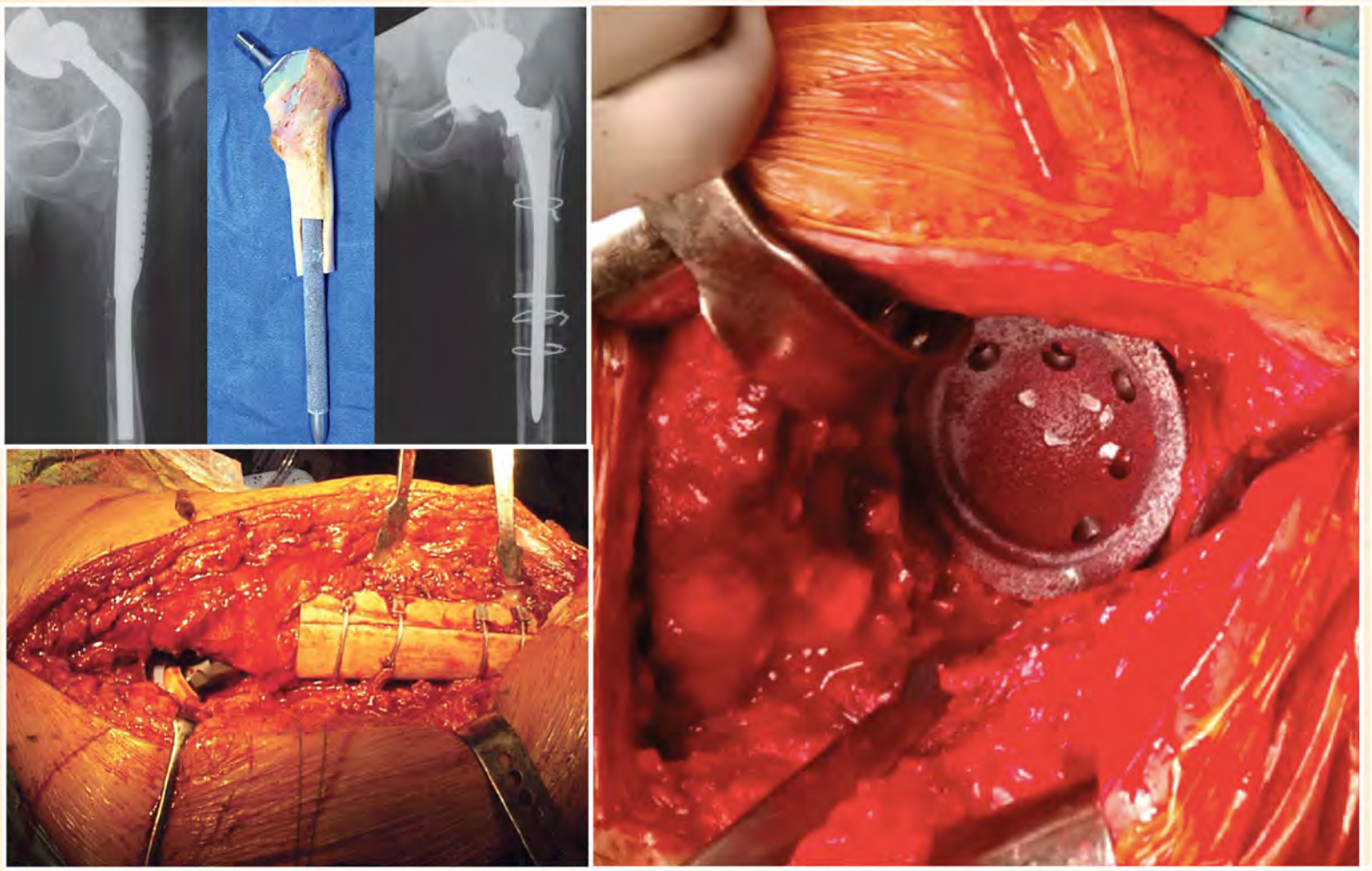
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Mastering Orthopedic Techniques

REVISION HIP ARTHROPLASTY

Editor

Rajesh Malhotra

Forewords

Robert B Bourne

Daniel J Berry

JAYPEE

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CHAPTER 3

Imaging of the Failed Hips

Deepak Gautam, Shivanand Gamanagatti, Rajesh Malhotra

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Introduction

Total hip arthroplasty (THA) is considered as one of the most successful orthopedic procedures, providing dramatic pain relief and early restoration of function, resulting in an improved quality of life. Modern THA systems are modular. This means that the femoral stem, head, acetabular shell and liner are separate pieces. This gives greater flexibility in customizing prosthesis sizing and fit. Bearing surfaces are the surfaces which articulate in the prosthetic joint. These will give different appearance on radiographs depending on the configuration. Options for bearing surfaces include metal on polyethylene, metal on metal, ceramic on ceramic, and ceramic on polyethylene. As more and more primary replacements are being done worldwide, number of patients requiring revision surgery is bound to increase. In a cumulative analysis of six national joint registries, rate of revision was estimated to be 1.29 revisions per 100 observed component years.[1] The leading causes of revision in total hip arthroplasty include aseptic loosening (55.2%), instability, infection and periprosthetic fractures.[2] Various imaging modalities are used to evaluate a failed hip.

Conventional Radiography (X-ray)

It is usually the first radiological investigation ordered. Advantages include universal availability, low cost, no metal artefact, and ease of longitudinal comparison.[3] Disadvantages include difficulty in differentiating between septic from aseptic loosening, inability to show soft tissue collections, inability to accurately quantify acetabular bone defects. Essential views include an anteroposterior view of pelvis, a true lateral view of the hip, and a frog lateral view. The region below the tip of femoral stem must be included in the radiograph **(Figure 3.1)**. Other views like oblique and false profile views may be useful to evaluate acetabular bone defects and the acetabular component positioning.[4] The initial films serve as a baseline study and are used as reference films for comparison with all future studies, since sequential radiography is the most valuable method for detecting complications. The initial postoperative films are obtained to look for possible dislocation or fracture and to see if the prosthesis is good positioned.

Computed Tomography

Computed tomography (CT) is very helpful in the evaluation of a painful hip prosthesis when radiographic findings are either normal or equivocal. CT can detect periimplant fluid and soft-tissue collections. Main advantage of CT scan is that it eliminates the overlapping

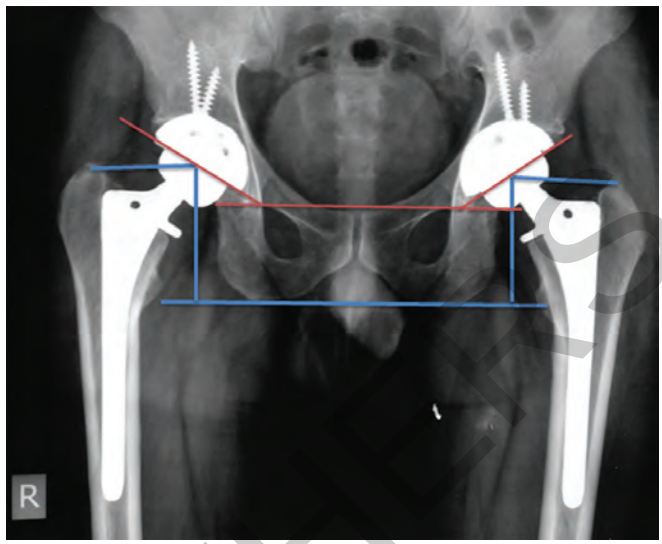


Figure 3.1: Anteroposterior radiograph of pelvis with both hips of a well functioning patient following bilateral sequential uncemented total hip arthroplasty. Note that the cup inclination, offsets and limb lengths are maintained in both sides. There is no evidence of osteolysis or loosening

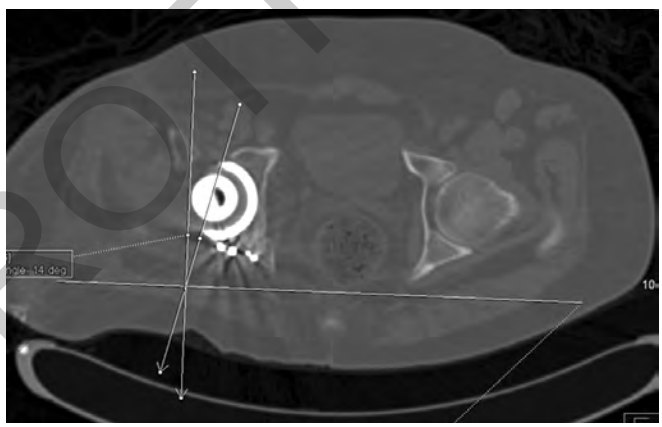


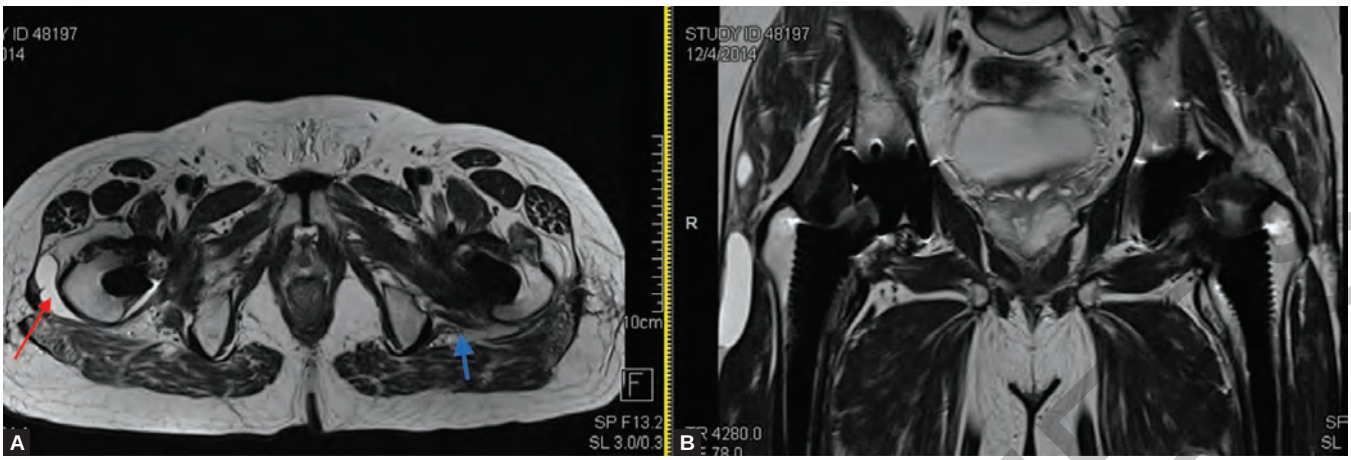
Figure 3.2: Axial CT image showing measurement of acetabular anteversion following total hip arthroplasty

shadows. Other advantages include localization and quantification of acetabular bone loss 57, accurate measurement of acetabular cup anteversion **(Figure 3.2)**. Disadvantages include increased cost, more radiation exposure, and, metal artifacts (modern multidetector CT images have been optimized to reduce metal artifacts either by increasing mAs or by extended CT scale protocol). Dual energy CT (DECT) scans can reduce artefact from the metallic implants and improve the imaging.[5-7]

Magnetic Resonance Imaging

Although conventional radiography and CT are very useful, they have poor soft tissue contrast, spatial resolution and specificity.[8] Advantages of magnetic resonance imaging (MRI) include lack of ionizing radiation, high soft tissue contrast, better delineation of soft tissue collections, and ability to detect early intracapsular particle wear (which precedes osteolysis).[9] Traditional MRI techniques were marred by the presence of metallic artifacts, which interferes with image interpretation.[10] However, recent introduction of metal artifact reduction sequence (MARS) is extremely useful in detection and characterization of the subtle soft-tissue findings.[11] MRI is not frequently used for evaluation of joint replacement complications, however, it is used in some settings such as periprosthetic fluid collections and to check the quality of musculotendineous cuff of the hip **(Figures 3.3A and B)**.[12,13]

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Figures 3.3A and B: Axial and coronal T2W MR images of bilateral THA showing collection around the greater trochanter on right side (red arrow) with intact posterior musculotendinous cuff of hip (blue arrow)



Figure 3.4: Anteroposterior (AP) radiograph demonstrating the green zones used to evaluate the femoral component

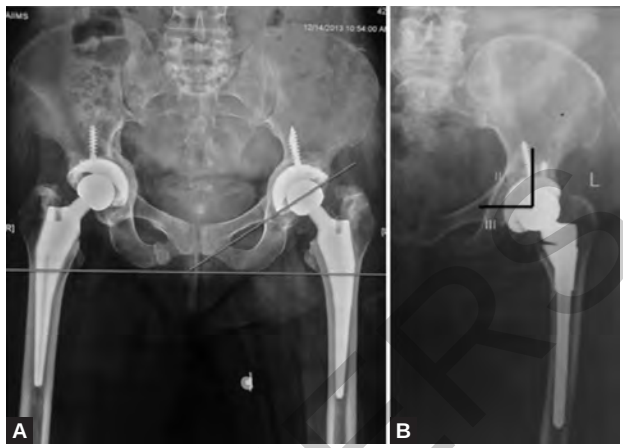
Ultrasonography

Ultrasonography (USG) is not ideally suited to evaluate a total hip replacement complications because of poor visibility. However, it is used as an initial screening tool to identify soft tissue collections, and also helps in guided aspiration of collections around the hip **(Figure 3.4)**.

Radionuclide Imaging

Conventional bone scintigraphy using ^{99m}Tc methylene diphosphonate (MDP), has been used in diagnosis of aseptic loosening and infection **(see Figures 6.9A to C)**. It has high sensitivity but poor specificity. Triple phase scan has been shown to increase the specificity. Sequential progression of uptake in the three phases is considered specific for infection.[14] Increased uptake in the absence of any complication is commonly seen for up to one year after surgery in cemented prostheses, while 10% may show increased uptake beyond one year too. Dual isotope scanning using sequential ^{99m}Tc/67Ga (Gallium Citrate) has been shown to improve diagnostic accuracy in diagnosis of infection.[15] 111-Indium and HMPAO can also be used for dual scanning along with ^{99m}Tc.

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Figures 3.5A and B: Normal acetabular component features. There are three zones numbered lateral to medial (I to III). The acetabular component should be angled (ischial tuberosity line and a line along the component margin) approximately 45 degrees, range 35–55 degrees

NORMAL RADIOGRAPHIC APPEARANCE

Irrespective of the type of implant used (cemented or non-cemented), there are fundamental positioning factors and measurements that can assist as a reference to follow-up patients with THA.

NORMAL FEMORAL COMPONENT

The femoral component can be cemented or uncemented. The stem should be in neutral or slight valgus position in relation to the femoral shaft. When placed in varus position (tip directed laterally), there is a tendency to loosening. The femoral component is divided into 7 zones on the AP and lateral radiographs **(Figure 3.4)**. Each zone of this system should be used to define the findings related to loosening or other complications. The radiographs should include atleast 5 cm beyond the component tip for comprehensive assessment.

NORMAL ACETABULAR COMPONENT

The acetabular component is positioned at angle of around 45 degrees to the ischial tuberosity line on the AP radiograph (range 35–55 degrees) and anteverted 10–20 degrees on the lateral radiograph. Like femoral component, it is divided into three zones on the AP radiograph for evaluation purposes **(Figures 3.5A and B)**. Baseline values are important in identifying potential complications related to the acetabular component during follow-up.

In patients with unipolar or bipolar hip arthroplasty, as there is no acetabular component, the acetabular cartilage thickness (joint space) should be estimated on follow-up images.

Complications

HIP REPLACEMENT COMPLICATIONS AND IMAGING APPROACHES

Table 3.1 shows hip replacement complications and imaging approaches.

Table 3.1: Hip replacement complications and imaging approaches

Complication incidence (%)	*Imaging approach*
Loosening Acetabular (6–28%) Femoral (6–18%)	Serial radiographs, CT
Deep infection (2–3%)	Serial radiographs, nuclear scan, PET, joint aspiration
Dislocation (3–7%)	Serial radiographs
Osteolysis (5–9%)	Serial radiographs, CT
Periprosthetic fractures (1–2%)	Serial radiographs
Heterotopic ossification (8–90%)	Serial radiographs, CT
Pseudotumor (1–69%)	USG, MARS

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MODES OF FAILURE

Aseptic Loosening or Osteolysis[16-19]

Radiolucency at the bone-cement or cement-implant interface in a cemented prosthesis is an indicator of loosening. Loosening is one of the most common complications following THR. Loosening has been reported to occur in 6–18% of femoral components and 6–28% of acetabular components. It is the most common reason for revision surgery. Serial radiographs may be diagnostic **(Tables 3.2 and 3.3)**.

RADIOGRAPHIC FEATURES OF LOOSENING[20,21] (FIGURES 3.6 TO 3.8)

Table 3.2: Femoral component

Cemented	*Noncemented*
• Lucent zones at bone cement or metal-cement interface >2 mm • Progressive widening or irregularity of lucent zone • Component migration especially varus • Cement fracture • Stem fracture	• Lucent zones at metal-bone interface >2 mm or progressing or new 1 mm lucency >2 years after surgery • Progressive subsidence • Migration >2 degrees • Shedding of beads or porous coating material

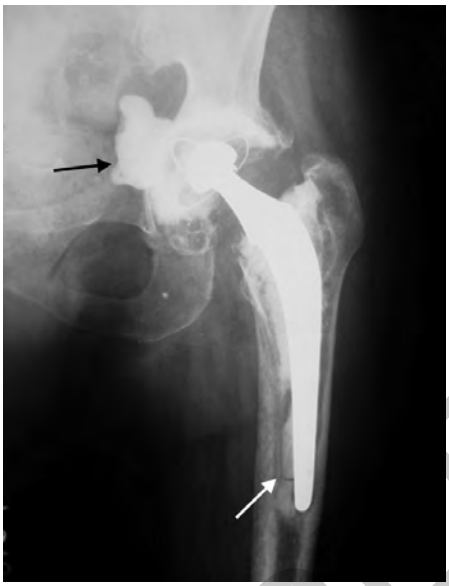
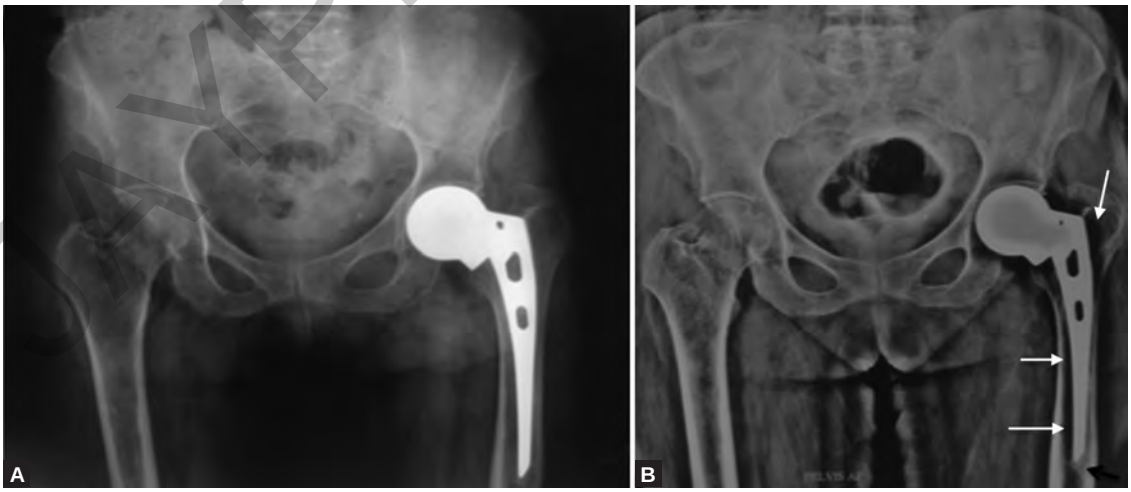
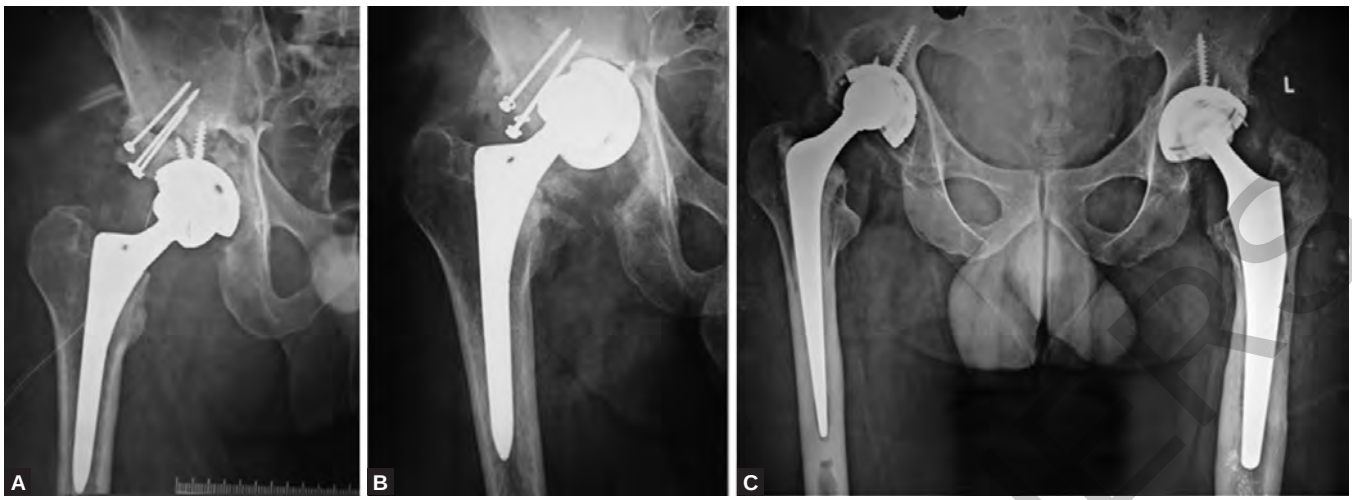


Figure 3.6: AP radiograph of left THA showing loose acetabular and femoral component with, lucent zone II, medial migration of acetabular cement mantle (black arrow) with cement fracture (white arrow) around the cemented femoral stem



Figures 3.7A and B: Serial AP radiographs of left hip hemiarthroplasty showing lucency in zone 1, 5, 6 of femoral stem (white arrow) and and hypertrophy of the lateral cortex (black arrow) at the tip of the stem suggestive of loosening

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Figures 3.8A to C: (A and B) Failure of cementless acetabular component due to inadequate support. Change in position of component is pathognomonic of loosening; (C) Failed cementless acetabular component with big area of osteolysis seen in supra acetabular and infra acetabular regions with ischial lysis and worn out polyethylene

Table 3.3: Acetabular component

Cemented	*Noncemented*
• Lucent zone >2 mm, especially in zone II • Progressive widening of lucent zones • Cement fracture • Migration or acetabular protrusio • Component fracture	• Lucent zones >2 mm or progressing • Component migration • Bead or porous coating shedding

Infection

Infection occurs in 2–3% of hip replacements. Signs of loosening are invariably present. Features on serial radiographs may be helpful; however joint aspiration and culture, are very useful to identify the organism. Localization of the organism is not always possible (28–92% accuracy). Radionuclide studies are useful for confirming infection. Imaging features are also useful. MRI can be very helpful in detecting soft tissue collections in infected cases. Radionuclide scans, although very sensitive for infection are not sensitive and cannot distinguish between septic and aseptic loosening.[22-26]

Radiographic features of infection following THR **(Figures 3.9A and B):**

- Signs of loosening
- Irregular lucency at bone-cement or metal-bone interfaces
- Osteolysis or areas of bone destruction
- Periosteal reaction.

Documented infection requires aggressive treatment consisting of component removal and single or 2-stage reconstruction.

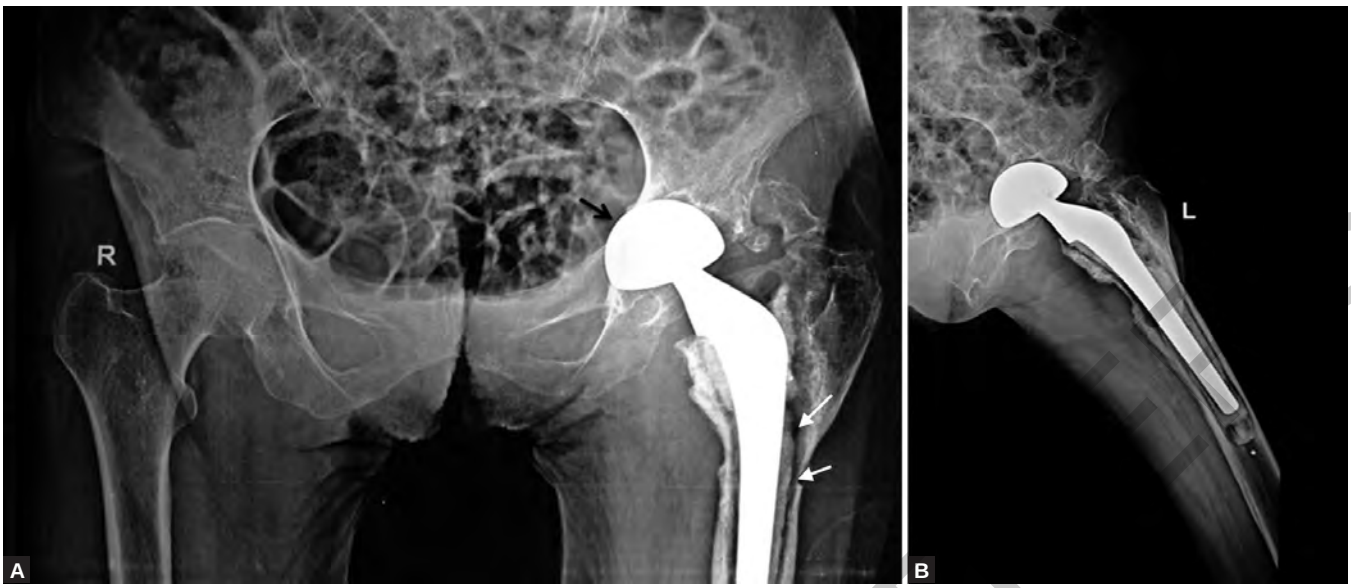
Instability and Dislocation

Dislocation of the femoral component occurs in 3–7% of patients.[27] This is the second most common indication for revision arthroplasty. Most dislocations occur in the early postoperative period during the initial weight bearing.

Risk factors for developing dislocation include:[28]

- Smaller modular heads
- Posterior surgical approach

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Figures 3.9A and B: AP and lateral radiographs of left hip hemiarthroplasty showing features of loosening of a cemented bipolar with complete lucencies around the cement column (white arrow) and cortical erosion. Acetabular bone loss is evident as protrusio (black arrow) due to septic infection



Figures 3.10A to C: Radiographs showing examples of implant dislocation due to (A) Vertically oriented cemented cup; (B) Poor soft tissue tension; (C) Fracture of greater trochanter

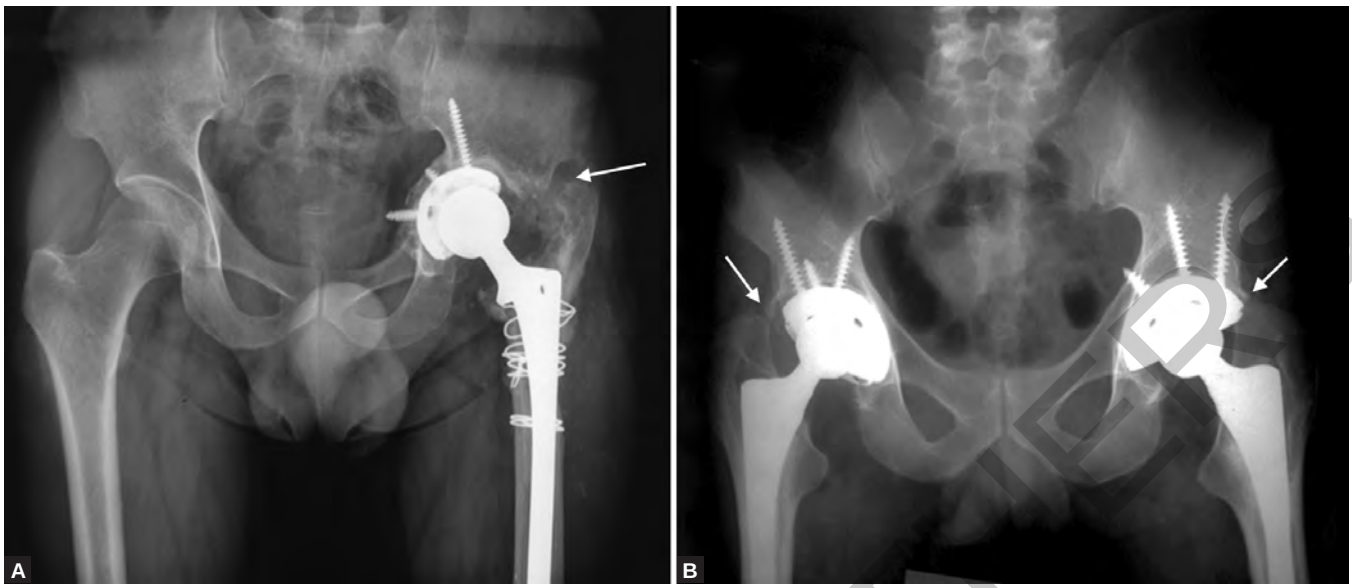
- Older patients
- Greater trochanteric avulsion
- Poor component position.

Dislocation is easily diagnosed on radiographs. Radiographs may show features which lead to an increased risk of dislocation **(Figures 3.10A to C)**. Anteversion of cup is difficult to measure on lateral radiographs, and CT is considered to be a better modality for evaluating acetabular anteversion **(Figure 3.2)**. Excessive anteversion increases the risk of anterior dislocation, whereas an insufficient anteversion or retroversion predisposes to posterior dislocation. Excessive inclination of cup is a risk factor for superior dislocation. Impingement also increases the risk of dislocation **(Figures 3.11A and B)**.

Heterotopic Ossification

Heterotopic new bone formation occurs in 15–50% of patients after hip arthroplasty, but a clinically significant limitation of range of motion is less common (1–5%).[29] Infection,

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Figures 3.11A and B: AP radiographs of THR showing examples of impingement of the greater trochanter (arrows), a significant risk factor for dislocation

post-traumatic arthritis, ankylosing spondylitis, and previous hip surgery are the predisposing factors. CT may be useful if intervention or revision surgery is required.

Preoperative anti-inflammatory medications or low-dose radiation therapy may reduce HO in higher-risk patients. Serial radiographs are adequate for diagnosis and classification.

The radiographic description of heterotopic ossification as described by Brooker on the anteroposterior radiograph on hip **(Figures 3.12A and B)**:[30]

- Grade 0, no heterotopic ossifications (HO)
- Grade 1, one or two foci of heterotopic ossification (HO) 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
- Grade 4, ossification that bridges the pelvis and femur.

Pseudotumor

A complication specific to metal-on-metal bearing as well as metal on polyethylene (trunnionosis), in total hip arthroplasty is the release of large amounts of metal ions. Periprosthetic soft tissue lesions have been described variously as metallosis,[31] aseptic lymphocytic vasculitis associated lesions (ALVAL),[32] adverse reaction to metal debris (ARMD),[33] and pseudotumors.[34]

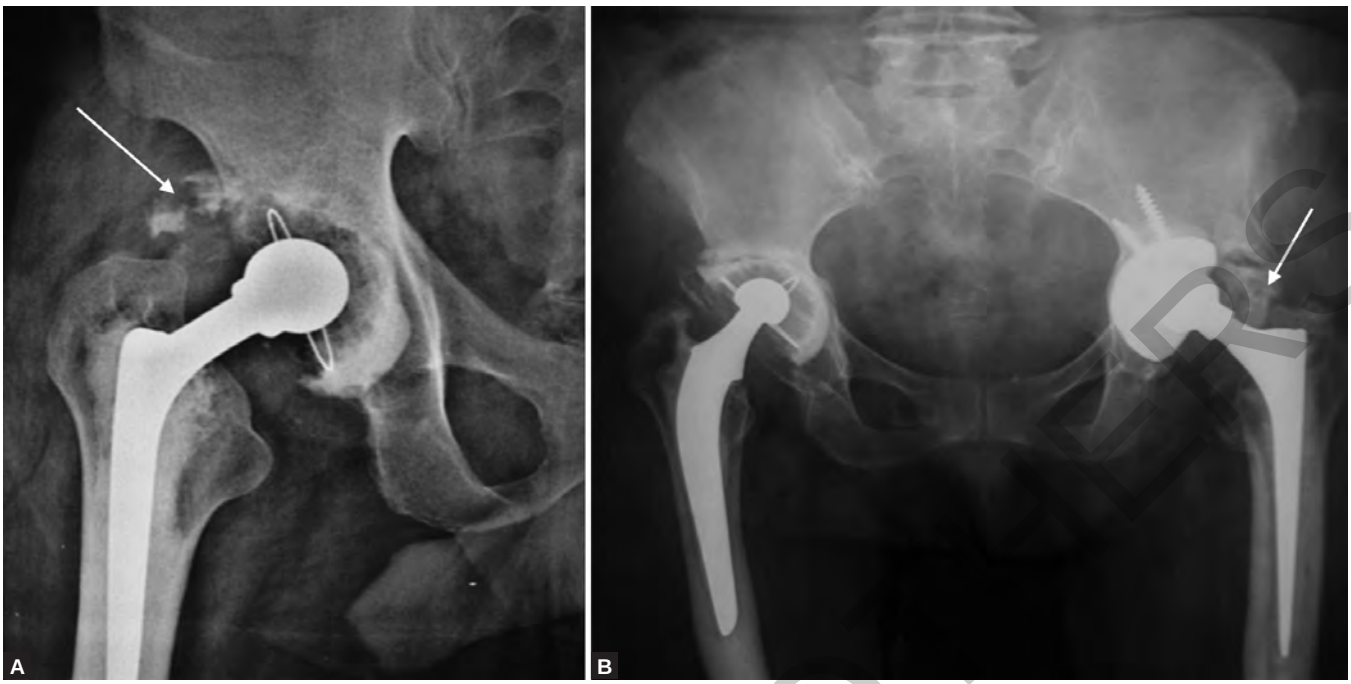
Pseudotumor is described a mass, which may be cystic or solid, and histopathologically it shows aseptic lymphocytic vasculitis and tissue necrosis.[34]

Radiographs are usually unremarkable.[35] Cystic or solid masses can be detected in periprosthetic soft tissue on MRI, CT, and ultrasound. There are three types of pseudotumors based on MRI **(Figures 3.13A and B)**: Type 1 (thin-walled cystic mass with wall < 3 mm); type 2 (thick-walled cystic mass with cyst wall > 3 mm but less than the diameter of the cystic component); and type 3 (predominantly solid mass).[36]

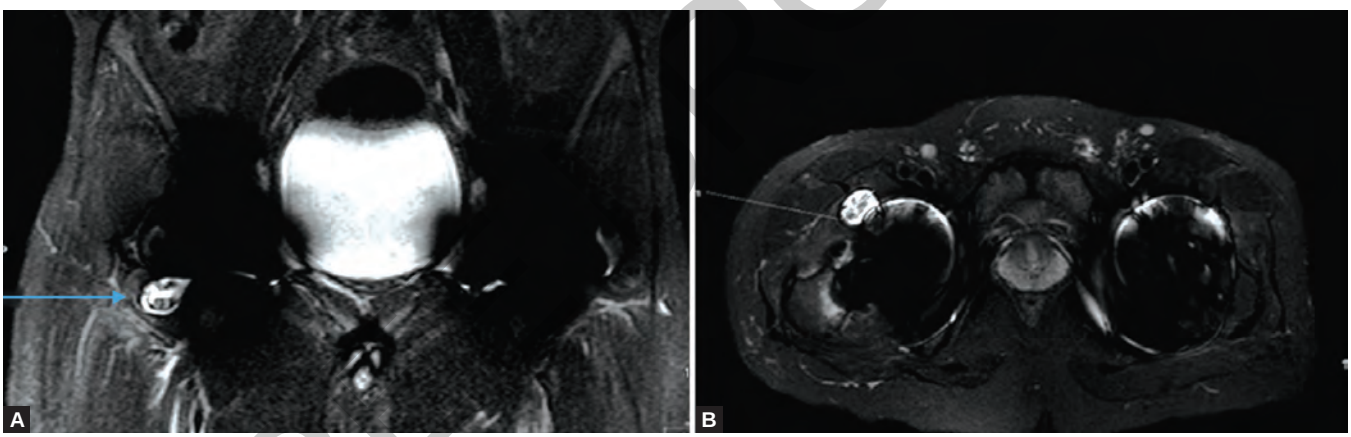
Periprosthetic Fracture

Periprosthetic fractures are more common around the femoral than the acetabular component, occurring in 1–2% of patients. The Vancouver classification (Duncan and Masri),[37] divides fractures into three major types, based on the location of the fracture

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Figures 3.12A and B: AP radiographs of THR showing examples of heterotopic ossification (arrows). (A) Brooker grade 2; (B) Brooker grade 3



Figures 3.13A and B: Coronal and axial MR images showing hyperintense lesion in periposthetic soft tissue suggesting of pseudotumor (arrow)

(Figures 3.14A and B), the amount of available proximal bone stock, and the stability of the stem.

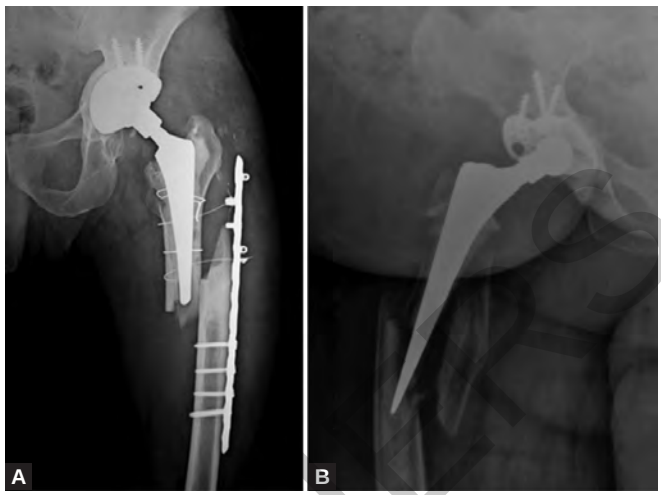
Type A: Fractures around the trochanters (peritrochanteric fractures)
Type B: Fractures occur around or just below the tip of the stem
Type C: Fractures occur so far below the femoral stem.

Intraoperative femoral fractures 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 riser" at this level caused by the difference in stiffness between the metal stem and bony shaft.[38]

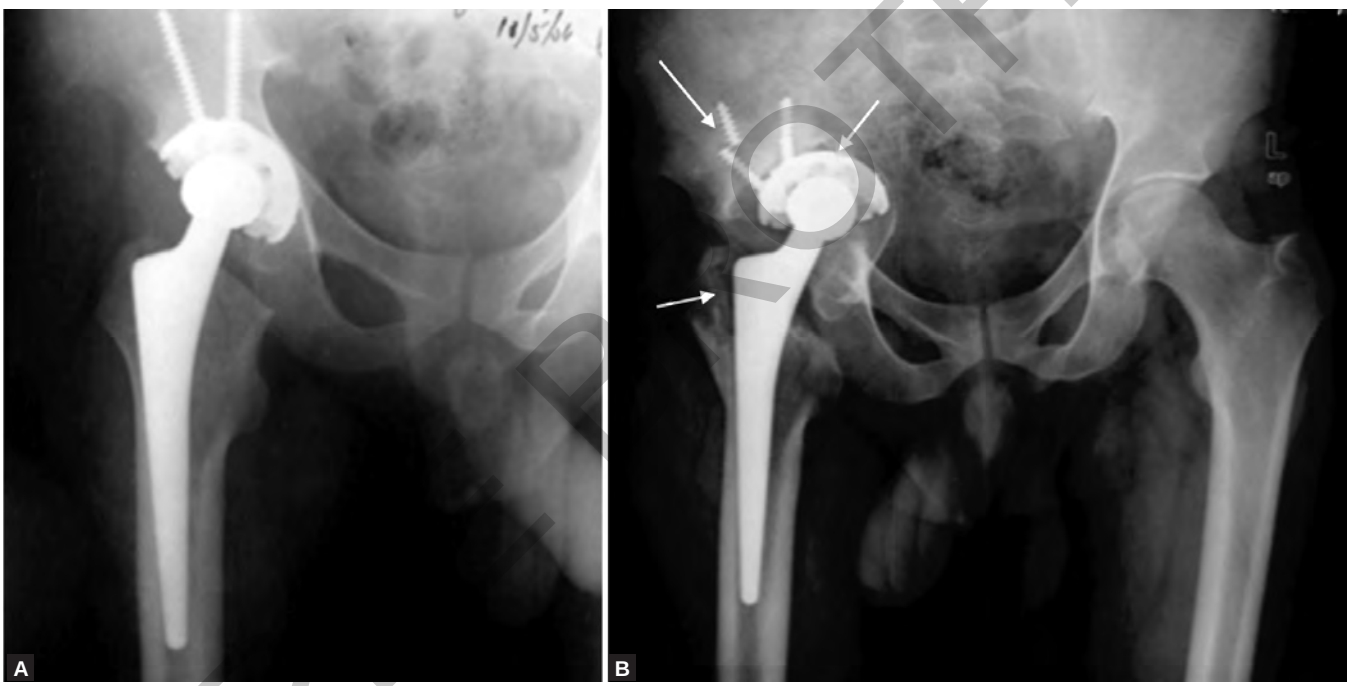
Pelvic Discontinuity

A pelvic discontinuity is an extreme case of bone defect in acetabulum and its preoperative recognition is extremely important to avoid a failed reconstruction. Cardinal signs of

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Figures 3.14A and B: AP radiographs of THA showing examples of type B periprosthetic fractures: (A) Type B periprosthetic fracture with failed internal fixation possibly due to inadequate purchase on the proximal fragment; (B) Type B periprosthetic fracture. Note that the stem is loose and the proximal femoral bone stock is poor



Figures 3.15A and B: Sequential AP radiographs showing development of pelvic discontinuity following the failure of cementless acetabular cup. Note the broken screws, change in position of the cup and severe osteolysis (arrows)

pelvic discontinuity on the recommended radiograph series[39,40] (AP pelvic radiograph, true lateral radiograph and Judet views of acetabulum) are visible fracture line, obturator ring asymmetry, and, medial migration of the inferior hemi pelvis **(Figures 3.15A and B)**. However, preoperative CT with 3D reconstruction helps in recognizing the bone defect of acetabulum prior to THR, if suspected on preliminary radiographs.

Conclusion

Despite the widespread and growing use of MRI, CT, and sonography in imaging the joint, serial radiography is still the mainstay in assessing and diagnosing a failed THA.

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The burgeoning number of hip arthroplasties being performed across the globe have, as a corollary led to an ever-increasing numbers of revision hip arthroplasty. Infection, instability and aseptic loosening continue to haunt us in spite of improvements in materials and techniques. The numbers of revisions remain too high for our comfort. There has been a long-felt need for a book on the techniques of revision hip arthroplasty. This book has managed to bring together a constellation of reputed arthroplasty surgeons from across the world. The book is a narration of their vast experience of managing failed total hip arthroplasties with skill, innovation and ingenuity. This comprehensive compendium will delight readers with easy-to-understand text, abundant illustrations and a variety of approaches to deal with the complex challenge of revising a failed total hip arthroplasty.



Rajesh Malhotra, an Orthopedist of an international reckoning is through and through an AIIMSONIAN excelling both at graduate and postgraduate levels distinguishing himself as a teacher and researcher par excellence. He volunteered to dedicate to the teaching profession to uplift the contemporary status of orthopedics for which he unhesitantly opted to climb up the ladder, crossing innumerable barriers, comprising senior resident, assistant professor, associate professor, additional professor and professor. Ultimately, he was immensely awarded to grace the prestigious Chair of Professor and Head, Department of Orthopedics, All India Institute of Medical Sciences (AIIMS), New Delhi, India.

He had training in 'Revision Joint Replacement and Bone Banking' at the Queensland Bone Bank, Brisbane, Australia. At present, he is Incharge of exclusively running the only functional cadaveric bone bank in India. He has several international publications pertaining to innovative applications of massive musculoskeletal allografts. He is routinely performing complex revisions using massive allografts. He has more than 500 articles to his credit published in national and international journals. He has authored/edited 13 books and contributed 45 chapters in various national and international books. He has delivered nearly 525 invited guest lectures in various national and international conferences. He is also an avid researcher and a popular teacher. He is the Secretary of Regional Fragility Fracture Network (India) and Convenor of the Orthopedic initiative of the Indian Society of Bone and Mineral Research (ISBMR). He is also a Member of several illustrious professional bodies including American Association of Hip and Knee Surgeons (AAHKS).

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