

Neck of femur fracture

Anatomy & Pathophysiology

BONY ANATOMY

- The hip is a multiaxial joint formed by the articulation between the pelvis and femur, connecting the axial skeleton and the lower extremity [10].
- The hemipelvis comprises three bones: the ilium, ischium, and pubis, which unite at the triradiate cartilage within the concave acetabulum [10].
- The acetabulum comprises an articular crescent-moon-shaped lunate surface and a nonarticular central fossa that serves as the attachment point for the ligamentum teres [10].
- The acetabulum is incomplete inferiorly, forming a notch through which vital blood vessels and nerves pass to supply the joint [10].
- The femoral head forms two-thirds of a sphere, with a small depression at its center from which the ligamentum teres extends to connect to the acetabular notch [10].
- The neck-shaft angle of the femur averages 125° [10].
- Normal version, defined as the head-neck angle in the frontal plane, averages 15 to 20° [10].
- The acetabulum is normally anteverted 15 degrees and obliquely oriented in the coronal plane 45 degrees caudally [16].
- The posterosuperior articular surface of the acetabulum is thickened to accommodate weight bearing [16].
- The femoral neck is normally anteverted approximately 14 degrees in relation to the femoral condyles, with a range of 1–40 degrees [16].
- The femoral neck-shaft angle averages 127 degrees, beginning at 141 degrees in the fetus [16].
- The mean femoral neck-shaft angle in the adult is 130° ± 7° [20].
- The mean anteversion of the femoral neck is 10° ± 7° [20].
- The two prime trabecular groups of the proximal femur are the principal tensile group and the principal compressive group [20].
- Secondary compressive and tensile trabecular groups also exist in the proximal femur [20].
- The weakest area in the femoral neck is located in the Ward triangle [20].

- The calcar femorale is a medial area of dense trabecular bone that transfers stress from the femoral shaft to the inferior portion of the femoral neck [20].
- Fractures of the proximal femur follow the path of least resistance [20].

LIGAMENTS AND CAPSULE

- The hip is surrounded by a dense fibrous capsule extending from the periphery of the acetabulum to the intertrochanteric line of the femoral neck [10].
- The capsule enhances joint stability by preventing translation of the femoral head in the acetabulum [10].
- The hip capsule attaches anteriorly and posteriorly along the periphery of the acetabulum outside the labrum [11].
- Inferiorly, the hip capsule is attached to the acetabular labrum [11].
- The capsule is attached to the femur anteriorly along the intertrochanteric crest [11].
- On the posterior side, the capsule attaches only partially, such that the basicervical region of the femoral neck and the intertrochanteric region of the femur are not intracapsular [11].
- The iliofemoral ligament is also known as the Y ligament of Bigelow; it originates at the AIIS and inserts at the intertrochanteric line [11].
- The iliofemoral ligament becomes taut in full extension, preventing anterior dislocation and hyperextension of the hip [11].
- The pubofemoral ligament attaches to the inferior and medial part of the capsule [11].
- The ischiofemoral ligament reinforces the posterior capsule and provides a check to internal rotation of the hip [11].
- The twisted orientation of the hip ligaments provides a screw mechanism for the hip in full extension [11].
- The ligamentum teres originates in the cotyloid fossa and attaches on the fovea of the femoral head [11].
- The iliofemoral ligament is the thickest and strongest of the three main ligaments supporting the hip [10].
- The medial portion of the iliofemoral ligament connects the anterior inferior iliac spine to the anterior intertrochanteric line, while the lateral portion originates slightly superior to the medial arm and attaches to the anterior greater trochanter [10].
- The iliofemoral ligament functions to limit external rotation, while in isolation, the lateral arm limits extension of the joint [10].
- The ischiofemoral ligament extends from the ischial margin of the acetabulum to the greater trochanter of the femur and restricts internal rotation motion [10].
- The pubofemoral ligament extends from the obturator crest of the pubic bone to the femoral neck and acts to limit abduction of the joint [10].
- Deep fibers from all three ligaments merge to form the zona orbicularis, which circumvents the femoral neck [10].

LABRUM

- The acetabular labrum is a fibrocartilaginous ring attached to the rim of the acetabulum that extends the articulating surface area and increases femoral head coverage [10].
- The labrum is triangular in cross section, which contributes to its ability to create a pressurized seal of the central compartment of the hip during loading [10].
- Only the external one-third of the labrum contains blood vessels, leaving the majority of the structure avascular and limiting its healing ability following injury [10].
- The labrum is highly innervated, with the presence of both mechanoreceptors and nociceptors [10].
- The labrum is absent in the area of the inferior acetabular notch, where the transverse acetabular ligament serves as the continuation of the labrum [10].
- The fibrocartilaginous labrum deepens the acetabulum, enhancing stability [7].
- Labral functions include load transmission, maintenance of vacuum seal, regulation of synovial fluid hydrodynamics, and joint lubrication [7].

VASCULAR ANATOMY

- The medial femoral circumflex artery is the main blood supply to the femoral head [20].
- The medial femoral circumflex artery terminates in the posterior aspect of the extracapsular arterial ring [20].
- The lateral femoral circumflex artery gives rise to the anterior aspect of the arterial ring [20].
- The superior and inferior gluteal arteries also contribute branches to the extracapsular arterial ring [20].
- The ascending cervical arteries originate from the extracapsular arterial ring and are divided into four distinct groups: lateral, medial, posterior, and anterior [20].
- The lateral group of ascending branches is the main blood supply to the femoral head [20].
- The ascending branches give off multiple perforator vessels to the femoral neck and terminate in the subsynovial arterial ring located at the margin of the articular surface of the femoral head [20].
- The lateral epiphyseal artery penetrates the femoral head and is believed to be the dominant blood supply to the femoral head from this system [20].
- Fractures that disrupt the ascending blood flow to the lateral epiphyseal vessel have an increased risk of osteonecrosis [20].
- The artery of the ligamentum teres arises from either the obturator or medial femoral circumflex artery and does not provide sufficient blood supply to maintain the viability of the femoral head [20].
- From birth to approximately 4 years of age, the major blood supply to the femoral head comes from the medial and lateral femoral circumflex arteries, with major contributions from the artery of the ligamentum teres [23].
- From the age of 4 years to adulthood, the posterosuperior and posteroinferior retinacular arteries from the medial circumflex artery are the major blood supply [23].

- In adulthood, the major blood supply to the femoral head is from the medial femoral circumflex and lateral epiphyseal arteries [23].
- Intramedullary femoral nails that use a piriformis fossa entry point in pediatric patients are undesirable because they would injure the posterolateral retinacular vessels and cause osteonecrosis of the femoral head [23].

PATHOPHYSIOLOGY OF FRACTURE HEALING

- Femoral neck fractures are considered intracapsular fractures, which are at higher risk of nonunion [20].
- Because of the absence of a periosteal or extraosseous blood supply, no callus forms during healing of femoral neck fractures [20].
- Fracture healing of femoral neck fractures occurs by intraosseous bone healing [20].
- Intertrochanteric fractures are considered extracapsular fractures [20].
- Callus formation is common in intertrochanteric fracture patterns, and nonunion is rare because of the absence of synovial fluid and the presence of an abundant blood supply [20].
- The characteristic differences between femoral neck fractures in young adult patients and typical osteoporotic femoral neck fractures contribute to a specific set of clinical problems [4].
- Treatment failure is frequently seen after femoral neck fractures, including nonunion, failed fixation, osteonecrosis, and malunion [4].
- Understanding and addressing the pathoanatomy of vertical femoral neck fractures is mandatory to minimize risks for treatment failure [4].
- Quality reduction and stable fixation for femoral neck fractures are vital elements in managing these at-risk fractures [4].

Clinical Presentation

HISTORY AND MECHANISM

- The diagnosis of a femoral neck fracture is based on history, physical examination, and radiographs [33].
- Most patients with femoral neck fractures give a history of a traumatic event [33].
- Patients with stress fractures of the femoral neck are an exception to the typical history of a traumatic event [33].
- Many young patients with high-energy femoral neck fractures have associated injuries, including head injuries, and may not be able to give a history [33].
- The index of suspicion for a femoral neck fracture must be extremely high because the consequences of a missed femoral neck fracture can be disastrous [33].
- In an alert patient with a femur fracture, the patient reports pain, swelling, and deformity and the inability to ambulate [35].
- The mechanism of injury may key the physician to associated injuries that can be overlooked initially [35].

PHYSICAL EXAMINATION

- The physical examination for a femoral neck fracture typically reveals an extremity that is shortened and externally rotated [33].
- In an alert patient with a femur fracture, the leg will appear shorter or angulated [35].
- Distracting injuries can make the diagnosis more challenging, especially in an obtunded patient [35].
- The physical examination for femur fractures begins with the Advanced Trauma Life Support (ATLS) protocol at initial presentation [35].
- The femur fracture can affect the primary survey by influencing the hemodynamic status of the patient [35].
- The femur and surrounding tissue are very vascular and can result in significant blood loss into the thigh even in a closed fracture [35].
- Up to 40% of isolated femoral shaft fractures required a transfusion, averaging 2.5 units of packed red blood cells during the initial hospitalization [35].
- The potential for blood loss is especially significant in patients with multiple long-bone fractures and elderly patients who have less cardiac reserve [35].
- Patients with isolated fractures who become hypotensive should have additional workup to rule out additional sources of blood loss before attributing the hypotension to the femur fracture [35].
- Visual inspection of the limb should be performed circumferentially to note any open wounds, abrasions, bruising, or soft tissue defects [35].
- It is easy to overlook a subtle open fracture if the entire limb is not visualized [35].
- A small posterior or medial open wound should not be overlooked [35].
- If a small wound is noted, it should be considered open and managed as such until proven otherwise [35].
- The joints above and below the fracture should be examined to look for dislocations, ligamentous injuries, and associated noncontiguous fractures [35].
- An associated hip dislocation is important to identify [35].
- A thorough motor and sensory examination should be performed to rule out neurologic injury [35].
- Injury to the surrounding nerves (obturator, femoral, sciatic) is uncommon, especially in closed femoral shaft fractures, but does occur [35].
- A vascular examination is performed to rule out vessel injury [35].
- The ankle–brachial index (ABI) has a high sensitivity and specificity for major arterial injury if the value is less than 0.90 [35].
- Vascular injuries were identified in 1.6% of patients with closed femoral shaft fractures [35].

IMAGING

- Standard anteroposterior pelvic and cross-table lateral views of the hip are necessary for diagnosing femoral neck fractures [33].
- A traction internal rotation view is often helpful for diagnosing femoral neck fractures [33].

- The cross-table lateral view is probably essential in enabling prediction of failure with fixation in Garden I and II femoral neck fractures [33].
- The entire femur should be imaged [33].
- MRI has become the imaging study of choice to evaluate occult femoral neck fractures [33].
- CT scans can yield useful information including degree of comminution for femoral neck fractures [33].

Investigations

RADIOGRAPHY

- Conventional radiographs remain critical in the initial imaging evaluation of the hip and can be used to diagnose fractures [2].
- A complete hip series usually consists of an anterior-posterior (AP) pelvis, a centered AP hip, a lateral view (frog-leg, cross-table, Dunn 45° or 90°), and a false-profile (Lequesne) view [2].
- Radiographs remain integral to the assessment of fractures and can be supplemented with CT to further investigate suspected occult fractures, define fracture morphology, and assist in preoperative planning [2].
- Radiographs can serially assess hardware positioning and evaluate symptomatic hardware related to open reduction and internal fixation and total hip arthroplasty [2].
- Plain radiographs are the first imaging studies obtained for patients presenting with hip pain and can determine the presence of fractures, degenerative changes, and abnormal joint morphology [27].
- Standard AP radiographs of the hip and pelvis are obtained to examine bony architecture, check for evidence of joint space narrowing or changes to bone quality, and quantify femoral head coverage [27].
- The Dunn view and frog leg view are appropriate to measure the alpha angle to determine the presence of impingement [27].
- Some studies have shown that radiographs, in particular the Dunn 45° view, may be more accurate for determining the alpha angle measurement than CT or MRI [2].
- For young adult femoral neck fractures, plain radiographs include AP and lateral views of the hip [24].
- For young adult femoral neck fractures, CT is performed to evaluate for associated acetabular and/or femoral head fracture and loose bodies in the joint [24].

COMPUTED TOMOGRAPHY

- CT overcomes the limitations of radiography by providing three-dimensional assessment of bony morphology and, to some degree, assessment of soft-tissue abnormalities [12].
- CT is helpful in fracture evaluation, particularly in the setting of negative radiographs, or for further defining fracture morphology in patients requiring surgical reduction [12].
- CT scans are effective for examining cortical and cancellous bone and can be used to create three-dimensional reconstructions of the hip for use in surgical planning [27].

- Measurements of femoral head coverage and acetabular and femoral impingement can also be performed reliably using CT images [27].
- Low-dose CT with three-dimensional reformats is particularly useful in surgical planning of complex or borderline deformities [3].

MAGNETIC RESONANCE IMAGING

- MRI is the modality of choice for patients suspected of soft tissue or intra-articular pathology, given its superior sensitivity and specificity [27].
- Conventional MRI is effective at identifying osteochondral injuries, musculotendinous pathologies, and inflammation [27].
- Magnetic resonance arthrography (MRA) is more appropriate to determine injuries to the labrochondral structures and the ligamentum teres and identify the presence of loose bodies and synovial chondromatosis [27].
- In the accurate detection and staging of articular cartilage lesions, the utility of MRA is reduced, with sensitivity reported to be less than 50% compared with arthroscopic findings [27].
- Recent advances in MRI imaging techniques, such as delayed gadolinium-enhanced MR imaging and T2* mapping, allow for a more in-depth analysis of the structure of articular cartilage [27].
- MRI is useful for the assessment of developmental dysplasia of the hip (DDH) and femoroacetabular impingement (FAI), as well as extra-articular pathologies, stress injuries of bone, and hip arthroplasties [30].
- Noncontrast MRI at 3T is generally adequate for diagnosing intra-articular pathology [30].
- If 3T imaging is unavailable, MRA can be considered at 1.5T for increased diagnostic accuracy [30].
- MRI is helpful in identifying femoral neck stress fracture in athletes and predicting patients that may require surgical intervention [30].
- MRI is helpful in assessing complications of conventional and resurfacing hip arthroplasties, particularly those with metal-on-metal bearing systems [30].
- Major findings that help predict histologic ALVAL scores include synovial thickening, synovitis, synovial volume, abductor disruption, and soft-tissue edema [30].
- For nondisplaced stress fractures of the femoral neck, MRI or bone scan is used to rule out occult fracture [24].
- MRI is more sensitive than bone scan if the injury is less than 24 hours old [24].
- A study showed that MRI diagnosed occult femoral neck fractures not found on 12% of thin cut CT scans [5].

ULTRASONOGRAPHY

- Ultrasonography provides real-time dynamic assessment of the hip and is useful in diagnosing soft-tissue abnormalities about the hip joint, and to a lesser degree, within the hip joint itself [12].
- Ultrasonography is particularly useful in providing real-time guidance during diagnostic and therapeutic procedures [12].

- Ultrasonography can be an effective modality to identify musculotendinous disruptions, effusions associated with intra-articular pathology, or inflammatory conditions, such as bursitis [27].
- Ultrasonography is being increasingly used for targeted injections into muscles, tendons, or intra-articularly around the hip, for use with corticosteroids or biologic treatments [27].
- Although ultrasonography is a valuable tool to examine pediatric hip conditions, its utility in evaluating the adult hip is limited [27].
- Ultrasonography allows bedside evaluation of the hip and can be used to guide interventions in the office setting [30].
- Ultrasonography cannot image inside bone because bone cortex reflects almost all sound waves [31].
- Internal joint structures are not well visualized unless they are in a superficial location [31].
- Image quality and interpretation depend on the experience of the ultrasonography technician and the radiologist [31].

GENERAL PRINCIPLES

- A thorough understanding of normal anatomy and biomechanics is necessary to identify pathology and determine the appropriate course of treatment [1].
- Because many hip conditions present with similar symptoms, a comprehensive clinical examination is required to determine a differential diagnosis [1].
- Findings from imaging studies should complement clinical examination findings to provide the most accurate diagnosis [1].
- A thorough history is essential to differentiating between common causes of hip pain [1].
- Clinical examination tests and imaging findings should be used to confirm a suspected clinical diagnosis [1].

Treatment

OPERATIVE MANAGEMENT

- Fracture management for femoral neck fractures in younger patients has evolved to improve implant mechanics and biology [4].
- Few biomechanical methods have been developed that appear to have improved outcomes for femoral neck fractures in young adults [4].
- New implants and ideas on implant application are imminent for the treatment of femoral neck fractures in young adults [4].
- Quality reduction and stable fixation are vital elements in managing at-risk femoral neck fractures [4].
- Preoperative planning is critical to minimize risks for treatment failure in vertical femoral neck fractures [4].
- Proximal femoral fractures are treated operatively unless the patient's medical condition means that surgery is contraindicated [36].

NON-OPERATIVE MANAGEMENT

- Nonoperative management of undisplaced intracapsular femoral neck fractures is associated with a higher prevalence of nonunion, avascular necrosis, and fracture displacement compared to operative treatment [36].
- Nonoperative management of proximal femoral fractures is associated with a higher mortality rate [36].
- Nonoperative management confines elderly patients, often with significant medical comorbidities, to bed for 4 to 6 weeks [36].
- Greater trochanter fractures with little or no displacement may be treated nonoperatively [36].
- Lesser trochanter fractures may be treated nonoperatively [36].
- In older patients, lesser trochanter fractures should be assumed to be metastatic fractures until proven otherwise [36].
- A rare stress fracture of the proximal femur may be treated nonoperatively [36].

OUTCOMES AND COMPLICATIONS

- Treatment failure after femoral neck fractures includes nonunion, failed fixation, osteonecrosis, and malunion [4].
- Substantial efforts have recently been made to improve mechanical testing models to better reflect in vivo findings for femoral neck fractures [4].
- Substantial efforts have recently been made to assemble large, multicenter clinical studies to evaluate patient treatment and outcomes for femoral neck fractures [4].

References

- [1] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Anatomy and Biomechanics, Evaluation, Clinical Examination, and Imaging of the Hip > Summary.
- [2] Orthopaedic Knowledge Update Sports Medicine 6. Imaging of the Hip > Radiography.
- [3] Aaos Comprehensive Orthopaedic Review 3. Nonarthroplasty Surgical Treatment of the Hip > I. Femoroacetabular Impingement.
- [4] Orthopaedic Knowledge Update Trauma. Femoral Neck Fractures in the Younger Patient > Summary.
- [5] Orthopaedic Knowledge Update Trauma. Femoral Neck Fractures in the Geriatric Population > Annotated References.
- [7] Miller S Review Of Orthopaedics. Genetics of musculoskeletal conditions and abnormalities are summarized in Table 1.27 > 2. Arthrology > Hip (Fig. 2.49).
- [10] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Anatomy and Biomechanics, Evaluation, Clinical Examination, and Imaging of the Hip > Osseous and Ligamentous Anatomy.

- [11] Aaos Comprehensive Orthopaedic Review 3. Surgical Anatomy of the Hip > IV. Hip Capsule and Ligaments.
- [12] Orthopaedic Knowledge Update Sports Medicine 6. Imaging of the Hip > Introduction.
- [16] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > LOWER EXTREMITY.
- [20] Aaos Comprehensive Orthopaedic Review 3. Fractures of the Hip > I. General Considerations.
- [23] Aaos Comprehensive Orthopaedic Review 3. Surgical Anatomy of the Hip > VI. Neurovascular Structures Surrounding the Hip.
- [24] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > YOUNG ADULT PROXIMAL FEMUR INJURIES.
- [27] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Anatomy and Biomechanics, Evaluation, Clinical Examination, and Imaging of the Hip > Imaging.
- [30] Orthopaedic Knowledge Update Sports Medicine 6. Imaging of the Hip > Summary.
- [31] Aaos Comprehensive Orthopaedic Review 3. Musculoskeletal Imaging^{*} > IV. Ultrasonography.
- [33] Campbell S Operative Orthopaedics 4 Volume Set. OPEN REDUCTION AND INTERNAL FIXATION OF BICONDYLAR INJURIES > DIAGNOSIS.
- [35] Rockwood And Green S Fractures In Adults. 51: Hip Dislocations and Femoral Head Fractures > *Signs and Symptoms of Femoral Shaft Fractures*.
- [36] Rockwood And Green S Fractures In Adults. 9: Principles of Nonoperative Management of Fractures > Proximal Femoral Fractures.