X-ray plays vital role in hip replacement surgery

June 16, 2005
By Pietro Melloni, MD, PhD [1] and Rafael Valls, MD [2]

Hip replacement procedures are becoming increasingly common as the population ages. Degenerative problems remain the main indication for this procedure, although patients with femoral head avascular necrosis, rheumatoid arthritis, complications of fracture, and hip dysplasia may also require hip replacement surgery.

The first hip replacements were performed about 50 years ago. As surgical techniques subsequently evolved, radiological criteria for evaluating prosthesis components and their complications adapted accordingly.

Our hospital has performed more than 200 hip replacements annually over the past 14 years. Surgeons have used a variety of materials to replace the hip joint, including metal, polyethylene, and ceramics. All patients undergo imaging examinations immediately after surgery, at six months, and then yearly or when necessary. This follow-up is most frequently done using plain-film x-rays, occasionally with ultrasound or CT, and, rarely, with MRI.

A retrospective review of 1854 patients (36 to 91 years old; male/female ratio 1:3) who underwent hip arthroplasty at our hospital in an eight-year period revealed that 5.2% experienced acute complications, and 9.2% developed complications later.

The acute complications included infection, cement extrusion, periprosthetic fracture, and immediate dislocation. Late complications, some of which occurred as long as 15 years after surgery, have included aseptic loosening, aggressive granulomatosis, stress shielding, heterotopic ossification, luxation, bone fractures, and prosthetic fracture.

Hip replacements can be cemented at the acetabular and/or femoral stem. Polymethylmethacrylate cement, used for filling the space between the bone and the prosthesis, provides the necessary fixation and force distribution. Cement-free prostheses are coated to provide a porous surface that enables fixation by bone ingrowth. Acetabular fixation may be completed with spikes or screws.

Our standard follow-up imaging evaluation of hip arthroplasty begins with routine plain-film radiography. It is important that the entire prosthesis is included on two orthogonal x-rays. Leg length, acetabular inclination, and varus or valgus stem position should be evaluated and compared with the immediately postoperative study.

Radiography of cemented prostheses will generally show a thin lucent line, less than 2 mm wide, along the cement-bone interface. This is a normal finding that represents fibrous tissue and is stable over time. The line is delimited from adjacent bone by a thin line of sclerosis, the demarcation line.¹ Lucency of 2 mm or more at the bone-ingrowth surface with cement-free arthroplasty is considered abnormal. Lucency that is less than 2 mm in width should be followed on consecutive plain films for progression. Well-defined areas of lucency around the prosthesis usually indicate bone resorption destruction (histiocytic response), but aseptic loosening and infection can demonstrate a similar appearance.²

COMMON COMPLICATIONS
Infection, which occurs in 1% of artificial joint replacements, can be a serious early complication, or it may appear months or even years after surgery. Radiological findings in patients with indolent infection can be unremarkable or show minimal changes,³,⁴ and a normal-appearing radiograph does not exclude infection.⁵

Sinus tract formation or bone destruction may occur with more aggressive infectious agents. Infection may also be present when postoperative imaging shows lytic lesions, progressive interfacial widening, periosteal reaction, or smooth endosteal scalloping with cement lucency, as is typical in aseptic loosening or aggressive granulomatosis disease.

Extensive bone destruction, air in the soft tissue and/or joint, extensive or aggressive periosteal...
reaction, and a wide or irregular lucent zone are the most suspicious radiological signs of infection. CT or ultrasound-guided joint aspiration or synovial biopsy can detect about 75% to 95% of prosthetic infections.\(^6\) Polymethylmethacrylate cement extrusion is another acute complication. It occurs most commonly through a defect in the medial acetabular wall. It is visible on initial radiographs. Intra-pelvic cement is usually asymptomatic.

Intraoperative or acute periprosthetic fracture is a rare complication in primary cemented prostheses, although it is relatively common in the follow-up of failed hip arthroplasty. It is usually found at the tip of the prosthetic stem; the pelvis is a less common location. This type of fracture is usually not displaced and is easily overlooked.

An artificial hip can generally be expected to last 12 to 15 years. In some cases, however, the hip prosthesis will loosen earlier, causing pain and/or instability. Mechanical loosening is the most typical indication for repeat surgery. Although precise definitions of loosening vary, a hip joint is probably loose if imaging shows a radiolucent zone greater than 2 mm wide.\(^7,8\) This zone may involve the prosthesis/bone interface, the cement/bone interface, or the cement/prosthesis interface, depending on the type of arthroplasty.

Definite loosening is diagnosed when a cemented component migrates (intra- or extramedullar) (Figure 1), changes alignment (varus or valgus; especially increasing varus orientation), or shows progressive widening of the radiolucent zone. Comparison between current and previous images is the best way to detect loosening.

Aggressive granulomatosis, also known as particle or cement disease (Figure 2), is caused by macrophage reaction on either the acetabular or femoral side of the arthroplasty. Lesions of aggressive granulomatosis present as extensive areas of radiolucency around the prosthesis, sometimes in association with smooth endosteal scalloping. Infection, which often has more aggressive features, is the main differential diagnosis.\(^2\) The prosthesis may remain stable even when large areas of osteolysis are present.

The presence of a prosthesis alters stress loading on a bone.\(^9\) Prostheses can induce increased bone density at points of contact (called stress shielding) and reduced bone mass and osteoporosis in areas of decreased loading. Localized bone loss typically occurs in the greater trochanter. This phenomenon has not been associated with a predisposition to loosening or prosthesis failure. Heterotopic calcification is relatively common, found in 15% to 50% of cases, and is usually asymptomatic. It can appear a few weeks after surgery and may take two years to mature.\(^7\) The supratrochanteral area between the pelvis and femur is the most common site of heterotopic calcifications. Predisposing factors include infection, ankylosing spondylitis, and previous surgery. Low-dose radiotherapy or indomethacin can prevent its occurrence.

Dislocation or luxation of hip arthroplasties may be caused by a patient's poor muscle tone, subsequent trauma, positional factors such as the patient placing the hip beyond the expected range of motion, or component malpositioning. These complications are more common in revision arthroplasties (patients who have received a replacement implant).

A dislocating hip should be evaluated for acetalabular component malpositioning (retroversion, abnormal lateral opening, or abnormal horizontal center of rotation), and ab-normal leg length due to a misplaced implant. Again, comparison with previous radiographs is helpful.

Bone fractures usually occur in patients with osteoporosis. The most common location is the tip of the stem. Patients may also present with insufficiency fractures due to increased physical activity. Prosthetic component fracture is rare but can occur in cases of severe trauma or metal fatigue. The acetalabular component almost never fractures. The tab used to lock the acetalabular component may be seen, but this does not represent a significant component failure. Fracture of the femoral component, also rare, is usually located in the distal portion of the stem.

Imaging evaluation of painful total joint arthroplasty has traditionally been performed using plain-film radiography, arthrography, and nuclear scintigraphy.\(^10\) All three diagnostic options provide clinical information on the status of the prosthesis, adjacent bone, and surrounding soft tissues, but all are hampered by poor specificity. Plain-film x-rays remain the cornerstone of diagnosis of hip arthroplasty complications, but ultrasound, CT, and MRI can play a complementary role in imaging specific problems that might arise.

An ultrasound examination performed shortly after surgery will show fluid collection corresponding to a hematoma and its delayed resorption. Hematoma of the joint is usually organized within three weeks after the operation. It can be visualized in all patients as a homogeneous region with a slightly echogenic appearance. It is not clearly distinguishable from surrounding tissue and is not compressible. Areas of low echogenicity are rarely seen. It is not possible to distinguish hematoma
from infection on ultrasound; percutaneous aspiration is necessary if clinical suspicion of infection is high (Figure 3).

CT is usually used to confirm prosthesis osteointegration (Figure 4A). We use different CT slices of the total hip prosthesis to analyze prosthesis osteointegration in the femur. CT can also help confirm radiologic suspicions of intraosseous lesions that are difficult to appreciate on plain-film x-ray (Figure 4B). Artifacts from metallic prostheses can be significantly minimized by using a multislice scanner and evaluating surrounding soft-tissue abnormalities immediately adjacent to the prosthesis. Plain-film x-ray nonetheless remains the primary method of evaluating the prosthesis and adjacent osseous structures.

MRI with optimized pulse sequences to reduce artifacts generated by the arthroplasty can provide clinically relevant information on the prosthesis and surrounding bone, soft tissue, and neurovascular structures, particularly around the femoral prosthetic stem (Figure 5).

Diagnostic-quality MRI of hip arthroplasty complications requires only simple modifications to standard MR sequences. MR image quality may improve with the advent of new materials for prostheses and alternative pulse sequences that avoid artifacts.

Careful attention to initial prosthesis placement and comparison of follow-up x-ray images enables detection of subtle abnormalities in patients with painful hip arthroplasties. Ultrasound, CT, and MRI each furnish clinical information on the status of the prosthesis, adjacent bone, and surrounding soft tissue to complement plain-film radiographs.

Ultrasound may have a special role in the evaluation of soft-tissue abscesses or fluid collections, and it is useful for guiding percutaneous aspiration of soft-tissue collections. The main advantage of ultrasound over CT and MRI is the lack of artifacts caused by metallic prostheses. But the modality is unable to evaluate deep soft-tissue structures farther away from prostheses. CT can best assess the osteointegration of hip prostheses, while MRI may help identify hip arthroplasty complications.

References
Links: