

Periprosthetic joint infection (hip)

Overview

- The risk of infection is lower with internal fixation than with arthroplasty [4].
- In comparative studies, infection rates following internal fixation range from 0% to 10% [4].
- In comparative studies, arthroplasty infection rates range from 0% to 18% [4].
- A recent series of over 3,000 intracapsular hip fractures recorded a deep infection rate of 1.26% for hemiarthroplasty [4].
- A recent series of over 3,000 intracapsular hip fractures recorded a deep infection rate of 0.18% after fixation [4].
- Other large modern series have reported infection rates of 5% to 6% after fixation [4].
- Infection following internal fixation usually has less serious consequences than deep infection following arthroplasty [4].
- Removal of implants after fracture healing may be all that is required for infection following internal fixation [4].
- Deep infection after arthroplasty is a difficult management problem, particularly in elderly frail patients [4].
- Excision arthroplasty to control infection is generally associated with very poor postoperative mobility [4].
- Older patients are usually wheelchair bound after excision arthroplasty [4].
- Immediate exchange arthroplasty has eradication of infection in 85% of cases after arthroplasty for osteoarthritis [4].
- Debridement and implant retention for management of infection after THA has success rates between 65% and 75% [4].
- De Toro reported a 44% success rate for debridement and implant retention in hemiarthroplasty deep infections [4].
- Guren et al. reported an infection eradication success rate of 15/35 (43%) for debridement and implant retention in hemiarthroplasty deep infections [4].
- Debridement and implant retention is worth considering if the infection is caused by a single antibiotic-sensitive organism [4].

- Nonoperative management with low-dose antibiotic therapy is an option for frail patients with organisms sensitive to common antibiotics [4].
- Carriage of methicillin-resistant *Staphylococcus aureus* is high in the hip fracture population [4].
- Methicillin-resistant *Staphylococcus aureus* is a common cause of deep infection in hip fracture cases [4].
- Single-stage exchange arthroplasty can be considered for fitter patients with a sensitive organism [4].
- Lora-Tamayo et al. reported a success rate of 63% for single-stage exchange arthroplasty in hemiarthroplasty deep infections [4].
- Excision arthroplasty and reimplantation when infection is under control is preferred for patients with a resistant organism or multiple infecting organisms [4].
- Infection is generally associated with a poor outcome in the hip fracture population [4].
- 1-year mortality rates of 40% to 50% have been reported in patients with prosthetic joint infection following hemiarthroplasty [4].

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 [9].
- The hemipelvis comprises three bones: the ilium, ischium, and pubis, which unite at the triradiate cartilage within the concave acetabulum [9].
- 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 [9].
- The acetabulum is incomplete inferiorly, forming a notch through which vital blood vessels and nerves pass to supply the joint [9].
- 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 [9].
- The neck-shaft angle of the femur averages 125° [9].
- Normal version, defined as the head-neck angle in the frontal plane, averages 15 to 20° [9].
- The mean femoral neck-shaft angle in the adult is 130° ± 7° [15].
- The mean anteversion of the femoral neck is 10° ± 7° [15].
- The two prime trabecular groups of the proximal femur are the principal tensile group and the principal compressive group [15].
- The weakest area in the femoral neck is located in the Ward triangle [15].
- 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 [15].

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 [9].
- 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 [9].
- 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 [9].
- The labrum is highly innervated, with the presence of both mechanoreceptors and nociceptors [9].
- The labrum is absent in the area of the inferior acetabular notch, where the transverse acetabular ligament serves as the continuation of the labrum [9].
- The hip is surrounded by a dense fibrous capsule extending from the periphery of the acetabulum to the intertrochanteric line of the femoral neck [9].
- The capsule enhances joint stability by preventing translation of the femoral head in the acetabulum [9].
- The iliofemoral ligament is Y-shaped, thickest, and strongest of the three main ligaments supporting the hip [9].
- The iliofemoral ligament functions to limit external rotation, while its lateral arm limits extension of the joint [9].
- The ischiofemoral ligament extends from the ischial margin of the acetabulum to the greater trochanter and restricts internal rotation motion [9].
- The pubofemoral ligament extends from the obturator crest of the pubic bone to the femoral neck and acts to limit abduction of the joint [9].
- Deep fibers from the iliofemoral, ischiofemoral, and pubofemoral ligaments merge to form the zona orbicularis, which circumvents the femoral neck [9].
- The hip capsule attaches anteriorly and posteriorly along the periphery of the acetabulum outside the labrum [10].
- The hip capsule is attached to the femur anteriorly along the intertrochanteric crest, but on the posterior side it attaches only partially, leaving the basicervical region of the femoral neck and intertrochanteric region extracapsular [10].
- The iliofemoral ligament becomes taut in full extension, preventing anterior dislocation and hyperextension of the hip [10].
- The twisted orientation of the hip ligaments provides a screw mechanism for the hip in full extension [10].
- The ligamentum teres originates in the cotyloid fossa and attaches on the fovea of the femoral head [10].

VASCULAR ANATOMY

- In adulthood, the major blood supply to the femoral head is from the medial femoral circumflex and lateral epiphyseal arteries [18].
- 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 [15].

- The lateral femoral circumflex artery gives rise to the anterior aspect of the extracapsular arterial ring [15].
- The ascending cervical arteries originate from the extracapsular arterial ring and are divided into four distinct groups: lateral, medial, posterior, and anterior [15].
- The lateral group of ascending branches is the main blood supply to the femoral head [15].
- The lateral epiphyseal artery penetrates the femoral head and is believed to be the dominant blood supply to the femoral head from this system [15].
- Fractures that disrupt the ascending blood flow to the lateral epiphyseal vessel have an increased risk of osteonecrosis [15].
- 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 [15].
- The common femoral vessels are the most commonly reported extrapelvic vascular structures that are injured during total hip arthroplasty [18].
- The most common mechanism for injury to the common femoral vessels during total hip arthroplasty is errant retractor placement anterior to the acetabulum [18].

MUSCULAR ANATOMY

- The primary hip flexor muscles are the iliopsoas, rectus femoris, and sartorius muscles [13].
- The gluteus maximus and hamstring muscles are the most important hip joint extensors [13].
- The abductors of the hip are predominantly the gluteus medius and minimus muscles [13].
- The gluteus medius and minimus muscles function together to maintain and abduct the femur during the stance phase of gait [13].
- The external rotators of the hip include the obturator internus and externus, superior and inferior gemelli, quadratus femoris, and piriformis muscles [13].
- The piriformis forms the reference structure for the posterior part of the hip, with structures identified by whether they originate above or below it [13].
- The superior gluteal nerve and artery exit the pelvis above the piriformis muscle [13].
- The sciatic nerve, inferior gluteal nerve, and inferior gluteal artery exit the pelvis below the piriformis muscle [13].
- In 10% of cases, the common peroneal component of the sciatic nerve can pass through the division in the piriformis [13].
- The most consistent internal rotators of the hip joint are the gluteus medius and tensor fascia latae muscles [13].

PATHOPHYSIOLOGY

- 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].
- 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 and reduced head-neck offset, 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].
- Hip microinstability refers to the femoral head micromotion within the acetabulum, which is a prolonged phenomenon that leads to cartilage damage and eventually osteoarthritis of the hip [19].
- The hip joint is relatively stable due to ball and socket bony anatomy and soft-tissue constraints such as the labrum, capsule, and ligamentum teres [19].
- Acetabular hip dysplasia can contribute to hip instability because of a shallow acetabular component [19].
- Periprosthetic joint infection (PJI) risk is higher for patients with multiple surgical procedures [5].
- PJI risk is higher with uncontrolled diabetes, morbid obesity, inflammatory arthritis, malnutrition, smoking, and chronic immunosuppression [5].
- Longer index procedure surgical time increases the risk for operative field contamination [5].
- Allogeneic transfusion may independently increase periprosthetic infection [5].
- Periprosthetic osteolysis is a macrophage-initiated biologic response to submicron polyethylene wear debris [5].
- Linear pattern osteolysis occurs in cemented and mechanically unstable components where debris accesses the implant bone interface through the effective joint space [5].
- Focal pattern osteolysis involves expansile osteolytic lesions that develop by accessing through areas where implant fixation is incomplete [5].
- Mechanical instability involves progressive loosening of initially well-fixed cemented components or progressive instability of stable fibrous noncemented implants [5].
- For noncemented components, initial implant stability is essential for osseointegration, and component subsidence is most commonly associated with failure to obtain adequate implant stability [5].
- A minimum of 35% ingrowth is required for acetabular fixation in noncemented components [5].
- Trunnionosis involves fretting and crevice corrosion that may occur in 2% or more femoral stem modular interfaces [5].
- Diagnosis of trunnionosis is made based on serum cobalt level > 1 ppb and cobalt ions >>> chromium ions [5].

- Trunnionosis should be considered as a potential cause of pain in symptomatic hips with increasing femoral head diameter (≥ 32 mm), cobalt-chromium heads coupled with titanium stems, flexible titanium stems, or cobalt-chromium modular necks [5].
- Adverse reaction to metal debris (ARMD) is a biologic reaction to metal wear products that is T cell mediated [5].
- ARMD can result in synovitis, acute lymphocyte vasculitis-associated lesions, and pseudotumor formation [5].
- Factors associated with increased metal particle generation include acetabular implant malposition, reduced or excessive clearance between the head and acetabulum, corrosion at modular junctions, smaller femoral head size (<46 mm) in hip resurfacing, and female sex [5].
- Increased femoral head size (>36 mm) has been associated with a clinical substantial reduction in dislocation rates [5].
- Increased femoral head size (>36 mm) has been associated with an increased incidence of groin pain [5].
- Increased femoral head size (>36 mm) has been associated with higher polyethylene wear rates among younger and more active patients [5].
- Increased femoral head size (>36 mm) has been associated with corrosion and loosening of the head-neck junction [5].
- Mechanical noise from hip implants has an incidence between 0.2% and 17.0% [5].
- Audible noise from hip implants has not been associated with implant failure or revision [5].
- Decreased femoral offset and inadequate leg length restoration can result in femoral neck impingement against the pelvis or acetabular implant [5].
- Decreased femoral offset and inadequate leg length restoration can result in decreased abductor mechanism efficiency due to a reduced moment arm [5].
- High abduction combined with high anteversion results in anterior instability with hip extension [5].
- Low abduction combined with low anteversion results in posterior instability with hip flexion [5].
- Female sex is associated with an increased dislocation rate [5].
- Osteonecrosis and femoral neck fractures are associated with an increased dislocation rate [5].
- Spinal fusion or limited lumbar spine mobility increases dislocation risk [5].
- Revision total hip arthroplasty carries an increased dislocation risk compared to primary total hip arthroplasty [5].
- Developmental dysplasia of the hip (DDH) is a gradually progressive disorder associated with distinct anatomic changes, many of which are initially reversible [12].
- 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 [12].
- A ridge of thickened articular cartilage called the neolimbus arises along the posterosuperior acetabular wall in unstable hips [12].

- In dislocated hips, the fatty tissue known as the pulvinar thickens in the depths of the acetabulum and may impede reduction [12].
- In dislocated hips, the ligamentum teres elongates and thickens, taking up valuable space within the acetabulum [12].
- In dislocated hips, the transverse acetabular ligament is often hypertrophic and may impede reduction [12].
- In dislocated hips, the inferior capsule assumes an hourglass shape, presenting an opening smaller in diameter than the femoral head [12].
- The iliopsoas tendon is pulled tight across the capsular isthmus in dislocated hips, contributing to narrowing and acting as a barrier to closed reduction [12].
- The blocking structure encountered in patients with DDH is not only the labrum but also a significant portion of the cartilaginous acetabulum itself [12].
- The cartilaginous acetabular anlage is essential for the normal growth and development of the acetabulum and should not be excised [12].
- Femoral changes in DDH include an increase in anteversion and some flattening of the femoral head as it lies against the ilium [12].
- Fractures of the proximal femur are distinguished by their anatomic location in relationship to the joint capsule [15].
- Femoral neck fractures are considered intracapsular fractures and are at higher risk of nonunion due to the absence of a periosteal or extraosseous blood supply [15].
- Intertrochanteric fractures are considered extracapsular fractures, and nonunion is rare because of the absence of synovial fluid and the presence of an abundant blood supply [15].
- The subtrochanteric portion of the femur contends with the highest compressive and tensile forces in the human skeleton [21].
- Significant fracture displacement in the subtrochanteric region occurs secondary to the pull of the iliopsoas, gluteus medius, and short external rotators on the proximal fracture segment [21].
- The unopposed pull of the adductors on the distal segment in subtrochanteric fractures often leads to femoral shortening [21].
- Comminution of the medial cortex in subtrochanteric fractures increases the demand of the fixation construct, surpassing loads of 1,200 lbs per square inch in a 200-lb person [21].
- Varus malreduction in subtrochanteric fractures leads to increased mechanical stress on the fixation construct by altering the weight-bearing force vector [21].

Clinical Presentation

HISTORY AND PHYSICAL EXAMINATION

- A careful history and physical examination are crucial in making the diagnosis of total hip infection [34].
- Early postoperative infection or acute hematogenous infection is often not difficult to diagnose [34].

- Late chronic infections can be challenging to distinguish from other causes of pain in a patient with a previous THA [34].
- Early or late acute infections may be characterized by pain, fever, or erythema [34].
- Pain unrelieved by a seemingly well-functioning arthroplasty may be a clue towards chronic infection [34].
- A history of excessive wound drainage after the initial arthroplasty is worrisome for infection [34].
- A history of multiple episodes of wound erythema is worrisome for infection [34].
- A history of prolonged antibiotic treatment by the operating surgeon is worrisome for infection [34].
- Physical examination focuses on the presence of painful hip range of motion [34].
- Physical examination focuses on the presence of swelling [34].
- Physical examination focuses on the presence of erythema [34].
- Physical examination focuses on the presence of sinus formation [34].
- Physical examination focuses on the presence of fluctuance [34].

RADIOGRAPHIC FINDINGS

- Radiographs of the affected hip are often normal or indistinguishable from aseptic loosening of the prosthesis [34].
- Progressive radiolucencies occasionally may be seen, indicating possible infection [34].
- Periosteal reaction occasionally may be seen, indicating possible infection [34].

LABORATORY EVALUATION

- Laboratory evaluation includes ESR, CRP, and D-dimer [34].
- Peripheral white blood cell (WBC) count is rarely elevated in late chronic infection [34].
- Peripheral white blood cell (WBC) count is not a sensitive screening tool for late chronic infection [34].
- ESR greater than 30 mm/h is reasonably sensitive and specific for the diagnosis of chronic infection [34].
- CRP greater than 10 mg/L is reasonably sensitive and specific for the diagnosis of chronic infection [34].
- The threshold for a positive D-dimer test has been reported to be 850 ng/mL [34].

HIP ASPIRATION

- Hip aspiration is warranted if one of the previously mentioned lab values (ESR, CRP, D-dimer) are elevated [34].
- Hip aspiration is warranted if the index of suspicion for infection is high despite normal lab values [34].
- Aspiration should not be undertaken until at least 2 weeks after discontinuation of antibiotic therapy [34].
- Aspiration is done in an outpatient setting with the patient under local anesthesia [34].
- Fluoroscopy or ultrasonography are useful for accurate insertion of the needle during aspiration [34].
- Aspiration is done with the same attention to sterile technique as a surgical procedure, including a full surgical scrub and preparation [34].

CQ HAND + UPPER LIMB

- Skin flora may be introduced into the cultures and confuse the results or introduced into the joint if sterile technique is not maintained [34].
- An 18-gauge spinal needle is inserted from anterior at a point just lateral to the femoral artery along a line from the symphysis pubis to the ASIS [34].
- As an alternative, the needle is inserted laterally, just superior to the greater trochanter [34].
- The tip of the needle must enter the joint and must be seen and felt to come in contact with the metal of the neck of the femoral component [34].
- Gentle rotation of the extremity helps bring fluid toward the needle if none is easily withdrawn after entering the joint [34].
- Aerobic and anaerobic cultures, and cell count with differential, are obtained from the aspirant [34].
- Leukocyte esterase test strip and alpha-defensin testing are additional synovial fluid markers for infection that have shown high sensitivity and specificity [34].
- Leukocyte esterase test strip and alpha-defensin testing should be obtained if sufficient fluid is available [34].

DIAGNOSTIC CRITERIA

- The International Consensus Meeting criteria for the diagnosis of periprosthetic hip or knee infection include both preoperative and intraoperative measures [34].
- Two positive periprosthetic cultures with phenotypically identical organisms is a major criterion diagnostic of infection if at least one is present [34].

Investigations

CLINICAL EXAMINATION

- 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].
- The impingement test involves hip flexion to 90 degrees, adduction, and internal rotation, which yields a pain response [32].
- The impingement test is not specific for femoroacetabular impingement (FAI) [3].
- Patients with FAI exhibit restricted hip internal rotation in 90° of flexion [3].
- The Patrick test involves positioning the leg in a figure-of-four position to elicit pain in the anterior or posterior hip region [32].
- Pain located over the posterior pelvis during the Patrick test indicates referred pain from L5 to S1 facets or the sacroiliac joint, not the hip joint [32].
- The Stinchfield test involves active straight-leg raise of approximately 20 cm against mild resistance, with pain felt in the anterior hip [32].

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 Dunn 45° view may be more accurate for determining the alpha angle measurement than CT or MRI [2].
- The alpha angle is used to assess femoral head-neck junction morphology, with normal values generally considered less than 50°–55° [2].
- Acetabular overcoverage and undercoverage are assessed on AP pelvis radiographs [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 [2].
- Femoral head extrusion index values greater than 25% are considered abnormal [2].
- The Tönnis angle is defined by the angle of the acetabular sourcil and a line parallel to the transverse pelvis axis [2].
- Tönnis angles between 0° and 10° are 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 “crossover” sign on AP pelvis radiographs 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, 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 total hip arthroplasty [2].

MAGNETIC RESONANCE IMAGING (MRI)

- MRI is the modality of choice for patients suspected of soft tissue or intra-articular pathology, given its superior sensitivity and specificity [23].
- Conventional MRI is effective at identifying osteochondral injuries, musculotendinous pathologies, and inflammation [23].
- Magnetic resonance arthrography (MRA) is more appropriate than conventional MRI for determining injuries to labrochondral structures and the ligamentum teres [23].
- MRA is used to identify the presence of loose bodies and synovial chondromatosis [23].

- The sensitivity of MRA for accurate detection and staging of articular cartilage lesions is reported to be less than 50% compared with arthroscopic findings [23].
- Delayed gadolinium-enhanced MR imaging and T2* mapping allow for a more in-depth analysis of the structure of articular cartilage [23].
- MRI is useful for 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].
- MRI is used when osteonecrosis is suspected [32].
- Gadolinium-enhanced MRI arthrogram is useful when labral pathology is suspected, especially when associated with FAI [32].
- MRI may identify gluteus medius and gluteus minimus tears in patients with lateral hip pain and abductor weakness [32].
- In cases of suspected fracture with normal or equivocal plain radiographs, MRI is the current additional imaging modality recommended where there is uncertainty about the presence of an intracapsular fracture [30].
- MRI is more accurate than CT in detecting occult hip fractures [30].
- MRI will demonstrate soft tissue problems that may be causing hip pain in the absence of a fracture [30].

COMPUTED TOMOGRAPHY (CT)

- CT scans are effective for examining cortical and cancellous bone and can be used to create three-dimensional reconstructions of the hip for surgical planning [23].
- Measurements of femoral head coverage and acetabular and femoral impingement can be performed reliably using CT images [23].
- CT overcomes the limitations of radiography by providing three-dimensional assessment of bony morphology [11].
- Combined with arthrography, CT can evaluate chondrolabral abnormalities in patients with contraindications to MRI [11].
- CT is helpful in fracture evaluation, particularly in the setting of negative radiographs or for further defining fracture morphology in patients requiring surgical reduction [11].
- Three-dimensional CT with pelvic remodeling may be indicated for preoperative planning for reconstruction associated with dysplasia surgery, FAI, posttraumatic arthritis, or other complex primary total hip arthroplasty [32].

- Low-dose CT with three-dimensional reformats is particularly useful in surgical planning of complex or borderline deformities [3].
- CT scanning is a more accurate investigation than technetium bone scan for detecting occult hip fractures but exposes the patient to further radiation [30].
- Multidetector CT scanning has reported 100% specificity and sensitivity for the diagnosis of hip fracture in patients with negative plain radiographs [30].
- CT scanning has reported sensitivity of 86% and specificity of 98% for detecting occult hip fractures [30].

ULTRASONOGRAPHY

- Ultrasonography provides real-time dynamic assessment of the hip and is useful in diagnosing soft-tissue abnormalities about the hip joint [11].
- Ultrasonography is particularly useful in providing real-time guidance during diagnostic and therapeutic procedures [11].
- Although ultrasonography is a valuable tool to examine pediatric hip conditions, its utility in evaluating the adult hip is limited [23].
- Ultrasonography can be an effective modality to identify musculotendinous disruptions, effusions associated with intra-articular pathology, or inflammatory conditions such as bursitis [23].
- Ultrasonography is increasingly used for targeted injections into muscles, tendons, or intra-articularly around the hip for corticosteroids or biologic treatments [23].
- Ultrasonography allows bedside evaluation of the hip and can be used to guide interventions in the office setting [28].

Treatment

RISK FACTORS AND PREVENTION

- Patients with multiple surgical procedures have a higher risk of periprosthetic joint infection [5].
- Uncontrolled diabetes, morbid obesity, inflammatory arthritis, malnutrition, smoking, and chronic immunosuppression are associated with higher periprosthetic joint infection risk [5].
- Longer index procedure surgical time is associated with a higher risk for operative field contamination [5].
- Antibiotics should be administered within 1 hour before skin incision [5].
- Allogeneic transfusion may independently increase the risk of periprosthetic infection [5].

NON-OPERATIVE MANAGEMENT

- Nonoperative management with low-dose antibiotic therapy to suppress infection is an option for frail patients with organisms sensitive to common antibiotics [4].
- Carriage of methicillin-resistant *Staphylococcus aureus* is high in the hip fracture population, and this organism is a common cause of deep infection [4].

DEBRIDEMENT AND IMPLANT RETENTION

- Debridement and implant retention for the management of infection after total hip arthroplasty has reported success rates between 65% and 75% [4].
- Debridement and implant retention for infection after hemiarthroplasty for intracapsular hip fracture has reported less favorable results for infection eradication compared to total hip arthroplasty [4].
- A 44% success rate for debridement and implant retention in hemiarthroplasty deep infections was reported by del Toro [4].
- An infection eradication success rate of 43% (15/35 cases) for debridement and implant retention in hemiarthroplasty deep infections was reported by Guren et al. [4].

SINGLE-STAGE EXCHANGE ARTHROPLASTY

- Single-stage exchange arthroplasty can be considered for fitter patients who tolerate major surgery if the infection is caused by a sensitive organism [4].
- A success rate of 63% for single-stage exchange arthroplasty in hemiarthroplasty deep infections was reported by Lora-Tamayo et al. [4].
- Immediate exchange arthroplasty has eradicated infection in 85% of cases following arthroplasty for osteoarthritis [4].
- According to the International Consensus on Musculoskeletal Infection, one-stage exchange is reasonable when effective antibiotics are available and systemic symptoms of sepsis are absent [35].
- Relative contraindications to single-stage treatment include lack of preoperative identification of the infecting organism, patients with multiple medical comorbidities, presence of sinus track(s), and soft-tissue compromise possibly requiring flap coverage [35].
- The use of antibiotic-containing cement or bone graft in the reconstruction is important for achieving success in single-stage exchange [35].

TWO-STAGE EXCHANGE ARTHROPLASTY

- Two-stage exchange arthroplasty is indicated for septic or medically compromised patients, unidentified organisms, virulent or drug-resistant bacteria, sinus tracts, and compromised surrounding soft tissues [35].
- Two-stage exchange is advantageous because it ensures the adequacy of debridement by allowing repeat debridement of soft tissues, necrotic bone, and retained cement before reimplantation [35].
- Two-stage exchange allows for the identification of infecting organisms, determination of sensitivities, and institution of appropriate antibiotic management for a prolonged period before reimplantation [35].
- Two-stage exchange allows for diagnostic evaluation for foci of persistent infection and eradication of distant sites of infection responsible for hematogenous spread [35].
- Two-stage exchange allows for an informed decision regarding whether the degree of disability from resection arthroplasty justifies the risks of implanting another prosthesis [35].
- Disadvantages of two-stage reconstruction include a prolonged period of disability, sizable cost including lost wages, delayed rehabilitation, and technical difficulty owing to shortening and scarring [35].

- Delayed reconstruction is associated with lower rates of recurrent infection in most studies [35].
- In a review of 168 patients treated with two-stage exchange, infection-free survival was 87.5% at 7 years average follow-up [35].
- The femoral component fixation method, with or without cement, had no effect on reinfection or mechanical complication rates in two-stage exchange [35].
- The decision regarding cemented or cementless reimplantation should be guided by available femoral bone stock, physiologic age, expected longevity of the patient, and reported infection cure rates with each technique [35].
- An administrative database study of over 10,000 patients treated with prosthesis removal and spacer placement found a 90-day mortality rate of 2.6% [35].
- The 90-day mortality rate for two-stage exchange was significantly higher than that for carotid endarterectomy, prostatectomy, and kidney transplantation [35].
- Duncan and Beauchamp described a technique of two-stage reimplantation using a prosthesis of antibiotic-loaded acrylic cement (PROSTALAC) implanted at the time of initial debridement [35].
- The PROSTALAC prosthesis is constructed intraoperatively by molding antibiotic-laden cement around a simplistic femoral component and an all-polyethylene acetabular component [35].
- PROSTALAC components are implanted with an interference fit without attempt to achieve cement intrusion to simplify extraction during the second stage [35].
- The articulated spacer in the PROSTALAC technique maintains leg length and improves control of the limb and mobilization [35].
- Biring et al. reported an overall 89% success rate with the PROSTALAC technique at 10- to 15-year follow-up [35].
- Other interval spacers of various types have reported infection eradication rates of 77% to 100% [35].
- Complications of interval prostheses other than recurrent or persistent infection include dislocation or fracture of the interval prosthesis [35].
- Parenteral antibiotics are continued for 6 weeks prior to reconstruction in two-stage exchange [35].
- Reconstruction is performed at approximately 3 months if the ESR and CRP are improving and repeat aspiration of the hip is negative [35].
- Reimplantation of a total hip can be difficult due to extensive scarring of the soft tissues and disuse osteoporosis [35].
- Restoration of limb length and full motion of the hip may not be achieved after reimplantation, and dislocation after surgery is not uncommon [35].
- The sciatic nerve may be encased in scar tissue near the posterior margin of the acetabulum and should be protected during reimplantation [35].

RESECTION ARTHROPLASTY (GIRDLESTONE)

- Results of modified Girdlestone resection arthroplasty after total hip replacement are generally not as satisfactory as results after hip joint infections requiring less bone and soft-tissue resection [35].

- Almost all patients require some sort of assistive device to walk after modified Girdlestone resection arthroplasty [35].
- Functional outcomes are poor in elderly patients, females, and patients with more extensive resection of bone from the proximal femur after modified Girdlestone resection arthroplasty [35].
- Most patients are unwilling to live with the constraints of a resection arthroplasty and will elect to undergo reimplantation of their prosthesis [35].

OUTCOMES AND MORTALITY

- Options of excision or exchange arthroplasty are major interventions likely to be poorly tolerated in patients with medical comorbidities [4].

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