the proximal tibia. The medial condyles of the femur and tibia should be viewed in profile. About half of the	**Figure 42. Lateral Positioning of the Knee** 

	distal to the medial epicondyle (Figure 42).[124] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	patella should be visualized free of femoral superimposition.[184]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003.[124] For educational purposes only.

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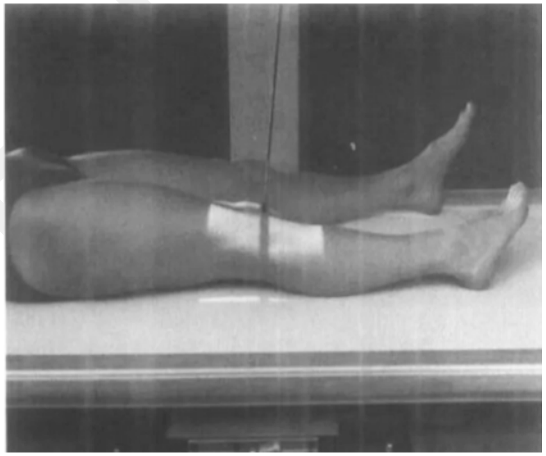
AP Medial Rotation	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The affected knee should be rotated medially 45°. • The central ray of the X-ray beam should be directed perpendicularly to a point .5 inch (1.3 cm) inferior to the patellar apex (Figure 43).[185-186] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • When performed properly, this view provides an unobstructed visual of the head of the fibula. The medial and lateral knee joint spaces can also be clearly viewed and measured.	**Figure 43. Oblique View of the Knee with Medial Rotation Positioning.** 

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			 Lecture 16. Knee Joint Basic Projections. SlideToDoc.com, Available at: https://slidetodoc.com/lecture-16-knee-joint-basic-projections-ap-lateral/. Accessed November 7, 2021; Strotmeyer et al. *Arch Sports Med*. 2017.[185-186] For educational purposes only.

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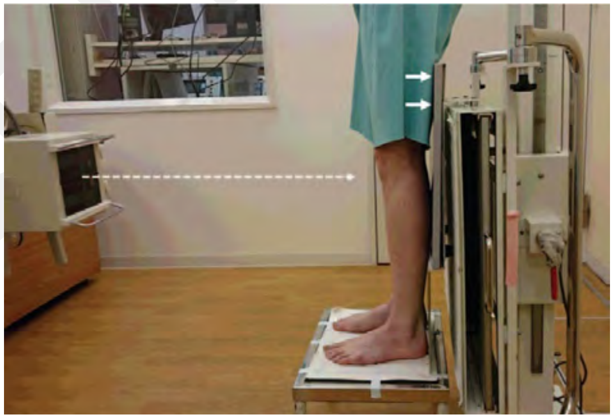
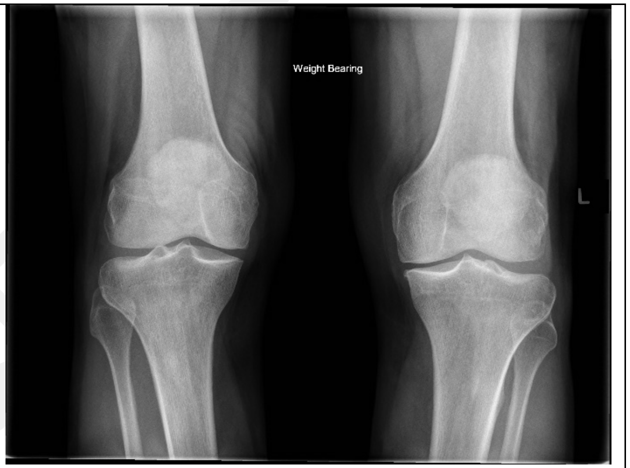
Weight-Bearing Projections			
AP (Weight-Bearing)	• Safely position the patient upright with the back of their knees centered to the vertical upright wall bucky and IR. • Adjust the patient's position to center their knees to the IR. The SID for the X-ray tube should be 40 in or 102 cm. • The patient's toes should be pointing straight ahead, with their feet separated enough to maintain their balance, and their body weight equally distributed across both feet. Ensure the patient can stay steady and maintain their balance	• This projection is part of a standard radiographic protocol. It is used for ruling out the presence of osteoarthritis in the knees and properly evaluating the joint space that may appear normal on nonweight-bearing imaging studies. Additionally, varus and valgus deformities can also be evaluated using this view.	**Figure 44. AP Positioning for Weight-Bearing Views of the Knees** 

	for the duration of the imaging study. • The central ray of the X-ray beam should be aimed .5 in (1.3 cm) below the apices of the patellae. Some protocols also recommend a 10° caudal angle (Figure 44).[187-188] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Kan et al. *Medicine (Baltimore)*. 2017; Murphy. Tibiofemoral osteoarthritis. Case study. Radiopaedia.org. Published October 2, 2016. Accessed November 2021.[187-188] For educational purposes only.

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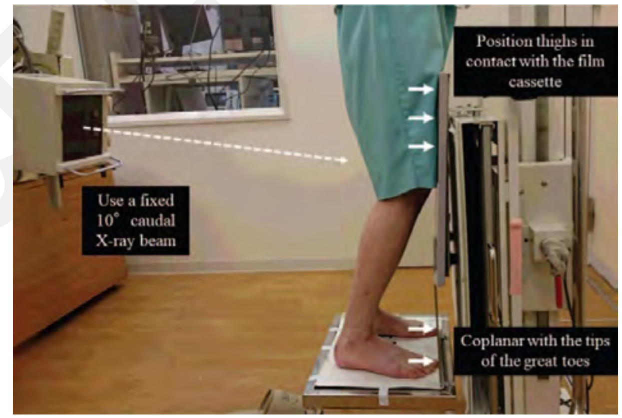
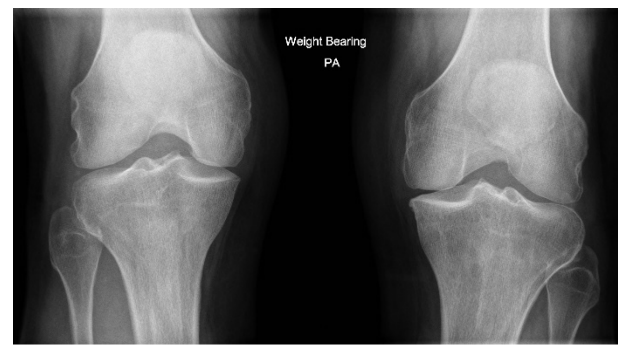
PA Weight-Bearing with Flexion (Rosenberg Method)	• Safely position the patient upright with the back of their knees centered to the vertical upright wall bucky and IR. • The patient's toes should be pointing straight ahead, with their feet separated enough to maintain their balance, and their body weight equally distributed across both feet. Ensure the patient can stay steady and maintain their balance for the duration of the imaging study.[189] • Position the patient so that their knees are flexed 45° to the IR and centered (Figure 45).[187-188]	• This projection is part of a standard radiographic protocol. It is used for ruling out the presence of osteoarthritis in the knees and properly evaluating the joint space that may appear normal on nonweight-bearing imaging studies.	**Figure 45. PA Positioning with Flexion for Weight-Bearing Views of the Knees (Rosenberg Method)**   Kan et al. *Medicine (Baltimore)*. 2017; Murphy. Tibiofemoral osteoarthritis. Case study. Radiopaedia.org. Published October 2, 2016.

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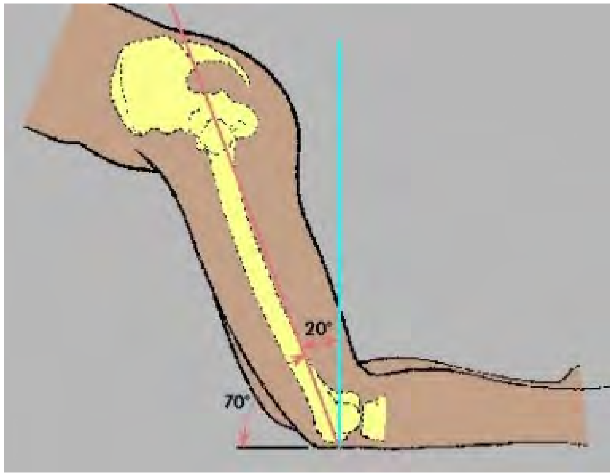
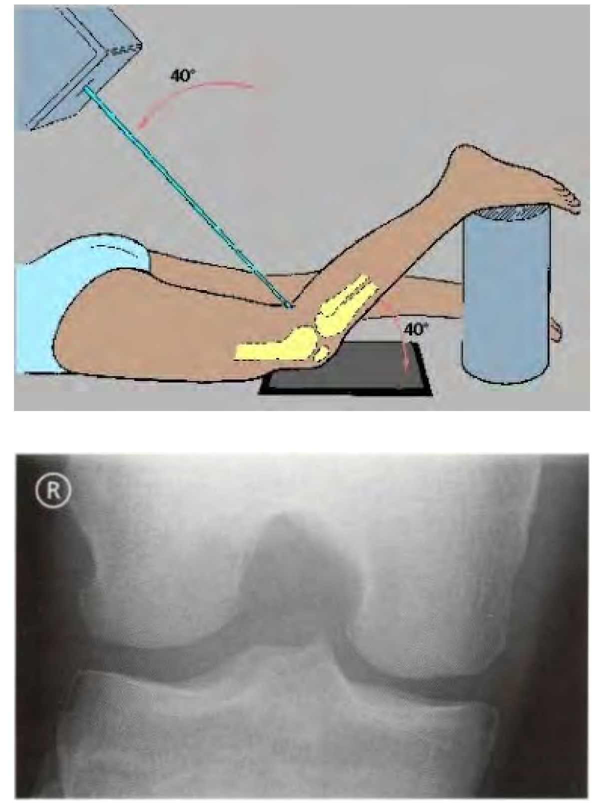
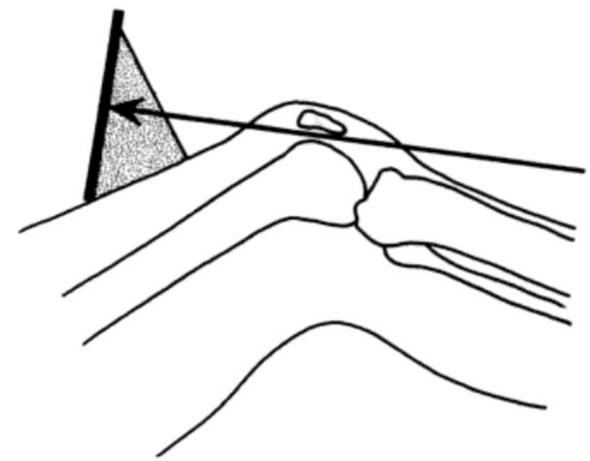
	• The central ray of the X-ray beam should be aimed .5 in (1.3 cm) below the apices of the patellae. Some protocols also recommend a 10° caudal angle. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		Accessed November 2021.[187-188] For educational purposes only.
Intercondylar Fossa Projections			
PA Axial Holmblad Method (Tunnel Projection)	• Position the patient in a prone kneeling position with the anterior aspect of their knees centered against the IR and the table. The SID for the X-ray tube should be 40 in or 102 cm.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • This projection is commonly referred to as	

	• Have the patient slowly bend their knees from full flexion to 70°. Ensure that the patient is safe and stable on the table in this position (Figure 46).[173,190] • The central ray of the X-ray beam should be placed underneath the affected knee; the IR should be centered to the popliteal crease and exit at the level of the patellar apex.[184] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	the Tunnel View. • When performed correctly, this view demonstrates the intercondylar fossa and posteroinferior articular surfaces of the condyles of the femur. It also demonstrates the medial and lateral intercondylar tubercles of the intercondylar eminence and tibial plateaus in profile.[191] • Variations of this method can be performed: o Partially standing o Partially standing using a wheelchair o Standing by a chair or wheelchair o Utilizing the upright wall bucky	**Figure 46. PA Axial Positioning for Intercondylar Fossa Views of the Knee** 

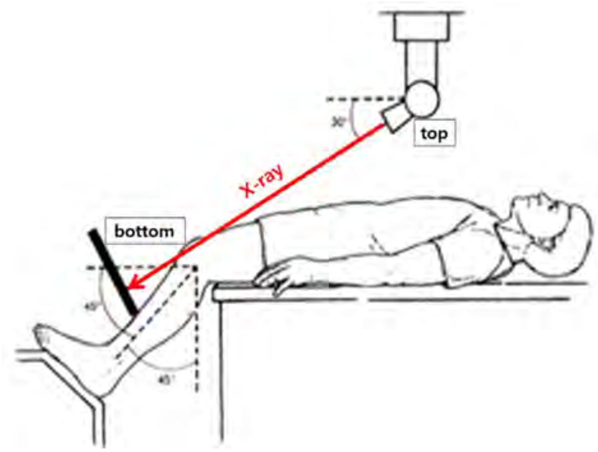
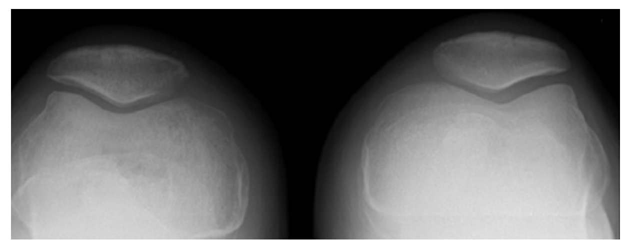
			 An example of patient positioning using the Holmblad method, or tunnel view approach, for imaging the intercondylar fossa of the knee. 6th Presentation Radiographic Technique of Femur Knee. SlideToDoc.com. Accessed November 2021; Babatunde et al. *Arthritis*. 2016.[173,190] For educational purposes only.

Camp-Coventry Method	• Position the patient in a prone kneeling position with the anterior aspect of their knees centered against the IR and the table. The SID for the X-ray tube should be 40 in or 102 cm. • The patient's knees should be bent slowly from full flexion to a 40° or 50° angle. The femoral part of the knee should be placed on the IR, and the rest of the foot should be comfortably supported. Ensure that the patient is safe and stable on the table in this position. • The central ray of the X-ray beam should be aimed perpendicular to the lower	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • When performed correctly, this view demonstrates the intercondylar fossa and posteroinferior articular surfaces of the condyles of the femur. It also demonstrates the medial and lateral intercondylar tubercles of the intercondylar eminence and tibial plateaus in profile.[191]	**Figure 47. Camp-Coventry Method Positioning for Intercondylar Fossa Views of the Knee**  6th Presentation Radiographic Technique of Femur Knee. SlideToDoc.com. Accessed November 2021; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique*

	leg, entering the superior aspect of the popliteal fossa, and exiting at the level of the patellar apex. The central ray should be angled 40° caudal when knee is flexed 40° and 50° caudal when knee is flexed 50° (Figure 47).[124,190] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		*and Projections*. 1st ed. The World Health Organization; 2003.[124,190] For educational purposes only.
Béclere Method	• The patient should be supine on the table; ensure the rest of their body is not twisted. The SID for the X-ray tube should be 40 in or 102 cm.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist.	

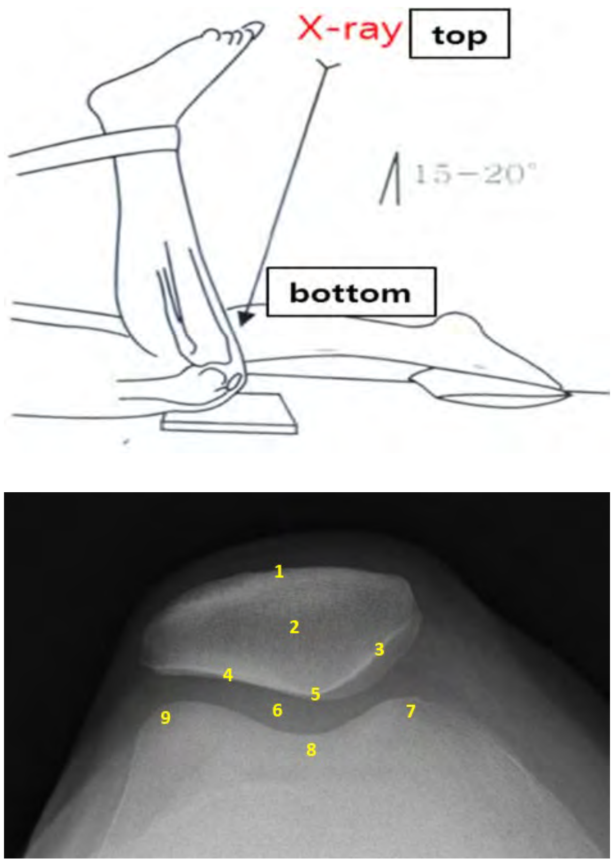
	• The affected knee should be flexed so that the long axis of the femur is 60° to the long axis of the tibia. A sandbag may be positioned under the patient's knee for support.[192] • The central ray of the X-ray beam should be perpendicular to the long axis of the lower leg. It should be aimed at the knee joint .5 in (1.3 cm) below the patellar apex (Figure 48).[107,193] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	• When performed correctly, this view demonstrates an open intercondylar fossa. • This view also demonstrates the posteroinferior surface of the femoral condyles, intercondylar eminence, and knee joint space.	**Figure 48. Béclere Method Positioning for Intercondylar Fossa Views of the Knee** 

			 Bull. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Bickle. Normal knee radiographs with tunnel view. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/75713. Published April 7, 2020. Accessed November 10, 2021.[107,192] For educational purposes only.

Patellofemoral Joint Projections			
Merchant Method	• The patient should be lying on the table supine, with knees safely hanging off of the edge of the table. • Support the patient's knees and lower legs/feet with an adjustable IR device that's specified for use for this view/method. • A pillow or foam wedge may be used under the patient's head and/or lower back to increase comfort, limit motion, and to relax the quadriceps femoris. • Using the stabilizing device, elevate the patient's knees	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. The protocol at most facilities is for this view to be performed in a bilateral manner to include both patellae. • When performed correctly, this view demonstrates bilateral patellae that are free from superimposition of all bony structures with clear visualization of the patellofemoral joint space.[197]	**Figure 49. Positioning for Bilateral Merchant Method View of the Knees**   Rhee et al. *J Biomed Eng Res.* 2020; Thomson et al. *J Orthop Trauma*. 2017.[195-196] For educational purposes only.

	approximately 2 in. and position the femora parallel to the tabletop (Figure 49).[195-196] • Flex the patient's knee to 40°; to show other potential patellofemoral disorders, the degree of angulation can be adjusted between 30° and 90°.[184,194] • Both legs should be held together with restraining devices at the calf level to control leg rotation and allow the patient to relax. • Place the IR perpendicular to the central ray so that it rests on the patient's shins. • With the patient's knee flexed to 40°, angle the	• <u>NOTE</u>: The increased OID may lead to magnification.	

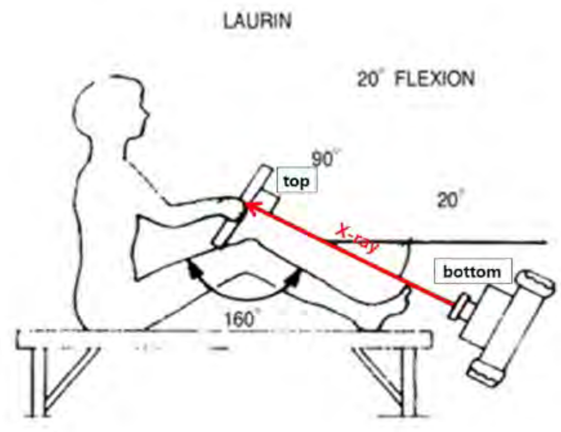
	central ray 30° caudad from the horizontal plane (60° from vertical) to achieve a 30° central ray–to–femur angle. The central ray should be aimed halfway between the patellae at the level of the patellofemoral joint (superior aspect of patella).[184] • To decrease magnification of the patella, the recommended SID should be between 48–72 in. (123 cm–183 cm).[184] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

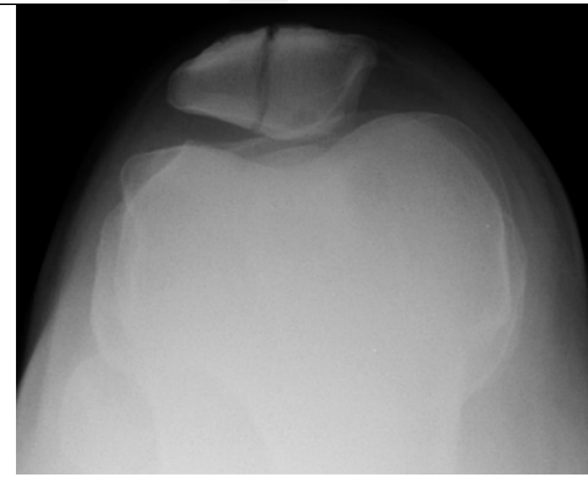
Settegast Method: Prone	• Place the patient in a prone kneeling position with the anterior aspect of the knees centered against the table. • The SID for the X-ray tube should be 40 in or 102 cm. • Safely and slowly, flex the patient's knee until the patella is perpendicular to the IR. This should **ONLY** be done if the patient is physically able to do so.[194] • If the patient needs assistance holding the position, a long bandage wrapped around the patient's ankle or foot may be used. Have the patient grasp the ends of the bandage over their	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. The protocol at most facilities is for this view to be performed in a bilateral manner to include both patellae.[194] • When performed correctly, this view demonstrates the affected patella free from superimposition of all bony structures with clear visualization of the patellofemoral joint space.	**Figure 50. Prone Positioning for the Settegast Method View of the Knee**  An illustration of positioning and band support for imaging the knee using the Settegast Method (A) and an annotated normal tangential

	shoulder to hold their leg in place. Gently adjust their leg so that the long axis of the leg is vertical.[194] • Place the IR transversely under the knee and center it to the joint space between the patella and the femoral condyles (Figure 51).[178,195] • The central ray of the X-ray beam should be directed perpendicularly to the joint space, between the patella and the femoral condyles, when the joint is perpendicular.[194] • When the joint is not perpendicular, the degree of central ray angulation depends on the degree of		projection of the knee (B). Annotated parts of the patella in (B) are: (1) the external cortical surface; (2) the patella; (3) the medial facet; (4) the lateral facet; (5) the median patellar ridge; (6) the femoropatellar joint; (7) the medial trochlear ridge; (8) the trochlear groove; and (9) the lateral trochlear ridge. Rhee et al. *J Biomed Eng Res*. 2020; Benoudina. Annotated normal tangential projection (knee). Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/46021. Published June 18, 2016. Accessed November 5, 2021.[178,195]

	knee flexion. Typically, the degree of angulation is between a 15°–20° cephalad-inferior direction.[173,194] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Settegast Method: Supine/Seated	• The patient should be safely positioned on the table in either a supine or sitting position and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient should flex the affected knee until the patella is perpendicular to	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. The protocol at most facilities is for this view to be performed in a bilateral manner to include both patellae.[194]	

	the IR. The patient should hold an appropriately sized IR centered to the knee joint space, properly secured with positioning device. • The central ray of the X-ray beam should be aimed through the joint space, between the patella and the condyles. The central ray angle will be determined by the degree of knee flexion that the patient is able to maintain. Tube angulation is typically between 15°–20° from the lower leg.[194] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and	• When performed correctly, this view demonstrates the affected patella free from superimposition of all bony structures with clear visualization of the patellofemoral joint space. • <u>NOTE</u>: This position requires acute flexion of the knees and an increased OID.	

	positioning immobilization devices as required.		
Inferior-Superior Skyline Projection (Laurin View)	• The patient should be semi-recumbent on the table holding an IR superior of the patella in the landscape orientation. • The SID for the X-ray tube should be 40 in or 102 cm. • The affected knee should be flexed 30° with the patient holding the IR.[173] • A support band may be used by the patient to hold their leg and safely keep it in position. • The central ray of the X-ray beam should be directed	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. The protocol at most facilities is for this view to be performed in a bilateral manner to include both patellae.[194] • When performed correctly, this view demonstrates the affected patella free from superimposition of all bony structures with clear visualization of the patellofemoral joint space.	**Figure 51. Inferior-Superior Positioning for the Skyline (Laurin View) of the Knee** 

	cephalad and superior 160° degrees from the vertical axis or 20° from the horizontal axis.[173] • The central ray of the X-ray beam should be aimed inferior to superior through the patella (Figure 51).[195,198] The X-ray tube should be below the level of the table; prior beginning the imaging study, RTs should ensure that the imaging facility/suite has this capability.[173] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Rhee et al. *J Biomed Eng Res.* 2020; Patel. Vertical fracture of patella. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/13920. Published May 31, 2011. Accessed November 12, 2021.[195,198]

Radiographic projections and positioning techniques for imaging the knee. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; PA = posteroanterior; RT = radiologic technologist; SID = source-to-image distance.

Whitley et al. *Clark's Positioning in Radiography*. 12th ed. CRC Press; 2005; Bull *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications; 2005; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Radiographic technique of femur, knee joint, patella and leg. Slideplayer.com Available at: https://slideplayer.com/slide/7782586/. Updated September 8, 2014. Accessed November 7, 2021; Murphy. Knee (Skyline Laurin view). Radiopaedia.org. Published January 15, 2017. Accessed November 12, 2021; Benoudina. Annotated normal tangential projection (knee). Case study. Radiopaedia.org. Published June 18, 2016. Accessed November 5, 2021; Gorton et al. Knee (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/42333. Published January 16, 2016. Accessed November 2021; Murphy. Knee (lateral view). Radiopaedia.org. Published November 14, 2019. Accessed November 2021; Lateral Knee Radiography. Wikiradiography.net. Available at: http://www.wikiradiography.net/page/Lateral_Knee_Radiography. Updated November 11, 2020. Accessed November 2021; Wertz. Lower limb. In: Lampignano JP, Kendrick LE, eds. *Bontrager's Textbook of Radiographic Positioning and Related Anatomy*. 10th ed. Elsevier; 2021:211-264; Lecture 16. Knee Joint Basic Projections. SlideToDoc.com, Available at: https://slidetodoc.com/lecture-16-knee-joint-basic-projections-ap-lateral/. Accessed November 7, 2021; Strotmeyer et al. *Arch Sports Med*. 2017; Kan et al. *Medicine (Baltimore)*. 2017;96:e9126; Murphy. Tibiofemoral osteoarthritis. Case study. Radiopaedia.org. Published October 2, 2016. Accessed November 2021; Hobbs. Osteoarthritis and the Rosenberg method. *Radiol Technol*. 2006; 6th Presentation Radiographic Technique of Femur Knee. SlideToDoc.com. Accessed November 2021; Reiff et al. *Br J Radiol*. 1991; Okamura et al. *J Exp Orthop*. 2021; Bickle. Normal knee radiographs with tunnel view. Case study. Radiopaedia.org. Published April 7, 2020. Accessed November 10, 2021; Rollins et al. *Merrill's Atlas of Radiographic Positioning and Procedures.* 14th ed. St Louis, Missouri: Elsevier; 2019; Rhee et al. *J Biomed Eng Res.* 2020; Thomson et al. *J Orthop Trauma*. 2017; Murphy. Knee (skyline Merchant view). Radiopaedia.org. Published January 16, 2017. Accessed November

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2021; Patel. Vertical fracture of patella. Case study. Radiopaedia.org. Published May 31, 2011. Accessed November 12, 2021.[83,107,124,158,173,178,181-198] For educational purposes only.

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The Femur

As outlined earlier in this course, the femur is representative of the longest, heaviest, and strongest bone in the human body.[38] The femur is divided into the following anatomical regions: head, neck, intertrochanteric, subtrochanteric, shaft, supracondylar, and condylar areas (Figure 11).[38,199] The neck is the weakest part of the femur and is the most common site of fracture. The main function of the femur is for bearing weight and gait stability.[200] The proximal end of the femur, more commonly known as the head, is a ball-shaped structure that's part of the hip joint (Figure 12).[39] There are 2 prominent bony protrusions at the proximal end of the femur: the greater trochanter and lesser trochanter. These bony protrusions are attached to muscles that move the hip and knee.[39] The medial and lateral condyle are separated by the intercondylar notch and join the femur to the tibia to form the knee joint.[22]

Proximally, the femur is composed of a specialized metaphyseal region, which is made up of the head, neck, and greater and lesser trochanters. Distally, the femur comprises the metaphyseal flare, which continues into the medial and lateral femoral condyles, separated by the intercondylar notch. The shaft, or diaphysis, is the segment inferior to the lesser and ending at the metaphyseal flair and condyles. Classically, the first 5 cm distal to the lesser trochanter is called the subtrochanteric region and is considered a separate fracture pattern.[201]

Fractures at the distal end of the femur are called supracondylar fractures (above the condyles) and often extend into the knee joint.[202] Fractures of the femoral shaft (diaphyseal) are one of the most common injuries treated by orthopedic surgeons, and they are often associated with trauma, typically involving a direct hit to the thigh or an indirect force transmitted through the knee, such as a car accident.[201]

Classification of distal femur fractures includes extra-articular, intra-articular unicondylar, intracondylar bicondylar, and pattern of fracture, including the degree of comminution.[202] There are 2 common classification systems that are used to describe diaphyseal (femoral shaft) femur fractures: The Orthopaedic Trauma Association Classification system and the Winquist and Hansen Classification system, which are as follows[199,203-204]:

The Orthopaedic Trauma Association Classification System

32A – Simple Fractures

- A1 - Spiral

- A2 - Oblique, an angle less than 30°
- A3 - Oblique, an angle less than 30°

32B – Wedge Fracture

- B1 - Spiral Wedge
- B2 - Bending Wedge
- B3 - Fragmented Wedge

32C – Complex Fracture

- C1 - Spiral
- C2 - Segmental
- C3 – Irregular

Winquist and Hansen Classification System

- Type 0: No comminution
- Type I: Insignificant comminution
- Type II: Greater than 50% cortical contact
- Type III: Less than 50% cortical contact
- Type IV: Segmental, with no contact between proximal and distal fragment

Table 13 details how to ensure that all types of femur injuries and fractures are imaged precisely and effectively.[83,124,136,205-208]

Table 13. Projections and Positioning Techniques for the Femur

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned on the table in a supine position with no hip rotation and to the proper SID for the X-ray (40 in or 102 cm). • The RT should make sure the femoral and tibial condyles are parallel.[206] • The bottom of IR should be positioned 2 in. distal to knee joint.[205] • The patient's lower limbs should be rotated internally 10°–15° so that	• This projection is part of a standard radiographic protocol. It is used for evaluating the femur for a disease process, trauma, lesions, foreign bodies, or other pathologies. • This view demonstrates the femur in its natural anatomical position allowing for assessment of suspected dislocations, fractures, localizing foreign bodies and osteomyelitis in the long bone.[207]	**Figure 52. AP Positioning for the Femur** 

	the femoral neck is in profile (Figure 52).[124,206] This should not be attempted if a fracture is suspected or clinically prohibited due to other injuries or the patient's limitations.[205] • The central ray of the X-ray beam should be perpendicular to the mid-femur. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 

			Examples of patient positioning and rotation of the legs 10° to 15° to depict the femoral neck in profile, with resultant radiograph. Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Er. Normal femur series. Case study. Radiopaedia.org. Available at: https://doi.org/10.53347/rID-79974. Published July 9, 2020. Accessed November 2021.[124,206]
Lateral	• The patient should be placed in a lateral recumbent position on the affected side. The unaffected limb should be placed behind the affected limb for support and be accessible to the proper SID for the X-ray (40 in or 102 cm).[205]	• This projection is part of a standard radiographic protocol. It is used for evaluating the femur for a disease process, trauma, lesions, foreign bodies, or other pathologies. • This view demonstrates the femur in an orthogonal position to the AP view, specifically for the	**Figure 53. Lateral Positioning of the Femur** 

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	• The patient's uninjured side should be rotated posteriorly 10° to 15° in order to prevent superimposition of the area of interest.[205] • The top of the IR should be placed at level of the ASIS.[205] • The central ray of the X-ray beam should be perpendicular to the mid-femur (Figure 53).[124,206] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	assessing the patient for suspected dislocations, fractures, localizing foreign bodies, and osteomyelitis in the long bone.[208]	 Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Er. Normal femur series. Case study. Radiopaedia.org. Available at: https://doi.org/10.53347/rID-79974. Published July 9, 2020. Accessed November 2021.[124,206]

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Radiographic projections and positioning techniques for imaging the knee. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; ASIS = anterior superior iliac spine; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; RT = radiologic technologist; SID = source-to-image distance.

Data from Whitley et al. *Clark's Positioning in Radiography*. 12th ed. CRC Press; 2005; Sandström. *The WHO Manual of Diagnostic Imaging: Radiographic Technique and Projections*. 1st ed. The World Health Organization; 2003; Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. Mosby; 1999; Femur and pelvic girdle. In: Lampignano et al, eds. *Bontrager's Textbook of Radiographic Positioning and Related Anatomy*. 9th ed. Elsevier; 2018; Er. Normal femur series. Case study. Radiopaedia.org. Published July 9, 2020. Accessed November 15, 2021; Er et al. Femur (AP view). Radiopaedia.org. Published May 21, 2020. Accessed November 15, 2021; Er et al. Femur (lateral view). Radiopaedia.org. Published July 19, 2020. Accessed November 15, 2021.[83,124,136,205-208] For educational purposes only.

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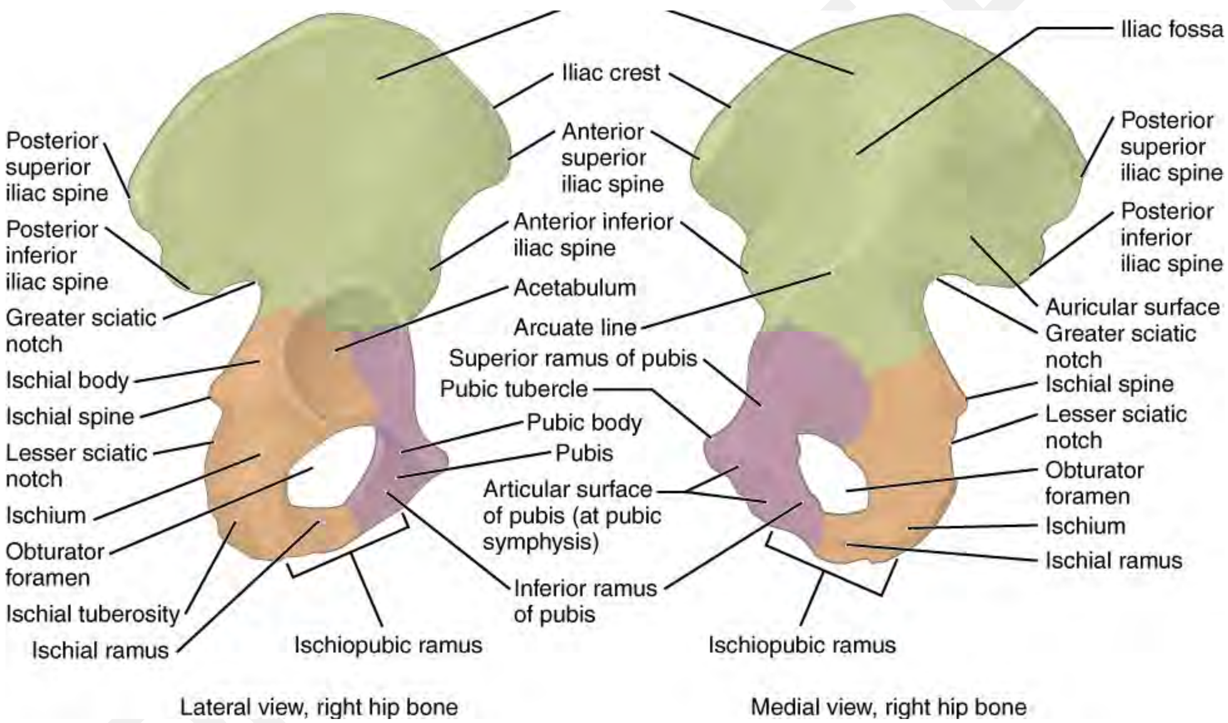
The Hip

The hip is a joint that connects the lower extremities to the axial skeleton. In addition to facilitating movement in all 3 major axes, the hip joint also facilitates weight-bearing. The head of the femur articulates with the acetabulum of the pelvis to form the hip joint. The acetabulum is a socket formed at the point of fusion and connection of the ilium, ischium, and pubis (Figure 54).[40,209] The head of the femur and the acetabulum together form a ball-and-socket joint with a large range-of-motion.[39]

Figure 54. The Hip Bone



Betts et al. The appendicular skeleton: The pelvic girdle and pelvis. In: *Anatomy & Physiology* [e-Book]. Houston, TX: OpenStax; 2021.[209] For educational purposes only.

As discussed earlier in this course, there are 2 prominent bony protrusions at the proximal end of the femur: the greater trochanter and lesser trochanter.[39] These protuberances offer attachment sites for muscles of the thigh and buttocks. Causes of pain around the hip joint may be clinically categorized as intra-articular, extra-articular, or referred pain from neighboring structures, such as the sacroiliac joint, the spine, the symphysis pubis, or the inguinal canal. Intra-articular causes of pain may include labral tears, chondromalacia, degenerative changes, intra-articular bone injury, ligamentum teres rupture, arthritis (inflammatory, infectious, etc), and various synovial proliferative disorders. Extra-articular causes of pain may include tendinopathy, bursitis, iliotibial band syndrome, muscle injury, and piriformis syndrome.[210]

Radiography of the hip is used in a patient's initial evaluation of hip pain, particularly for imaging traumatic and/or sports injuries. Radiography also allows the radiologist and/or treating physician to categorize the patient's hip as being either normal, dysplastic, or with impingement signs (pincer, cam, or a combination of both). Pathologic processes such as osteoarthritis, inflammatory diseases, AVN, infections, and tumors may also be diagnosed; causes of referred hip pain, such as sacroiliitis can also be identified.[211] Radiography, however, may not detect or accurately characterize some hip fractures and bone marrow edema associated with early AVN or early osteomyelitis; for these suspected conditions, MRI is the diagnostic modality of choice.[210]

Radiography in Hip Arthroplasty

Hip arthroplasty is one of the most common procedures performed for the treatment of patients with advanced osteoarthritis.[212] Radiography is also the initial imaging study that's performed for any patient who has already undergone a total hip replacement surgery (Figure 55).[213-214] The hip prosthesis is usually made up of the femoral stem, the femoral head (ball) that attaches to the stem, an acetabular cup, and a fixation agent to secure the stem into the femur.[215] Fractures of the prothesis mostly occur in the femoral stem of the implant, representing a metal-fatigue stress fracture. This typically occurs in prostheses that are secure distally but are loose or mobile proximally, which results in fractures through the middle or proximal third of the stem. Any postoperative X-rays must include the entire prosthetic device in the imaging receptor FOV.[212]

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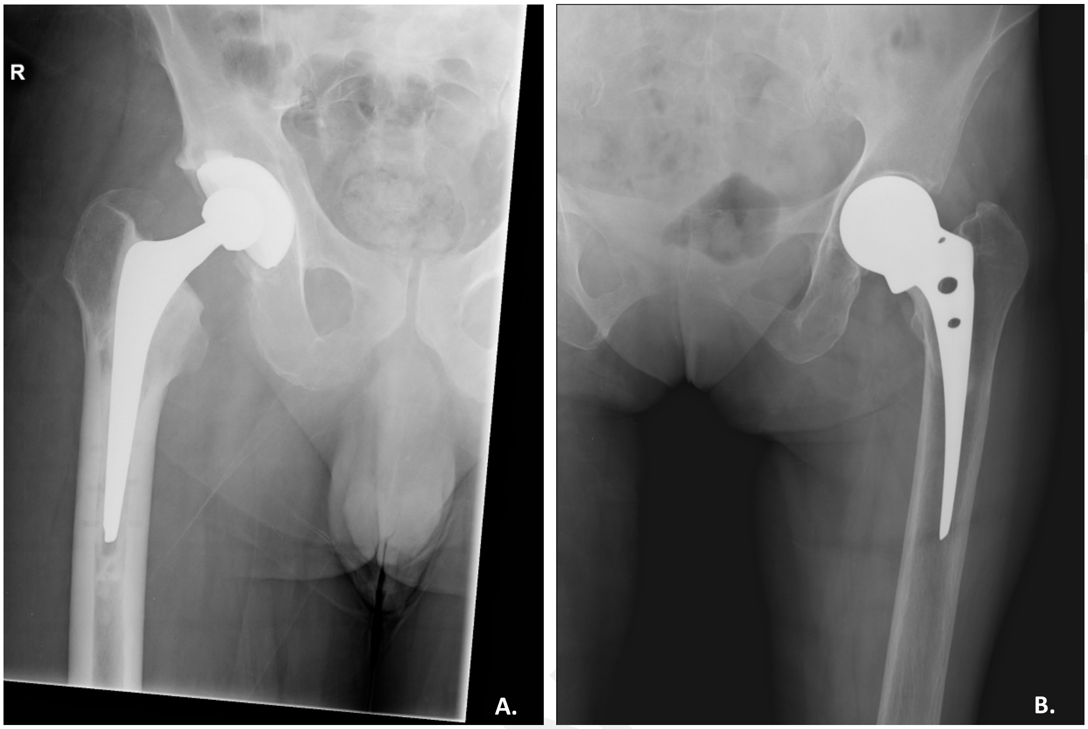
Figure 55. Radiographs of the Hip



Examples of how a total hip arthroplasty (A) and a (dislocated) hip prothesis (B) appear on X-ray.

Hacking. Total hip arthroplasty. Case study. Radiopaedia.org. Published June 22, 2015. Accessed November 18, 2021; Patel. Hip prosthesis. Case study. Radiopaedia.org. Published March 13, 2010. Accessed November 18, 2021.[213-214] For educational purposes only.

Hip Radiograph Protocols and Strategies

Many departmental protocols are based on whether the study is needed for imaging a traumatic injury or for a possible pathological condition, such as osteoarthritis. Most protocols call for weight-bearing radiographs for all patients in the initial workup who present with possible osteoarthritis. Typically, an AP radiograph of the pelvis is the first projection that should be evaluated when assessing adult patients who present with nontraumatic hip pain.[216] The patient's lower extremities should be positioned approximately 10° to 15° of internal rotation, which decreases the femoral anteversion and allows for better visualization of the femoral neck.[217]

The Cleaves Method

The second projection that should be employed in imaging and diagnosis is the Cleaves method (commonly known as the “frog-leg” lateral view). In order to obtain a proper modified Cleaves method radiograph of the hip, the patient should be supine, with the affected limb flexed at the knee approximately 30° to 40°, with the hip abducted 45°.[216] This view allows for the visualization of the anterior and posterior aspects of the femoral neck, as well as the lateral aspect of the femoral head and proximal femur.[218]

The Löwenstein View

An alternative to the frog-leg lateral view is the Löwenstein view. For this view, the patient should be turned onto the affected hip at least 45°, with a hip flexion angle of 90°, and an internal rotation angle of 45° in a supine position. Images of each side are then taken vertically from the groin region.[219] Additional views of the pelvis and hip, including the 45° and 90° Dunn view as well as Lequesne's false-profile view, can give treating physicians more information about the condition of the patient’s femur and acetabulum. However, these views are not routinely ordered during the initial evaluation of a patient who presents with generalized hip pain and are primarily used to assess femoral morphology and femoral anterior coverage.[216]

Lateral Projections

If a fracture and/or dislocation is suspected, the patient may not be able to position their leg for the frog-leg view without significant pain and/or possible additional injury. Aside from the standard AP projection, the best way to image a patient with a traumatic injury to the hip is to use the axiolateral inferosuperior projection, also known as the Danelius-Miller method; this is a lateral projection where the patient is supine, and the contralateral hip is flexed. The central ray of the X-ray beam should be positioned parallel to the table and effectively be aimed through the groin area without dorsal angulation.[220] This view is also referred to as a cross-table, or “shoot-through,” lateral view that displays the hip and pelvis at 90° from the AP radiograph.[220] This horizonal beam lateral hip radiograph provides the radiologist with an orthogonal view (90° from the AP radiograph) of the neck of the femur to the AP projection.[221]

Air Gap Technique

The air gap technique is an imaging method used to reduce the amount of scattered X-ray radiation reaching the imaging receptor from the imaged anatomy, thus reducing quantum noise and improving image contrast.[222] This technique is commonly used instead of a conventional grid for certain positions for which it is appropriate based on the imaging receptor-to-object distance.[222]

Regarding the concept of using an air gap, experts and researchers in the field have noted that the:

> "Air gap is an additional distance between a patient and an image detector. The gap decreases the likelihood for scattered X-ray radiation to reach the detector, as radiation is partially absorbed and scattered in the air. Air gap technique offers advantages over conventional grids, as the latter may, for example, lead to image artifacts, typically related to the misalignment of the grid. In the air gap technique, the OID is increased compared to the imaging with a conventional grid, which results in magnified image. To reduce magnification, SID can be increased, albeit in some cases imaging geometry may pose limitations for this increase."[222]

In DR, what also supplements the air gap technique is the use of virtual grid suppression software.[222-228] Using the air gap technique combined with grid suppression software should also provide dose reduction without the need for compensating with a conventional radiographic grid.[229]

Table 14 outlines the ideal views and positioning techniques for imaging patients with injuries and conditions of the hip.[83,216,219,221,230-235]

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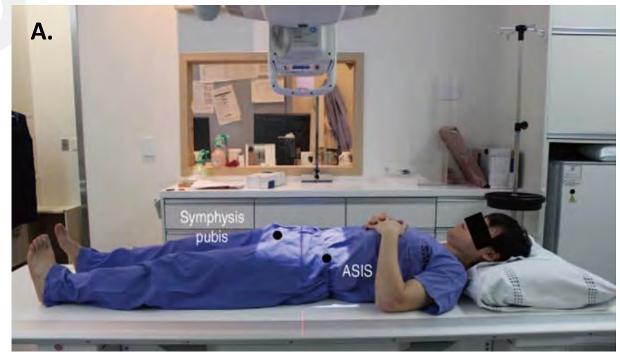
Table 14. Projections and Positioning Techniques for the Hip

Radiographic Projection	Radiographer to Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
Imaging Patients with General Hip Pain (Nontraumatic Injuries)			
AP Bilateral Pelvis-Hips/ AP View of the Injured Hip	• The patient should be safely positioned on the table in a supine position with no hip rotation and accessible to the proper SID for the X-ray (40 in or 102 cm). • The patient's lower limbs should be rotated internally 15°–25° from the hip; **do not attempt this if a fracture is suspected** or is physically prohibitive due to other injuries (Figure 56).[219,230-232]	• This projection is part of a standard radiographic protocol. It is used for evaluating the hip and pelvis when a patient presents with hip pain that appears not to be caused by trauma. • The AP view of the pelvis demonstrates: o The entirety of the bony pelvis from superior of the iliac crest to the proximal shaft of the femur if bilateral	**Figure 56. AP Views of the Pelvis and Hip** 

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	• The central ray of the X-ray beam should be perpendicular to the incident on the median line, just above the pubic symphysis. If only the affected hip is being imaged, then collimation should be around that region, centering near the greater trochanter in the midline of the femur.[219] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	o That both sides of the iliac wings and obturator foramina are symmetric; the distance between the superior border of the pubic symphysis and the tip of the coccyx should be between 1 cm and 3 cm. o That the obturator foramina appear symmetrical o That the iliac wings are equally concave o That the greater trochanters of the proximal femur are in profile[230]	 

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- An AP view of the affected hip demonstrates:
  - The entirety of the hip and proximal femur, with the long axis of the femur running parallel to the long axis of the image
  - The greater trochanter, in profile, signifying adequate internal rotation of the limb

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In a supine position (A), the image should be taken toward the middle of the line connecting the upper part of the symphysis pubis and ASIS; either both patellae should be facing forward, or the patient’s lower extremities should be internally rotated by 15°–20° (B) to accommodate femoral anteversion in anteroposterior hip radiographs. Resultant
</td>
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			normal X-rays of the hip/pelvis (C) and an image of a comminuted fracture through the left proximal third femoral diaphysis (D) that is transversely oriented exemplify this particular view. Lim et al. *Hip Pelvis*. 2015; Murphy. Pelvis (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/44863. Published May 6, 2016. Accessed November 22, 2021; Lukies. Normal pelvis and both hips. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/51246. Published February 8, 2017. Accessed November 23, 2021.[219,230-231] For educational purposes only.
The Cleaves Method (“Frog-Leg” Lateral view)	• The patient should be safely positioned on the table in a supine position with no hip rotation and accessible to the proper SID for the X-ray (40 in or	• This projection is part of a standard radiographic protocol. It is used for evaluating the hip and pelvis for a bony disease process such as osteoarthritis or other	

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	102 cm). • The patient's affected limb should be flexed at the knee approximately 30° to 40°; the hip should be abducted 45°.[216,219,233] • Only if the patient is able to, without pain or discomfort, the patient should slowly position their legs so that the soles of their feet are touching (Figure 57).[219,233] • If the study is only imaging the affected hip, the central ray of the X-ray beam should be aimed at the greater trochanter in the midline of the femur.[219]	pathologies. • This view allows for visualization of the anterior and posterior aspects of the femoral neck, as well as the lateral aspect of the femoral head and proximal femur.[235]	**Figure 57. Positioning for the Cleaves Method/Frog-Leg (Bilateral) View of the Hip** 

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	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Lim et al. *Hip Pelvis*. 2015; Bickle. Normal frog leg lateral radiograph. Case study. Radiopaedia.org. Available at: https://radiopaedia.org/cases/75853. Published April 9, 2020. Accessed November 25, 2021.[219,233] For educational purposes only.
Imaging Patients with Hip Trauma (For Ruling out Fractures)			
AP Bilateral Pelvis-Hips/ AP View of the Injured Hip	• The patient should be safely positioned on the table supine; the SID for the X-ray tube should be 40 in or 102 cm.	• This projection is part of a standard radiographic protocol. It is used for evaluating the hip and pelvis for trauma or	**See Figure 56.**

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	• The RT should make sure the median sagittal plane is 90° to the table, and the ASIS is equidistant from the radiographic tabletop.[83] • The central ray of the X-ray beam should be perpendicular to the incident on the median line just above the pubic symphysis. • If only the affected hip is being imaged, then collimation should be around that region, centering near the greater trochanter in the midline of the femur (see Figure 56 above).[219,230-232]	injury and to rule out fracture. • An AP view of the pelvis demonstrates: o The entirety of the bony pelvis from superior of the iliac crest to the proximal shaft of the femur if bilateral o That both sides of the iliac wings and obturator foramina are symmetric; the distance between the superior border of the pubic symphysis and the tip of the coccyx should be between 1 cm and 3	

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	• When using this technique to image a traumatic injury, **do not rotate the patient's lower extremities**; doing so could cause further injury. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	cm. o That the obturator foramina appear symmetrical o That the iliac wings are equally concave o That the greater trochanters of the proximal femur are in profile[230] • An AP view of the affected hip demonstrates: o The entirety of the hip and proximal femur, with the long axis of the femur running parallel to the long axis of the	

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		image • The greater trochanter, in profile, signifying adequate internal rotation of the limb	
Axiolateral Inferosuperior Projection (Danelius-Miller Method)	• The patient should be safely positioned on the table supine; the SID for the X-ray tube should be 40 in or 102 cm. • RTs should instruct the patient to put both arms on their chest, with their fingers interlocked. The patient's affected side should be positioned closest to the IR.[219] • The IR should be angled approximately 20°–45° to	• This projection is part of a standard radiographic protocol. It is used for evaluating the hip and pelvis for trauma or injury and to rule out fracture. • This view demonstrates the lesser trochanter in profile, while the proximal femoral shaft superimposes the greater trochanter.[221] • The femoral neck should be central to the image and should show no signs of radiographic	**Figure 58. Positioning for the Axiolateral Inferosuperior Projection (Danelius-Miller Method)** 

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	match the angle of the neck of femur (observed on the AP pelvis/hip) (Figure 58); this helps prevent elongation or foreshortening of anatomy being imaged.[219,221] • The IR should be placed in a landscape orientation superior to the iliac crest, allowing for adequate imaging of the femoral neck. Ensure the edge of the IR is superior to the iliac crest to ensure anatomy inclusion.[221] • The patient's unaffected hip can now be flexed and abducted. The flexed unaffected leg should be	foreshortening or elongation distortion. • There should be clear visualization of the articular surface of the acetabulum and the head of the proximal femur. • NOTE: Since the unaffected leg has been elevated, there should be no obstructing soft tissue artefact. • NOTE: Based on the patient's body habitus, any of the following scatter radiation limitation devices, if available, may be utilized to improve contrast and image quality: o Air gap technique	 B. Patient positioning using the Danelius-Miller Method for the modified Lorenz View (A) with resultant radiograph (B); this is also known as the cross-table lateral view. The patient's hip should be positioned horizontally, with the beam directed laterally. Lim et al. *Hip Pelvis*. 2015.[219] For educational purposes only.

	placed on a dedicated positioning stand. As this is likely very uncomfortable for the patient, their leg should only be positioned upwards for a limited amount of time.[221] • The central ray of the X-ray beam should be aimed perpendicular to the long axis of the neck of femur. The IR should be adjusted to match this angle.[221] • The technical centering point is 13 cm distal to the neck of femur, anecdotally known as centering at the most superior region of the groin.[221]	o Virtual grid suppression software o Conventional antiscatter grid o Compensating filter	

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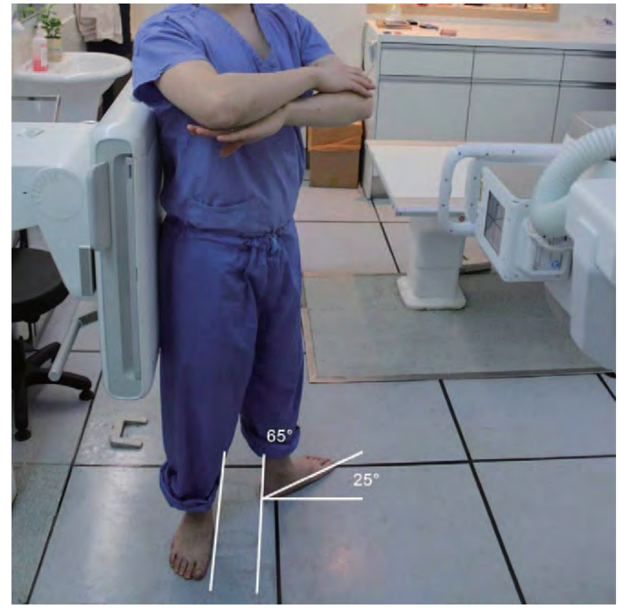
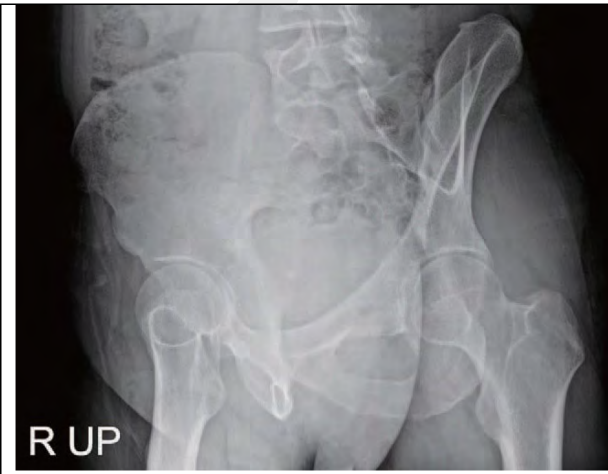
	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Supplemental Views of the Hip			
Löwenstein View	• The patient should be safely positioned on the table supine with no hip rotation; the SID for the X-ray tube should be 40 in or 102 cm. • The patient should be turned onto the affected hip at least 45°, with a hip flexion angle of 90°, and an internal rotation angle of 45° in a supine position. Images of each side are then taken	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the radiologist. • The Löwenstein view is used to evaluate the sphericity of the femoral head, joint congruency, and the shape and offset of the head-neck junction.[219]	**Figure 59. Positioning for the Löwenstein View of the Hip** 

	vertically from the groin region (Figure 59).[219] • The central ray of the X-ray beam should be aimed at the greater trochanter in the midline of the femur.[219] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Lim et al. *Hip Pelvis*. 2015.[219] For educational purposes only.
Lequesne's False-Profile View	• RTs should gently maneuver the patient into a standing position, with the back of their knees centered to the vertical wall bucky and IR.	• This projection is a nonroutine ancillary projection and is utilized as ordered by the referring clinician or recommended by the	

	• The patient's back should be placed against the IR and tilted 65° anteriorly in relation to the IR (Figure 60).[219] Both lower limbs should be rotated externally, with the foot of the affected limb placed perpendicular to the IR. The contralateral limb should be parallel to the upright IR.[219] • The central ray of the X-ray beam should be aimed towards the greater trochanter in the midline of the femur. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning	radiologist. • The Lequesne's false-profile view is so named, because it corresponds to the profile of the head and of the proximal femur and not the acetabulum.[235]	**Figure 60. Positioning for Lequesne's False-Profile View of the Hip** 

	immobilization devices as required.		Lim et al. *Hip Pelvis*. 2015.[219] For educational purposes only.

Radiographic projections and positioning techniques for imaging the knee. The IR can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; ASIS = anterior superior iliac spine; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; RT = radiologic technologist; SID = source-to-image distance.

Data from Whitley et al. *Clark's Positioning in Radiography*. 12th ed. CRC Press; 2005; Clohisy et al. *J Bone Joint Surg Am*. 2008; Lim et al. *Hip Pelvis*. 2015; Murphy. Hip (horizontal beam lateral view). Radiopaedia.org. Published May 17, 2016. Accessed November 17, 2021; Murphy. Pelvis (AP view). Radiopaedia.org. Published May 6, 2016. Accessed November 22, 2021; Lukies. Normal pelvis and both hips. Case study. Radiopaedia.org. Published February 8, 2017. Accessed November 23, 2021; Murphy. Bilateral femoral fractures (Clements-Nakayama view). Case study. Radiopaedia.org. Published October 1, 2017. Accessed November 23, 2021; Bickle. Normal frog leg lateral

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Conclusions

Considering radiographs are the most important and most often used first-line modality in clinical imaging, standardized patient positioning techniques and adhering to departmental protocols are essential for evaluating a patient with many possible pathologies, particularly with traumatic injuries or possible pathologies to the lower extremities. The benefits of using diagnostic radiography as a first-line modality include low radiation dose, low cost, universal availability, and the ability to perform mobile examinations when necessary. Diagnostic radiography can be used to evaluate patients for arthritis (degenerative and inflammatory processes), bone tumors (lytic and sclerotic primary and metastatic disease), infections, foreign bodies, dislocations, and fractures, among many possible conditions. The importance of appropriate patient positioning and employing accurate exposure settings when taking diagnostic radiographs of the hip, femur, knee, lower leg, ankle, foot, calcaneus, and toes are essential in diagnosing both traumatic and nontraumatic injuries or disease processes. The use of nonroutine projections in imaging and diagnosis can sometimes play a part in detecting diseases or injuries that may have been missed on standard imaging views. As a result, RTs play crucial role in executing accurate positioning techniques, ensuring equipment and departmental protocols are adhered to, and caring for the patient during imaging studies, all of which yield a successful diagnostic imaging study of the lower extremities.

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