Surgical Anatomy of the Hip Joint

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1.1 Overview

The hip joint is the largest ball-and-socket joint in the human body. It consists of the femoral head and the acetabulum. Connecting the pelvis and the lower limb, the hip joint is the pivot of the transmission of body weight from the trunk to the lower limbs; it also has very important roles in retaining balance, supporting the weight of the upper body and walking. The cuplike acetabulum forms at the union of three pelvic bones—the ilium, pubis, and ischium, with the prominent rim augmented by the ring-shaped fibrocartilaginous lip, the acetabular labrum, which extends the joint beyond the equator and makes the joint stable as well as flexible at the same time. The joint capsule is tough and tight, with multiple ligaments around it. Iliofemoral ligament, the strongest one among these ligaments, lies in front of the joint capsule, also known as the Y ligament or Bigelow ligament. This ligament can limit hyperextension of the hip joint, strengthen the joint capsule, and help to maintain the upright posture. There is a 1.2-cm-long V-shaped ligament between the deep acetabulum and the femoral head. It is called the femoral head ligament, which contains vessels to nourish femoral head. The femoral head is hemispherical, and the femoral head is oriented medially and anteriorly. In the center of the femoral head, there is a fossa, where the femoral head ligament attaches, and the rest is the articular surface, covered by a lubricated layer called hyaline cartilage. The cup-shaped acetabulum and the spherical femoral head make the joint congruent. The hip movements have three mutually perpendicular main axes, all of which pass through the center of the femoral head, resulting in three degrees of freedom and three pair of principal directions: flexion and extension; lateral rotation and medial rotation; and abduction and adduction (Fig. 1.1).

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1.1.1 Acetabulum

The acetabulum is located at the midpoint of the line connecting the anteroinferior iliac spine and the ischial tuberosity. It is a deep hemispherical recess with an average diameter of 4.5 cm; it is oriented laterally and distally. The acetabulum consists of three parts: ilium, ischium, and pubis. Contributing two-fifths of the structure is the ischium, which provides lower and side boundaries to the acetabulum (posterior wall). The ilium forms the dome, providing a little less than two-fifths of the structure of the acetabulum. The rest (anterior wall) is formed by the pubis, near the midline. It is bounded by a prominent uneven rim. At the lower part of the acetabulum is the acetabular notch, on which the transverse acetabular ligament attaches. There is a small hole between the deep part of the acetabulum and the notch, called the acetabular hole, through which the blood vessels that nourish the acetabulum pass. The acetabulum grasps almost half the femoral ball, a grip augmented by a ring-shaped fibrocartilaginous lip, the acetabular labrum, which extends the joint beyond the equator. This will make the hip joint more stable.

1.1.2 Proximal Femur

Proximal femur includes femoral head, femoral neck, the greater trochanter, and the lesser trochanter. It is supported by the femoral neck, and its diameter ranges from 4.5 to 5.5 cm. The surface of the femoral head is coated by articular cartilage and fits the acetabulum. The articular surface of the femoral head is larger than that of the acetabulum, which increases the range of motion of the femoral head. Usually, the anterior, upper-lateral, and posterior edges of the femoral head are not covered by the acetabulum. These parts of the cartilage surface around the femoral head contact with the articular cartilage surface of the acetabulum only when the hip joint is extremely flexed or extended. The articular cartilage surface can be divided into three areas: The area on the stress axis that projects to the femo-

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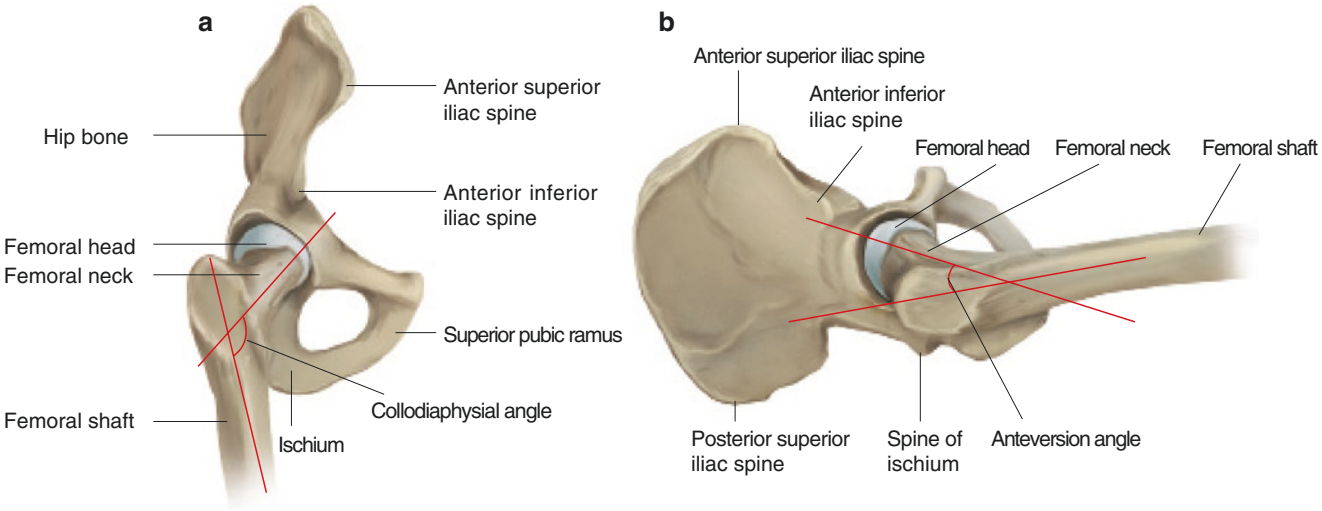

Fig. 1.1 Osseous composition of hip joint. (**a**) Anterior view; (**b**) Lateral view

ral head is the pressure-bearing area, the inner side and the outer edge of the femoral head are the non-pressure-bearing areas. The fovea capitis is a small, concave, depression within the head of the femur that serves as an attachment point for the ligament tears, a conduit of a small artery to the head of the femur, that is, the foveal artery. This artery is not present in everyone but can become the only blood supply to the bone in the head of the femur when the neck of the femur is fractured or disrupted by injury in childhood.

1.1.3 Femoral Neck

The flattened pyramidal process of bone between the femoral head and the femoral shaft is called the femoral neck. The angle between the longitudinal axes of the femoral neck and shaft is called the neck-shaft angle (NSA). Through NSA, the weight of the upper body can transmit from the narrow hip weight-bearing area to the wide base of the femoral neck. This angle also increases the range of motion of the lower limbs. The NSA of an adult is about 127 ° (male 132 °, female 127 °). The NSA in children is larger, about 160 °, and will decrease with age. If the NSA is less than 110 °, it is called coxa vara, and if it is more than 140 °, it is called coxa valga (Fig. 1.1a). On the coronal section, the angle formed between the long axis projection line of the neck and the line connecting femoral condyles is called the femoral anteversion or torsion. The adult anteversion is 10 °~15 ° (male 12.2 °, female 13.2 °, Fig. 1.1b). Hip external rotators are much stronger than internal rotators. This fact is considered to be the cause of the formation of anteversion. The anteversion is a measurement of the angle between the long axis of the neck and the coronal axis of the femoral condyles, the knee, and the ankle.

1.2 Anterior Surgical Approach to the Hip and the Anatomical Characteristics

The groin separates the anterior part of the hip and the abdomen. The inguinal ligament, which lies in the deep, is an important structure in this area. The ligament runs from the pubic tubercle to the anterior superior iliac spine. The iliopectinal arch forms a septum which subdivides the space deep to the inguinal ligament into a lateral muscular lacuna and a medial vascular lacuna. They are important passages between the abdomen/pelvic cavity and anteromedial thigh region.

The sartorius muscle originates from the anterior superior iliac spine, runs obliquely across the upper and anterior part of the thigh in an inferomedial direction, inserts into the superomedial surface of the tibia. The anterior hip region is divided into two triangular areas by sartorius. The medial one includes the femoral nerve and the femoral artery and vein. It is an important structure to be protected cautiously during hip surgery. The anterolateral area is mostly covered by muscles, with less important blood vessels and nerves. Therefore, it is a common area for various surgical approaches (Fig. 1.2).

1.2.1 Anatomy of the Anterolateral Hip Region and Common Approaches

1.2.1.1 Anatomical Landmarks

1.2.1.1.1 Anterior Superior Iliac Spine

Located at the anterior extremity of the iliac crest of the pelvis, it provides attachment for the inguinal ligament, sartorius muscle, and tensor fasciae latae muscle. It can also be used as a landmark when measuring the length of the lower

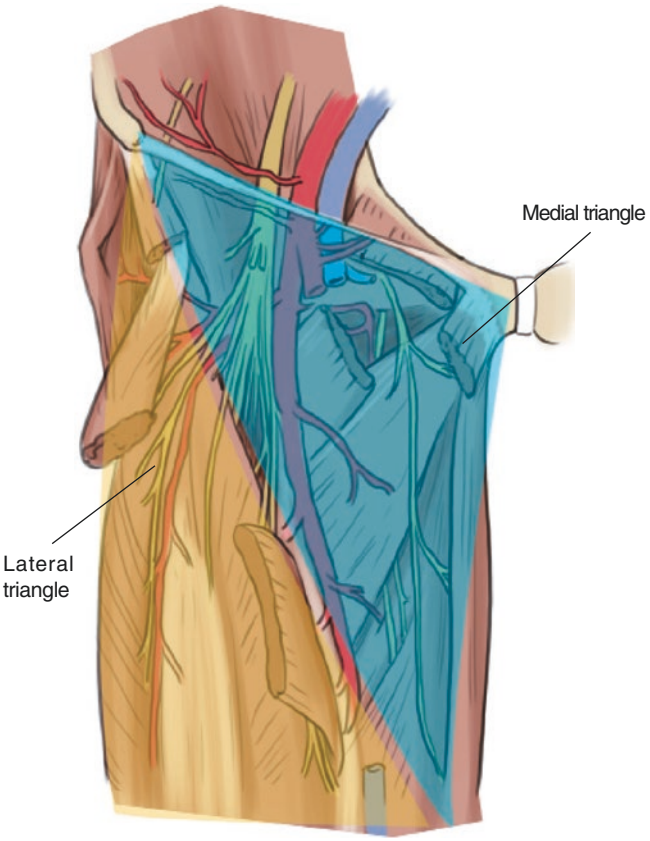

Fig. 1.2 Divisions of hip anterior triangulation

limbs. Because the lateral femoral cutaneous nerve runs near it, the anterior superior iliac spine is seldom used as a bone donor site.

1.2.1.1.2 The Greater Trochanter of the Femur

It is a large, irregular, quadrilateral eminence on lateral proximal femur, and it is directed lateral and medially and slightly posterior. The greater trochanter of femur serves for the insertion of the tendons of many hip abductors and external rotators. Its superior border is difficult to be felt because of the attachment of the fascia lata between the iliac crest and the tip of the greater trochanter. However, if the thigh is abducted and the fascia lata is relaxed, the greater trochanter is easy to be touched.

1.2.1.1.3 Median Point of Inguinal Ligament

Press hard below the midpoint of the inguinal ligament and rotate the lower limb. Then feel the femoral head rotating under the fingers.

1.2.1.2 Anatomy of Superficial Structures

The anterior approach of the hip joint usually enters between the sartorius muscle and the tensor fasciae latae muscle, and the lateral approach enters between the tensor fasciae latae muscle and the gluteus medius. These two approaches will

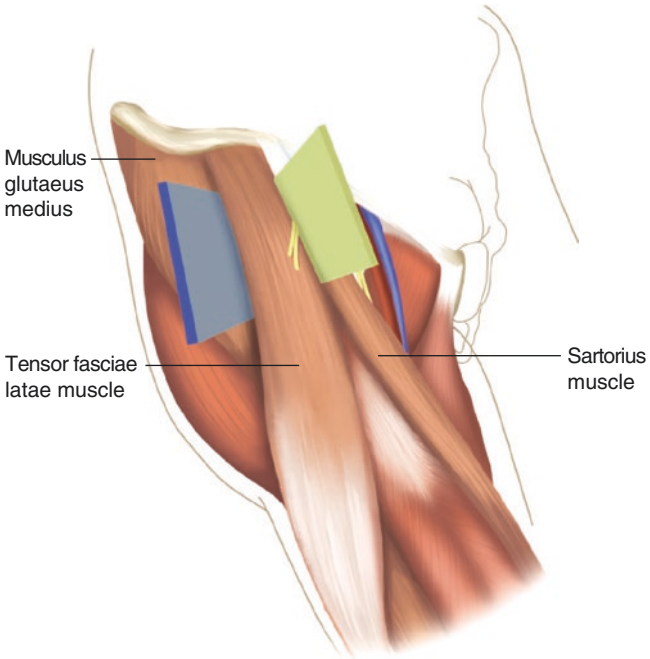

Fig. 1.3 Common inter-muscle space via anterior approach

go through the following structures: the fascia lata, the sartorius muscle, and the tensor fasciae latae muscle (Fig. 1.3).

1.2.1.2.1 Sartorius Muscle

It is the longest muscle in the human body, located on the medial side of the anterior (lateral) approach, originating from the anterior superior iliac spine and part of the notch between the anterior superior iliac spine and the anterior inferior iliac spine. It runs obliquely across the upper and anterior part of the thigh in an inferomedial direction. The lateral femoral cutaneous nerve is often passing through in the superficial layer of the origin of the muscle. The nerve should be protected during the operation. The upper part of the sartorius muscle receives the blood supplies from the branch of the profound femoral artery and the lateral circumflex artery. Both arteries are about 10-cm below the anterior superior iliac spine and enter the muscle at its medial edge. The muscular branches of the femoral nerve that innervate the sartorius muscle are accompanied by the blood vessels (forming the vascular bundle) into the muscle. Therefore, through this approach, the muscle is transected below the anterior superior iliac spine and is pulled to the medial side, which will protect the vessels and nerves.

1.2.1.2.2 Tensor Fascia Latae Muscle

It locates between the sartorius and gluteus medius and in front of the lateral approach to the hip joint. The muscle is triangular, sharing the same origin, the anterior part of the iliac crest, with the sartorius muscle. After running down with Sartorius, Tensor fascia latae muscle is inserted between

the two layers of the iliotibial band of the fascia lata about the junction of the middle and upper thirds of the thigh. Rectus femoris runs between the two muscles. The tensor fasciae latae muscle is 16-cm long, 3-cm wide, and 1.3-cm thick. Tensor fasciae latae mainly receives blood supply from the ascending branch of the lateral femoral circumflex artery and is innervated by the superior gluteal nerve. Because of the overlap between the posterior margin of tensor fascia lata and the anterior margin of gluteus medius, it is difficult to locate the gap between the two muscles through the lateral approach.

1.2.1.3 Deep Anatomy

The muscles located deeply in the anterior lateral hip region, from medial to lateral side, include the rectus femoris, the iliopsoas, gluteus medius, and gluteus minimus.

1.2.1.3.1 Rectus Femoris

The rectus femoris muscle is one of the four quadriceps muscles. It is fusiform in shape, with an anterior straight tendon rising from the anterior inferior iliac spine, a flat and thin reflected tendon rising from a groove above the rim of the acetabulum and the capsule. The two unite at an acute angle and spread into an aponeurosis which is prolonged downward on the anterior surface of the muscle, and from this, the muscular fibers arise. Its superficial fibers are arranged in a bipenniform manner, the deep fibers running straight down to the deep aponeurosis. The muscle ends in a broad and thick aponeurosis and, gradually becoming narrowed into a flattened tendon, is inserted into the base of the patella together with the vastus medialis and the vastus lateralis. The rectus femoris muscle receives blood supplies from multiple vessels, mainly the descending branch of the lateral femoral circumflex artery; it is innervated by the femoral nerve. Two bundles of vessels and nerves enter the muscle from the upper and middle part of the medial margin. During the dissection of deep structures through the anterior (lateral) approach, it is safe to go through the gap lateral to the muscle. It can protect the vessels and nerves mentioned above.

Cut off the origin of the rectus femoris or retract it medially. The vastus intermedius, covered by fascia, lies deep to the rectus femoris. Under the fascia runs lateral femoral circumflex artery that is divided into ascending, descending, and transverse branches: the ascending branch supplies the tensor fascia lata muscle and sartorius muscle, etc.; the descending branch supplies the lower part of the quadriceps and the knee joint; the transverse branch passes lateralward over the vastus intermedius, pierces the vastus lateralis, and winds around the femur, just below the greater trochanter, anastomosing on the back of the thigh with the medial femoral circumflex artery, the inferior gluteal artery, and the perforating arteries of the profunda femoris artery. The branch

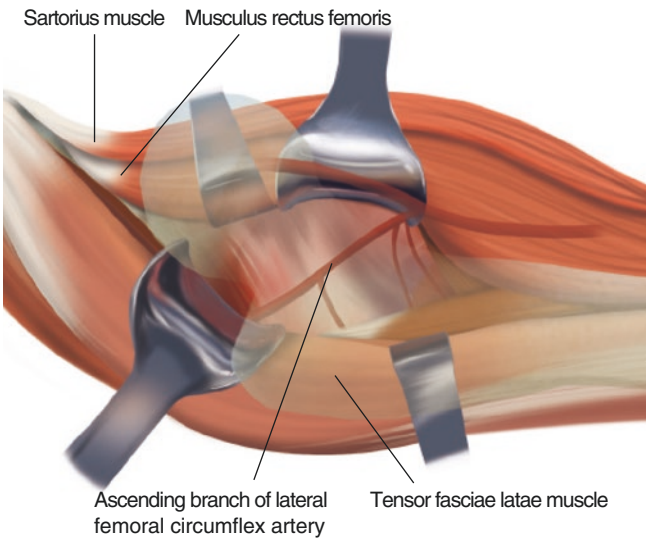

Fig. 1.4 Interface and anatomy of ascending branch of lateral femoral circumflex artery

of the lateral femoral circumflex artery that extends to the anterior part of the femoral neck and travels in front of the iliopsoas muscle through the lateral margin to the deeper layer. The branches supply the base of the femoral neck along the intertrochanteric line, the joint capsule, and the femoral neck in the capsule. The artery supplies the neck in the joint capsule is large, and it is located along the femoral neck under the synovial membrane. The reticular artery near the medial femoral circumflex artery is one of the blood supplies of the femoral head, traveling to the upper part of the femoral neck. During the operation, the ascending branch of the lateral femoral circumflex artery should be cut and ligated to reveal the origin of the vastus intermedius and the anterior joint capsule (Fig. 1.4).

1.2.1.3.2 Iliopsoas

The iliopsoas refers to the joined psoas, and the iliacus muscles and the psoas major unites with the iliacus at the level of the inguinal ligament and crosses the hip joint to insert on the lesser trochanter of the femur and some fibers insert on the joint capsule. The muscle is covered by the upper part of the sartorius muscle and the rectus femoris from the front, adjacent to the femoral nerve and blood vessels. The posterior (deep) surface is attached to the anterior medial side of the joint capsule with a bursa between them. The bursa communicates with the joint cavity; it disappears with the degenerative change of the joint, resulting in adhesion of iliopsoas tendon to the anteromedial wall of the capsule. During the dissection of deep structures through the anterior (lateral) approach, the fibers inserting on the joint capsule must be carefully peeled off and then be retracted medially to enlarge the surgical field.

1.2.1.3.3 Anterior Capsule, Ligaments, and Blood Supplies

The capsule of the hip joint is cylindrical, thick, and tough, which is divided into the outer fibrous layer and the inner synovial layer. The fibrous layer originates from the acetabular rim, the transverse ligament of the acetabulum, and the outside of the acetabular labrum. In the distal part, the anterior part attaches to the intertrochanteric line. The posterior part attaches to the intertrochanteric crest 1.25 cm to the lesser trochanter (i.e., the lateral 1/3 of the femoral neck). The anterior part of the femoral neck is completely encapsulated in the capsule. The fibrous membrane is composed of superficial longitudinal fibers and deep transverse fibers; some fibers are spiral, oblique, and arcuate. The anterior wall and the upper wall are very thick. The medial and inferior medial wall is very thin even after the enhancement of the iliofemoral ligament. Under the iliopsoas tendon, the fibrous layer is absent, forming the weak part of the articular capsule. Therefore, medial inferior and inferior posterior dislocations are more common after a great amount of force being applied to the hip joint.

The synovial layer of the articular capsule is thin, soft, and lubricated, which is composed of thin layers of loose connective tissue, lined with a single layer of squamous epithelium—mesothelium. The edge connects with articular cartilage. The synovial epithelium secretes synovial fluid, which is slightly alkaline. In addition to lubrication effect, it is also a medium for material metabolism for structures within the joint, for example, articular cartilage. The surface of the femoral neck is covered by synovium. The proximal margin of the synovium originates from the acetabular rim and covers the acetabular labrum and adipose tissue. Ligamentum teres is also covered by the synovium. At the distal end, the synovial membrane folds upward at the attachment of the fibrous membrane, covering the femoral neck and reaching the rim of the joint surface of the femoral head. Under the femoral neck, the synovial membrane forms several folds under which run blood vessels that nourish the head and the neck. Therefore, if the synovium and the blood vessels running under it remain undamaged after femoral neck fracture, the healing of the fracture will be more easily to be achieved. The synovial cavity sometimes communicates with the bursae iliopectinea.

The lateral and medial femoral circumflex arteries form an arterial ring at the base of the femoral neck outside the capsule. Then, four vascular bundles branch off superior medially from the ring to the anterior, posterior, superoposterior, and inferoposterior part of the femoral neck, which is generally arranged in groups and rarely dispersive. They are called the anterior retinacular arteries, posterior retinacular arteries, superoposterior retinacular arteries, and inferoposterior retinacular arteries. The combination of posterior and superoposterior retinacular arteries is referred to as the superoposterior retinacular arteries. These vascular bundles pierce the joint capsule at its attachment on the femoral neck, running between the fibrous layer and synovial layer of the articular capsule over the surface of the femoral neck until the inferior sulcus of the head. They anastomose with each other under the synovium of the articular cartilage margin to form an intracapsular artery ring. These intraarticular arteries are thin and often incomplete. The superior and inferior arteries are often reticular; the anterior and posterior ones are often absent. The reticular arteries give off the physeal arteries and metaphyseal arteries. After the physis disappears, the metaphyseal and physeal arteries anastomose, widely, and nourish the femoral head and neck together. Some reticular arteries that enter the femoral neck anastomose nutrient artery of the femur. After the blood vessels enter the femoral head, they anastomose with the nutrient arteries and artery to the ligament of head of the femur. Retinacular arteries are tenuous and attach to the surface of the femoral neck. Focal hematoma, edema, or fracture displacement can damage the arteries, resulting in avascular necrosis of the femoral head.

1.2.2 Anterior Medial Anatomy of the Hip Region

Unlike the anterior lateral triangle, the medial triangle is bounded superiorly by the inguinal ligament, medially by the medial border of the adductor longus muscle and laterally by the medial border of the sartorius muscle. Its floor is formed by the pectineus and iliopsoas muscle as well as their fascia. The two muscles form a triangular fossa, fossae iliopectinea, whose tip is the projection of the lesser trochanter; the femoral vessels pass through the fossa. Generally, this area remains undisturbed during the operations; it mainly includes adductors, femoral vessels, and femoral nerve.

1.2.2.1 Femoral Artery

It enters the femoral sheath, within the femoral triangle, from behind the midpoint of inguinal ligament as the common femoral artery, a continuation of the external iliac artery. Then, it runs into the adductor canal, and becomes the popliteal artery as it passes through an opening in adductor Magnus near the junction of the middle and distal thirds of the thigh. In addition to the superficial epigastric artery, the superficial circumflex iliac artery, and the superficial external pudendal artery, the femoral artery gives off the profunda femoris artery that arises from the posterior side of the femoral artery about 3–4 cm below the inguinal ligament. At its origin, the profunda femoris artery gives off the medial and lateral femoral circumflex arteries, and during its course, it gives off three or four perforating arteries. The femoral artery

is superficial in the upper part of the femoral triangle, which is more likely to be injured, leading to an aneurysm or pseudoaneurysm. The artery is adjacent to the femoral vein, which can cause arteriovenous fistula more easily.

1.2.2.2 Femoral Vein

Accompany with femoral artery, Femoral vein descends from medial toward posterior to artery at the lower tip levels of femoral triangle mentioned above. There are several deep veins of the thigh that drain into the femoral vein. About 8 cm below the inguinal ligament, deep veins of the thigh drain into the femoral vein. About 2.5 cm below the inguinal ligament, the great saphenous vein drains into the femoral vein through the cribriform fascia of the saphenous hiatus.

The lateral femoral cutaneous nerve and genitofemoral nerve are located in this area. The genitofemoral nerve runs in the groove between the iliacus and the psoas, over the surface of the Iliacus, through the gap between muscles to the thigh, lateral to the femoral artery. The femoral nerve gives off anterior and posterior divisions 3–4 cm below the inguinal ligament. The two divisions give off several cutaneous branches (anterior cutaneous branch, saphenous nerve) and muscle branches with the superficial circumflex iliac artery running through them.

1.3 Lateral Surgical Approach to the Hip and the Anatomical Characteristics

The greater trochanter of the femur is an important structure on the lateral side of the hip joint. It is the mechanical fulcrum of hip abduction and external rotation. It is also an important structure for controlling the movement of the pelvis and lower limbs. As the midpoint of the lateral and posterior approach, it lies superficially and is covered by the fascia lata. The lateral hip region can be divided into the upper and the lower part by the great trochanter. The gluteus medius and the gluteus minimus connect the upper lateral portion of the great trochanter and the pelvis. Vastus lateralis connects the lower portion and distal femur (Fig. 1.5).

1.3.1 Anatomical Landmarks

1.3.1.1 Anterior Superior Iliac Spine

It is easy to palpate the anterior superior iliac spine at the anterior part of the iliac crest by moving the fingers from distal to proximal.

1.3.1.2 The Greater Trochanter

On the upper thigh, it can be palpated at the lateral hip region with the leg moving in the sagittal plane (Fig. 1.6).

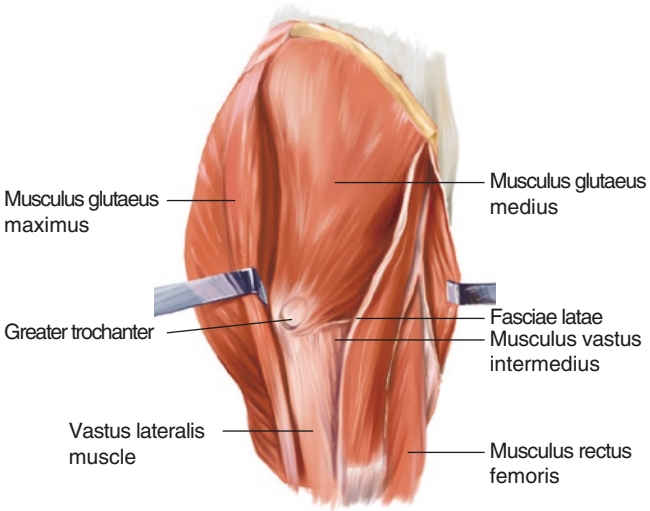

Fig. 1.5 The muscle junctions of femoral greater trochanter

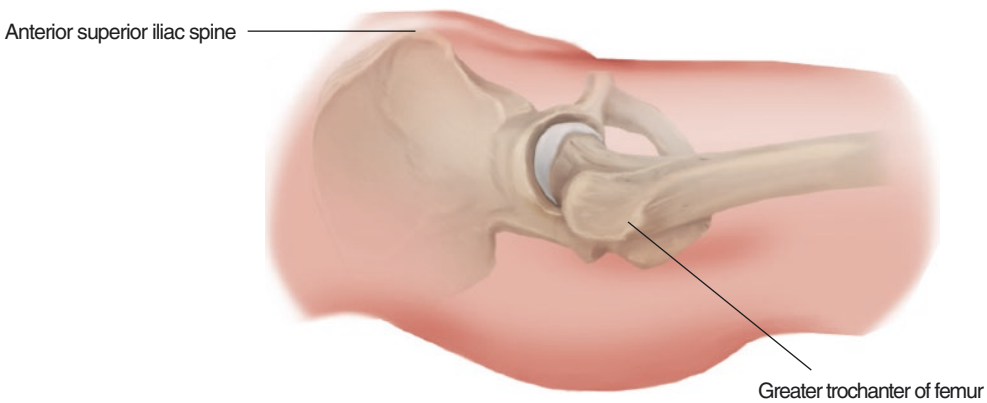

Fig. 1.6 Surface signs commonly used in lateral hip approach

1.3.2 Superficial Anatomy

1.3.2.1 Fascia Lata

It is the deep fascia of the thigh, firm and tenacious, enclosing the thigh muscles. It originates from the inguinal ligament and iliac crest; the deep fascia of the leg is continuous above with the fascia lata; posterior continuation becomes the gluteal muscle fascia. The upper part of the fascia lata covers the sartorius muscle and the gluteus medius with a single layer and encloses the tensor fasciae latae and gluteus maximus with two layers. The fascia lata and the upper part of the tensor fascia lata are tightly connected; the fascia lata is thickened at its lateral side where it forms the iliotibial tract.

1.3.2.2 Gluteus Medius

It is situated on the outer surface of the pelvis; the superior anterior part of the muscle is beneath the skin; the posterior lower part is covered by the gluteus maximus; the anterior part is adjacent to tensor fascia lata and is partially covered by it. The piriformis locates posterior to the gluteus medius and the gluteus maximus beneath it. The whole muscle is broad, thick, and radiating. It originates on the outer surface of the ilium, and the fibers of the muscle converge into a strongly flattened tendon that inserts on the lateral surface of the greater trochanter. There is 1 ~ 2 bursa(s) separates the tendon of the muscle from the surface of the trochanter over which it glides. The paralysis of this muscle can lead to gluteus medius gait and positive Trendelenburg sign. Deep branches of superior gluteal vessels and superior gluteal nerves run between the gluteus medius and the gluteus minimus; the two muscles are nourished and innervated by these vessels and nerve. The lower part of the gluteus medius locates on the lateral side of the upper part of the rectus femoris, and the two muscles are innervated by different nerves, and through the gap between them, the joint capsule can be exposed safely.

1.3.2.3 Gluteus Minimus

It is situated immediately beneath the gluteus medius, and the anterior fibers join the latter. The shape, origin, insertion, function, blood supply, and innervation of the gluteus minimus are the same as the gluteus medius. Therefore, it can be regarded as a part of the gluteus medius. The greater trochanter is often cut off and turned upward together with the insertion of these two muscles to fully expose the joint capsule through a lateral approach.

1.3.2.4 Vastus Lateralis

Vastus Lateralis locates lateral to rectus femoris and midfemoris muscle. It originates from the lateral femoral muscle crest at the base of the greater trochanter, surrounds the upper femur from the posterolateral side. When the greater trochanter needs to be exposed through lateral approach, the origin of this muscle needs to be cut and pulled distally (Fig. 1.7).

1.3.2.5 Vessels and Nerves to Be Protected Through the Lateral Approach

Important vessels and nerves are the deep branch of superior gluteal vessels and superior gluteal nerves. The deep branch of the superior gluteal artery lies under the gluteus medius and immediately subdivides into the superior and inferior divisions: the superior division, running forward, nourishes the gluteus medius, minimus, and ilium, anastomosing with the deep iliac circumflex artery and the deep branch of the medial femoral circumflex artery; the inferior division, run-

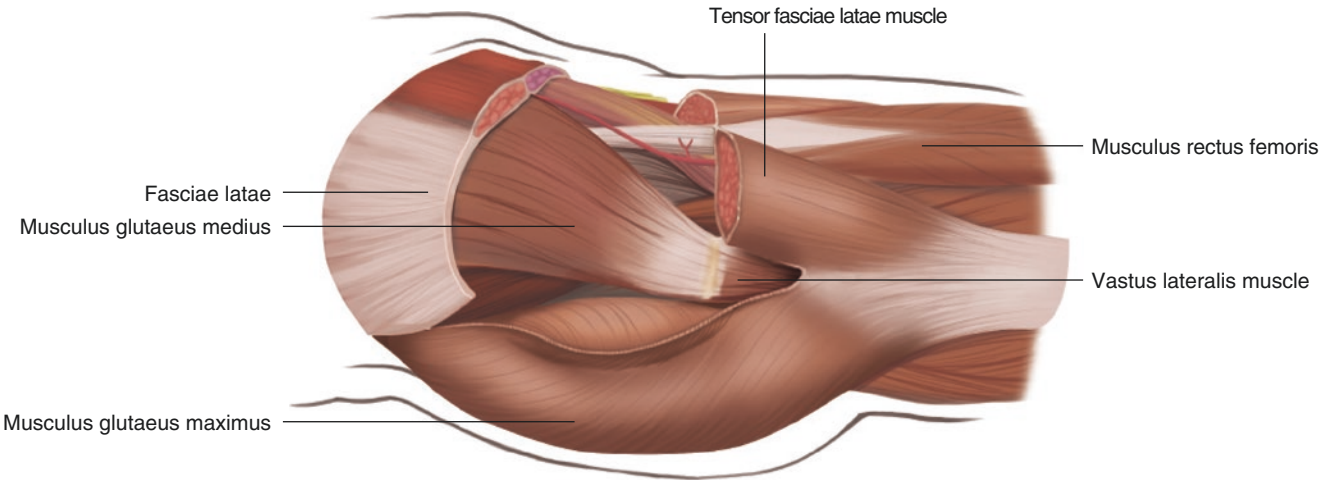

Fig. 1.7 Deep anatomy of lateral hip joint

ning distally, nourishes the gluteus medius, minimus and the hip joint, and the arteries to the trochanteric fossa anastomose with the inferior gluteal artery and the deep branch of medial femoral circumflex artery. The superior gluteal nerve innervates the gluteus medius, minimus, and tensor fascia lata. Below the tensor fascia lata, there are ascending branches, transverse branches, and descending branches of the lateral femoral circumflex artery. The superior gluteal nerve gives off superior and inferior branches: the superior branch runs along the upper margin of the gluteus minimus; the inferior branch runs between the gluteus medius and minimus, innervating the gluteus medius, minimus, and tensor fascia lata.

The superior gluteal artery leaves the pelvis through the greater sciatic foramen above the piriformis, accompanied by the superior gluteal nerve and the superior gluteal vein, where its average diameter is 3.1 mm. Then, the artery gives off two branches: the superficial and the deep. The former nourishes the gluteus maximus. The latter runs deep to the gluteus medius and gives off into the superior and inferior branches. The superior branch advances along the superior margin of the gluteus minimus, anastomosing with the deep iliac circumflex artery and the ascending branch of the lateral femoral circumflex artery around the anterior superior iliac spine. The inferior branch advances laterally between the gluteus medius and the gluteus minimus, nourishing the two muscles, and giving off vessels piercing the gluteus minimus to nourish the hip joint. The branch to the trochanteric fossa anastomoses with the inferior gluteal artery and the deep branch of the medial femoral circumflex artery.

When performing surgery around the sacroiliac joint, the surgeon should be careful not to damage the superior gluteal artery. Because when it is severed, the artery tends to retract into the pelvic cavity. If necessary, an emergent laparotomy should be performed to ligate the internal iliac artery. Otherwise, massive internal bleeding could happen.

1.4 Posterior Surgical Approach to the Hip and the Anatomical Characteristics

The posterior part of the hip joint is covered by two layers of muscles: the gluteus maximus and the external rotators (including the piriformis, obturator internus, superior and inferior gemellus, and quadratus femoris). The sciatic nerve descends vertically through the two layers of muscle and passes the surgical field of the posterior approach area. According to the positional relationship between the approach and the gluteus maximus, there are currently two different opinions on this approach. Marcy-Fletcher advocates that the posterior approach passes through the anterior margin of the gluteus maximus, i.e., between the gluteus maximus (innervated by the inferior gluteal nerve) and the gluteus medius (innervated by the superior gluteal nerve). Because of the neural interface, the approach accords with the requirements of anatomy. Moore and Osborne advocate the approach should pass through the fibers of the gluteus maximus. Although the latter does not utilize the neural interface, it was more commonly used in clinic because the hip joint can be fully exposed without causing obvious denervation.

1.4.1 Anatomical Landmarks

1.4.1.1 The Great Trochanter

The great trochanter of the femur is a large, irregular, and quadrilateral eminence. It locates on the junction of the neck and the shaft; it is directed lateral and medially and slightly posterior. It is about the width of the palm below the iliac crest, which locates on the midpoint of the line connecting the anterior superior iliac spine and the ischial tuberosity. The skin incision through the posterior approach is usually centered on it.

1.4.1.2 Posterior Superior Iliac Spine

Protuberance at the posterior end of iliac crest.

1.4.1.3 Ischial Tuberosity

It is a large swelling posteriorly on the superior ramus of the ischium. It can be easily palpated at the lower edge of the gluteus maximus when the hip joint is flexed (Fig. 1.8).

1.4.1.4 Body Surface Projection

1. Piriformis: The surface projection of the upper margin of the piriformis draws from the posterior superior iliac spine and the great trochanter; the surface projection of

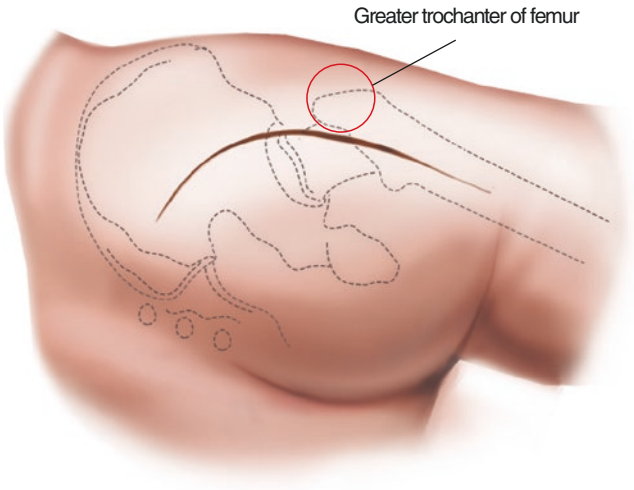

Fig. 1.8 Hip joint posterior approach and surface signs

the lower edge of the piriformis is a line connecting the midpoint between the posterior superior iliac spine and the tip of the coccyx and the greater trochanter.
2. It descends from the upper thirds of the line connecting the posterior superior iliac spine and the ischial tuberosity to the midpoint of the line connecting the ischial tuberosity and the great trochanter.
3. Superior gluteal vessels and nerve: It is situated at the upper thirds of the line connecting the superior anterior iliac spine and the tip of great trochanter.
4. Inferior gluteal vessels and nerve: It locates on the midpoint of the line connecting the posterior superior iliac spine and the ischial tuberosity.

1.4.2 Superficial Anatomy

The gluteus maximus is the superficial muscle in the posterior hip region, which is approximately square. It arises from the posterior gluteal line of the inner upper ilium and the posterior surface of the lower part of the sacrum, the base of the spine. The fibers are directed obliquely downward and lateralward. The gluteus maximus has two insertions: the iliotibial band of the fascia lata and the gluteal. The deep fascia connects the fascia lata, which together surround the gluteus maximus and tensor fascia lata in the posterior part of the hip as well as the gluteus medius. The gluteus maximus, the fascia lata (over the surface of the gluteus medius) and the tensor fascia lata form a muscular sheath in this region, called the pelvic "deltoid muscle" (Fig. 1.9).

The gluteus maximus receives blood supplies mainly from the superior and inferior gluteal arteries. The superior gluteal artery, nourishing the upper part of gluteus maximus, passes out of the pelvis above the upper border of the piriformis muscle; the inferior gluteal artery, nourishing the lower part of gluteus maximus passes out of pelvis below the lower border of the piriformis muscle. The branches anastomose with each other; they have rich blood flow.

The gluteus maximus is innervated by the inferior gluteal nerve. The nerve enters the deep surface of the medial part of gluteus maximus (near the origin of the muscle) below the lower border of the piriformis and innervates the whole muscle. Therefore, the gluteus maximus fibers should be separated in the lateral part and the insertion through the fibers in order to protect the nerve; even if it is separated at the medial part, the nerve trunk will not be damaged.

1.4.3 Deep Anatomy

The deep muscles behind the hip joint are piriformis, gemellus superior, obturator internus, gemellus inferior, and quadratus femoris from top to bottom. They are adjacent to the deep surface of the gluteus maximus. Between the two layers of muscles are there some loosening connective tissue, making it easy to separate the layers; the joint capsule is anterior to these hip external rotators, some of which, therefore, should be severed to expose the capsule through a posterior approach. It is vital to be familiar with the anatomy of these muscles as well as the vessels and nerves passing out of the pelvis, especially the piriformis and structures superior and inferior to it. It is the key to perform a safe operation in this area (Fig. 1.10).

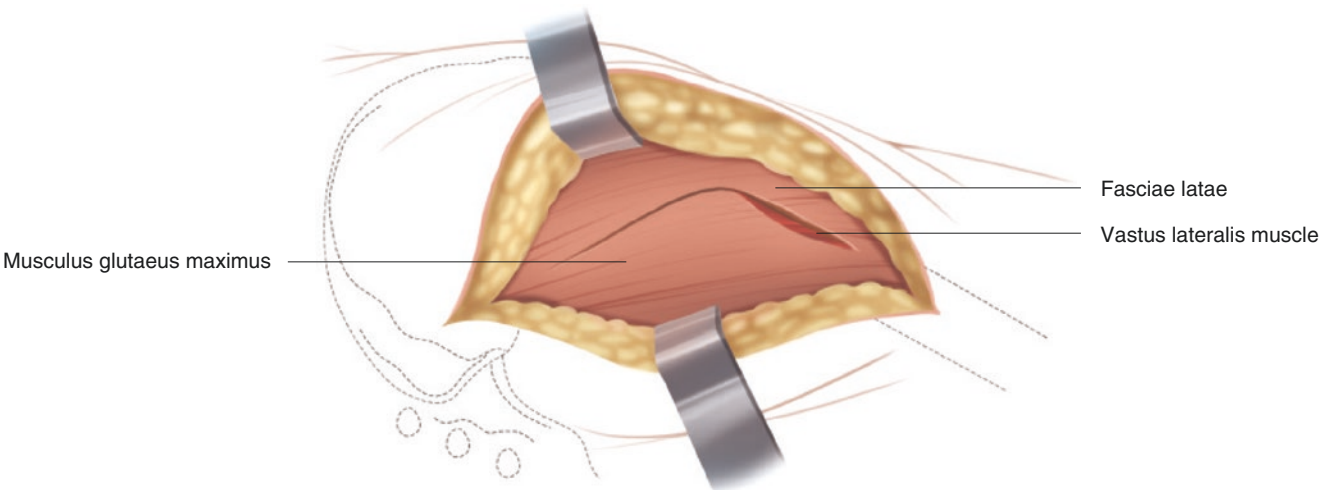

Fig. 1.9 Superficial anatomy of posterior approach in hip joint

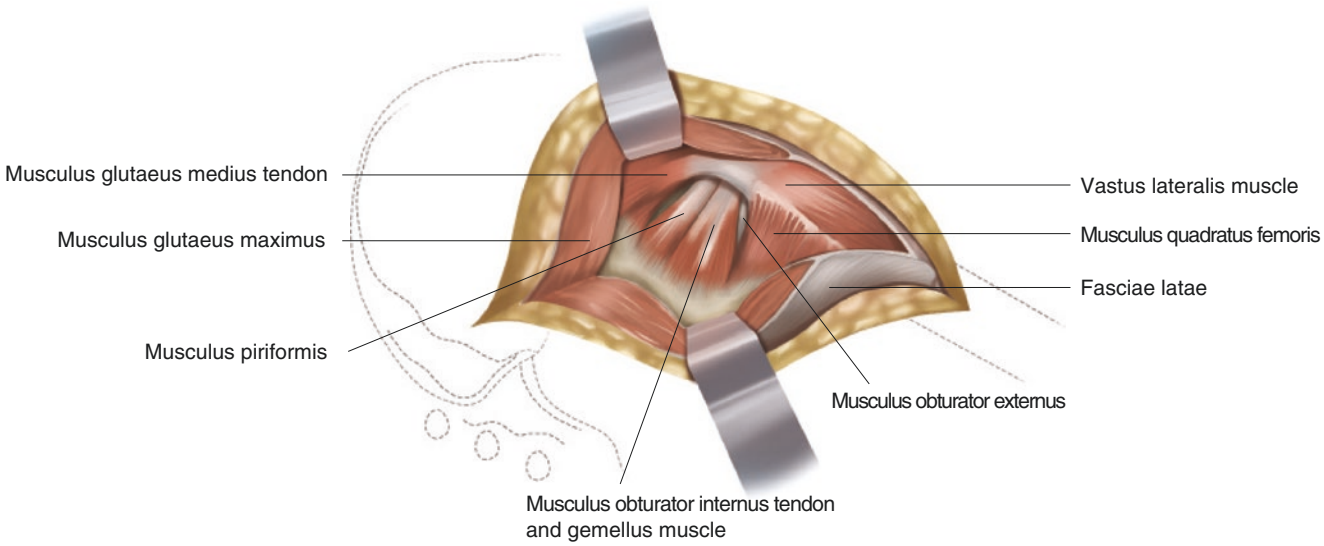

Fig. 1.10 The main muscle groups in posterior approach of hip joint

1.4.3.1 Piriformis

The piriformis is a flat muscle, pyramidal in shape. It originates from the anterior (front) part of the sacrum, exits the pelvis through the greater sciatic foramen, runs posteriorly to the hip joint, and inserts on the greater trochanter of the femur. The piriformis divides the greater sciatic foramen into an inferior and superior part. The nerve and vessels that emerge superior to the piriformis are the superior gluteal nerve and superior gluteal vessels (lateral to medial). Inferiorly, it is the same, and the sciatic nerve, the posterior femoral cutaneous nerve, and the internal pudendal vessels also travel inferiorly to the piriformis. The nerve of the obturator internus and the quadratus femoris pass out of the pelvis through the inferior part and enter the muscles. In addition, the relationship between the sciatic nerve and the piriformis is various. And the nutrient branch of the inferior gluteal artery often runs along with the sciatic nerve.

1.4.3.2 Obturator Internus

It locates below the piriformis. It is one of the few muscles in the human body whose fibers bend at a right angle. It goes around the lesser sciatic notch and shares the same insertion, the trochanteric fossa, with the gemellus muscles.

1.4.3.3 Quadratus Femoris

It is situated below the obturator internus and the inferior gemellus. Its fibers pass laterally from the ischial tuberosity to the greater trochanter. The quadratus femoris is a flat, quadrilateral skeletal muscle. At the lower edge of the insertion, a cross anastomosis is formed by the ascending branch of the first perforating artery, the descending branch of the inferior gluteal artery, and the transverse branch of the medial and lateral circumflex femoral artery. Because its blood supplies are very rich, the quadratus femoris should be protected carefully during the surgeries to avoid unmanageable bleeding.

1.4.4 Vessels and Nerves to Be Protected Through the Posterior Approach

The sciatic nerve and the superior and inferior gluteal artery are easily damaged through the posterior approach to the hip joint.

1.4.4.1 Sciatic Nerve

The nerve passes beneath piriformis and through the greater sciatic foramen, exiting the pelvis, then traveling between the superficial and deep layers of muscles. It is usually surrounded by adipose tissue and not easy to notice. Paying attention to its location can avoid iatrogenic injury. If the retractor is improperly placed and the muscles are pulled excessively, or if the artificial femoral head is reduced in the acetabulum without protecting the nerve, damages can be caused to the sciatic nerve, resulting in flaccid paralysis of the muscle below THE knee joint. The severed external rotators of the hip joint should be retracted medially together with the sciatic nerve. Then place the retractor in the incision. This technique can protect the nerve from iatrogenic injuries.

1.4.4.2 Superior and Inferior Gluteal Artery

The position of these arteries entering the hip region is in the medial part of the piriformis. Surgical approaches usually avoid passing through this area. However, since the two arteries leave the pelvic via the upper and lower borders of

the piriformis, they give off many branches to enter and nourish the gluteus maximus. When the gluteus maximus is bluntly dissected, these arterial branches are easily injured, causing much bleeding. Given this anatomical feature, these branches should be recognized and ligated before dissection to prevent the small blood vessels from retracting into the muscle, which can cause uncontrollable bleeding. As the pelvic fracture happens, the superior or inferior gluteal artery can be pierced by the fracture ends of the greater sciatic notch. After being severed, the vessels can retract into the pelvis. Under this circumstance, the extraperitoneal approach is required to enter the pelvis. The proximal internal iliac artery is then ligated to control the bleeding.

1.5 Blood Supplies of the Hip Joint

The blood supplies of the adult hip joint can be mainly divided into vessels nourishing the acetabulum and ones nourishing the proximal femur. Four arteries nourish the proximal femur: medial and lateral circumflex femoral artery, obturator artery, and femoral nutrient artery. With the growth and development of the human body, the main blood supply of femoral head is continually changing, and there are numerous individual variations. The main blood supply to the acetabulum is the superior and inferior gluteal artery. In addition, arteries such as the first perforating branch of the profound femoral artery and obturator artery form much collateral circulation around the hip joint. The study of these blood supplies is important for the understanding of the growth and development of the hip joint as well as the pathophysiology of various diseases and trauma.

1.5.1 Blood Supplies Around the Hip Joint

1.5.1.1 Medial Femoral Circumflex Artery

The medial femoral circumflex artery originates from the femoral artery and the profound femoral artery, and winds around the posterior side of femur proximal to the less trochanter, moving toward the greater trochanter. Occasionally, the medial femoral circumflex artery may arise directly from the femoral artery, the origin of the lateral femoral circumflex artery. After passing through the pectineus and iliopsoas, the perforating branch of the medial femoral circumflex artery anastomoses with the lateral femoral artery, the first perforating artery, and the inferior gluteal artery near the lower edge of the obturator muscle. In addition, an acetabular branch is sent out, along with the articular branch of obturator artery, traveling below the transverse acetabular ligament, then, entering the acetabulum. This branch anastomoses with the articular branch of the obturator artery. The medial circumflex femoral artery gives off posterior inferior retinacular artery between the medial capsule and the obturator muscle, and gives off posterior retinacular artery at the intertrochanteric crest (posterolateral to the capsule). It also gives off branch anastomosing with the superior gluteal artery. The artery continues to travels to the lateral side, and the terminal branch becomes the posterior superior retinacular artery that is running obliquely behind the hip capsule and passing over the intertrochanteric fossa. The posterior superior retinacular artery, vital blood supply of the hip joint, nourishes the femoral head, the neck, and the greater trochanter. The medial and lateral femoral circumflex arteries communicate with each other and form an extraarticular artery ring. When the medial femoral circumflex artery ascends from the trochanteric fossa, it gives off many small branches entering the bone through the nutrient foramen to nourish the base of the femoral neck. There are 3–4 branches here going through the lateral attachment of the capsule, advancing proximally beneath the thickened synovium of the femoral neck. It eventually reaches the junction of the femoral head and neck. And enters the femoral head via 4–5 large vascular foramina at the edge of the articular cartilage whose number is relatively constant.

1.5.1.2 Lateral Femoral Circumflex Artery

The lateral femoral circumflex artery originates directly from the femoral artery or the profound femoral artery in the femoral triangle and is generally larger than the medial femoral circumflex artery. The two arteries form an extraarticular ring that encircles the base of the femoral neck. The lateral femoral circumflex artery forms the anterior portion of the ring, and the medial femoral circumflex artery forms the medial, posterior, and lateral portions. However, only 10% of the rings are complete. Behind the sartorius and rectus femoris, the lateral femoral artery and divides into ascending, transverse, and descending branches. The ascending branch nourishes the tensor fascia lata, sartorius muscle; The descending branch runs downward, entering the lower part of the quadriceps and the muscle as far as the knee; the transverse branch pierces the vastus lateralis, and winds around the femur, just below the greater trochanter, anastomosing on the back of the thigh with the medial femoral circumflex artery, the inferior gluteal artery, and the perforating arteries of the profunda femoris artery. The branch of the lateral femoral circumflex artery that extends to the anterior part of the femoral neck travels along the lateral margin to deep layers in front of the iliopsoas muscle. It supplies the base of the femoral neck along the intertrochanteric line, the neck where the joint capsule attaches, and the femoral neck within the capsule. The artery entering the neck within the capsule is large. It travels along the femoral neck beneath the synovial membrane. Near the retinacular artery of the medial femoral

circumflex artery, it gives off divisions to the femoral head that ends at the upper part of the femoral neck.

1.5.1.3 Obturator Artery

The obturator artery usually originates from the anterior trunk of the internal iliac artery and passes anterodistally beneath the parietal peritoneum in the pelvis. The obturator artery exits the pelvis through the obturator canal and divides into the anterior and posterior terminal branches. The anterior branch walks along the anterior edge of the obturator and is nourish the obturator externus and anastomoses with the posterior branch and the branch of the medial femoral circumflex artery. The posterior branch walks along the posterior edge of the obturator, and nourishes the adjacent muscle. An acetabular division enters the acetabulum through the acetabular notch to the soft tissue in the joint. One of them reaches the femoral head concave through the ligamentum teres and enters the inferomedial femoral head. This artery is called artery to the ligament of the femoral head, which is the only blood supply of the femoral head that does not pass through the femoral neck. It is the main source of blood supply to the femoral head before the physis closes. The obturator artery gives off a branch to pubis in the superomedial pelvis, which ascends behind the pubis and anastomoses with the inferior epigastric artery and collateral branch of the obturator artery. The obturator artery forms a vascular ring at the attachment of the obturator externus. There are many branches in the acetabulum's fat and synovium. Artery to the ligament of the femoral head is only a division of the acetabular branch. At the posterior aspect of the acetabulum, the branch from the inferior gluteal artery anastomoses with the obturator artery ring, and it enters into the posterior part of the acetabulum.

1.5.1.4 Superior Gluteal Artery

The superior gluteal artery is the continuation of the posterior trunk of the internal iliac artery. It passes through between the lumbosacral trunk and the first sacral nerve; it exits the pelvis above the superior margin of the piriformis muscle. The branch supplies the gluteal muscle, the superior portion of the acetabulum, the upper part of the joint capsule, the great trochanter, and so on. When the superior gluteal artery travels out from the ischiatic notch, it immediately gives off a descending branch to the posterior edge of the acetabulum and the posterior portion of the joint capsule; the other branch runs transversely along the ilium under the gluteus minimus, and the branch supplies the muscle.

1.5.1.5 Inferior Gluteal Artery

The inferior gluteal artery is the continuation of the anterior trunk of the internal iliac artery. It descends behind the internal pudendal artery and travels between the second and the third sacral nerves. It escapes from the pelvis below the piriformis to the deep side of the gluteus maximus. The branches of it nourish the gluteus maximus, joint capsule, sciatic nerve, buttocks, and the skin of back thigh. The communicating branch arises from the inferior gluteal artery, traveling downward to form the cruciate anastomosis with the first perforating branch of the profound femoral artery and the medial and lateral femoral circumflex arteries. In addition, to give off a large number of branches to supply the gluteus maximus, the inferior gluteal artery sends out two main branches to supply the deep structures of the hip joint. The transverse branch crosses and nourishes the sciatic nerve, and gives off a branch traveling downward that is called posterior acetabular artery, which supplies the lower, posterior margin of the acetabulum, and adjacent fibrous joint capsules. The trunk continues to travel through the obturator externus, the gemellus superior, the gemellus inferior, and the piriformis. There are many small branches entering these muscles and the superoposterior edge of the greater trochanter. Medial to the sciatic nerve, a branch travels downward between the nerve and the posterior part of the acetabulum, going around the ischium, and anastomoses with the obturator artery at the lower part of the acetabulum, the notch of the ischial tuberosity, and outside the obturator to supply the lower part of the acetabulum.

1.5.1.6 Femoral Profound Artery

The first perforating branch of the profound femoral artery originates from the femoral artery at the level of the adductor Magnus and passes through the upper part of the adductor Magnus. Below the attachment of the gluteus maximus, it gives off branches to supply the gluteus maximus and the adductor Magnus. A large branch ascending along the femur and gives off two divisions: one to inferoposterior part of the less trochanter below the quadratus femoris; the other one to inferoposterior part of the great trochanter anastomoses with the inferior gluteal artery and the medial and lateral femoral circumflex artery. The area is nourished by these vessels (Fig. 1.11).

1.5.2 Blood Supply to the Head and Neck of the Femur

1.5.2.1 Retinacular Arteries

It is also called sub-synovium arteries, cervical ascending or artery capsular arteries, and metaphyseal artery. Retinacular arteries enter the femoral neck near the physis; it is the main blood supply to the femoral head. The lateral and medial femoral arteries form an arterial ring at the base of the femoral neck outside the capsule between the trochanters. The arterial ring gives off four vascular bundles to the medial superior part of the neck. They are called anterior, posterior, superoposterior, and inferoposterior retinacular arteries. The

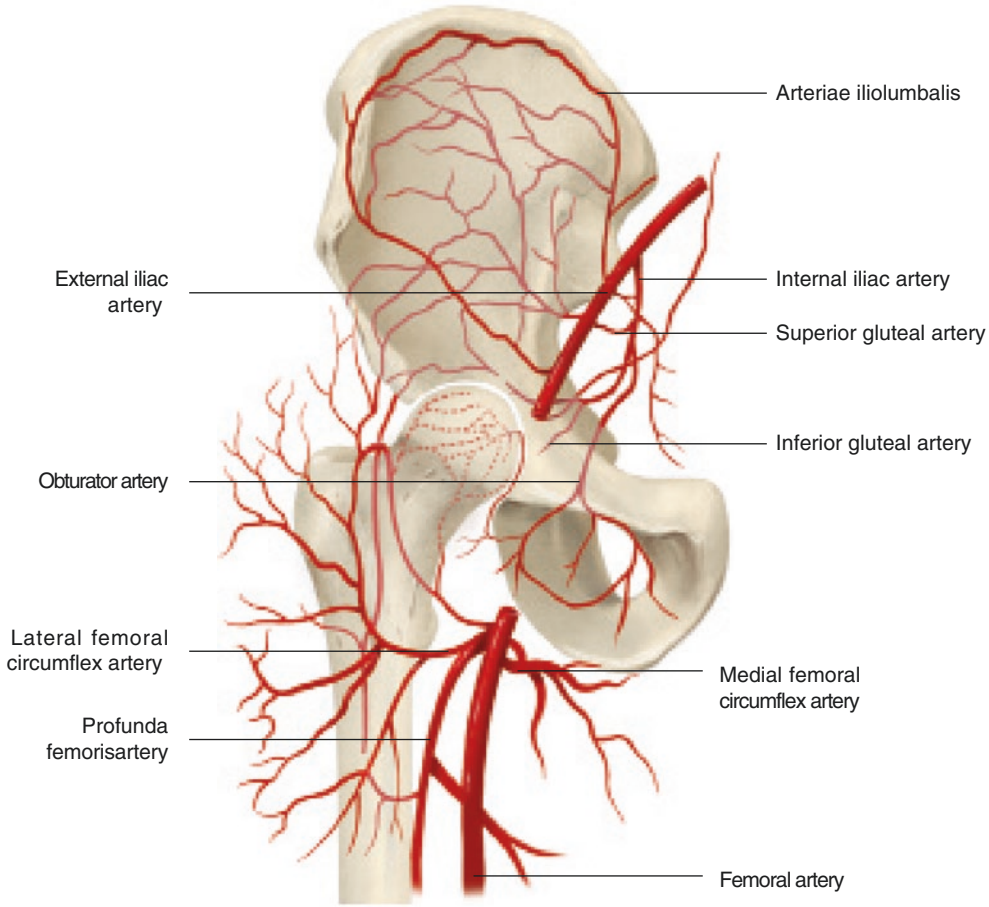

Fig. 1.11 Blood supply around hip joint

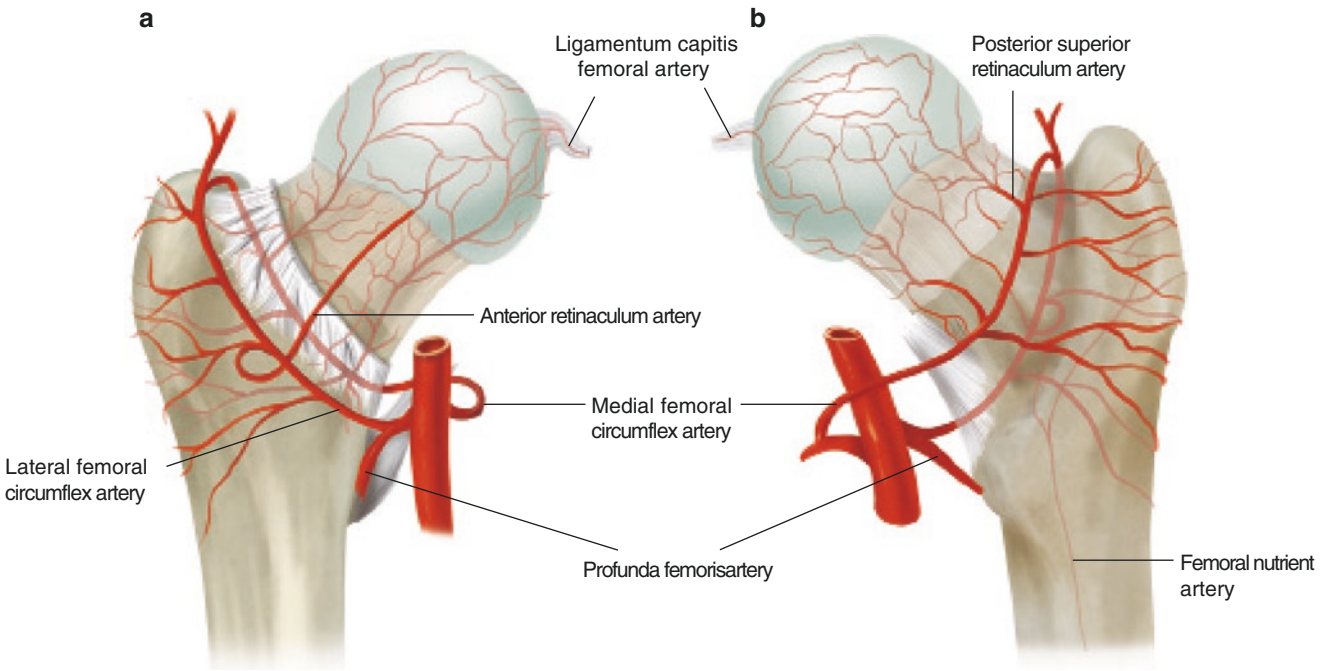

Fig. 1.12 Blood supply for femoral head. (**a**) Anterior view; (**b**) Posterior view

posterior and the superoposterior retinacular arteries are often called the superoposterior retinacular arteries. These vascular bundles pass through the attachment of the joint capsule at the femoral neck, and travel between the fibrous and the synovial layer of the joint capsule. An intraarticular arterial ring is formed eventually, under the synovial membrane, when the bundles reach the margin of the articular cartilage on femoral head (Fig. 1.12a). This arterial ring is tenuous and often incomplete. The upper and lower parts are often reticulated, and the anterior and posterior parts are often absent. The retinacular arteries give off branches to epiphysis and metaphysis. After the physis closes, these vessels anastomose with each other to nourish the femoral head and neck. Branches that enters the femoral neck anastomose with the nutrient arteries of the femur; those enter the femoral head anastomose with the nutrient arteries and the artery to the ligament of the femoral head. Retinacular arteries are tenuous and run over the surface of the femoral neck. Therefore, focal hematoma, edema, or displaced fracture ends can injure the vessels. Torsion of the vessels can lead to ischemia or avascular necrosis of the femoral head. Of the blood supply to the femoral head, 70% comes from the retinacular arteries, 25% from the nutrient artery, and only 5% from the artery to the ligament of the femoral head (Fig. 1.12b).

The femoral head has less blood supply than the femoral neck does. The higher the site of the femoral neck fracture is, the less blood supply will remain at the upper end of the fracture. The degree of displacement determines the severity of the vascular injury. The amount of remain vessels determines whether the femoral head can survive. After the fracture, the nutrient arteries in the femoral neck are all broken. When the displacement is massive, the superoposterior retinacular arteries are most likely to be damaged. Superoposterior displacement, accompanied by external rotation of the lower extremity, can also damage the inferoposterior retinacular arteries, causing the ischemia of the femoral head. The degree of vascular injury is proportional to the degree of displacement of the fracture. Therefore, it is not advisable to use large-weight traction to reduce the fracture in the early stage. Early weight-bearing is not the main cause of avascular necrosis of the femoral head, but the direct cause of the collapse of the necrotic femoral head that fails to complete the creeping substitution.

After a femoral neck fracture, the artery to the ligament of the femoral head becomes the blood supply compensation, especially for the partially necrotic femoral head that can regain partial blood supply from the artery. When the fracture is significantly displaced, most of the proximal blood supply is lost, and it is often difficult for the bone tissue to survive unless receiving the blood supply from the distal end. Poor realignment, imperfect fixation, and early weight-bearing can cause malunion or nonunion. Correct reduction and strong fixation can restore the blood supply to the head and neck of the femur after fracture, make the fracture heal and restore the height of the collapsed head through the creeping substitution. The size of the necrotic head depends on the extent of damage to the artery. Maintaining the artery to the ligament of the femoral head is important for the survival of the femoral head. From the perspective of surgical intervention, the diameter and location of the implants, as well as surgical techniques, have a great impact on the blood supply. Thick screws make the risk of avascular necrosis much higher than three pins. The former may damage the nutrient artery, artery to the ligament of the head and blood supply to the anterior femoral head. Pins have less effect on blood supplies, but superoposterior 1/4 region of the femoral head should be undisturbed to protect important vessels. The closer the needle runs in the central area of the head and neck, the less likely to damage the blood supply. In the medial third of the femoral head, because there is an anastomosis of the lateral epiphyseal artery and artery to the ligament of the head, this is the safe area for insertion of the pins. If the fracture line passes through the superolateral junction of head and neck and the displacement is significant, the injury of the lateral epiphyseal artery is the main cause of avascular necrosis of the femoral head.

1.5.2.2 Artery to the Ligament of the Femoral Head

Most of this artery originates from the branch of the obturator artery, which has many variations in different people and age. Some scholars believe that the artery provides about 1/3 of the blood supply to the femoral head, while others believe that it has less contribution, and the probability of hardening and occlusion of this artery increases with age. With a few exceptions, artery to the ligament of the femoral head is not as important as the superior and inferior retinacular arteries.

1.5.2.3 Nutrient Artery of the Femur

It originates from the perforating artery of the profound femoral artery. It enters the medullary cavity through nourishing canals in the middle of the femoral shaft, and gives off two branches to the two ends of the femur. When traveling, it winds the central sinus. The superior branch runs proximally within the medullary canal, through the femoral neck to the femoral head.

On the one hand, the nutrient arteries give off parallel branches to reach the ends, and at the same time, the branches form the endosteum vascular network that gives off branches piercing the cortical bone to the periosteum where the endosteum and periosteal vascular network anastomose with each other. Adult nutrient arteries nourish the femoral head and neck, and in children, the artery is blocked by the physis.

However, some scholars believe that some small arteries can pierce the physis to the femoral head.

1.5.3 Blood Supplies to the Acetabulum

The blood supplies to the acetabulum also come from nearby arteries. The medial and lateral femoral circumflex artery, the obturator artery, the superior gluteal artery, and the inferior gluteal artery form an arterial ring around the acetabulum. The ring gives off a branch to nourish the capsule. The superior gluteal artery mainly nourishes the superior part; the inferior gluteal artery supplies the posterior acetabulum and the nearby joint capsule. The acetabular branch of the obturator or the medial femoral circumflex artery enters the acetabulum and becomes the artery to the ligament of the femoral head. Furthermore, it also nourishes the soft tissue in the acetabulum and nearby hip bone. These branches anastomose with a vascular ring at the base of the neck, and the acetabular branch anastomoses with the nutrient artery of the internal iliac artery.