How Do I Get Out of This Jam? Overcoming Common Intraoperative Problems in Primary Total Hip Arthroplasty

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Abstract
Prompt attention is typically required in managing intraoperative problems associated with total hip arthroplasty. There is often limited time for consultation or a review of the literature. The treating surgeon should be familiar with treatment options, favored treatment methods, and should be able to implement the most appropriate and optimal treatment for his or her patient. Common intraoperative complications associated with primary total hip arthroplasty include difficulty gaining sufficient exposure, problems with cup fixation, challenges with implant anteversion, intraoperative fracture of the femur, and difficulties with intraoperative limb length and hip instability.

Some intraoperative challenges during primary total hip arthroplasty (THA) can be anticipated, whereas other problems develop unexpectedly. In either instance, having state-of-the-art knowledge about how to handle such challenges or problems when they occur is essential to getting out of a jam and implementing a strategy for successful resolution. The goal of this chapter is to review management strategies for some of the most common intraoperative problems that can occur during primary THA. These problems include difficulty with exposure, problems gaining initial implant fixation, intraoperative fracture, suboptimal stability, and limb-length discrepancy. A knowledge of possible problems will prepare the surgeon for such an eventuality and allow him or her to formulate a successful management approach.

Exposure Problems
Gaining adequate exposure during any surgical procedure, including primary THA, is essential for obtaining optimal performance during the rest of the procedure. The following sections discuss how to gain greater exposure,
when needed, during anterolateral and posterior approaches to the hip.

**Anterolateral Approach: How to Get More Exposure**

Transgluteal approaches, including the anterolateral approach and the direct lateral approach, are versatile muscle-splitting approaches to the hip that allow for excellent exposure at the time of both primary and revision THA. Although many variations of these approaches have been described, the common features include dividing some portion of the anterior abductor musculature from the posterior musculature, delivering the femur anteriorly, and preserving the posterior soft-tissue attachments. Preservation of the posterior soft-tissue structures confers lower rates of postoperative dislocation after transgluteal approaches compared with a posterolateral approach. This section describes several techniques that may be useful when a difficult exposure is encountered at the time of a transgluteal approach to THA.

**Preoperative Planning**

Transgluteal approaches, including both primary and revision procedures, can be used to expose the hip for a wide variety of pathologies and may be favored when there is a substantial risk for postoperative hip instability. Although access to the posterior column of the acetabulum is possible with a transgluteal approach, many surgeons favor a posterolateral approach in the event that such access is anticipated (for example, pelvic disassociation requiring posterior column plating).

Several patient factors may indicate a predisposition to a more difficult exposure and should be identified preoperatively (Table 1). When a more challenging exposure is anticipated, the surgeon should not attempt to use small incisions and, in such instances, consideration should be given to taking down a greater proportion of the anterior abductor musculature (50% to 60%), rather than attempting to work through a more minimalist exposure. If prior surgical scars are present, they should be used whenever possible.

**Dislocation**

Several techniques may be used to facilitate dislocation during a difficult exposure. It is critical to avoid the tendency to extend the abductor split beyond 4 to 5 cm above the tip of the greater trochanter because this may endanger the superior gluteal nerve. Instead, the surgeon should work distally to proximally, while maintaining adduction and external rotation of the thigh. It is important to ensure that a release of the vastus musculature was performed as distally as needed to expose the inferior extent of the hip capsule. With multiple retractors on the anterior musculotendinous sleeve, the surgeon can visualize the entire anterior capsule from the intertrochanteric line to the acetabular rim. The full extent of the capsule is then incised in line with the femoral neck, and a capsulectomy can be performed. Alternatively, capsular flaps can be elevated and preserved for

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**Table 1**

<table>
<thead>
<tr>
<th>When to Anticipate a More Challenging Exposure</th>
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<tr>
<td>Prior surgery</td>
</tr>
<tr>
<td>Deformity (for example, congenital, posttraumatic, or protrusio)</td>
</tr>
<tr>
<td>Stiffness/joint contractures</td>
</tr>
<tr>
<td>Heterotopic bone</td>
</tr>
<tr>
<td>Obesity</td>
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<tr>
<td>Muscle bulk</td>
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later repair. Subperiosteal release of the remaining capsule along the base of the femoral neck inferiorly all the way back to the lesser trochanter is the best method for improving exposure and allowing anterior dislocation. If this final maneuver does not allow for dislocation, an in situ femoral neck osteotomy can be performed. However, overzealous rotational force on the femur should be avoided, especially in osteoporotic bone.

**Acetabular Exposure**

Before placing the retractors for acetabular exposure, the surgeon should ensure that the femoral neck osteotomy was appropriate for the planned reconstruction because underresection of the femoral neck will obstruct the view of the acetabulum. In general, the limb is placed in an extended and slightly externally rotated position to facilitate acetabular exposure. Initially, the abductors are retracted anteriorly with a handheld retractor, whereas the femur is retracted posteriorly with a large bone hook around the calcar. Careful release of the tight inferior capsule at this point enhances inferior exposure and allows further translation of the tissues—both anterior and posterior.

Three or four retractors (Figures 1 and 2) are then placed sequentially around the acetabulum to allow for safe and accurate component preparation and implantation (Table 2). Each retractor is responsible for the exposure of one quadrant of the socket. It is important to balance the retractors to center the exposure over the socket because too much retraction on one side may result in underexposure on the other side.

**Femoral Exposure**

Failure to take down enough of the abductors at the time of the initial

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### Table 2: Acetabular Exposures

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Retractor(s) and Use</th>
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<tbody>
<tr>
<td>Anterior-inferior</td>
<td>Smooth cobra under the capsule/iliopsoas; provides excellent exposure of this quadrant</td>
</tr>
<tr>
<td>Anterior-superior</td>
<td>Pointed wide cobra into anterior column; retracts the abductors anteriorly</td>
</tr>
<tr>
<td>Posterior-inferior</td>
<td>Pointed narrow cobra (or Hohmann) into the ischium; retracts the femur posteriorly</td>
</tr>
<tr>
<td>Posterior-superior</td>
<td>Smooth or pointed narrow cobra onto the posterior wall; rarely needed to elevate the overhanging capsule</td>
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*Figure 1* Intraoperative photograph of a three-retractor acetabular exposure. The femur is retracted posteriorly (right side of image) by the narrow cobra retractor placed in the ischium. Two separate retractors expose the anterior quadrants.

*Figure 2* Intraoperative photographs of acetabular exposure. In four-retractor acetabular exposure (A), the fourth retractor is added to the posterior-superior quadrant (upper-right) only if needed to improve visualization of this quadrant. In four-retractor exposure with an acetabular reamer (B), complete exposure is obtained to allow for safe and accurate component preparation.
exposure will become immediately clear to the surgeon at the time of femoral exposure. In general, a more generous initial abductor release will facilitate exposure and minimize iatrogenic abductor trauma during femoral preparation. Failure to release a sufficient amount of the abductor musculature may exacerbate the risk of femoral stem varus and flexion malpositioning inherent in this approach.

The limb is typically placed into a sterile pocket in a position of flexion and external rotation. Rotation beyond 90° may help protect the posterior abductors that are still attached to the trochanter. Retrograde pressure on the knee can further assist with delivering the hip from the wound. The femur is then framed with three retractors (Figure 3) to allow for safe and accurate component preparation and implantation (Table 3).

**Posterior Approach: How to Get More Exposure**

When using the posterior approach, the patient is placed in the lateral decubitus position and an incision is made along the posterior border of the greater trochanter, extending from the tip of the trochanter to the vastus lateralis ridge. The gluteus maximus fascia is split in line with the muscle fibers. The hip capsule and the external rotators are incised off the femur and preserved as one layer. If additional exposure is required distally, the quadratus femoris also can be released. To relax the posterior capsule, the inferior capsule is incised to the level of the transverse acetabular ligament. Three to four retractors are placed. One retractor is placed anteriorly, which retracts the femur anterior to the socket; one or two retractors are placed inferior at the level of the transverse acetabular ligament; and one retractor is placed posterior along the posterior column (Figure 4).

Femoral exposure is optimized with a wide Hohmann retractor inserted above the lesser trochanter to improve visualization of the calcar during femoral preparation. In addition, a hip skid is inserted under the greater trochanter to protect the skin and elevate the femur (Figure 5). Elevation of the femur improves access to the femoral canal and prevents excessive skin retraction. All retractors must be removed to facilitate reduction, especially when using contemporary, larger diameter femoral heads. The femur is easily visualized with a retractor placed proximal to the lesser trochanter.

Errors to avoid while preparing the femur include placing the femoral component in varus and substantial retroversion. Using the posterior approach, there is limited visualization of the proximal femur, and there is a risk of damaging the skin and soft tissues while preparing the femur. To optimize visualization, specialized retractors are available that protect the skin edges and elevate the femur to improve visualization. Another simple way to improve visualization is to orient the surgical room lights to be coplanar with the femoral canal. During preparation of the femoral canal, an effort should be made to sufficiently lateralize the reamers to avoid varus placement. Another common mistake
is to place the cup in retroversion secondary to inadequate exposure and retraction of the femur anteriorly. Because bleeding can substantially limit visualization, care should be taken to control even small amounts of bleeding from the start of the procedure.

**Tips for the Difficult Exposure**

In patients who are large, muscular, stiff and/or who have had prior surgeries (particularly if bony deformity is present), exposure can be challenging. For patients who are obese or muscular, it is helpful to use large retractors and protect the skin during femoral preparation.

**Intraoperative Component Fixation, Fractures, and Implant Positioning**

Optimizing initial implant stability is the key to pain relief and durable fixation after THA with cementless components, and optimizing implant position is integral to decreasing the risk of dislocation and optimizing bearing surface wear. Intraoperative fractures need to be dealt with effectively to ensure that they do not lead to a symptomatic postoperative fracture or problems with component fixation.

**The Cup Press-Fit Is Not Good**

Long-term, cementless fixation depends on bone ingrowth to a porous metal acetabular component. In the canine model, bone ingrowth occurs when there is less than 40 μm of movement between the metal component and the host bone. In addition to stability, ingrowth requires direct contact between the porous surface and the host bone. Retrieval studies have demonstrated that where gaps exist, fibrous attachment, not bony ingrowth, occurs. Therefore, obtaining osteointegration of the cup is optimized by a combination of a large area of cup-bone contact and stability relative to host bone.

Cadaver studies provide guidance for obtaining the best balance of stability and contact. It is possible to oversize a component and obtain stability at the rim but not have good contact at the dome. Conversely, a slightly undersized component will have excellent bone contact at the dome but may not have adequate initial implant stability. Cadaver studies support underreaming the acetabulum by 1 mm to obtain the best balance between stability and bone contact. They also demonstrate that when screws are used, there is no benefit to using more than two screws for additional stability. When secured with supplemental screw fixation, line-to-line reaming, which provides less inherent stability, provides acceptable bone contact and stability.

The guidelines to optimize surgical technique were verified by clinical studies documenting 5-year results with a single cup design. In the first study, the cup had little or no initial stability but was stabilized with screw fixation. In the second study, the same cup design was slightly oversized for a stable press-fit without screws. Both studies showed no evidence of loosening at a minimum follow-up of 5 years. Subsequently, studies have shown durable 15- to 20-year fixation with 95% to 97% survivorship with or without supplemental acetabular screw fixation.

Assuming that most surgeons typically oversize an acetabular component by 1 to 2 mm, it is important to recognize the roles that implant geometry, porous-coating roughness, reamer tolerance, and cup tolerance can have on intraoperative press fit. Implants that are less than 180° of a hemisphere will have a much different feel and look at the time of insertion. When using 180° hemispheric cups, a tighter fit at
the rim and more exposure of the cup superolaterally are likely. Ultraporous surfaces will feel more stable than traditional porous coatings; however, they are probably not needed for most primary acetabular arthroplasty cases. When new acetabular reamers, trials, or implants are first used, the instruments and implants can be checked against a set of size gauges until the tolerances are deemed comfortable (Figure 6). A set of reamers that is 1 mm smaller than labeled combined with a cup that is 1 mm larger than labeled could lead to a pelvic fracture when inserted.

Patients at risk for complications with a press-fit implant include those with a small-diameter acetabulum, acetabular dysplasia, or osteoporosis. The reasons for a poor press fit include inadequate exposure, instrument or implant tolerance variations, soft-tissue interposition, and insufficient bone contact to obtain stability. When the press fit is not good, the first step is to improve exposure and ensure that soft tissue is not interposed between the acetabular rim and the acetabular shell. The cup can be wiggled and rotated to allow soft tissue to escape from between the bone and the metal acetabular cup. Typically, a cup will not easily rotate when the porous coating is in contact with healthy bone. In contrast, if there is soft-tissue interposition, the cup will rotate more easily and may have a slippery feel.

If there is no soft-tissue interposition and the surgeon has good exposure with 360° of acetabular visualization, the most likely cause of a poor press fit is a lack of bone contact. Better bone contact requires additional reaming. If the cup is uncovered, as is frequently the case with dysplastic hips, then medial reaming (without increasing the diameter) will improve bone contact and stability. It is rarely necessary to ream beyond the floor of the acetabular fovea to obtain enough lateral coverage. The exception is Crowe type III or IV acetabular dysplasia (Figure 7). A cementless technique has been described in which reaming creates a medial wall defect to obtain a good press fit for these difficult situations. This extensive medial reaming is performed only if the anterior and posterior columns are intact. If the cup has good lateral coverage but the press fit is still not good, the surgeon can consider reaming for a larger diameter acetabular component. This is a common scenario; however, exposure must be good, the reamer must be centered in the acetabulum, and the columns must be thick enough to allow for more bone removal anteriorly and posteriorly.

Supplemental acetabular screw fixation is a proven method to improve initial implant fixation. Even if the press fit is good, many surgeons will use one or two screws in every case for “insurance.” It is worth noting the real and theoretical risks of screw fixation. The risk of vascular injury is real. The safe zone for screw fixation is the posterior-superior quadrant of the acetabulum (Figure 8). The external iliac vessels are at risk when screws are placed in the anterior-superior zone, just as the obturator nerve and vessels are at risk when screws are placed in the anterior-inferior quadrant. Cup screw holes pose a theoretical risk to long-term fixation by expanding the effective joint space and allowing joint fluid access to the pelvic bone, which can lead to retroacetabular osteolysis. This is evident on long-term radiographic studies and has been confirmed.
with postmortem studies. However, for cross-linked polyethylene bearings, it is currently a theoretic risk because it has not yet created an important clinical problem. Safe acetabular screw fixation technique requires careful and controlled drilling as well as recognizing that small acetabula or patients with osteoporotic bone present the greatest challenge for screw fixation. Small-diameter cups allow limited visibility and require more acute angles for the drill and the screw because of limited space. Osteoporotic bone has less “feel” when the drill is about to penetrate a pelvic cortex, and the screw can easily strip the bone if it is overtightened. Surgeons should identify patients at risk of poor press fit of an implant and should ensure adequate exposure. Knowledge of the implant and instrument tolerances improves the chances of achieving the recommended 1- to 2-mm difference between the prepared bone and component size. When the press fit is not good, additional reaming should be considered. Medial reaming improves lateral coverage, and larger diameter reaming improves peripheral fit. Screws are an excellent way to improve initial implant fixation and can be used in all cases. If there are concerns about acetabular stability, postoperative protected weight bearing may minimize micromotion and allow bony ingrowth to occur.

### The Socket Is Overreamed or Cracked

In preparing the acetabulum for insertion of the acetabular component and in selecting and inserting the component, the surgeon must make several choices to obtain initial implant fixation that will assure bone ingrowth. Historically, in the early days of cementless acetabular fixation, acetabula were reamed to the same size as the component to be inserted with adjunct fixation achieved with screws, lugs, or spikes. Long-term follow-up of the best of these constructs has demonstrated revision rates of less than 3% at 20 years.

Some constructs demonstrate radiolucent lines around stable components and osteolysis around the screw holes. Such findings led surgeons to underream the acetabulum in relationship to the acetabular component to obtain a stable press-fit fixation in an effort to abandon or limit the number of screw holes that provide access channels for polyethylene wear particles. In the early days of using press-fit components, surgeons learned that excessive underreaming (≥ 2 mm and even less in osteoporotic bone) could induce acetabular fractures through the greater sciatic notch, the quadrilateral plate, or the medial wall. They also began to recognize that sufficient impaction forces were required to assure stable seating of the component and avoid medial gaps between the bone and the component. It is now known that certain shell geometries (for example, elliptic versus hemispheric) have a higher propensity to induce fractures. Even with this knowledge, surgeons occasionally encounter a situation in which the component is loose on insertion, even after preparing the acetabulum (underreaming) for a press-fit component or situations in which the acetabulum has cracked or fractured when the component was inserted.
Inadequate Press Fit or Overreaming

Inadequate press fit occurs in the case of osteoporotic bone, especially if the patient has a dysplastic (vertically inclined and shallow) acetabulum with or without a relatively wide mediolateral diameter. This scenario requires component placement with less acetabular inclination than the native acetabulum when there is no superior bony support. If the component chosen does not allow for a stable press fit, the first step is to ream more medially in the acetabulum, which in some instances provides better superior support and coverage and allows an adequate press fit. However, if an adequate press fit is not obtained with a no-hole component and adequate screw supplemental fixation cannot be obtained with a cluster-hole component (sometimes screws through the holes that are present will not allow adequate purchase because superior bone is absent in the shallow acetabulum), a multihole cup should be placed. Secure fixation should be obtained using all screw holes that provide fixation of the shell to bone and that do not risk injury to surrounding neurovascular structures (Figure 9).

Cracks or a Displaced Fracture

Cracks or a displaced fracture can be related to excessive force with impaction, excessive underreaming, or the use of more aggressive press-fit designs (such as elliptically shaped components). However, cracks or a displaced fracture can occur in a routine situation with osteoporotic bone or in acetabula that are sclerotic in one area and osteoporotic in another. If a component is seated more medially than the position of the trial component, the surgeon should explore the greater sciatic notch with a finger to feel if there is an incomplete or a complete fracture of the posterior column. If a nondisplaced fracture occurs with a no-hole component, this chapter’s authors recommend replacing it with a multihole component to act as an internal plate, placing one or two screws on each side of the fracture to attempt to obtain purchase of the far cortex with these screws. If a cluster-hole or a multihole component was used, the component should be positioned to allow the insertion of screws on both sides of the fracture. If a markedly displaced fracture occurs, an external plate for supplemental fixation is recommended (Figure 10). If a fracture (posterior column [Figure 11] or medial wall [Figure 12]) is discovered on the postoperative radiograph and screw augmentation was used, touch-down weight bearing for 6 weeks may help prevent displacement. If a no-hole component was used and press fit was thought to be adequate during surgery, touch-down weight bearing can lead to an uncompromised result. If there was concern regarding stability during surgery and/or structural concern based on the radiographs (such as a displaced posterior column or medial wall fracture), the surgeon may consider immediate revision to a multihole cup with supplemental fixation with a plate if needed.

Optimizing Component Anteversion

The success of THA depends on many factors. One of the measurable parameters for success is component placement in the correct amount of anteversion. Component version has been a topic of importance since the time that early results of THA were reported. The recommendation for acetabular orientation included 45° of lateral inclination and neutral to 5° of anteversion. A dislocation rate of 1.5% was considered...
low and attributed to component placement as well as reattachment of the trochanter, thus tightening the abductors and other soft tissues of the hip.

Lewinnek et al\textsuperscript{26} reported a series of 300 THAs, including 9 (3\%) with a postoperative dislocation. Based on the findings, an acetabular component safe zone for hip stability was described. A safe zone of $15^\circ \pm 10^\circ$ of acetabular anteversion and $40^\circ \pm 10^\circ$ of lateral inclination resulted in a 1.5\% dislocation rate, but acetabular component orientation outside this range resulted in a 6.1\% dislocation rate.

Combined anteversion of the acetabular and femoral components also has received attention. Dorr et al\textsuperscript{27} used CT to evaluate 47 successful THAs and measured a combined anteversion of $37.6^\circ \pm 7^\circ$ (range, $19^\circ$ to $50^\circ$). Ninety-six percent (45 of 47) of the hips were in the safe zone of $25^\circ$ to $50^\circ$ of combined anteversion. Failed anteversion of the component can lead to any one of several complications. Excessive anteversion correlates with anterior hip dislocation, and decreased anteversion or relative retroversion correlates with posterior dislocation.\textsuperscript{26}

Component impingement, accelerated component wear, and liner fracture or dislodgement also are associated with abnormal component version.\textsuperscript{28,29} Although wear has typically been associated with polyethylene, wear also can occur with hard-on-hard bearings. For example, metal-on-metal bearing wear and its associated complications have been described with abnormal component positioning because of either excessive anteversion or cup abduction.\textsuperscript{30}

Griffin et al\textsuperscript{31} evaluated metal ion levels and then used risk stratification to determine the factors associated with wear and metallosis. Of the risk stratification factors studied, component position (increased anteversion or increased cup abduction) was an important factor. Soft-tissue impingement, particularly of the iliopsoas, is another well-described complication typically associated with an acetabular component that is placed in a position making
it anteriorly prominent, including retroversion or inadequate medialization.\(^{32}\) (Figure 13).

Patients with developmental dysplasia of the hip, Legg-Calvé-Perthes disease, or other childhood hip diseases have increased native anteversion of the hip.\(^{33}\) Abnormal anteversion also can occur in patients with malunited hip fractures. Retroversion is associated with femoral acetabular impingement, slipped capital femoral epiphysis, malunited fractures (such as transverse acetabular fractures) and overcorrected acetabular or femoral osteotomies.

Preoperative planning to assess hip anteversion and help the surgeon prepare to place the component correctly is essential to optimal outcomes. For example, patients with hip dysplasia (Crowe type III or IV) frequently have excessive acetabular and femoral anteversion.\(^ {33,34}\) (Figure 14). In one study, preoperative CT measurements for combined anteversion for the patients with developmental dysplasia of the hip treated with THA averaged 73.7° before and 39.2° after THA. Forty-six of 47 hips (35 patients) had a combined anteversion between 25° and 50° and none of the patients had a dislocation.\(^ {33}\)

After preoperative planning is completed, the surgeon must rely on intraoperative techniques to guide correct component placement to maximize hip stability and avoid the other complications associated with malpositioned components. Anatomic structures are commonly used and are reported to be reliable markers for component placement and correct component version.\(^ {33,36}\) The transverse acetabular ligament is located across the inferior aspect of the acetabulum and serves as a useful guide for component placement. In general, the acetabular component opening should be coplanar or parallel to the transverse acetabular ligament. The acetabular component may be placed in slightly more anteversion for a patient who was treated with a posterior hip approach. Griffin et al.\(^ {37}\) evaluated the CT scans of 218 normal hips of patients who had the studies performed for other purposes. The authors measured the angle of the acetabular rim in

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**Figure 13** A 70-year-old man presented with reports of severe groin pain associated with active hip flexion. AP (A) and lateral (B) radiographs demonstrate the retroverted and prominent (arrow) acetabular component. The patient underwent an iliopectas bursa injection that relieved his symptoms. The hip was revised to place the component in appropriate anteversion, and symptoms resolved. C, The postoperative lateral hip radiograph shows the change in the position of the component.

**Figure 14** A 40-year-old woman had severe pain associated with hip arthrosis. The AP radiograph of her hip is marked with the true acetabulum (arrows). The anatomic placement of the acetabular component can result in excess limb lengthening. One option for the femoral side is subtrochanteric femoral shortening.
Overcoming Common Intraoperative Problems in Primary Total Hip Arthroplasty

The acetabular notch angle is another technique that uses the patient’s anatomic landmark to assist in acetabular component placement. The acetabular notch angle is defined as the angle created at the intersection of a flat line from the sciatic notch along the posterior acetabular ridge and the line from the posterior to the anterior acetabular ridge. Because the line from the sciatic notch along the acetabular posterior ridge has inclination, the notch acetabular plane is not horizontal. When the acetabular component is aligned toward the notch, an additional 10° to 15° of anteversion are created for component placement (Figure 15).

Navigation is a third technique to assist with component placement. The primary advantage of computer navigation is improved accuracy of component placement, but its disadvantages are a learning curve, the cost of the CT scan if navigation is image based, the cost of computer navigation software, and the increased time needed to perform the navigation technique. It is too soon to determine if navigation will be used routinely to help surgeons with component placement.

Femoral component version is normally dictated by a patient’s anatomy, and there are limits to what can be done to change the version at the time of surgery, unless the surgeon chooses to cement the stem or use a modular uncemented stem or another type of uncemented stem that allows anteversion adjustment. Uncemented stems, particularly metaphyseal-filling designs, are placed in the amount of version dictated by a patient’s anatomy. Emerson reported slightly more anteversion (8.1°) of the replaced hip compared with the nonsurgical hip. He attributed this to the anatomic constraints of the host bone when the femoral component is inserted. Dorr et al noted similar findings. Because the femur dictates femoral component version, these authors...
suggested that the femoral component should be placed first. The acetabular component is then oriented based on the femoral component version. The surgeon has more ability to adjust the femoral component version with a cemented component.

One of the final steps of surgery is confirming the correct component placement by using intraoperative techniques of measuring joint stability and component impingement (Figure 16). The patient’s hip should be assessed for instability and impingement before the final selection of implants. With the trial components or implants in place, the hip should be placed through a range-of-motion (ROM) assessment for stability and impingement of the components. After thorough preoperative evaluation and intraoperative execution of this plan for correct component placement and orientation, an unstable hip is unusual. However, if the hip is unstable, the surgeon must first assess for bone or soft-tissue impingement, offset, and leg lengths to be certain that these are not contributing to hip instability. If these problems are present, they should be corrected. If the hip continues to be unstable in one direction (such as anteriorly or posteriorly), then cup repositioning should be strongly considered.

The Femur Is Cracked
Intraoperative femoral fractures are an infrequently encountered problem. However, it is important for the surgeon to develop strategies preoperatively to recognize the patient who is at risk for a femoral fracture and develop intraoperative strategies to minimize insertion fractures. In addition, the surgeon should be prepared to manage intraoperative fractures should they occur.

The key to avoiding fractures is identifying the patient who is at risk. Patients who are at particular risk are those with osteopenia or a femoral deformity in either the sagittal or the coronal plane. In addition, femoral stenosis can predispose a patient to an insertional proximal femoral fracture. Careful two-plane templating is essential to prevent intraoperative fractures and should be done preoperatively. Patients who have had previous surgery of the proximal femur also are at risk. Stress risers that can initiate an intraoperative fracture can be produced in patients who had a core decompression, dynamic hip screw placement, or intramedullary nailing. The surgeon should be particularly cognizant of the potential for a femoral fracture when dealing with a patient with acetabular protrusio. Forceful attempts to dislocate the hip in this situation can lead to a spiral femoral fracture; this risk can be mitigated by performing an in situ neck cut.

A variety of intraoperative strategies will minimize insertion fractures, including meticulous proximal femoral cleansing to minimize the wedge effect of retained bone in the prepared proximal femur. Inspection of the calcar before and after insertion of the implant is very important. Calcar defects before insertion of the implant should be recognized so that after insertion the surgeon can be confident that there has been no change in the appearance of the proximal femur. Proximal femoral fractures from the insertion of implants can be extremely subtle; if there has been any change in the appearance of the proximal femur, it usually portends a nondisplaced fracture that will worsen with weight bearing. Therefore, it is important to be aware of the appearance of the proximal femoral anatomy before inserting the implant.

When inserting a femoral implant, it is important to use consistent hammer blows. Force should not increase as the seating goal is reached. The surgeon should pause periodically during the insertion process to allow the bone to expand slightly as a result of its viscoelastic property. The surgeon’s assistant should focus on visual progression of the implant during insertion. Auditory feedback also should be used to determine the final seating. When the tone changes, the implant has usually reached its resting point. A good principle is that when the implant stops, the surgeon should stop striking the implant. If the implant seats deeper in the proximal femur than the last broach, a fracture should be suspected.

All hip surgeons occasionally break a femur, and haste in solving the problem usually will make the problem worse. After a fracture has occurred, the fracture line should be exposed until its termination, so a plan can be made for stable fixation. Calcar fractures are the most common types of intraoperative proximal femoral fractures. These fractures usually occur in the anteromedial corner and are usually nondisplaced. When nondisplaced, they have the appearance of a thin, almost hair-like line. Nondisplaced calcar fractures are best treated with cerclage, using a wire or cable, usually placed just above the lesser trochanter. The cerclage stabilizes the fracture, prevents further displacement, and provides a stable bone envelope for implant fixation. If the fracture is displaced, the implant should be removed from the femur, the fracture should be exposed until its termination, and a cerclage wire should be placed around the fracture and distal

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to the termination of the fracture. In some cases, the surgeon may choose to switch to a femoral component that gains primary fixation distally to avoid relying on the proximal femoral metaphysis for support of the implant. The liberal use of intraoperative radiographs is an important adjunct to treatment.

Levering on the trochanter with a broach, an implant, or a retractor is a common cause of trochanteric fractures. It is important to clear the lateral trochanteric bed to avoid these issues. Vigorous retraction on the trochanter also should be avoided. Nondisplaced trochanteric fractures can usually be treated with a tension-band wiring technique. Displaced fractures are difficult to treat because of their small surface area. Strategies to treat these fractures

Figure 16  Algorithm for guiding component placement and assessing hip stability. FAI = femoroacetabular impingement, SCFE = slipped capital femoral epiphysis, PAO = periacetabular osteotomy, THA = total hip arthroplasty.
include reduction and tension-band wiring, claw fixation, or trochanteric advancement. Proper hip reduction techniques can mitigate the incidence of these fractures. The hip should be reduced with pressure on the implant or the calcar, not the trochanteric bone.

Shaft fractures are quite rare in primary surgery and are frequently associated with altered anatomy or stress risers. Oblique spiral fractures can occur during dislocation in the presence of protrusio or when proximal femoral hardware is present. It is very important to dislocate the hip when approaching the hip before hardware removal. If the hardware is removed initially and there is a difficult dislocation, this can lead to an oblique spiral fracture. The treatment of shaft fractures is dependent on the amount of displacement. If a nondisplaced longitudinal crack occurs, it usually heals uneventfully with protected weight bearing. Displaced fractures should be exposed and, depending on the fracture pattern, can be wired, plated, or instrumented with a longer stem.

Postfracture treatment typically includes limited weight bearing. Touchdown weight bearing for 6 weeks should lead to uneventful healing, with gradual progression to full weight bearing during the next 4 weeks. For trochanteric fractures, flexion and abduction exercises should be avoided for 6 weeks.

The Hip Is Not Stable

Hip instability continues to be among the most common complications after THA and is devastating for the patient and frustrating for the surgeon. Incidence rates of postoperative instability vary in the literature depending on the series and a multitude of variables, including patient, surgical, and implant factors. Although dislocations cannot be eliminated, an algorithmic approach to assessing and managing intraoperative instability will assist the surgeon in minimizing the probability of postoperative instability.

Preoperative Assessment

Minimizing the risk of intraoperative and postoperative instability begins with the preoperative assessment to identify patients who are at risk, proactively discuss risk factors, and create a plan to minimize risk. Not all patient factors are modifiable, but some can be changed. Patients at an increased risk for instability include the morbidly obese, the elderly, and alcohol and substance abusers. Certain diagnoses have an increased risk of postoperative instability, including patients with a neuromuscular disorder such as Parkinson disease and those with developmental dysplasia of the hip.

Intraoperative Assessment

With trial components in place, the surgeon begins the assessment by first confirming that leg lengths and offset have been restored. This is followed by assessing component orientation and then bringing the hip through a ROM to identify the presence of bone, component, or soft-tissue impingement.

A key goal in performing a THA is to restore the desired leg length and offset. It is necessary to have a reproducible methodology to consistently achieve this goal, and there are several described techniques. The surgeon can carefully plan the biomechanical restoration on preoperative imaging. Postoperative radiographs should then reflect such preoperative planning (Figure 17). Although this technique is valuable, it does not provide the surgeon with intraoperative feedback that can be translated into a change at the time of surgery. An alternative technique includes using a fixed device in the pelvis, with another marker of some type on the femur (Figure 18). This technique provides an accurate assessment of both leg length and offset before dislocation and then with trial components in place and gives the surgeon intraoperative feedback to maximize the ability to adequately restore offset and leg length. Another technique applies if surgery is performed with the patient supine. An intraoperative AP radiograph is obtained, and offset and leg length are compared with the contralateral limb. A final technique involves simple palpation of known bony landmarks, such as the contralateral knee, and comparison with the surgical side with trial components in place. Although this technique is routinely used, it is somewhat subjective and experience dependent.

The surgeon should develop an intraoperative technique to assess the orientation of the acetabular and femoral components. There is a great range of variability in acetabular component placement, and malpositioning increases the probability of postoperative dislocation. In general, the accepted goal of acetabular component orientation is 35° to 45° of cup abduction and 15° to 20° of anteversion. The accepted goal of femoral component orientation is 10° to 15° of anteversion.
After a thorough evaluation of component orientation, the surgeon should make any necessary changes, such as changing the cup position if it appears outside the desired range. With the current generation of press-fit shells, it is relatively easy to disimpact the shell, change the orientation, and reimpact the shell. Additional screw fixation can be added if desired. Although correct acetabular component orientation is critical, lipped or face-changing liners can be used to make minor adjustments. The hip is then taken through a full ROM assessment to look for signs of instability and impingement.

Impingement can be bone to bone, component to component, or bone to component. The removal of osteophytes and correct component orientation are the keys to minimizing impingement. Impingement must be carefully assessed and corrected with trial or in-place components.

Many intraoperative options are currently available to assist in maximizing stability. After leg length and offset have been restored, correct component orientation has been confirmed, and impingement has been ruled out, there are additional options available to augment stability. Increasing the femoral head diameter will improve stability. The surgeon should be familiar with the implant system being used to balance the risks and benefits of increasing the femoral head diameter, which will improve intraoperative stability, and decreasing polyethylene thickness. Increasing the lateral offset also will improve stability, which can be achieved with an offset polyethylene liner, a high-offset femoral component, or both.

It is imperative to understand that occasionally a limb may need to be made slightly longer than the preoperative plan to achieve stability. If all of the described methods have been performed and the hip is still tending toward instability, it may be necessary to use a longer ball length if stability can be substantially improved. This is not an intraoperative error; it is a reality. The key is that all patients must be informed of this possibility preoperatively so that they are aware of this potential outcome and will be more accepting of a longer limb length.

The Limb Length Is Not Correct

There is some controversy about the importance of limb-length discrepancies before and after primary THA. Many patients with osteoarthritis or other hip disorders, which may require a THA for the treatment of pain and disability, have a shorter limb preoperatively. However, because this condition has developed gradually, patients may have adapted to this shortening and be unaware of the discrepancy. After sciatic nerve palsy, a symptomatic limb-length discrepancy is the second most frequent cause of litigation after THA. There are several reports that limb-length discrepancies, especially overlengthening, may adversely affect patient outcomes after the procedure, including patient satisfaction, gait, and energy expenditure with ambulation.

There is no standard definition of a limb-length discrepancy after a primary THA, but a greater than 1 cm difference is widely accepted as an indication of a discrepancy. It also
is important to distinguish between a true limb-length discrepancy (measured clinically or radiographically) and an apparent or a functional limb-length discrepancy. The latter has numerous causes, including fixed pelvic obliquity; degenerative arthritis of the lumbar spine, with scoliosis and pelvic tilt; and tightness or contracture of the anterolateral soft tissues of the arthritic hip (the capsule, the rectus femoris, or the iliotibial band).  

Preoperative Leg-Length Evaluation

The surgeon’s evaluation of leg length associated with primary THA has three distinct time phases: preoperative evaluation and patient counseling, intraoperative examination, and postoperative patient support and counseling. In the preoperative evaluation, the passive ROM assessment of the hips is measured, and a tape measure is used to check leg lengths. The distance from the anterior superior iliac spine to the medial malleolus is the true leg length, and the distance from the umbilicus to the medial malleolus is the functional or apparent discrepancy. Lumbar spine radiographs are obtained if suggested by a patient’s history of lumbar spine problems or surgery or if the physical examination suggests a deformity of the lumbar spine, which may contribute to a patient’s perception of leg-length.

When considering primary THA, every patient should be informed that the surgeon cannot guarantee hip stability and equal leg length in every procedure, and the limb may feel longer in the early postoperative period. Preoperative radiographic templating is the single most important method to achieve acceptable leg lengths after a primary THA. Templating can be performed with analog printed AP pelvis radiographic (with known office magnification) and acetate templates provided by the implant manufacturer or digital radiographs and preloaded digital templating software, provided that a magnification marker is present on the radiograph. The surgeon can then preoperatively select the femoral neck osteotomy site, plan the acetabular component size and position, and plan the femoral component offset and neck length to provide the appropriate amount of lengthening desired. There are two caveats of templating: (1) with a varus hip, the neck cut may need to be lower, and a high or extended offset femoral component with a short modular head may be required to prevent overlengthening and (2) with a valgus hip, the neck cut may need to be higher, and a standard offset is used to prevent shortening or excessive femoral offset.

Intraoperative Evaluation

Several methods have been described to intraoperatively determine the correct leg length. Commercially available devices have a pin that is inserted into the ilium before dislocation and femoral neck resection, and a caliper or a ruler is used to measure the distance from this pin to some point visible in the proximal femur (Figure 18). This distance is remeasured after a trial femoral component has been inserted and the hip reduced. An AP pelvic radiograph can be taken intraoperatively after reducing the trial femoral component and making a radiographic measurement.

Surgeons who perform THA using a direct anterior approach with the patient supine use intraoperative fluoroscopy to measure leg lengths, whereas others prep and drape both legs and measure the medial malleoli by direct visual inspection. This chapter’s authors usually perform a variety of intraoperative tests with direct visualization after the trial femoral component is in place. These generally include ROM to determine hip stability and the presence of any impingement. A so-called shuck test (or push-pull test) is usually performed, with changes made if there are more than a few millimeters separation of the head from the acetabulum. The type of anesthesia (spinal or general) and the presence of intravenous muscle paralytic agents can influence this test. Many surgeons also check the amount of knee flexion possible with the hip joint fully extended, with the presumption that if the hip has been excessively lengthened, there will be a tight rectus femoris tendon and limitation of full knee flexion. Unfortunately, none of these tests is completely reliable, and surgical judgment and experience influence the interpretation.

The Hip Is Too Short

If the hip and leg length are too short intraoperatively, the hip will dislocate easily with bone-to-bone impingement. The shuck or push-pull test will show too much acetabulum-femoral head separation. However, this depends on the anesthetic technique, whether the hip was short or contracted preoperatively, and if the surgeon released the anterior or the posterior capsule as part of the surgical approach.

If the hip appears too short intraoperatively, the acetabular component position should be reevaluated because the center of rotation of the hip may have been elevated. The height of the femoral neck cut is rechecked to determine if it is less than was planned preoperatively, and an intraoperative radiograph can be obtained to confirm femoral and acetabular component positioning. A
solution for these problems includes increasing the prosthetic modular neck length; however, it is important to remember that this will also increase femoral offset. The use of a longer femoral neck may necessitate the use of a skirted femoral head, which can lead to impingement. If modular head options do not provide enough neck length, another option is to upsize the femoral component, leaving it “proud” of the femoral neck osteotomy. After this, an additional trial reduction should be performed. It should be noted that there is a risk of fracture of the proximal femur when greatly increasing the size of the femoral component.

The Hip Is Too Long

If the leg is too long intraoperatively, in some cases, the femoral head cannot be reduced into the acetabulum or can be reduced only with great difficulty. Often, if the hip is too long, it will have a flexion contracture or cannot be extended to the neutral position. In most instances, there will be no shuck of the hip. With the trial hip in maximum extension, the knee may not be able to be flexed past 90° to 100°.

If the hip appears to be too long intraoperatively, the femoral neck cut is reassessed. If it appears to be the correct planned amount, the neck length is reduced, if possible. The offset also could be decreased. If the hip had a fixed flexion contracture preoperatively, an anterior capsule release can be considered. Often, the femoral neck cut is longer than was planned, and the hip cannot be reduced. In that situation, the femoral trial component must be removed, additional femoral neck should be resected, and a smaller femoral broach should be passed deeper into the metaphysis to achieve stability. Additional trial reduction is then performed. The position of the acetabular component must also be assessed, as the component may have been placed too low in the acetabulum or left too far lateralized. An intraoperative radiograph is often useful to identify the source of excessive length.

Postoperative Evaluation

One of the authors of this chapter (PFL) routinely obtains an AP pelvic radiograph in the postanesthesia care unit, and the radiographic leg length of the replaced hip is measured. If the leg is more than 3 to 4 mm longer than planned, the patient is counseled that day, before standing and beginning ambulation. The patient should be reassured that the length was necessary for stability, and the body generally adapts to the new hip. A shoe lift is not prescribed for either leg in the hospital or during the first 6 weeks after surgery. It is important to confer with the patient’s physical therapist before ambulation is started to prevent alarming or confusing the patient about any leg-length discrepancy. At 6 weeks postoperatively, if the patient has a functional leg-length discrepancy, physical therapy with supervised gentle stretching of the lumbar spine and hips is recommended. A shoe lift is rarely prescribed, except when the leg-length discrepancy is greater than 1 to 2 cm and the patient has a rigid spinal deformity. Revision related to a leg-length discrepancy is rare. If required, revision is performed only for a short leg if there is recurrent dislocation or for a long leg if the hip is greater than 2 cm longer than the contralateral hip and the patient is very symptomatic with hip, buttock, or lumbar pain and sciatica.

Summary

Intraoperative complications are an inevitable potential part of any surgical procedure, including THA. With knowledge of the risk factors for the most common complications, the rate of these events may be reduced. A firm understanding of treatment strategies can optimize patient outcomes.

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References


**Video Reference**
