

# Revision hip replacement

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## Anatomy & Pathophysiology

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### OSSEOUS 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 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 to connect to the acetabular notch [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 mean femoral neck-shaft angle in the adult is 130° ± 7° [18].
- The mean anteversion of the femoral neck is 10° ± 7° [18].
- The two prime trabecular groups of the proximal femur are the principal tensile group and the principal compressive group [18].

- The weakest area in the femoral neck is located in the Ward triangle [18].
- 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 [18].

## 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 the continuation of the labrum [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 and is the thickest and strongest of the three main ligaments supporting the hip [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 in isolation, the 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 support posteriorly 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 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 is attached to the femur anteriorly along the intertrochanteric crest, while on the posterior side it attaches only partially, leaving the basicervical region of the femoral neck and the intertrochanteric region of the femur not intracapsular [9].
- The iliofemoral ligament becomes taut in full extension, preventing anterior dislocation and hyperextension of the hip [9].

- The iliofemoral ligament may become very contracted in severe hip arthritis and may require release at surgery to relieve an internal and flexion contracture of the hip [9].
- The pubofemoral ligament attaches to the inferior and medial part of the capsule and may cause a hip adduction contracture [9].
- The ischiofemoral ligament reinforces the posterior capsule and provides a check to internal rotation 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 basicervical and intertrochanteric crest regions are extracapsular [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 ischiofemoral and pubofemoral ligaments are weaker but provide additional stability [5].
- The hip joint capsule is tight in extension and internal rotation, and relaxed in flexion and external rotation [5].
- The ligamentum teres arises from the apex of the cotyloid notch and attaches to the fovea of the femoral head [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

- 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 the age of 4 years to adulthood, the posterosuperior and posteroinferior retinacular arteries from the medial circumflex artery are the major blood supply to the femoral head [21].
- In adulthood, the major blood supply to the femoral head is from the medial femoral circumflex and lateral epiphyseal arteries [21].
- The medial femoral circumflex artery is the main blood supply to the femoral head and terminates in the posterior aspect of the extracapsular arterial ring [18].
- The lateral femoral circumflex artery gives rise to the anterior aspect of the extracapsular arterial ring [18].
- The superior and inferior gluteal arteries also 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 based on their anatomic relationship to the femoral neck [18].
- The lateral group of ascending branches is the main blood supply to the femoral head [18].
- 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 [18].
- The lateral epiphyseal artery penetrates the femoral head and is believed to be the dominant blood supply to the femoral head from this 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].
- 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 that are 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 but may also come directly from the femoral artery [21].
- The superior gluteal vessels are branches of the posterior division of the internal iliac artery and are closest to the hip as they exit from the sciatic notch [21].
- Superior gluteal artery injury can occur with the placement of screws in the region of the sciatic notch [21].
- The inferior gluteal vessels and internal vessels are branches of the anterior division of the internal iliac artery and exit the pelvis between the piriformis and coccygeus muscles [21].
- The inferior gluteal vessels can be injured by screws in the posterior column that are at least 5 mm past the bony margin [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 all 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].

- Most often, the sciatic nerve 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 muscles [16].
- The iliopsoas muscle has origins along the iliac crest, iliac fossa, sacra ala, iliolumbar ligaments, sacroiliac ligaments, bodies of T12 through L4 vertebrae, transverse processes of L1 through L5, 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].
- Excessive internal rotation of the hip for prolonged periods during surgery can cause injury to the sciatic nerve underneath the gluteus maximus tendon, resulting in sciatic nerve palsy [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 different components: anterior, middle, and posterior [16].
- The gluteus medius and minimus muscles function together to maintain and abduct the femur during the stance phase of gait [16].
- A Trendelenburg lurch is an attempt by the body to compensate for abductor weakness by bringing the center of gravity closer to the hip center, forcing the patient to lean toward the affected side [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 piriformis forms the reference structure for the posterior part of the hip, with structures identified by whether they originate above or below it [16].
- The most consistent internal rotators of the hip joint are the gluteus medius and tensor fascia latae muscles [16].

## **PATHOPHYSIOLOGY**

- Femoroacetabular impingement (FAI) is 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].
- Three types of FAI are recognized: cam, pincer, and combined cam/pincer [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, and 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, difficulty with prolonged sitting, walking, running, or pivoting, and an insidious onset or onset following minor trauma [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, but the test is not specific for FAI [3].
- DDH is a gradually progressive disorder associated with distinct anatomic changes, many of which are initially reversible [13].
- In unstable hips at birth, 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 hips that remain dislocated, 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, eventually presenting an opening smaller in diameter than the femoral head [13].
- The iliopsoas tendon is pulled tight across the capsular isthmus in dislocated hips, contributing to narrowing and acting as a barrier to closed reduction [13].
- The capsule narrows through a “Chinese finger-trap” mechanism in dislocated hips [13].
- Femoral changes in DDH include an increase in anteversion and some flattening of the femoral head as it lies against the ilium [13].
- Excessive pressure on the

## Investigations

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### CLINICAL EXAMINATION AND HISTORY

- A thorough history is essential for differentiating between common causes of hip pain [1].
- Clinical examination tests and imaging findings should be used to confirm a suspected clinical diagnosis [1].
- Patients with symptomatic femoroacetabular impingement (FAI) frequently present with activity-related groin pain exacerbated by hip flexion activities [3].
- Patients with symptomatic FAI may experience difficulty with prolonged sitting, walking, running, or pivoting [3].
- The onset of symptoms in FAI is often insidious or follows minor trauma [3].
- The impingement test (flexion, adduction, internal rotation) elicits pain in patients with FAI but is not specific for the condition [3].

### 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].
- Radiographs can be used to diagnose fractures, developmental dysplasia of the hip (DDH), femoroacetabular impingement (FAI), and osteoarthritis [2].
- Acetabular morphology is assessed on AP pelvis radiographs to evaluate overcoverage and undercoverage [2].
- The femoral head-neck junction morphology is often assessed using the alpha angle [2].
- Some studies indicate that radiographs, particularly the Dunn 45° view, may be more accurate for determining the alpha angle measurement than CT or MRI [2].
- The Tönnis angle is defined by the angle of the acetabular sourcil and a line parallel to the transverse pelvis axis, with values between 0° and 10° considered normal [2].

- The lateral center-edge angle of Wiberg is the angle between a line from the center of the femoral head perpendicular to the transverse pelvis axis and a second line from the center of the femoral head to the superolateral most point of the acetabulum [2].
- Center-edge angles of 20°–40° are considered normal, while angles from 20° to 25° are considered borderline [2].
- The femoral head extrusion index is defined by the length of the femoral head that lies beyond the acetabulum as a percentage of the total horizontal width of the femoral head, with values greater than 25% considered abnormal [2].
- Coxa profunda is diagnosed when the fossa line touches or is medial to the ilioischial line on an AP pelvis radiograph [2].
- The “crossover” sign on an AP pelvis radiograph indicates acetabular retroversion related to lateralization of the anterior acetabular wall relative to the posterior acetabular wall [2].
- Pelvic tilt or rotation may lead to false-positive and false-negative “crossover” signs on AP pelvis radiographs [2].
- For neutral pelvic tilt on an AP pelvis radiograph, the sacrococcygeal joint should be between 3 and 5 cm above the superior border of the symphysis pubis [2].
- Radiographs can serially assess hardware positioning and evaluate symptomatic hardware related to open reduction and internal fixation and total hip arthroplasty [2].
- Radiographs remain integral to the assessment of fractures and can be supplemented with CT to investigate suspected occult fractures, define fracture morphology, and assist in preoperative planning [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].
- 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].
- The Dunn view and frog leg view are appropriate to measure the  $\alpha$  angle to determine the presence of impingement [25].
- 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 [25].

## MAGNETIC RESONANCE IMAGING (MRI)

- MRI is the modality of choice for patients suspected of soft tissue or intra-articular pathology due to 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 than conventional MRI for determining injuries to the labrochondral structures and the ligamentum teres [25].

- MRA is used to 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 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].
- Delayed gadolinium-enhanced MR imaging and T2\* mapping were effective at detecting early changes to the articular cartilage surfaces of patients with hip dysplasia and femoroacetabular impingement [25].
- MRI provides information regarding the integrity of the acetabular labrum and articular cartilage [3].
- MRI can assess the anatomy of the proximal femur as well as the version of the acetabulum and femur [3].
- The sensitivity of MRI to acetabular rim chondral lesions is limited [3].
- 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].
- 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].
- MRI is useful for the assessment of developmental dysplasia of the hip (DDH) and femoroacetabular impingement (FAI) [28].
- MRI is useful for assessing extra-articular pathologies and stress injuries of bone [28].
- For nondisplaced stress fractures, MRI is more sensitive than bone scan if the injury is less than 24 hours old [22].
- MRI is used to rule out occult femoral neck fractures [22].
- A 93% rate of MRI abnormalities of the ipsilateral knee is associated with hip dislocations [22].

## COMPUTED TOMOGRAPHY (CT)

- CT overcomes the limitations of radiography by providing three-dimensional assessment of bony morphology [10].
- CT provides some assessment of soft-tissue abnormalities [10].
- Combined with arthrography, CT can evaluate chondrolabral abnormalities, specifically in patients with contraindications to MRI such as pacemakers [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].
- 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 be performed reliably using CT images [25].
- Low-dose CT with three-dimensional reformats is particularly useful in surgical planning of complex or borderline deformities [3].
- The multiplanar and 3D capabilities of CT make it an invaluable tool for assessing bone morphology, though at higher cost and radiation dose [28].
- 3D volume renderings are useful to aid in preoperative planning in FAI and subspine impingement [28].
- CT is performed after reduction of hip dislocations to evaluate for associated acetabular and/or femoral head fracture and loose bodies in the joint [22].
- CT is used to evaluate the location and size of femoral head fracture fragments and rule out associated acetabular fracture [22].

## ULTRASONOGRAPHY

- Ultrasonography provides real-time dynamic assessment of the hip [10].
- Ultrasonography is useful in diagnosing soft-tissue abnormalities about the hip joint and, to a lesser degree, within the hip joint itself [10].
- Ultrasonography is particularly useful in providing real-time guidance during diagnostic and therapeutic procedures [10].
- Ultrasonography can be used at the time of clinical evaluation and provides real-time guidance during therapeutic and diagnostic procedures in the office setting [28].
- 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 increasingly used for targeted injections into muscles, tendons, or intra-articularly around the hip for corticosteroids or biologic treatments [25].
- Ultrasonography cannot image inside bone because bone cortex reflects almost all sound waves [29].
- Internal joint structures are not well visualized by ultrasonography unless they are in a superficial location [29].
- Ultrasonography provides dynamic assessment of structures such as tendon and nerve subluxation [29].
- Ultrasonography can be used to guide targeted therapy, such as injections and ablations [29].
- Image quality and interpretation of ultrasonography depend on the experience of the ultrasonography technician and the radiologist [29].

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