Review paper

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Sonoanatomy of the ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves: a practical guide for US-guided injections

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Abstract

The ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves are the major sensory nerves that may be involved in chronic groin and genital pain with a significant impact on the quality of life of patients. The diagnosis remains clinical, and US-guided diagnostic injections using an anesthetic may aid in confirming the clinical suspicion. The anatomy of the peripheral nerves can be successfully studied using imaging. High-resolution ultrasound is increasingly used in the clinical setting for visualizing small peripheral nerves, and magnetic resonance imaging provides an anatomical overview of the relationship between small nerves and surrounding structures. In this pictorial assay, we review the anatomy and clinical relevance of the ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves. We summarize the various techniques for ultrasound identification, and present the ultrasound-guided infiltration techniques for injecting the ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves. Corresponding magnetic resonance images and clinical photos of the probe placement technique are provided for anatomical correlation. This paper is aimed to serve as a practical technical guide for physicians to familiarize themselves with the ultrasound anatomy of the major inguinal sensory nerves and to enable successful ultrasound identification and ultrasound-guided diagnostic or therapeutic infiltrations for pain management of the ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves.

Introduction

The ilioinguinal, iliohypogastric, genitofemoral, obturator, and pudendal nerves are the major sensory nerves that may be involved in chronic groin and genital pain[1–3]. High-resolution ultrasound (US) is increasingly used in the clinical setting for imaging small peripheral nerves both by radiologists and non-radiologists[4,5]. Compared to the small field of view of US, magnetic resonance (MR) has the advantage of providing an anatomical overview of the relationship between nerves and surrounding structures, and may provide an excellent anatomical correlation to US. This review is aimed to serve as a practical guide for physicians to familiarize themselves with the imaging anatomy of major sensory nerves of the groin area on US in correlation to MR, in order to enable successful diagnostic scanning and US-guided infiltration.

Ilioinguinal and iliohypogastric nerves and the genital branch of the genitofemoral nerve

Anatomy

The iliohypogastric (IHN), ilioinguinal (IIN), and genitofemoral (GFN) nerves are branches of the lumbar plexus, deriving from the T12–L1 nerves, the L1 and the L1–L2, respectively[4,6,7].

The IHN arises at the lateral border of the proximal psoas muscle 5–9 cm laterally and cranially to the posterior superior iliac spine, then crosses obliquely in front of the quadratus lumborum muscle, and enters the transversus abdominis muscle 2.0–12.3 cm dorsally to the anterior superior iliac spine (ASIS)[1,4]. It then divides between that muscle and the obliqus internus abdominis into the lateral cutaneous, anterior, and genital branches, supplying the skin over the lower part of the rectus abdominis or mons pubis. The area where the nerve is found to have the least anatomical variability is on the quadratus lumborum muscle[1].

The IIN arises from the lateral border of the psoas major just below the IH within 4.4–8.6 cm cranially to the posterior superior iliac spine, and enters the transversus abdominis at the area of the anterior iliac crest with a very variable course[1,4]. In relation to the ASIS, the IIN penetrates the abdominal wall within 0.5–13.0 cm dorsally, and supplies the skin of the superomedial thigh, the skin over the root of the penis and anterior scrotum in men and the mons pubis and labium majus in women[1]. The area where the nerve is found to have the least anatomical variability is on the quadratus lumborum muscle[1].

The GFN courses anterior to the psoas muscle and the common and external iliac arteries. Above the inguinal ligament, it divides into the genital (external spermatic) and the femoral (lumboinguinal) nerves[1,4]. Both branches are located medially to the IHN and IIN, and centrally on the psoas muscle. The genital branch of the GFN runs retroperitoneally, and enters the abdominal wall at the area of the internal inguinal ring, forming a circle around the ring to reach the scrotum or the labia majora. The femoral branch of the GFN passes underneath the inguinal ligament to follow the external iliac artery, and then enters the sheath of the femoral vessels, lying superficial and lateral to the femoral artery[1,4,7]. The genital GFN branch supplies the skin of the anterolateral scrotum or labium majus, and contains a motor branch to the cremaster muscle. The femoral GFN branch innervates the skin of the anterior upper thigh below the inguinal ligament or the femoral triangle[4].

The distance between the GF, IH and II is the shortest centrally on the psoas muscle[1]. There are many variations and communications between the sensory branches of these nerves, implying the need for examining these three nerves as a whole in the proper clinical setting[7,8].

Clinical relevance

Entrapment or injury of the IIN, IHN, and GFN, known as border nerve pain syndrome, leads to chronic burning neuropathic pain and/or paresthesia spreading from the lower abdomen to the inguinal region, the superomedial aspect of the thigh, the scrotum, and the labia majora, resulting in severe adverse impact on normal daily activities or work[9,10]. The distinction between IIN/IHN and GFN entrapment is challenging due to their overlapping sensory innervation[11]. These nerves are at risk to injury from lower abdomen incision leading to post-operative groin pain known as inguinodynia or post-herniorrhaphy pain syndrome[5]. IIN/IHN entrapment or injury may present after herniorrhaphy (54%), appendectomy, hysterectomy, abdominoplasty, and orchiectomy[5,9,12]. Post-operative GF entrapment is rare (0.3%), mainly occurring after vasectomy, nephrectomy, urethral sling, Pfannenstiel incision, appendectomy, and retroperitoneal operations including aortic aneurysm repair[13]. Other less common causes of border nerve pain syndrome include trauma, compression by a pelvic lesion or endometriosis, bicycle riding or tight clothing[10].

Obturator nerve

Anatomy

Originating from the L2–4 nerve roots, the obturator nerve (OBN) pierces the psoas muscle, runs through the obturator foramen, and extends to the anterior thigh dividing into the anterior and posterior branches. The area of bifurcation is usually located within the obturator canal, less commonly in the pelvis or in the thigh. The branches are separated by the adductor brevis muscle at the level of the thigh[14]. The OBN supplies the skin of the medial thigh and above the medial side of the knee, and provides motor innervation of the adductor muscles. No cutaneous innervation is provided in more than half of individuals[14].

Clinical relevance

Entrapment of the OBN, also known as "obturator tunnel syndrome" includes symptoms such as groin and medial thigh pain (73%), weakness of the adductor muscle, and paresthesia along the lateral peroneal region[15]. Patients may also present with deep pain or sensory loss in the medial thigh from the pubic area to the medial knee, which can be stimulated by forced extension, abduction, and internal rotation of the hip (Howship–Romberg sign)[16].

The OBN is prone to compression after prolonged lithotomy position during gynecological or urological operations[17] and after total hip arthroplasty (0.7–1%), mainly caused by cement extrusion[18]. It partially innervates the knee joint capsule and the gracilis muscle, and may be blocked in total knee arthroplasty or during harvesting of the gracilis tendon in anterior cruciate ligament reconstruction[14]. It also gives sensory innervation to the hip joint; so obturator nerve blockade may be used to control acute pain after hip surgery[14].

Pudendal nerve

Anatomy

Originating from the S2–S4 nerve roots, the PDN courses distally and posteriorly between two muscles, the piriformis and coccygeus muscles, to exit the pelvis through the greater sciatic foramen[19,20]. It then runs between the sacrotuberous (ST) and sacrospinous (SS) ligaments at the level of the inferior posterior ischial spine (IPIS) on the medial side of the internal pudendal artery (IPA)[19,20]. Then, it passes through the lesser sciatic foramen to enter into Alcock's canal[19], finally dividing into three terminal branches; the inferior rectal branch, the perineal branch, and dorsal sensory nerve of the penis or clitoris[19,20]. It supplies the skin of the penis or clitoris, the perineal area, and the posterior scrotum or labia majora. It carries sensory, motor, and autonomic fibers; however, injury causes sensory rather than motor deficits[20].

Clinical relevance

PDN entrapment causes pudendal neuralgia, a chronic severe disabling neuropathic condition[20]. Symptoms are highly variable depending on the level of nerve damage and the presence of anatomic variations, including hyperalgesia, paresthesia, allodynia and burning sensation at the perineum and genital area, increased urinary urgency, painful sexual intercourse, and foreign body sensation in the rectum[19]. Pain may worsen with sitting, and may radiate to the lower limbs[19]. Damage to the nerve may lead to fecal incontinence[20]. Pudendal neuralgia may result from mechanical injury, including compression or stretching of the nerve, and from non-mechanical causes, such as viral infections, multiple sclerosis, and diabetes mellitus[20]. It is a common complication after pelvic surgery, but it can also be caused by direct trauma to the buttocks, vaginal delivery, chronic constipation, excessive cycling, or prolonged sitting[20]. There are four types of pudendal nerve entrapment syndrome depending on the level of compression, including proximally below the piriformis muscle, as the pudendal nerve exits the greater sciatic notch (type 1), entrapment between sacrospinous and sacrotuberous ligaments (type 2), entrapment in Alcock's canal due to obturator internus muscle spasm (type 3), and entrapment of terminal branches (type 4)[21]. The most common site of entrapment is Alcock's canal and between the sacrospinous and sacrotuberous ligaments[21,22]. The diagnosis of pudendal neuralgia remains clinical, and US-guided diagnostic injections using anesthetic may aid in confirming the clinical suspicion[21,22]. US-guided PDN block at the level of the inferior posterior ischial spine (IPIS) is as accurate as fluoroscopically-guided injections[23].

Ultrasound identification and guided injection

Ilioinguinal and iliohypogastric nerves

The nerves can be imaged using US at a level superior to the anterior superior iliac spine (ASIS), where they pierce the abdominal wall muscles, and/or at a level distal to the ASIS. Using the ASIS as a landmark, a linear high-frequency probe (12–18 MHz) is placed in a slightly oblique plane medially to the ASIS and then shifted 3 to 5 cm superior to it. The iliac crest appears in the

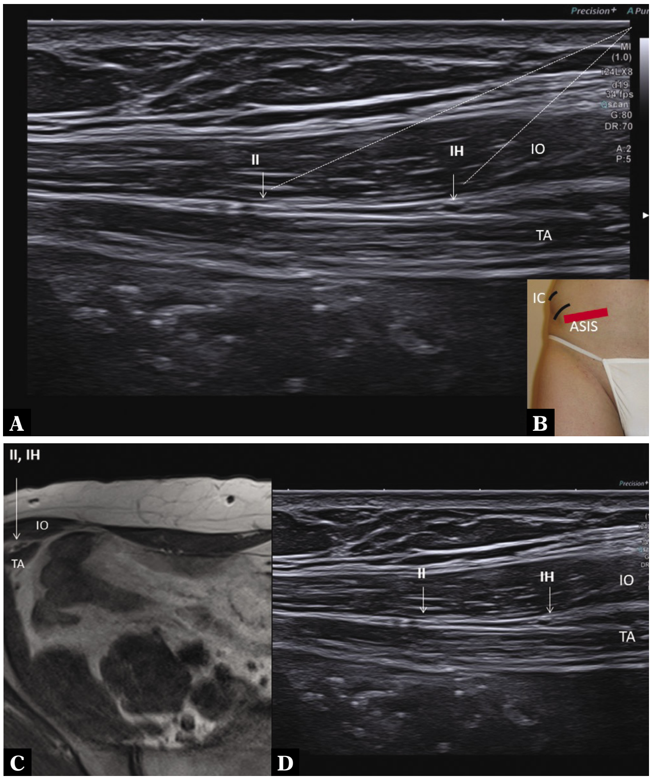

Fig. 1. A. *US image of the right ilioinguinal (II) and iliohypogastric (IH) nerves at the fascial plane between the internal oblique (IO) and transversus abdominis (TA) muscles at a level just distally to the ASIS. The dotted straight lines indicate the direction of the needle tract from medial to lateral during US-guided injection with an in-plane approach.* **B.** *Corresponding topographical anatomy photo of the right lower abdomen with the red line indicating the probe position. IO – internal oblique muscle; TA – transversus abdominis muscle; IC – iliac crest; ASIS – anterior superior iliac spine.* **C.** *Axial Pd-w MR image of the right ilioinguinal (II) and iliohypogastric (IH) nerves (arrow) at the fascial plane between the internal oblique (IO) and transversus abdominis (TA) muscles at a level just distally and medially to the ASIS.* **D.** *Corresponding US image acquired with probe positioning as shown in B. IO – internal oblique muscle; TA – transversus abdominis muscle; ASIS – anterior superior iliac spine*

US image with three layers of the abdominal muscles attached to it: the external oblique, the internal oblique, and the transversus abdominis[4,5,24]. Inside the muscle fascia, between the second (internal oblique muscle) and third muscle layer (transverse abdominal muscle), both the IHN and the IIN nerves can be imaged in proximity to each other, with the IH nerve running medially to the IIN. The nerves usually appear as a single hypoechoic round fascicle[4,5,24]. Color Doppler is useful to differentiate the nerves from the deep circumflex iliac artery also located in the same fascial plane[4,5,24]. Just distally and medially to the ASIS, the external oblique becomes an aponeurosis and is no longer visible as a muscle layer, with the IIN and IHN nerves located between the remaining two muscle layers (Fig. 1). Using an in-plane approach, the needle is inserted aiming towards the fascial plane between the internal oblique abdominal

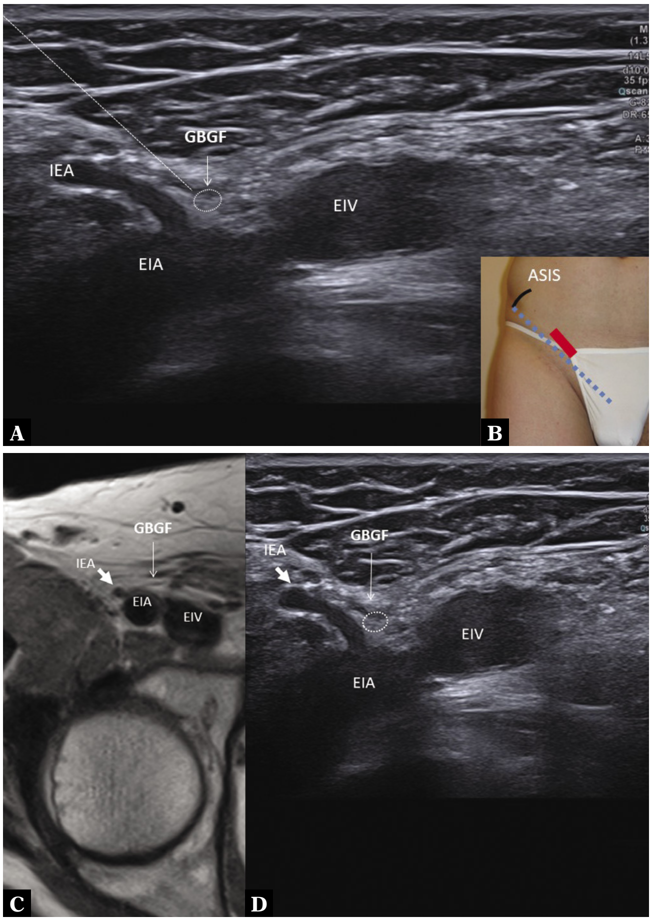

Fig. 2. A. *US image of the right genital branch of the genitofemoral nerve (GBGF, dotted oval line) at a level of the inferior epigastric artery (IEA) origin. The dotted straight lines indicate the direction of the needle tract from lateral to medial during US-guided injection with an in-plane approach.* **B.** *Corresponding topographical anatomy photo of the right lower abdomen with the red line indicating the probe position. The anatomical landmarks are the ASIS (curved line) and course of the inguinal ligament (straight dotted line from ASIS to pubic tubercle). EIV – external iliac vein; EIA – external iliac artery; ASIS – anterior superior iliac spine.* **C.** *Axial Pd-w MR image of the right genital branch of the genitofemoral nerve (GBGF, thin arrow) lying superficial to the EIA at the level of the IEA origin (thick arrow).* **D.** *Corresponding US image acquired with probe positioning as shown in B. The GBGF is shown as dotted oval line. IEA – inferior epigastric artery, EIV – external iliac vein; EIA – external iliac artery*

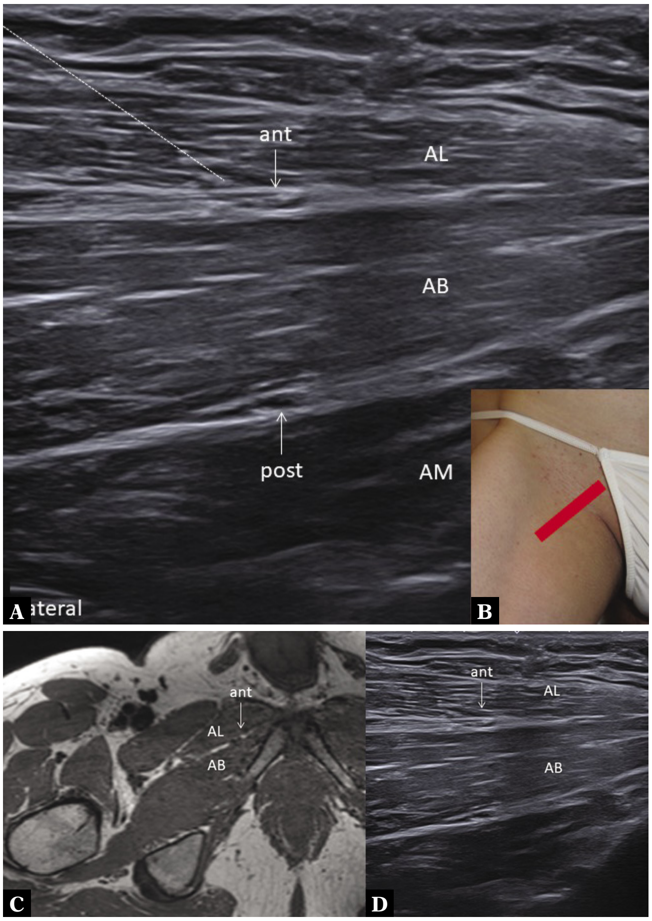

Fig. 3. A. *US image of the right obturator nerve branches (arrows) and the adductor muscles. The dotted straight line indicates the direction of the needle tract from lateral to medial during US-guided injection with an in-plane approach.* **B.** *Corresponding topographical anatomy photo of the groin area with the red line indicating the probe position. AL – adductor longus; AB – adductor brevis; AM – adductor magnus; ant – anterior branch of the obturator nerve; post – posterior branch of the obturator nerve.* **C.** *Axial Pd-w MR image of the right anterior branch of the obturator nerve (arrow).* **D.** *Corresponding US image acquired with probe positioning as shown in B. AL – adductor longus; AB – adductor brevis; ant – anterior branch of the obturator nerve*

muscle (superficial layer) and the transverse abdominal muscle (deep layer). After using Doppler US to avoid injecting into the deep circumflex iliac artery, the injectate is released under direct US guidance to surround the nerve fascicles and dissect the muscle plane (Fig. 1).

Genital branch of the genitofemoral nerve

The US landmark is the ASIS and the inguinal ligament, which stretches between the ASIS and the pubic tubercle. A linear high-frequency probe (7–18 MHz) is placed on the ASIS, parallel to the inguinal ligament and shifted 2 cm upwards along the external iliac artery lying deep to the ligament (Fig. 2). The inferior epigastric artery emerges from the external iliac artery superficially, running medially towards the deep portion of the rectus abdominis muscle. The genital branch is located superficially to the external iliac artery at the level of the inferior epigastric artery origin[4,5,24]. Using an in-plane approach, the needle is inserted laterally, targeting the lateral side of the inferior epigastric artery origin, identified using Doppler US (Fig. 2).

Obturator nerve

A linear high-frequency probe is placed in a transverse plane on the pectineus muscle covering the medial part of

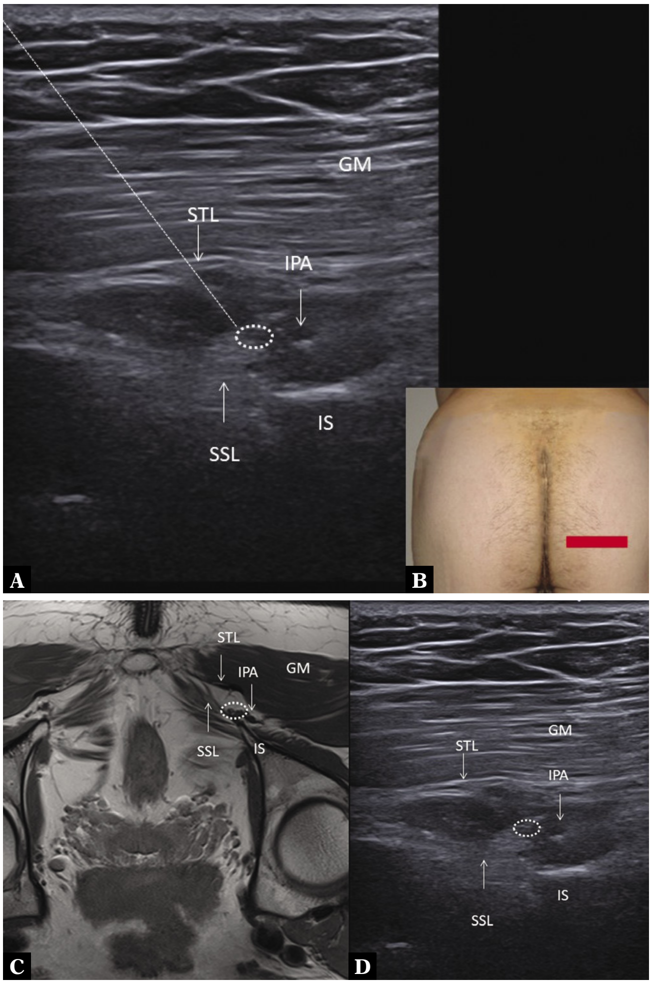

Fig. 4. A. *US image of the pudendal nerve (dotted oval line) and associated anatomical structures at the level of the ischial spine. The dotted straight line indicates the direction of the needle tract from medial to lateral during US-guided injection with an in-plane approach* **B.** *corresponding topographical anatomy photo of the gluteal area with the red line indicating the probe position. IS – ischial spine; STL – sacrotuberous ligament; SSL – sacrospinous ligament; IPA – internal pudendal artery; GM – gluteus maximus muscle.* **C.** *Axial Pd-w MR image of the right gluteal area at the level of the ischial spine showing the pudendal nerve (dotted oval line) and the associated anatomical structures. The MR image is rotated, so that the gluteal area lies on the top of the image, to allow anatomical matching to the US image.* **D.** *Corresponding US image of the pudendal nerve (dotted oval line) and associated anatomical structures at the level of the ischial spine, acquired with probe positioning as shown in B. IS – ischial spine; STL – sacrotuberous ligament; SSL – sacrospinous ligament; IPA – internal pudendal artery; GM – gluteus maximus muscle*

the superior ramus of the pubic bone. The probe is shifted downwards in an oblique axial orientation to reveal the adductor muscles: the adductor longus (AL) lying superficial to the adductor brevis (AB) muscle, and the deeper adductor magnus muscle (AM). The anterior and posterior branches are located in the fascial plane superficial and deep to the AB, respectively. The anterior branch has a US visibility rate of about 100%, thus being invariably visible, whereas the posterior branch is commonly not visualized with US[25,26].

Various US-guided techniques can be used, and can be classified according to whether the approach is distal or proximal towards the fascial plane between the AB and AM[25,26]. The easiest approach to perform a block is to target the anterior branch, which is quite superficial and always visible, and then provoke proximal spread of the injectate to achieve block of the OBN at a more proximal location[26]. This distal block is performed by targeting the plane between the AL and AB, with the patient in supine position with the thigh slightly abducted and externally rotated (Fig. 3). The transducer is placed along the adductors just below the inguinal ligament. In this position, the pectineus, adductor longus, adductor brevis, and adductor magnus muscles are visible. Using an in-plane approach, the needle is inserted laterally to medially, pointing towards the anterior branch at the fascial interface between the adductor longus and adductor brevis muscles (Fig. 3)[25,26]. The proximal spread is facilitated by applying pressure just distal to the puncture site[26].

Pudendal nerve at the ischial spine

Depending on the patient's body habitus, a linear high-frequency probe (3–12 MHz) or a low-frequency (2–5 MHz) curved array probe is used. The patient is positioned prone. At the level of the ischial spine, two linear hyperechoic structures are identified medially: the sacrotuberous (superficially) and sacrospinous (deeper) ligaments (Fig. 4). The PDN can be identified medially to the internal pudendal and inferior gluteal arteries between the ligaments as a hypo- or hyperechoic fascicular structure[22]. The PDN may not be directly evident in more than 50% of cases, whereas the artery is consistently visualized using B-mode or Doppler in nearly all cases[27].

Several techniques have been described to locate the ischial spine[22,23,27–30]. Scanning may start either cephalad or caudal to the ischial spine. According to the most commonly described techniques, the probe is initially positioned at the posterior gluteal region along the line connecting the greater trochanter and the posterior superior iliac spine[27–29]. The probe is then moved inferomedially until the greater sciatic notch is visualized as a gap and at its lateral border the ilium is visualized as a curved hyperechoic line. By moving the transducer further caudally in a parallel way, the ischium becomes progressively straighter to form the ischial spine that appears as a straight, hyperechoic line. At this level, both the pudendal artery and PDN can be visualized, both lying medially to the spine. Alternatively, the probe is placed at a more caudal level, in a transverse plane on the ischial tuberosity and then shifted upwards to reveal the sacrotuberous ligament as a moderate hyperechoic line superior to it[22]. The ischial spine is the hyperechoic straight line continuous with the posterior acetabulum, lateral to the sacrotuberous ligament (Fig. 4).

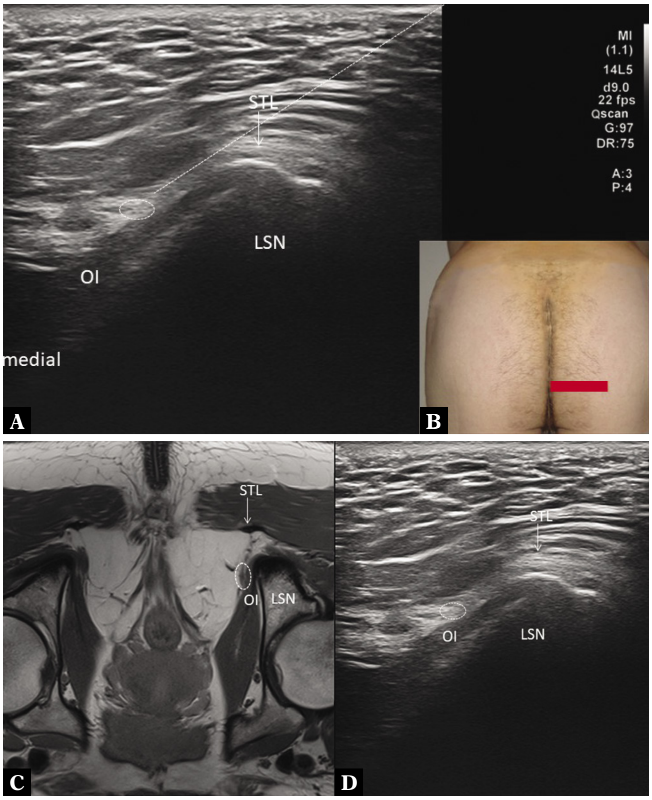

Fig. 5. A. *US image of the pudendal nerve (dotted oval line) and associated anatomical structures at the level of the lesser sciatic notch at the entrance of Alcock's canal. The dotted straight line indicates the direction of the needle tract from lateral to medial during US-guided injection with an in-plane approach* **B.** *Corresponding topographical anatomy photo of the gluteal area with the red line indicating the probe position. LSN – lesser sciatic notch; STL– sacrotuberous ligament; OI – obturator internus muscle* **C.** *Axial Pd-w MR image of the right gluteal area at the level of Alcock's canal showing the pudendal nerve (dotted oval line) and the associated anatomical structures. The MR image is rotated with the gluteal area on the top of the image to allow anatomical matching to the US image.* **C.** *Axial Pd-w MR image of the right gluteal area at the level of Alcock's canal showing the pudendal nerve (dotted oval line) and the associated anatomical structures. The MR image is rotated with the gluteal area on the top of the image for anatomical association to US.* **D.** *Corresponding US image of the pudendal nerve (dotted oval line) and associated anatomical structures at the level of Alcock's canal, acquired with probe positioning as shown in B. LSN – lesser sciatic notch, STL – sacrotuberous ligament; OI – obturator internus muscle*

Using an in-plane approach under real-time US guidance, a long 22-gauge needle is inserted medially to laterally, and directed towards the medial side of the internal pudendal artery in the plane between the sacrotuberous and sacrospinal ligaments (Fig. 4). The injectate is released in the interligamentous plane[22,23,27–30].

Pudendal nerve at Alcock's canal

At the level of Alcock's canal, the PDN is more superficial, so a linear high-frequency probe (3–12 MHz) can be used. The bony anatomic landmark is the lesser sciatic notch (Fig. 5). Scanning starts from the ischial spine in the axial plane, and the probe is moved caudally to the lesser sciatic notch. Superficial to the convex bony surface of the lesser sciatic notch, there is the obturator internus muscle. The pudendal nerve is located just superficial and medial to the obturator internus muscle, and can be identified based on its characteristic fascicular pattern[22] (Fig. 5). Using an in-plane and lateral-to medial approach, the needle is advanced to reach the nerve superficial to the obturator internus muscle[22].

Conclusion

The anatomy of the major sensory nerves of the groin can be successfully studied using imaging techniques such as high-resolution US and MR. Familiarity with the anatomy of the major sensory nerves of the groin is important for the diagnosis and US-guided management of related pain syndromes. Although these procedures are usually performed by anesthesiologists in the setting of a pain management clinic, increased awareness of the clinical relevance and the US identification technique of those nerves by radiologists could potentially make those procedures more widespread in the clinical setting of a musculoskeletal ultrasound practice.

Conflict of interest

Authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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