Surgical approaches for total hip arthroplasty

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Abstract: The total hip arthroplasty (THA) has dramatically changed the quality of life patients debilitated by hip arthrosis since its modern inception in the 1950s. THA may be accomplished through a myriad of approaches with the most common being the posterior, direct lateral, and direct anterior approaches (DAAs). The survivorship of THA via these approaches are comparable. A plethora of recent reports demonstrate that each approach has its own unique profile of advantages and disadvantages that surgeons must navigate. This review outlines the three most common approaches for THA including technical pearls, complication profiles, and clinical outcomes.

Keywords: Total hip arthroplasty (THA); surgical approaches; direct anterior; posterior; direct lateral

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Introduction

Total hip arthroplasty (THA) has been lauded as one of the most successful surgeries since its inception in the 1950s (1,2). The Charnley low-friction arthroplasty revolutionized treatment for disabling hip arthritis (3). Over the decades since, THA has evolved greatly and has proven to be a reliable operation in relieving pain and dysfunction associated with severe hip arthrosis (4-10). Cost-effectiveness for THA for significant disability has been evaluated and found to be cost-saving per episode of hip arthrosis (11). The demand for THA is projected to increase in future decades (12-14).

Surgical approach for THA is an area of interest in the current orthopaedic literature (15-30). The surgeon must have a thorough understanding of the anatomy in order to optimize exposure and implore precise technique to minimize complications and optimize patient outcomes. The most commonly used approaches worldwide for THA include the posterior approach (PA), direct lateral approach (DLA), and the direct anterior approach (DAA) (31). The purpose of this review is to outline the anatomy and technique for each of these approaches while highlighting the differences and similarities in complication profiles and outcomes amongst these three popular approaches.

Posterior approach

The PA is the most commonly used surgical approach for THA worldwide (31). There have been several iterations of the PA since it was first described by von Langenbeck in 1874 (32). The modern-day PA was popularized by Moore in 1957 and referred to as the "Southern" approach (33). As the first modern-day approach, its intent was to limit bone and soft-tissue damage and avoid non-union often seen with the transtrochanteric approach. This approach spares the abductor musculature while providing the opportunity for wide exposure of the acetabulum and femur (34).

The PA is performed with the patient positioned in the lateral decubitus position on a traditional operating room (OR) table. Studies have shown that the pelvis must be stabilized properly when in the lateral decubitus position to avoid "pelvic drift" during the surgery (35,36). Asayama *et al.* (35) demonstrated that the pelvis frequently shifts 14.5° anteriorly during the operation from placement of an anterior pelvic retractor, pulling the femur anterior during exposure of the acetabulum. If this movement is not appreciated, the acetabular component may be placed in a relative retroversion (36). Firm stabilization of the pelvis is achieved with proper positioning via a peg board or padded hip positioners (32) (*Figure 1A*). An axillary roll

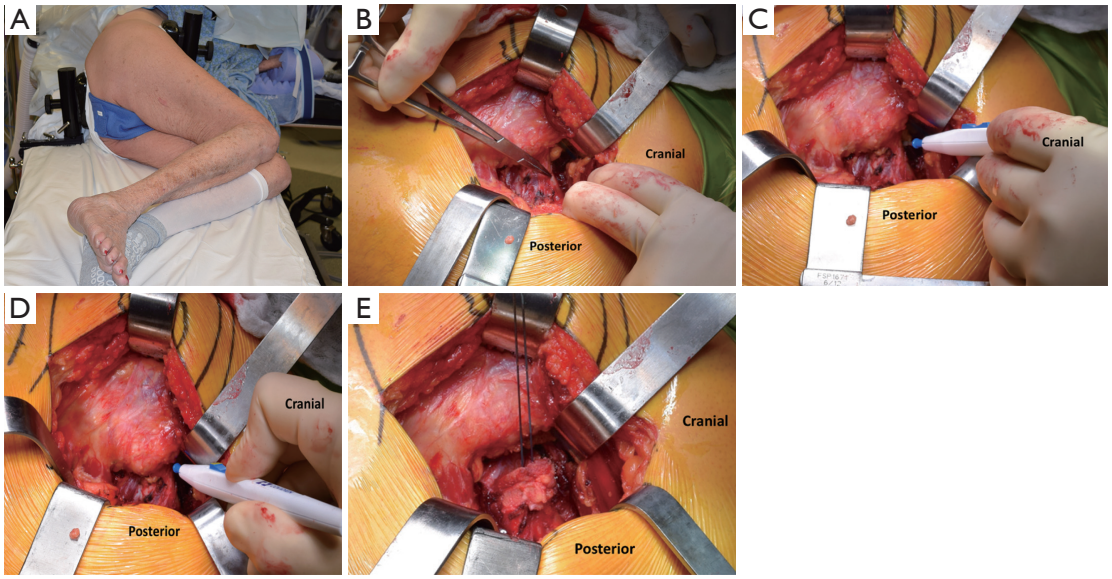

Figure 1 Positioning and exposure for the posterior approach THA. (A) Photograph of a properly positioned and stabilized pelvis using hip positioners; (B) intraoperative photographs demonstrating the piriformis (tonsil) and short external rotator tendons; (C) with the posterior border of the gluteus medius retracted antero-superiorly, the posterior capsule and external rotator tendons are incised using electrocautery, starting along the superior margin of the piriformis tendon and extending to the piriformis recess; (D) after the piriformis tendon is released, dissection is continued distally along the greater trochanter to complete the external rotator and posterior capsular release. This creates an "L" shaped flap of capsule and external rotator muscles; (E) the piriformis tendon, short external rotator tendons, and posterior capsule are tagged together with a heavy non-absorbable suture. THA, total hip arthroplasty.

is placed under the contralateral axilla in order to prevent a brachial plexopathy. The limb is then prepped and draped according to surgeon preference. While there is not a wide consensus on the optimal skin preparation, it is thought that a preparatory stick or solution with alcohol may be superior (37). Moreover, when iodine-impregnated, adhesive plastic draping is used, studies have reported a decreased incidence of drape lift off during the procedure when DuraPrep (3M Health Care, Minneapolis, MN, USA) was used as opposed to ChloraPrep (CareFusion, Inc., Leawood, KS, USA) or povidine-iodine scrub and paint (38,39). Lift-off of the adhesive drape facilitates bacterial entry into the wound. Alexander *et al.* demonstrated that a decreased incidence of drape lift-off during the procedure decreases the risk of surgical site infection six-fold (40).

The length of skin incision with any surgical approach is variable based on patient obesity, severity of joint destruction and stiffness as well as comfort level of the surgeon. Minimal differences in skin incision length have not been associated with clinical outcomes and therefore it is wise for the surgeon to extend the incision if exposure difficulties are encountered. The senior author has utilized incision lengths of 3–6 inches while utilizing the PA. Based on observations of excessive scaring in revision of THAs performed with 3-inch skin incisions, believed secondary to excessive retraction forces, he favors a skin length of 4–5 inches in most cases.

With the hip flexed 60°–70°, a straight, 4–5 inch skin incision is extended from approximately one inch distal to the vastus lateralis tubercle and continued proximally over the greater trochanter, in line with the longitudinal axis of the femoral diaphysis. Moving the incision proximally enhances exposure for femoral canal preparation which shifting it distally facilitates acetabular preparation. The iliotibial band and gluteal fascia overlying the gluteus maximus muscle (GMM) are incised. The GMM is then split longitudinally along the axis of its muscle fibers. A Charnley retractor is placed to retract the GMM for exposure. When placing the posterior arm of the Charnley retractor, the surgeon must be mindful of the sciatic nerve as it runs immediately posterior to the short external rotators (SERs) but might not be visible. The SERs and piriformis tendons are then identified and tenotomized with electrocautery at their insertion on the proximal femur.

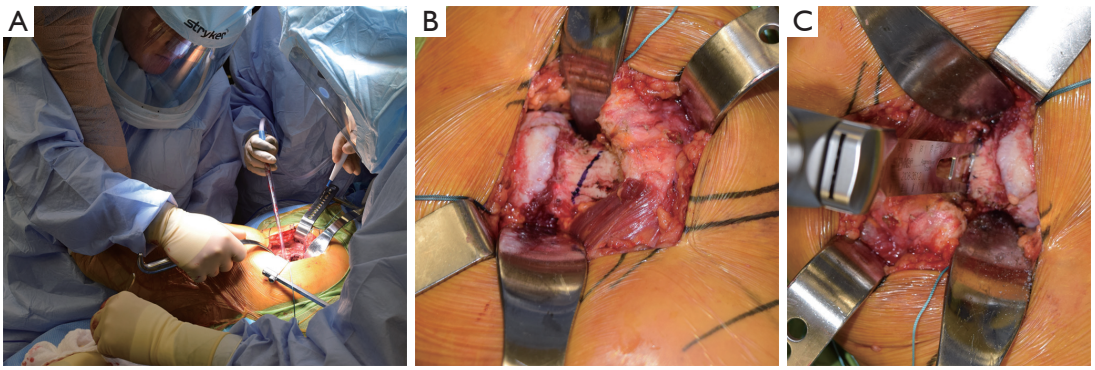

Figure 2 Femoral neck osteotomy during posterior approach THA. (A) With the leg positioned in flexion, internal rotation, and the femur held parallel with the floor the femoral neck is cut with an oscillating saw with blade perpendicular with the femoral neck; (B) planned femoral neck osteotomy marked with white line; (C) femoral neck osteotomy marked with dashed white line. THA, total hip arthroplasty.

The capsule is initially incised along the proximal edge of the piriformis and extended to the piriformis insertion into the piriformis recess (*Figure 1B*,*C*). This is critical to avoid shortening of the SER tendons due to incising them posterior to their true attachment onto the proximal femur. The incision is then extended distally to complete the SER and posterior capsular release. This results in an "L" shaped SER-posterior capsular flap (*Figure 1D*). In most cases, the SER release involves the piriformis, superior and inferior gemellus, and obturator internus muscles. If exposure difficulties are encountered, the release can extend distally into the quadratus femoris muscle. In rare cases, partial or complete release of the conjoined tendon of the GMM tendon can be performed to gain adequate mobilization of the proximal femur and acetabular exposure.

A heavy, non-absorbable suture is used to secure the proximal corner of the posterior capsule and the piriformis and obturator tendons (*Figure 1E*). Additional SER anchoring sutures can be added if the surgeon desires. Next, the hip is dislocated by an assistant with flexion, adduction, internal rotation, and gentle traction of the leg (*Figure 2A*). Using a hip hook around the femoral neck is wise during dislocation to reduce torque and possible proximal femoral fracture. If dislocation is difficult, osteophytes around the neck or acetabulum may be removed. In the setting of a severely contracted hip, partial or full release of the GMM insertion, rectus femoris tendon, and/or incision of the inferior capsule may be necessary. An *in situ* femoral neck osteotomy may also be used to avoid risk of iatrogenic fracture of the femoral neck. This is more frequently seen in the setting of coxa profunda. The neck osteotomy should be carried out using an oscillating or reciprocating saw blade oriented perpendicular to the femoral neck and according to the coronal plane template (*Figure 2B*,*C*).

Acetabular exposure is accomplished by anteriorly retracting the femur with a retractor placed over the anterior column at the 2 or 10 o'clock position, based on the hip side being operated on (*Figure 3A*). To facilitate anterior mobilization of the femur, the tensioned superior capsule is sharply incised (*Figure 3B*). The posterior joint capsule is retracted using a posterior acetabular retractor or a self-retaining retractor, such as a Charnley peg, placed into the base of the ischium. A sharp, bent retractor or an additional Charnley peg may be used at the 12 o'clock position should a robust gluteus medius muscle be obscuring proper visualization. Lastly, a Hohmann-type of retractor is placed in the region of the transverse acetabular ligament (TAL) to complete acetabular exposure (*Figure 3C*). Following exposure of the acetabulum, the labrum and pulvinar are sharply dissected. Next, acetabular reaming (*Figure 3D*) and component placement with proper anteversion and inclination are carried out utilizing landmarks, such as the posterior wall and TAL, as well as orientation of the reamer shaft relative to the floor.

The proximal femur is exposed with an assistant controlling the leg in a flexed, internally rotated, and adducted fashion. A two-pronged retractor is commonly placed along the medial calcar while a Hohmann retractor is positioned at the posterior aspect of the tip of the greater trochanter to retract the gluteal muscles and allow easy access to the femoral medullary canal (*Figure 4*). Any remaining soft tissue along the saddle of the femoral neck as it confluences with the greater trochanter is remove to facilitate lateralization of the femoral component (FC)

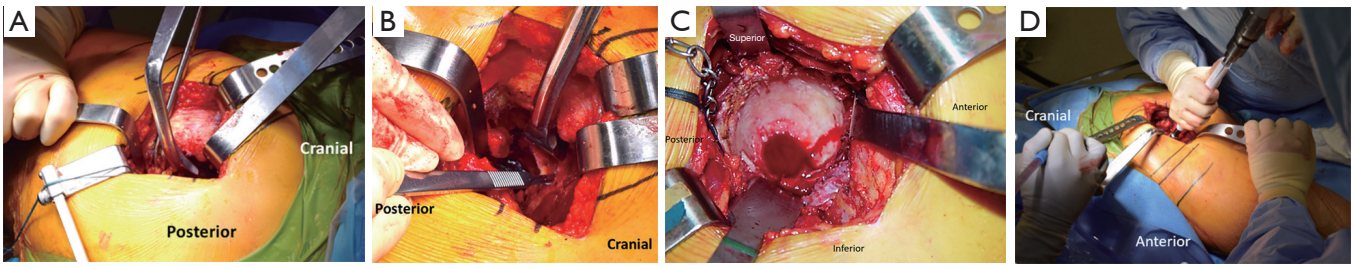

Figure 3 Acetabular exposure during a left posterior approach THA. (A) Sharp, bent retractor placed over the anterior column of the pelvis retracting the femur anteriorly; (B) intraoperative photograph demonstrating sharp release of the tensioned anterior-superior capsule to ease anterior mobilization of the femur; (C) intraoperative photograph of the exposed acetabulum via an anterior retractor placed over the anterior acetabular lip retracting the femur anteriorly, an ischial pin retracting the posterior capsule, an inferior retractor placed at the level of the transverse acetabular ligament, and a right-angled retractor positioned superiorly; (D) intraoperative photograph of acetabular reaming. THA, total hip arthroplasty.

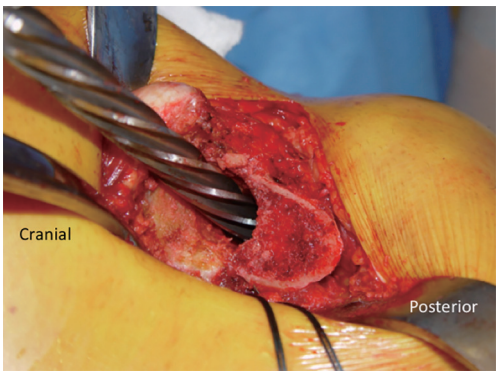

Figure 4 Proximal femoral exposure during a posterior approach THA. THA, total hip arthroplasty.

during preparation. FC preparation and implantation is then carried out in this position. Following component placement and reconstitution of hip stability, the posterior hip capsule and SERs are repaired in anatomic position through a series of transosseous bone tunnels and/or a transtendinous stitch through the gluteus medius insertion at the piriformis recess (*Figure 5*). Repair of the posterior capsule and SERs have been shown to decrease post-operative dislocation rates following PA THA (41,42). The fascia lata, GMM, and iliotibial band are then closed with a running, barbed suture or interrupted sutures followed by routine subcutaneous and skin closure.

Direct lateral approach

The DLA is the second most common exposure for THA (31). The modern iteration of the DLA was first described by Hardinge in 1982 (43). This approach allows for sufficient exposure of the acetabulum and femur, while allowing latitude for an extensible exposure of the femur if needed (34). Perhaps the most significant purported benefit of the DLA compared to other popular approaches is a low dislocation rate presumably due to the preservation of the posterior stabilizers of the hip joint (17,44,45).

Similar to the PA, the patient is positioned and padded in the lateral decubitus position. A specialized hip drape, or a sterile bag, is incorporated in the draping process to allow the operative leg to be and hang over the side of the operating table to aid the exposure and maintain sterility during femoral preparation.

With the hip flexed to 45°, a straight, 4–5 inch skin incision is centered over the greater trochanter. The iliotibial band is incised, centered over the femur, with care taken to not inadvertently cut the gluteus medius muscle. The fascia lata is incised to the proximal extent of the skin incision. Next, a Charnley retractor is placed at the level of the greater trochanter to retract the incised iliotibial band. The greater trochanteric bursa is incised and reflected posteriorly to better visualize the "fan-like" orientation of the gluteus medius muscle fibers (*Figure 6A*). At the junction of the anterior one-third and posterior two-thirds of the muscle belly, the fibers of the gluteus medius muscle become more vertically oriented. At this junction, the muscle belly is incised sharply along its fibers (*Figure 6B*). This split is carried down to the greater trochanter, approximately one centimeter distal to its tip. As the split is carried into the tendinous portion of the insertion on the trochanter, it is sharply angled distally along the vastus ridge with care not to disrupt the vastus

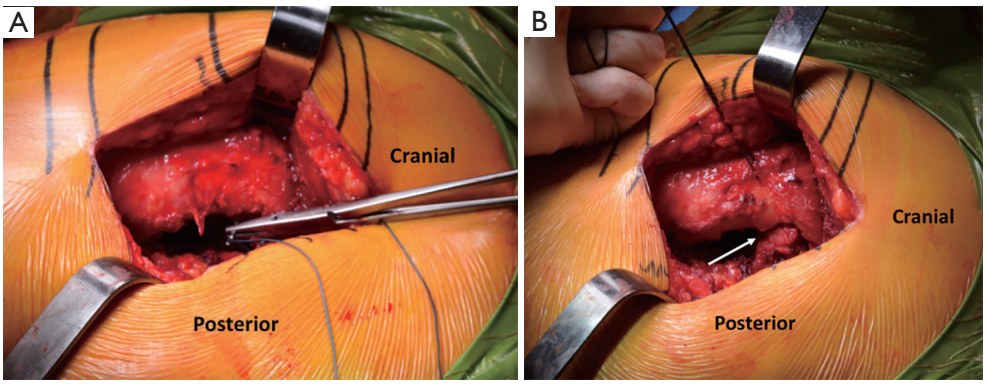

Figure 5 Capsular repair following left posterior approach THA. (A) The previously placed anchoring suture following SER and capsular release are passed in medial-to-lateral direction through the abductor insertional tendon at the piriformis recess; (B) once tensioned, the SER tendons and posterior capsule are restored back to their anatomic position (arrow). THA, total hip arthroplasty; SER, short external rotator.

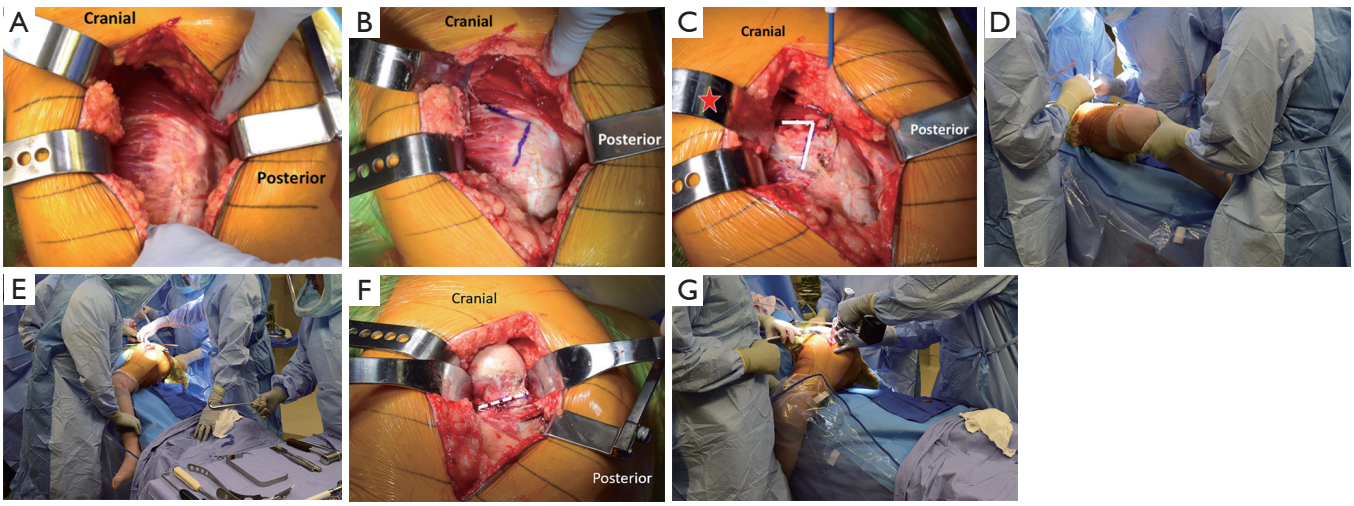

Figure 6 Exposure of the hip joint during a left direct lateral approach THA. (A) "Fan-like" orientation of gluteus medius muscle inserting on the greater trochanter; (B) blue line depicting planned tenotomy of gluteus medius tendon; (C) following tenotomy of the gluteus medius tendon, planned tenotomy of gluteus minimus tendon denoted by white lines (note: gluteus medius muscle is being retracted by a Meyerding retractor marked with star); (D) slight external rotation of the limb helps place tension on the soft tissues when tenotomizing the gluteus medius and minimus tendons; (E) dislocation maneuver involves flexion, adduction and external rotation of the limb; (F) planned femoral neck osteotomy denoted with white dashed line; (G) orientation of leg during a direct lateral approach femoral neck osteotomy. THA, total hip arthroplasty.

lateralis. It is critical to leave a cuff of tendon intact to repair the tenotomy at the end of the case. The interval between the gluteus medius and gluteus minimus muscles is then sharply developed (*Figure 6C*). Next, the assistant controlling the operative extremity will slightly flex, externally rotate and abduct the leg to place tension on the gluteus minimus muscle (*Figure 6D*). The gluteus minimus insertion is then tenotomized with care to preserve a cuff of tendon on the greater trochanter for later repair. The gluteus minimus tendon is tagged at the proximal and distal corners of the tenotomy. A Meyerding retractor is used to retract the tenotomized gluteus medius and minimus muscles. The joint capsule should be clearly apparent at this point without additional exposure. At this point, surgeons may perform a partial capsulectomy to aid in dislocation of the hip. The capsule is split along the extent of femoral

neck carried distal to the vastus ridge. The inferior portion of the capsule is then excised with electrocautery. Finally, the hip is dislocated with flexion, external rotation, and adduction (*Figure 6E*). Once dislocated, the foot is placed in the sterile pouch on the side of the table opposite the surgeon. A femoral neck osteotomy is next completed with an oscillating or reciprocating saw after placement of cobra retractors on either side of the neck (*Figure 6F,G*). After the neck cut, the leg is brought back in a resting position on top of the contralateral leg in order to begin acetabular preparation.

Exposure of the acetabulum begins by placing a wide, bent Hohmann retractor between the labrum and capsule at the 4 o'clock position for a right hip and the 8 o'clock position for a left hip. A curved, wide posterior retractor moves the femur posterior and is placed between the labrum and capsule at the 7 o'clock position for a right hip and at the 5 o'clock position for a left hip (*Figure 7*). To widen the exposure, tension is placed on the anterior and posterior retractors while the inferior capsule is divided down to the pectineus muscle. Following removal of the labrum, pulvinar, and rim osteophytes, acetabular reaming and component placement is carried out in the standard fashion.

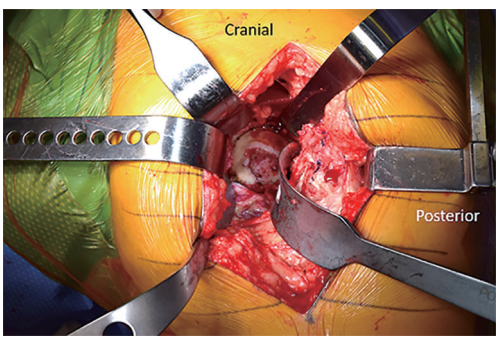

Figure 7 Intraoperative photograph of retractor placement to obtain acetabular exposure during a left direct lateral approach THA. THA, total hip arthroplasty.

Exposure of the proximal femur begins with removal of the Charnley retractor. The assistant should then hold the operative extremity in flexion, external rotation, and adduction. The foot is placed into the sterile bag opposite the surgeon. A cobra retractor is placed lateral at the greater trochanter and is used to retract the iliotibial band and fascia lata. A femoral neck retractor is placed along the medial calcar, proximal to the lesser trochanter. Finally, a wide, bent retractor is placed posterior to the proximal femur in order retract the intact, posterior two-thirds of the gluteus medius muscle (*Figure 8A*). Femoral preparation and component placement are then carried out in the standard fashion (*Figure 8B*). To reduce the reconstructed hip joint, the assistant should apply gentle traction while extending, internally rotating and abduction the hip back to a neutral position. During reduction, the surgeon should guide the head into the acetabulum while ensuring the tenotomized gluteus medius and minimus muscles do not become entrapped.

After reconstruction and a thorough irrigation of the joint, the gluteus minimus and medius tendons are repaired back to anatomic position with several interrupted absorbable stitches (*Figure 9A*). The split in the gluteus

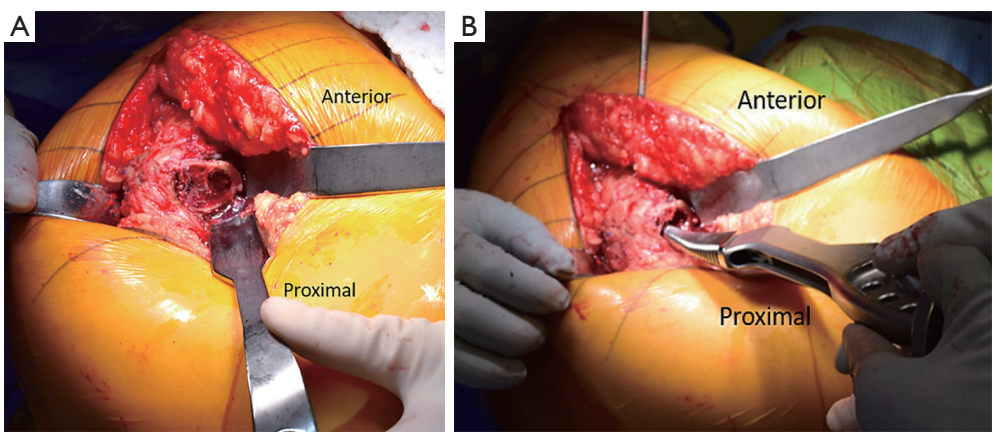

Figure 8 Proximal femoral exposure during a left direct lateral approach THA. (A) Retractor placement surrounding the proximal femur; (B) broach-preparation of the proximal femur for a femoral component. THA, total hip arthroplasty.

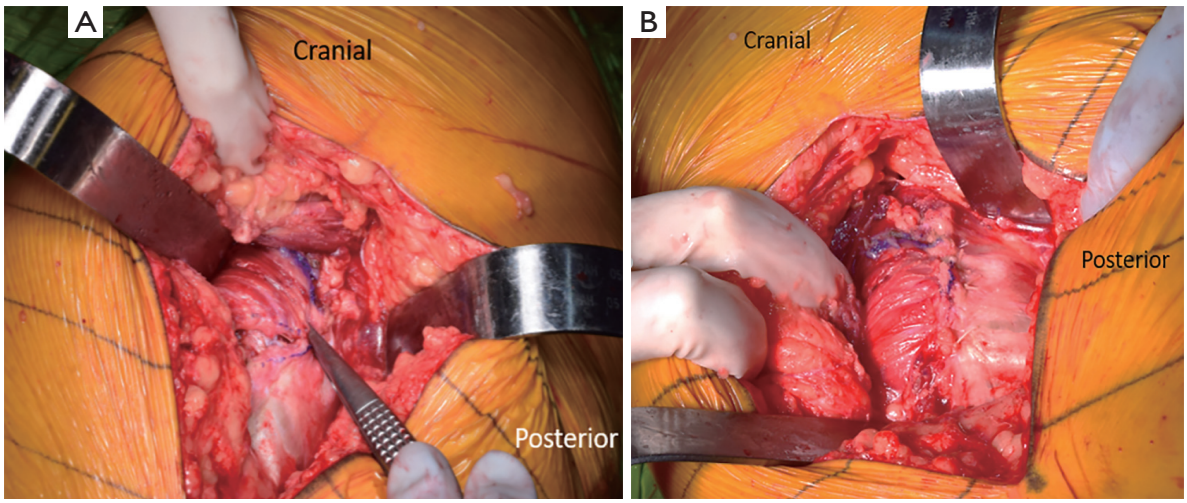

Figure 9 Abductor repair follow joint reconstruction. (A) Approximation of repair to the gluteus medius tendon; (B) following repair of the gluteus medius tendon.

medius muscle is loosely closed with a running braided, absorbable suture while ensuring not to strangle the muscle (*Figure 9B*). Finally, the fascia lata, iliotibial band, subcutaneous tissue, and skin are closed according to surgeon preference.

Direct anterior approach

The DAA was described by Smith-Peterson (46) in the early 20th century and was subsequently modified in the 1950s by Heuter (47). This approach has gained considerable popularity in the last decade (31,48). Proponents of the DAA cite its intermuscular, internervous plane, low dislocation rate, and earlier functional recovery compared to other popular approaches (15,23,30,48-51). With the approach performed in the supine positioned either on a standard or specialized orthopaedic table, intraoperative fluoroscopy can be used for optimal component positioning (52,53).

A DAA THA begins with positioning the patient supine on either a radiolucent OR table or a specialized traction table, the former of which is preferred at our institution. The pubic symphysis is positioned at the break in the table to allow for lowering of the distal half of the table during femoral exposure. An arm board is attached distally to the OR table on the contralateral side to facilitate abduction of the contralateral leg and abduction of the operative extremity during femoral preparation. Both extremities are prepped and draped using a double leg drape.

The anterior superior iliac spine (ASIS) is used as reference to mark the DAA incision. Beginning 1-inch lateral to the distal aspect of the ASIS, a 4–5 inch skin incision is carried distally towards the ipsilateral fibular head (*Figure 10A*). The obliquity of the incision is helpful in not only protecting the tensor fascia lata (TFL) throughout the procedure but also protective of the proximal aspect of the incision during femoral preparation. The incision is carried down to the fascia overlying the TFL (*Figure 10B*). A fasciotomy is sharply carried out in line with the TFL fibers. Using two Alice clamps on the medial aspect of the fasciotomy, the fascia is the sharply elevated from the TFL. Then using blunt finger dissection, the interval is found between the TFL and sartorius muscles is developed. The lateral femoral cutaneous nerve (LFCN) travels in the facia overlying the sartorius muscle and is protected by dissecting deep to the fascia overlying the TFL. This interval is marked by a "yellow fat-stripe" (*Figure 10C*). Using two Meyerding retractors, the perforating vessels of the ascending branch of the lateral femoral circumflex artery are identified and centered within the exposure by adjusting the Meyerding retractors. These vessels are the cauterized. The superior aspect of the femoral neck is identified using blunt finger dissection. A cobra retractor is placed along the superior femoral neck in an extracapsular fashion (*Figure 10D*). A second cobra is placed in an extracapsular fashion along the inferior neck by sweeping away the overlying, pericapsular fat (*Figure 10E*). Next, the interval between the capsule and the rectus femoris muscle is developed with a Cobb elevator. Once the interval is developed, a sharp, bent Hohmann retractor is placed

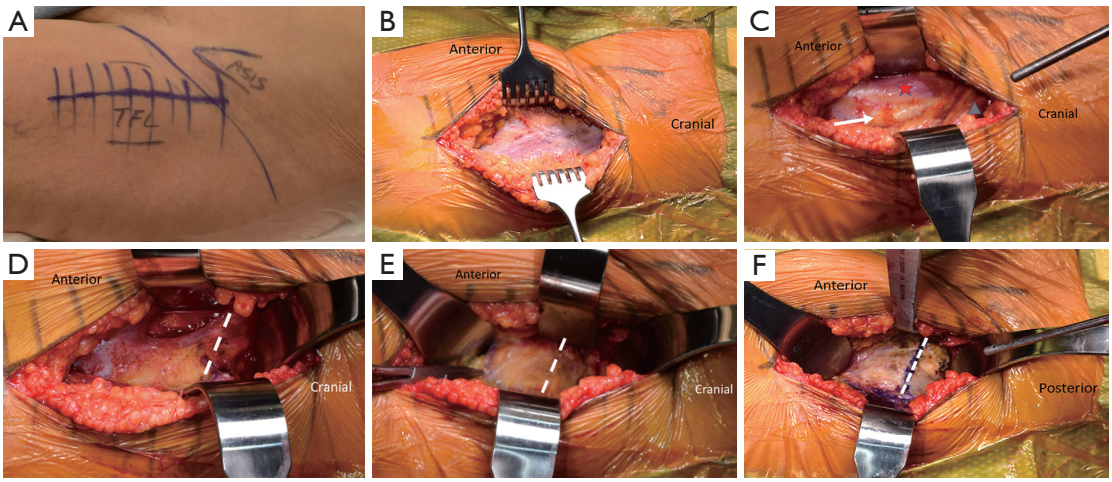

Figure 10 Positioning and exposure for a DAA THA. (A) Skin incision for DAA THA; (B) incision made through skin and Scarpa's fascia to reveal the fascia overlying the TFL muscle; (C) dissection plane between sartorius muscle (red star) and TFL (gray triangle) noted by yellow fat stripe (white arrow); (D) a Cobra retractor is placed superior to femoral neck (white dashed line) in an extracapsular fashion; (E) a Cobra retractor is placed inferior to femoral neck (white dashed line) in an extracapsular fashion; a tonsil points to the visible perforating vessels from the ascending branch of the lateral femoral circumflex artery; (F) pericapsular fat is removed with electrocautery. The white dashed line depicts the planned incision for the capsulotomy. DAA, direct anterior approach; THA, total hip arthroplasty; TFL, tensor fascia lata.

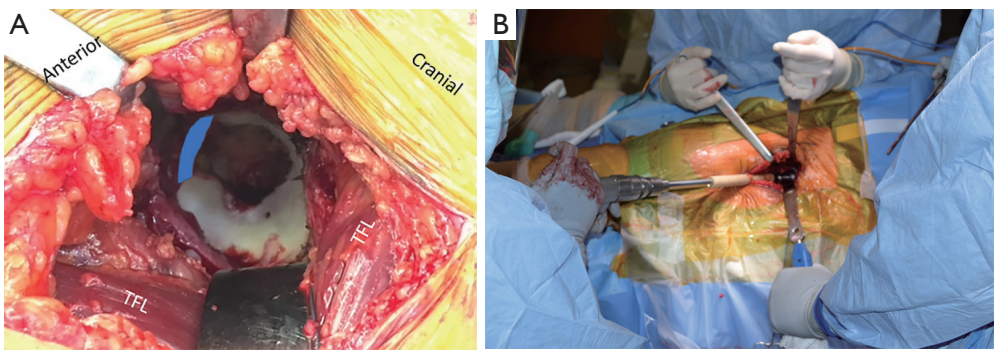

Figure 11 Exposure of the acetabulum using a left DAA THA. (A) Retractor placement surrounding the acetabulum. The transverse acetabular ligament is highlighted in blue; (B) acetabular reaming. DAA, direct anterior approach; THA, total hip arthroplasty.

over the anterior column of the pelvis, in line with femoral neck. Next, an anterior capsulotomy or capsulectomy is carried out followed by moving the cobra retractors to an intracapsular position on either side of the neck (*Figure 10F*). Using an oscillating or reciprocating saw, a femoral neck osteotomy is performed according to pre-operative templating. With gentle traction and 45° of external rotation of the leg, the femoral head is removed using a corkscrew.

Acetabular preparation begins by placement of the sharp, bent Hohmann retractor in the soft-spot between the labrum and capsule at the 4 o'clock position for a right hip and at the 8 o'clock position for a left hip. The sharp, bent Hohmann retractor remains intact at the 2 o'clock position for a right hip and at the 10 o'clock position for a left hip. Finally, a posterior retractor is placed between the labrum and capsule around the posterior-inferior acetabular wall at the 8 o'clock position for a right hip and 4 o'clock position for the left hip (*Figure 11A*). The labrum and rim osteophytes are removed circumferentially, followed by the pulvinar. Acetabular reaming and component placement are then carried out with or without the use of intraoperative fluoroscopy (*Figure 11B*).

After completing the acetabular reconstruction and

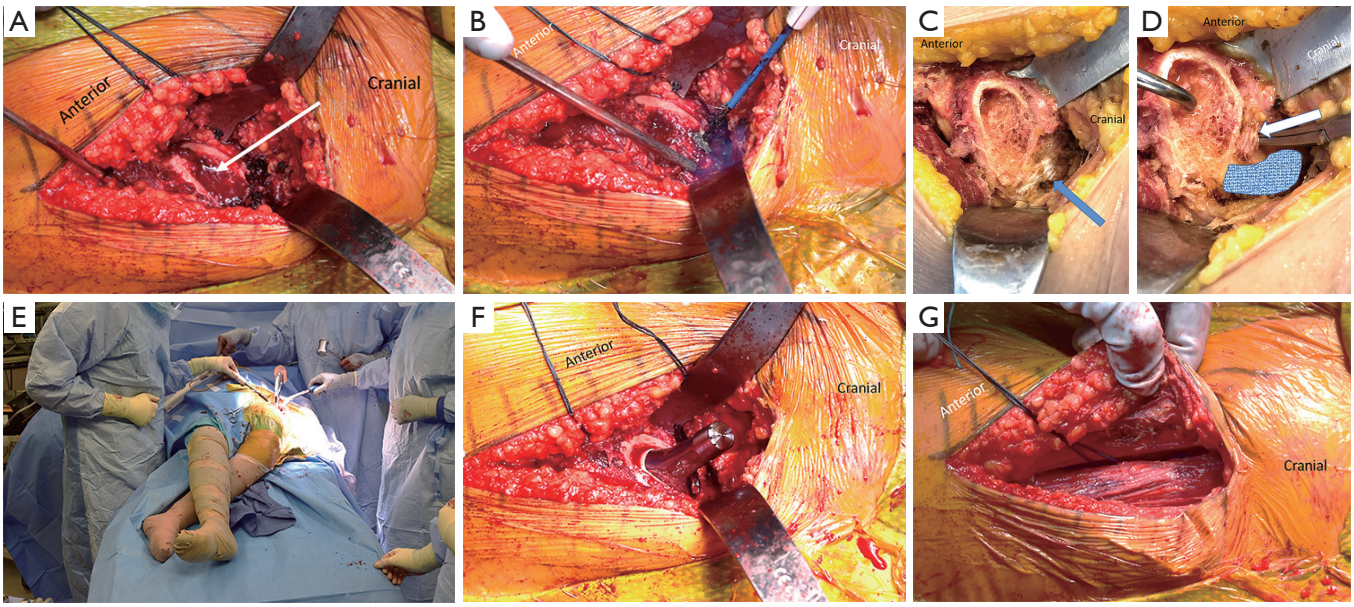

Figure 12 Exposure of the proximal femur in a left DAA THA. (A) Retractor placement surrounding the proximal femur (arrow) after release of superior capsule from the greater trochanter; (B) additional release of the conjoined tendon may be required for elevation of the femur; (C) cadaveric exposure of the proximal femur during a left DAA. The blue arrow points to an intact conjoined tendon; (D) cadaveric exposure of the proximal femur during a left DAA. White arrow pointing to a partially-released conjoined tendon. Morphology of greater trochanter is highlighted in blue; (E) following appropriate releases of the proximal femur, the leg is externally rotated and adducted under the contralateral extremity for proper exposure for femoral component preparation; (F) following placement of femoral component; (G) TFL muscle remains intact following left DAA THA. DAA, direct anterior approach; THA, total hip arthroplasty; TFL, tensor fascia lata.

removal of acetabular retractors, the assistant controlling the leg will externally rotate the extremity to 90°. The pubofemoral ligament should be released along the medial calcar of the remaining femoral neck. An intramedullary bone hook is placed along the medial calcar. The surgeon should first pull laterally to clear the greater trochanteric from the posterior wall of the acetabulum followed by a lateral-anterior pull vector. The superior capsule is episiotomized from its insertion on the anterior greater trochanter (*Figure 12A*). If more elevation of the proximal femur is required, the legs may be lowered at the break in the table. Additionally, a rolled stack of sterile towels may be placed underneath the proximal thigh to aid in elevating the femur. If yet more elevation is required, the conjoined tendon, comprised of the obturator internus, superior gemellus, and inferior gemellus tendons, may be released (*Figure 12B-D*). The obturator externus tendon insertion, which is located more posterior and medial in the piriformis fossa, is critical to posterior hip stability and should be kept intact. As a general rule, elevation of the proximal femur within the wound is considered sufficient once the medial calcar is at the level of the anterior margin of the acetabulum. At this point, still with the bone hook in hand pulling lateral and anterior, the contralateral leg is abducted (or elevated on a padded, sterile Mayo stand), while the operative extremity is adducted and held in 90° of external rotation (*Figure 12E*). A femoral neck retractor is placed along the medial aspect of the proximal femur, proximal to the lesser, which helps lateralize the proximal femur within the wound. A pronged, greater trochanteric retractor is placed over the lateral greater trochanter between the capsule and gluteus minimus tendon. Routine femoral preparation and component placement is then performed (*Figure 12F*). After final component placement, the fascia overlying the TFL is closed in an interrupted or running fashion (*Figure 12G*). Routine subcutaneous tissue and skin closure should be performed according to surgeon preference.

Outcomes

The success of THA is found in consistent, long-term

survivorship of 89–94% (4-9,54) and excellent patient satisfaction ranging from 87% to 95% (55-58). In recent years, the optimal approach has been hotly debated. Proponents of the DAA tout its intermuscular and internervous planes, and report evidence for a faster recovery (15,30,49,59), earlier discontinuation of assistive devices (30,50), and more normal gait characteristics (60). However, there is also a plethora of literature detailing a steep learning curve associated with DAA (61-63), higher complication rates (16,64,65), and early failure (17,66,67). While the DAA for THA is strongly marketed as superior to the other approaches (68,69), there is no evidence demonstrating the superiority of any approach beyond 3 months following the procedure (15,20-22,70,71).

Infection is a rare but devastating complication in THA (72). In several large studies, the incidence of prosthetic joint infection (PJI) following THA ranges from 0.2–1.2% (18,73,74). Retrospective studies have shown that there is no difference in rates of PJI between approaches (18,71,75). However, a few retrospective studies have cited greater wound complications with the DAA especially in patients with BMIs over 28 kg/m^2 (27,67,76).

Instability following THA is another complication of concern for patients and surgeons. A large evaluation of Medicare patients following elective THA in the United States reports a dislocation of 3.9% (73). However, the current literature suggests that dislocation rates may be related to surgical approach. Masonis and Bourne performed a systematic review and found a dislocation rate of 0.55% and 3.23% for the DLA and PA, respectively (44). In a meta-analysis, Kwon *et al.* reported dislocation rates 0.43% and 1.01% for the DLA and PA, respectively (45). Higgins *et al.* performed a recent meta-analysis demonstrating dislocation rates of the DAA (0.3%) compared to the PA (1.2%) (25). In a recent, multi-institution study, Meneghini *et al.* evaluated the etiologies of 342 revision THAs (17). They reported a revision rate for instability of 11.6% (40/342). They found that the majority of these revisions had the primary procedure performed via the PA (47.5%) or DAA (37.5%) compared to the DLA (15.0%) (P<0.001). A critique of this study is the lack of reporting of primary THAs performed during the study period. Therefore, the authors could not report a true incidence of dislocation stratified by approach. Angerame *et al.* recently performed a single institution study of nearly 7,000 primary THAs (2,431 DAA; 4,463 PA) and evaluated for early failure as deemed by revision surgery within 5 years of the index procedure (18). The authors reported a rate of THA failure by means of instability of 0.25% (6/2,431) for the DAA and 0.49% (20/4,463) for the PA (P=0.04, OR =2.78, 95% CI: 1.01–7.68). Registry studies have demonstrated similar findings suggesting lower dislocation rates with the DAA and DLA compared to the PA (28,77). Single cohort studies have reported overall dislocations rates of 0.6–1.0% for DAA, 0.3–0.6% for the DLA, and 1.7–5.3% for the PA (29,48,78-84). Despite convincing reports, the literature is not entirely clear on superiority of a single approach as there are reports of insignificant differences in instability rates between approaches (26,71).

The learning curve (50–100 cases) for the DAA has been clearly established in the literature (61-63). Perhaps, the most challenging part of the DAA is the femoral exposure. Difficulties with femoral exposure may result in varus malalignment and, therefore, undersizing of the FC. Furthermore, a difficult exposure and inability to elevate the femur may lead to intraoperative fracture which has been shown to be more prevalent in the DAA (1.0–5.7%) (48,64,71,85-87) but still have been reported the DLA (4.0%) and PA (1.0%) (88,89). Unlike acetabular component aseptic loosening or failed osseointegration, the FC loosening with the DAA has been found to be a significant cause of failure in recent years (17,73,86,90). Meneghini *et al.* found a higher risk of revision surgery for FC aseptic loosening with the DAA (26.4%, 34/112) and DLA (23.8%, 31/130) compared to the PA (8.4%, 7/83) (P=0.005) (17). Both Angerame *et al.* and Eto *et al.* found an increased risk of revision surgery for FC loosening with the DAA compared the PA (18,90).

Abductor muscle insufficiency is common in the immediate post-operative period following the DLA. As the gluteus medius and minimus are partially incised and repaired during the procedure, abductor insufficiency may result and is manifested as muscle weakness, a Trendelenburg gait or sign, pain, or abnormal gait mechanics (44). At the authors' institution, patients are able to weight-bear as tolerated following a DLA THA but are restricted for the first six weeks with no active abduction. Abductor insufficiency, however, may persist in 4–20% according to a systemic review by Masonis and Bourne (44). A meticulous, anatomic repair of the abductors at the end of the procedure is critical to avoiding abductor insufficiency. While more prevalent with the DLA, abductor insufficiency may be seen with either DAA or PAs (91).

Nerve injury is a devastating complication following THA, and, although infrequent, may be debilitating for patients. Depending on the surgical exposure, the LFCN,

the superior gluteal nerve (SGN), the femoral nerve, and the sciatic nerve are the nerves most at risk during THA. The LFCN is at highest risk for injury with superficial dissection during the DAA given that it runs on top of the fascia overlying the sartorius muscle (92,93). The femoral nerve and SGN are may also be injured during the DAA, however, given their proximities to the exposure, at a less frequent rate (94). The SGN is most often injured during the DLA with reported rates ranging from 2.2% to 42.5% (95-98). Jacobs and Buxton defined a "safe-area" of 5 cm proximal to the tip of the greater trochanter where dissection through the gluteus medius muscle is considered safe from SGN injury (99). With its proximity to the posterior aspect of the hip joint, sciatic nerve injury has been shown to be higher in the PA (100). While more debilitating than LFCN or SGN injuries, femoral and sciatic nerve injuries are less common and occur at rates of 0.0–2.3% and 0.1–0.7%, respectively (98,100-102).

Conclusions

A number of surgical approaches may be used to perform THA. The DAA, DLA, and PA are the most common approaches used today. As discussed in this review, there is not a consensus on the most optimal approach as each exposure has a unique set of advantages, disadvantages, and risks. Currently, there is a paucity of high-quality comparisons of these approaches. Surgeons should select their optimal surgical exposure based on their comfort, anatomical familiarity, and experience with a given approach.

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