A major neurovascular injury during total hip arthroplasty (THA) is uncommon. Nevertheless, these are worrisome due to their devastating consequences. As more THAs are performed each year, the chances of this potentially life- or limb-threatening injury increase. It is crucial for the orthopedic surgeon to have a thorough understanding of the anatomy of the region and the potential complications.

This article reviews the exposures to the acetabulum for simple and complex primary THA, as well as revision cases, with particular attention to the neurovascular anatomy of the region.

**ANATOMY**

**Bone**

The three-dimensional pelvic anatomy is complex and often hard to understand. Several vital vascular and visceral structures are contained within and immediately around the bony pelvis. The bony pelvis is formed by the ilium, ischium, and pubis (Figure 1). The acetabulum is located at the junction of these three bones. These bones unite anteriorly at the pubic symphysis and posteriorly to the sacrum to form a ring of bone, which connects the torso to the lower limbs.

**Vascular Structures**

The proximity of the major vessels to bone, and therefore their risk for injury during acetabular surgery, varies. Knowledge of vessel location is important because extensive exposure of the acetabulum may be required for complex revision THA.

The major vascular structures located within and around the pelvis are the internal and external iliac, femoral, internal pudendal, obturator, and superior and inferior gluteal vessels. Damage to any of these vessels by retraction, drilling, reaming, or dissection can cause massive hemorrhage, which can lead to exsanguination within minutes.

The common iliac artery divides at the L5-S1 vertebral disk. The anterior division, the external iliac artery, continues distally to become the common femoral artery, whereas the posterior division becomes the internal iliac artery. The internal iliac artery branches again into a posterior division, which gives rise to the superior gluteal artery, and an anterior division, which gives off the obturator artery before dividing into the inferior gluteal artery and internal pudendal artery.

The external iliac artery and vein are immobile and lie close to the pelvis, and thus are at highest risk for injury in...
THA (Figure 2). The external iliac vein has been shown to lie within 7 mm of the anterior column of the pelvis at the anterior inferior iliac spine and within 4 mm at the acetabular dome. The external iliac artery is at less risk due to its thicker intima and increased distance from the bone. It lies within 10 mm of the bone at the anterior inferior iliac spine and within 7 mm at the acetabular dome. The common femoral artery lies anterior and medial to the hip capsule. Only the iliopsoas lies between the vessel and capsule at this point. The femoral vein lies medial to the artery and is thus less likely to be injured. The obturator vessels also are at risk, lying fixed within 1 mm of the bony surface at the quadrilateral surface, with their only protection being the interposition of the obturator internus muscle.

At the sciatic notch, the superior gluteal vessels are at greatest risk, lying an average of 5 mm from the notch. Injury to the superior gluteal artery as a complication of THA is rare, but has been reported. The ischial spine, the inferior gluteal vessels lie an average of 6 mm and the pudendal vessels an average of 12 mm from the posterior column. Both, however, are mobile and well protected by a layer of fat. The medial and lateral femoral circumflex arteries arise from the deep femoral artery and are vulnerable to retractors placed near the femoral neck.

**Neuroanatomy**

The primary nerves of the region are the sciatic, femoral, inferior and superior gluteal, and obturator. The most common nerve injury during THA is to the peroneal division of the sciatic nerve, followed by superior gluteal, obturator, and femoral nerves. Injury to these structures can lead to loss of function and poor outcomes.

The femoral nerve is the most lateral structure within the femoral triangle. It lies on the psoas muscle belly at the approximate midpoint between the anterior superior iliac spine and pubic tubercle. Its relationship to the acetabulum is anterior, thus it is primarily at risk during capsule dissection rather than during reaming or drilling. The superior gluteal nerve traverses the interval between the gluteus medius and minimus muscles. It is generally well protected as long as the dissection does not extend >5 cm above the greater trochanter. The inferior gluteal nerve is rarely injured because it inserts into the gluteus maximus proximal and medial to the area, which is split during the posterior approach to the acetabulum. The obturator nerve runs with the obturator vessels.

The most common nerve injury during THA is to the sciatic nerve. Several reasons exist, some of which remain conjectural. It has been postulated that these are common because of the sciatic nerve anatomic location. In a review of normal computed tomography (CT), the sciatic nerve was found to lie closest to the posterior column of the pelvis at the acetabular dome, at an average of 9 mm. It also was shown to be more protected at the ischial spine, as the short external rotator muscles are interposed between the nerve and bone at this point; the nerve was an average 15 mm away from the ischial spine.
Quadrant System

The acetabular quadrant system described by Wasielewski et al. is useful for determining the location of planned acetabular screw fixation in THA to avoid neurovascular complications. The quadrants are formed by drawing a line from the anterior superior iliac spine through the center of the acetabulum and bisecting that line at the center of the acetabulum to form four equal quadrants. The line from the anterior superior iliac spine to the center of the acetabulum serves as the dividing line between anterior and posterior, and the bisecting line as the division between superior and inferior (Figure 3).

In cadaver studies, the posterior-superior and posterior-inferior quadrants were shown to have the thickest bone and best potential for obtaining secure fixation with the least risk for injury to vessels. The anterior-superior quadrant (the quadrant of death) and the anterior-inferior quadrant were shown to be the most dangerous quadrants for screw fixation due to the thin bone and close proximity of the vessels to bone in that region (Figure 4).

Approaches

The anterolateral and posterior approaches are the most common surgical approaches to the acetabulum during THA. Both approaches offer excellent visualization of the acetabulum. Comparing lateral- and posterior-oriented approaches, lateral approaches offer better exposure, although posterior approaches are more popular. The ilioinguinal and anterior (extended iliofemoral) approach are described as these approaches are often used for more extended exposures. In general, the surgical approach chosen for acetabular revision is likely to be the same as that used for the primary surgery unless other factors are involved, such as the need for increased exposure.

Posterior Approach

The posterior approach to the acetabulum is the least technically demanding approach for THA and offers good visualization of the acetabulum, especially of the posterior wall. It is the most commonly used approach for THA in the United States. The patient is placed in the lateral position. Because the approach involves splitting of the gluteus maximus in line with its fibers, no internervous plane is present. The sciatic nerve is protected by the short external rotators after they are detached from their insertions on the femur and reflected medially (Figure 5).

Damage to the inferior gluteal artery is the main vascular risk of the posterior approach. This vessel has many intramuscular branches, which often are cut when the gluteus maximus is split, and they must be identified and cauterized during dissection. For the trauma surgeon dealing with complex pelvic fractures involving the greater sciatic notch, the inferior gluteal artery also is at risk as it exits the pelvis just below the lower border of the piri-formis.

The most common nerve injury occurring during the posterior approach is contusion to the sciatic nerve. This can be minimized by avoiding excessive...
traction and ensuring that the nerve is well protected by the short external rotators. Maintaining the hip in an extended position may also decrease the risk of injury by keeping the nerve out of the operative field. Unless specifically indicated, no attempt to dissect the nerve from its surrounding perineural fat should be made.

**Anterolateral Approach and Modifications**

The anterolateral approach is a common approach for THA. It offers excellent exposure to the acetabulum. The patient is placed in the lateral position, and the dissection is carried through the intermuscular plane of the tensor fascia lata and gluteus medius. Some surgeons prefer to perform a trochanteric osteotomy, whereas others prefer to detach the anterior two-thirds of the gluteus medius from its insertion on the greater trochanter.

A modification of this approach is the Hardinge, which detaches the anterior two-thirds of the gluteus medius and continues in continuity with a soft-tissue sleeve incorporating a split in the proximal vastus lateralis.

The main risks associated with the anterolateral approach are femoral artery and vein laceration, which are vulnerable to retractors placed too far anteriorly. The anterior retractor should be placed at the 1-o’clock position for the right hip and the 11-o’clock position for the left hip. Care should be taken to ensure that the tip of the retractor is placed directly on bone and does not pierce the psos muscle, the only barrier between the acetabulum and femoral vessels. Another reasonable alternative is to pass a blunt curved retractor (eg, a blunt Homan) into the pelvis at the anterior acetabulum. Because the femoral nerve is the most lateral structure in the femoral triangle, it also is vulnerable to retractors and excessive retraction. Any modification of this approach that splits the glutaeus medius puts the superior gluteal nerve at risk (Figure 6).

The transverse branch of the lateral femoral circumflex artery may be encountered when splitting the vastus lateralis during this approach and must be cauterized or ligated.

**Anterior Approach and Modifications**

This approach is primarily used for open reduction of developmental hip dislocations, but offers access to the anterior column and anterior lip of the acetabulum. The patient is in the supine position. The superficial dissection exploits the internervous plane between the sartorius (femoral nerve) and tensor fascia latae. The femoral structures are protected provided the dissection does not stray out of the plane of the sartorius and tensor fascia latae superficially and the glutaeus medius and rectus femoris more deeply. The ascending branch of the lateral femoral circumflex artery crosses the operative field at the proximal interval between the sartorius and tensor fascia latae and must be ligated or coagulated.

More extensive exposure of the medial wall and anterior column can be provided by incising the origin of the sartorius at the anterior superior iliac spine, as well as the direct head of the rectus at the anterior superior iliac spine. Smith-Petersen et al modified this approach by cutting the tensor fascia latae distal to the myofascial portion to allow access to the femoral neck and trochanteric area. A further modification of the anterior approach has been described by Light and Keggi, which involves a lateral dissection splitting the medial fibers of the tensor fascia latae medially to provide a mus-
cle cuff to protect the lateral femoral cutaneous nerve and to minimize nerve complications for THA.

**Ilioinguinal Approach**

The ilioinguinal approach provides improved visualization of the pelvic inner surface and anterior column and medial wall of the acetabulum. This approach is effective for acetabular fractures involving the anterior wall, anterior column, and associated anterior and posterior hemitransverse fractures, both column, and transverse fractures. Advantages of this approach include excellent cosmesis, rapid recovery, and reduced heterotopic bone formation compared with other extensile approaches.

The patient is placed supine or in a lazy lateral decubitus position. The principle of this approach is to dissect closely along the inner wall of the pelvis and lift each muscular and neurovascular structure off of the bone without avulsing or tearing it. Three windows are present in this approach, each providing access to different structures. The first window allows access to the anterior sacroiliac joint, internal iliac fossa, and upper anterior column. The second window, which lies between the iliopsoas with accompanying femoral nerve and iliac vessels, allows access to the pelvic brim, quadrilateral surface, and superior pubic ramus. The third window allows access to the pubic symphysis, superior ramus, quadrilateral surface, and the retropubic space.

Nerves at risk during this approach include the femoral nerve, which lies under the inguinal canal on the anterior surface of the iliopsoas muscle. It may be injured by retraction or lacerated during dissection. The lateral femoral cutaneous nerve often is divided at the anterior superior iliac spine unless it can be easily retracted without tension.

The femoral vessels run medial to the iliopectineal fascia and are at risk as previously described. The inferior epigastric artery lies medial to the deep inguinal ring and must be ligated.

Other structures at risk include the bowel, bladder, and spermatic cord.

**Preoperative Planning**

Complex acetabular revision surgery is challenging. As with all preoperative evaluations, a detailed history is paramount. Relevant questions include the indications for the index procedure and any subsequent procedures, as well as the implant type, if known. Other relevant questions include history of infection and prior neurovascular complications.

**History**

The physical examination should document sensation and motor function of the entire lower extremity, as well as a thorough vascular examination, including bruises or any other abnormalities that might alert the surgeon to a possible vascular injury. If a neurological deficit exists, electromyogram nerve conduction studies may be useful as part of the preoperative assessment for complete documentation. Examination should document range of motion of both hips and knees, as well as contractures or limb-length discrepancies.

**Imaging**

Plain radiographs are essential for bone stock assessment. Significant bony defects may exist in the acetabulum secondary to osteolysis. These defects may preclude screw placement in the optimal quadrants. Additionally, bone loss can lead to improper revision component placement unless care is taken to ensure its correct anatomic positioning. If extensive osteolysis is suspected, CT is recommended as plain radiographs underestimate the extent of lysis.

In revision situations, medial migration of the acetabular component may exist. Preoperatively, it is important to determine the location of any intrapelvic cement or hardware in relation to major vascular and visceral structures. In these cases, angiography or CT may assist the
surgeon by demonstrating the vascular anatomy of the pelvic region in relation to the proposed operative field. Several case reports have described vascular pseudoaneurysms developing after unrecognized vascular injury during primary THA, and proper visualization of these potential hazards is critical in avoiding damage to these structures during dissection.\(^1\)\(^2\)\(^3\)

A radiograph can also ascertain various deformities of the acetabulum and femur. For example, in developmental hip dysplasia, the following bony abnormalities may be found and should be given consideration for exposure: increased femoral anteversion; small, osteoporotic femur; shallow or dysplastic acetabulum; and a subluxated or dislocated femur.

**Operative Technique**

As with all surgery, the key to successful acetabular surgery is careful and meticulous dissection. Often, the tissue planes are disrupted and the normal anatomy is distorted. Anatomic landmarks may be present, depending on the degree of bone loss. Careful identification of remaining normal landmarks is vital. Knowledge of the acetabular quadrant system and its landmarks is essential.

**Component Removal**

The goal of the surgeon when removing existing components is to preserve as much bone stock as possible and minimize the risk of neurovascular injury. Care should be taken to interrupt the interface between the bone and cement when removing cemented acetabular components. The most important thing to remember is not to create a segmental defect. Rim fracture should be avoided to further preserve the structural integrity of the acetabulum and thus reduce the risk of neurovascular injury. Intrapelvic cement extruded through screw holes can snag the external iliac vessels when the component is removed. In these cases, preoperative imaging with either contrast enhanced CT or angiography offers the surgeon options and a roadmap to the vascular anatomy. Some surgeons perform a two-stage procedure for extruded, intrapelvic cement.

When removing press-fit porous ingrowth components, similar care should be taken to disrupt the interface between the bone and component before removing the component. Curved and straight osteotomes of varying sizes can be used to disrupt this interface and to gently lever the component free from the bone. Finally, any soft-tissue adhesions should be properly ligated or coagulated, rather than torn free. A similar technique has been described using a punch, inserted through a separate stab incision in the posterior-lateral acetabulum, to disrupt the bone-implant interface.\(^1\)\(^8\)

**Avoiding Arterial and Venous Injuries**

The etiology of vascular injuries may be direct or indirect damage. Indirect damage can be due to stretching, tearing, or compression. Direct damage can be caused by excessive reaming or misplacement of retractors. Oftentimes, these indirect or direct injuries cannot be distinguished. A previous review of the vascular injuries sustained during THA revealed the most common etiology of vascular injury as thromboembolic, followed by laceration, pseudoaneurysm, and arteriovenous fistula. The left side was more commonly involved than the right, and the overall mortality was 7%, with a 15% incidence of major and 4% incidence of minor amputations.\(^1\)\(^3\) Damage to the external iliac artery is more common than to the external iliac vein.\(^1\)\(^9\) Both structures are in close proximity to the acetabular dome and need to be avoided. The mechanism of injury usually is due to retractors placed too far medially in the region proximal to the transverse acetabular ligament. To minimize this risk, anterior retractors should be placed directly on the anterior column.

Excessive reaming of the acetabulum can cause injury to the external iliac vein. Inadvertent laceration from transacetabular screw fixation and acetabular component migration can lead to damage of this fragile vessel.\(^1\)\(^8\)\(^2\)\(^0\) Avoidance of the anterior quadrants can decrease these risks. The anteroinferior quadrant is especially at risk for cement impingement leading to damage to either the obturator nerve, vein, or external iliac vein or artery. The risk of external iliac artery and vein damage from cement extrusion and the heat of polymerization can be avoided by careful cementing technique, including the liberal use of bone graft to fill any defects.

Damage to the femoral vessels is most commonly due to aberrant retractor placement.\(^1\)\(^7\)\(^2\)\(^1\) Care should be taken to ensure that the retractor tip is placed directly on bone, and that the iliopsoas is not interposed between the retractor tip and bone. Extruded cement,\(^2\)\(^2\) acetabular cup migration,\(^1\)\(^6\) and capsule dissection\(^2\)\(^3\) have also been implicated in damage to the femoral vessels.

The inferior and superior gluteal arteries can be injured by poor placement of transacetabular screws, or by pin retractors placed near the sciatic notch.\(^2\) Proper drilling technique, including direct palpation guidance, can decrease this risk. Although rare, laceration of the obturator vessels can occur from indirect contact by osteophytes or pieces of cement, or by direct violation by a retractor placed into the superior-lateral corner of the obturator foramen.

**Retroperitoneal Approach for Uncontrolled Bleeding**

When facing a complex acetabular revision or uncontrollable bleeding, the orthopedic surgeon should also be familiar with the retroperitoneal approach to the acetabulum. This approach has been described as a two-stage procedure for revision total THA and as an emergency procedure for intrapelvic control of a major vascular injury.\(^2\)\(^4\)\(^2\)\(^5\) This approach can be used when the surgeon is concerned during complex acetabular revisions in the following situations: intrapelvic dislocation, protrusion with...
no bony barrier, intrapelvic cement or implants, and anomalous vessels or path detected on preoperative angiography. This approach lowers the risk of damaging intrapelvic vessels, which may be inaccessible through standard approaches to the hip.

For two-stage revisions, the patient is placed in the lateral decubitus position, and the posterior pad is removed to allow the patient to assume a slightly more supine “lazy lateral” position. The retroperitoneal approach is performed to remove any intrapelvic cement and mobilize the vessels. The posterior pad is then replaced and the patient returned to the lateral position, and the second stage revision of the joint through either a lateral or posterior approach is performed. The advantage of this technique is that it allows for a combined anterior and lateral or posterior approach to the acetabulum during a single operation. A similar technique can be used in an emergency without repositioning the patient, should immediate intrapelvic vascular control be required.

The curvilinear incision for the retroperitoneal approach is made starting approximately 3 cm medial to the anterior superior iliac spine and ending at the inguinal ligament, over the femoral artery (Figure 7). The subcutaneous tissue, external and internal obliques, and the transversus abdominis muscles are divided to enter the retroperitoneum. At this level, the external iliac vein lies posterior to the artery. For emergency control of severe bleeding, a vessel loop can be used to temporarily ligate the external iliac vessels until the bleeding vessel can be cauterized or ligated. For two-stage revisions, these vessel loops can be loosely brought out of the wound, and the wound packed and skin temporarily closed in the event that intrapelvic proximal vascular control is needed during the joint revision stage.26

Ideally, the orthopedic surgeon should be comfortable with the initial retroperitoneal exposure and clamping of the large feeder vessels of the pelvis until a vascular surgeon performs the definitive vascular procedure. It should be noted that ligation as a damage control procedure for major vascular injury is a valid option, provided the consequences are understood. In most patients, ligation of the iliac, common femoral, and superficial femoral arteries results in critical limb ischemia and should be followed by open fasciotomy of all thigh and lower leg compartments, as compartment syndrome is common postoperatively and often difficult to diagnose in these patients. Conversely, all limb veins can be ligated without severe complications.26

If hemorrhage continues, but the patient is stable, selective arterial embolization may be another option. This procedure has been used in pelvic fractures for control of bleeding. In large centers where emergency angiography is readily available, it offers a less invasive, perhaps more precise method for identifying and embolizing select vessels without extensive surgical dissection, which could cause worsening hemorrhage. Halpern et al27 reported a case of delayed massive bleeding from the inferior gluteal artery, which was selectively embolized using angiography.

Postoperative Care

Several postoperative considerations exist for patients after severe bleeding complications. The patient should be closely monitored and aggressively resuscitated. Drain output should be followed closely. Laboratory studies should include serial hematocrits and coagulation panels. The surgeon should have a low threshold for re-exploration of the wound if high drain outputs persist or signs of active bleeding such as tachycardia, hypotension, or a falling hematocrit are present.

Avoiding Nerve Injury

Following primary THA, the incidence of nerve palsy has been reported to be approximately 1.3%, but may be as high as 5.2% for primary THA performed for developmental dysplasia or dislocation.2 For revision surgery, the incidence may be as high as 7.6%.19 Sciatic nerve palsy is the most common nerve injury following THA, with estimates ranging from 0.5%-2%.28,29 Clinically, patients with a sciatic nerve palsy complain of weakness or inability to dorsiflex the foot. Approximately 50% of these injuries have been related to lengthening and increasing lateral displacement of the leg, 22% from direct injury, 20% from bleeding complications, and 10% from postoperative dislocations. Leg lengthening should be minimized to ≤6% of the limb length. Thus, small individuals will be at increased risk, as well as females due to size and less muscle mass. Improved outcome may be expected from patients who have full or returning motor function postoperatively. During surgery, the surgeon should minimize the tension on the sciatic nerve by maintaining the knee in a flexed position as much as possible, and femoral shortening osteotomy in the dislocated dysplastic hip should be considered to reduce the risk of nerve palsy.19

Femoral nerve palsies are most often caused by retractor placement. Clinically, patients with femoral nerve palsies have weakness or loss of quadriceps function. In general, femoral nerve palsies occur in combination with sciatic nerve palsies; however, they may occur independently. The incidence of
Hematomas

The formation of a hematoma can produce immediate or delayed onset nerve palsy subsequent to THA. When it involves the gluteal compartment, the sciatic nerve is at risk.\(^{31}\) The same is true for a hematoma around the iliacus, which can cause femoral nerve palsy, especially after perforation of the medial wall in complex or revision THA. Symptoms associated with the formation or secondary nerve palsy include excessive pain exacerbated by passive stretch of the involved compartment.

Aneurysm/Pseudoaneurysm

Unrecognized injury to vascular structures during THA may not result in immediate hemorrhage because of vasoconstriction temporarily occluding the arterial lumen. The manifestation of these injuries may include arteriovenous fistula between the common femoral artery and vein, false aneurysm of the common femoral artery, and hip dislocation from a false aneurysm of the common femoral artery secondary to protrusio of the acetabulum during total hip arthroplasty.\(^{15}\) Aneurysm/Pseudoaneurysm of the external iliac artery can cause migration of a threaded acetabular component.\(^{23}\)

Summary

Total hip arthroplasty is a common and relatively safe procedure with consistently good results. Despite its popularity and excellent results, THA is a major operation with several major neuromuscular structures within reach of retractors, scalpels blades, drills, screws, and reamers. A thorough knowledge of their anatomic location and proximity to the operative field, along with a basic understanding of the principles of vascular surgery can help avoid potentially devastating consequences. Specifically, the surgeon should avoid placement of screws in the anterior-superior quadrant, be vigilant when placing retractor, and avoid excessive tension on the sciatic nerve.

Avoiding Other Surgery-Related Complications

Deep venous thrombosis (DVT) is estimated to occur in up to 70% of patients after THA without prophylaxis, with fatal pulmonary embolism occurring in 2%. With appropriate prophylaxis, either mechanical or pharmacologic, the incidence of DVT and pulmonary embolism decreases significantly. Mobilization of the femoral vessels during dissection and kinking during dislocation of the femoral head has been implicated in the etiology of DVT. During revision THA, care must be taken to minimize the insult to all neurovascular structures during surgery to lessen the chance of developing DVT and subsequent complications.

Postoperative limb ischemia can result from THA. In patients with pre-existing atherosclerosis, various intraoperative maneuvers required for positioning and dislocating the hip have been implicated.\(^{11}\) Another possible mechanism is occlusion of the external iliac artery by protrusio of the acetabular component.\(^{24}\)

REFERENCES


