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Current Concepts of Hip Arthroplasty for Radiologists

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Current Concepts of Hip Arthroplasty for Radiologists: Part 2, Revisions and Complications

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OBJECTIVE. This article reviews the imaging features of revisions and complications of hip replacement arthroplasty and relates these features to the current understanding about how and why these failures occur.

CONCLUSION. Short-term failures of hip replacements are most commonly the result of instability and dislocation. Complications ranging from osteolysis caused by granulomatous reaction to particulate wear debris lead to many long-term failures. Attempts to reduce wear debris through changes in design and materials have reduced the rate of some complications but have resulted in new ones. Infection remains a devastating complication that is difficult to resolve.

Keywords: complications, hip arthroplasty, imaging, radiography, resurfacing hip arthroplasty

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Given sufficient time, hip joint replacements may fail and require revision. Survival rates are the standard outcome measure for joint replacement arthroplasty and are expressed as the percentage of prostheses remaining within living patients at a given time. However, survival of the prosthesis does not necessarily mean a good clinical outcome. The mean revision rate for total hip arthroplasty (THA), based on National Joint Replacement Registry datasets from six countries (Finland, Sweden, Norway, Denmark, New Zealand, and Australia), is 1.29 revisions per 100 observed component years [1]. This revision rate corresponds to a survival rate of 93.6% after 5 years and 87.1% after 10 years. In 2009, approximately 58,000 revision THAs were performed in the United States, representing approximately 13% of all THAs performed [2] and exceeding previous estimates of utilization [3]. As newer generations of prostheses are implanted using improved surgical techniques, the patterns and types of complications have changed [4]. This article reviews current issues relating to the failure and revision of hip replacements with an emphasis on radiographic features. A companion article, part 1 [5], reviews current issues relating to primary hip replacement arthroplasty and the expected radiographic appearances.

Osteolysis and Aseptic Loosening

THA failures that occur 5 or more years after implantation are mostly the result of osteolysis; osteolysis leads to aseptic loosening and periprosthetic fractures [6–8]. Particles of bone cement, polyethylene, titanium alloy, cobalt-chromium alloy, stainless steel, and ceramic released from implant surfaces by mechanical wear have all been implicated in this process, and particle size, particle load, particle type, and host response may be important factors.

Osteolysis is a biologic process that is initiated by macrophage phagocytosis of particulate debris. An aseptic foreign body granulomatous reaction ensues, and the regions of osteolysis are filled with granulation tissue with phagocytosed particulate debris. Cell-mediated activation of osteoclasts has a prominent role in osteolysis, but inhibition of osteoblasts may also be involved [7]. Osteolysis first occurs where joint fluid has access to bone and may then progress like a membrane around the cement-bone interfaces in cemented THA and around the metal-bone interfaces in cementless THA. The implant becomes separated from the host bone, resulting in mechanical loosening. In the presence of a continuing supply of new particles, osteolysis is an unceasing, relentless process [8].

Osteolysis may be observed radiographically as a thin zone of radiolucency that may slowly extend around the bone-cement or bone-prosthesis interface (Fig. 1). Massive localized osteolysis may also occur in the bone adjacent to components (Fig. 2). The most common cause of periprosthetic lucency is mechanical loosening and osteolysis due to either "particle disease" or infection, which can look similar radiographically.

Instability and Dislocation

Instability of the joint and recurrent dislocations are common complications after THA. The reported rate of dislocation varies from 0.5% to 10% after primary THA and increases to approximately 10–25% after revision procedures [9]. The risk of dislocation is influenced by multiple factors including the age and sex of the patient, the surgical approach, the surgical technique, the design of the prosthesis, the underlying diagnosis, the lifetime of the prosthesis, and the patient's compliance with restrictions [10] (Fig. 3). Most dislocations occur in the early postoperative period during the initial weight bearing. The surgical approach is related to the direction of dislocation. Posterior approaches predispose to posterior dislocation and anterior approaches, to anterior dislocation [11, 12].

Early dislocation within the first 3 months after surgery is usually caused by laxity of the immature pseudocapsule of the joint and surrounding soft tissues. Atraumatic dislocation occurring between 3 months and 5 years after surgery is usually caused by component malposition. Dislocation occurring more than 5 years after placement is usually the result of gradual stretching of the pseudocapsule and surrounding soft-tissue laxity, and women are at greater risk than men [13]. This temporal classification is useful because it highlights the differences in the causes of dislocation in each category that, in turn, determine the type of treatment that is selected.

Early dislocation is often successfully treated with nonoperative means. In contrast, late dislocation occurs after 5 years and generally requires surgical treatment [14].

Revision THA for late dislocations may use larger femoral head sizes, constrained acetabular liners, and tripolar prostheses. Larger femoral head sizes are associated with decreased dislocation rates and may also decrease the risk for osteolysis and aseptic loosening in the long term [15]. Constrained acetabular liners fit into normal metal acetabular shells but can be closed around the femoral head like a clamshell to lock it in place; a metal ring around the periphery keeps the liner closed (Fig. 4). Once placed, the ring should never move relative to the liner or shell. Tripolar prostheses consist of a bipolar component with a polyethylene-lined metal head placed inside a constrained acetabular liner placed inside a metal acetabular shell (Fig. 5) or a bipolar component with a polyethylene head placed inside a highly polished metal shell. In both types, motion may occur within the bipolar component as well as between the bipolar component and the acetabular component. Dislocation rates are decreased with tripolar components [16] but unique modes of failure may occur because of their complexity [17].

Infection

Deep joint infection after THA is a serious complication that requires surgical and prolonged medical management. The costs of treating an infection after THA are reported to be at least US$50,000 per patient [18]. Reported infection rates in the literature are currently 1–2% for primary THA and are higher after total hip revision [19]. There is no one specific test that offers great specificity and sensitivity for the diagnosis of infection. False-negative and false-positive culture results have been reported in more than 10% of joint fluid aspirates [2]. Berbari et al. [20] performed a meta-analysis of the accuracy of serologic markers for periprosthetic joint infections. They found that diagnostic accuracy was best for interleukin 6, followed by C-reactive protein level, erythrocyte sedimentation rate, and WBC count, although only a few studies included interleukin 6.

Radiographic findings can vary from completely normal to frank bone destruction mimicking loosening or particle disease. A distinction between septic and aseptic loosening often cannot be made on a single radiograph. Usually, previous radiographs are necessary for comparison. Aseptic loosening usually takes a slowly progressive course, whereas infection usually occurs with a rapid time course and an aggressive appearance [21]. Although the appearance of osteolysis cannot distinguish infectious from noninfectious loosening, the presence of femoral periosteal reaction or an adjacent soft-tissue collection is highly predictive [22] (Fig. 6).

In North America, delayed or two-stage exchange is considered the standard treatment of infected hip arthroplasty. With the two-stage procedure, the infected prosthesis is removed and the hip undergoes a thorough débridement, leaving it free of any foreign material. The interval period between removing the infected prosthesis and implanting a new prosthesis is 6 weeks to 3 months. During this interval, IV antibiotics are administered to help eradicate infection, and a temporary cement spacer laden with antibiotics may be used in the hip joint [23] (Fig. 7A). The prosthesis of antibiotic-loaded acrylic cement (PROSTALAC) system was first developed to allow functional hip movement by creating a temporary joint prosthesis surrounded by antibiotic-loaded cement [24]. The current design consists of an articulating polyethylene acetabular liner and a metal femoral head prosthesis. The nonarticulating surfaces are coated or embedded with antibiotic-loaded acrylic cement. The radiographic appearance is that of a slim, tapered femoral stem and attached femoral head with a wide zone of surrounding bone cement from the femoral neck distally that also projects above the margins of the proximal femoral bone. The acetabular component appears to be almost entirely composed of cement except for a thin uniform radiolucent rim of the polyethylene liner cup that encompasses the femoral head [25] (Fig. 7B). Complications after PROSTALAC insertion include dislocation, periprosthetic fracture, and superimposed infection [23] (Fig. 7C).

Periprosthetic Fracture

Periprosthetic fractures occur more often around the femoral than the acetabular components. The increased risk for fracture after revision THA is probably because of compromised bone quality and focal bone deficiencies. The Vancouver classification, which was introduced by Duncan and Masri [26], is divided into three major types. The types are based on the location of the fracture, the amount of available proximal bone stock, and the stability of the stem. Type A fractures are peritrochanteric fractures (subtypes: A_L = lesser trochanter and A_G = greater trochanter). Type B fractures occur around or just below the tip of the stem (subtypes: B_1 = well-fixed stem, B_2 = not-well-fixed stem, B_3 = poor bone stock in the proximal femur and not-well-fixed stem). Type C fractures occur so far below the femoral stem that their treatment is independent of the presence of a hip replacement in situ (Fig. 8).

Intraoperative femoral fractures may occur during placement of the femoral stem and are more frequently associated with cementless components than cemented ones. Postoperative femoral fractures may also occur any time after the surgery, typically at the level of the tip of the femoral stem because of "stress risers" at this level caused by the difference in stiffness between the metal stem and bony shaft (Fig. 9). The cause of postoperative periprosthetic femoral fractures is most often a minor episode of trauma. Intraoperative periprosthetic acetabular fractures are a phenomenon ascribable to the use of press-fit cementless acetabular components. Acute postoperative acetabular fractures are uncommon and occur primarily as a result of either a traumatic event or osteolysis [27] (Fig. 10).

Complications associated with trochanteric reattachment after disruption of the greater trochanter, either from acute fracture or chronic nonunion, manifest with significant functional deficits (Fig. 11). These complications include pain, limp, weakness, bursitis, and dislocation [28]. Improved union rates have been suggested with the use of a claw plate that can grip the trochanteric fragment.

Femoral neck fracture is the most common complication of resurfacing arthroplasty that is not present in THA. The incidence of femoral neck fracture in metal-on-metal hip resurfacing arthroplasty ranges from 0% to 2.4% in various retrospective studies, which represents a marked improvement from the 7–12% fracture rate seen with metal-on-polyethylene implants [29]. Femoral fractures have multifactorial causes usually related to deficiencies in surgical technique; the significance of vascular changes remains controversial [30].

Soft-Tissue Abnormalities

Heterotopic new bone formation occurs in 15–50% of patients, but a clinically significant limitation of motion is rare (1–5%) [31]. Predisposing factors include infection, posttraumatic arthritis, ankylosing spondylitis, and previous hip surgery.

Recently, Pavlou et al. [32] reported that the combination of male sex, total cemented prosthesis, and lateral approach increased the rate of developing heterotopic ossification by 85%. In selected patients, both low-dose radiation and nonsteroidal antiinflammatory drugs have been shown to be effective. Nonsteroidal antiinflammatories, particularly indomethacin, are a very acceptable form of prophylaxis and affect inflammation primarily by inhibiting the conversion of arachidonic acid to prostaglandins through the cyclooxygenase pathway. Indomethacin may be preferred in certain patients, including young women of childbearing age. Radiation is preferred in patients with known gastrointestinal intolerance to these medications or with a history of peptic ulcer disease [33].

The radiographic description of heterotopic ossification is performed on the anteroposterior view utilizing the Brooker classification [34]: grade 0, no heterotopic ossification; grade 1, one or two foci of heterotopic ossification less than 1 cm each; grade 2, ossification or osteophytes occupying less than half the space between the femur and pelvis; grade 3, ossification or osteophytes occupying more than half the space between the pelvis and femur; and grade 4, ossification that bridges the pelvis and femur (Fig. 12).

Pseudobursae are irregular recesses that communicate with the joint and are detected on arthrography or sonography. Pseudobursae may track large distances around the hip joint, and although they may be associated with infection, they can be an incidental finding (Fig. 13). This diagnosis is an important one because pseudobursitis may be treated conservatively with steroid and anesthetic injections. The presence of irregular walls, sinus tracks, bone destruction, or debris in the cavity suggests infection [35].

A particular disadvantage of the metal-on-metal bearing in hip arthroplasty is the release of large amounts of very small wear particles and metal ions. The long-term biologic consequences and the clinical effects of these raised metal ions remain largely unknown. Metal ion levels may be influenced by the type, design, and positioning of the implant. The deposition of metallic wear particles in periprosthetic tissues induces a spectrum of changes. Periprosthetic soft-tissue lesions have been described variously as metallosis [36], aseptic lymphocytic vasculitis–associated lesions [37], adverse reaction to metal debris [38], and pseudotumors [39].

Metallosis is the macroscopic staining of soft tissues and is associated with abnormal wear, usually of the bearing surface or at the modular head-neck junction [36] (Fig. 14). Metallosis may also occur in conventional THA after polyethylene liner failure allows the metal components to abrade against each other (Fig. 15). The diagnosis of aseptic lymphocytic vasculitis–associated lesions is a histologic diagnosis that may occur with metallosis, effusion, soft-tissue necrosis, or pseudotumor formation [37]. Pseudotumor describes a mass, which may be cystic or solid, and histology tends to show aseptic lymphocytic vasculitis–associated lesions and tissue necrosis [39]. The term "adverse reaction to metal debris" is an umbrella term including metallosis, aseptic lymphocytic vasculitis–associated lesions, and pseudotumors [38]. There appears to be no clear consensus in the literature defining the boundaries of each term or agreement that all metallosis develops into pseudotumors or that aseptic lymphocytic vasculitis–associated lesions are necessarily present [40].

Investigators have suggested that these abnormal soft-tissue reactions may be attributed to two causes: wear-related cellular cytotoxicity and hypersensitivity [41]. Radiographs usually show normal findings, but in advanced cases there may be evidence of loosening or femoral neck narrowing in resurfacing arthroplasty [42]. Cystic or solid masses can be detected on MRI, CT, and ultrasound. There are three types of pseudotumors based on MRI findings: Type 1 are thin-walled cystic masses (cyst wall < 3 mm); type 2, thick-walled cystic masses (cyst wall > 3 mm but less than the diameter of the cystic component); and type 3, predominantly solid masses [43].

There is no evidence to suggest gadolinium is useful when no lesion is seen on the unenhanced scan [44] (Figs. 16 and 17).

Component Failure

Component failure can affect the femoral, acetabular, and other supplementary fixation components. The stem of the femoral component can break, representing a metal-fatigue stress fracture, because the metal stem is more stiff and less yielding than the surrounding femoral bone; however, the incidence of this fracture depends on the geometry and metal composition of the stem [21] (Fig. 18A). The modular component of femoral stem can dissociate (Fig. 18B), and the sintered beads of a femoral stem may shear off. Metal bead shedding is defined as opaque microfragments separated from the porous-coated femoral stem (Fig. 19). These metal beads are seen in the soft tissue adjacent to the joint, and their increase in number on follow-up indicates loosening. In addition to gradual full-thickness wear, the acetabular liner can frankly break and dissociate from the metal acetabular shell (Fig. 20). Massive acetabular bone deficiency is the most challenging reconstruction in revision THA surgery, and surgical options include structural and morselized bone grafting, metallic augments, use of a pelvic reinforcement cage or ring, and major column acetabular allograft [45] (Fig. 21). These supplementary fixation components such as acetabular screws, acetabular-constrained liners, fixation cables, and wires can break and displace.

Complications of Hemiarthroplasty

In hemiarthroplasty, the femoral head and neck are replaced by a prosthesis that articulates with the native acetabulum. The metal-on-cartilage bearing may eventually lead to loss of acetabular cartilage and then to erosion of the subchondral bone. Progressive remodeling of the bone may lead to protrusio acetabuli or the formation of an articular cavity (Fig. 22). In one study of revision of bipolar hemiarthroplasty, acetabular erosion was a factor contributing to the need for revision in 21 of 25 cases [46]. The incidence of acetabular erosion appears higher in those with unipolar hemiarthroplasty than in those with bipolar hemiarthroplasty [47]. In one study of 679 hemiarthroplasties of various types inserted for displaced femoral neck fractures, the cumulative proportion of prostheses surviving 5 years was 90%, declining at 10 years to 85%; bipolar hips had a higher survivorship than unipolar hips [48].

Conclusion

As newer generations of prostheses are implanted using improved surgical techniques, the patterns and types of complications have changed. Short-term failures of hip replacements are most commonly the result of instability and dislocation. Osteolysis caused by granulomatous reaction to particulate wear debris leads to many long-term failures. Attempts to reduce wear debris through changes in design and materials have reduced the rate of some complications but have resulted in new ones. Infection remains a devastating complication that is difficult to resolve.

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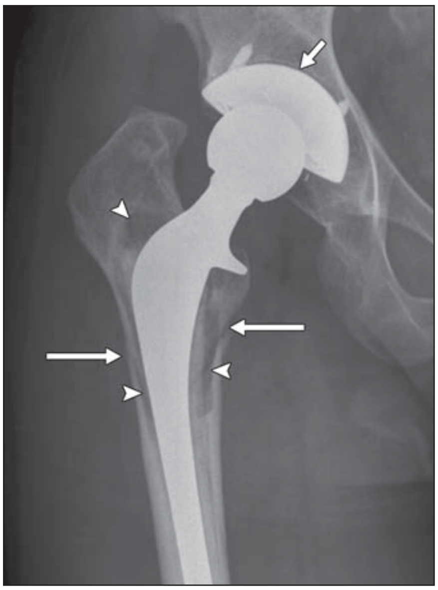
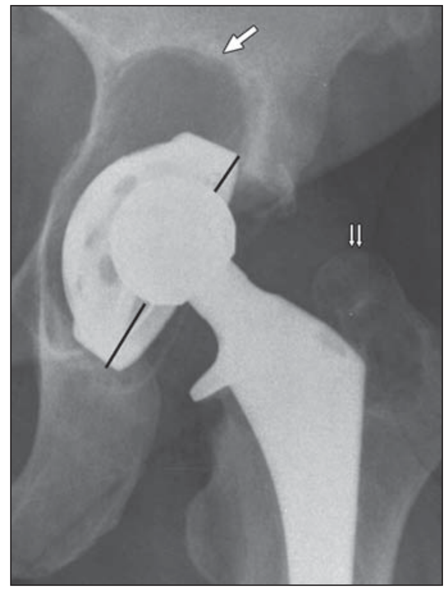
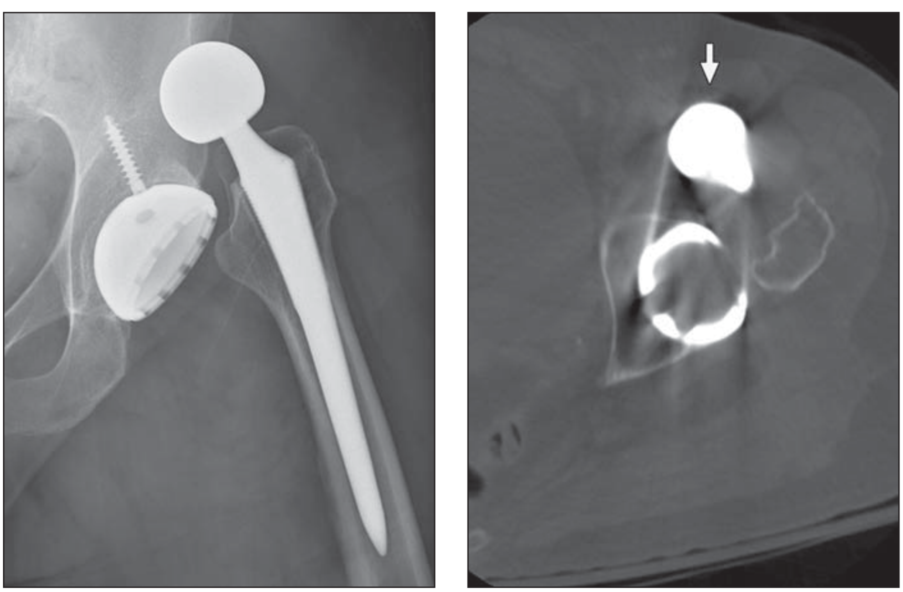


Fig. 1—Osteolysis and fracture. Anteroposterior radiograph of hybrid right total hip arthroplasty shows periprosthetic lucency more than 2 mm long in femoral zones 1 and 7 at cement-bone interface (*arrowheads*). Thin zone of lucency is present around cementless acetabular component in acetabular zone II (*short arrow*). There is subtrochanteric fracture of femoral shaft (*long arrows*).

Fig. 2—Osteolysis in 65-year-old woman. Anteroposterior radiograph of left total hip arthroplasty shows geographic, globular periprosthetic lucency in acetabular zones I and II (*single arrow*) and in femoral zone 1 (*double arrows*). Femoral head is asymmetrically seated in acetabular cup (*black lines*) indicating excessive acetabular liner wear. Acetabular cup remains in its original position but is at high risk for mechanical loosening.





A B

Fig. 3—Dislocation in 64-year-old woman.
A, Anteroposterior radiograph of left total hip arthroplasty shows anterosuperior dislocation of femoral prosthesis.
B, Corresponding axial CT image shows anteriorly dislocated femoral head (*arrow*).

Fig. 4—Anteroposterior radiograph of left cementless total hip arthroplasty shows properly-positioned retaining ring of constrained acetabular liner (*arrow*).
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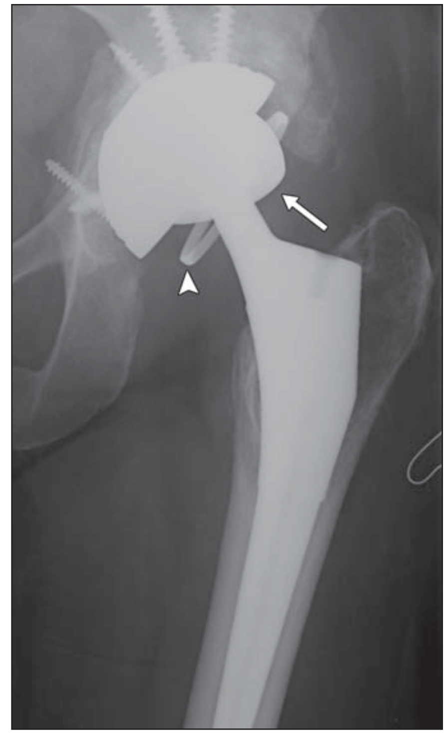
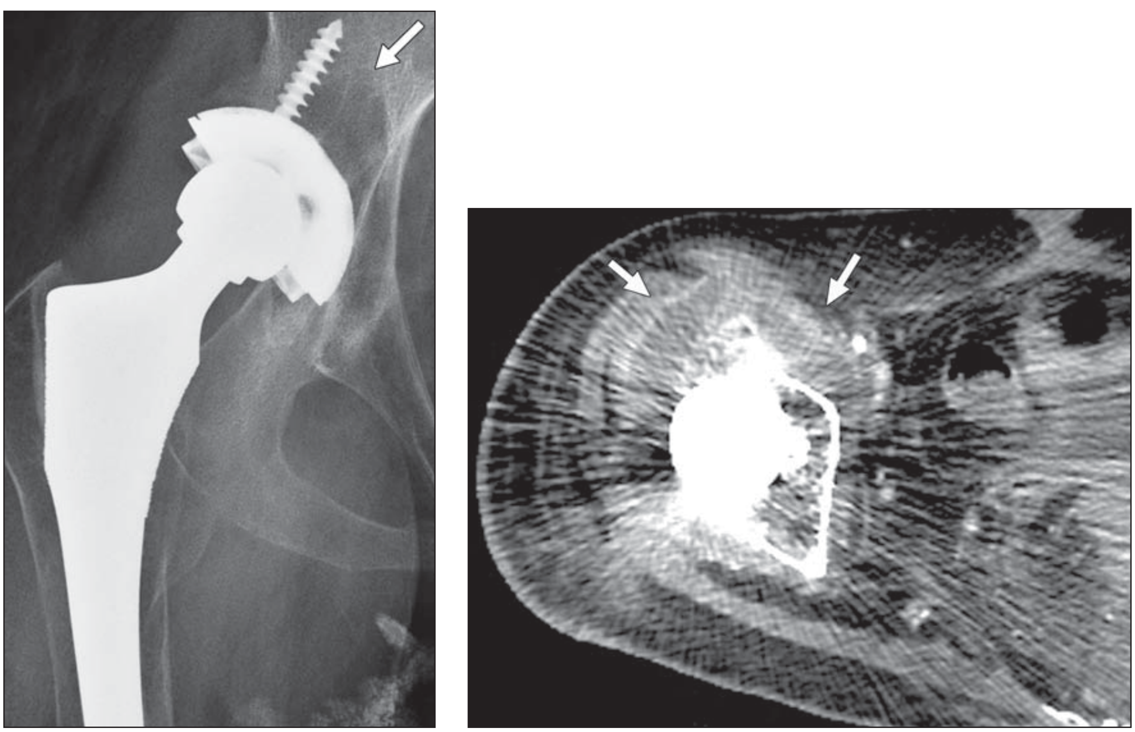


Fig. 5—Anteroposterior radiograph of total hip arthroplasty in 55-year-old woman shows tripolar prosthesis consisting of bipolar femoral component with polyethylene-lined metal head (*arrow*) placed inside constrained acetabular liner (*arrowhead*) placed inside metal acetabular shell. →



A B

Fig. 6—Infection in 43-year-old woman.
A, Anteroposterior radiograph of right total hip arthroplasty shows acetabular periprosthetic lucency in zone II (*arrow*).
B, Corresponding contrast-enhanced axial CT image shows periarticular (periprosthetic) fluid collection (*arrows*) that turned out to be abscess by *Pseudomonas aeruginosa.*

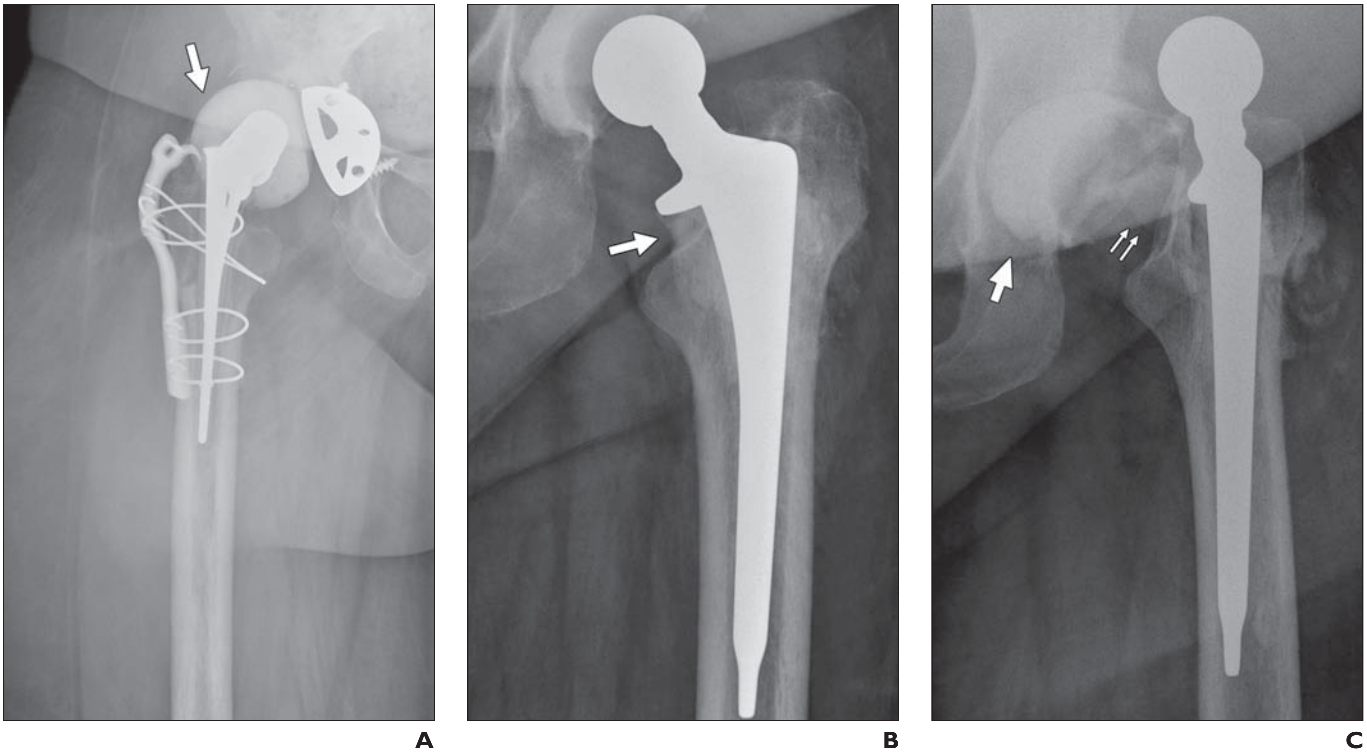


Fig. 7—Treatment of infected total hip arthroplasty (THA) in 48-year-old woman.
A, Anteroposterior radiograph of revised right THA with femoral spacer laden with antibiotics (*arrow*).
B, Initial postoperative anteroposterior radiograph of revised, infected left THA in 58-year-old woman shows prosthesis of antibiotic-loaded acrylic cement (PROSTALAC) implant. Surrounding bone cement projects above margins of proximal femoral bone (*arrow*).
C, Follow-up anteroposterior radiograph in same patient as in **B** shows loosening of PROSTALAC cup (*single arrow*), extruded cement in joint (*double arrows*), and dislocated femoral prosthesis.

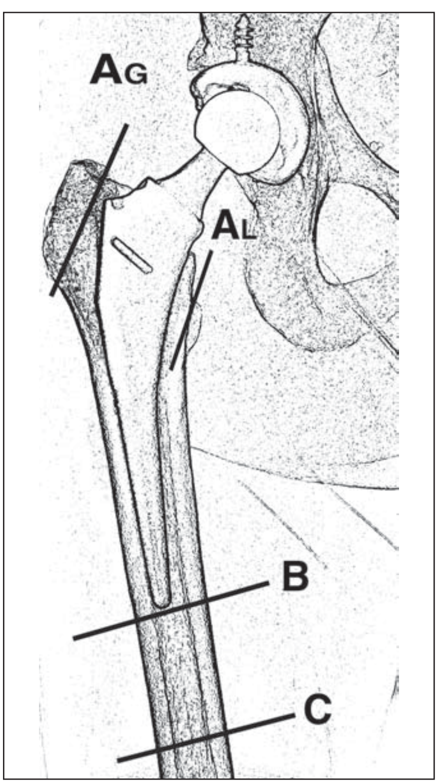


Fig. 8—Vancouver classification of periprosthetic femoral fracture. Type A fractures are peritrochanteric fractures (subtypes: A_L = lesser trochanter and A_G = greater trochanter). Type B fractures occur around or just below tip of stem. Type C fractures occur so far below femoral stem that their treatment is independent of presence of hip replacement in situ.)
←

Fig. 9—Periprosthetic femoral fracture. Anteroposterior radiograph of left bipolar hemiarthroplasty in 62-year-old woman shows periprosthetic femoral shaft fracture at level of tip of femoral stem because of “stress riser.” →

Fig. 10—Periprosthetic acetabular fracture. Anteroposterior radiograph of left total hip arthroplasty in 76-year-old man shows periprosthetic acetabular lucency in zones I and II (*long arrow*) due to loosening and periprosthetic fracture along inferior edge of cup (*short arrow*).
←

Fig. 11—Greater trochanteric fracture. Anteroposterior radiograph of left total hip arthroplasty shows greater trochanteric fracture with bony fragment displaced superiorly (*arrow*). →

Fig. 12—Heterotopic ossification. Anteroposterior radiograph of left total hip arthroplasty shows heterotopic ossification (*arrow*) occupying more than half of the space between pelvis and femur (Brooker grade 3).

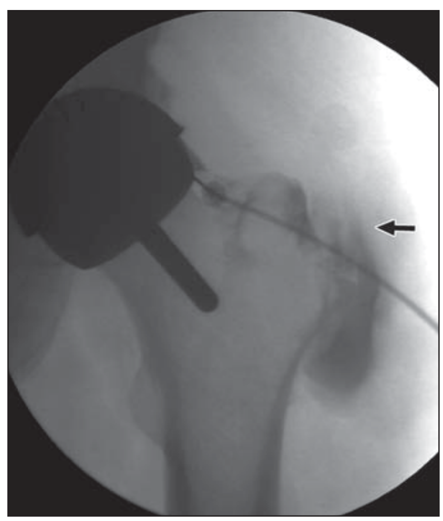


Fig. 13—Pseudobursa in metal-on-metal bearing. Spot arthrographic image of left total hip resurfacing arthroplasty in 52-year-old man shows irregular collection of contrast agent along lateral aspect of femur (*arrow*); this finding is consistent with pseudobursa.

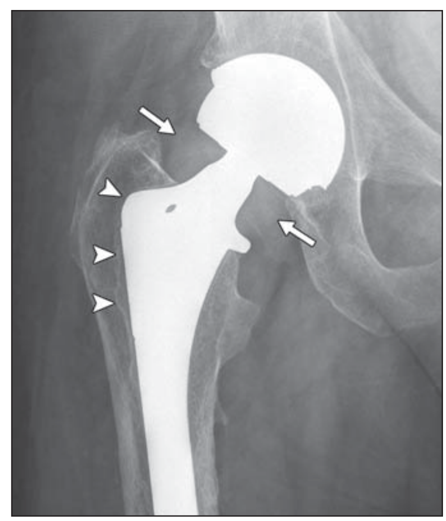


Fig. 14—Metallosis and osteolysis in metal-on-metal bearing. Anteroposterior radiograph of right large-headed total hip arthroplasty in 48-year-old man shows metallosis manifested as cloudlike radiodensity (*arrows*) surrounding neck of femoral component. Osteolysis is present in femoral zone 1 (*arrowheads*).

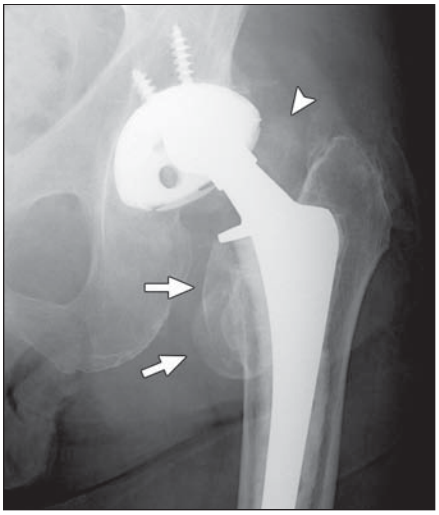
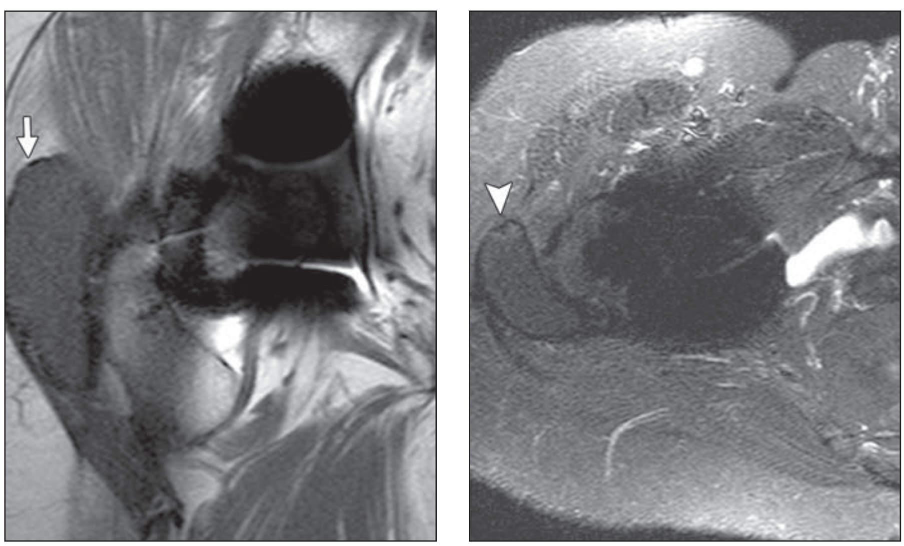


Fig. 15—Metallosis after polyethylene failure. Anteroposterior radiograph of left total hip arthroplasty in 65-year-old woman. Failure of polyethylene liner allowed femoral head to abrade acetabular cup. Bubblelike hyperdensities (*arrows*) represent deposited metallic debris outlining joint space. Other abnormal amorphous cloudy radiodensities in periprosthetic region (*arrowhead*) are also visualized.

Fig. 16—Cystic pseudotumor in metal-on-metal bearing. Radiographs of right resurfacing total hip arthroplasty with metal-on-metal bearing in 55-year-old man were normal (not shown). However, coronal STIR MR image of right hip shows periprosthetic cystic mass (*arrow*) consistent with pseudotumor.

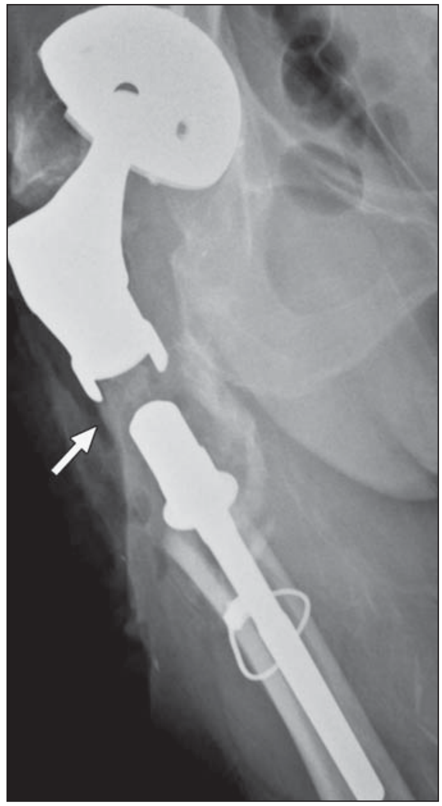


A

B

Fig. 17—Solid pseudotumor in metal-on-metal bearing. Radiographs (not shown) of cementless right total hip arthroplasty with metal-on-metal bearing in 69-year-old woman were normal.
A, Coronal T1-weighted MR image shows periprosthetic ovoid mass with low signal intensity (*arrow*).
B, Mass (*arrowhead*) shows low signal intensity on axial STIR MR image. Patient's serum chromium level was 125.9 ng/mL (reference, 0.0–0.3 ng/mL) and cobalt level was 105 ng/mL (reference, 0.0–0.9 ng/mL).

A



B

Fig. 18—Component failure: femoral stem.
A, Anteroposterior radiograph of right unipolar hemiarthroplasty in 70-year-old woman shows broken femoral stem of Austin-Moore hemiarthroplasty.
B, Anteroposterior radiograph of right total hip arthroplasty in 63-year-old woman shows dissociation of modular femoral stem (*arrow*) with dislocation.

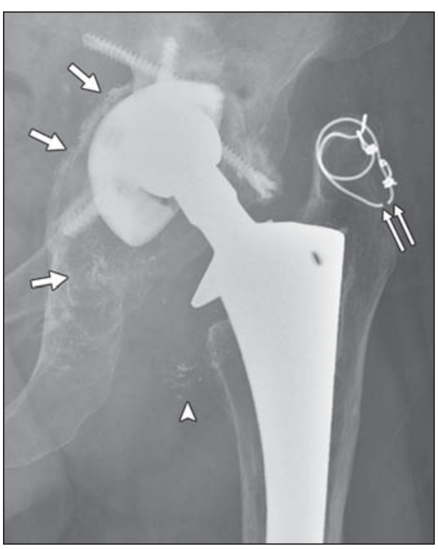


Fig. 19—Bead shedding. Anteroposterior radiograph of noncemented left total hip arthroplasty in 49-year-old man shows excessive polyethylene wear, osteolysis, loosening of acetabular cup, and bead shedding. Small metal spheres shed from porous coat of acetabular cup may be seen in osteolysis cavity (*single arrows*) and in soft tissues (*arrowhead*). Greater trochanteric cerclage wire (*double arrows*) is broken.

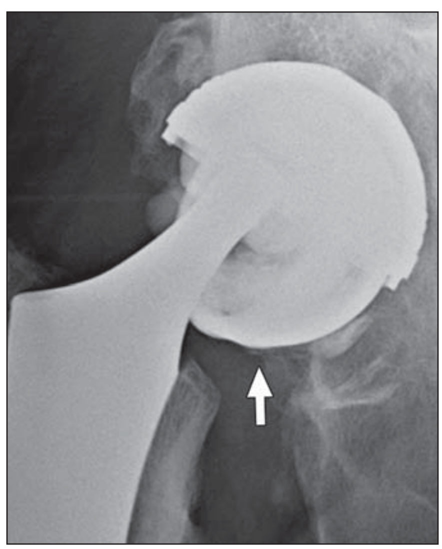


Fig. 20—Ceramic component failure. Coned anteroposterior view of right total hip arthroplasty with ceramic-on-ceramic bearing in 64-year-old man shows ceramic liner (*arrow*) is fractured and dislocated from metal back shell.

Fig. 21—Acetabular reconstruction cage. Anteroposterior radiograph of left revised total hip arthroplasty shows acetabular reconstruction cage (*arrow*). Bone graft and cement have been used to fill acetabular deficiency behind cage. There is polyethylene liner.

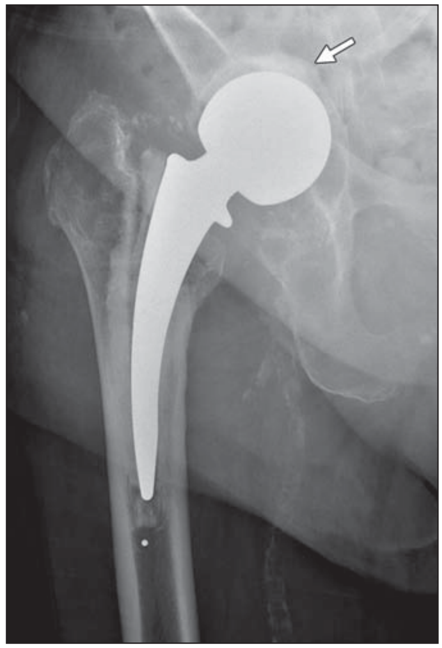


Fig. 22—Complications of hemiarthroplasty. Anteroposterior radiograph of right unipolar hemiarthroplasty in 92-year-old woman shows remodeling of native acetabulum (protrusio acetabuli) (*arrow*).

FOR YOUR INFORMATION

This article is part of a self-assessment module (SAM). Please also refer to "Current Concepts of Hip Arthroplasty for Radiologists: Part 1, Features and Radiographic Assessment," which can be found on page 559.

Each SAM is composed of two journal articles along with questions, solutions, and references, which can be found online. You can access the two articles at www.ajronline.org, and the questions and solutions that comprise the Self-Assessment Module by logging on to www.arrs.org, clicking on *AJR* (in the blue Publications box), clicking on the article name, and adding the article to the cart and proceeding through the checkout process.

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