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Ultrasound-guided pain interventions in the hip region

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ABSTRACT

To accomplish successful ultrasound-guided interventions for the management of pain in the hip region, a thorough understanding of the essential anatomy of the hip joint and adjacent structures is required. This is also the basis for the acquisition of high-quality dynamic real-time sonoanatomical images. This review article addresses the anatomy, sonoanatomy, and ultrasound-guided interventional approach to 3 key structures in this region—the intra-articular hip, the femoral nerve, and the obturator nerve—using important anatomical landmarks.

Introduction

The evaluation of hip pain is one of the most challenging areas for the musculoskeletal specialist. The difficulties in performing "blind" injections of these structures are mostly because of the complex anatomy of the hip region associated with important superficial and deep neurovascular structures. Musculoskeletal ultrasound (MSUS) is a convenient tool for visualizing the periarticular structures and important aspects of the joint itself. Owing to the limitations of the clinical examination in this region, the use of MSUS can enhance the diagnostic precision in this area but requires a thorough knowledge of regional anatomy. From an anatomical standpoint, the "hip" includes the innominate bone (composed of the pubis, ilium, and ischium) and the proximal femur along with the periarticular structures that support and facilitate hip joint function.

The distinct anatomical structures that are discussed in this review include the intra-articular hip, the obturator nerve, and the femoral sensory nerves. The components for each structure can be organized into a sonoanatomical "checklist" with important anatomical landmarks that guide the sonologist. Probe and patient positioning, a discussion of the significant landmarks, and an introduction to the basic pathology are discussed so as to clarify the guided injection technique and its indications.

Understanding and continual adjustment of the basic parameters of the ultrasound (US) machine (depth, focus, frequency, and gain) are critical to maximizing the US image. The important structures of the hip region vary greatly in appearance, dimension, and depth from the fine delicate superficial sensory nerves to deep periarticular structures such as the labrum and capsula with intervening layers of tissues that can test the limits of both gray-scale and Doppler modalities. It is also essential that the sonologist be familiar with the other important capabilities of the machine such as the variety of probes available to multiple software features including "virtual convex," which creates a convex beam using a linear probe, the ability to "steer" the US beam to maintain the beam as close to 90° as possible to the "reflecting" structural interfaces to assure maximal acquisition of the reflected energy, the use of tissue harmonics, and the ability to capture an extended or panoramic image. Important to the acquisition of an optimal MSUS image is the positioning of the region of interest and the real-time dynamic maneuvering of this area as this clearly represents one of the clearest advantages over other imaging modalities, especially with guidance of interventions. Subtle movements of

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the US probe by continually reorienting the probe with finely controlled movements of the sonologist's hand are essential to utilize this high-frequency, high-resolution tool to its optimal extent, teasing out tissue distinctions approaching a microscopic level. This becomes particularly evident when examining smaller-caliber nerves along their variable trajectory in the extremities.

Intra-articular hip joint

Anatomy and sonoanatomy

The hip joint is the articulation formed by the head of the proximal femur and the acetabulum of the innominate bone. Thus, the acetabulum is a cartilaginous covered cavity composed of the union of the 3 pelvic bones: the ilium, pubis, and ischium. Surrounding the acetabular opening and augmenting the acetabular surface area, the labrum, a triangular fibrocartilaginous structure that inserts into the circular margin of the acetabulum, amplifies the contact area between the acetabulum and the cartilage-covered spherical surface of the femoral head.

The osseous anatomy of the hip provides the points of attachment for a number of myotendinous, capsular, and ligamentous structures that are important in hip motion and stabilization and, therefore, become essential sonographic landmarks.[1] During the MSUS examination, it is essential to obtain as sharp and bright a hyperechoic profile of the bony cortex of the femoral head and the acetabulum (indicating a 90° axis between the beam and the insonating surface) as is possible to optimize the visualization of the overlying articular capsule and its focal ligamentous thickening, referred to as the iliofemoral ligament, to better observe alterations that may be significant and to assume accurate interventional guidance (Table 1). To receive an intra-articular guided injection, the patient is placed in a supine decubitus position with the hip in neutral position or with slight external rotation. Anterior hip flexion or marked rotation of the leg should be avoided in this initial position.

It is necessary to decrease the frequency to 8-10 MHz and ensure appropriate depth and focal position before initiating the examination of the relatively deep structure. Longitudinal and transverse images, aligned to the oblique axis of the femoral neck should be obtained. The probe is first placed along the longitudinal plane of the femoral neck to examine the anterior synovial recess at the junction of the femoral head and neck, using the hyperechoic bony profile of the femoral head as a landmark. The examiner should initially apply pressure with the probe at the beginning of the examination, thus optimizing the visualization of this bony landmark. The pressure is then decreased to allow visualization of fluid that might have been displaced. In large patients, it may be helpful to first locate the shaft of the femur in the midthigh with the probe in the transverse axis and then scan proximally until the bony profile of the femur begins to widen at the junction of the neck and shaft, and then make the probe oblique along the longitudinal axis of the femoral neck, sliding it proximally to find the anterior recess of the hip. The probe is moved from the proximal position to the distal position and from side to side to scan the entire recess (Figure 1). Proximally, the joint capsule is attached to the acetabulum and labrum, whereas, distally, it inserts along the intertrochanteric line, which extends superiorly and inferiorly to the junction of the femoral neck with the greater and lesser trochanters, respectively. Relevant to the sonoanatomy of this anterior region, the distal aspect of the capsule reflects upon itself, forming a double layer of arching fibers, with the thicker superficial component inserting directly and a thinner deep layer reflecting proximally toward the articular surface from this distal attachment. As a consequence, the MSUS image of the normal capsule is thick and hyperechoic and should not be confused with a pathologic condition such as synovitis. It is noteworthy that the anterior capsular thickening is also the result of focal capsular thickening with this reinforcement termed the iliofemoral ligament. The probe can then be rotated into the transverse axis of the femoral neck for further delineation of these structures, particularly if abnormalities are noted. The probe is now rotated vertically into the true longitudinal axis to the femur. This position allows the examiner to see the anterior inferior iliac spine (AIIS) medially, with the direct insertion of the rectus femoris tendon, and facilitates the visualization of the anterior labrum a bit laterally, the site of most labral pathology. The anterior labrum appears homogeneous, hyperechoic, and triangular, analogous to a meniscus, and is mobile with hip motion. The muscles overlying this region include the iliopsoas muscle, close to the capsule of the hip joint with its tendon posterior and medial within the muscle belly; the superficial sartorius muscle, originating at the anterior superior iliac spine (ASIS) with its characteristic triangular shape, crossing over the psoas from lateral proximally to distal medially located under the soft tissue and surrounded by a hyperechoic line that corresponds to its fascia; and the more distal rectus femoris with its obvious direct tendinous insertion at the AIIS. At the level of the AIIS, medial movement of the probe along the superior ramus of the pubis reveals the neurovascular bundle composed, lateral to medial, of the femoral nerve, artery, and vein.

The relevant anatomical landmarks that should be identified before the injection are the femoral head, acetabulum, femoral neck, and neurovascular bundle.

Table 1 – Checklist intra-articular hip joint.

Bone and joint
Acetabulum
Femoral head
Labrum
Capsule
Iliofemoral ligament
Anterior synovial recess
Muscles
Sartorius
Rectus femoris
Iliopsoas
Neurovascular
Femoral artery and vein
Femoral nerve

Fig. 1 – *Hip joint*. Probe placement (red bar) for in-plane (IP) lateral to medial hip joint aspiration or injection. (Color version of figure is available online.)

Indications and technique for intra-articular hip guided injections

MSUS can easily demonstrate an effusion or synovial hypertrophy within the hip joint in the longitudinal axis to the femoral neck. The main finding is the distension and bulging of the joint capsule, represented by convexity of the capsular profile with loss of the normal concave profile. Arthrocentesis (often associated with intra-articular injection in noninfectious conditions) is essential to ascertain the etiology of the capsular distension. The actual needle placement is done with the patient in the same position as for the examination, with the probe also positioned over the long axis of the femoral neck so as to perform an in-plane guided needle introduction. It is important to identify the femoral neurovascular bundle before needle placement. Needle localization and visualization is enhanced by a number of maneuvers such as tilting the probe or utilizing beam steer to put the beam as perpendicular to the needle as possible and simply wiggling the needle and with it, the surrounding tissues as well. Pressure is required to penetrate the capsule, but impaling the bony cortex should be avoided if possible owing to the associated pain experienced by the patient. Finally, if the distal needle is poorly visualized, a small amount of saline can be injected under the guidance of Doppler imaging to ensure intracapsular positioning, particularly in large patients. A 21-gauge spinal needle with entry angle dependent on patient girth angling 60° will be used to reach the intra-articular hip joint space. Limitations include the large learning curve and the training necessary to be skilled during the procedure.

Nerves

Obturator nerve

Sonoanatomy

The obturator nerve is the largest nerve formed from the anterior rami of the L2, L3, and L4 roots and is formed within the psoas muscle. It runs into the pelvis at the medial aspect of the muscle, passing behind the common iliac vessels. It exits the pelvis through the upper anterior aspect of the

Table 2 – Checklist obturator nerve.

Bones
Pubis
Femoral shaft
Muscles
Adductor longus
Adductor brevis
Adductor magnus
Gracilis
Sartorius
Nerves
Anterior and posterior branches of the obturator nerve

Fig. 2 – *Hip joint.* **Longitudinal extended view; 12-5 MHz. Extended longitudinal view of the hip joint showing the acetabulum (1), hyperechoic labrum (2), capsular iliofemoral ligament (3), femoral head (4), anterior recess (5), and overlying musculotendinous structures: sartorius (6), iliopsoas (7), and rectus femoris (8), with direct tendon insertion at the AIIS (9). The white line represents the trajectory of the needle for lateral to medial inguinal ligament (IL) placement within the hip joint space.**

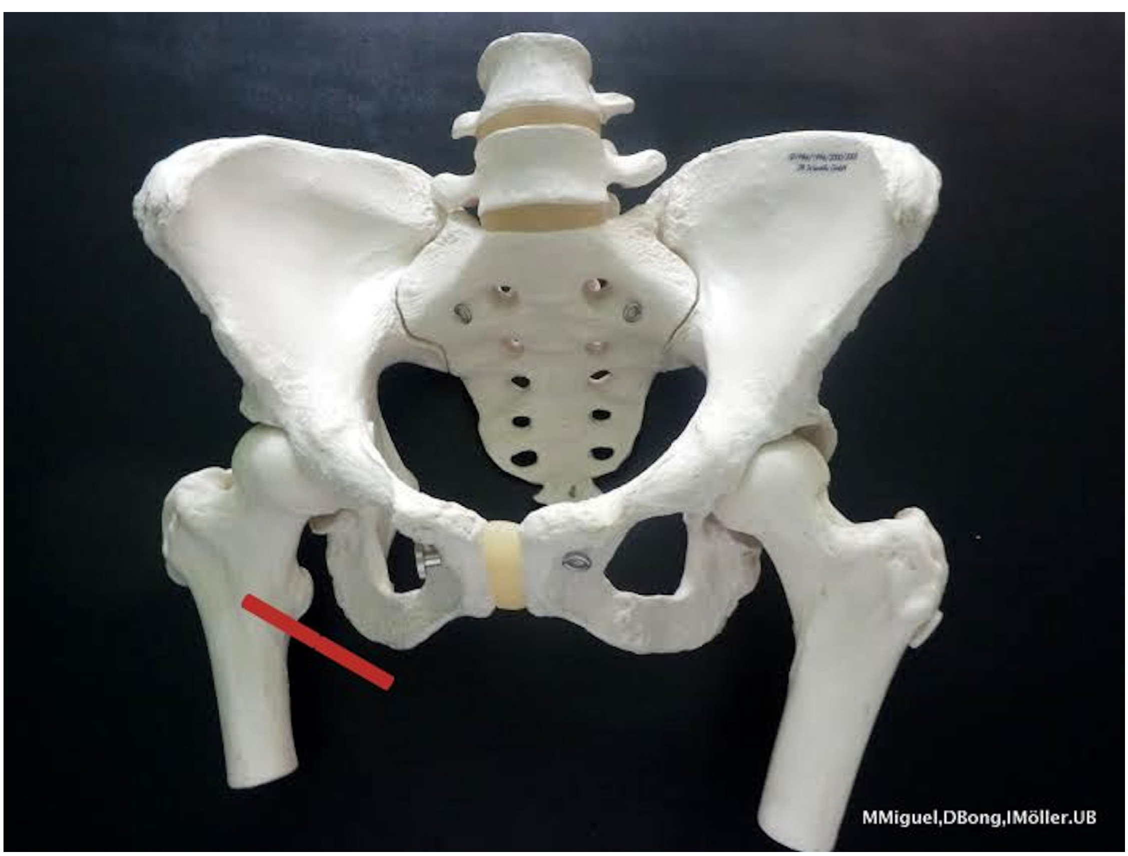

Fig. 3 – *Obturator nerve.* **Probe placement (red bar) for in-plane (IP) lateral to medial infiltration of the anterior and posterior branches of the obturator nerve. (Color version of figure is available online.)**

Table 3 – Checklist lateral femoral cutaneous nerve.

Bones	
	Ilium
	Anterosuperior iliac spine
Ligament	
	Inguinal ligament
Muscle	
	Sartorius
	Iliacus
Nerves	
	LFCN and branches

obturator foramen and divides into an anterior and posterior branch in this region. The nerve is visible by ultrasonography, distal to its division. The anterior division runs in the fascia between the anterior surface of the adductor brevis and initially deep to pectineus and then deep to adductor longus to eventually contribute to the subsartorial plexus along with the medial femoral cutaneous nerve and the saphenous nerve in the adductor canal. It innervates the adductor longus, adductor brevis, and gracilis muscles and gives sensory innervation to the hip and skin of the medial thigh. The posterior division runs between the fascial planes of the adductor brevis and the adductor magnus muscles. Proximally, from superficial to deep, the adductor longus, brevis, and magnus muscles are "stacked" upon each other when imaged with the probe placed over the very proximal aspect of the readily visible and palpable adductor longus, with all 3 abutting posteriorly on the anterior aspect of the gracilis. This provides a reference point to identify the obturator nerve divisions that are visible in the interfascial muscle planes. Distally, at the junction of the middle and lower third of the medial aspect of the thigh, the sartorius muscle overlies the adductor (Hunter) canal, providing an excellent landmark for localizing the subsartorial plexus, which is accompanied by the femoral artery and vein (Table 2).

The supine decubitus position, hip in external rotation and slightly abducted with the knee semiflexed in the "frog-leg" position, is used for the guided injection of the obturator nerve. The probe is placed medially, slightly below the inguinal crease, close to the pubis, and transversally over the readily palpable and visible adductor longus muscle with its intramuscular tendon. This is an excellent reference point. The probe is then moved proximally almost to the pubis and also slightly posteriorly to include the leading edge of the gracilis. At this level, the US image shows the muscle pattern

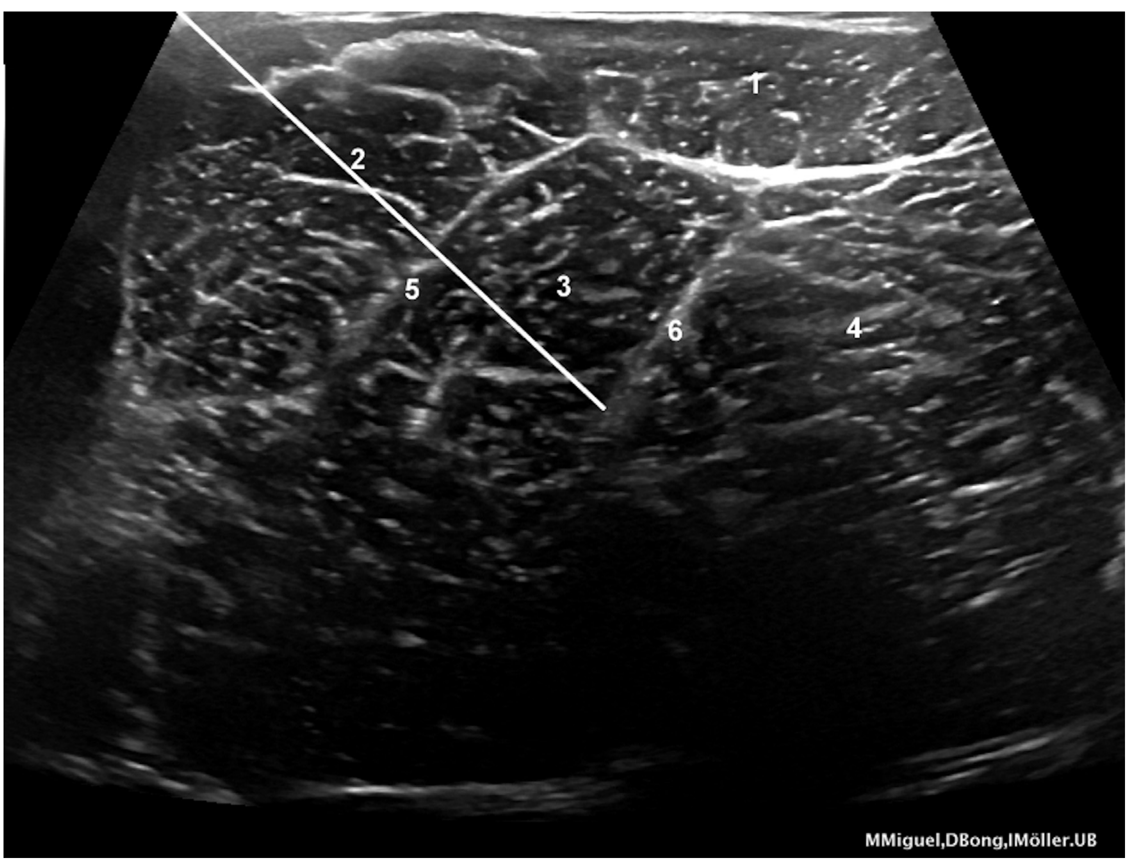

Fig. 4 – *Obturator nerve.* Transverse virtual convex image; 12-5 MHz. Transverse view over the proximal adductors with the superficial and posterior gracilis muscle (1), the more anterior adductor longus muscle (2) with its prominent intramuscular tendon, and the adductor brevis muscle (3) sandwiched between the deep adductor magnus (4) and longus muscles. In the fascia between the adductors are the anterior (5) and posterior (6) divisions of the obturator nerve (5). The white line represents the trajectory of the needle for lateral to medial IL placement in the fascial sheath between the adductor brevis and magnus muscles. The needle is then withdrawn (and redirected if necessary) to the more proximal fascial plane between adductor brevis and longus muscles.

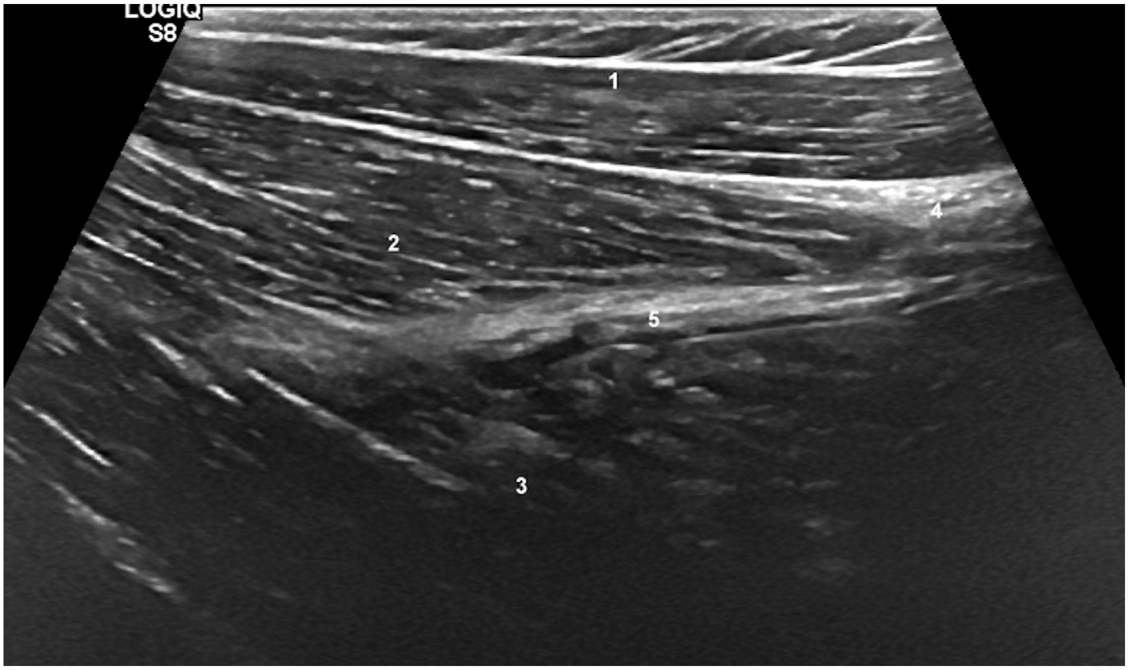

Fig. 5 – *Obturator nerve*. Longitudinal view; 12-5 MHz. Longitudinal view with respect to the adductor longus muscle (1) (note the hyperechoic and linear intramuscular tendon). Below are the adductor brevis (2) and magnus muscles (3). The anterior (4) and posterior (5) divisions of the obturator nerve are visualized in position for in-plane ultrasound-guided infiltration.

of the gracilis medially, with the adjacent muscle bellies of—from superficial to deep—the adductor longus, brevis, and magnus muscles. The divisions of the obturator nerve can be seen in the fascial boundaries between the adductor muscles (Figures 2 and 3). Distally, the sartorius muscle can be identified medially with the neurovascular bundle located posterior to it, corresponding to the subsartorial plexus.

Relevant landmarks to identify before the procedure are the intramuscular tendon of the adductor longus muscle, the gracilis muscle, and the sartorius muscle.

Indications and technique for obturator nerve blockade

The obturator nerve is most commonly compressed as it passes through the obturator canal. There are multiple etiologies including pelvic trauma or fractures, cement herniation in hip arthroplasty, tumor, and endometriosis. The patient notes paresthesias and pain, often worsening with extension or lateral movement of the lower limb. These symptoms can be accompanied by numbness over the medial thigh in a variable distribution. Weakness of the adductor muscles can be present in chronic or severe nerve compression. Adductor weakness can be a useful sign in assessing efficacy of obturator nerve blockade, but it should be noted that a portion of the adductor magnus muscle is innervated by the sciatic nerve and the pectineus muscle by the femoral nerve (with an occasional small branch from the obturator). The posterior branch of the obturator nerve provides articular branches to the medial aspect of the knee joint. Obturator nerve blockade in addition to femoral nerve blockade in a painful knee after knee arthroplasty is controversial. Infiltration is performed with an interfascial injection using a needle of 21-22 gauge between the adductor brevis and magnus muscles when the objective is to block the posterior division and between the pectineus and adductor brevis muscles proximally to block the anterior division.[2] At the level of the subsartorial plexus and by means of neurostimulation, a selective block of the anterior obturator division can be accomplished (Figures 4 and 5).[3]

Table 4 – Checklist femoral nerve.

Bones
Ilium
ASIS
Ligament
Inguinal ligament
Muscle
Iliopsoas
Vessels
Femoral artery and vein

Femoral sensory nerves

Sonoanatomy of the lateral femoral cutaneous nerve

The lateral femoral cutaneous nerve (LFCN) is a purely sensory nerve formed by L2 and L3. It innervates the skin of the upper lateral thigh. It runs forward to the ASIS, where it generally penetrates the inguinal ligament at a variable distance to its attachment to the ASIS, ranging from 3 mm to 7 cm medial of the ASIS.[4]

The LFCN has several distinct branching patterns with the most common occurring caudal to the inguinal ligament with an anterior and posterior division.[5] Often, it can be readily identified superficial to the sartorius muscle between the skin and subcutaneous tissue and the fascia lata in its medial continuation (Table 3).

Fig. 6 – *Lateral femoral cutaneous nerve*. Probe placement (red bar) for in-plane (IP) lateral to medial infiltration of the lateral femoral cutaneous nerve adjacent to the ASIS at the insertion of the inguinal ligament. (Color version of figure is available online.) (Figures 6, 7 and 8).

With the patient in supine position, the LFCN can be localized by first palpating the ASIS and then placing the proximal end of the probe directly over it and aligning parallel to the inguinal ligament. By rocking the probe, the fascicular echotexture of the LFCN can be identified in many cases. If the nerve is not visualized in this manner, the triangular shape of the superficial sartorius muscle can be readily found medial and distal to the inguinal ligament as it courses in a medial and oblique direction from its origin at the ASIS. The nerve should be visible superficial to the sartorius muscle in the fascial tissue covering it. The LFCN can be followed proximally to the point where it emerges near the ASIS (Figures 4 and 5). Relevant landmarks to identify before the guided injection are the inguinal ligament, the ASIS, and the sartorius muscle.

Indications and technique for LFCN blockade

Meralgia paresthetica is a relatively common syndrome characterized by dysesthesia, numbness, and hypersensitivity over the anterolateral region of the thigh. This syndrome has been described after injury during local or regional surgery in up to 17% of the cases. It can be idiopathic, associated with obesity, diabetes, or pregnancy. Tight belts around the waist can be an additional cause of LFCN compression.[6] Symptoms may worsen by walking or prolonged standing. Using the probe technique described earlier to localize the LFCN, a 22-gauge spinal needle is inserted by an in-plane lateral approach, but in a short axis relative to the nerve, to infiltrate local anesthetic, usually with corticosteroid, in the superficial tissues about the nerve.[7]

Sonoanatomy for the femoral nerve

The femoral nerve arises from the posterior divisions of the anterior primary rami of L2, L3, and L4. It is formed within the psoas muscle, passing through it to lie in the groove between the psoas and iliacus muscles. Distally, it is located over the iliacus tendon and enters the thigh underneath the inguinal ligament, lateral to the femoral artery. In the femoral triangle, it divides into anterior and posterior, the branches that in turn straddle the lateral circumflex femoral artery. The saphenous nerve, its most distal component, exits the femoral triangle to enter the adductor or the Hunter canal beneath the sartorius muscle where it crosses over the femoral artery. Within the canal, this purely sensory nerve is a component of the subsartorial plexus, which includes the saphenous nerve, other branches of the femoral nerve (medial femoral cutaneous nerve and the branch to vastus medialis) and a branch of the anterior division of the obturator nerve. The saphenous nerve then penetrates the deep fascia of the canal to exit, usually, between the sartorius and gracilis muscles to provide sensory innervation to the aspect of the leg running distally with the greater saphenous vein (Table 4).

With the patient in the supine position, the transducer is positioned in the short axis over the inguinal crease to identify the pulsatile circular anechoic femoral artery that persists despite compression. The femoral vessels are located in the

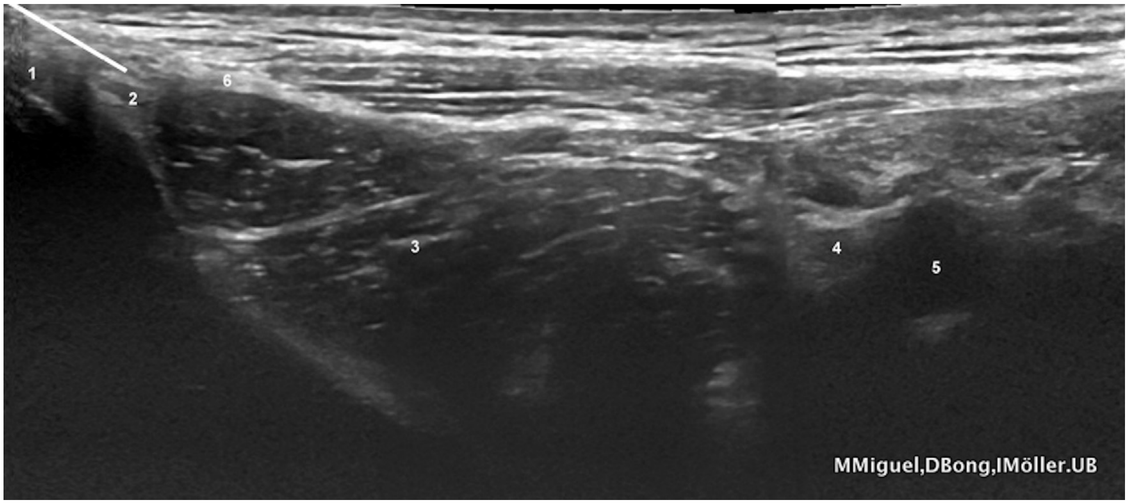

Fig. 7 – *Lateral femoral cutaneous nerve (LFCN).* Transverse view; 12-5 MHz. Transverse view of the LFCN (2) with the probe oriented over the ASIS and roughly longitudinal to the inguinal ligament (6). The medial neurovascular bundle with the femoral nerve (4) and artery (5) can be noted. The white line in the upper left-hand corner represents the trajectory of the needle for lateral to medial IL placement adjacent to the fascicular nerve.

lacuna vasculorum separated from the lateral lacuna musculorum by a hypoechoic iliopectineal ligament. Slight side-to-side shifting of the stationary transducer helps to localize the fascicular pattern of the femoral nerve lateral to the artery (Figure 6).

The femoral artery and vein and the iliopsoas muscle and tendon are relevant anatomical landmarks to perform the guided injection in this region.

Indications and technique for femoral nerve blockade

In addition to local anesthesia, femoral nerve injection is also indicated for pain over the distribution of the nerve including the hip joint, the anterior and medial thigh down to the knee, and a variable part of skin on the medial leg and foot.

To inject the femoral nerve in plane, the needle is obliquely inserted lateral to medial to target the deep border of the femoral nerve. Confirmation of needle placement is a vital part of the procedure to avoid risk of intravascular injection. After penetrating the fascial planes of the fascia lata and iliacus, a small bolus of local anesthetic is injected to assure correct needle placement with the fluid being noted around the nerve.[8]

Based on the theoretical existence of a suprainguinal compartment, Winnie et al[9] described the lumbar plexus block by

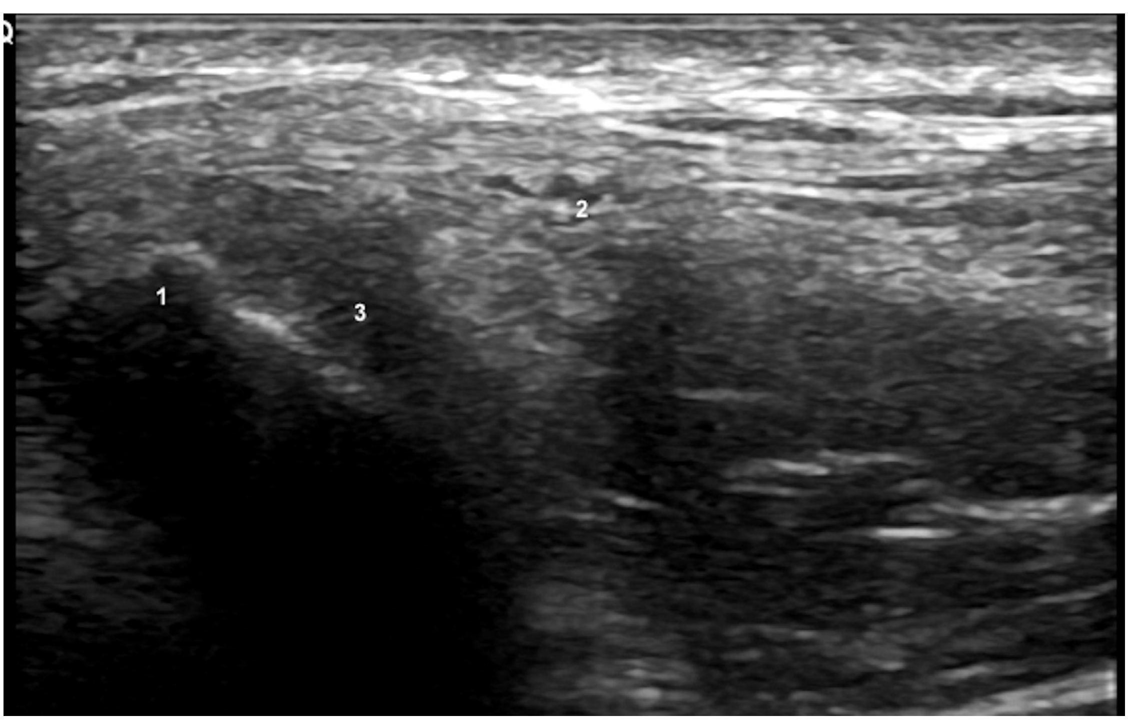

Fig. 8 – *Lateral femoral cutaneous nerve*. Transverse view; 12-5 MHz. The probe has been shifted slightly caudally from the ASIS (1) to show the LFCN (2) over the sartorius muscle (3).

Fig. 9 – ***Femoral nerve.*** **Probe placement (red bar) for in-plane (IP) lateral to medial infiltration of the femoral nerve. (Color version of figure is available online.)**

Fig. 10 – ***Femoral neurovascular bundle.*** **Transverse virtual convex; 12-5 MHz. Transverse view of the inguinal region with the neurovascular bundle consisting (from lateral to medial) of the femoral nerve (1), femoral artery (2), and femoral vein (3). The iliopectineal ligament (not shown) separates the inguinal structures into a lateral compartment (lacuna musculorum) containing the femoral nerve, iliopsoas muscle (5), and tendon (4) with the medial compartment (lacuna vasculorum) containing the femoral artery and vein. The white line represents the trajectory of the needle for lateral to medial IL placement beneath the femoral nerve after passing through the fascia.**

an anterior approach or the "3-in-1" concept. According to the "3-in-1" concept, a large volume of local anesthetics is injected over the femoral nerve to spread underneath the fascia iliaca. When combined with distal compression, the local anesthetic spreads proximally, reaching the lumbar plexus. Unfortunately, several studies have repeatedly failed to demonstrate the reliability of this technique to obtain block of the lumbar plexus or the obturator nerve.[10,11] This guided injection is useful in cases of acute trauma. In the face of a fractured neck of the femur, the use of a nerve stimulator instead of US to localize the nerve would result in muscular contraction, pain, and risk of fracture displacement. US provides an extra margin of safety, especially in large patients[12] (Figures 9 and 10).

Summary

- The knowledge of the essential anatomy of the hip is the basis for comprehensive US evaluation and intervention.
- Detailed systemic US examination based on an anatomical checklist is critical for the thorough examination of the hip.

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