BACK TO BASICS: RADIOGRAPHY OF THE UPPER EXTREMITIES

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ABSTRACT

Conventional radiography remains the imaging modality of choice for most applications in the upper extremity. The most common indication for radiographs of the upper extremity is acute trauma. The shoulder, humerus, elbow, forearm, wrist, and hand are common radiographic series that are useful in diagnosing an acute fracture, dislocation, or other traumatic injuries a patient may sustain to the upper body. Evaluating other bony pathologies in the upper extremity is also most frequently performed with radiography as the initial evaluation and diagnostic modality. Other imaging modalities such as computed tomography, sonography, and magnetic resonance imaging play an important supplementary role in helping to diagnose patients with soft tissue injuries. It is important that the radiographer understand all the components of the imaging chain that lead to the production of high-quality diagnostic radiographs. This course will provide detailed reviews of the anatomy and bones of the upper body including as well as ideal patient positioning for both standard and nonstandard projections of the fingers (digits and thumb), the hand (metacarpals), the wrist, the forearm, the elbow joint, the humerus, the shoulder, the glenohumeral joint, the scapula, the clavicle, and the acromioclavicular 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 the clinical setting is its role in musculoskeletal imaging for both acute trauma or evaluation of bony pathology. The radiographers need to be aware of the various positions and techniques required to provide the clearest view of the anatomy in question. Correct positioning goes hand-in-hand with the proper radiographic exposure settings to provide a diagnostic quality radiograph at the lowest patient dose possible. The first step in achieving a successful X-ray imaging study of the upper extremities is to understand the basics of the anatomy being imaged.

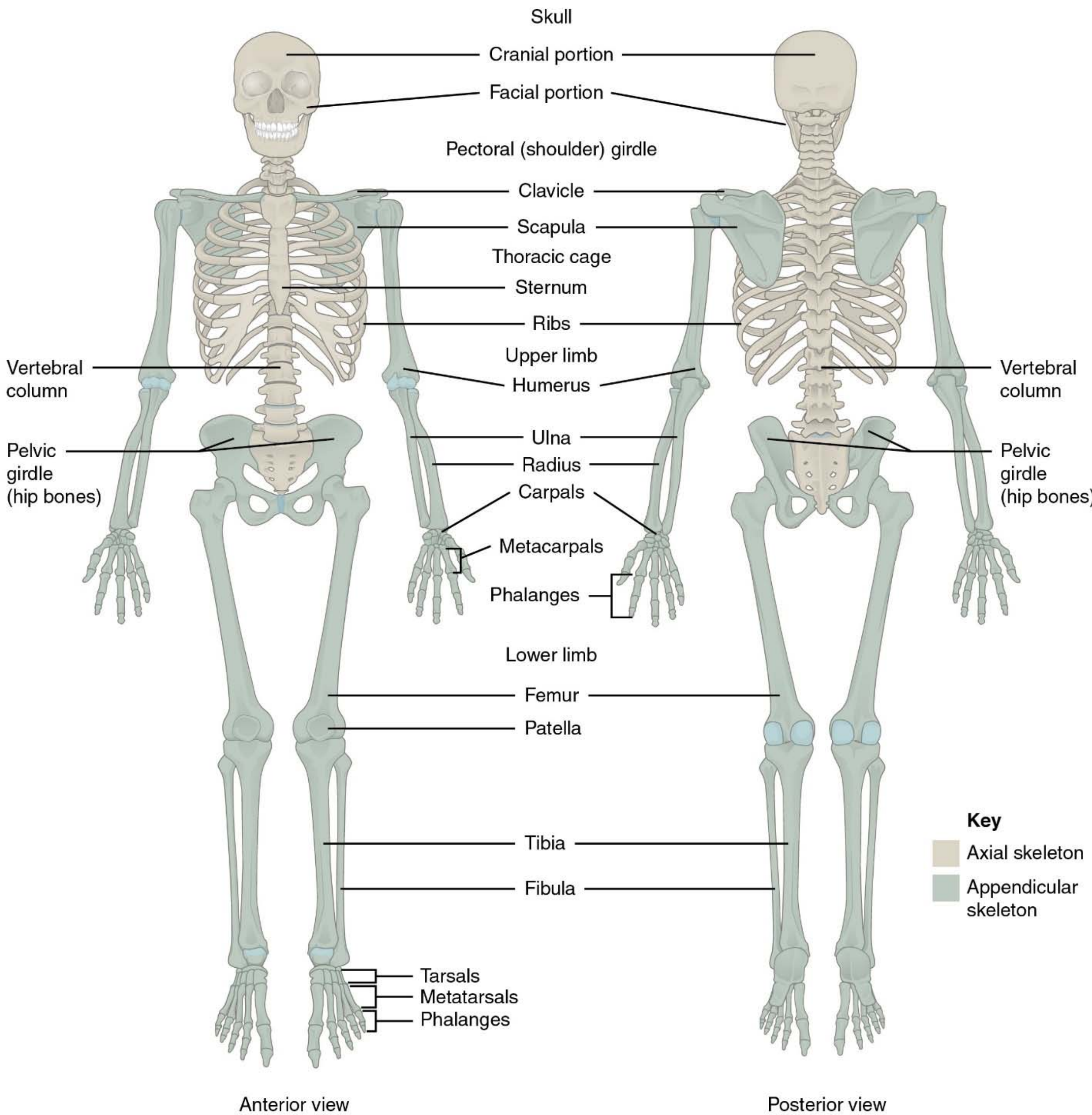
An Overview of the Skeletal Anatomy of the Upper Extremities

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).

Figure 1. Axial and Appendicular Skeleton



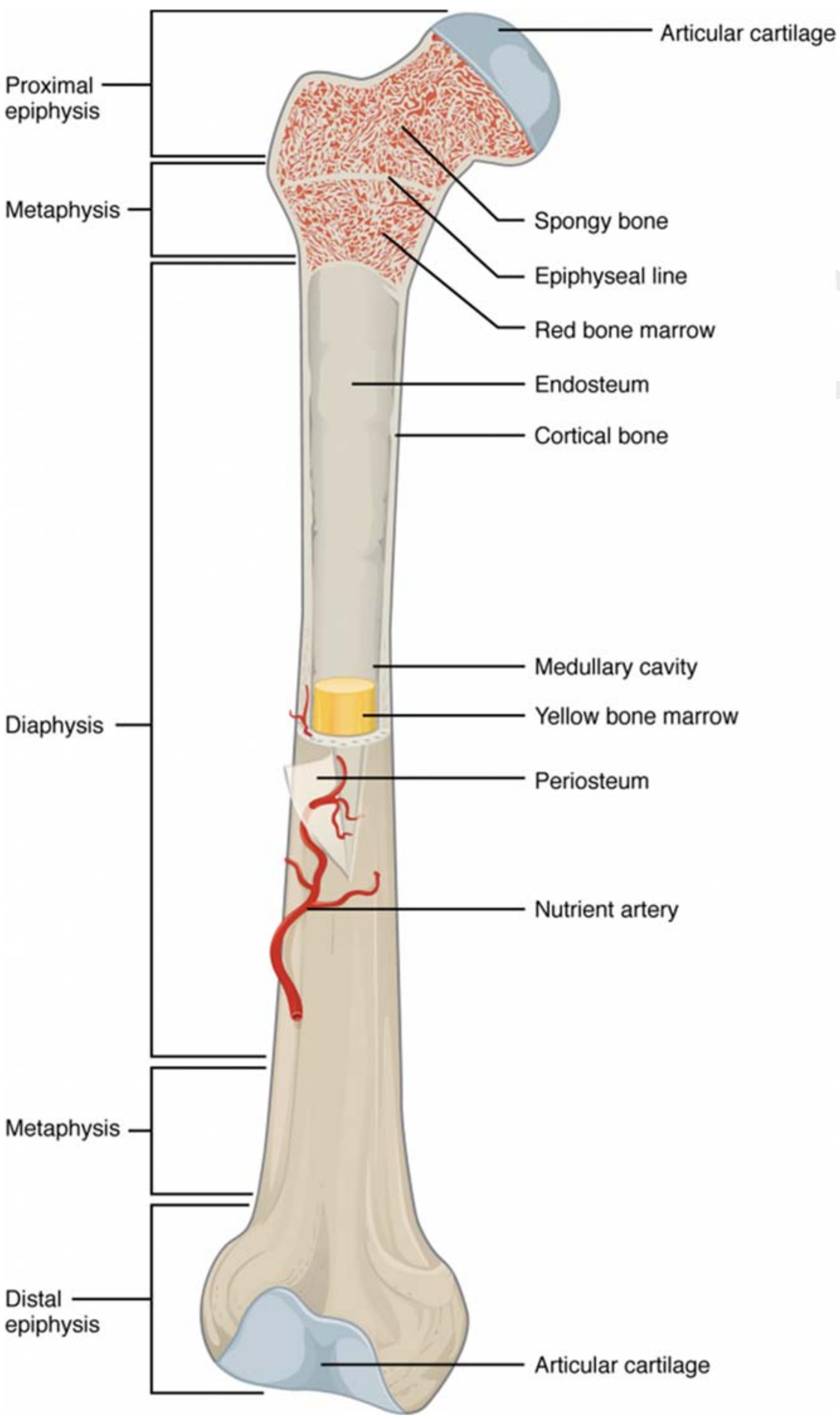
Betts et al. Divisions of the skeletal system. In: *Anatomy and Physiology*. Houston, TX: OpenStax; 2021.[7] For educational purposes only.

The skeletal system contains 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. Bone tissue is made up 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.

Figure 2. Anatomy of a Long Bone



A typical long bone with its various anatomical features.

Biga et al. Bone structure. In: *Anatomy & Physiology* [e-book]. 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 the radiographer 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 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, usually at the bone's proximal and distal portions, which is essential for bone growth.
- Facet: A smooth, flat, surface where bone articulates with another bone. When connected with another flat bone or another facet, they create a gliding joint.
- Fissure: An open region in a bone that usually houses 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.
- 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.

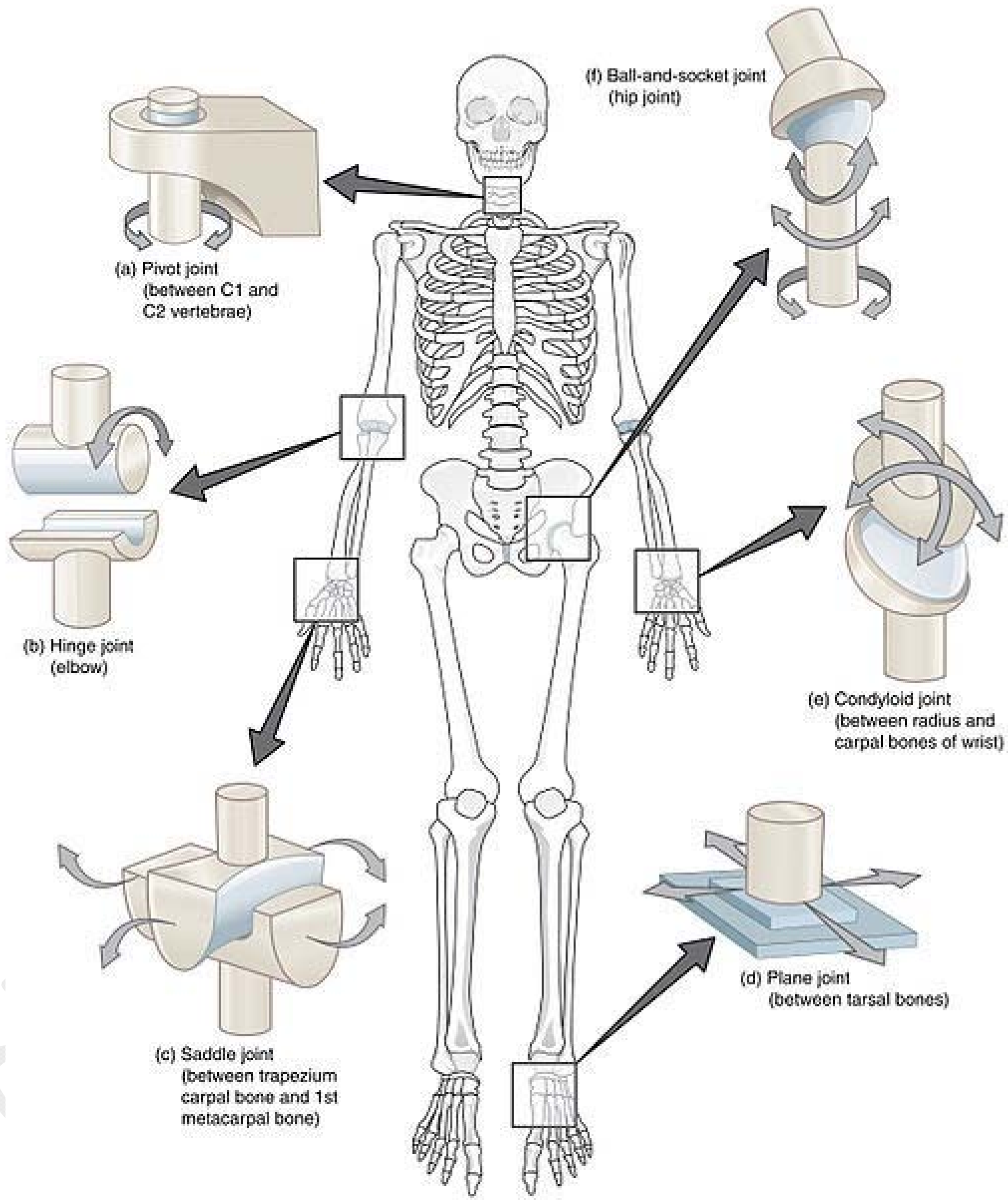
Joints

A joint is defined as a point where 2 bones come together. The main function of the joint is to enable movement to occur 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 ability 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 joint, also known as symphysis, 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 freely mobile (diarthroses or diarthrodial) and are considered to be the main functional joints of the body. They are further classified as follows, which are pictured in Figure 3[13-15]:
    - Ball-and-socket joints: An articulation between the rounded head of one bone (ball) and the concavity of another (socket). This type of joint provides the greatest range-of-motion as it allows movement in multiple planes. An example is the shoulder joint or hip joint.
    - Condyloid joints: 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 joints: An articulation between the convex end of one bone and the concave end of another; examples include the elbow and interphalangeal joints.
    - Pivot joints: Allow for rotation around a central axis; an example is the proximal radioulnar joint.
    - Planar joints: Also called gliding joints, they are the articulation between bones that are both flat and of similar size. An example is the acromioclavicular joint (AC joint) between the acromion of the scapula and the clavicle.
    - Saddle joints: Biaxial joints that allow movement in 2 planes (abduction and adduction as well as flexion and extension). The thumb is an example of a saddle joint.

Figure 3. Examples of Synovial Joints



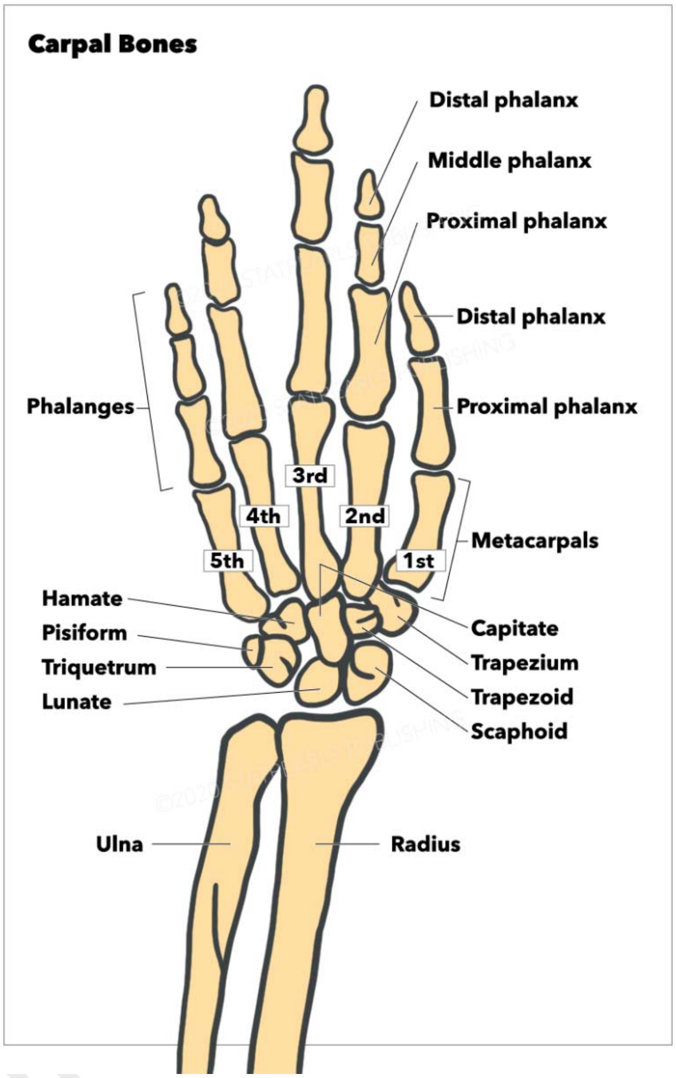
Synovial Joints: Structure of Synovial Joints. In: *Anatomy & Physiology* [e-book]. Lumen Learning; 2021. Accessed March 2021.[15] For educational purposes only.

Bones of the Upper Extremities

Fingers (Digits), Hand, and Wrist

Anatomically, the fingers are named and define as digits, which are labeled by number and location. For example, the second digit is also named the middle phalanx.[16] A total of 27 bones make up the hand: 14 phalanges, 5 metacarpals, and 8 carpals (Figure 4).[17] The metacarpophalangeal (MCP) joint is the point where the bones of the hand (metacarpals) meet the bones of the fingers. The index finger, long finger, ring finger, and small fingers each have proximal, middle, and distal phalanges.[18] The proximal phalanges form MCP joints with their associated metacarpal bones, while the thumb only has a proximal and distal phalanx.[16-17] The head of each proximal phalanx articulates with the base of each middle phalanx to form proximal interphalangeal (PIP) joints. The head of each middle phalanx articulates with the base of each distal phalanx to form distal interphalangeal (DIP) joints. On radiography, the reference points for hand joints are the palmar or volar surface (the palm side), the dorsal surface (the back of the hand), the radial side (toward the thumb), and the ulnar side (toward the little finger).[16-17]

Figure 4. Carpal Bones



Tang A, Varacallo M. Anatomy, Shoulder and Upper Limb, Hand Carpal Bones. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021. Illustration by Emma Gregory.[17] For educational purposes only.

The carpal bones are bones of the wrist that connect the distal aspects of the radial and ulnar bones of the forearm to the bases of the 5 metacarpal bones of the hand.[17] Eight short bones make up the wrist, or carpals. The carpal bones are divided into a distal and proximal row.[16] The proximal row of carpal bones (moving from radial to ulnar) are the scaphoid, lunate, triquetrum, and pisiform, while the distal row of carpal bones (also from radial to ulnar) comprises the trapezium, trapezoid, capitate, and hamate.[17] The wrist is made up of the following joints[16-17]:

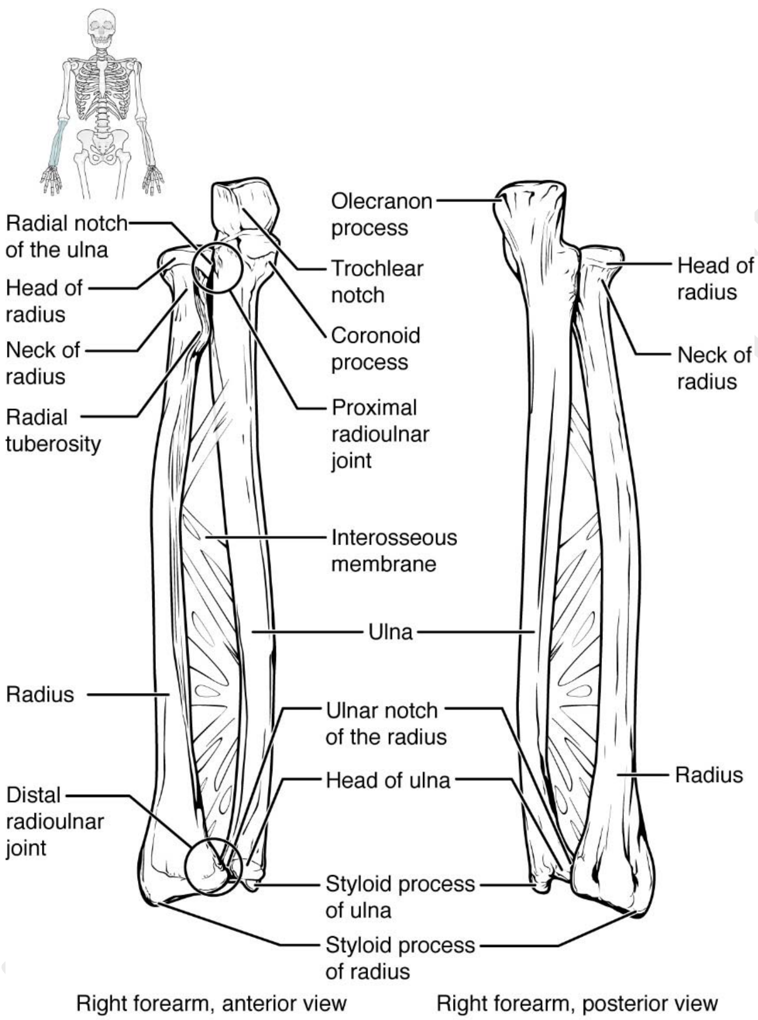
- Radiocarpal Joint: Consists of the radius, one of the forearm bones, and the first row of wrist bones consisting of the scaphoid, lunate, and triquetrum.
- Ulnocarpal Joint: Includes the ulna, one of the forearm bones, as well as the lunate and triquetrum.
- Distal Radioulnar Joint: Located at the wrist where the 2 forearm bones meet.
- Scaphotrapeziotrapezoid Joint: is located at the base of the thumb in the wrist. It is made up of 3 wrist bones: the scaphoid, the trapezium, and the trapezoid.

The scaphoid is the largest of the carpal bones, which can be palpated near the base of the thumb. It's also the most frequently fractured bone in the wrist. The capitate is centrally located and is the largest carpal bone. The hamate has the appearance of a wedge and has a hook on the anterior surface called the hook of the hamate.[17] The association of the hamate and pisiform bones forms the medial margin of the carpal groove.

Forearm-Elbow Joint

The forearm of the upper extremity extends from the elbow to the wrist and provides the bony and muscular structure that allows the hand to move in many different positions and orientations. The 2 bones that make up the forearm (the radius and ulna) function together and allow flexion and extension at the elbow and wrist.[19] The radius is on the lateral side, and the ulna on the medial side.[14] The proximal ulna articulates with both the distal humerus (forming the ulnohumeral joint) and the proximal radius (forming the proximal radioulnar joint).[19] The posterior and superior portions of the proximal ulna make up the olecranon process, which forms the bony tip of the elbow. The olecranon process, the coronoid process, and trochlear notch all articulate with the trochlea of the humerus.[19-21] The elbow joint is surround by 2 fat pads, an anterior pad lying within the coronoid fossa, and a slightly larger posterior pad located within the olecranon fossa (Figure 5).[20]

Figure 5. The Ulna and the Radius



An illustration of the bony components of the ulna and the radius in the forearm.

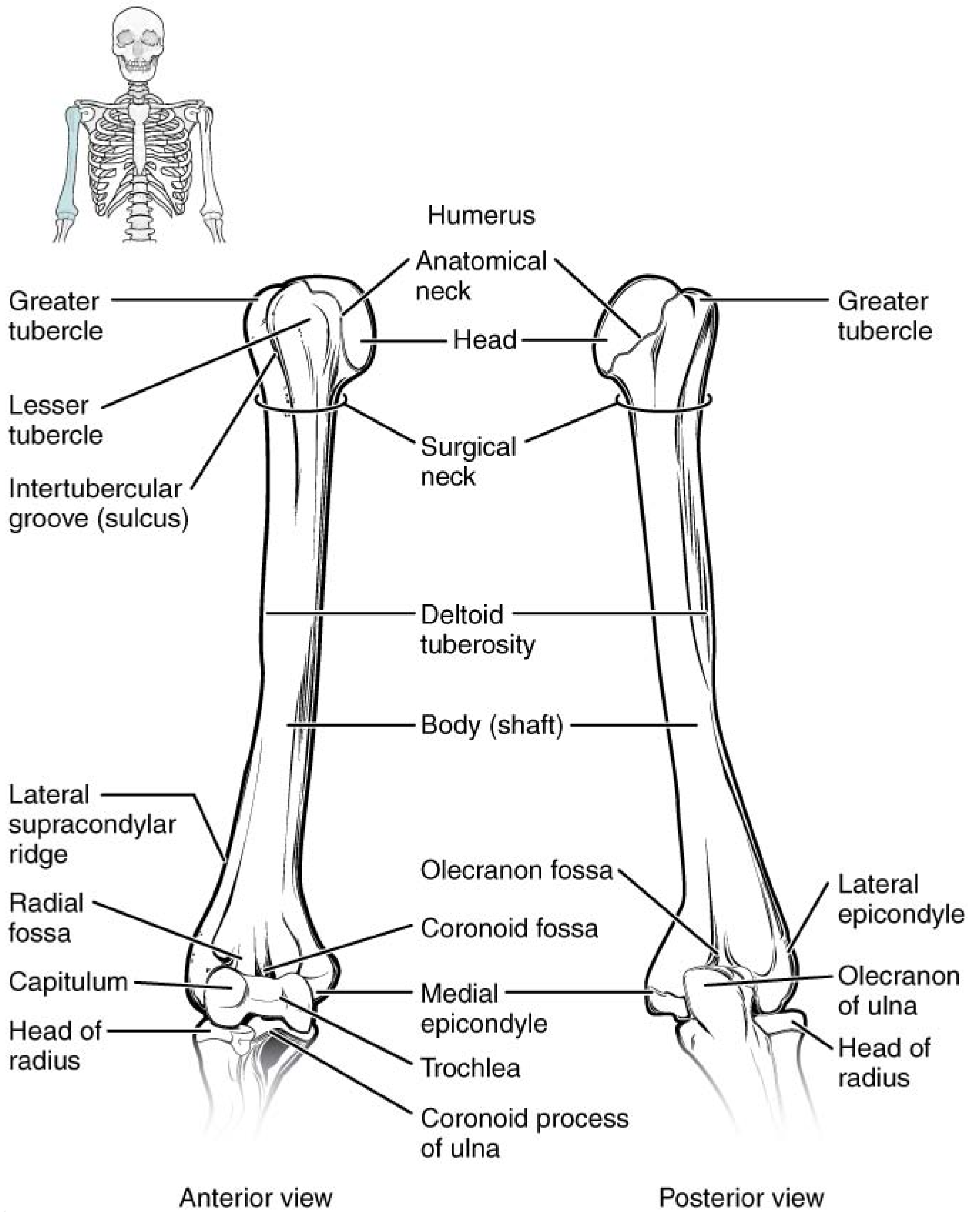
The Skeletal System: Bones of the Upper Limb. In: *Anatomy and Physiology* [e-book]. Lumen Learning; 2021.[20] For educational purposes only.

Radial head and neck fractures are the most common elbow fractures encountered in adults and can be classified by the Mason-Johnston system. These fractures can be very subtle and are sometimes missed; on occasion, a displaced anterior fat pad may be the only radiographic sign of a radial head/neck fracture. Additionally, distal humerus fractures and coronoid process fractures are not uncommon. Some uncommon fracture/dislocations of the elbow that include forearm and wrist pathology are the Monteggia, Essex-Lopresti, and Galeazzi fractures/dislocations.[22-23]

Humerus

The humerus is the largest bone of the upper extremity.[15] The shaft or body of the humerus is the long mid-portion of the bone. It moves proximally with the glenohumeral joint and distally with the radius and ulna at the elbow. At the distal portion of the humerus, the bone widens and forms the medial and lateral epicondyles. Located on the lateral side of the proximal humerus is a bony region called the greater tubercle; the smaller lesser tubercle of the humerus is located on the anterior aspect of the humerus. Both the greater and lesser tubercles serve as attachment sites for muscles that move across the shoulder joint.[20] The greater tubercle has 3 facets: the superior, the middle, and the inferior, which serve as the insertion sites for the supraspinatus, infraspinatus, and teres minor tendons.[24] The distal end of the humerus has 2 articulation areas, which join the ulna and radius bones of the forearm to form the elbow joint. The prominent bony projection on the medial side is the medial epicondyle of the humerus (Figure 6).[20] The much smaller lateral epicondyle of the humerus is located on the lateral side of the distal humerus.[20]

Figure 6. The Humerus and Elbow Joint



An illustration of the bony components of the elbow joint to the proximal portion of the humerus.

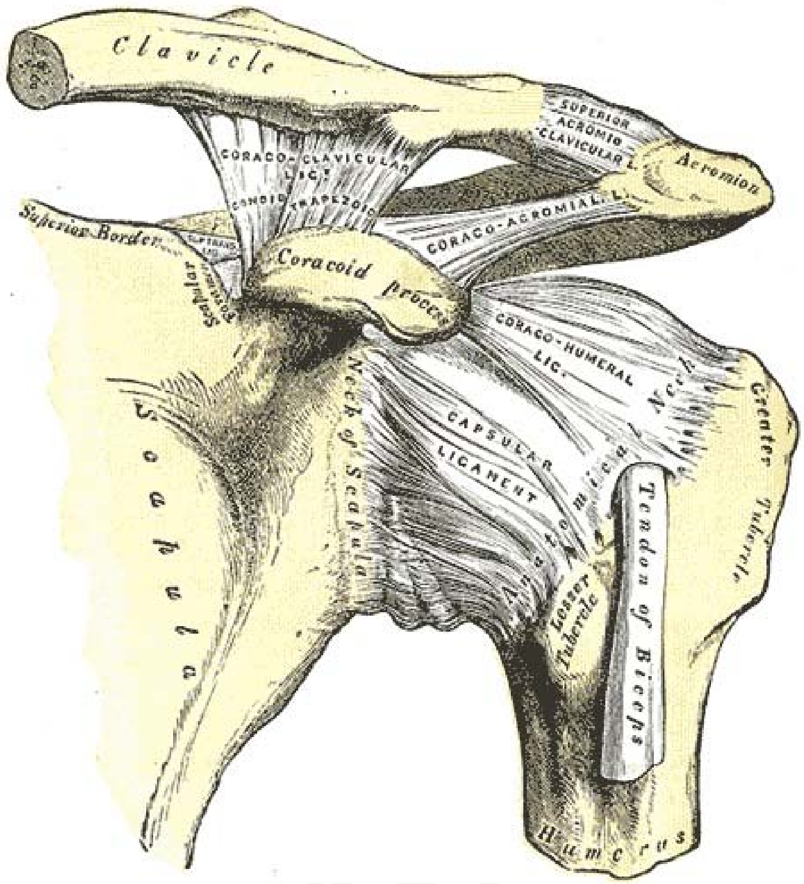
The Skeletal System: Bones of the Upper Limb. In: *Anatomy and Physiology* [e-book]. Lumen Learning; 2021.[20] For educational purposes only.

Shoulder Girdle (Glenohumeral and Sternoclavicular Joints)

The shoulder is a ball-and-socket type of joint formed by articulation between the head of humerus and glenoid portion of the scapula.[25] It's an intricate anatomical structure that is composed of 4 separate articulations, including the glenohumeral, AC, sternoclavicular, and scapulothoracic joints (Figure 7).[25]

- Sternoclavicular joint**:** A synovial saddle joint that is the only joint that connects the upper limb to the axial skeleton. It's a cartilage-lined joint formed by incongruent articular surfaces. This represents a double-gliding joint.
- AC joint: A plane synovial joint that connects the acromion of the scapula to the clavicle. This represents a gliding joint.
- Scapulothoracic joint: This is not considered a true joint but more of an articulation of the scapula gliding over the posterior thoracic cage.
- Glenohumeral joint: A highly functional ball-and-socket synovial joint. The glenohumeral joint provides the largest range-of-motion of all the body's large joints.

Figure 7. The Left Shoulder



Miniato MA, Anand P, Varacallo M. Anatomy, Shoulder and Upper Limb, Shoulder. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[25] For educational purposes only.

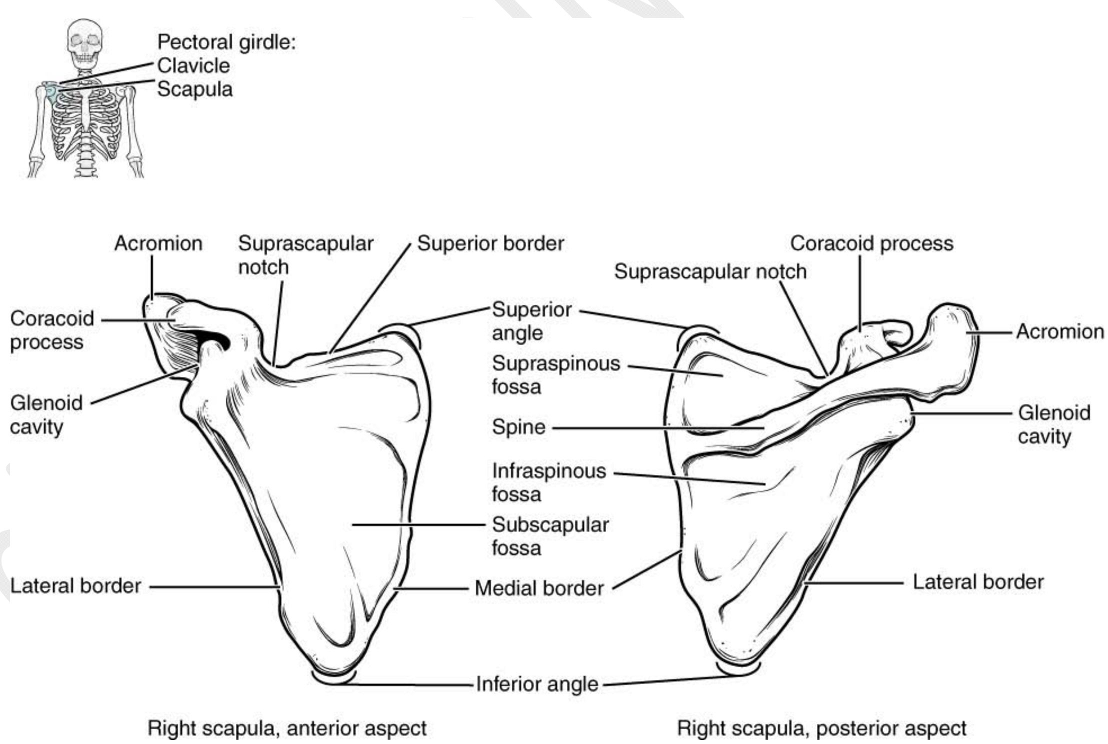
Occasionally, anterior dislocations and the often related posterolateral humeral head compression fracture (Hill-Sachs deformity) can present diagnostic issues. The less often related anterior glenoid fracture (Bankart lesion) is not easily recognized. Posterior dislocation may be suspected when the humeral head appears to be internally rotated on both anteroposterior internal and external rotation views, related to the fixed position of the dislocated head.[26] Posterior shoulder dislocations are much less common than anterior dislocations (1.1 vs 23.9 cases/100 000 population per year) but are much more frequently misdiagnosed at initial presentation (up to 79% of the time).[27] For these types of possible injuries, magnetic resonance imaging (MRI) is considered to be the most comprehensive imaging study of the anatomic structures in this part of the body. MRI is also considered to be the imaging standard for the evaluation of labral pathologic abnormalities and is the ideal modality for evaluating rotator cuff tears and radiographically occult fractures, among other indications.[28]

Scapula-Clavicle (Pectoral Girdle) and AC Joint

Scapula

The pectoral girdle is made up of the clavicle and the scapula, which attach the upper limb to the sternum of the axial skeleton. The scapula (or the shoulder blade) is a flat, triangular-shaped bone with a prominent ridge located on its posterior surface, which is positioned on the posterior aspect of the shoulder. This ridge extends out laterally, where it forms the bony tip of the shoulder and connects with the lateral end of the clavicle. Anatomically, the clavicle is the only long bone horizontally positioned in the body.[29] The scapula has several important anatomical topographic landmarks (Figure 8).[29]

Figure 8. The Scapula



The isolated scapula is shown here from its anterior (deep) side and its posterior (superficial) side.

The Appendicular Skeleton: The Pectoral Girdle. In: *Anatomy and Physiology I*. OpenStax College/Rice University; 2021.[29] For educational purposes only.

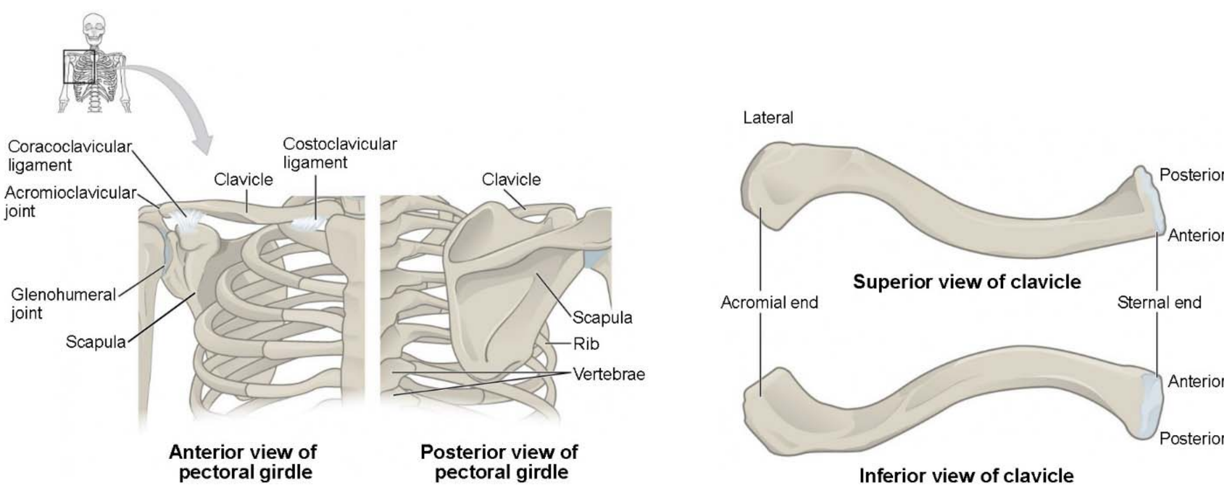
The 3 borders of the scapula, named for their anatomical locations, are: the superior border, the medial border, and the lateral border. The corners of the triangular scapula, at either end of the medial border, are the superior angles, located between the medial and superior borders. The inferior angles are positioned between the medial and lateral borders and are the most inferior aspects of the scapula. They serve as attachment points for several strong muscle groups involved in shoulder and upper limb movements.[30]

The scapula also has 2 prominent anatomical bony projections. The hook-like coracoid process (coracoid = "shaped like a crow's beak") is located at the lateral end of the superior border, between the suprascapular notch and glenoid cavity. The other prominent projection of the scapula is located on the posterior surface and is named the spine of the scapula. The acromion forms the bony tip of the superior shoulder region and articulates with the lateral end of the clavicle; together, they form the AC joint.[28] The clavicle, acromion, and spine of the scapula merge together to form a V-shaped bony line that, which is the attachment point of the neck and back muscles that act on the shoulder, as well as the additional muscles that pass across the shoulder joint to act on the arm.[28]

Clavicle

The clavicle includes 3 main regions: the medial end, the lateral end, and the shaft. The medial end is referred to as the sternal end of the clavicle (Figure 9).[29] The medial end has a triangular shape and articulates with the manubrium region of the sternum. This in turn forms the sternoclavicular joint, which is the only bony articulation between the pectoral girdle of the upper limb and the axial skeleton. The clavicle can transmit forces acting on the upper limb over to the sternum and axial skeleton. It also provides a barrier and protection for the underlying nerves and blood vessels as they pass between the trunk of the body and the upper limb. The clavicle is the most fractured bone in the body.[29] Such fractures often occur because of the force exerted on the clavicle when a person falls onto their outstretched arms or when the lateral shoulder receives a strong strike or trauma.[29-30]

Figure 9. The Clavicle

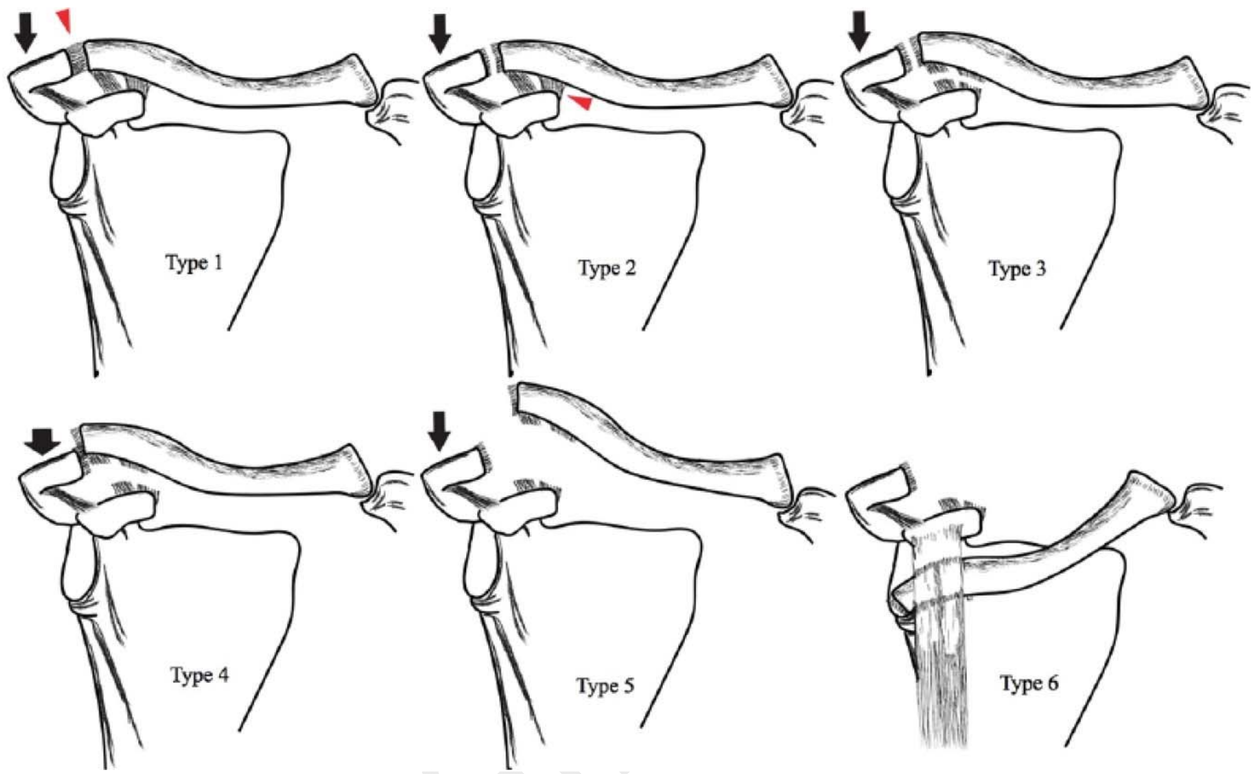


The Appendicular Skeleton: The Pectoral Girdle. In: *Anatomy and Physiology I*. OpenStax College/Rice University; 2021.[29] For educational purposes only.

Acromioclavicular (AC) Joint

The AC joint is a diarthrodial joint bordered by the lateral process of the clavicle articulating with the acromion process as it projects anteriorly off the scapula.[31-32] The AC joint is primarily stabilized by the AC ligament, which is made up of an anterior, posterior, inferior, and superior component.[32] The AC joint has dynamic and static stabilizers, and it is movable in all planes, so it is not a limited anatomical structure. AC joint injury is a common diagnosis after an acute shoulder trauma and is often found among athletes involved in contact sports. The normal AC joint can translate 4 mm to 6 mm in the anterior, posterior, and superior planes under 70-N (Newton) loads. The management of a dislocation of the AC joint depends on its grade and severity (Figure 10).[33] The most common mechanisms of injury to the AC joint include falling on an outstretched arm or direct trauma to the apex of the shoulder with the arm in adducted position.[33] To date, there is no consensus on a gold standard for diagnostic measures needed to classify acute AC joint injuries.[34]

Figure 10. The AC Joint and Common Injuries



The classic Rockwood classification of the AC joint injury. Type 1 is only a sprain of the AC ligament (red arrow in Type 1), whereas the ligament is torn in type 2 injury (red arrow in Type 2). In Type 3, both the AC and the CC ligaments are torn, but there is no more than 100% displacement of the distal clavicle. In Type 4, both ligaments are torn with posterior displacement of distal clavicle. Type 5 depicts a complex injury where the deltotrapezial fascia is stripped from its attachment, whereas in Type 6, injury the clavicle is moved into subcoracoid position.

AC = acromioclavicular; CC = coracoclavicular.

Sirin et al. *EFORT Open Rev*. 2018.[33] For educational purposes only.

Radiographic Equipment, Digital Imaging Capture Devices, and Imaging Parameters

Radiographic Equipment

Radiographic 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[35-37]:

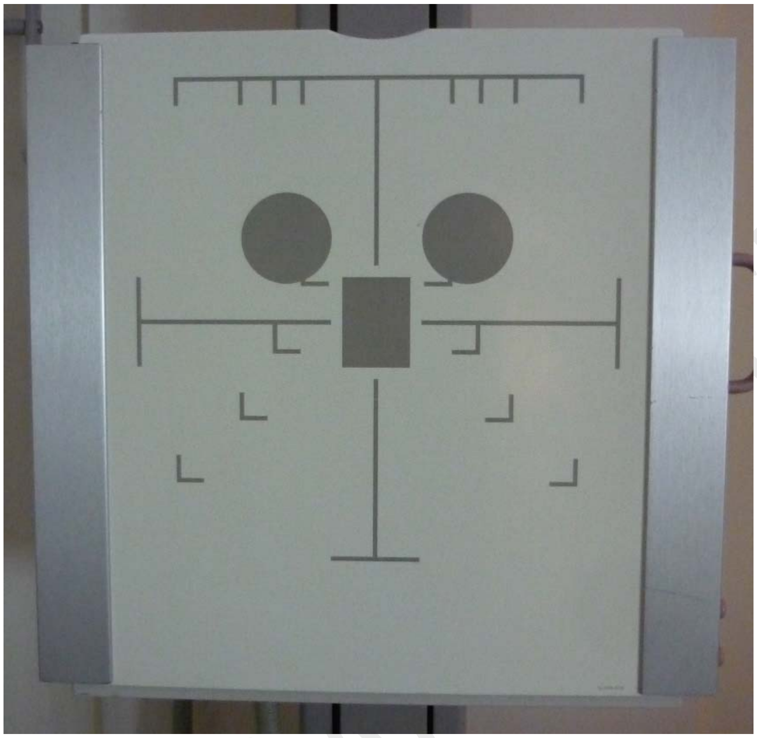
- X-ray tube
- Collimator (X-ray beam limiting device)
- Operation console for the radiologic technologist (RT) to set exposure settings and protective barriers
- High-voltage X-ray generator available in various types (single-phase, high frequency, three-phase, both 6- and 12-pulse), and power ratings (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 (PACS) for imaging viewing, transmission, and data storage

Other critical components of the radiographic imaging chain include:

- <u>Automatic exposure control (AEC)</u>: AEC was developed for the purpose of achieving more consistent exposures, reducing repeated exposures, and ultimately reducing unnecessary radiation exposure to patients.[37-38] The difference in AEC systems lies in the type of device that is used to convert radiation into electricity.[39] 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.[40] The more common type of AEC system uses ionization chambers (Figure 11).[41]

  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 upwards or downward 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.*[41-44]

Figure 11. Ionization Chambers



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

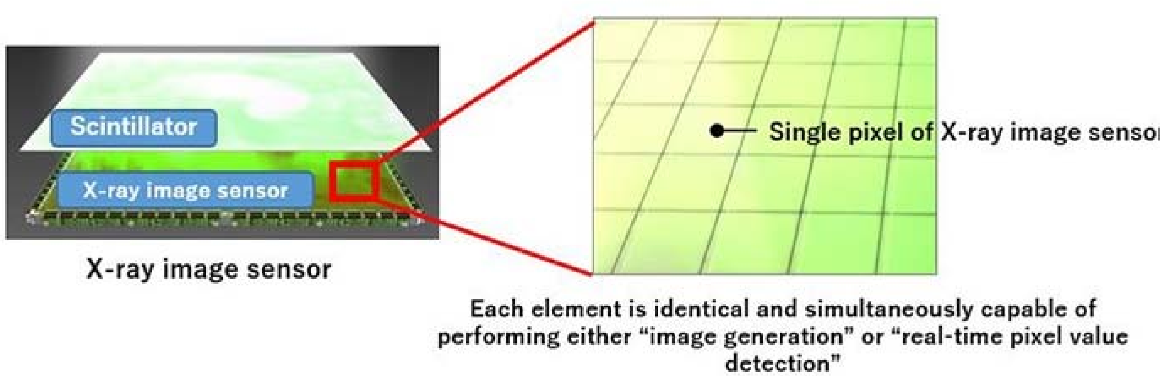
Basic Physics of Digital Radiography/The Source. WikiBooks.org. Updated 2021. Accessed March 20, 2021.[41] For educational purposes only.

Anatomically programmed radiography (APR): Some AEC systems are designed in the form of APR operating consoles.[38,40,45] With an APR system, the RT can select a part of the anatomy and position 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.[38,40,45] 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.[41-43] 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[37,42-43,46]:

- When the anatomical region being imaged is too small in overall size, especially when performing pediatric upper extremity orthopedic radiography.
- 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 and 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 in the X-ray generator. This is a cutting-edge and evolving technology that 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 12).[47] 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.[47]

Figure 12. Built-In AEC Assistance



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

Canon announces new built-in AEC assistance technology for X-ray image sensors [press release]. Tokyo, Japan: Canon Inc; March 25, 2021.[47] 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."[48] 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).[49-50] 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.[37] 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.[50] DDR uses several approaches to directly convert X-ray energy to digital data without the need for a separate scanning step.[37] 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 commonly used.

Flat-panel DR detectors, or mobile detectors, are what are classically associated with digital detectors.[38] 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).[50] 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.[48-50] 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.[49]

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).[48-51] MTF defines border characteristics or how clearly and sharply edges can be distinguished.[49] It is one thing to be able to discern individual line pairs, but MTF is an indication of how sharp the line pairs appear.[49,52] MTF measures spatial resolution, which is critical when looking for finite detail in bone radiography to reveal either pathology or subtle fractures.[49] 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 detector dose to achieve the same output image quality that a system with lower DQE achieves with correspondingly higher detector dose.[53] Table 1 outlines a comparison between CR and flat-panel DDR systems.[39,53-58]

Table 1. 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 into *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.

Technological Benefits	• Low initial cost investment • Compatible with a wide range of traditional radiographic systems • Effective workflow for smaller or low-volume clinics • Multiple CR plate sizes allow for greater flexibility. • 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 and viewing • High maintenance cost plus quality assurance • CR involves more steps because cassette processing takes longer, which causes gaps in workflow.	• 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

	• CR plates need to be replaced every few years due to degradation.	bucky 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 MP. The Benefits of Digital Radiography. *e*RADIMAGING.com. Published August 1, 2015. Accessed March 12, 2021; Tsoukatos G. 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. Accessed March 29, 2021; Giering L. Pediatric Digital Radiography: Minimizing Exposure. *e*RADIMAGING.com. Published April 1, 2016. Accessed April 3, 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 April 1, 2021; Rowlands. *Phys Med Biol*. 2002.[37,52,54-58] For educational purposes only.

Imaging Parameters

Exposure Factors and Extremity Technique Charts

RTs must consider the following concepts and exposure and technique considerations when performing upper extremity bone radiography[59-61]:

- 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.[43] Techniques using a higher kVp along with a lower mA notably reduces patient dose, regardless of the image receptor type.[43,61] 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.[35,43,61] 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.[43-44] 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.[43] Proper documentation is required in order to make changes and adjustments as required for image optimization.[43] Using measuring calipers is the most accurate way to determine the size of the body part being radiographed in order to identify which imaging technique to select from the chart.[43] 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.[42] 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.[55]

<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.[38] They differ in their construction, indications, benefits, and risks.[62-63]

The appropriate radiographic exposure settings to image extremities with casts is based on the type of material the cast is made of, its thickness, and whether it is still wet or completely dry.[38] The general rule of thumb is most large, full plaster casts require a doubling of the mAs or a 12% to 15% increase in kVp.[38] 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.[38,53] 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.[38,64]

<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 radiographed.[43,55-56] In recent years, the American Association of Physicists (AAPM) 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.[43,55,65] This collaboration yielded a follow-up report in 2018 that provided additional updates on changes with manufacturers' EIs.[64-65] It is important to note that the EI is not representative of an individual patient dose metric.[43,48,55] Table 2 outlines the standardized terminology when referring to the various EIs used in DR.[55,67]

Table 2. 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 L. Pediatric Digital Radiography: Minimizing Exposure. *e*RADIMAGING.com. Published April 1, 2016. Accessed April 3, 2021; International Electrotechnical Commission (IEC). Medical Electrical Equipment-Exposure Index of Digital X-Ray Imaging Systems-Part 1: Definitions and Requirements for General Radiography. Geneva, Switzerland: IEC; 2008.[55,67] 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 utilizes grids when radiographic exposure exceeds 70 kVp or when the anatomy being imaged is more than 10 cm in measured thickness.[67-69] In pediatric DR applications where the body measurements are less than 12 cm of thickness, grids are not recommended due to the increase in exposure factors that are required.[68-70] Conventional grid specifications and choices are based on the parameters below[68-72]:

- 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.[52]

- Grid Frequency: The number of lead strips or line pairs per inch or line pairs per millimeter (lp/m).
- Grid Patterns: The most common grid pattern is known as a parallel linear format. There are 2 linear arrangements[68]:
  - Short dimension: Lead strips parallel to short dimension; also known as a "decubitus" grid
  - Long dimension: Lead strips parallel to long dimension, which is the standard configuration
- Contrast Improvement Factor: Ratio of the contrast of a finished radiograph made with the grid when compared to the contrast of a radiograph made without the grid.[68]
- 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.[68]

Embedding an antiscatter radiographic grid into the CR plate offers the radiographer the full flexibility of having a grid within a digital capture device at the ready.[68-69] An example of an imaging procedure that would benefit from this configuration is cross-table shoulder radiography.[71] Recently, commercial software packages (referred to virtual grid suppression software) have been developed from various X-ray equipment manufacturers that have eliminated the need for using antiscatter grids.[68,70] Radiographic grid suppression software removes the stationary grid patterns, thus preventing moiré artifact (a summation artifact caused by the scanning laser beam overlapping with the grid line structure) from being generated on the resultant image.[49,52] 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.[49-50] 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.[48-49,70] 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.[68] When performing upper extremity radiography, it may be beneficial to use an antiscatter grid when performing cross-table projections or imaging large body parts such as a transthoracic view of the humerus.[71-72]

Imaging Various Fracture Types

Upper 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.[73] Even though most minor bony injuries are difficult to detect on conventional DR, X-ray may be more specific than MRI in being able to determine possible causes of injury due to its ability to visualize calcification patterns and periosteal reactions of the bony tissue.[74]

Injuries (eg, fractures, dislocations, and sprains) are broken down to 2 major classifications: acute and chronic.[75] Upper 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 3).[75]

Table 3. 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* [e-Book]. Houston, TX: OpenStax; 2021.[75]

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 (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.[76] But, the differences in inflammatory and noninflammatory joint disease may be more difficult to image, recognize, and classify.[77] Additional imaging may be required such as 3D computerized tomography (CT) or MRI for soft tissue detail and evaluation.

Proper Patient Positioning Concepts

It is important that the RT communicates well with and provides good direction to the patient in order 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 is a necklace, bra, brace, etc, that must be removed in a private changing booth if necessary. If the upper arm or shoulder is being imaged, the RT should request that the patient put on a hospital gown. If the patient is a woman of childbearing age, the RT 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.[78]

These techniques go hand-in-hand with setting up the proper SID and utilization of accessories such as grids, cassette holders, and other devices.[52] Understanding patient positioning requires the RT to know the basic terminology relating to patient positioning, which includes[79-81]:

- *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.
- When imaging the wrist and forearm, it is more common to use the terms *radial* and *ulnar* instead of medial and lateral.

When a radiographer joins a new medical 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 protocols are made up from a variety of factors including, but not limited to, the following[79-81]:

- 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 United States 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 or not 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.

Radiographic positioning pertains to the way the radiographer 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.[78] 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.[79] For X-rays of the upper extremity, the standard SID is 40 inches (102 cm).[83]

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."[80] The table should be in a locked position and not be free-floating. The RT 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. The RT 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 the RT use the appropriate side markers to note that the anatomical region being radiographed is either right or left. Best practice parameters from the American College of Radiology (ACR) indicate that RTs should use lead anatomic side markers that are placed on the image receptor. The guidelines also state that electronic annotations of an anatomic side during digital postprocessing is not an acceptable substitute for using physical markers on the receptor.[43,46,67,84]

Below is a summary of key radiographic positioning concepts when performing upper extremity bone radiography[85-90]:

- 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.
- 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" (AC joints), doing so should also 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.
- 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.

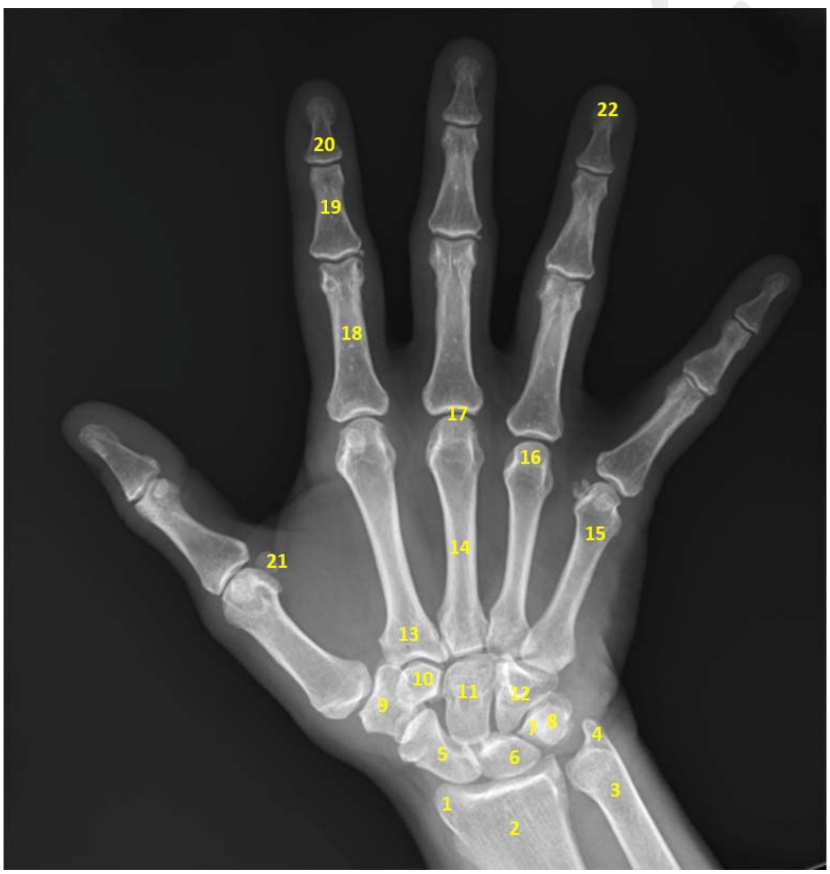
Imaging Concepts and Techniques

Fingers (Digits and Thumb)

The 5 digits of the hand start with the metacarpophalangeal (MCPJ) and are formed by the phalanges (Figure 13).[91-92] The fingers are formed by 3 phalanges: proximal, middle, and distal phalanx.[91] The configuration of each phalanx is similar to the metacarpal bones: each is composed of a base, shaft, neck, and head that is formed from 2 condyles.[86,91] The phalanges reduce in size from proximal to distal. There are 2 joints between the 3 phalanges in each finger, which are the proximal interphalangeal joints (PIPJ) and distal interphalangeal joints.[91] Common injuries to the fingers include[93]:

- Crush (tuft) fracture: This is a common fracture, where the tuft region of the finger is crushed, and the resultant injury is a marginal chip or a comminuted fracture.
- Mallet injury: This is caused by a direct blow to a finger. The result is an avulsion of the extensor tendon at its insertion to the base of the distal phalanx.
- Volar plate avulsion: This is also a common fracture and is secondary to a hyperextension injury; it is sometimes associated with dislocation of the PIPJ.
- Spiral or transverse fracture: This type of injury is usually caused by a direct blow to the finger.

Figure 13. Bones of the Hand on X-ray



1. Metaphysis of radius
2. Metaphysis of ulna
3. Styloid process of ulna

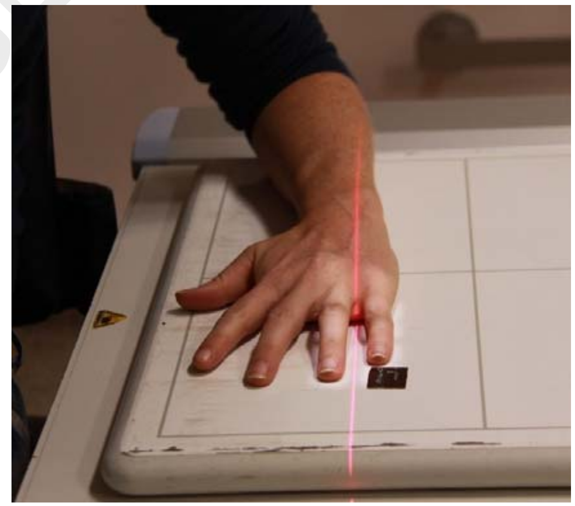
4. Scaphoid
5. Lunate
6. Triquetrum
7. Pisiform
8. Trapezium
9. Trapezoid
10. Capitate
11. Hamate
12. Base of second metacarpal
13. Shaft of third metacarpal
14. Neck of fifth metacarpal
15. Head of forth metacarpal
16. Metacarpophalangeal joint
17. Proximal phalanx
18. Middle phalanx
19. Distal phalanx
20. Sesamoid bones (flexor pollicis brevis, adductor pollicis)
21. Terminal tuft

Radiographic anatomy of the fingers (digits), thumb, hand, and wrist.

Benoudina S. Normal radiographic anatomy of the hand. Radiopaedia.org. Available at: https://radiopaedia.org/cases/normal-radiographic-anatomy-of-the-hand. Updated 2020. Accessed April 29, 2021.[92] For educational purposes only.

Table 4 outlines the techniques for optimal imaging of the fingers.[80,85-86,94-97]

Table 4. Projections and Positioning Techniques for the Fingers

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
PA	• The patient should be safely positioned at the end of the table (seated) and accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to place their hand down (palm side down) with the fingers spread onto the IR on the tabletop. • The central ray of the X-ray beam should be directed perpendicular to the PIPJ of the digit being imaged (Figure 14).[94]	This projection is part of a standard radiographic protocol (Figure 15).[95] It is used for evaluating the digit being radiographed for a disease process, trauma, lesions, foreign bodies, or other pathology.	**Figure 14. Posteroanterior Positioning of the Fingers**  Posteroanterior positioning the left fifth digit of the hand. Grant K. Finger series: positioning and radiographs: Case study. Radiopaedia.org.

	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		Published October 18, 2015. Accessed May 2, 2021.[94] For educational purposes only. **Figure 15. Right Second Digit on X-Ray**  Standard X-rays of the right second digit of the hand (PA, oblique, and lateral views). Ng J. Finger series. Case study. Radiopaedia.org. Published August 7, 2019. Accessed May 2021. Case courtesy of Dr Craig Hacking.[95] For educational purposes only.

PA Oblique	• The patient should be safely positioned at the end of the table (seated) and accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The central ray of the X-ray beam should be directed perpendicular to the PIPJ of the digit being imaged. • Gently position the hand oblique 45° towards the fifth metacarpal. • The central ray of the X-ray beam is directed perpendicular to the PIPJ of the digit being imaged. • Tight collimation to the anatomy being imaged with proper right or left	This projection is part of a standard radiographic protocol (Figure 15).[95] It is used for evaluating the digit being radiographed for a disease process, trauma, lesions, foreign bodies, or other pathology.	

	marker annotation and positioning immobilization devices as required.		
Lateral	• The patient should be safely positioned at the end of the table (seated) and accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to place their forearm on the table resting the ulnar aspect on the IR. • Have the patient gently extend the phalanges while placing the thumb at a 45°–90° angle to the hand. • The central ray of the X-ray beam is directed	This projection is part of a standard radiographic protocol (Figure 15).[95] It is used for evaluating the digit being radiographed for a disease process, trauma, lesions, foreign bodies, or other pathology.	

	perpendicular to the PIPJ of the digit being imaged. • 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 finger (digit) radiography. The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

CR = computed radiography; DDR = direct digital radiography plate; IR = image receptor; PA = posteroanterior; PIPJ = proximal interphalangeal joints; SID = source-to-image distance.

Data from: Whitley et al. *Clark's Positioning in Radiography.* 12th ed. London, England: CRC Press; 2005; Carroll et al. *Adaptive Radiography with Trauma, Image Critique and Critical Thinking*. Clifton Park, NY: Delmar Cengage Learning; 2014; Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Clifton Park, NY: Thomson Delmar Learning; 2006; Grant K. Finger series: positioning and radiographs: Case study. Radiopaedia.org. Available at: https://doi.org/10.53347/rID-40332. Published October 18, 2015; Ng J. Finger series. Case study. Radiopaedia.org. Available at: https://doi.org/10.53347/rID-70172. Published August 7, 2019; Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. Vol 2. 9th ed. New York, NY: Mosby; 1999; Murphy C, Popovitch. Image quality, digital technology, and radiation protection. In: Bontrager KL, Lampignano JP. *Textbook of Radiographic Positioning and Related Anatomy*. 7th ed. St Louis, MO: Mosby Elsevier; 2010.[80,85-86,94-97] For educational purposes only.

Common injuries to the thumb include[93,98]:

- Gamekeeper's thumb (also known as skier's thumb or break dancer's thumb): An abduction type of thumb injury that mostly occurs when there is an avulsion of the attachment of the ulnar collateral ligament and an outward distraction of the thumb, which is sometimes associated with a bony avulsion fracture.
- Bennett's fracture/dislocation: An oblique fracture of the base of the first metacarpal and subluxation or dorsal dislocation of the first metacarpal.
- Rolando fracture: A comminuted articular fracture of the base of the thumb metacarpal.

Table 5 outlines techniques for optimal imaging of the thumb.[80,85-86,96-97,99-100]

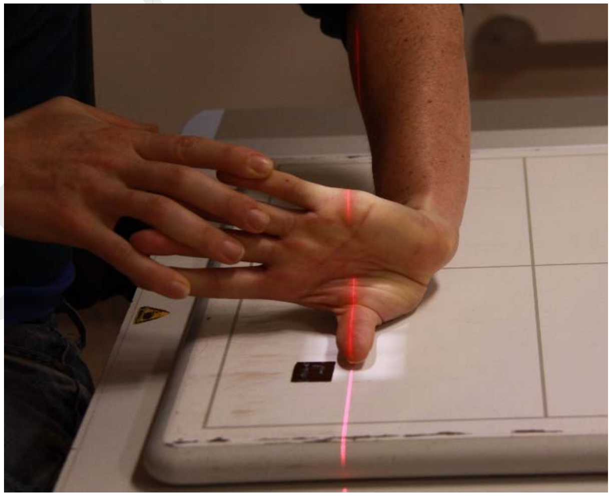
Table 5. Projections and Positioning Techniques for the Thumb

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to rest the posterior aspect of the thumb on the CR cassette or DDR image receptor while holding the other fingers away with the other hand. • The central ray of the X-ray beam should be perpendicular to the first MCPJ (Figure 16).[99] • Tight collimation to the anatomy being imaged	This projection is part of a standard radiographic protocol. It is used for evaluation of the thumb for a disease process, trauma, lesion(s), foreign bodies, or other pathology.	**Figure 16. Positioning for AP and PA Left Thumb Projections**  

	with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Grant K. Thumb series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40334.

			Published October 18, 2015. Accessed May 2021.[99] For educational purposes only.
Oblique (PA)	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to place their hand down (palm side down) with the fingers spread onto either the CR cassette or DDR IR, which is flat on the tabletop. • The PA position of the hand is the oblique position of the thumb. • The central ray of the X-ray beam should be	This projection is part of a standard radiographic protocol. It is used for evaluation of the thumb for a disease process, trauma, lesion(s), foreign bodies, or other pathology.	

	directed perpendicular to the first MCPJ. • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		
Lateral	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm).	• This projection is part of a standard radiographic protocol. It is used for evaluation of the thumb for a disease process, trauma, lesion(s), foreign bodies, or other pathology.	

	• The patient should be instructed to place their forearm on the table, resting the ulnar aspect on the CR cassette or DDR IR. • Gently rotate the thumb to place it in a true lateral position (Figure 17).[99] • The central ray of the X-ray beam should be directed perpendicular to the first MCPJ. • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on	• The lateral fan view offers a view of the individual middle and distal phalanges, avoiding overlap.	**Figure 17. Positioning for Lateral Projection of the Thumb** 

	the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Grant K. Thumb series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40334.

			Published October 18, 2015. Accessed May 2021.[99] For educational purposes only.
PA, Stress View	- The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). - From a PA position of the hand, have the patient slightly elevate both hands obliquely. - The RT should then instruct the patient to touch the tips of both thumbs together and push against each other gently (Figure 18).[100] - Do not allow the patient to drop their thumbs; be sure the thumbs are kept parallel to the cassette at	- This projection is a nonroutine ancillary projection and may be ordered by the referring clinician or recommended by the radiologist. - This projection is used for evaluating a tear of the ulnar collateral ligament of the thumb at the MCPJ due to acute hyperextension of thumb (also known as the gamekeeper's, the skier's thumb, or the break dancer's thumb).	**Figure 18. PA Stress View of the Thumbs** 

	all times. Ensure that the patient's hands are rotated enough to the thumb and parallel to IR for a true PA projection of both thumbs. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Wolf et al. *J Hand Surg Am*. 2009.[100] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; MCPJ = metacarpophalangeal joint; PA = posteroanterior; SID = source-to-image distance.

Data from: Whitley et al. *Clark's Positioning in Radiography.* 12th ed. London, England: CRC Press; 2005; Carroll et al. *Adaptive Radiography with Trauma, Image Critique and Critical Thinking*. Clifton Park, NY: Delmar Cengage Learning; 2014; Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Clifton Park, NY: Thomson Delmar Learning; 2006; Ballinger et al; *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. New York, NY: Mosby; 1999; Murphy, Popovitch. Image quality, digital technology, and radiation protection. In: Bontrager et al. *Textbook of Radiographic Positioning and Related Anatomy*. 7th ed. St Louis, MO: Mosby Elsevier;2010:41-42; Grant K. Thumb series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40334. Published October 18, 2015. Accessed May 2021; Wolf et al. *J Hand Surg Am*. 2009.[80,85-86,96-97,99-100]
For educational purposes only.

Hand (Metacarpals)

The main body of the hand is formed by the 5 metacarpal bones and is commonly referred to as the palm (Figure 13).[91-92] Because the hand is both exposed and in constant use, it's a high risk for injury, and as a result, hand injuries are the most common skeletal injuries and account for 10% to 20% of ED visits.[93] The metacarpal bones of the hand are numbered 1 to 5, with 1 corresponding to the thumb and 5 corresponding to the little finger. The neck of metacarpal is the most fracture common site, specifically in the 2 ulnar border digits, 4 and 5.[91] Common injuries or degenerative diseases to the hand include [93,101]:

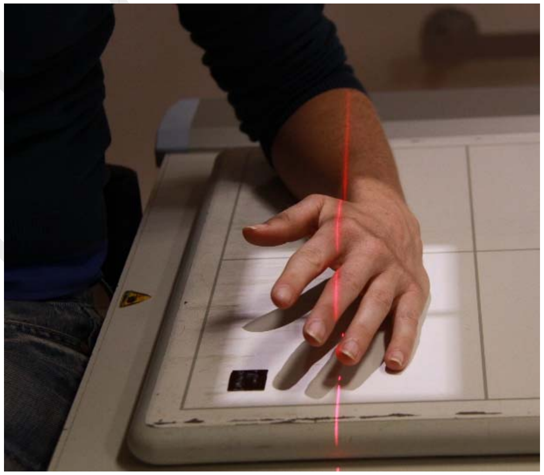
- Punch fracture (Boxer's fracture): This fracture is usually caused by the patient punching something. The neck of the metacarpal is fractured, and there is volar displacement of the head.
- Oblique or even transverse fractures of the shaft or base of the metacarpals can occur in one or more metacarpal.
- Arthritic changes: This can be seen in both osteoarthritis (caused by degermation of the cartilage) and rheumatoid arthritis (systemic inflammatory autoimmune disease).

Table 6 outlines techniques for optimal imaging of the hand. [80,85-86,96-97,102-105]

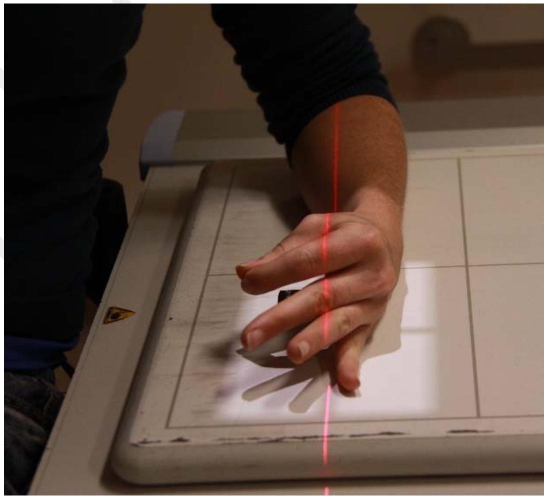
Table 6. Projections and Positioning Techniques for the Hand

Radiographic Projection	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
PA	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • If possible, the affected arm should be flexed at 90° so that the patient's arm and hand can rest on the table. • The patient should be instructed to place their hand down (palm side down) with the fingers spread onto either the CR cassette or DDR IR which is flat on the tabletop.	This projection is part of a standard radiographic protocol. It is used for evaluating the phalanges, metacarpal bones, carpal bones, and distal radius and ulna for a disease process, trauma, lesions, foreign bodies, or other pathology.	**Figure 19. Positioning for a PA Projection of the Hand** 

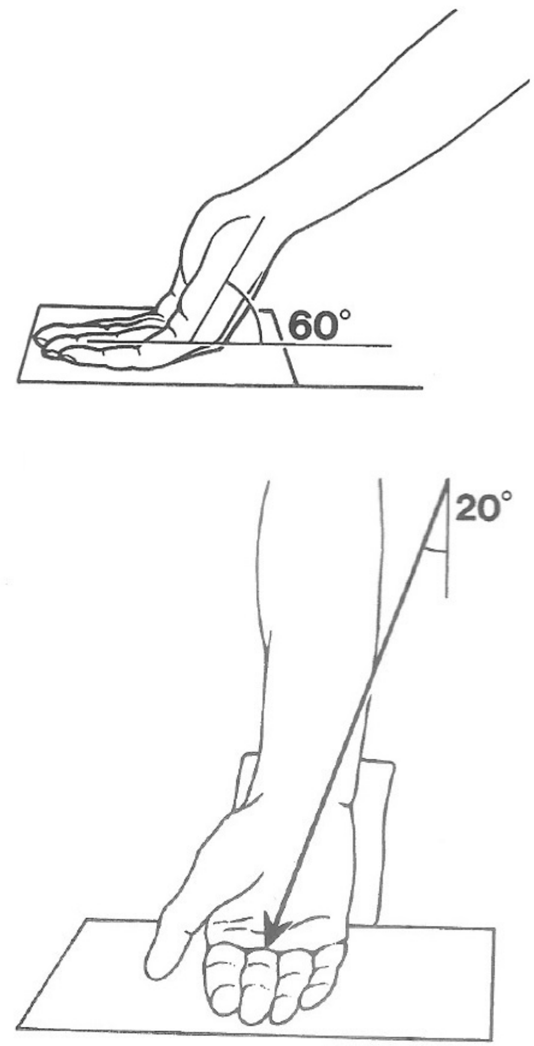
	• The central ray of the X-ray beam should be directed perpendicular to the third metacarpal (Figure 19).[102] • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Grant K. Hand series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40336. Published October 18, 2015. Accessed May 2021.[102] For educational purposes only.

PA Oblique	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • If possible, the affected arm should be flexed at 90° so that the patient's arm and hand can rest on the table. • The patient should be instructed to place their hand down (palm side down) with the fingers spread onto either the CR cassette or DDR IR, which is flat on the tabletop. • The patient should be instructed to oblique the hand 45° towards the fifth metacarpal. The central ray of the X-ray	This projection is part of a standard radiographic protocol. It is used for evaluating the phalanges, metacarpal bones, carpal bones, and distal radius and ulna for a disease process, trauma, lesions, foreign bodies, or other pathology.	**Figure 20. Positioning for a PA Oblique Projection of the Left Hand** 

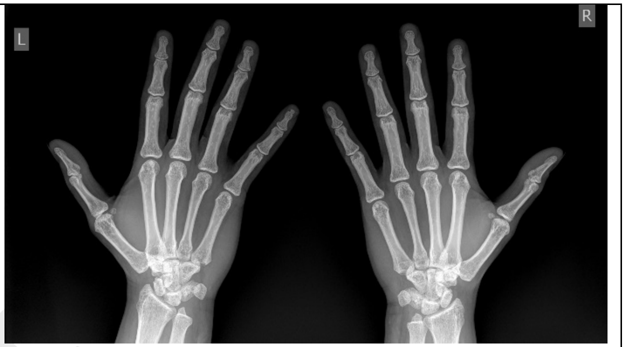
	beam should be directed perpendicular to the third metacarpal (Figure 20).[102] • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Grant K. Hand series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40336. Published October 18, 2015. Accessed May 2021.[102] For educational purposes only.
Lateral	• The patient should be safely positioned at the end of the table (seated) accessible to the proper	• This projection is part of a standard radiographic protocol. It is used for evaluating the phalanges, metacarpal	

	SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to place their forearm on the table resting the ulnar aspect on the CR cassette or DDR IR. • Have the patient gently extend the phalanges while placing the thumb at a 45° to 90° angle to the hand. The central ray of the X-ray beam should be directed perpendicular to the second metacarpal (Figure 21).[102] **<u>OR</u>** • Have the patient place their hand in the lateral position with their fingers extended and fanned out to	bones, carpal bones, distal radius, and ulna for a disease process, trauma, lesions, foreign bodies, or other pathology. • The lateral fan view offers a view of the individual middle and distal phalanges, avoiding overlap.	**Figure 21. Positioning for a Lateral Projection of the Left Hand** 

	demonstrate a lateral view of all the fingers as well as the metacarpals. This projection would be an LM lateral (thumb pointed up) also known as a *fan lateral*. • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		 Grant K. Hand series: positioning and radiographs (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40336. Published October 18, 2015. Accessed May 2021.[102] For educational purposes only.

Brewerton	• The patient is safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • Have the patient place the dorsal aspect of the fingers on IR. • RTs should instruct the patient to flex the MCPJs of the affected hand to 60° and then evert the thumb (Figure 22).[103] • The central ray of the X-ray beam should be directed perpendicular to the second metacarpal. • Tight collimation to the anatomy being imaged with proper right or left marker annotation.	This protection is a nonroutine ancillary projection and utilized as either ordered by the referring clinician or recommended by the radiologist. This projection is utilized for the evaluation of subtle carpometacarpal fractures, such as collateral ligament avulsion fractures.	**Figure 22. Positioning for a Lateral Projection of the Right Hand** 

	• Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography.* Toolkit Publications, 2005.[103] For educational purposes only.
Norgaard (Ball-Catcher Position)	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be instructed to have both hands in a supinated position, while the dorsal surfaces are placed on the IR. The patient's hands are then rotated	• The Norgaard (ball-catcher position) projection is a nonroutine ancillary projection and is typically ordered by the referring clinician or recommended by the radiologist. • This projection is a tangential view of the metacarpal heads. This is the recommended	**Figure 23. Positioning for the Norgaard (Ball-Catcher) Position** 

	medially by 45° to assume a position likened to one about to receive or catch a ball ("catching-hands") (Figure 23).[104-105] • Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.	view for examining erosions at the base corners of the proximal phalanges due to rheumatoid arthritis.	 Knipe H. Both Hands Series – Normal (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/76539. Published April 23, 2020. Accessed May 2021.[105] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; LM = lateromedial; MCPJ = metacarpophalangeal joint; PA = posteroanterior; RT = radiologic technologist; SID = source-to-image distance.

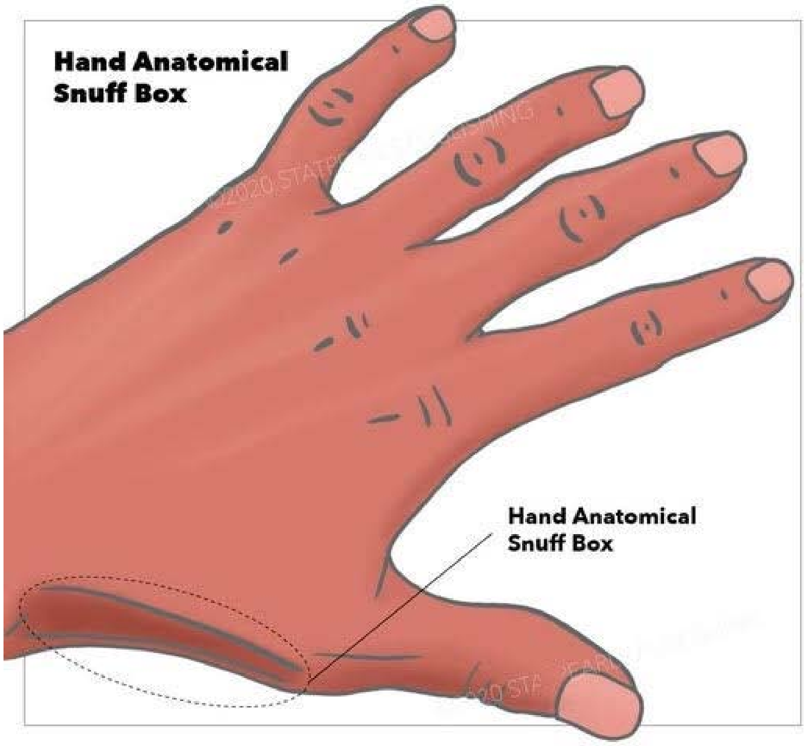
Data from: Whitley et al. *Clark's Positioning in Radiography.* 12th ed. London, England: CRC Press; 2005; Carroll et al. *Adaptive Radiography with Trauma, Image Critique and Critical Thinking*. Clifton Park, NY: Delmar Cengage Learning; 2014; Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Clifton Park, NY: Thomson Delmar Learning; 2006; Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. Vol 2. 9th ed. New York, NY: Mosby; 1999; Murphy et al. Image quality, digital technology, and radiation protection. In: Bontrager et al. *Textbook of Radiographic Positioning and Related Anatomy*. 7th ed. St Louis, MO: Mosby Elsevier;2010:41-42; Grant K. Hand series: positioning and radiographs (Case study) Radiopaedia.org. Available at: https://radiopaedia.org/cases/40336. Published October 18, 2015. Accessed May 2021; Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography.* Toolkit Publications, 2005; Shetty A, Murphy A. Hand (Ball-Catcher View). Radiopaedia.org. Available at: https://radiopaedia.org/articles/29823. Updated 2021. Accessed May 2021; 105. Knipe H. Both Hands Series – Normal (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/76539. Published April 23, 2020. Accessed May 2021.[80,85-86,96-97,102-105.] For educational purposes only.

Wrist

The most common fracture of the wrist involves the scaphoid (also known as the navicular bone). The initial radiographic evaluation of the wrist consists of PA, oblique, and lateral views and potentially a PA ulnar deviated view with 45° of extension (the "scaphoid view").[24] The anatomical snuffbox, also known as the radial fossa, is a topographic surface anatomy characteristic and functions in conjunction with other anatomical features in locating the scaphoid bone of the wrist (Figure 24).[106] It's a triangular depression located on the lateral aspect of the dorsum of the hand on the radial side. This part of the hand was so nicknamed during a time in history when this part of the hand typically held snuff, or ground tobacco.[107]

As a result of the scaphoid's curved shape and palmar inclination, X-ray evaluation can be challenging particularly with the distal tubercle and waist segments.[24] The standard pronated oblique view generally shows fractures of the scaphoid tubercle. However, the detection of nondisplaced scaphoid fractures can be significantly improved with the use of dedicated scaphoid views.[108-109] These may include magnification views, specialty views, or any combination of the following: a PA or AP ulnar deviation view, a semipronated oblique view with ulnar deviation, lateral scaphoid view, "stecher position" view, ulnar oblique scaphoid view, 30-degree semipronated oblique PA view, 60-degree semipronated oblique PA view, and elongated oblique view.[109]

Figure 24. Hand Anatomical Snuffbox



Hallett S, Ashurst JV. Anatomy, Shoulder and Upper Limb, Hand Anatomical Snuff Box. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021.[106] For educational purposes only.

When performing conventional radiography of the wrist, there may be both standard and specialty views that make up departmental protocol. Dedicated scaphoid specialty views can provide high quality X-rays of the wrist, because the extended ulnar deviated position elongates the scaphoid and reduces the bone's natural flexed position, limiting bony overlap.[24]

Common injuries and fractures of the wrist include[24,110-114]:

- Hook of the hamate fracture: This is a volar excrescence extending from the distal hamate. The carpal tunnel view, which is an optional 20° supine oblique view, may aid in the visualization trauma to the hamate, because the positioning allows isolation of the hook from the remainder of the carpus.[24]
- Colles' fracture: This is the most common injury to the wrist as a result of a fall on an outstretched hand causing axial compression combined with a bending movement. The

classic Colles' fracture is a transverse fracture, with or without comminution, in conjunction with dorsal displacement of the distal surface of the radius.[110]

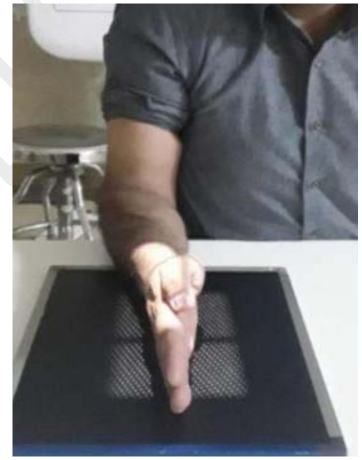
- Scaphoid fracture: These fractures are commonly seen in young, active patients and may occur due to a fall on the outstretched arm or a forced dorsiflexion injury of the wrist. Three common classifications used for scaphoid fracture include the Mayo classification, the Russe classification, and the Herbert classification.[111]
- Smith's fracture: Smith's fracture is a fracture of the distal radial metaphysis or epiphysis, with or without articular involvement.
- Barton's fracture: This is a fracture of the dorsal rim of the radius that displaces along with the carpus, producing a fracture subluxation.[112]
- Hutchinson's fracture: This fracture is also known as a "chauffeur's fracture" and is a fracture of the styloid process of the radius.[113]
- Lunate dislocation: This is a result of a disruption of the complex intercarpal and radiocarpal ligaments that hold the carpus in its normal position.[114]
- Carpal tunnel syndrome: This condition is a result of compression of the median/ulnar nerve within the carpal tunnel. There is a dedicated plain radiograph projection used to assess the osseous carpal tunnel, but it is limited in evaluating this disorder.[115]
- Arthritis: Conventional wrist radiography can identify patients with arthritis and degenerative changes, which play a clinical role in differentiating inflammatory arthropathy such as rheumatoid arthritis from osteoarthritis.

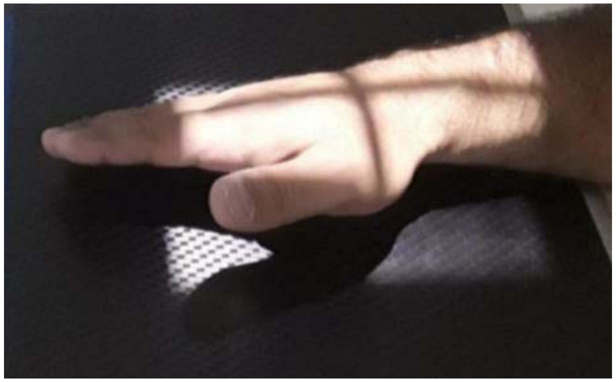
Table 7 outlines techniques for optimal imaging of the wrist.[80,115-120]

Table 7. Projections and Positioning Techniques for the Wrist

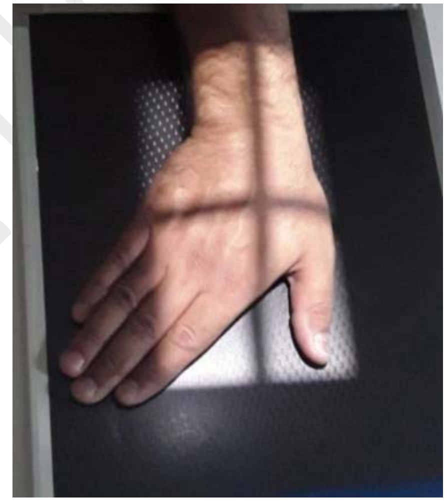
Radiographic Projection	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
PA	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should instruct the patient to gently extend their arm, resting their forearm on the table, with their palm on the IR. • The central ray of the X-ray beam should be directed perpendicular to the middle of the carpal bones of the wrist (Figure 25).[116]	This projection is part of a standard radiographic protocol. It is used for evaluation of the carpal bones, distal radius, and ulna along with the proximal metacarpal region for disease process, trauma, lesions, foreign bodies, or other pathology.	**Figure 25. PA Projection Positioning for the Wrist**  Rabie et al. *J Orthop Spine Trauma*. 2020.[116] For educational purposes only.

	• Tight collimation to the anatomy being imaged with proper right or left marker annotation. • Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		
Lateral	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should instruct the patient to gently rest their forearm on the	• This projection is part of a standard radiographic protocol. It is used for the evaluation of the phalanges, metacarpal bones, carpal bones and distal radius, and ulna for disease process, trauma, lesions, foreign	

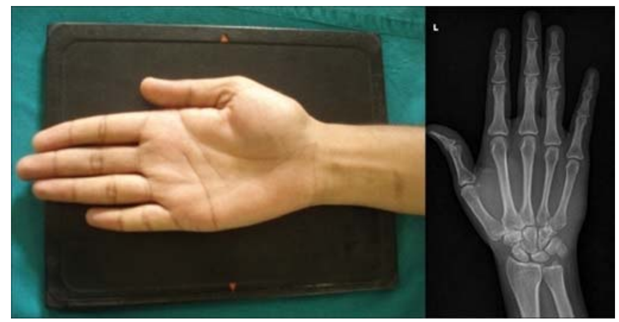
	table and their palm on the IR. • From the PA position, RTs should ask the patient to flex their elbow 90° and rest the medial side of their forearm on the IR. • Ensure the thumb is placed in a superior position to the metacarpal. • The central ray of the X-ray beam should be directed perpendicular to the middle of the carpal bones of the wrist (Figure 26).[116] • Tight collimation to the anatomy being imaged with proper right or left marker annotation.	bodies, or other pathology. • On a true lateral view of a normal wrist, the long axis of the third metacarpal should be coaxial (parallel) with the long axis of the radius. The pisiform should project directly over the dorsal pole of the scaphoid.[109]	**Figure 26. Lateral Projection Positioning for the Wrist**  Rabie et al. *J Orthop Spine Trauma*. 2020.[116] For educational purposes only.

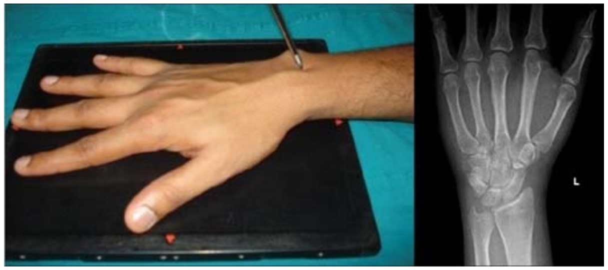
	• Proper use of immobilization or positioning devices (eg, radiolucent sponges, sandbags not placed on the image FOV due to their radiolucent consistency) as needed to minimize any patient motion.		
PA External Oblique	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should instruct the patient to gently extend their arm, resting their forearm on the table, with their palm on the IR.	• This projection *may be* part of a standard radiographic protocol, or considered an ancillary view, as ordered or requested by the treating clinician. • This projection is used for evaluating the phalanges, metacarpal bones, carpal bones and distal radius, and ulna for a disease process, trauma, lesions, foreign	**Figure 27. PA External Oblique Projection Positioning for the Wrist**  Rabie et al. *J Orthop Spine Trauma*. 2020.[116] For educational purposes only.

	• From the PA position, RTs should ask the patient to oblique their wrist 45° externally onto the IR (Figure 27).[116] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	bodies, or other pathology. • It is especially useful in detecting scaphoid tuberosity and waist fractures as well as dorsal margin triquetral fractures.[117]	
PA in Ulnar Deviation	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The RT should ask the patient to gently extend their arm, resting their forearm on the table,	• This projection *may be* part of a standard radiographic protocol, or considered an ancillary view, as ordered or requested by the treating clinician. • This projection is used for evaluating the phalanges, metacarpal bones, carpal bones and	

	with their palm on the IR. • Holding the joint in place, move the elbow away from the patient's body while turning the hand outward (toward the little finger). • The central ray should be perpendicular to the scaphoid (Figure 28).[116] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.	distal radius, and ulna for a disease process, trauma, lesions, foreign bodies, or other pathology. • It is especially useful in evaluating the scaphoid and adjacent joint space. Due to the wrist being placed in ulnar deviation, the scaphoid rotates its distal pole dorsally and ulnarly and appears elongated. This elongated position allows for better visualization of scaphoid fractures. The scaphoid can also be brought out more to profile by extending the wrist by 20° or by angling the beam	**Figure 28. Projection Positioning for the Wrist with Ulnar Deviation**  Rabie et al. *J Orthop Spine Trauma*. 2020.[116] For educational purposes only.

		towards the wrist by 20°.[117]	
PA in Radial Deviation	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The RT should ask the patient to gently extend their arm, resting their forearm on the table, with their palm on the IR. • Holding the joint in place, move the elbow toward the patient while turning the hand medially (toward the thumb). • The central ray should be perpendicular to the scaphoid (Figure 29).[117]	• This projection *may be* part of a standard radiographic protocol, or considered an ancillary view, as ordered or requested by the treating clinician. • This is used for the evaluation of the phalanges, metacarpal bones, carpal bones and distal radius, and ulna for a disease process, trauma, lesions, foreign bodies, or other pathology. • It is especially useful in evaluating the intercarpal joint spaces on the medial side of the wrist.	**Figure 29. PA Projection Positioning of the Wrist with Radial Deviation**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	• Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.		
AP	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The RT should ask the patient to gently extend their arm, resting their forearm on the table, with their palm on the IR. • The dorsum of the wrist and the hand should be placed flat against the IR, and the central ray	• This projection *may be* part of a standard radiographic protocol, or considered an ancillary view, as ordered or requested by the treating clinician. • This projection may also be ordered if the patient cannot be successfully and/or comfortably positioned for a standard PA view. • The projection shows the ulnar styloid projecting from the	**Figure 30. AP Projection Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	should be centered over the capitate head (Figure 30).[117] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.	center of ulnar head in contrast with the PA view where it is at the ulnar border.[117]	
Radiocarpal Joint View	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The RT should ask the patient to gently extend their arm, resting their forearm on the table, with their palm on the IR.	• This projection is a nonroutine ancillary projection and may be ordered by the referring clinician or recommended by the radiologist. • This projection elongates the scaphoid and shortens the capitate, which may provide better visualization of any	**Figure 31. Radiocarpal Joint Projection Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	• The angle of the central ray of the X-ray beam should be 25° to 30° towards the elbow, centered just distally to Lister's tubercle, for better visualization of the radiocarpal articulation (Figure 31).[117] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.	scaphoid abnormalities.[117]	
Carpal Boss or Off-Lateral View	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm).	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist.	

	• The RT should instruct the patient to place both hands in a supinated position while the dorsal surfaces are on the IR. • This lateral view is taken with the ulnar side of the wrist resting on the cassette, in minimal ulnar deviation and 30° supination. The central beam should pass tangent to the dorsal prominence (Figure 32).[117] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.	• This projection can visualize the dorsal carpal boss on a tangent and allows the distinction between (1) a separate os styloideum, (2) a bony prominence attached to the second or third metacarpal base or apposing surface of the trapezoid or capitate bones, (3) degenerative osteophytes, or (4) a fracture of the dorsal prominence.[117]	**Figure 32. Carpal Boss View/ Off-Lateral View Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.
Wrist-Tangential Projection for	• The patient should be safely positioned at the	• This projection is a nonroutine ancillary	

Carpal Tunnel View (Gaynor-Hart Method)	end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should position the patient’s wrist dorsiflexed, with either the ventral aspect of the wrist (Gaynor-Hart method) or the palm placed on the IR at a 75° angle. The hand being examined should be hyperextended by the patient by grasping their fingers with their other hand. Care should be taken when performing this projection, as many patients may not be able to dorsiflex the wrist to the angle required (Figure 33).[117]	projection and may be ordered by the referring clinician or recommended by the radiologist. • This projection can visualize uncommon fractures involving the hook of hamate and the pisiform.[117]	**Figure 33. Wrist-Tangential Projection Positioning for Carpal Tunnel View of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	• The wrist should be slightly rotated toward the radius to prevent image overlap of the pisiform and hamate bones. • The central beam should be angled 25° to 35°, directing proximally at the volar surface of the carpus in line with the third metacarpal.[118] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.		
Lateral Flexion and Extension Views	• The patient should be safely positioned at the end of the table (seated) accessible to the proper	• This projection is a nonroutine ancillary projection and may be ordered by the referring	

	SID for the X-ray tube (40 in or 102 cm). • From the PA position, RTs should ask the patient to flex their elbow 90° and rest the medial side of their forearm on the IR. • The wrist should be in a true lateral position on both radiographs. The extension and flexion of the wrist is recognized by observation of the long axis of the third metacarpal extended dorsally and flexed volarly, respectively, relative to the long axis of the radius and ulna. (Figure 34) (Figure 35.).[117] • The central beam is directed perpendicular	clinician or recommended by the radiologist. • These specialty views demonstrate extension and flexion at the radiocarpal and midcarpal joints in normal wrists. • They can also be used to evaluate carpal instability patterns and assist in distinguishing between a true instability pattern versus normal variance.[117]	**Figure 34. Lateral Extension Projection Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only. **Figure 35. Lateral Flexion Projection Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	to the film and centered to the waist of the scaphoid.[117] • Tight collimation to the anatomy being imaged, with proper right or left marker annotation and positioning immobilization devices as required.		
AP View (Clenched Fist View)	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should ask the patient to gently extend their arm, resting their forearm on the table and their palm on the IR. • The dorsum of the wrist and hand are placed flat	• This projection is a nonroutine ancillary projection and may be ordered by the referring clinician or recommended by the radiologist. These specialty views effectively demonstrate any scapholunate diastasis.	**Figure 36. AP View (Clenched Fist View) Positioning of the Wrist**  Bhat et al. *Indian J Plast Surg*. 2011.[117] For educational purposes only.

	against the IR, and the central ray should be centered over the capitate head. RTs should ask the patient to gently clench their fist (Figure 36).[117] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
PA (Scaphoid View; Stecher Method)	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should center the patient's wrist with their palms facing down on the IR with a 20°	• This projection is a nonroutine ancillary projection and may be ordered by the referring clinician or recommended by the radiologist. • The primary purpose of this projection is to obtain an elongated	

	extremity angle sponge under the receptor. • Position the wrist in an ulnar flexion position. • An alternative positioning technique is to place the IR flat on the table and angle the central ray 20° degrees toward the elbow. • The central ray should be perpendicular to the scaphoid near the anatomical snuffbox. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	view of the scaphoid bone without superimposition. • This projection is utilized for the evaluation of subtle carpometacarpal fractures, such as collateral ligament avulsion fractures as well as arthritic conditions of the hand.	

The IR used 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; SID = source-to-image distance.

Data from: Whitley et al. *Clark's Positioning in Radiography.* 12^{th} ed. London, England: CRC Press; 2005; Copeland et al. Wrist Imaging. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021; Rabie et al. *J Orthop Spine Trauma*. 2020; Bhat et al. *Indian J Plast Surg*. 2011; Lad et al. Understanding Wrist X-ray. Indian Society for Surgery of the Hand Web site. Available at: https://issh.org/pdf/monthly_updates/2020-8-Understanding-Wrist-X-ray.pdf. Published August 2020. Accessed May 12, 2021; Shetty et al. Wrist series. Radiopaedia.org. Available at: https://radiopaedia.org/articles/29869. Revised 2021. Accessed May 2021; Möller TB, Reif E. *Pocket Atlas of Radiographic Positioning: Including Positioning for Conventional Angiography, CT, and MRI*. Stuttgart, Germany: Thieme; 2009.[80,115-120] For educational purposes only.

Forearm (Wrist and Elbow Joint)

The radius and ulna form the bony components of the forearm with joint articulations proximally at the elbow and distally at the wrist.[24] Routine forearm radiography studies typically includes a PA or AP and lateral projections (Figures 33–35).[117] Elbow radiography studies usually consists of AP, lateral, and oblique views, which are used to evaluate the alignment of the joints and any intraarticular injuries.[24] If more focus is required on either the wrist or elbow joint, additional specialty projections are required.

The most common injuries that lead to a combined fracture pattern in the forearm are due to falls with the elbow in extension and the forearm in excessive pronation.[121] Besides the basic types of forearm fractures, other classifications of less common fracture/dislocations of the forearm include[122-124]:

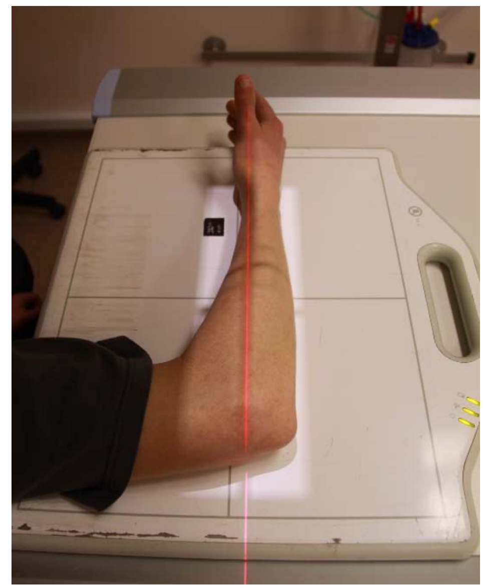
- Monteggia: This is the most common type of fracture of the forearm and is often caused by dislocation. Specifically, this fracture is a dislocation of the radial head and fracture of the proximal ulnar shaft.[122]
- Galeazzi: This is a fracture of the radial shaft associated with dislocation of the distal ulna head. Chronic instability may develop if the distal radioulnar joint is found to be injured.[122]
- Essex-Lopresti: This type of injury is a pattern of forearm joint lesion characterized by fracture of the radial head with combined proximal radioulnar joint, interosseous membrane, middle radioulnar joint, and distal radioulnar joint disruption.[123]
- Torus: Also known as a “buckle” fracture. With this fracture, the top layer of bone on one side of the bone is compressed, which causes the opposite side to bend away from the growth plate.[124]

Table 8 outlines techniques for optimal imaging of the forearm.[125-130]

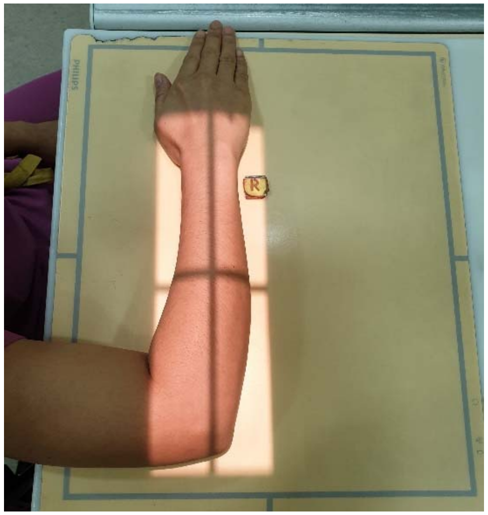
Table 8. Projections and Positioning Techniques for the Forearm

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's forearm should be in a supine position, and the dorsal surface should be kept in contact with the cassette, with extension at the elbow joint. • RTs should make sure that both the elbow joint and wrist joints are in the IR FOV (Figure 37).[125-126]	• This projection is part of a standard radiographic protocol. It is used to image from the wrist to the elbow joint (radius and ulna) to evaluate the radius and ulna for disease process, trauma, lesions, foreign bodies, or other pathology. • The patient's arm should be rotated externally to ensure that the trochlea and capitulum are seen in profile.[127]	**Figure 37. AP View Positioning of the Forearm** 

	• The central ray of the X-ray beam should be directed to the middle of the carpal bones of the wrist. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Grant K. Forearm series: Radiographic positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40075. Published October 6, 2015. Accessed May 2021;

			Hacking C. Normal forearm series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37491. Published June 10, 2015. Accessed May 2021.[125-126] For educational purposes only.
Lateral	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's elbow should be flexed to 90°, and the medial aspect of the wrist, forearm, and elbow joint should be placed in contact with the IR (Figure 38).[125-126] • The shoulder, elbow, and wrist should be in the same horizontal plane.[127]	• This projection is part of a standard radiographic protocol. It is used to evaluate from the wrist to elbow joint (radius and ulna) for disease process, trauma, lesions, foreign bodies, or other pathology. • The radius and ulna should almost completely overlap on the lateral projection of the forearm.	**Figure 38. Lateral View Positioning of the Forearm** 

	• The central ray of the X-ray beam should be directed to the middle of the carpal bones of the wrist. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

			Grant K. Forearm series: Radiographic positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40075. Published October 6, 2015. Accessed May 2021; Hacking, C. Normal forearm series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37491. Published June 10, 2015. Accessed May 2021.[125-126] For educational purposes only.
PA	• The patient should be safely positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • With the patient in a 90° elbow flexion position, the palmar aspect of the forearm from wrist to elbow should be kept in contact with the receptor,	• This projection *may be* part of a standard radiographic protocol or considered an ancillary view as ordered by the referring clinician or recommended by the radiologist. • This projection is used for evaluating the wrist to elbow joint (radius and ulna) for disease	**Figure 39. PA View Positioning of the Forearm** 

	ensuring the same horizontal plane (Figure 39).[128-130] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	process, trauma, lesions, foreign bodies, or other pathology. • Additionally, this view is ideal for patients who are unable to move their arm and cannot be positioned for a standard AP view of the forearm to evaluate for suspected radius and/or ulna dislocations or fractures.	 PA views of the forearm revealed combined Monteggia and Galeazzi fractures. Er A. Trauma forearm positioning (photo) (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/76100. Published April 14, 2020. Accessed May 2021; Hacking C. Combined Monteggia and Galeazzi fractures (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/48694.

			Published October 20, 2016. Accessed May 2021.[129-130] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; MCPJ = metacarpophalangeal joint; PA = posteroanterior; SID = source-to-image distance.

Data from: Grant K. Forearm series: Radiographic positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40075. Published October 6, 2015. Accessed May 2021; Hacking C. Normal forearm series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37491. Published June 10, 2015. Accessed May 2021; Shetty A, Murphy A. Elbow (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/elbow-ap-view-2. Updated September 2021. Accessed 2021; Er A, Murphy A. Pediatric forearm (PA view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/76442. Published April 22, 2020. Accessed 2021; Er A. Trauma forearm positioning (photo) (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/76100. Published April 14, 2020. Accessed May 2021; Hacking C. Combined Monteggia and Galeazzi fractures (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/48694. Published October 20, 2016. Accessed May 2021.[125-130] For educational purposes only.

Elbow Joint

Radial head fractures are one of the most common fractures of the elbow. They make up about one-third of all elbow fractures and 3% of fractures overall in adults.[131-132] Fractures of the radial head typically occur due to a fall on an outstretched hand. A lateral radiograph of the elbow will show the normal anterior fat pad, which lies against the anterior surface of the distal humerus.[132] If a joint effusion is present due to trauma, it will displace the fat pad anteriorly and produce the radiographic "sail sign."[26] The posterior fat pad is not visible on normal radiographs of the elbow.[132]

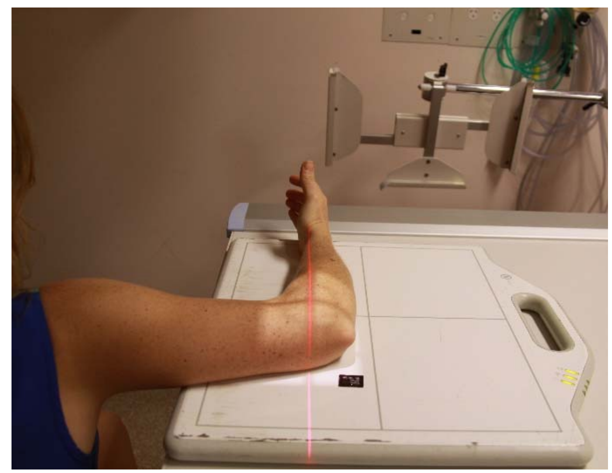
In general, elbow trauma can subdivided as follows[132]:

- Soft tissue injuries range from mild, superficial soft tissue injuries (eg, simple contusions, strains, or sprains) to severe traumatic incidents.
- The osseoligamentous type of complex fracture, with or without dislocation, can be classified as simple or complex.
    - A simple fracture refers to no associated fracture accompanying the dislocation.
    - A complex fracture refers to an associated fracture accompanying the dislocation.
- "Terrible triad" type of elbow injuries
    - Elbow dislocations
        - The second-most common type of dislocation (after dislocation of the shoulder); most are posterior dislocations
        - Typically, posterolateral direction with associated lateral collateral ligament complex injury
    - A radial head/neck fracture
    - Coronoid fracture

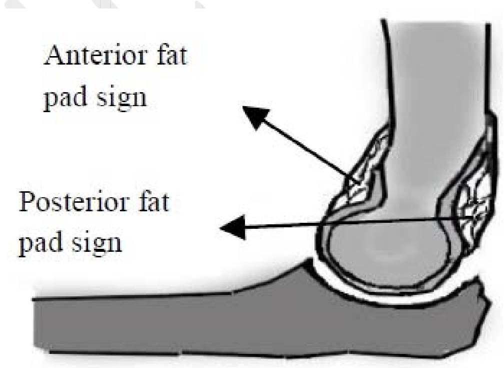
Table 9 outlines techniques for optimal imaging of the elbow joint.[133-144]

Table 9. Projections and Positioning Techniques for the Elbow Joint

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• The patient is safely positioned at the end of the radiographic table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's arm should be fully extended. Their forearm should be placed in a supine position and kept in contact with the table by lowering the patient's shoulder joint to the level of the table and putting them in the same plane as the IR (Figure 40).[133-134] • The central ray of the X-ray beam should be	• This projection is part of a standard radiographic protocol. It is used to evaluate the elbow joint for disease processes, trauma, lesions, foreign bodies, or other pathology. • With this view, the radiologist can assess the medial and lateral epicondyles, the radiocapitellar joint, and trochlear articular surface.	**Figure 40. AP View Positioning of the Elbow Joint** 

	directed to the middle of the elbow joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation.		Grant K. Elbow series: patient positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40387. Published October 19, 2015. Accessed May 2021; Hacking C. Normal elbow series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37494. Published June 10, 2015. Accessed May 2021.[133-134] For educational purposes only.
Lateral	• The patient is safely positioned at the end of the radiographic table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's elbow should be placed in a 90° flexion position with the medial border of the palm and forearm kept in contact with the IR (Figure 41).[133-135]	• This projection is part of a standard radiographic protocol. It is used for the evaluation of the elbow joint for disease process, trauma, lesions, foreign bodies, or other pathology. • The lateral view also allows a diagnostic radiographic examination of the ulna-trochlear joint, coronoid	**Figure 41. Lateral View Positioning for the Elbow Joint** 

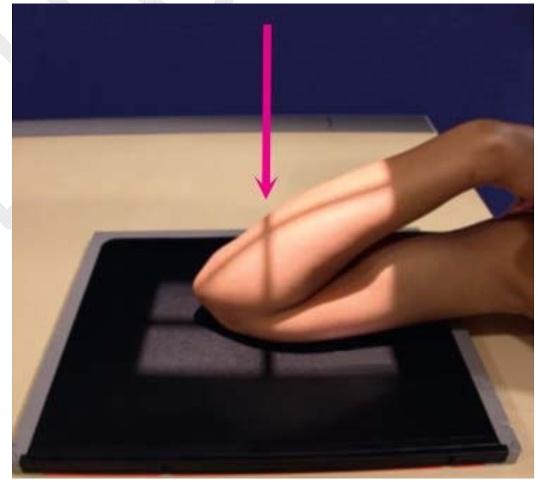
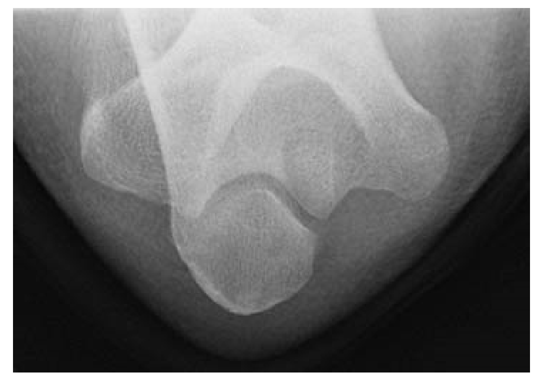
	• The shoulder, elbow, and wrist should be kept in the same horizontal plane. • The RT should ask the patient to rotate their hand so that the thumb is pointing towards the ceiling, ensuring all aspects of the arm from the wrist to the humerus are in the same plane. • The central ray of the X-ray beam should be directed to the middle of the elbow joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	process, and the olecranon process.[137] • This view is also used to assess: the anterior humeral line, the radiocapitellar line, the olecranon, coronoid process, radial head, fat pads, and congruency of the ulnohumeral joint (Figure 42).[137-138] • There should be superimposition of the distal radius and ulna on the X-ray indicating a proper lateral position. When the elbow is flexed to 90°, the anconeus and tricep muscles compress the posterior fat pad within the olecranon fossa, which is crucial for	 Grant K. Elbow series: patient positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40387. Published October 19, 2015. Accessed May 2021; Bickle I. Normal lateral elbow radiograph (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/46432. Published July 5, 2016. Accessed May 2021.[133-135] For educational purposes only.

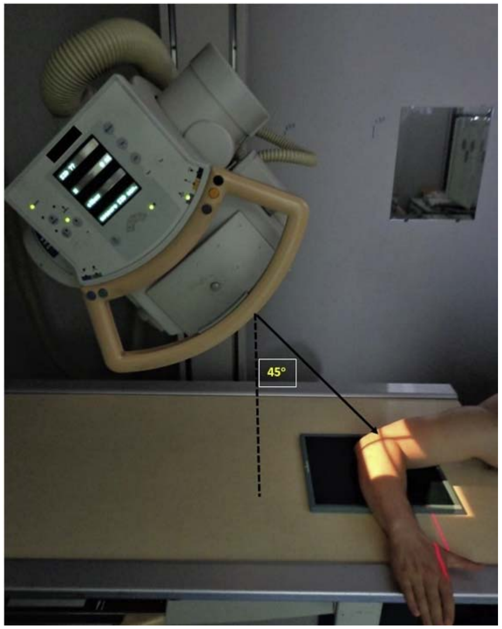
		viewing the fat pad sign.[140]	**Figure 42. Anterior and Posterior Fat Pads of the Elbow Joint**   Hedayat et al. *J Orthop Spine Trauma*. 2019.[138] For educational purposes only.

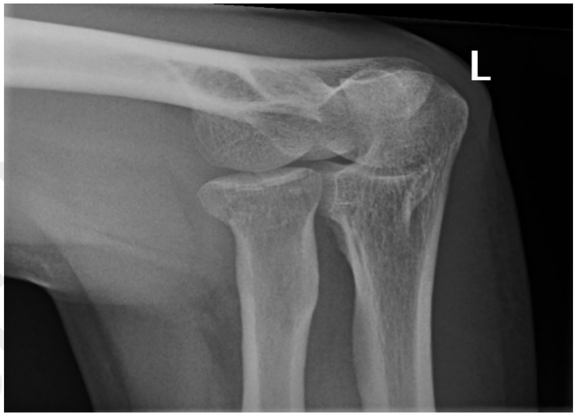
Internal Oblique	• The patient is safely positioned at the end of the radiographic table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient should be seated with their palm facing upwards and their arm fully extended medially. RTs should ask the patient to rotate their elbow no more than 45°. • If the patient is able to, RTs should ask the patient to fully extend their forearm in a pronated position. • RTs should ensure that the anterior portion of the elbow is roughly 45° from the IR.	• This projection is part of a standard radiographic protocol. It is used for the evaluation of the elbow joint for disease process, trauma, lesions, foreign bodies, or other pathology. • This view best demonstrates the coronoid process of ulna.	

	• Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
External Oblique	• The patient should be positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • RTs should ask patients to fully extend their arm and forearm, in a supinated position, which should be kept in contact with the table; this can be achieved by lowering the patient's shoulder joint to the table level, which must	• This projection is part of a standard radiographic protocol. It is used for the evaluation of the elbow joint for disease process, trauma, lesions, foreign bodies, or other pathology. • This view also demonstrates the radial head and neck without superimposition.	

	be in the same plane as the IR.[133] • The patient should be seated with their palm facing upwards and arm fully extended laterally.[133] • RTs should instruct the patient to rotate their entire arm so that anterior surface of elbow joint is 45° to the IR.[133] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Acute Flexion (AP, Jones Method)	• The patient should be positioned at the end of the table (seated) accessible to the proper	• This is a nonroutine ancillary projection and *may be* ordered by the treating clinician or	

	SID for the X-ray tube (40 in or 102 cm). • The distal humerus should be placed on the image receptor with the patient's arm remaining in flexion (Figure 43).[140] • If the patient is physically able to, RTs should place the patient's hand in a supinated position. • The central ray of the X-ray beam should be directed to the middle of the elbow joint and angled 45° towards the long axis of the humerus.[136] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning	recommended by the radiologist. • This is a modified projection; it may be requested when a conventional AP is view is not possible due to the patient's inability to straighten their arm as a result of their injuries. • This modified view is often used to evaluate suspected supracondylar fractures in younger patients; however, it can also be utilized in acute elbow trauma imaging.[141]	**Figure 43. Acute Flexion (AP, Jones Method) Positioning of the Elbow Joint**   Benoudina S. Normal elbow (AP acute flexion view) (Case study). Radiopaedia.org. Available

	immobilization devices as required.		at: https://radiopaedia.org/cases/73474. Published January 27, 2020. Accessed May 2021.[140] For educational purposes only.
Sitting Axial LM Projection (Coyle's View or Trauma Oblique View)	• The patient should be positioned at the end of the table (seated) accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's elbow should be in a 90° flexion position, with the medial border of the palm and forearm kept in contact with the IR.[136] • The patient's shoulder, elbow, and wrist should be kept in the same horizontal plane.[136] • The X-ray tube should be angled 45° in an LM projection with the central ray (CR) directed	• This is a nonroutine ancillary projection and *may be* ordered by the treating clinician or recommended by the radiologist. • The sitting axial LM projection (Coyle's view) is performed for any patient with a suspected radial head fracture or dislocation.[144] • It is also the recommended view for evaluating the capitellum of the distal humerus. The Coyle view and its variations provide alternative views of the	**Figure 44. Sitting Axial LM Projection (Coyle's View or Trauma Oblique View) Positioning of the Elbow Joint** 

	to the mid-elbow joint (Figure 44).[142-143] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	radial head without the superimposition of the ulna allowing clearer evaluation of the region.[144]	 Vampertzis et al. *J Clin Orthop Trauma*. 2020; Alabd M. Radial head fracture (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/51316. Published February 10, 2017. Accessed May 2021.[142-143] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; LM = lateromedial; MCPJ = metacarpophalangeal joint; PA = posteroanterior; SID = source-to-image distance.

Data from: Grant K. Elbow series: patient positioning (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/40387. Published October 19, 2015. Accessed May 2021; Hacking C. Normal elbow series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37494. Published June 10, 2015. Accessed May 2021; Bickle I. Normal lateral elbow radiograph (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/46432. Published July 5, 2016. Accessed May 2021; Shetty A, Murphy A. Elbow (lateral view). Radiopaedia.org Available at: https://radiopaedia.org/articles/31133. Published September 21, 2014. Accessed May 20, 2021; Guglielmi G, Bazzocchi A, eds. *Imaging of the Upper Limb, An Issue of Radiologic Clinics of North America*. Philadelphia, PA: Elseiver; 2019; Hedayat et al. *J Orthop Spine Trauma*. 2019; Er A, Shetty A. Forearm (lateral view). Radiopaedia.org Available at: https https://radiopaedia.org/articles/31107. Published September 20. 2014. Accessed May 15, 2021; Benoudina S. Normal elbow (AP acute flexion view) (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/73474. Published January 27, 2020. Accessed May 2021; Murphy A. Elbow (acute flexion AP). Radiopaedia.org. Available at: https://radiopaedia.org/articles/59931. Published April 30. 2018. Accessed May 2021; Vampertzis et al. *J Clin Orthop Trauma*. 2020; Alabd M. Radial head fracture (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/51316. Published February 10, 2017. Accessed May 2021; Murphy A. Elbow (Coyle's view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/48527. Published October 12, 2016. Accessed May 20, 2021.[133-144] For educational purposes only.

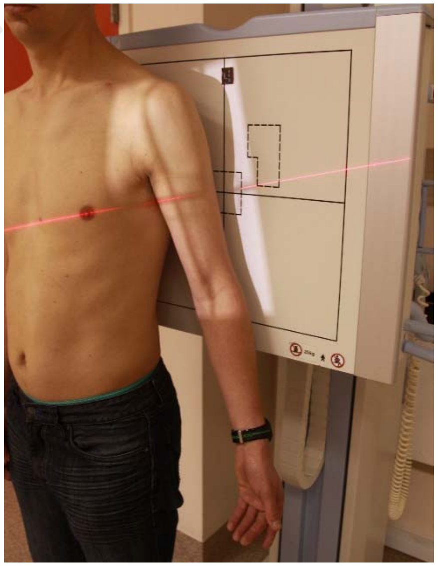
Humerus

As with any long bone, if a fracture is suspected or evident, the patient positioning options for imaging the injury need to be taken into consideration in order to obtain high-quality diagnostic images. Great care should be taken to avoid manipulation of the humerus, which could result in further injury to the fracture site. Whenever possible, the humerus should remain in a neutral position during examination.[145-146]

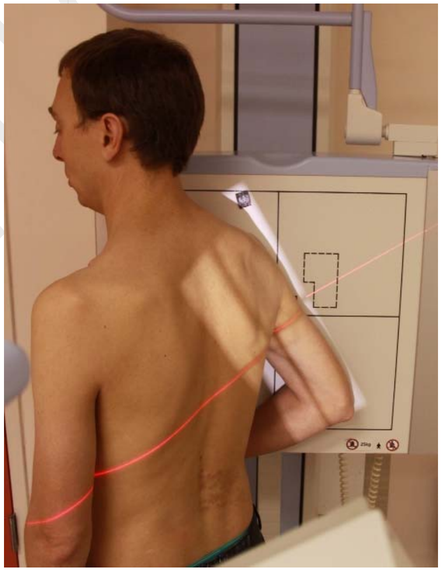
The greater tuberosity, which is a large area of bone located at the top of the humerus, is the largest tubercle at the humeral head. Its size and role as a tendon attachment site predisposes it to frequent injury.[24] As a result, fractures of the greater tuberosity make up 19% of all humeral fractures.[147] Most fractures of the humerus occur either distally at the elbow joint or proximally near the shoulder.[144-145] Radiographic views of the humerus are often performed in order to exclude large humeral shaft fractures. They may also be performed if an occult fracture is suspected at either the proximal or distal end of the humerus. An elbow or shoulder imaging series may also needed, however, consultation with the treating clinician or the radiologist is reccomended.[146] A large component of humerus fractures may also involve the surgical neck, and this area is better evaluated with radiographic views of the shoulder..[148-150]

Table 10 outlines techniques for optimal imaging of the humerus.[150-153]

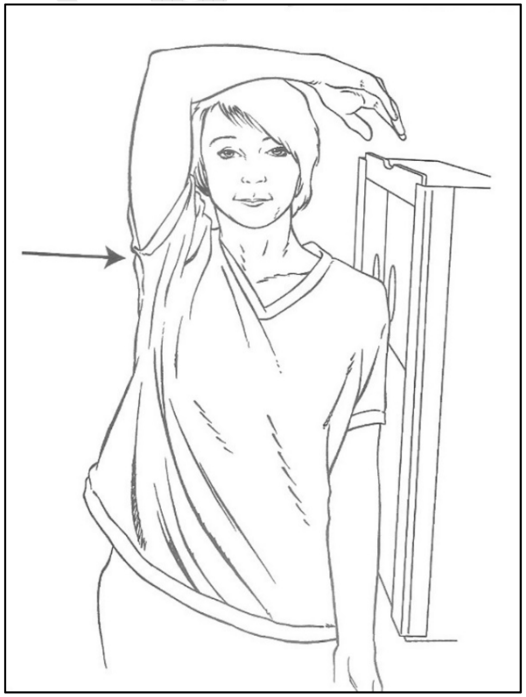
Table 10. Projections and Positioning Techniques for the Humerus

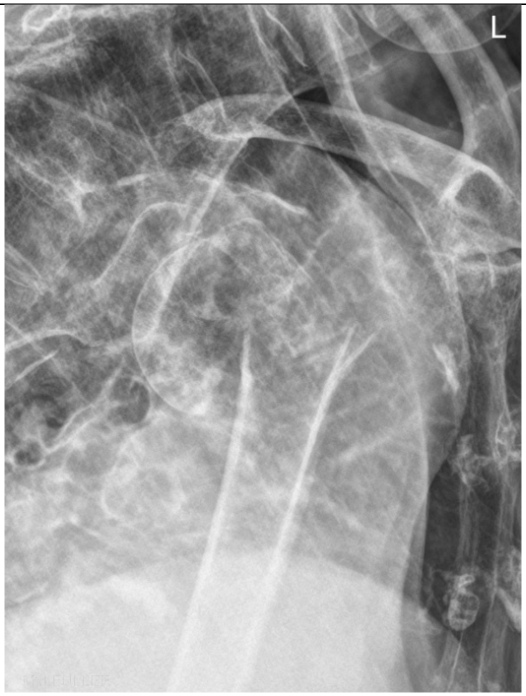
Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient's affected arm should hang at their side with their hand in the supinated position (Figure 45).[151] • The central ray of the X-ray beam should be directed to the middle of the shaft of the humerus. • Tight collimation to the anatomy being radiographed with	• This projection is part of a standard radiographic protocol. It is used for evaluating the humerus for disease process, trauma, lesions, foreign bodies, or other pathology. • It is important to note when the hand is placed in the supinated position, it will demonstrate the humerus in its natural anatomical position on X-ray. On a correctly positioned AP projection, the shoulder will appear in external rotation and the elbow	**Figure 45. AP View Positioning for Imaging the Humerus** 

	proper right or left marker annotation and positioning immobilization devices as required.	will be in the AP position.[152]	 Grant K. Humerus: standard radiographic series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/39526. Published September 9, 2015. Accessed May 2021.[151] For educational purposes only.
Lateral	• If the patient can safely stand, they should be positioned at the upright wall bucky with the proper SID for the X-ray	This projection is part of a standard radiographic protocol. It is used for evaluating the humerus for disease process,	

	tube set to 40 in or 102 cm. • The patient should stand facing the upright wall bucky with the injured side closest to the IR. • The RT should then rotate the patient so that the lateral aspect of the affected shoulder, the arm, and the elbow are all in contact with the upright wall bucky (Figure 46).[151] • The patient's elbow should be flexed 90° (or as close to 90° as possible). • The central ray of the X-ray beam should directed to the middle of the shaft of the humerus. **<u>OR</u>**	trauma, lesions, foreign bodies, or other pathology.	**Figure 46. Lateral View Positioning for Imaging the Humerus** 

	• The patient should be placed in front of the bucky, in the standing position. The RT should then instruct the patient to roll their arm inward and place the palm of their hand on their hip. Doing so will internally rotate the shoulder and place the elbow in the lateral position. • The central ray of the X-ray beam should directed to the middle of the shaft of the humerus. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Grant K. Humerus: standard radiographic series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/39526. Published September 9, 2015. Accessed May 2021.[151] For educational purposes only.

Transthoracic Lateral (Lawrence Method)	• If the patient can safely stand, they should be positioned at the upright wall bucky with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient should stand facing the upright wall bucky with the injured side closest to the IR. • The RT should then ask the patient to raise the unaffected arm above their head (Figure 47).[103,150] • The central ray of the X-ray beam should be directed through the patient's mid-chest laterally. The humerus will be appear superimposed over a	• This is a nonroutine ancillary projection and *may be* ordered by the treating clinician or recommended by the radiologist. • It is useful to determine gross fracture position and alignment. • The RT needs to make sure the exposure factors are set properly to compensate for proper penetration of the mid-chest wall and the attenuation of X-ray beam due to its thickness.	**Figure 47. Transthoracic Lateral (Lawrence Method) View Positioning for Imaging the Humerus** 

	sectional lateral view of the chest.[153] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography.* Toolkit Publications, 2005; Transthoracic Lateral Shoulder. WikiRadiography.net Available at: http://www.wikiradiography.net/page/Transthoracic_Lateral_Shoulder. Accessed May 25, 2021.[103,150] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; MCPJ = metacarpophalangeal joint; PA = posteroanterior; SID = source-to-image distance.

Data from: Transthoracic Lateral Shoulder. WikiRadiography.net Available at: http://www.wikiradiography.net/page/Transthoracic_Lateral_Shoulder. Accessed May 25, 2021; Grant K. Humerus: standard radiographic series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/39526. Published September 9, 2015. Accessed May 2021; Shetty A, Murphy A. Humerus (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/35282. Published March 30, 2015. Accessed May 2021; Hacking, C., Murphy, A. Humerus (lateral view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/39533. Published September 8, 2015. Accessed May 2021.[150-153] For educational purposes only.

Shoulder (Glenohumeral Joint-Scapula)

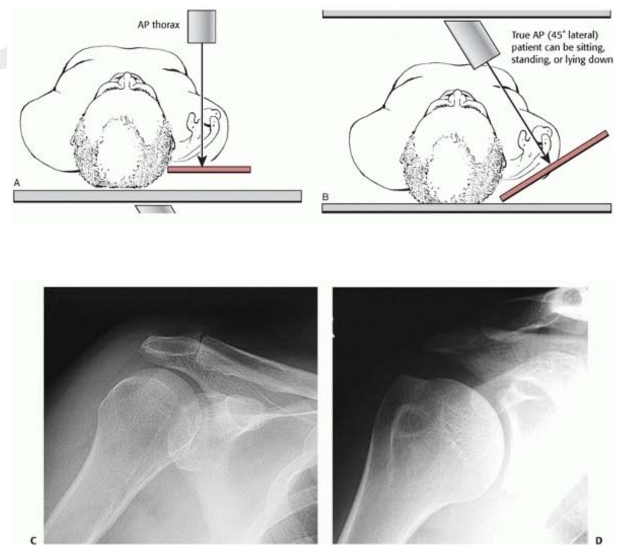
The glenohumeral joint provides the largest range of motion of all the body's large joints, which is maintained by a coordinated interaction of dynamic and static stabilizers.[24] Acromial spurring, bursitis, impingement, rotator cuff strains, tendonitis, and traumatic injuries to the shoulder are common reasons for both acute and chronic shoulder pain.[154] The diagnostic radiographic evaluation should begin with AP internal, anteroposterior external, scapular Y, and axillary views of the injured shoulder based upon the patient's clinical condition. The anatomical relationship between the humeral head and glenoid is best evaluated on axillary and scapular Y views, because the humeral head is seen along the posterior margin of the glenoid, inferior to the acromion, in the setting of a posterior dislocation. Evaluation of glenohumeral joint alignment is more difficult to see on an AP view, because the humeral head may not appear to be displaced.[24]

The main reason for a patient to undergo shoulder radiography is acute trauma, which may be diagnosed as shoulder instability, impingement, and rotator cuff injuries.[154] Common and important findings in shoulder radiography include the following[21]:

1. Clavicle fracture
2. AC joint separation
3. Anterior shoulder dislocation and posterior shoulder dislocation
4. Posterior dislocation (lateral scapula)
5. Bankhart fracture
6. Hill-Sachs deformity
7. Humeral head fracture

Table 11 outlines techniques for optimal imaging of the shoulder.[85-86,155-184]

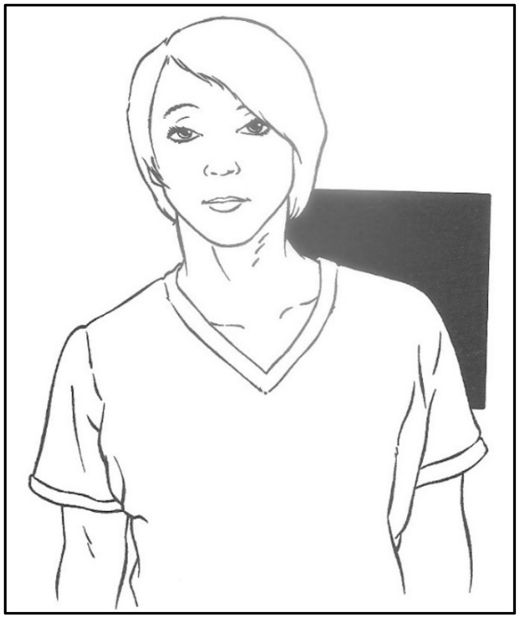
Table 11. Projections and Positioning Techniques for the Shoulder

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP (For the Shoulder in a Neutral Position)	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient's midcoronal plane should be positioned parallel to the IR, with their back against the IR. • The patient's glenohumeral joint on their affected side should be positioned at the center of the IR.[155]	• This projection is part of a standard radiographic protocol. It is used for evaluating the shoulder (glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology. • This view demonstrates the shoulder in its natural anatomical position, allowing for adequate radiographic visualization of the entire clavicle and scapula, as well as the glenohumeral, AC, and sternoclavicular joints	**Figure 48. AP Neutral Positioning for Imaging the Shoulder**  Positioning technique for obtaining AP thorax and true AP (top panel) radiographs of the shoulder. In the AP view, the radiograph represents an oblique view of the shoulder joint. In a true AP view, the X-ray beam is

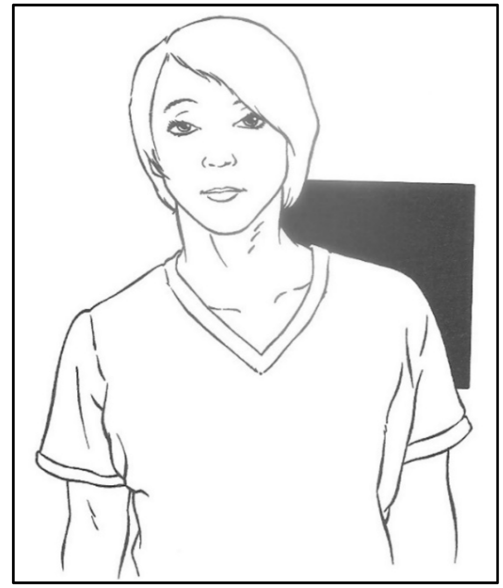
	• The RT should slightly rotate the patient approximately 5° to 10° toward the affected side. The body of the scapula should be laying parallel to the IR (Figure 48).[155-156] • The patient's affected arm should be in a neutral position by their side. • The central ray of the X-ray beam should be directed 2.5 cm inferior to the coracoid process **<u>OR</u>** 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint.[155] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and	that make up the shoulder girdle.[155] • On a correctly positioned projection, the shoulder will appear in external rotation, and the elbow will be in the AP position.	parallel to the joint, so that there is minimal overlap between the humeral head and the glenoid surface. The views of the shoulder AP and shoulder true AP (bottom panel) are demonstrated. Glenohumeral Joint Subluxations, Dislocations, and Instability. TeachMe Orthopedics Web site. Available at: https://teachmeorthopedics.info/glenohumeral-joint-subluxations-dislocations-and-instability/. Published April 25, 2021. Accessed June 7, 2021.[156] For educational purposes only.

	positioning immobilization devices as required.		
AP, Glenoid View (Grashey Method)	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient's midcoronal plane should be positioned parallel to the IR, with their back against the IR. • The glenohumeral joint of the affected side should be placed at the center of the IR.[155] • The RT should gently rotate the patient 30° to 45° toward the affected	• This projection is usually part of a standard radiographic protocol. It is used to evaluate the shoulder (glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology. • This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist. • This view is ideal for evaluating the glenoid rim, the glenohumeral joint, and the articular surface of the humerus.	**Figure 49. AP Glenoid View (Grashey Method) Positioning for Imaging the Shoulder**  Berritto et al. *Acta Biomed*. 2018.[158] For educational purposes only.

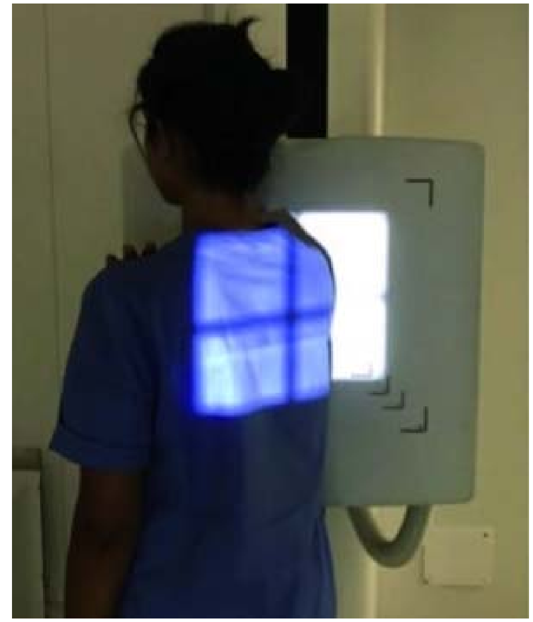
	side to show the glenohumeral joint space (Figure 49).[157-158] • The RT should abduct the patient's arm slightly while internally rotating the humerus. • The central ray of the X-ray beam should be directed perpendicular to the glenoid cavity at a point 2 inches medial and 2 inches distal to the superolateral border of the shoulder (2.5 cm inferior to the coracoid process or 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint). • Tight collimation to the anatomy being imaged with proper right or left marker annotation and	It demonstrates the glenoid cavity in profile, providing a true AP view of the shoulder joint and the ability to determine if there is a dislocation of the humeral head.[157] • This view can also be used to visualize the joint space for subtle fractures such as a Bankart (an anterior labrum or glenoid injury) lesion or post-dislocation-relocation.	

	positioning immobilization devices as required.		
AP, Internal Rotation	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The midcoronal plane of the patient should be parallel to the IR, with the patient's back is against the IR. • The glenohumeral joint of the affected side should be placed at the center of the IR.[155] • The RT should slightly rotate the patient 5° to 10° toward the affected	• This projection is part of a standard radiographic protocol. It is used for evaluation of the shoulder (glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology. • This projection demonstrates the humeral head superimposing the glenoid of the scapula. It better visualizes the lesser tubercle of the humerus in profile and can be used to detected suspected Hill-Sachs (posterolateral humeral	**Figure 50. AP View Positioning of the Shoulder with Internal Rotation** 

	side. The body of the scapula should be parallel with the IR (Figure 50).[103,159] • The affected arm should be internally rotated. • The central ray of the X-ray beam should be directed 2.5 cm inferior to the coracoid process or 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	head impacted fracture) lesions.[160]	 Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications, 2005; Morgan M. External and internal rotation views of the shoulder (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37170. Published May 28, 2015. Accessed June 2021.[103,159] For educational purposes only.
AP, External Rotation	• If the patient can safely stand, they should be	• This projection is part of standard radiographic protocol. It is used for	

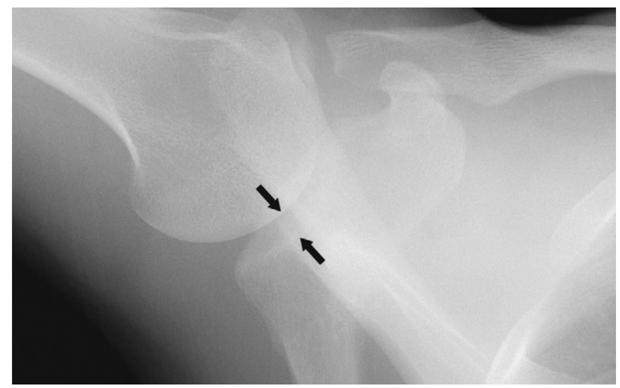
	positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The midcoronal plane of the patient should be parallel to the IR, with the patient's back against the IR. • The glenohumeral joint of the affected side should be positioned at the center of the IR. • The RT should slightly rotate the patient 5° to 10° toward the affected side. The body of the scapula should be parallel to the IR (Figure 51).[103,159] • The affected arm should be rotated externally.	evaluating the shoulder (glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology. • When the external rotation view is performed correctly, the greater tubercle is positioned in profile laterally, and the lesser tubercle is located anteriorly.[161]	**Figure 51. AP View Positioning of the Shoulder with External Rotation** 

	• The central ray of the X-ray beam should be directed 2.5 cm inferior to the coracoid process, or 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Bull S. *Skeletal Radiography: A Concise Introduction to Projection Radiography*. Toolkit Publications, 2005; Morgan M. External and internal rotation views of the shoulder (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37170. Published May 28, 2015. Accessed June 2021.[103,159] For educational purposes only.
Scapular-Y View (PA Oblique Projection)	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent	• This projection is part of a standard radiographic protocol. It is used to evaluate the shoulder	

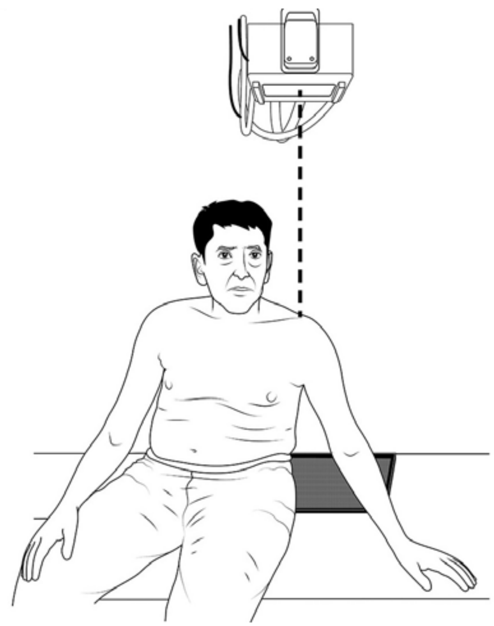
	on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The lateral scapula (Y-view) positioning technique can be either AP or PA. These positions can be further subcategorized based on the patient's arm position (Figure 52).[158] • <u>The PA Approach (Erect Position)</u>[158]: o *"Arm on hip:"* The patient's chest should be in a very lateral position. o *"Napoleon technique:"* Cross-arm adduction with the hand of the affected arm placed on the opposite	(glenohumeral joint) and scapula for disease process, trauma, lesions, foreign bodies, or other pathology. • When performed correctly, this projection provides a complete representation of the scapula. The lateral and medial borders of the scapula are superimposed without other overlapping structures. • The acromion and coracoid form a "Y" or "peace sign" shape with the body of the scapula. The head of the humerus should be	**Figure 52. Y-View Positioning for Imaging the Scapula** 

	shoulder. The examined scapula tends to roll into the lateral position with minimal chest rotation. o The scapula should be end-on to the upright IR; this can be confirmed by palpating the scapula border. o Essentially, the patient's position is a 60° right anterior oblique for the right scapula and the same angle, but in a left anterior oblique position, for the left scapula. o Caudal angulation should be considered, since it is	normally centered to the middle of the "Y" shape. The acromion and distal end of the clavicle form a "roof" over the shoulder joint.[158] This projection also provides the following information: • A profile view of the scapula • It demonstrates the degree and direction of any suspected humeral head dislocations of the glenohumeral joint. • It can evaluate fractures of the scapular body, acromion, coracoid process, and proximal humerus.	 Berritto et al. *Acta Biomed*. 2018.[158] For educational purposes only.

	common for patients to lean or stoop forward when positioned for lateral scapula radiography. o The central ray of the X-ray beam should be directed perpendicular to the center of the scapulohumeral joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Inferosuperior Axial (Lawrence Method)	• The patient should be safely placed in a supine position on the table with the proper SID for	• This projection is part of a standard radiographic protocol. It demonstrates the proximal humerus,	

	the X-ray tube set to 40 in or 102 cm. • The patient’s affected arm should be abducted 90° or an angle that is safe for the patient. • The shoulder and head should be slightly turned away from the affected shoulder. • The IR should be positioned as close to the patient’s neck and affected shoulder as possible, held in place with the appropriate type of IR holder. • The need for angulation of the central ray will vary depending on the amount of arm abduction. With most patients, this will be between 15° to 30°,	scapulohumeral joint, lateral portion of the coracoid process, and AC joint. • It is also critical in the evaluation of patients with suspected shoulder dislocations. This view accurately shows the direction and severity of shoulder head displacement relative to the glenoid. It also reveals the presence and size of head compression fractures of the glenoid and fractures of the humeral tuberosities.[164] • If the patient is limited by their injuries to correctly position for this view, similar diagnostic information	**Figure 53. Axillary (Lawrence Method) Lateral Glenohumeral Joint Imaging Positioning**   Goud et al. *Eur J Radiol*. 2008.[162] For educational purposes only.

	increasing the angle with the increased arm abduction (Figure 53).[162-163] • The central ray of the X-ray beam should be directed horizontally through the axilla. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	can be obtained by performing other positioning maneuvers as demonstrated in Figure 54.[156] • The superoinferior projection (below) may also provide similar information.	**Figure 54. Axillary Lateral and Trauma Axillary Positioning for Imaging the Glenohumeral Joint**   The resulting X-ray of the axillary lateral projection (top left panel) is demonstrated. Glenohumeral Joint Subluxations, Dislocations, and Instability. TeachMe Orthopedics Web site. Available at:

			https://teachmeorthopedics.info/glenohumeral-joint-subluxations-dislocations-and-instability/. Published April 25, 2021. Accessed June 7, 2021.[156] For educational purposes only.
Superoinferior (Trauma Axial)	• The patient should be safely positioned in a supine position on the table accessible to the proper SID for the X-ray tube (40 in or 102 cm). • The patient's affected arm should be abducted with the elbow resting on the IR (which should be placed at the height of the mid-thoracic region).[165] • The patient's arm must be abducted enough so that the glenohumeral joint is central to the image detector (the	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist. • It is performed in place of an inferosuperior axial projection if the patient is unable to position themselves correctly due to injury.	**Figure 55. Superoinferior (Trauma Axial) Positioning for Imaging the Shoulder** 

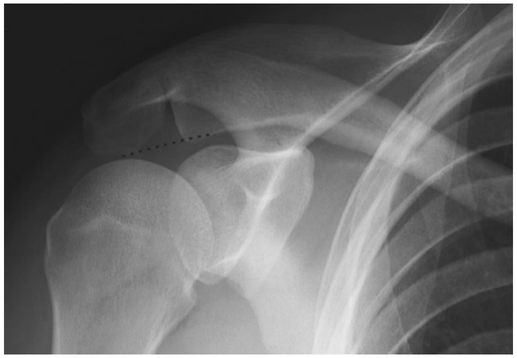
	patient may need to lean slightly). • The patient's head should be tilted away from the unaffected side (and slightly forward if possible); the RT should use the collimation light to ensure the patient's head will not be in the FOV and inadvertently irradiated.[165] • The central ray of the X-ray beam should be directed to the glenohumeral joint with a 5° to 15° tube angle towards the patient's elbow (Figure 55).[166] • **<u>OR</u>** if the patient cannot stand, an alternate view may be used with the patient sitting close to the end of the table.		 Senna et al. *Rev Bras Ortop*. 2016.[166] For educational purposes only.

	• The RT should place the IR close to the patient and instruct them to hold the hand of their affected side and raise their arm to a position as close to a 90° angle as possible (to the long axis of the body).[166] • The patient should then lean laterally over the IR until their shoulder joint is positioned over the center. • The patient should then rest their elbow on the table. • The RT should gently flex the patient's elbow and place their hand in a prone position (if possible).[166]		

	• Have the patient tilt their head towards the unaffected shoulder. • Direct the central ray of the X-ray beam to the shoulder joint at an angle of 5° to 15° towards the elbow. • Tight collimation of the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Apical Oblique (Garth View)	• The patient should be sitting in an erect position or seated against the upright wall bucky with the proper SID for the X-ray tube set to 40 in or 102 cm.	• This projection is a nonroutine ancillary projection and may be ordered by the referring clinician or recommended by the radiologist.	

	• The patient's midcoronal plane should be parallel to the IR, with the patient's back against the IR. • The glenohumeral joint of the affected side should be at the center of the IR. • The patient should be gently rotated 30° to 45° (posterior oblique positioning) toward the affected side to show the glenohumeral joint space. • If possible, the patient should rest the affected side's hand on the unaffected shoulder. • The central ray of the X-ray beam should be directed 2.5 cm inferior	• This view is useful for examining the relationship between the humeral head and the glenoid fossa (Figure 56).[167] • In normal radiographs, the humeral head is at the same level of the glenoid fossa. Both areas are commonly injured in anterior dislocation of the shoulder.[168]	**Figure 56. Apical Oblique (Garth View) X-Ray of the Glenohumeral Joint**  Hacking C. Normal shoulder x-ray - Garth view (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/53068. Published April 30, 2017. Accessed 2021.[167] For educational purposes only.

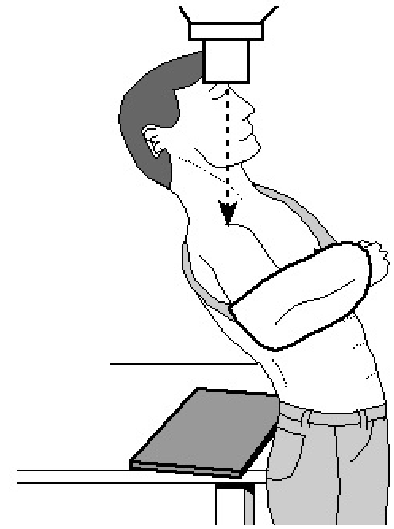
	to the coracoid process, or 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

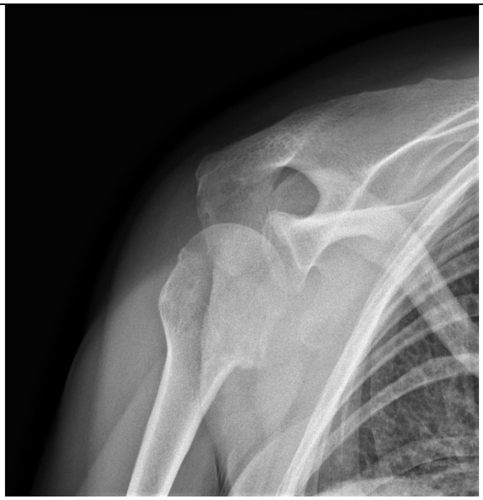
Rockwood Tilt View	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient's midcoronal plane should be parallel to the IR, with the patient's back against the IR. • The glenohumeral joint of the affected side should be positioned at the center of the IR. • The X-ray beam should be projected from the anterior direction at a 30° caudal angle (Figure 57).[162]	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist. • This projection best depicts the acromion component of the glenohumeral joint.	**Figure 57. Rockwood Tilt View Positioning for Imaging the Acromion**   Goud et al. *Eur J Radiol*. 2008.[162] For educational purposes only.

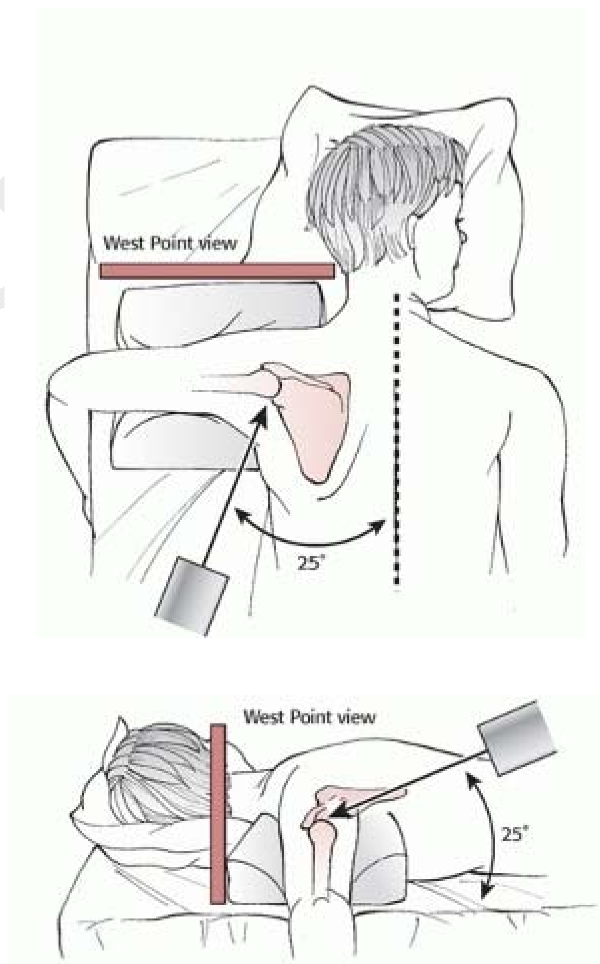
	• The central ray of the X-ray beam should be directed 2.5 cm inferior to the coracoid process, or 2 cm inferior to the lateral clavicle at the level of the glenohumeral joint. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		
Stryker Notch View	• The RT should position the patient supine on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The affected arm should be raised and abducted above the shoulder with	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist.	

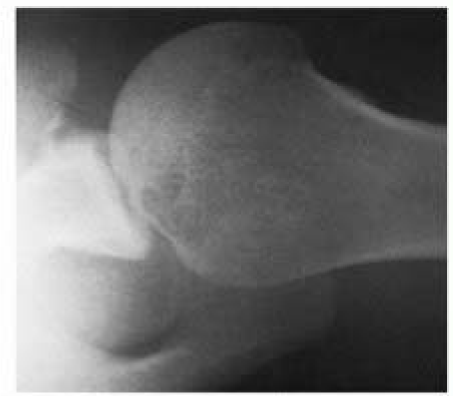
	the elbow flexed and the patient's hand placed on the top of their head. • The X-ray tube should be tilted 10° to 15° cephalad (Figure 58).[169] • The central ray of the X-ray tube should be directed to the center of the coracoid process. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.	• This projection is useful in detecting humeral head fractures associated with anterior dislocation of the shoulder. It provides a clear visualization of the posterolateral margin of the humeral head.	**Figure 58. Stryker Notch View Positioning for Imaging the Posterolateral Margin of the Humeral Head** 

			 Kostretzis et al. *Open Orthop J*. 2017.[169] For educational purposes only.
Velpeau View	• The patient should be erect (or sitting erect) facing away from the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The IR should be placed on the table behind the	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist.	

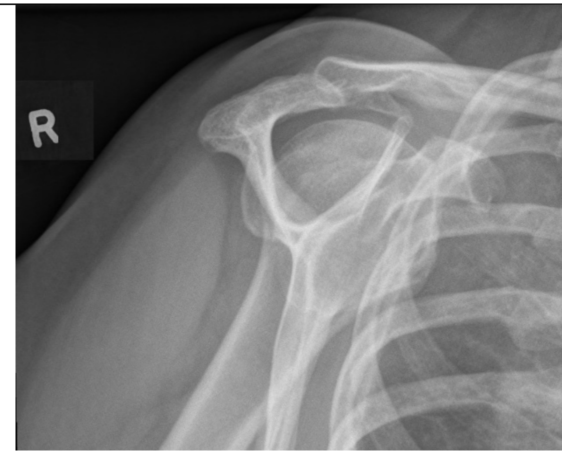
	patient and beneath the shoulder (Figure 59).[170-171] • The RT should direct the patient to lean 30° backwards toward the table (allowing for an axial view of the shoulder).[172] • The X-ray tube should be directed straight up and down and centered at the glenohumeral joint (be sure to check that it casts a shadow on the IR to determine correct position). • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning	• This view of the glenohumeral joint is a modified axial projection performed in the context of shoulder immobilization. This view is performed with the patient erect, leaning backwards at a 30° angle. • This view will demonstrate the anterior and posterior humeral head and the glenoid fossa and is useful for useful for suspected posterior dislocations. • RTs may encounter some patients who are postsurgical or have a complicated humeral head and/or neck	**Figure 59. Velpeau View Positioning for Imaging the Anterior and Posterior Humeral Head and the Glenoid Fossa** 

	immobilization devices as required.	fracture who may be unable to assume this type of axillary position.[172]	 UW Medicine Orthopaedics and Sports Medicine. Patient Articles: Clinical Presentation of Glenohumeral Instability. UW Medicine Web site. Available at: https://orthop.washington.edu/patient-care/articles/shoulder/clinical-presentation-of-glenohumeral-instability.html. Accessed November 2021; Morgan M. Velpeau view of the shoulder (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/85739. Published January 6, 2021.[170-171] For educational purposes only.

West Point View	• The patient should be in the prone position on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The RT should place the patient's shoulder on a sponge to elevate it approximately 8 cm. • The patient's arm should be abducted approximately 90° with their forearm hanging over the table (Figure 60).[156] • The IR should rest on the superior part of the affected shoulder. • The patient's head should be tilted away from the injured shoulder.	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist. • The West Point view is a very specific projection used to assess the anteroinferior glenoid rim often in the context of recurrent instability for glenoid bone loss.[173]	**Figure 60. West Point View Positioning for Imaging the Anteroinferior Glenoid Rim** 

	• The X-ray tube should be positioned in the same plane at the glenohumeral joint, directed at a 25° angle medially and a 25° angle cephalad, centered inferior and medial to the AC joint.[156] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Glenohumeral Joint Subluxations, Dislocations, and Instability. TeachMe Orthopedics Web site. Available at: https://teachmeorthopedics.info/glenohumeral-joint-subluxations-dislocations-and-instability/. Published April 25, 2021. Accessed June 7, 2021.[156] For educational purposes only.
Tangential Supraspinatus Outlet View (Neers Method)	• The patient should be positioned in an erect or sitting position, facing the upright wall bucky, with the proper SID for the X-ray tube set to 40 in or 102 cm.	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist.	

	• The RT should rotate the patient in an anterior oblique position, so that the anterior portion of the patient's shoulder is touching the upright IR detector.[174] • The patient should now be in a posteroanterior position; the RT should gently rotate the patient's affected shoulder 45° to 60° towards the IR. • The scapula should be end-on to the upright wall bucky; this can be done via palpation of the scapula border. • The degree of anterior rotation can vary from patient to patient.	• The outlet view is performed to assess subacromial impingement. This view is often performed instead of a lateral shoulder view for the impingement series only. • This projection is most commonly seen in orthopedic clinics and closely resembles a lateral scapular projection but incorporates a 10° to 15° caudal angulation of the X-ray tube.[177]	**Figure 61. Tangential Supraspinatus Outlet View (Neers Method) Positioning** 

	• The X-ray tube should then be placed at a 10° to 15° caudal angulation. (Figure 61).[175-177] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 This view allows for the assessment of subacromial impingement. Shoulder: Tangential Projection – Neer Method. Radtechonduty.com. Available at: http://www.radtechonduty.com/2012/04/tangetial-projection-supraspinatus.html. Published April 24, 2012. Accessed June 2021; Murphy A. Subacromial impingement (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/48224. Published September 27, 2016. Accessed June 2021.[175-176] For educational purposes only.

Bernageau View	• If the patient can safely stand, the RT should position the patient at the upright wall bucky with the proper SID for the X-ray tube set to 40 in or 102 cm. • The patient should be placed in an anterior oblique position; the patient's arm that's closes to the IR should be fully abducted at 135°. Only if physically possible, the patient's hand should be resting on their head. • The X-ray central ray is directed 30° caudal and in the plane of the scapula (Figure 62).[178] • Tight collimation to the anatomy being imaged	• This projection is a nonroutine ancillary projection and *may be* ordered by the referring clinician or recommended by the radiologist. • For determining glenoid bone loss, the West Point axillary and Bernageau projections are frequently used. • The Bernageau view is the best projection to detect Bankart (anterior labrum or glenoid injury) lesions since the X-ray central ray is tangent to the anteroinferior aspect of the glenoid.	**Figure 62. Bernageau View Positioning for Imaging the Shoulder** 

	with proper right or left marker annotation and positioning immobilization devices as required.		 This projection may be used to view/diagnose Bankhart lesions as well as determine the extent of glenoid bone loss. Saliken et al. *BMC Musculoskelet Disord*. 2015.[178] For educational purposes only.

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AC = acromioclavicular; AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; FOV = field-of-view; IR = image receptor; PA = posteroanterior; SID = source-to-image distance.

Data from: Carroll et al. *Adaptive Radiography with Trauma, Image Critique and Critical Thinking*. Clifton Park, NY: Delmar Cengage Learning; 2014; Carlton et al. *Principles of Radiographic Positioning and Pocket Guide*. 2nd ed. Clifton Park, NY: Thomson Delmar Learning; 2006; Murphy A. Shoulder (AP view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/45849. Published June 10. 2016. Accessed May 2021; Glenohumeral Joint Subluxations, Dislocations, and Instability. TeachMe Orthopedics Web site. Available at: https://teachmeorthopedics.info/glenohumeral-joint-subluxations-dislocations-and-instability/. Published April 25, 2021. Accessed June 7, 2021; Morgan M, Murphy A. Shoulder (AP glenoid view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/35615. Published April 14, 2015. Accessed June 1, 2021; Berritto et al. *Acta Biomed*. 2018; Morgan M. External and internal rotation views of the shoulder (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/37170. Published May 28, 2015. Accessed June 2021; Murphy A, Knipe H. Shoulder series. Radiopaedia.org. Available at: https://radiopaedia.org/articles/45087. Updated 2021. Accessed May 27, 2021; Morgan M, Murphy A. Shoulder (external rotation view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/37169. Published May 28, 2015. Accessed May 27, 2021; Goud et al. *Eur J Radiol*. 2008; Murphy, A. Shoulder (inferosuperior axial). Radiopaedia.org. Available at: https://radiopaedia.org/articles/52966. Published April 27, 2017. Accessed June 1, 2021; Rockwood et al, eds. *Rockwood and Matsen's The Shoulder.* Philadelphia, PA: Elsevier; 2017; Murphy A. Shoulder (superior-inferior axial view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/52965. Published April 27, 2017. Accessed June 1, 2021; Senna et al. *Rev Bras Ortop*. 2016; Hacking C. Normal shoulder x-ray - Garth view (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/53068. Published April 30, 2017. Accessed 2021; Abrams et al. Shoulder Dislocations Overview. In: *StatPearls* [Internet]. Treasure Island, FL: StatPearls Publishing; 2021; Kostretzis et al. *Open Orthop J*. 2017; UW Medicine Orthopaedics and Sports Medicine. Patient Articles: Clinical Presentation of Glenohumeral Instability. UW Medicine Web site. Available at: https://orthop.washington.edu/patient-care/articles/shoulder/clinical-presentation-of-glenohumeral-instability.html. Accessed November 2021; Morgan M. Velpeau view of the shoulder (Case study). Radiopaedia.org. Available at:

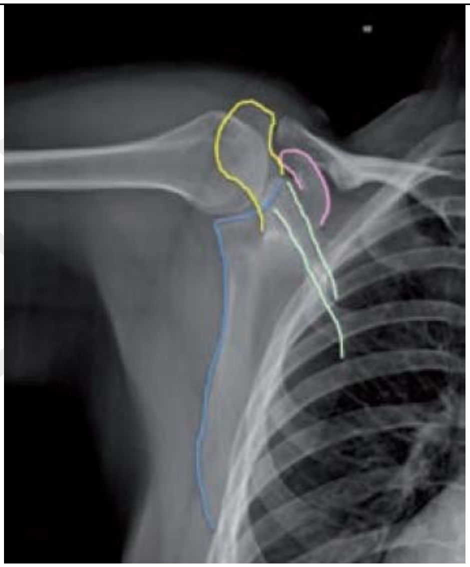
https://radiopaedia.org/cases/85739. Published January 6, 2021; Murphy A, Bel, D. Shoulder (Velpeau view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/85647. Updated August 24, 2021. Accessed June 2021; Knipe H. Shoulder (West Point view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/85644. Published January 4, 2021. Accessed June 2021; Murphy A. Shoulder (lateral scapula view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/48252. Published September 27, 2016. Accessed June 1, 2021; Shoulder: Tangential Projection – Neer Method. Radtechonduty.com. Available at: http://www.radtechonduty.com/2012/04/tangetial-projection-supraspinatus.html. Published April 24, 2012. Accessed June 2021; Murphy A. Subacromial impingement (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/48224. Published September 27, 2016. Accessed June 2021; Murphy A. Shoulder (outlet view). Radiopaedia.org. Available at: https://radiopaedia.org/articles/53686. Published May 31, 2017. Accessed June 1, 2021; Saliken et al. *BMC Musculoskelet Disord*. 2015; Bianchi et al. Shoulder radiography. In: Davies AM, Hodler J, eds. *Imaging of the Shoulder: Techniques and Applications*. Berlin, Germany; Springer-Verlag; 2006; Kwong et al. *Ann Joint*. 2017; Vande Berg et al. *J Belg Soc Radiol*. 2016; Corbett. *Radiol Technol*. 2019; Kilcoyne et al. *AJR Am J Roentgenol*. 1989; Shoener. *Rad Notes: A Pocket Guide to Radiographic Procedures*. Philadelphia, PA: FA Davis; 2011.[85-86,155-184] For educational purposes only.

Scapula

The scapula is a flat triangular bone that is encased superficially and anteriorly by the rib cage (Figure 8).[24,29,184] The surrounding muscles, including the rotator cuff, serve as a protective layer, dissipating any impact that may be directed toward the scapula.[24] As a result of this muscular support, fractures of the scapula are rare and account for less than 1% of all fractures and 5% of all shoulder fractures.[185-186] Evaluation by diagnostic radiography can be difficult because of the complex scapular anatomy and osseous and soft tissue overlap.[158] Therefore, RTs needs to provide adequate visualization of the different parts of the scapula on each X-ray view, including the coracoid process, glenoid, and acromion, as well the 3 scapular articulations (scapulothoracic, glenohumeral, and AC) for any incongruity for the radiologist to evaluate. The standard radiographic views for evaluation of the scapula are the scapular Y-view (Figure 52) and the anteroposterior projection, outlined in Table 12[158] If conventional radiography does not provide a complete series of images for a successful diagnostic evaluation, then CT with 3D reconstructions should be offered as an option by the radiologist to treating physician.[24]

Table 12. Projections and Positioning Techniques for the Scapula

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Example
AP	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. • The scapula of the patient's affected side should be centered at the IR. • The arm on the patient's affected side should be abducted with their hand supine; this position will "pull" the scapula away from the ribs.	• This projection is part of a standard radiographic protocol when evaluating the scapula. It is used to evaluate the scapula and glenohumeral joint for disease process, trauma, lesions, foreign bodies, or other pathology. • This view demonstrates the complete anatomy of the scapula, which includes the acromion, coracoid process, spine, and body. The lateral scapular border should be visualized without costal superposition.[158]	**Figure 63. AP View Positioning Techniques for Imaging the Scapula** 

	• The RT should slightly rotate the patient 5°, causing the body of the scapula to lay parallel to the IR (Figure 63).[158] • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Berritto et al. *Acta Biomed*. 2018.[158] For educational purposes only.

The IR used 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; SID = source-to-image distance.

Data from: Berritto et al. *Acta Biomed*. 2018.[158] For educational purposes only.

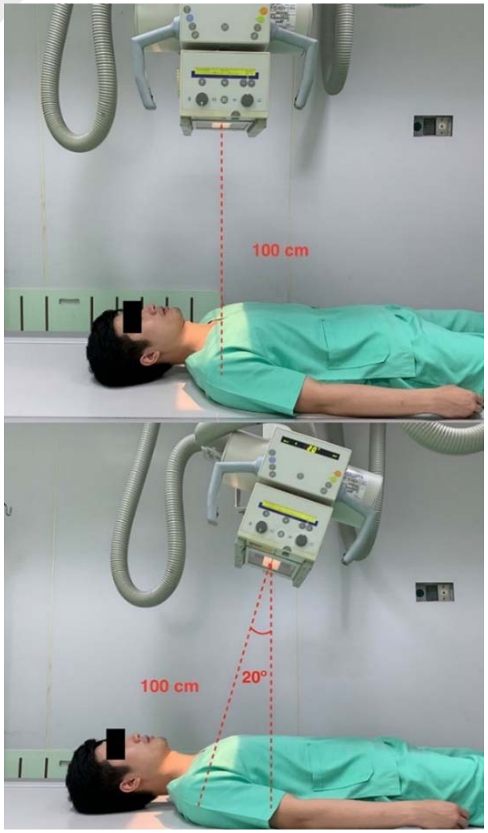
Clavicle

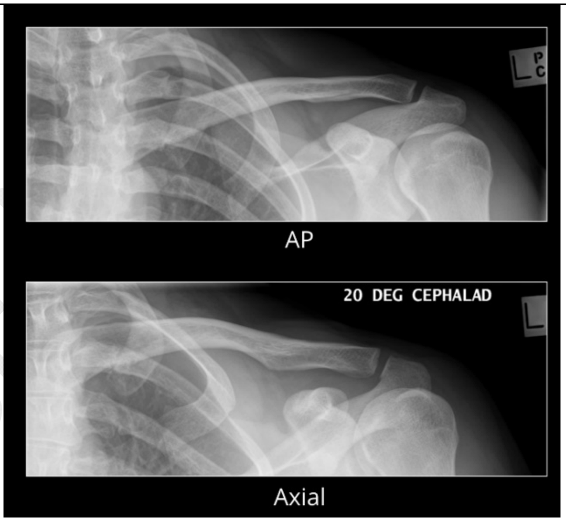
Clavicle fractures are common and account for 2.6% to 10% of all fractures and for approximately 44.1% of all fractures in the upper girdle region of the body.[188] The clavicle can be fractured or dislocated secondary to other injuries, and treatment of these fractures is usually a nonsurgical intervention.[189-190] A direct hit to the shoulder is the most common cause of midshaft clavicle fractures.[191] Most patients who sustain a clavicle fracture will give a history of a direct fall onto the shoulder or a fall onto an outstretched hand.

A common trauma radiography series of the clavicle will include an AP shoulder view and an AP clavicle view with cephalic angulation.[191] This series is most suitable for patients that exhibit the clinical signs of an isolated clavicle fracture.[192] The AP shoulder view (neutral position) (Figure 48) is useful in diagnosing other (unsuspected) shoulder girdle bony injuries.[156,192] The "coned down" AP and AP-cephalic angle views should be included to avoid missing subtle clavicle fractures. The tube angulation can typically range from 15° to 30°. The greater the tube angulation that's applied, the greater the superior projection of the clavicle. This cephalic angle view also has the potential to provide an improved visualization of the nature of the fracture and determine the degree of displacement.[192-193]

Table 13 outlines techniques for optimal imaging of the clavicle.[192-195]

Table 13. Projections and Positioning Techniques for the Clavicle

Radiographic Projection/View	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. This view may also be performed with the patient in the supine position laying on the table. • The RT should adjust the patient's body so that the clavicle is centered to the midline of the table or vertical upright IR. • The patient's arms should be hanging at	• This projection is part of a standard radiographic protocol. It is used to evaluate the shoulder (glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology. • On a true AP projection, the lateral half of the clavicle should be seen above the scapula, with the medial half superimposing the thorax.	**Figure 64. AP and Cephalic-Angle View Positioning for Imaging the Clavicle** 

	their sides in a neutral position. • The central ray should be centered to the midpoint of the clavicle (Figure 64).[193-194] • The RT should instruct the patient to suspend respiration at the end of exhalation to obtain a more uniformly dense image. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		 Kongmalai et al. *J Orthop Surg (Hong Kong).* 2020; Ng J. Clavicle series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/71804. Published October 24, 2019. Accessed June 15, 2021.[193-194] For educational purposes only.
AP, Axial	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent	• This projection is part of a standard radiographic protocol. It is used to evaluate the shoulder	

	on the table with the proper SID for the X-ray tube set to 40 in or 102 cm. This view may also be performed with the patient in the supine position laying on the table. • The RT should adjust the patient's body so that the clavicle is centered to the midline of the table or vertical upright IR. • The patient's arms should be hanging at their sides in a neutral position. • The central ray of the X-ray beam should be angled 15° to 30° cephalad to the midclavicle. Thinner patients will likely require more angulation	(glenohumeral joint) for disease process, trauma, lesions, foreign bodies, or other pathology • With this projection, most of the clavicle should be projected above the scapula and ribs. Only the medial portion of the clavicle should be superimposed by the first and second ribs.[195] • Along with the AC and SC joints, the clavicle should also be clearly demonstrated in a horizontal placement.[192]	

	to project the clavicle off of the scapula and ribs. o <u>For the standing lordotic position</u>, a 0° to 15° angle is recommended. o <u>For the supine position</u>, a 15° to 30° angle is recommended (Figure 64).[193-194] • The RT should instruct the patient to suspend respiration at the end of exhalation to obtain a more uniformly dense image. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AC = acromioclavicular; AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; PA = posteroanterior; SC = sternoclavicular; SID = source-to-image distance.

Data from: Ahmad N. Boning up on humerus, clavicle, and AC joint positioning. AuntMinnie.com Available at: https://www.auntminnie.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=57446. Published February 18, 2003. Accessed June 12, 2021; Kongmalai et al. *J Orthop Surg (Hong Kong).* 2020; Ng J. Clavicle series (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/71804. Published October 24, 2019. Accessed June 15, 2021; Lampignano JP. Humerus and shoulder girdle. In: *Textbook of Radiographic Positioning and Related Anatomy*. 7th ed. St Louis, MO: Mosby Elsevier;2010.[192-195] For educational purposes only.

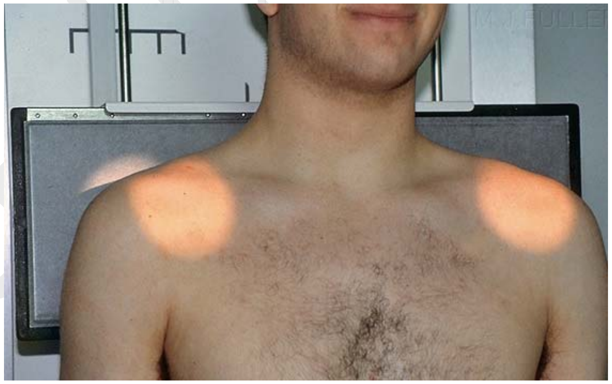
Acromioclavicular (AC) Joint

Pain from the AC joint is usually due to localized degenerative changes or a history of injury (Figure 10).[33,196] Injury to the AC joint is common among athletes and young people and accounts for more than 40% of all shoulder injuries.[197] Diagnostic radiography is the initial imaging modality of choice for diagnosis and classification of AC joint injuries as injuries to this joint may not always be evident on regular radiographic views. If an AC joint injury is suspected, a Zanca view is often helpful and is obtained by tilting the X-ray beam 10° to 15° in a cephalic angle.[197-198] The Zanca view can also be helpful in imaging AC joint pathology such as distally projecting osteophytes.[198] The use of weighted stress radiographs is controversial in evaluating patients with possible AC separation with a general consensus still undetermined; it is generally still at the discretion of the treating physician and/or radiologist to order.[199-200] Without weighted X-ray images, the normal measurement of AC joint space is less than 5 mm; the right and left AC joint spaces should differ no more than 2 mm to 3 mm.[201]

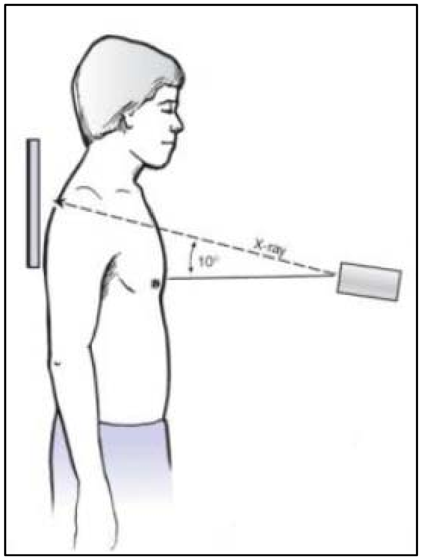
Table 14 outlines techniques for optimal imaging of the AC joint.[96,192,198,202-208]

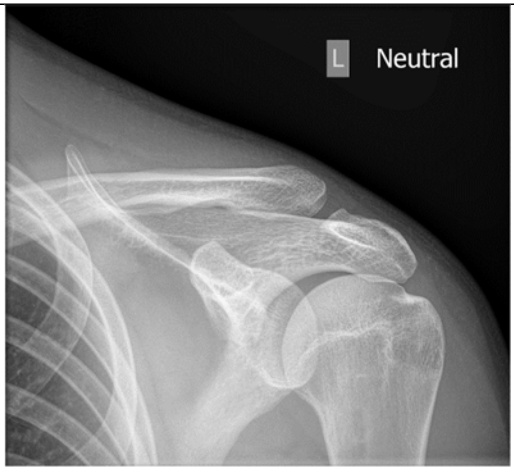
Table 14. Projections and Positioning Techniques for the AC Joint

Radiographic Projection	Patient Positioning Techniques	Standard or Supplemental Views and Clinical Applications	Examples
AP	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 72 in or 183 cm. • It is important to image the AC joint with the patient in the upright position as AC joint dislocation may reduce itself in the recumbent position.[96] • The RT should center the midline of the body to the midline of the upright IR.	• This projection is part of a standard radiographic protocol. It is used for evaluating the AC joint for disease process, trauma, dislocation, lesions, foreign bodies, or other pathology. • The erect bilateral view demonstrates the AC joint in the anteroposterior plane, and it is best view in order to examine the widening of the AC joint and separation of the joint space.[202]	**Figure 65. "Cone Down" AP View of the AC Joint**  Hacking C, Murphy A. Acromioclavicular joint series. Radiopaedia.org. Available at: https://radiopaedia.org/articles/37932. Published June 26, 2015. Accessed June 25, 2021.[202] For educational purposes only.

	• To avoid rotation, the RT should make sure that the patient is bearing weight equally on both feet. • With the patient's arms hanging in a neutral position (at their sides), the RT should adjust the patient's shoulders so that they are in the same horizontal plane. • Depending on department protocol, the projection may be directed towards the AC joint in question only ("cone-down") (Figure 65), or bilaterally, comparing both the injured and uninjured AC joints.[202-204] • The central ray of the X-ray beam should be		**Figure 66. AP Bilateral Positioning for Imaging the AC Joint**   Fuller MJ. Applied Radiography: Acromioclavicular Joint Radiography. Wikiradiograhy.net. Available at: http://www.wikiradiography.net/page/Acromioclavicular_Joint_Radiography. Accessed June 2021; Walters et al. *Arthrosc Sports Med Rehabil*. 2021.[203-204] For educational purposes only.

	horizontal to the IR and centered towards the AC joint (centered midline if acquiring bilateral AC joints in the same view (Figure 66).[203-204] • The RT should instruct the patient to suspend respiration at the end of exhalation to obtain a more uniformly dense image. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

AP, Zanca View	• If the patient can safely stand, they should be positioned at the upright wall bucky or recumbent on the table with the proper SID for the X-ray tube set to 72 in or 183 cm. • It is important to image the AC joint with the patient in the upright position as AC joint dislocation may reduce itself in the recumbent position.[96] • The RT should center the midline of the body to the midline of the upright IR. • To avoid rotation, the RT should make sure that the patient is bearing weight equally on both feet.	• This projection is part of a nonroutine ancillary radiographic protocol. It is used for evaluating the AC joint for disease process, trauma, dislocation, lesions, foreign bodies, or other pathology. • This view is used to rule out displacement of the AC joint when it is suspected yet not confirmed on the AP view. Cephalic angulation allows the AC joint to be viewed free of superimposition.[202]	**Figure 67. AP and Cephalic Angle View Positioning for Imaging the AC Joint** 

	• With the patient's arms hanging in a neutral position (at their sides), the RT should adjust the patient's shoulders so that they are in the same horizontal plane. • Depending on department protocol, the projection may be directed towards the AC joint in question only ("cone-down"), or bilaterally, comparing both the injured and uninjured AC joints.[202] • The central ray of the X-ray beam should be angled 10° to 15° in a cephalic angle towards the AC joint (centered midline if acquiring images of bilateral AC		 Muthukumar et al. *Nat J Clin Orthop*. 2017; Knipe H. Normal acromioclavicular joint - Zanca view (x-ray) (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/68155. Published May 16, 2019. Accessed July 5, 2021.[205-206] For educational purposes only.

	joints in the same view (Figure 67).[205-206] • The RT should instruct the patient to suspend respiration at the end of exhalation to obtain a more uniformly dense image. • Tight collimation to the anatomy being imaged with proper right or left marker annotation and positioning immobilization devices as required.		

The IR used can be either a conventional film/screen cassette, CR cassette, or DDR plate.

AC = acromioclavicular; AP = anteroposterior; CR = computed radiography; DDR = direct digital radiography; IR = image receptor; SID = source-to-image distance.

Data from: Ballinger et al. *Merrill's Atlas of Radiographic Positions and Radiologic Procedures*. 9th ed. New York, NY: Mosby; 1999; Ahmad N. Boning up on humerus, clavicle, and AC joint positioning. AuntMinnie.com Available at: https://www.auntminnie.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=57446. Published February 18, 2003. Accessed June 12, 2021; Vanarthos et al. *AJR Am J Roentgenol*. 1994; Hacking C, Murphy A. Acromioclavicular joint series. Radiopaedia.org. Available at:

https://radiopaedia.org/articles/37932. Published June 26, 2015. Accessed June 25, 2021; Fuller MJ. Applied Radiography: Acromioclavicular Joint Radiography. Wikiradiograhy.net. Available at: http://www.wikiradiography.net/page/Acromioclavicular_Joint_Radiography. Accessed June 2021; Walters et al. *Arthrosc Sports Med Rehabil*. 2021; Muthukumar et al. *Nat J Clin Orthop*. 2017; Knipe H. Normal acromioclavicular joint - Zanca view (x-ray) (Case study). Radiopaedia.org. Available at: https://radiopaedia.org/cases/68155. Published May 16, 2019. Accessed July 5, 2021; et al. *Am J Sports Med*. 1981; Hegazy et al. *Open Orthop J*. 2016.[96,192,198,202-208] For educational purposes only.

Conclusions

Considering radiographs are the most important and frequently used first-line modality in clinical imaging, standardized patient positioning techniques and departmental protocols are essential in evaluating any pathology of the body part being imaged. The benefits of diagnostic radiography are relatively low radiation dose to the patient, low cost, universal availability, and the ability to perform mobile examinations when necessary. Perhaps the most important role of radiography in the clinical setting is its role in musculoskeletal imaging. Diagnostic radiography can be used to evaluate for arthritis (degenerative and inflammatory processes), bone tumors (lytic and sclerotic primary and metastatic disease), infection, foreign bodies, dislocations, and fractures. The importance of appropriate patient positioning and radiographic exposure settings are key to producing diagnostic radiographs. Multiple projections assist in characterizing pathology, dislocations, and fractures. Nonroutine projections can potentially lead to missed diagnoses and should be considered if diagnosis is uncertain. As a result, RTs play crucial role in the execution of positioning techniques in image acquisition as well as carrying out standard departmental protocols in the day-to-day imaging performed in the clinical setting.

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