A Review Paper

Surgical Challenges in Complex Primary Total Hip Arthroplasty

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Abstract

Complex primary total hip arthroplasty (THA) is defined as primary THA in patients with compromised bony or soft-tissue states, including but not limited to dysplastic hip, ankylosed hip, prior hip fracture, protrusio acetabuli, certain neuromuscular conditions, skeletal dysplasia, and previous bony procedures about the hip. Intraoperatively, provisions must be made for the possible use of modular implants and/or bone grafts. In this article, we review the principles of preoperative, intraoperative, and postoperative management of patients requiring a complex primary THA.

U.S. surgeons annually perform more than 150,000 total hip arthroplasties (THAs), 90% of which are primary procedures.[1] Improved surgical technique and instrumentation have expanded the clinical indications for THA to include patients who previously would not have been considered eligible for this procedure. Such complex cases, which often require modular implants[2] and/or bone grafting similar to that used in revision arthroplasty, fall into the categories of dysplastic hip, ankylosed hip, fractures about the hip, protrusio acetabuli, neuromuscular conditions, skeletal dysplasias, and previous bony procedures about the hip.

Indications for complex THA include pain not relieved with conservative treatment and functional impairment with radiographic evidence of hip degeneration. Contraindications include active sepsis and major medical comorbidities. Preoperative range of motion (ROM) should be assessed, the Thomas test should be used to determine presence of flexion contracture, and limb-length discrepancy should be documented with the patient in the supine and upright positions (with use of blocks for standing, allowing the extent of limb-length correction to be estimated).[3]

Standard anteroposterior (AP) and lateral x-rays of the hips should reveal underlying hip pathology and facilitate surgical planning and component templating (Figure 1).[4] Special imaging modalities, including computed tomography (CT) of the hip, may be useful in complex hip arthroplasty. CT provides 3-dimensional information about anterior and posterior column deficiencies, socket size, and thickness of the anterior and posterior walls and allows visualization of the external iliac vessels to ensure

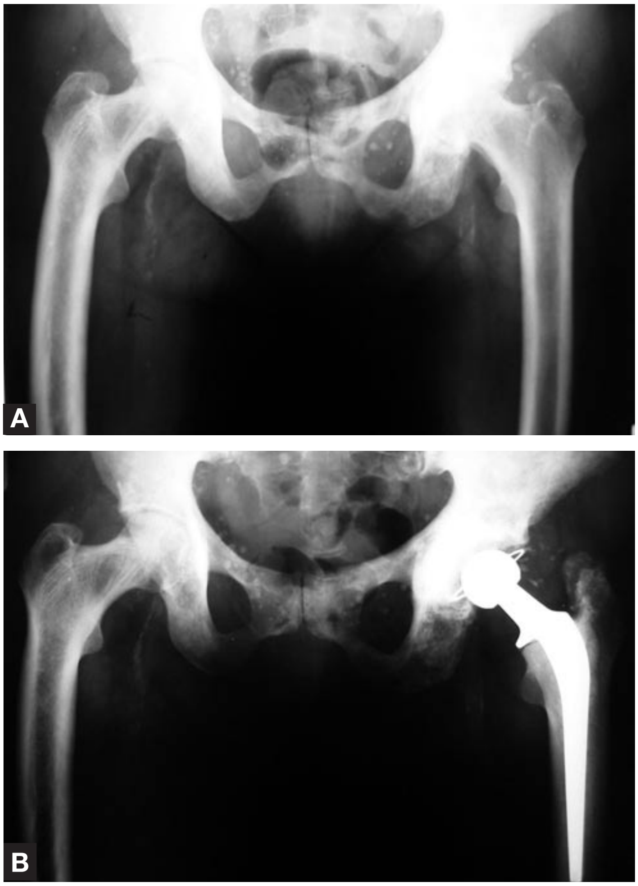

Figure 1. Preoperative **(A)** and postoperative **(B)** anteroposterior x-rays of a 68-year-old woman with Paget disease who presented with radiodense sclerotic acetabular bone requiring cementing of the acetabular liner to achieve good fixation.

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Am J Orthop. 2007;36(10):534-541.

that they can be avoided during placement of anchorage screws for autograft.[5]

Challenges in clinical evaluation and surgical intervention vary according to disease entity. We describe these challenges in the following sections.

Hip Dysplasia

Hip dysplasia is the most common cause of secondary osteoarthritic degeneration of the hip.[6] Although developmental dysplasia of the hip (DDH) is the predominant type, other conditions are associated with similar findings, such as Perthes disease and neuromuscular diseases.[7] In the initial phases of hip dysplasia, pelvic osteotomies[7] may obviate or delay the need for hip arthroplasty, though later degeneration of the hip warrants consideration for THA. On the basis of disease severity, anatomical aberrations determine the complexity of the arthroplasty procedure.[8] The dysplastic hip is characterized by these features[9-11]:

•There may be significant femoral head subluxation, with the head articulating with a false acetabulum instead of the true acetabulum.

•The true acetabulum is often porotic, triangular, and shallow, with a thick posterior ischial wall and thin anterior acetabular walls.

•The true acetabulum can be distinguished from the false acetabulum by presence of a fibrofatty pulvinar and presence of a capsular attachment at its rim.

•The neurovascular structural anatomy is often altered but not usually shortened.

•There is accentuated femoral neck anteversion.

•The proximal femur is hypoplastic, with a stenotic medullary canal.

•The greater trochanter is posteriorly oriented, which compromises the abductor lever arm.

Crowe and colleagues[12] classified hip dysplasias by quantifying the acetabular deficiency into 4 subtypes. The hip is categorized as subluxed if the medial head–neck junction distance referenced off the interteardrop line is at least 10% of the measured height of the pelvis on the AP x-ray of the pelvis and is quantified as follows:

Group	Subluxation
I	<50%
II	50% to 75%
III	75% to 100%
IV	>100%

An alternative classification scheme is based on the position of the femoral head in relation to the acetabulum.[11,13,14] The 3 types of hip dysplasia are:

Dysplasia. The femoral head has relative articulation with the native (true) acetabulum, despite subluxation.

Low dislocation. The femoral head articulates with a false acetabulum, which partially overlaps the true acetabulum.

High dislocation. The femoral head migrates superiorly and posteriorly and articulates only with the false acetabulum.

Given the complexity in operating on Crowe group IV/high-dislocation hips and the increased likelihood of failure, Charnley and Feagin[15] recommended against reconstruction in these cases. Modern implants, we believe, make this recommendation no longer applicable. We prefer a surgical technique that uses a transverse osteotomy for subtrochanteric femoral shortening and derotation for high-riding developmental dislocation as it reduces the complexity of the acetabular and femoral reconstruction.[16]

Other surgeons prefer the transtrochanteric approach, which not only reduces the complexity of the acetabular and femoral reconstruction but facilitates tensioning the abductors to improve stability at the end of the procedure by advancing it distally and laterally.[9,11] Trochanteric migration has not been associated with an increased dislocation rate.[11]

The longevity of a THA performed for dysplastic hips is determined by how closely a near-restoration of normal anatomy with stable fixation of the components is achieved.[17] By approximating the site of the native acetabulum (inferior, medial, and anterior), the joint reaction forces decrease, and improved survivorship of acetabular components results.[18-24] During medialization, we direct the reamer posteromedially to prevent destruction of the deficient anterior wall.[9,17] The thin anterior wall increases the tendency to position the cup in excessive anteversion, which can increase the anterior dislocation rate, especially if the femoral component is also placed in excessive anteversion.[9] Some investigators have suggested that medialization can be achieved by performing a type of acetabuloplasty called cotyloplasty.[11,13] Cotyloplasty involves creating a controlled fracture of the medial wall, augmenting with autogenous bone graft, and then cementing a small acetabular component onto the deepened acetabular cavity.

In some cases, acetabular deficiency leads to exposure of the superior portion of the acetabular component and a resulting need for bone graft augmentation.[5,15,25] Rim augmentation can be performed with femoral head autograft or allograft, thereby eliminating the segmental defect and restoring bone stock for future revision surgery.[10,17,26] Any peripheral segmental bone defects can be converted to contained defects using metal meshes with bone grafts with cemented cups.[17] After anchorage of the bone graft, any gap between the ilium and the bone graft can be packed with morselized bone graft to augment bony union.[5,25] Histologic studies after impaction bone grafting of the acetabulum in revision arthroplasty reveal neovascularization of the bone graft with eventual bone incorporation.[26,27] Failure of bony incorporation with resorption, however, leads to cup failure.[28-30] Moreover, some authors have reported that, even with bony union, these cemented cups tend to loosen and fail.[31] Failure of the acetabular sockets is correlated with younger age and increased cup coverage by the graft. As patients with DDH are more likely to require revision arthroplasty, we prefer using uncemented acetabular implants.

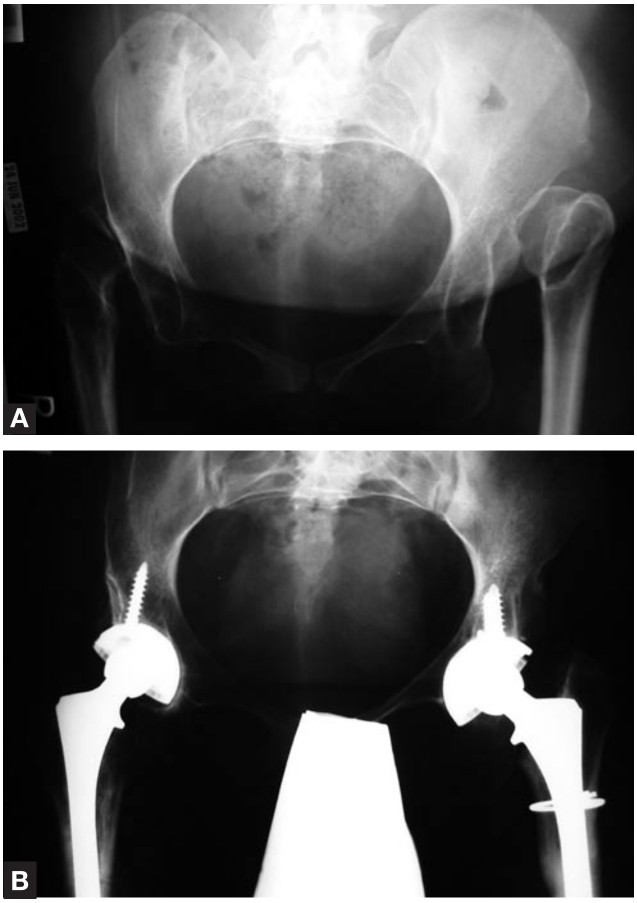

Figure 2. **Preoperative (A) and postoperative (B) anteroposterior x-rays of a 29-year-old woman who presented with bilateral severe dysplastic hips (Crowe type IV) and underwent a staged bilateral total hip arthroplasty. Subtrochanteric osteotomies were performed to prevent proximal femoral migration.**

In high dislocations of the hip, there is significant affected-side limb shortening associated with extensive soft-tissue contracture. It has been suggested that up to 7 cm of lengthening can be achieved if the entire capsule and all osteophytes and shelves are excised, the iliopsoas tendon is released, and the intraoperative assessment of sciatic nerve tension is not excessive.[10] To avoid problems, however, we prefer to keep limb lengthening within 2 to 4 cm.[10,32-34] In some instances, hip reduction after arthroplasty may be impossible, and a femoral diaphyseal shortening osteotomy or a femoral neck shortening is required (Figure 2).[10,11,16,32,35]

In rare situations, it may not be possible to restore the hip to its anatomical center; consideration should then be given to adopting a high hip center, as it reduces the complexity of the surgical procedure, the need for bulk femoral grafts, and the risk for overtensioning the sciatic nerve.[25,36] At our institution, we favor restoring the native hip center of rotation[11,17,25] for these reasons:

•In a high hip center, the lever arm of body weight is greater than the abductor lever arm, resulting in increased force on the hip joint, which can lead to progressive loosening of the acetabular component.[18,37]

Figure 3. **Anteroposterior x-ray of a 42-year-old woman who presented with severe developmental dysplasia of the hip and a significantly anteverted femoral neck. A modular S-ROM total hip system (DePuy Orthopaedics, Warsaw, Indiana) was used to restore hip mechanics.**

•Shear forces associated with a high hip center increase the rate of acetabular component loosening.[19,38-43]

•Quality of bone stock is lower in the high hip center than in the native acetabulum. Destruction of this bone stock can make later revision more difficult.[25]

•A high hip center is associated with insufficiency of the abductors, limping, and persistent limb-length discrepancy. Restoration of limb length requires a long-neck component or even a skirted head. These components can be associated with impingement, leading to dislocation.[44-46]

•A high hip center increases valgus deformity in the knee, correction of which requires a long femoral neck.[10]

Postoperative neurologic complications are a significant concern with arthroplasty in the dysplastic hip, but they can be avoided with meticulous surgical technique and adequate postoperative care.[13,47] Intraoperatively, one needs to be aware of the neural anatomy about the hip in order to carefully position retractors. Furthermore, tension in the sciatic nerve can be minimized by placing the hip and knee in flexion for the first 3 to 4 postoperative days.[10,11]

In developmental hip disease, especially in the high-dislocation group, the femoral diaphysis is particularly narrow, which may necessitate use of small components, sometimes even custom components.[9,48] Often, the failure rate is higher on the femoral side in these hips (Figure 3).[11] The abnormal proximal femoral anatomy also lends itself to an increased risk for intraoperative fractures.[32]

For DDH, overall outcome after hip arthroplasty is determined by disease severity at presentation.[49,50] Hip arthroplasty in DDH is associated with reduction in pain (in the hip, lumbosacral spine, and knee), improved hip function, and correction of static body balance.[10] Mean rate of polyethylene wear has been reported to be approximately 0.11 mm/y in patients with DDH.[51] Because of the hypoplastic acetabulum, component loosening with later need for revision has been reported in up to 43% of cases.[9] The 15-year survival rate of components ranges from 67% to 94%[11]; one author cited a 20-year survival rate of 78%.[10]

Hip Ankylosis

Ankylosis of the hip can occur spontaneously or be acquired surgically. Spontaneous and surgical fusions present different operative challenges during THA, as both retained hardware and anatomical deformity of the proximal femur increase the complexity of the procedure. Historical and current indications for surgical hip fusion include Legg-Calve-Perthes disease, congenital dysplasia of the hip, slipped capital femoral epiphysis, juvenile rheumatoid arthritis, significant degenerative changes in a young patient, recurrent hip infections, and tumor resection.[52,53] Spontaneous hip fusion has been associated with tuberculous and pyogenic arthritis, osteoarthritis, trauma, inflammatory arthritis, and ankylosing spondylitis.[52-55]

In general, a fused hip is painless and, if in a functional position, provides a stable platform for ambulation.[56,57] Fusion takedown and conversion to a THA may be indicated to facilitate sitting or for unrelenting back and knee pain, inability to perform functional activities (driving, work), or nonunion or malunion of fusion.[52,53,58]

Preoperative evaluation should include assessment of the degree of limb shortening, deformity, presence of a joint line, need to remove fusion hardware, presence of a greater trochanter, and hip abductor function as indicated by muscular contraction.[52,54,56,59,60] Electromyography[57,59] or magnetic resonance imaging (Figure 4) may be necessary to confirm the adequacy of hip abductor innervation.

Surgical exposure is difficult because of loss of hip ROM. Although some authors have described using a posterolateral approach[61,62] and an anterolateral approach,[57] at our institution we prefer a direct lateral approach.[52,54,56,63] The crucial step in the procedure is identification of the surgical landmark—that is, the vastus tubercle. The latter ridge marks the distal limit for performing a standard trochanteric osteotomy, which increases hip exposure.

An in situ femoral neck osteotomy is performed by angling the saw blade in line with the native acetabulum and leaving sufficient quantity of bone in the ilium.[8] Culture specimens should be taken to rule out infection in cases of previous infection.[52,56] The true acetabular cavity can be identified by triangulating the 3 vital surgical landmarks: the obturator foramen inferiorly, the sciatic notch posteriorly, and the pubic bone or anterior inferior iliac spine anteriorly.[61] Intraoperative x-rays taken with an inferior acetabular retractor in the estimated position of the inferior landmark can confirm the position before reaming. During reaming, identification of pulvinar-like tissue in the inferior acetabulum is a good indication of the correct position. Nevertheless, the true position of anteversion and abduction of the cup may be skewed because of overall abnormal pelvic fixed abnormalities. If this aberrant anatomy is not appreciated, excessive cup anteversion with anterior dislocation of the cup may occur.

Femoral canal preparation can be challenging because of abnormal proximal femoral anatomy with a sclerotic femoral canal. One must be prepared to use modular implants to accommodate anatomical deficiencies or abnormalities.

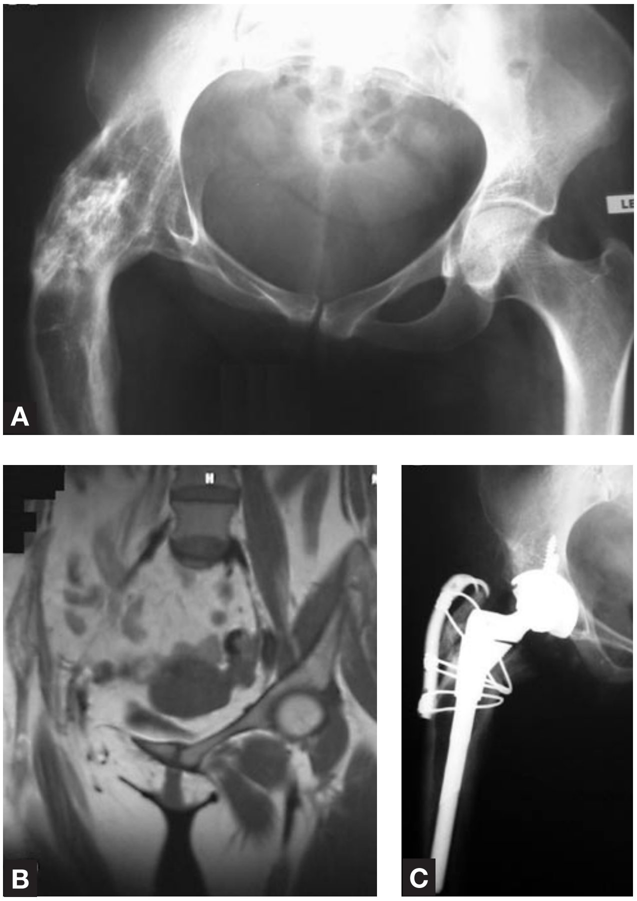

Figure 4. **(A)** Anteroposterior x-ray of a 34-year-old woman with a surgical fusion of the hip performed 15 years previously for recurrent tuberculous arthritis of the right hip. **(B)** Given the patient's symptoms of back pain and functional activity restriction attributable to the fused right hip, total hip arthroplasty was indicated. This magnetic resonance image was obtained to evaluate the hip abductors, which were noted to be attached to the greater trochanter. **(C)** Anteroposterior x-ray obtained after total hip arthroplasty with transtrochanteric approach and modular implants shows satisfactory outcome.

Some authors have suggested using antibiotic-impregnated cement for both components to decrease risk for infection,[53,54] but others have reported no significant difference with use of cemented and cementless techniques in this category of patients.[61] After femoral and acetabular preparation, assessment with trial components should be done. If there is difficulty in reduction, or if the trochanteric fragment cannot be reduced at an abduction angle of <25°, the hip abductors must be adequately released from the iliac wing, and consideration may have to be given to revising the femoral osteotomy.[56] Other authors have recommended avoiding elevation of the abductor mass from the iliac wing to prevent vascular injury and eventual scarring.[60]

After completion of the THA, we typically perform a percutaneous adductor tenotomy if the abduction angle is limited (<30°).[54] The postoperative regimen is dictated by the quality of the osteotomized trochanteric fragment and the hip abductor muscle. For cases involving a small osteotomized fragment or thin and fibrotic abductor musculature, one author recommended immobilization in abduction for 2 to 3 weeks after surgery.[54] Use of indomethacin is often suggested as prophylaxis against heterotopic ossification, which is notably higher in this group of patients.[53,54,56,59,60,62,64] When using indomethacin, one must be aware that incorporation of bone grafts can be compromised because of its effects on bone metabolism.[65,66] For patients who cannot tolerate the indomethacin regimen, a single dose of 700- to 800-cGy radiation therapy on postoperative day 1 can provide adequate heterotopic ossification prophylaxis.

Patients who have had spontaneous fusion or an arthrodesis after age 15 generally have a good outcome after hip arthroplasty.[52-54] In contrast, for patients who have had arthrodesis before puberty or have underdevelopment of the hip and greater trochanter, results are poor, secondary to a lack of abductor mechanism development.[54,63] Outcomes associated with patient satisfaction after this procedure include back pain relief, increased hip ROM, and improvement in limb-length discrepancy.[54,56,60] Satisfactory postoperative walking ability depends on the presence of grade 3/5 gluteal musculature strength, restoration of normal hip biomechanics, and continued physical therapy.[56,64] In these patients, the complication rate for hip arthroplasty is significantly higher than for routine THA—as high as 48%.[53,60,62] Complications include deep vein thrombosis, heterotopic ossification, infection, nerve palsy, perforation of the posterior shaft of the femur, failure of trochanteric fixation, dislocation, accelerated polyethylene wear, and, most commonly, aseptic loosening of the femoral component.[54,56,58,61,67] In a large series, Joshi and colleagues[54] reported 72.8% survivorship at 26 years.

Hip Fractures

Hip fracture configurations vary according to the energy of transferred force and patient age. Only cases with acetabular fractures would be considered complex primary hip arthroplasty. Whereas in young adults fractures are most often associated with high-energy trauma, fractures in the elderly can occur with minor trauma, such as when a patient with osteoporosis falls from a standing height. The prognosis is often poor for certain injury patterns and in patients with osteopenic bone.[68,69] At our institution, we consider THA a viable form of treatment for specific patients with specific fracture patterns.[70]

Bellabarba and colleagues[71] reviewed patients who underwent THA after previous closed management of displaced acetabular fractures. The intermediate-term clinical results of THAs for posttraumatic arthritis were similar to those for nontraumatic arthritis (Figure 5). Arthroplasties after open reduction and internal fixation (ORIF), however, were associated with significantly longer procedures, need for hardware removal, more blood loss, presence of heterotopic ossification, and increased risk for infection.[72,73] The indications for acute arthroplasty are intra-articular comminution, full-thickness abrasive loss of the articular cartilage, impaction of the femoral head, and impaction of an acetabulum that involves >40% of the joint surface and/or the weight-bearing region.[74] McKinley and Robinson[75] concluded that primary arthroplasty is the definitive treatment in the elderly population, as initial ORIF is likely to compromise a later salvage THA by disturbing the blood supply to surrounding soft tissues and initiating scar tissue and heterotopic bone formation. Patients who underwent THA after failed ORIF had more complications (particularly, increased superficial infections and dislocations), higher revision rates, worse prosthetic survival rates, and worse functional outcomes.

Figure 5. Anteroposterior x-ray of a 47-year-old woman who underwent total hip arthroplasty 2 years after being treated with open reduction and internal fixation for an acetabular fracture (from a motor vehicle accident) that had progressed to degenerative arthritis. Two screws encountered during reaming were removed; the rest of the original hardware was not removed because it was not hindering the surgical procedure.

The exact surgical approach may have to be modified according to fracture configuration. For acetabular fractures, consideration should be given to reducing the acetabular fragments in which fracture fixation is accomplished using cables and multiple screws based on standard AO principles (Arbeitsgemeinschaft für Osteosynthesefragen).[74,76] For posterior wall fractures with a bony defect of >40%, a structural allograft should be used. Failure to recognize these posterior wall deficiencies increases the likelihood of placing the acetabular components in retroversion, thereby increasing the risk for later dislocation.[8] Adequate reduction of central protrusion helps to avoid excessive cup medialiazation.[74]

Protrusio Acetabuli

There are 2 main types of protrusio acetabuli[8]:

Primary. Arthrokatadysis, which affects young women mainly.

Figure 6. Anteroposterior x-ray of a 50-year-old woman shows bilateral acetabular protrusio with rheumatoid arthritis. The breach in Kohler's line is distinct.

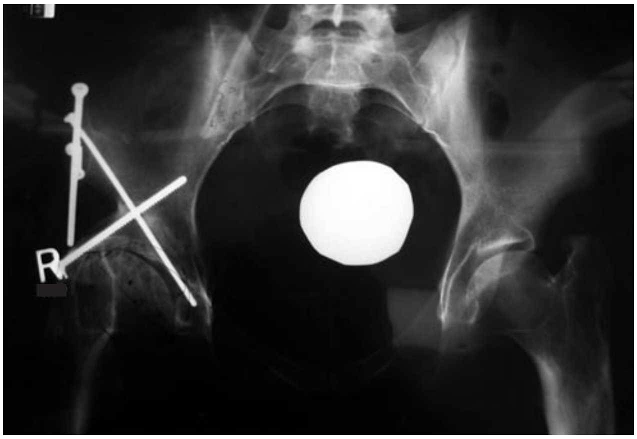

Figure 7. Anteroposterior x-ray of a 27-year-old woman who had realignment osteotomy for developmental dysplasia of the hip at age 11 and was now presenting with degenerative arthritis of the right hip.

Secondary. Central fracture dislocation of acetabulum, Paget disease, Marfan syndrome, rheumatoid arthritis, ankylosing spondylitis, osteomalacia, sickle cell disease (Figure 6).[77-79]

Although the cause of protrusio may be obvious in trauma, in other conditions certain mechanisms have been proposed. In sickle cell disease, protrusio acetabuli has been attributed to pelvic marrow hyperplasia that weakens the bone, leading to a discontinuity in the Kohler line.[77,78]

The technical principles to consider when performing THA in these patients include:

- The hip dislocation may be difficult and thus necessitate an in situ femoral neck osteotomy.
- The hip center should be restored to within 10 mm of its anatomical location for improved cup survivorship.[80]
- Medialization should be avoided and reaming limited primarily to the periphery of the acetabulum.
- Peripheral rim support should be maintained when a cementless acetabular cup is used.
- The cavitary defect behind the cup should be augmented with particulate cancellous bone graft and impaction grafting techniques.[81]
- Excessive limb-lengthening may be avoided by doing a low femoral neck resection and using components with increased medial offset.[8]

Outcomes of cemented primary THAs in patients with protrusio acetabuli have been shown to be similar to those of cementless primary THAs at a mean follow-up 60 months.[82]

Neuromuscular Conditions

Patients with neuromuscular conditions can be divided into those with decreased muscle tone (eg, poliomyelitis, Down syndrome, myelomeningocele) and those with increased muscle tone (eg, cerebral palsy, Parkinson disease, stroke).[83] Patients with these conditions may require THA because of subsequent hip dysplasia attributable to abnormal neuromuscular tone or progressive degenerative changes.

Patients with Down syndrome represent a significant percentage of cases of hip dysplasia, and their management is similar to that of patients with DDH. In general, relative lack of muscle tone rules out hip arthroplasty in patients with myelomeningocele[84] and leads to poor outcomes in patients with a history of poliomyelitis, though use of constrained liners may allow successful hip replacement in selected cases. Patients with cerebral palsy develop progressive femoral head subluxation caused by muscular imbalance, spasticity, soft-tissue contractures, coxa valga, accentuated femoral anteversion, and increased acetabular index. One often needs to perform adductor tenotomies and use hip spicas after surgery.[83,85]

Pain relief and functional improvement can be expected in the majority of patients with neuromuscular conditions in general and cerebral palsy specifically.[83,86] As the functional demands of patients with cerebral palsy are low, prosthesis survival can be as high as 95% at 10 years; however, because of spasticity and muscular imbalances there is a high rate of dislocation.[86]

Skeletal Dysplasias

Being of short stature and having significant joint deformities predispose patients with skeletal dysplasia to accelerated degenerative changes about the hip.[87] Patients often have degenerative changes in multiple joints, including the spine, and therefore a diagnostic fluoroscopy-guided local anesthetic injection into the hip joint may be needed to differentiate hip pain from spine pain.[87,88] The small osseous anatomy with periarticular deformity necessitates careful preoperative planning with appropriate implant selection and possibly a modular or custom prosthesis. These patients have a higher predisposition to cervical spinal instability and may require fiber-optic intubation if general anesthesia is used.[87,89] The revision rate in these patients is particularly high (29%) because of aseptic loosening of the cup and/or stem, periprosthetic fracture, infection, and/or extensive osteolysis.[87,90]

Previous Orthopedic Procedures About the Hip

Patients with early degenerative diseases about the hip may have undergone offloading procedures, such as a periacetabular osteotomy (Figure 7). Disease progression and abnormal biomechanics about the hip joint may result in degenerative changes requiring THA. The basic principles of hip arthroplasty apply, with these additional considerations:

•In situ hardware should be assessed during preoperative planning. If the hardware interferes with preparation of the acetabulum and/or femur, one can consider proceeding in 2 stages: an initial first stage to remove hardware followed by a period of approximately 3 months to allow for bony union and soft-tissue healing before performing the definitive procedure.

•Careful preoperative templating should be done to assess the need for a corrective proximal femoral osteotomy and determine the angle of correction.[91]

•Use of hand reamers to identify the small femoral canal can be difficult because of sclerotic bone, which requires use of small drill bits, high-speed burrs, and guidance by image intensifiers. These measures also reduce the risk for femoral perforation and femoral fractures.

•Distorted anatomy increases the risk for implant malposition, with a high probability for intraoperative technical difficulties.[92]

•Correction of metaphyseal-diaphyseal angular and translational deformities can often be achieved with a step-cut proximal femoral osteotomy with fixation obtained using fully porous-coated modular implants. The osteotomy is generally located at the apex of the deformity.[91,93]

Mean time to union at the osteotomy site is approximately 30 weeks, and use of offloading braces or hip spicas is advocated with progressive weight-bearing on the basis of serial radiologic reviews.[91] Peters and colleagues[93] reported that, in patients with previous triple innominate osteotomy who then underwent THA, functional results were generally inferior, even though radiologic outcomes were good. THA performed with concurrent proximal femoral osteotomy is associated with increased rates of intraoperative fracture, dislocation, nonunion of osteotomy, aseptic loosening of components, and infection.[91-94]

Summary

With improvements in instrumentation, implant material properties, and surgical techniques, the indications for primary THA have expanded. Nevertheless, in complex cases, both surgical exposure and subsequent placement of components can be significant challenges. Results depend on multiple factors, including age at presentation, disease pathology, and overall bone and/or soft-tissue deficiencies. With proper surgical technique, good to excellent results can be expected, though outcomes are still inferior to those of uncomplicated primary THAs.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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