

Adverse reaction to metal debris

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 [8].
- The hemipelvis comprises three bones: the ilium, ischium, and pubis, which unite at the triradiate cartilage within the concave acetabulum [8].
- The shape and depth of the acetabulum are formed by the appearance of ossification centers around the end of the first decade of life, with complete fusion occurring around 18 to 19 years of age [8].
- The ilium is a large flat bone that forms the majority of the coxal bone [8].
- The iliac crest terminates anteriorly at the anterior superior iliac spine (ASIS) and posteriorly at the posterior superior iliac spine (PSIS) [8].
- The anterior and posterior inferior iliac spines (AIIS and PIIS) are located inferior to the ASIS and PSIS [8].
- The greater sciatic notch is located directly below the PIIS and serves as the passage for the large sciatic nerve to exit the pelvis [8].
- The ischium is a small L-shaped bone that forms the posteroinferior margin of the pelvis [8].
- The ischial tuberosity is a thickened portion of the ischial body that serves as a large attachment site for multiple muscle groups [8].
- The pubis bone consists of a body and two rami that connect superiorly to the ilium and inferiorly to the ischium to form the obturator foramen [8].
- The obturator foramen is covered by a strong membrane that provides surface area for muscle attachments [8].
- The hemipelvises unite anteriorly at the pubic symphyses and articulate posteriorly with the sacral ala to form the sacroiliac (SI) joint [8].
- 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 [8].

- The acetabulum is incomplete inferiorly, forming a notch through which vital blood vessels and nerves pass to supply the joint [8].
- The femoral head forms two-thirds of a sphere, with a small depression at its center from which the ligamentum teres extends [8].
- The neck-shaft angle of the femur averages 125° [8].
- Normal version, defined as the head-neck angle in the frontal plane, averages 15 to 20° [8].
- The acetabulum is normally anteverted 15 degrees and obliquely oriented in the coronal plane 45 degrees caudally [14].
- The posterosuperior articular surface of the acetabulum is thickened to accommodate weight bearing [14].
- The inferior surface of the acetabulum contains the acetabular (cotyloid) notch, which is bound by the transverse acetabular ligament [14].
- The femoral neck is normally anteverted approximately 14 degrees in relation to the femoral condyles, with a range of 1–40 degrees [14].
- The femoral neck-shaft angle averages 127 degrees, beginning at 141 degrees in the fetus [14].
- The femoral head ossification center appears between the fourth and seventh months of postnatal life and grows until physal closure during late adolescence [11].
- Three acetabular epiphyseal centers develop as the child matures: the os acetabulum (appears ~8 years), the acetabular epiphysis (ossifies ~8 years, fuses ~18 years), and a posterior ischial epiphysis (develops ~9 years, fuses ~17 years) [11].
- The majority of acetabular shape development is determined by approximately 8 years of age [11].

SOFT TISSUE ANATOMY

- 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 [8].
- 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 [8].
- 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 [8].
- The labrum is highly innervated, with the presence of both mechanoreceptors and nociceptors [8].
- The labrum is absent in the area of the inferior acetabular notch, where the transverse acetabular ligament serves as its continuation [8].
- The hip is surrounded by a dense fibrous capsule extending from the periphery of the acetabulum to the intertrochanteric line of the femoral neck [8].
- The capsule enhances joint stability by preventing translation of the femoral head in the acetabulum [8].
- The iliofemoral ligament is Y-shaped, thickest, and strongest of the three main hip ligaments [8].

- 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 [8].
- The iliofemoral ligament functions to limit external rotation, while its lateral arm limits extension of the joint [8].
- The ischiofemoral ligament extends from the ischial margin of the acetabulum to the greater trochanter of the femur, providing posterior support and restricting internal rotation motion [8].
- The pubofemoral ligament extends from the obturator crest of the pubic bone to the femoral neck and acts to limit abduction of the joint [8].
- Deep fibers from all three main hip ligaments merge to form the zona orbicularis, which circumvents the femoral neck [8].
- The hip capsule attaches anteriorly and posteriorly along the periphery of the acetabulum outside the labrum, and inferiorly to the acetabular labrum [9].
- The capsule attaches to the femur anteriorly along the intertrochanteric crest, but only partially on the posterior side, leaving the basicervical region of the femoral neck and intertrochanteric region extracapsular [9].
- The iliofemoral ligament becomes taut in full extension, preventing anterior dislocation and hyperextension of the hip [9].
- The twisted orientation of the hip ligaments provides a screw mechanism for the hip in full extension [9].
- The ligamentum teres originates in the cotyloid fossa and attaches on the fovea of the femoral head [9].
- The sacrospinous and sacrotuberous ligaments create the boundaries of the greater and lesser sciatic foramina [9].
- The piriformis muscle and the sciatic nerve exit from the greater sciatic foramen [9].
- The short external rotator muscles exit from the lesser sciatic foramen [9].
- The hip joint capsule extends anteriorly to the intertrochanteric crest but posteriorly only partially across the femoral neck [5].
- The iliofemoral ligament (Y ligament of Bigelow) is the strongest ligament in the body and attaches the AIIS to the intertrochanteric line in an inverted Y manner [5].
- The capsule is tight in extension and internal rotation, and relaxed in flexion and external rotation [5].
- The ligamentum teres transmits an arterial branch of the posterior division of the obturator artery to the femoral head, which is less significant in adults [5].

NEUROVASCULAR ANATOMY

- The medial femoral circumflex artery is the main blood supply to the femoral head in adults [18].
- The lateral femoral circumflex artery gives rise to the anterior aspect of the extracapsular arterial ring [18].
- The superior and inferior gluteal arteries contribute branches to the extracapsular arterial ring [18].

- The ascending cervical arteries originate from the extracapsular arterial ring and are divided into lateral, medial, posterior, and anterior groups [18].
- The lateral group of ascending branches is the main blood supply to the femoral head [18].
- The lateral epiphyseal artery penetrates the femoral head and is believed to be the dominant blood supply to the femoral head from the ascending branch system [18].
- Fractures that disrupt the ascending blood flow to the lateral epiphyseal vessel have an increased risk of osteonecrosis [18].
- 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 [18].
- 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 [21].
- From age 4 years to adulthood, the posterosuperior and posteroinferior retinacular arteries (from the medial circumflex artery) are the major blood supply [21].
- In adulthood, the major blood supply to the femoral head is from the medial femoral circumflex and lateral epiphyseal arteries [21].
- The common femoral artery arises from the external iliac artery as it passes underneath the inguinal ligament [21].
- The common femoral artery passes anterior and medial to the hip capsule [21].
- The common femoral vessels are the most commonly reported extrapelvic vascular structures injured during total hip arthroplasty [21].
- The most common mechanism of injury to the common femoral vessels is errant retractor placement anterior to the acetabulum [21].
- The profundus or deep femoral artery arises from the lateral aspect of the common femoral artery approximately 3.5 cm below the inguinal ligament [21].
- The lateral circumflex artery arises from the lateral side of the proximal profundus femoris artery [21].
- The medial circumflex artery most commonly comes from the posteromedial profundus femoris artery and traverses between the pectineus and psoas muscles [21].
- The superior gluteal vessels are branches of the posterior division of the internal iliac artery and exit from the sciatic notch [21].
- The inferior gluteal vessels are branches of the anterior division of the internal iliac artery and exit the pelvis between the piriformis and coccygeus muscles [21].
- The superior gluteal nerve and artery exit the pelvis above the piriformis muscle [16].
- The pudendal nerve, internal pudendal artery, nerve to the obturator internus, posterior femoral cutaneous nerve, sciatic nerve, inferior gluteal nerve, inferior gluteal artery, and nerve to the quadratus femoris exit the pelvis below the piriformis [16].
- In 10% of cases, the common peroneal component of the sciatic nerve can pass through the division in the piriformis [16].

- The sciatic nerve most often passes below the piriformis and is situated on top of the short external rotators [16].

MUSCULAR ANATOMY

- The average range of motion of a normal hip is approximately 120° of flexion, 30° of extension, 45° of abduction, 20° to 30° of adduction, 35° of internal rotation, and 45° of external rotation [16].
- Normal gait function requires hip flexion of 30°, hyperextension of 10°, abduction and adduction of 5°, and internal and external rotation of 5° [16].
- The primary hip flexor muscles are the iliopsoas, rectus femoris, and sartorius [16].
- The iliopsoas muscle has origins along the iliac crest, iliac fossa, sacral ala, iliolumbar ligaments, sacroiliac ligaments, T12-L4 vertebral bodies, L1-L5 transverse processes, and intervertebral disks [16].
- The rectus femoris crosses the hip and knee joints; its straight head originates from the AIIS and its reflected head from the supra-acetabular tubercle [16].
- The sartorius muscle originates on the ASIS, crosses the hip and knee joints, and inserts on the medial aspect of the tibia and pes anserine complex [16].
- The tensor fasciae latae muscle originates laterally on the anterolateral edge of the iliac crest and acts to flex, abduct, and rotate the hip [16].
- The gluteus maximus and hamstring muscles are the most important hip joint extensors [16].
- The gluteus maximus originates from the sacrum, coccyx, and sacrotuberous ligaments [16].
- The hamstring muscles originate on the ischial tuberosity [16].
- The abductors of the hip are predominantly the gluteus medius and minimus muscles [16].
- The gluteus medius has three components: anterior, middle, and posterior [16].
- The gluteus medius and minimus function together to maintain and abduct the femur during the stance phase of gait [16].
- The adductor muscles of the hip include the adductor brevis, adductor longus, adductor magnus, pectineus, and gracilis [16].
- The external rotators of the hip include the obturator internus and externus, superior and inferior gemelli, quadratus femoris, and piriformis muscles [16].
- The obturator internus muscle originates from the inner component of the obturator foramen and emerges through the lesser sciatic foramen [16].
- The piriformis muscle originates from the greater sciatic foramen and inserts onto the greater trochanter [16].
- The most consistent internal rotators of the hip joint are the gluteus medius and tensor fascia latae muscles [16].

PATHOPHYSIOLOGY OF DEVELOPMENTAL DYSPLASIA

- Developmental dysplasia of the hip (DDH) is a malformation of anatomic structures that have developed normally during the embryologic period [13].
- In unstable hips, the posterosuperior rim of the acetabulum loses its sharp margin and becomes flattened and thickened in the area over which the femoral head slides [13].
- A ridge of thickened articular cartilage called the neolimbus arises along the posterosuperior acetabular wall as the head rides in and out of the socket [13].
- In dislocated hips, the fatty tissue known as the pulvinar thickens in the depths of the acetabulum and may impede reduction [13].
- The ligamentum teres elongates and thickens in dislocated hips, taking up valuable space within the acetabulum [13].
- The transverse acetabular ligament is often hypertrophic in dislocated hips and may impede reduction [13].
- The inferior capsule of the hip assumes an hourglass shape in dislocated hips, presenting an opening smaller in diameter than the femoral head [13].
- The iliopsoas tendon is pulled tight across the capsular isthmus, contributing to narrowing and acting as a barrier to closed reduction [13].
- Excessive pressure on the cartilaginous upper femur can cause a loss of vascular perfusion, resulting in necrosis of chondrocytes [11].
- Trochanteric overgrowth in conditions like Perthes disease is actually normal trochanteric growth in the presence of upper femoral undergrowth [11].
- Excessive adductor pull or inadequate abductor muscle function results in a valgus deformity of the upper femur [11].

PATHOPHYSIOLOGY OF FEMOROACETABULAR IMPINGEMENT

- Femoroacetabular impingement (FAI) is recognized as a common cause of hip dysfunction and secondary osteoarthritis [3].
- In FAI, distinct structural abnormalities produce repetitive impingement between the acetabulum and the femoral head-neck junction [3].
- Cam impingement involves femoral-based abnormalities such as an aspherical femoral head, reduced head-neck offset, or femoral retroversion, resulting in repetitive abutment of the acetabular rim and femoral head-neck junction [3].
- Pincer impingement involves acetabular-based disorders such as acetabular retroversion, global overcoverage, or acetabular protrusio, creating abnormal abutment of the acetabular rim and femoral head-neck junction [3].
- Impingement abnormalities can cause labral tears, degeneration, or ossification [3].
- Impingement abnormalities can cause acetabular cartilage delamination [3].
- Impingement abnormalities can cause secondary osteoarthritis [3].

- Patients with symptomatic FAI frequently present with activity-related groin pain exacerbated by hip flexion activities [3].
- Patients with FAI exhibit restricted hip internal rotation in 90° of flexion [3].
- The impingement test (flexion, adduction, internal rotation) elicits pain in patients with FAI, though the test is not specific for the condition [3].

Investigations

GENERAL PRINCIPLES

- A thorough understanding of normal anatomy and biomechanics is necessary to identify pathology and determine the appropriate course of treatment for hip conditions [1].
- A comprehensive clinical examination is required to determine a differential diagnosis because many hip conditions present with similar symptoms [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].

RADIOGRAPHY

- Conventional radiographs remain critical in the initial imaging evaluation of the hip [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].
- The AP pelvis view is used to assess acetabular anatomy, including version, acetabular coverage, and femoral head sphericity [3].
- Various lateral views, most commonly the 45° Dunn view and frog-leg lateral, can be used to assess femoral head sphericity and head-neck offset [3].
- The Dunn 45° view may be more accurate for determining the alpha angle measurement than CT or MRI [2].
- Radiographs can serially assess hardware positioning and evaluate symptomatic hardware related to open reduction and internal fixation and total hip arthroplasty [2].
- 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 [25].

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 [25].
- Conventional MRI is effective at identifying osteochondral injuries, musculotendinous pathologies, and inflammation [25].

- 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 [25].
- The utility of MRA in the accurate detection and staging of articular cartilage lesions is reduced, with sensitivity reported to be less than 50% compared with arthroscopic findings [25].
- 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 [25].
- MRI is helpful in assessing complications of conventional and resurfacing hip arthroplasties, particularly those with metal-on-metal bearing systems [28].
- Major MRI findings that help predict histologic ALVAL scores include synovial thickening, synovitis, synovial volume, abductor disruption, and soft-tissue edema [28].
- Noncontrast MRI at 3T is generally adequate for diagnosing intra-articular pathology [28].
- If 3T imaging is unavailable, MRA can be considered at 1.5T for increased diagnostic accuracy [28].
- MRI is helpful in identifying femoral neck stress fracture in athletes and predicting patients that may require surgical intervention [28].

COMPUTED TOMOGRAPHY

- 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 [25].
- Measurements of femoral head coverage and acetabular and femoral impingement can also be performed reliably using CT images [25].
- CT overcomes the limitations of radiography by providing three-dimensional assessment of bony morphology and, to some degree, assessment of soft-tissue abnormalities [10].
- Combined with arthrography, CT can evaluate chondrolabral abnormalities, specifically in patients with contraindications to MRI [10].
- CT is helpful in fracture evaluation, particularly in the setting of negative radiographs, or for further defining fracture morphology in patients requiring surgical reduction [10].
- Low-dose CT with three-dimensional reformats is particularly useful in surgical planning of complex or borderline deformities [3].

ULTRASONOGRAPHY

- Ultrasonography provides real-time dynamic assessment of the hip and is useful in diagnosing soft-tissue abnormalities about the hip joint [10].
- Ultrasonography is particularly useful in providing real-time guidance during diagnostic and therapeutic procedures [10].
- Although ultrasonography is a valuable tool to examine pediatric hip conditions, its utility in evaluating the adult hip is limited [25].

- Ultrasonography can be an effective modality to identify musculotendinous disruptions, effusions associated with intra-articular pathology, or inflammatory conditions, such as bursitis [25].
- Ultrasonography is being increasingly used for targeted injections into muscles, tendons, or intra-articularly around the hip [25].
- Ultrasonography cannot image inside bone because bone cortex reflects almost all sound waves [29].
- Internal joint structures are not well visualized unless they are in a superficial location [29].

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