ESSENTIALS OF PRE- AND POST-OPERATIVE EVALUATION OF TOTAL HIP ARTHROPLASTY

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Abstract

Total Hip Arthroplasty is one of the most successful surgical interventions in the history of orthopedic surgery. Multiple factors affect Total Hip Arthroplasty stability such as soft tissue tension, component position, surgical approach and patient compliance. Most common indication of Total Hip Arthroplasty is end-stage, symptomatic osteoarthritis. This study aimed at defining detailed evaluation of total hip joint Arthroplasty before and after surgery. This review article was conducted by using deferent previously published articles considering effective preoperative and postoperative assessment of total hip Arthroplasty. Preoperative detailed history, examination along with preoperative radiographic assessments and postoperative CT and/or plain radiographic assessments are mandatory for successful outcome. Total Hip Arthroplasty could be performed by different surgical approaches with the posterior one being the most commonly applied.

Keywords: *Total Hip Arthroplasty, Surgical Approach, Osteoarthritis*

1. INTRODUCTION

Total Hip Arthroplasty (THA) is one of the most successful surgical interventions in orthopedic surgery (Murphy et al., 2010).Enhancement in surgical techniques and rehabilitation after the surgery, have fundamentally magnified effectiveness and success of this operation, since its first implantation in 1950s (Khanduja, 2017). Goals of THA are restoring rotation center and length of the leg, but the anatomical challenges in achieving these goals may contribute to postoperative instability (Rowan et al., 2018). Postoperative unstable THA increase costs of hip Arthroplasty and hospital costs by up to 300% (Abdel et al., 2015). Multiple factors affect surgeon's ability to place acetabular component accurately, like experience of the surgeon, knowledge and skills of the physician, surgical approach that was favored and, body mass index of the patient (Shon et al., 2005).

The procedure provides very effective outcomes but it has potential complications, which could be divided to general and procedural-related complications. One of the most important procedure related complication is dislocation, with a reported incidence of 1-10%, complications related to cup position including impingement, wear and frequent revision surgeries (Park & Merchant, 2018).

In spite of widespread use of sonography CT and MRI in joint imaging, postoperative conventional radiograph is the gold standard in the evaluation of hip arthroplasty, since it's available, cheap, and without any metal artefact. CT has high patient radiation exposure compared to plain radiography. Serial radiograph techniques is the most beneficial method to evaluate for complications (Vanrusselt et al., 2015).

Numerous factors influence THA stability such as soft tissue tension, component position, surgical approach and patient compliance. The traditional belief regarding the optimal positioning of components in total hip arthroplasty is to have a cup inclination and anteversion within a range of 40° ± 10° and 15° ± 10°, respectively. This range is considered a "safe zone" according to Lewinnek, and it has been shown to decrease the risk of dislocation following the procedure (Abdel et al., 2016). Goals of this article are developing effective practical assessment techniques in order to enhance outcome of total hip Arthroplasty. This study aimed at defining detailed evaluation of total hip joint Arthroplasty before and after surgery.

2. RESEARCH METHODS

This review article was conducted by using deferent previously published articles considering effective preoperative and postoperative assessment of total hip Arthroplasty in order to create an efficient practical standard evaluation for a highly improved successful outcome of total hip Arthroplasty.

3. RESULTS AND DISCUSSION

3.1. Anatomy of hip joint

The hip joint is structured as a ball and socket joint enclosed by articular cartilage, a synovial membrane, and a ligamentous capsule. The acetabulum, which is cup-shaped, is created by a combination of three bones: the ileum making up 40% of the structure, the ischium making up 40%, and the pubis making up 20%, as depicted in Figure 1 (Schünke et al., 2014).

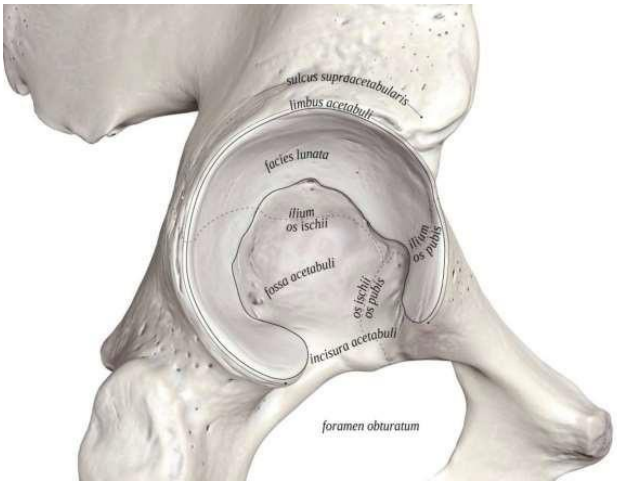

Figure 1. Acetabulum with contribution of ilium, ischium and pubis

These three bones are separated in skeletally immature individuals by tri-radiate cartilage, fuses by the age of 14-16 and completed by around 23 years (Moore, 2018). The cartilage that covers the acetabulum is shaped like a crescent, with its widest and thickest part being on the acetabular roof. It is surrounded by a bony rim and extended by the acetabular labrum. The acetabular fossa, also known as the

Cotyloid fossa, is mostly lined by the articular surface and contains fibro-fatty tissue. The transverse acetabular ligament lines the inferior part of the fossa in the region of the transverse acetabular notch as depicted in Figures 2 and 3 (Schünke et al., 2014).

The femoral head is protected by articular cartilage on around 60-70% of its surface, leaving a central area called the fovea capitis exposed for the ligamentum teres to attach. Connecting the head of the femur to the shaft is a neck, with the angle between the neck and shaft typically around 125°± 5° in healthy adults. Additionally, the femoral neck is angled about 15°-20° forward from the coronal plane in a position known as anteversion (Schünke et al., 2014). As shown in Figures 2 and 3.

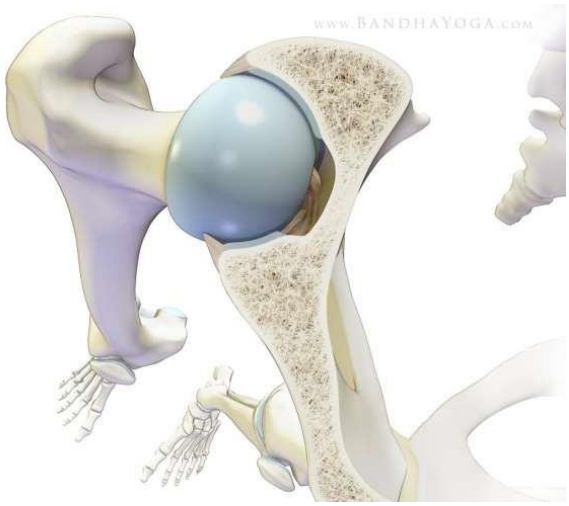

Figure 2. Hip joint with Cotyloid fossa and labrum

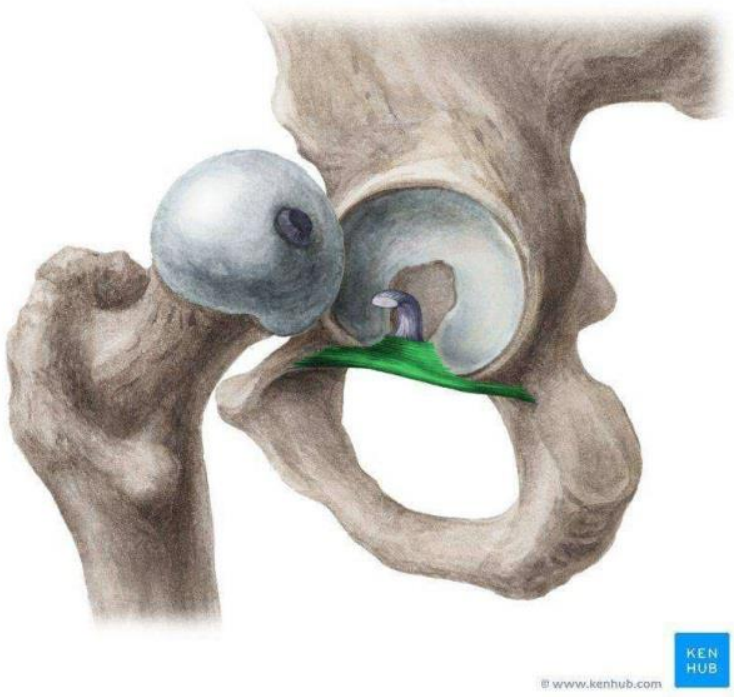

Figure 3. Transverse acetabular ligament

The femoral head receives its blood supply from the medial and lateral circumflex femoral arteries, as well as the artery of the ligamentum teres, which stems from the obturator artery. The medullary supply is also an essential source of blood for the femoral head (Schünke et al., 2014).

The blood supply to the hip joint comes from arteries such as the superior gluteal arteries, as well as the medial and lateral circumflex femoral arteries (Al-Talalwah, 2015) as shown in Figure 4.

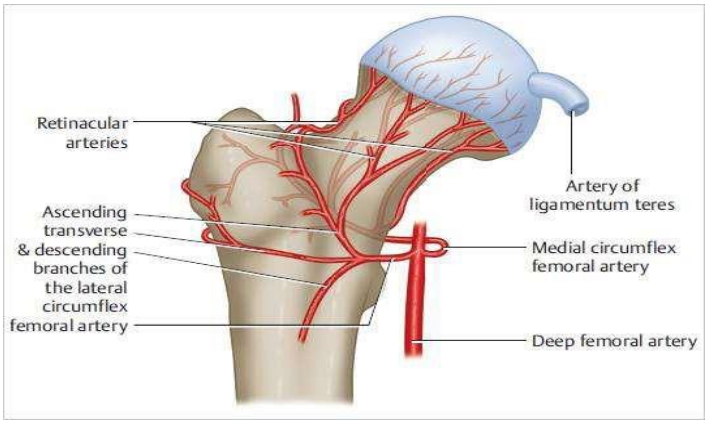

Figure 4. Blood supply of femoral head

The hip joint is innervated by several nerves: the femoral nerve in the front, the obturator nerve below, the sciatic nerve on the side, and the superior gluteal nerve behind it (Moore, 2018). The neurovascular components around the hip include: In the front, the femoral (from medial to lateral) vein, artery, and nerve. Behind, the sciatic nerve. Above, the superior gluteal nerve and its accompanying artery (Schünke et al., 2014).

There are 22 muscles around the hip to provide stability in addition to the movements of the hip; these can divided to three main groups: outer hip muscles, inner hip muscles, and adductor muscles (Schünke et al., 2014).

The hip moves in various directions and the main muscles responsible for each movement are as follows: Flexion is controlled by the iliopsoas, sartorius, rectus femoris, and pectineus. Extension is managed by the gluteus maximus, semitendinosus, semimembranosus, and biceps femoris. Abduction involves the gluteus medius, gluteus minimus, piriformis, and tensor fasciae latae. Adduction is carried out by the adductor longus, brevis, magnus, pectineus, and gracilis. External rotation is governed by the biceps femoris, gluteus maximus, obturators, piriformis, gemelli, and quadratus femoris. Internal rotation is influenced by the anterior fibers of gluteus medius and minimus, as well as the tensor fasciae latae (Schünke et al., 2014).

The amount of hip joint flexion is influenced by the position of the knee, which can help relax the hamstrings and improve flexibility. The extension of the hip joint is restricted by the joint capsule and the iliofemoral ligament, as illustrated in Figure 5 (Schünke et al., 2014).

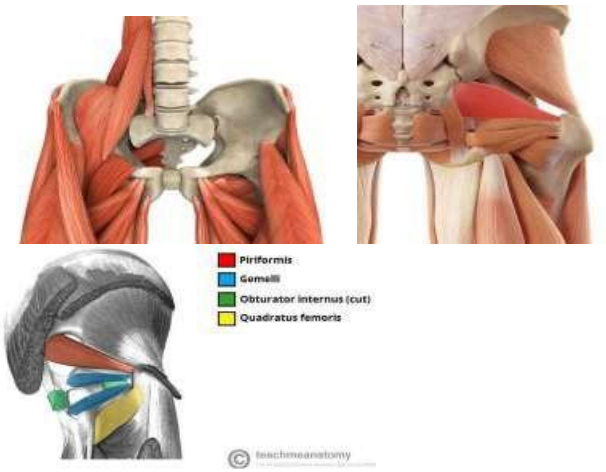

Figure 5. Muscles of hip joint

Three extra-capsular ligaments connect pelvis and femur to reinforce hip capsule. These ligaments consist of: iliofemoral, pubofemoral, ischiofemoral, annular ligament and the ligamentum teres. It encircles the femoral head like a buttonhole, has no mechanical function only transmits blood vessels (Schünke et al., 2014). See Figure 6.

The most powerful ligament in the hip joint, known as the Iliofemoral ligament or ligament of Bigelow, stretches from the front lower part of the iliac spine to the front intertrochanteric line in a shape resembling an inverted Y. Its main purpose is to prevent excessive hyperextension of the hip joint. The Pubofemoral ligament connects the upper part of the pubic ramus to the lower femoral neck, offering resistance against extreme abduction of the hip. The Ischiofemoral ligament, the thinnest of the three, runs from the ischial rim of the acetabulum and attaches to the femoral neck. Its primary role is to stabilize the hip joint when it is fully extended (Moore, 2018).

Furthermore, there exists a structure known as the annular ligament, composed of circular fibres within the hip joint's articular capsule. These fibers encircle the femoral neck like a collar. On the front side, they merge with the inner layer of the iliofemoral ligament and connect to the anterior inferior iliac spine (Moore, 2018).

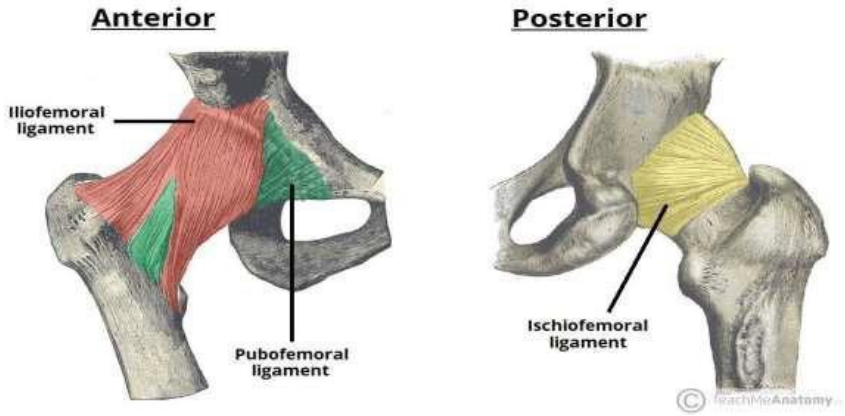

Figure 6. Ligaments of hip joint

3.2. Biomechanics of Hip Joint

The hip joint is analysed in two dimensions to determine joint forces. Simplified two-dimensional analysis in the frontal plane is used to estimate static loading at the hip joint. When weight is evenly distributed on both legs, the centre of gravity is positioned between the hips with equal force on each hip. Under this loading condition, the body weight minus the leg weight is evenly supported by the femoral heads, resulting in vertical vectors (Byrne et al., 2010).

During single leg stance, the effective centre of gravity shifts away from the supporting leg as the non-supporting leg is considered in the body mass affecting the weight-bearing hip (Byrne et al., 2010) (refer to Figure 7).

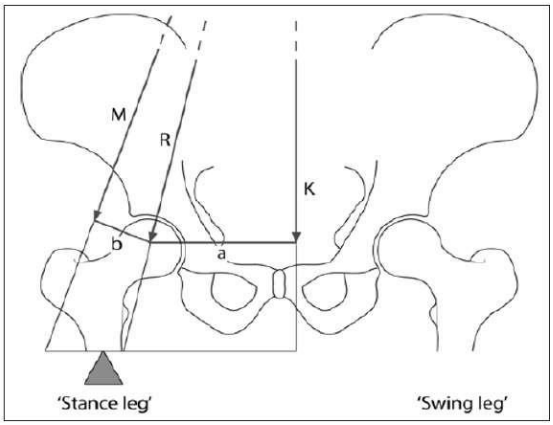

Figure 7. Biomechanics of hip

The force acting downwards results in a rotational movement around the centre of the femoral head, which is generated by a combination of body weight, K, and the moment arm, a (the distance from the femur to the centre of gravity). Counteracting this movement are the abductor muscles, M, which include the upper fibres of the gluteus maximus, tensor fascia lata, gluteus medius and minimus, obturator internus, and piriformis (Byrne et al., 2010).

The abductor muscles also create a turning force around the centre of the femoral head, but their moment arm is shorter than the effective lever arm of the body weight. Therefore, the total force of the abductors needs to be a multiple of the body weight (Byrne et al., 2010).

The magnitude of these forces is determined by the lever arm ratio between the moment arm of body weight and that of the abductor muscles (a:b) (Byrne et al., 2010). In the case of a single leg stance, the typical force levels are three times that of the body weight, correlating to a ratio of 2.5. Increasing the lever arm ratio will consequently increase the required force from the abductor muscles for walking, as well as the force on the femoral head (Byrne et al., 2010).

Individuals with shorter femoral necks experience greater hip forces, while those with wider pelvises also have higher hip forces. This explains why women, who have wider pelvises to accommodate childbirth, tend to experience more hip fractures and requires hip replacements due to arthritis compared to men (Burr et al., 1977).

Using a cane or walking stick in the opposite hand is a method to decrease the joint reaction force. The combined force from the cane and abductor muscles generates a force opposite to that of the effective body weight, as depicted in Figure 8 (Byrne et al., 2010).

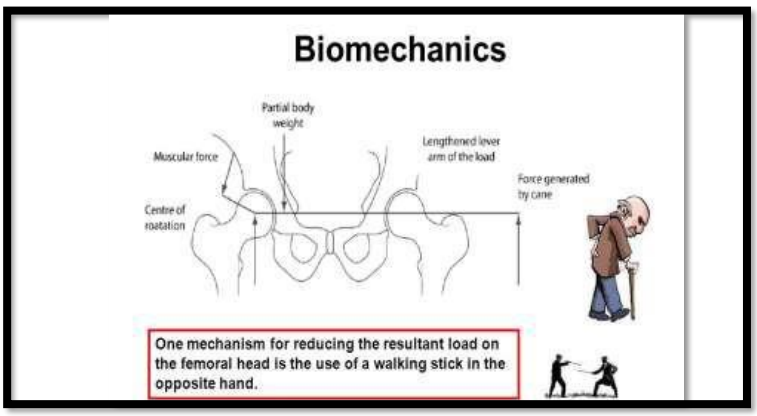

Figure 8. Effects of using cane

In two-dimensional static analysis, the joint reaction force can be halved (from 3 times body weight to 1.5 times body weight) with the application of around 15% body weight to the cane (Byrne et al., 2010).

Using a cane for support can lead to a notable decrease in joint reaction force because the force between the cane and the ground is exerted at a much greater distance from the hip center compared to the abductor muscles. Therefore, even with a light load on the cane, it plays a significant role in reducing the strain on the abductor muscle group (Byrne et al., 2010).

As a ball-and-socket joint, the hip has three principle axes of motion, all pass through the hip center of rotation, accordingly the joint has 3 degrees of freedom allowing movement in 6 principle directions, as shown in Figure 9; these are: Transverse axis: Flexion (anteversion), and extension (retroversion). Sagittal axis: Adduction and abduction. Longitudinal axis: internal, and external rotation (Schünke et al., 2014).

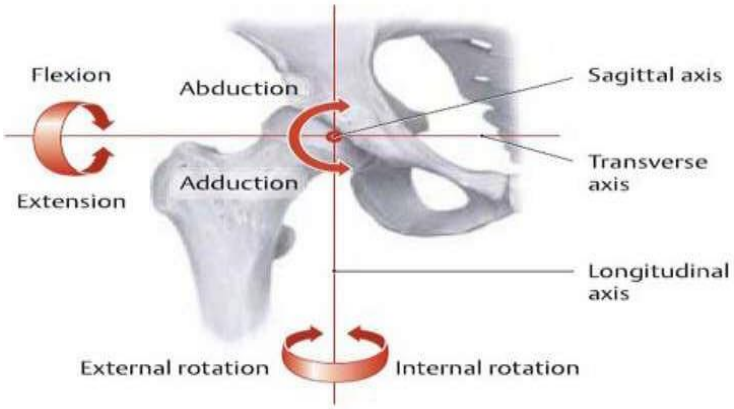

Figure 9. Movement plane of hip joint

3.3. Biomechanics of THA

Placement of the acetabular component has been a topic of debate when it comes to finding the best cup position and alignment. If this is not done properly, it can lead to reduced hip functionality and an increased risk of dislocations, mainly due to wear and tear on the joint (Bonnin et al., 2012).

The positioning of the cup is usually discussed in relation to the pelvis. The side-to-side placement is measured using the acetabular offset: the shortest distance between the center of rotation and a perpendicular line to the interteardrop line, extending to the furthest point of the teardrop projection (Bonnin et al., 2012).

The total offset from the acetabular and femoral components should be the same as the combined offset. During total hip arthroplasty surgery, restoring the combined offset is crucial to maintain the tension in the abductor muscle group. Over-tensioning can cause friction with the iliotibial band and pain in the trochanter, while under-tensioning can lead to instability in the replaced hip (Cassidy et al., 2012). If the rotation center of the replaced hip is shifted to the side compared to the native hip, the femoral offset must be reduced, which can result in higher joint reaction forces and more wear. Conversely, adjusting the acetabular component towards the middle may increase the femoral offset and reduce reactionary forces in the joint, leading to less wear (Cassidy et al., 2012).

Shifting the cup in a more upward direction results in a 0.1% increase in joint load for every millimeter of upward displacement of the hip center of rotation. This is significantly lower compared to the 0.7% increase per millimeter when moving the center of rotation of the hip joint to the side (Bicanic et al., 2009).

The positioning of the acetabular cup during total hip arthroplasty (THA) affects the potential for stem-cup impingement and the likelihood of dislocation (Biedermann et al., 2005), in the future, the wear rate is mainly affected by the size of the weight-bearing surface (Little et al., 2009).

The inclination of the acetabular cup is determined using a radiograph of the pelvis in the anteroposterior position. The angle of cup abduction, which reflects the radiological inclination of the cup, is the angle between the interteardrop line and the major axis of the cup projection. The anteversion of the radiographic cup is the angle between the acetabular axis and the coronal plane, and is calculated based on the ratio of the short and long axes on the anteroposterior pelvic view.

When the abduction angle decreases, the acetabular component becomes more horizontal, leading to an increased weightbearing area in the anterosuperior region but a decrease in coverage in the posteroinferior area. By increasing the cup anteversion, the weightbearing area in the anterosuperior region decreases while the coverage in the posteroinferior area increases (Brown & Callaghan, 2008).

The region of the joint where weight is most supported at the front must be wide enough to evenly distribute pressure, while it is also important to have enough coverage at the back for stability when the joint is moved in certain ways, such as bending, rotating internally, and bringing the limb towards the body (Brown & Callaghan, 2008) (Figure 10).

Femoral anteversion plays a significant role in stability, as more anteversion allows for greater internal rotation but can lead to the femoral neck rubbing against the acetabular rim sooner during external rotation, which could potentially cause the hip joint to dislocate forwards (Van Houcke et al., 2017).

To ensure a wide range of movement without any obstruction, it is essential to consider the combined anteversion of the femoral stem and acetabular cup in relation to the inclination of the cup (Dorr et al., 2009). It is generally recommended to have a cup abduction angle of 40° ± 10° and a combined anteversion of around 40° for optimal results (Leslie et al., 2009), with recent recommendations indicating an abduction angle of 40° ± 5° as the best inclination for the acetabular cup according to most surgeons (Abdel et al., 2016) (Brown & Callaghan, 2008).

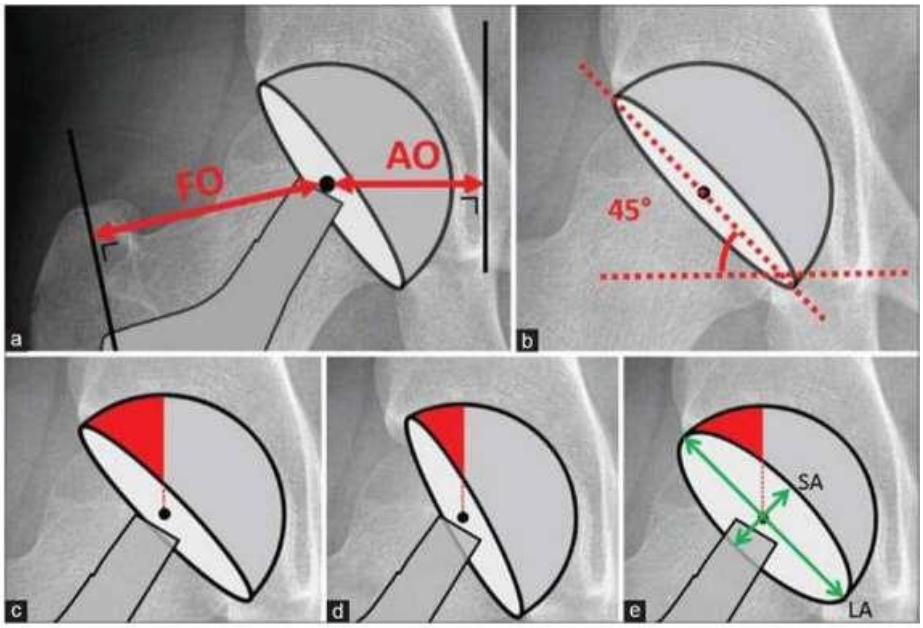

Figure 10. (a) Assessing AO and FO. (b) Cup abduction angle determined by the angle formed by the inter teardrop line and the major axis of cup projection. (c) The weightbearing area in the front and top of a cup with 45° abduction and 15° tilt, (d) diminished weightbearing area in the front and top when the cup is positioned at 60° abduction, (e) decreased weightbearing area in the front and top with greater cup tilt compared to the scenario outlined in (c) of the same diagram, green arrows indicate SA and LA of the cup. Anteversion angle = asin (SA/LA) *180/pi. AO: Acetabular distance from the center, FO: Distal distance of the femur, SA: Short axis, LA: Long axis (Van Houcke et al., 2017)

3.4. THA Indications

End-stage, symptomatic hip osteoarthritis (OA) is most common indication for THA. Moreover, hip osteonecrosis, congenital hip disorders, and inflammatory arthritis are other indications of THA (Murphy et al., 2010).

3.4.1. Pre-operative Patient Evaluation

We should properly select patients for THA, whether the pain is sufficient to indicate surgery, reasonable life expectancy or would the patient be bedridden after surgery due to other comorbidities. Patients' general condition should be well enough to tolerate the intervention. Also, assessment for cardiopulmonary, infections and thromboembolism should be done. Aspirin and other antiplatelet medications should be stopped 7-10 days prior to surgical intervention, oral anti-coagulants should be stopped for a sufficient time to ensure the return of normal coagulation studies, bridging program with short acting anti-coagulant as enoxaparin may be used. Pyogenic dermal lesions should be eradicated, urinary retention and dental problems should be addressed before surgery (Dorr et al., 2009).

Physical examination starts with general assessment of the patient to local assessment of the range of hip motion, weakness of abductor complex assessed by trendelenburg's test, hip fixed flexion contractures assessed by Thomas' test, assessment of the spine, lower and upper extremities. Any fixed spine deformities such as scoliosis or lordosis, limb length inequality and if any deformity is present in the lower limb, must be addressed before surgery (Dorr et al., 2009).

Pre-operative conventional radiographs should be taken with at least anteroposterior (AP) and lateral views to evaluate structural integrity of acetabulum, to estimate size of implant required with templating, how much reaming would be needed and if any bone graft to be taken into account. Additional CT-scan or MRI may be required in some cases (Dorr et al., 2009).

Pre-operative planning must include use of plastic overlay templates supplied by prosthesis manufacturing company and this removes much of the guesswork during surgery and therefore shortening surgical time (Dorr et al., 2009).

Investigations should be sent prior to surgery including complete blood count, renal functions, blood sugar, glycated hemoglobin for diabetics, virology screening tests, coagulation profile, urinalysis, erythrocytes sedimentation rates, in addition to chest x- rays and other investigations according to the associated comorbidities (Dorr et al., 2009).

3.4.2. Radiological Evaluation of Hip

Conventional radiography is the main diagnostic imaging tool to assess for hip. Radiographs are cheap, available and expose patients to small amounts of radiation. Most common radiographic views are anterioposterior AP view of pelvis and cross-table lateral view of affected hip as shown in Figure 11 (Goyal, 2015).

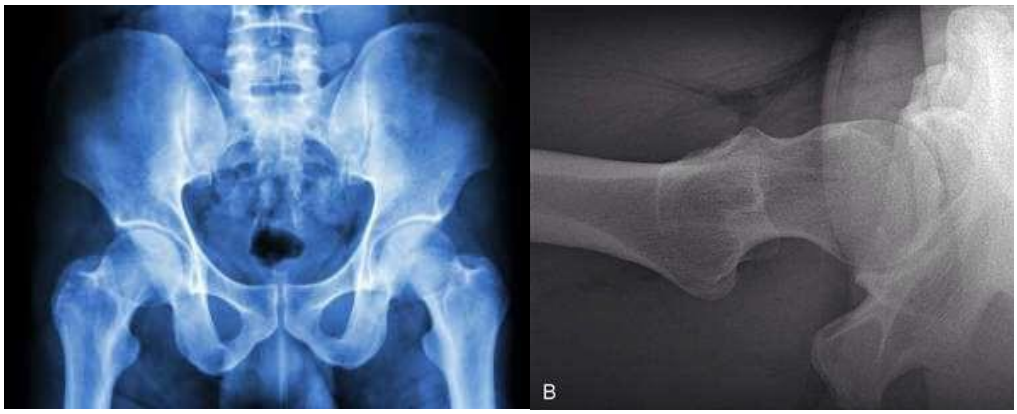

Figure 11. AP and cross table lateral hip radiograph

On an X-ray image in Figure 12, significant landmarks can be easily identified. The iliopectineal (iliopubic) line is created by the curved line of the ilium and the upper edge of the top pubic ramus, extending to the pubic symphysis. This line forms a section of the front column of the acetabulum, as mentioned by Ruiz Santiago et al. (2016). The ilioischial line of Köhler starts at the inner edge of the iliac wing and runs along the inner edge of the ischium to the ischial tuberosity. It belongs to the rear column of the acetabulum, as mentioned by Ruiz Santiago et al (2016). In normal circumstances, the floor of the acetabular fossa is positioned two mm to the lateral side of the ilioischial line in men and one mm in women (Ruiz Santiago et al., 2016). The teardrop shape symbolises the combination of shadows, with its central part relating to the inner cortex of the pelvis and the outer edge linked to the acetabular notch and the front lower section of the quadrilateral plate (Troelsen et al., 2010). It doesn't occur at birth but rather forms over time due to the pressure of the femoral head (Ruiz Santiago et al., 2016).

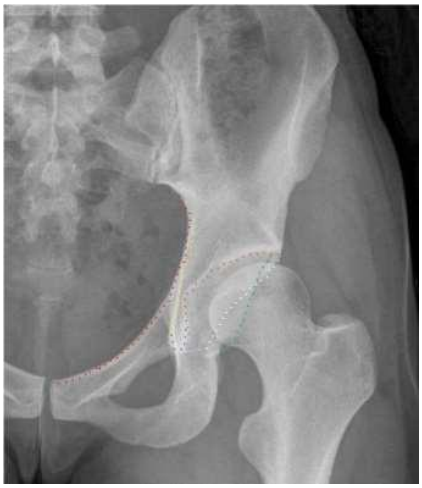

Figure 12. (a) Iliopectineal line (red line), ilioischial line (yellow line), tear drop (blue line), acetabular fossa (brown), and anterior (white) and posterior (green line) wall of the acetabuli showing mild upper crossover sign

In adults, normal hip joint space ranges from 3 to 5 mm and should be uniform. Values below 2 mm are consistent with joint space narrowing (Troelsen et al., 2010). In

normal conditions the acetabulum covers around 75% of femoral head (Ruiz Santiago et al., 2016).

Anteversion have different definitions in relation to different planes and landmarks, the angle between acetabular axis projection into transverse plane and left-right axis is named true anteversion, whereas the angle between acetabular axis and coronal plane is best called planar anteversion. Finally the angle between the acetabular axis projection into sagittal plane and cranial-caudal axis is called operative anteversion (Pankaj et al., 2017). Most accurate method to measure anteversion is by using advanced CT cross-sectional imaging, rather than plain conventional radiographs (Kalteis et al., 2006), but CT scan is expensive with high radiation exposure. We can measure antevesion either in AP view or cross table lateral view. Anteversion of acetabular component can be measured by different methods on plain AP radiographs as shown in Figure 13. On the other hand, measurement of anteversion with lateral cross table view is shown in Figure 13f and the technique for cross-table lateral view is shown in Figure 14 in which the affected lower limb is internally rotated by 15°- 20° in supine position with flexed hip and knee joints on the other side, to inhibit radiographic interference (Liaw et al., 2006).

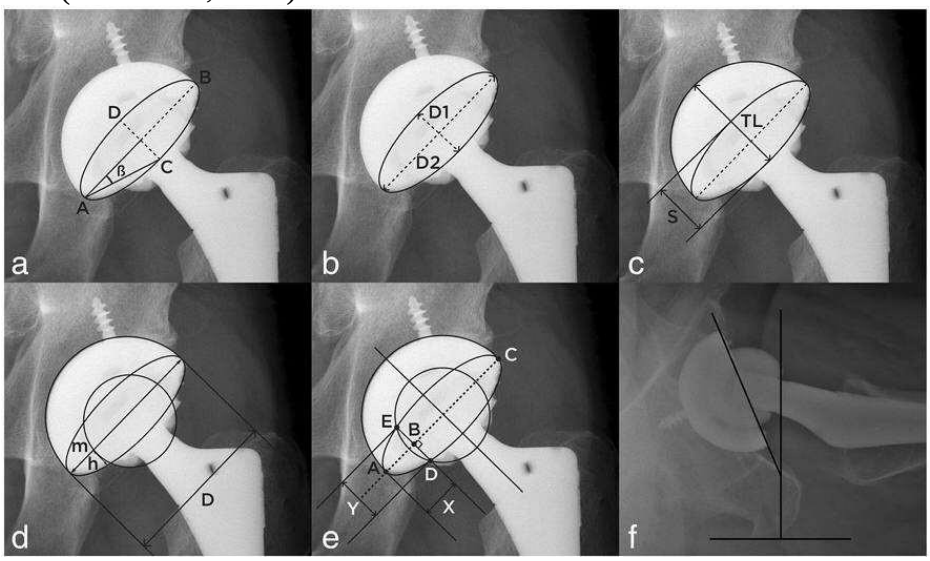

Figure 13: (a) Liaw et al method depiction. β angle is used to calculate anteversion. (b) Lewinnek et al method depiction. Long and short axes of ellipse are used to calculate anteversion. (c) Widmer's method depiction. Short axis of ellipse and total length of acetabular component are used to calculate anteversion. (d) Hassan et al method depiction. Long axis of ellipse and the head edge are used to calculate anteversion. (e) Ackland et al method depiction. Each perpendicular distance from the end of ellipse to the cross section between tangent and diametrical line is used to calculate anteversion. (f) Woo and Morrey method depiction, the cross-table lateral radiograph is used to calculated anteversion (Nho et al., 2012)

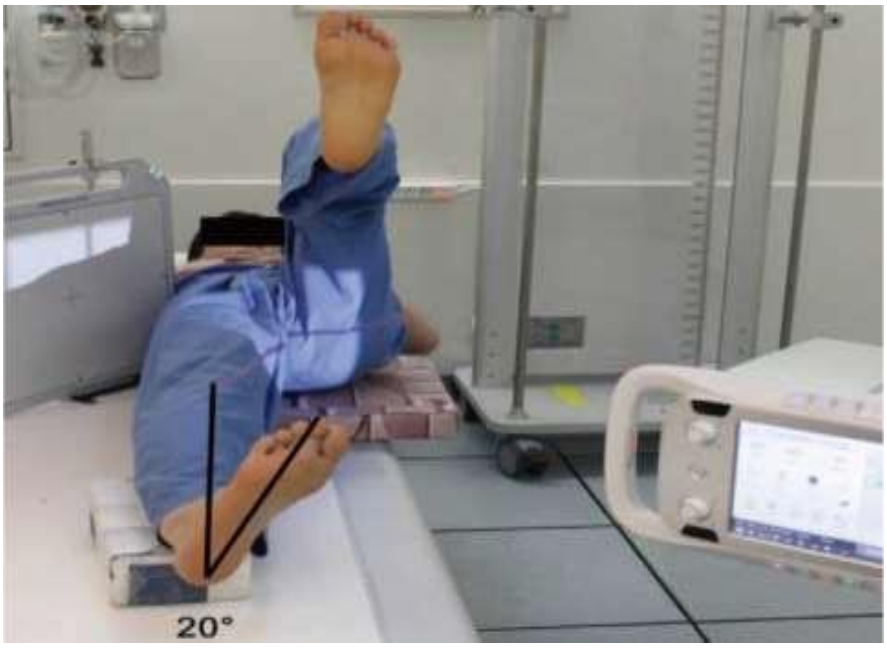

Figure 14. Technique of lateral cross table view (Lim & Park, 2015)

3.4.3. Surgical Approaches to the Hip

The methods for accessing the hip joint capsule are categorised into different approaches such as anterior, anterolateral, lateral, posterior and medial approaches. These various surgical techniques offer efficient exposure to the anatomy, ensuring safe execution of surgical procedures. The posterior approach is often preferred for total hip replacement surgeries due to its ability to preserve the abductor mechanism, resulting in quicker rehabilitation (Mortazavi et al., 2014).

The skin cut is made 10 cm away from the back upper hip bone and continues outwards and downwards towards the greater thigh bone. The thick connective tissue and the covering of the buttocks are then cut along the same line as the skin cut. The muscle fibers of the largest buttock muscle are carefully separated along the same line as the skin cut. This ensures that the branches of the main blood vessels and nerves in the top half of the muscle, as well as those in the lower half, are kept intact. The large nerve running down the back of the leg is then located and safeguarded. The short muscles responsible for rotating the leg outwards are gently cut free from their attachment on the thigh bone. The muscles are then moved inwards to protect the large nerve running down the back of the leg, and now the joint covering is visible (Mortazavi et al., 2014).

The anterior method, also referred to as the anterior iliofemoral or Smith-Petersen method, provides effective visibility of the acetabulum and helps in avoiding damage to the abductor mechanism (Mortazavi et al., 2014).

The initial concept of the direct lateral approach was presented in 1954 by McFarland and Osborne, with further improvements made by Hardinge in 1982. One of the main drawbacks of this method is the risk of weakened abductors and potential harm to the superior gluteal nerve and blood vessels following surgery (Mortazavi et al., 2014).

The Watson-Jones anterolateral approach, which has been modified by Charnley, Harris, and Muller, takes advantage of the intramuscular space between the tensor fasciae latae and gluteus medius muscles (Mortazavi et al., 2014).

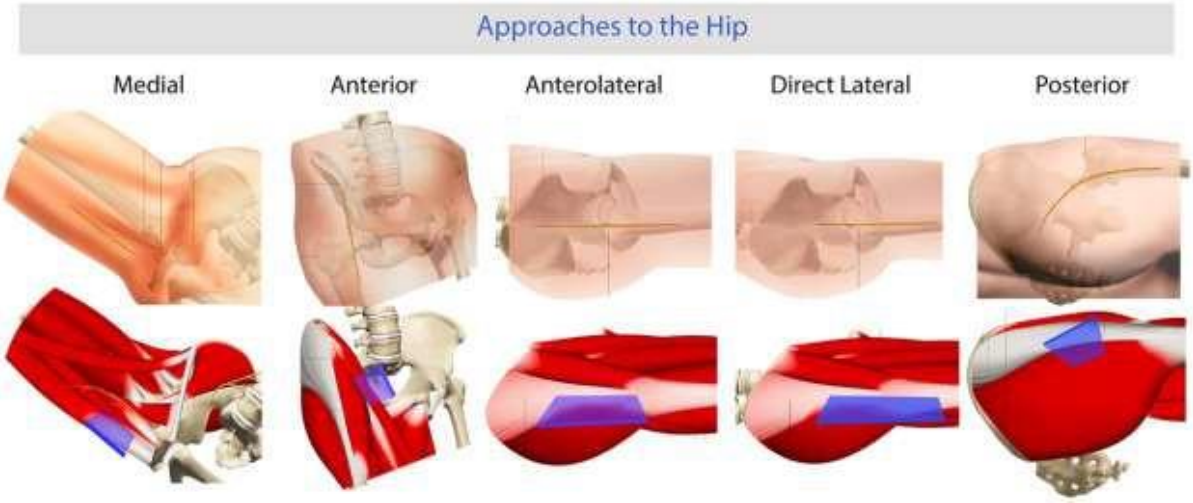

Figure 15. Approaches to hip joint

4. CONCLUSION

Hip replacement surgery is considered a highly successful procedure within the field of orthopedic medicine. Advances in surgical techniques and post-operative rehabilitation have significantly improved the effectiveness and outcomes of this operation since it was first introduced in the 1950s. The main objectives of total hip arthroplasty (THA) are to restore the rotation centre and leg length, though there are challenges in achieving these goals due to anatomical factors which can contribute to post-operative instability. Instability after THA surgery can significantly increase the overall costs of the procedure and hospital expenses by as much as 300%. Various factors, such as the surgeon's experience, the surgical approach taken, and the patient's body mass index, can impact the surgeon's ability to accurately place the acetabular component during the procedure.

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