# 8 Deep Gluteal Syndrome

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## Introduction

Posterior hip pain often represents a diagnostic challenge, and the examiner must be aware of the deep gluteal space abnormalities in order to obtain a correct diagnosis and treatment plan. The sources of symptoms can include conditions in one or more of the following hip layers: osseous, capsulolabral, musculotendinous, neurovascular, and kinematic chain.

Deep gluteal syndrome is characterized by non-discogenic, extra-pelvic sciatic nerve compression presenting with symptoms of pain and dysesthesias in the buttock area, hip or posterior thigh, and/or as radicular pain [1]. The nomenclature piriformis syndrome was widely utilized in the early years to characterize patients with deep gluteal pain, since the piriformis muscle was considered the only structure to compress the sciatic nerve in the deep gluteal space. However, the progress in diagnostic and surgical techniques has demonstrated a number of structures entrapping the sciatic nerve: fibrous bands containing blood vessels [2, 3], gluteal muscles [1], hamstring muscles [4, 5], the gemelli-obturator internus complex [6, 7], bone structures [8], vascular abnormalities [9, 10], ischiofemoral impingement, greater trochanteric impingement, and space-occupying lesions [11, 12]. Considering the variation of anatomical entrapment, the term "deep gluteal syndrome" [1] is preferred to describe the entrapment of the sciatic nerve in the deep gluteal space. The sciatic nerve can be also affected in locations above and below the deep gluteal space, as in intra-pelvic vascular and gynecologic abnormalities [13]. Furthermore, entrapments can occur in more than one place in the same nerve fiber or coexist with lumbosacral root compression. Considering the sciatic nerve can be entrapped by structures in each layer of the hip, a comprehensive physical examination with a thorough understanding of anatomy and biomechanics is critical in cases of deep gluteal pain.

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## Deep Gluteal Space Anatomy

A complete review of anatomy is comprehensively described in Chap. 1; however, a short review of the deep gluteal space and sciatic nerve


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anatomy will be given. The deep gluteal space is anterior to the gluteus maximus muscle and posterior to the acetabular column, hip joint capsule, and proximal femur. Other anatomical limits include the linea aspera (lateral), the sacrotuberous ligament and falciform fascia (medial), the inferior margin of the greater sciatic notch (superior), and the distal border of the ischial tuberosity (inferior) (Fig. 8.1). The sacrotuberous and sacrospinous ligaments create the greater and lesser sciatic foramen, which communicate the deep gluteal space with the true pelvis and ischioanal fossa. The sacrotuberous ligament is normally composed of two parts: a ligamentous band and a membranous falciform process [14]. Both sacrospinous and sacrotuberous ligaments are anatomically close to the pudendal nerve and may be involved in the entrapment of this nerve (Fig. 8.2).

The piriformis muscle occupies a central position in the buttock and is an important reference for identifying the neurovascular structures emerging above and below it (Fig. 8.3). This

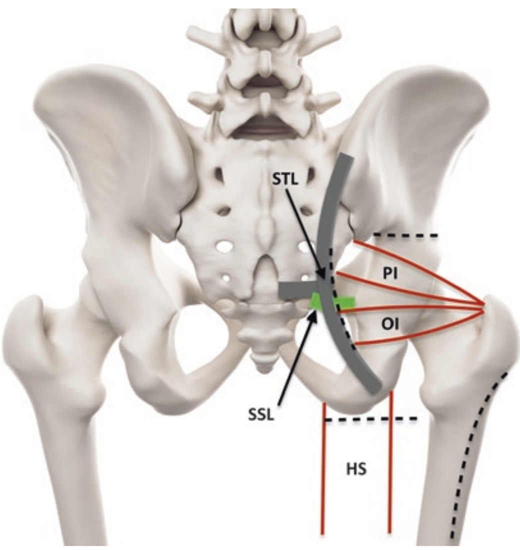


**Fig. 8.1** Limits (dashed lines) of the deep gluteal space beneath the gluteus maximus muscle: lateral, linea aspera; medial, sacrotuberous ligament and falciform fascia; superior, inferior margin of the greater sciatic notch; and inferior; the distal border of the ischial tuberosity. *STL* sacrotuberous ligament, *SSL* sacrospinous ligament, *PI* piriformis muscle, *OI* obturator internus muscle, *HS* hamstring muscles

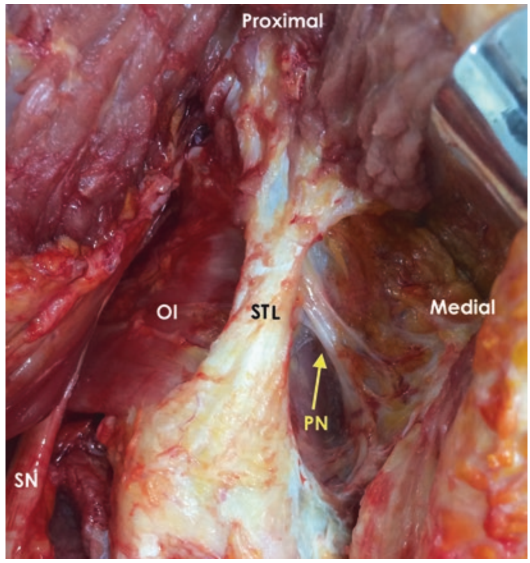


**Fig. 8.2** Cadaveric dissection of the pudendal nerve (yellow arrow) running beneath the sacrotuberous ligament. *OI* obturator internus muscle, *STL* sacrotuberous ligament, *SN* sciatic nerve, *PN* pudendal nerve

muscle arises from the ventrolateral surface of the sacrum, gluteal surface of the ileum, and sacroiliac joint capsule. The distal attachment of the piriformis is at the medial side of the upper border of the greater trochanter, often partially blended with the common tendon of obturator/gemelli complex [15–17]. Distal to the piriformis muscle is the cluster of short external rotators: the gemellus superior, obturator internus, gemellus inferior, and quadratus femoris muscle. At the ischium tuberosity, the long head of biceps femoris and semitendinosus have a common tendinous origin. The semimembranosus muscle also originates from the ischium, lateral and anteriorly to the long head of the biceps/semitendinosus muscles common origin [18] (Fig. 8.4).

Seven neural structures exit the pelvis through the greater sciatic notch: posterior femoral cutaneous nerve, superior gluteal nerve, inferior gluteal nerve, nerve to obturator internus, nerve to quadratus femoris muscle, pudendal nerve [19], and sciatic nerve (Fig. 8.3). Table 8.1 is a summary of the usual motor and sensory functions for each nerve. Accompanying the respective nerves are the

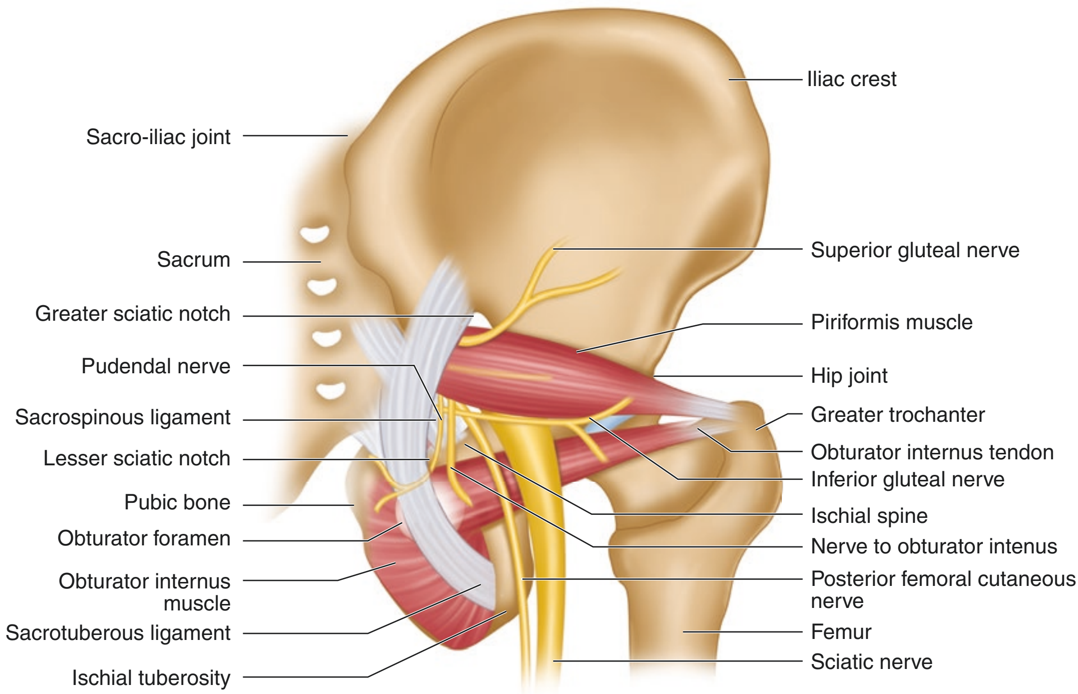


**Fig. 8.3** Schematic illustrating the nerve anatomy of the deep gluteal space

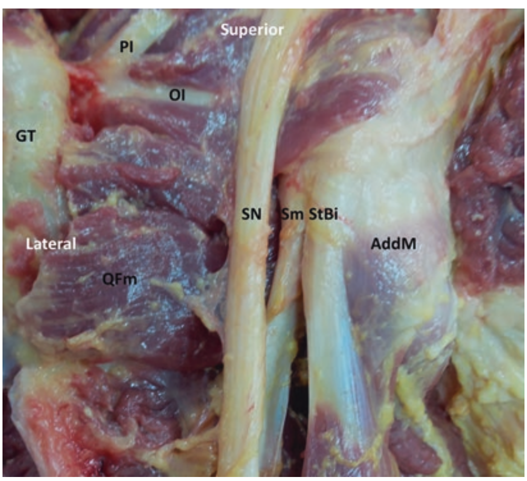


**Fig. 8.4** Posterior view of a left hip. Origin of the hamstring muscles at ischial tuberosity. The semimembranosus muscle origin (Sm) is anterior and lateral to the conjoint origin of the semitendinosus and long head of the biceps femoris muscles (St/Bi). *GT* greater trochanter (posterior view), *PI* piriformis tendon, *OI* obturator internus tendon, *QFm* quadratus femoris muscle, *SN* sciatic nerve, *AddM* adductor magnus muscle origin

superior gluteal vessels, inferior gluteal vessels, and internal pudendal vessels.

The anatomic positions of the inferior gluteal artery (IGA) and medial circumflex femoral artery (MCFA) are relevant within the deep gluteal space. The IGA enters the deep gluteal space with the inferior gluteal nerve and supplies the gluteus maximus muscle. This artery also gives a superficial arterial branch that crosses the sciatic nerve laterally between the piriformis and superior gemellus muscles. Another branch of the IGA is the descending branch, which runs along the posterior femoral cutaneous nerve in a frequency of 72% according to a cadaveric study [21]. The MCFA follows the inferior border of the obturator externus and crosses over its tendon and under the external rotators and piriformis muscle [22]. The existence of an anastomosis between the inferior gluteal artery and the medial femoral circumflex artery is frequent [23] (Fig. 8.5).

**Table 8.1** Summary of function of the nerves in the deep gluteal space

| Nerve | Motor innervation | Sensory innervation |
|---|---|---|
| Posterior femoral cutaneous nerve | | Gluteal region, perineum and posterior thigh, and popliteal fossa |
| Superior gluteal nerve | Gluteus medius, gluteus minimus, and tensor fascia lata | |
| Inferior gluteal nerve | Gluteus maximus | |
| Nerve to obturator internus | Superior gemellus and obturator internus | |
| Nerve to quadratus femoris | Inferior gemellus, and quadratus femoris | Hip capsule |
| Pudendal nerve | Perineal muscles, external urethral sphincter, and external anal sphincter | |
| Sciatic nerve | Semitendinosus, biceps femoris, semimembranosus, extensor portion of the adductor magnus and leg and foot musculature | Leg and foot, except for the saphenous nerve dermatome |

Source: Moore [20] and Standring (Gray's Anatomy) [17]

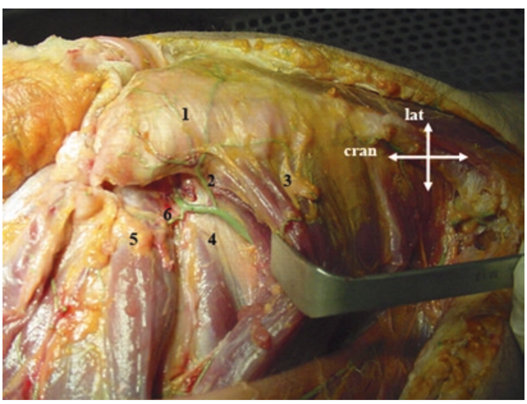


**Fig. 8.5** Deep branch of the medial femoral circumflex artery. Posterior aspect of the right hip, demonstrating the anatomic position of the deep branch of the medial femoral circumflex artery. (1) greater trochanter, (2) trochanteric branch of the medial femoral circumflex artery, (3) quadratus femoris muscle, (4) obturator externus muscle, (5) obturator internus and gemellus muscles, and (6) anastomotic branch to the inferior gluteal artery. *Cran* cranial, *Lat* lateral (Reprint with permission from Kahlor et al. [22])

## Sciatic Nerve Anatomy and Biomechanics

The sciatic nerve is formed by the L4-S3 ventral rami in the sacral plexus. Nerve fibers of the fibular and tibial components maintain a pattern of fiber separation in these branches and in the sciatic nerve. The sciatic nerve physically splits in tibial and fibular divisions at highly variable locations from the pelvis to the popliteal fossa, although this split is more frequent at the distal thigh [24]. Often, the split is oblique and may not be seen in a uniplanar MRI view [25]. Most sciatic neural fibers are destined to motor and sensory innervation distal to the knee. However, important branches arise from the nerve in the deep gluteal space and thigh. A summary of the sciatic nerve branches in the thigh is depicted in Fig. 8.6 according to Seidel et al. [26] and Sunderland and Hughes [25].

Neural tissue and non-neural tissue compose the sciatic nerve. The ratio neural/non-neural tissue changes from 2/1 at the level of piriformis muscle to 1/1 at the mid-femur, i.e., there is an increase in the non-neural tissue contribution as the sciatic nerve courses distally [27] (Fig. 8.7). The composition of the sciatic nerve also varies during the aging process, with increase in connective tissue and decrease of myelinated nerve fibers [28].

The nerve fibers of the sciatic nerve do not course between the tibial and fibular divisions [17]. However, fibers are often changing from one fascicle to another within each division [25]. Sunderland reported 6 mm as the maximum length of nerve trunk with a constant fascicular pattern, although an individual fascicle can maintain the same neural fibers for greater distances [25]. In general, most fascicles contain fibers for the majority, if not all, of the peripheral branches. Nevertheless, there is a tendency of grouping fibers for different muscles with similar function, for example, the fibers for the hamstring muscles are located anterior-medially in the proximal portion of the sciatic nerve. A progressive arrangement is found until the appearance of fascicles with nervous fibers exclusively destined to specific branches [25].

The sciatic nerve has a segmental arterial supply by branches of the inferior gluteal artery,

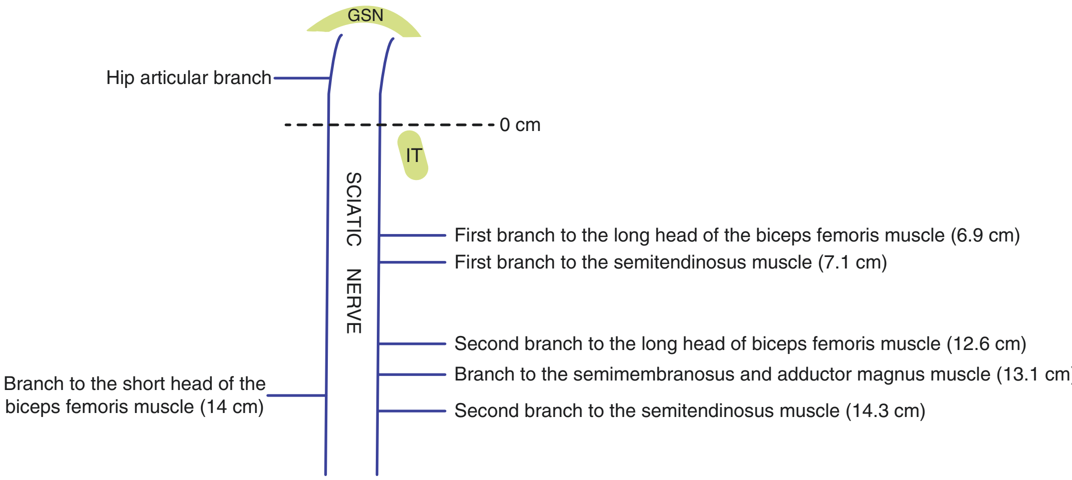


**Fig. 8.6** Schematic showing the branches of the sciatic nerve before the physical separation in tibial and fibular nerves. The mean distance from the ischial tuberosity (IT) to the branch emergence is described between brackets. *GSN* greater sciatic notch, *IT* ischial tuberosity. Sunderland and Hughes [24] served as reference for the location of the BSH branch and Seidel et al. [26] for the other branches

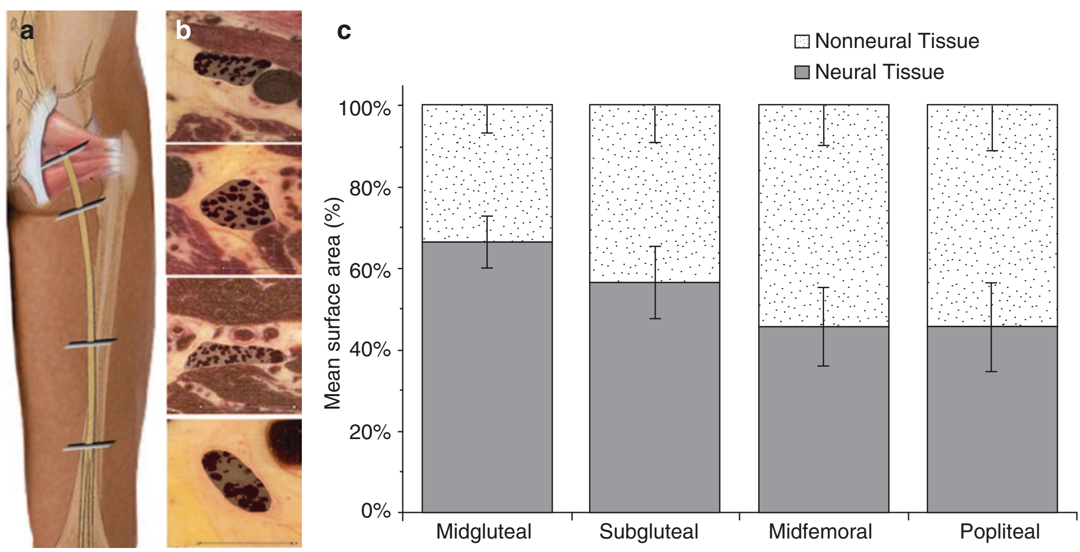


**Fig. 8.7** Non-neural and neural tissue composition of the sciatic nerve at different locations. (**a**) Schematic diagram showing four locations of analysis: midgluteal, subgluteal, midfemoral, and popliteal sciatic nerve. (**b**) Transversal view of the sciatic nerve at the four locations, with details of the demarcated neural contents (right; black dots) and epineural areas (gray fields). (**c**) Relative values (percentages) of neural versus non-neural tissue inside the epineurium (means SDs). Reprint with permission from Moayeri [27]

medial circumflex femoral artery (MCFA), and perforating arteries of the thigh (usually the first and second) [29–31]. The venous drainage of the sciatic nerve is performed through the perforators to the femoral profunda system in the thigh and to the popliteal vein at the knee [32] (Fig. 8.8). Nonfunctioning sciatic veins have been related to sciatic nerve symptoms [9].

The sacral plexus is anatomically close to the internal iliac vessels, their branches and tributaries. The superior gluteal vessels run either between the lumbosacral trunk (L4-L5 ventral

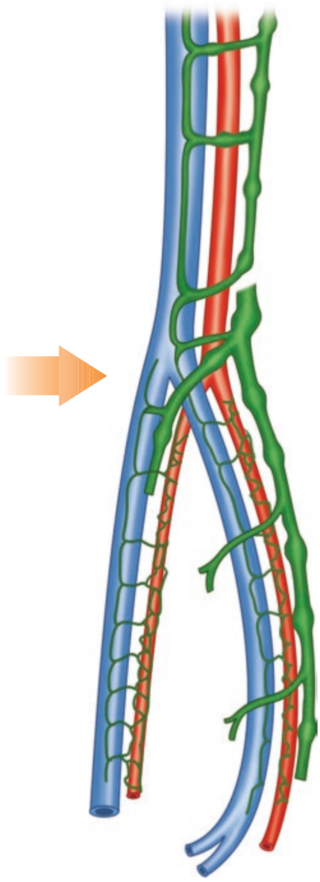

**Fig. 8.8** Schematic diagram of the venous drainage of the sciatic nerves. Arrows designate the level of the knee. From proximal to distal, the dominant venous drainage of the sciatic nerve is via the perforators of the profunda system in the thigh and directly to the popliteal vein at the knee. In the leg, the tibial and peroneal nerves drain predominantly to the plexus around their accompanying arteries as well as to muscular veins. Reprinted with permission from Del Pinãl and Taylor [32]

rami) and first sacral ventral ramus or between the first and second sacral rami, whereas the inferior gluteal vessels lie between either the first and second or second and third sacral rami (Fig. 8.9a, b) [17, 33]. The ovaries are close to the sacral plexus, although on the left side, the sigmoid is usually between the ovary and sacral plexus. The intimate anatomic relation between the iliac vessels, ovaries, and sacral plexus is an important consideration in sciatica caused by sacral plexus vascular compression and endometriosis [34].

The sciatic nerve is the terminal branch of the sacral plexus and courses anterior to the piriformis muscle in the pelvis. Variation in the relationship between the sciatic nerve and the piriformis muscle is present in 16–17% of the subjects and can be a cause of sciatic nerve entrapment [35, 36]. After leaving the piriformis muscle, the sciatic nerve runs posteriorly to the obturator/gemelli complex and quadratus femoris muscle, located at an average of 1.2 ± 0.2 cm from the most lateral aspect of the ischial tuberosity and maintaining an intimate relationship with the hamstring origin [18] (Fig. 8.4). The sciatic nerve then enters the thigh posteriorly to the adductor magnus muscle and crosses anteriorly the long head of the biceps femoris. Next, the nerve runs between the semimembranosus and biceps before accessing the popliteal fossa.

Under normal conditions, the sciatic nerve is able to stretch and glide in order to accommodate moderate strain or compression associated with joint movement. During a straight leg raise with knee extension, the sciatic nerve experiences a proximal excursion of 28.0 mm [37] at 70–80° of hip flexion. Strain of the sciatic nerve increases 6.6% relative to the extended hip [37]. Fleming et al. measured the sciatic nerve strain throughout ten hip arthroplasty procedures [38]. The strain increased on average 26% during hip flexion with the knee in extension. This amount of strain is significant and may cause nerve dysfunction. An animal study reported the nerve conduction was completely blocked after stretching of 12% of the nerve length during 1 h [39]. At 6% strain, the authors found a decrease of 70% in amplitude of the action potential after 1 h [39]. The changes in femoral bone morphology may influence sciatic nerve kinematics during hip mobilization [2]. Therefore, it is always important to assess osseous parameters, including femoral and acetabular versions (Fig. 8.10a, b). Hip flexion, adduction, and internal rotation increases the distance between the greater trochanter and posterior superior iliac spine and the distance between the greater trochanter and ischial tuberosity. This hip position stretches the piriformis muscle and causes a narrowing

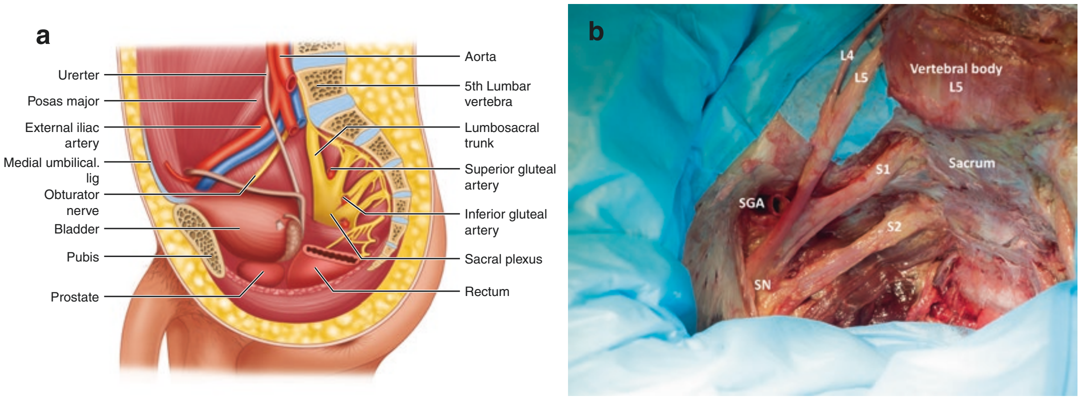


**Fig. 8.9** (**a**) Superior and inferior gluteal arteries crossing the sacral plexus before accessing the deep gluteal space. (**b**) Cadaveric dissection of the intra-pelvic showing a close relationship between the superior gluteal artery (SGA) and nerve roots (L4, L5, S1, S2) forming the sciatic nerve (SN)

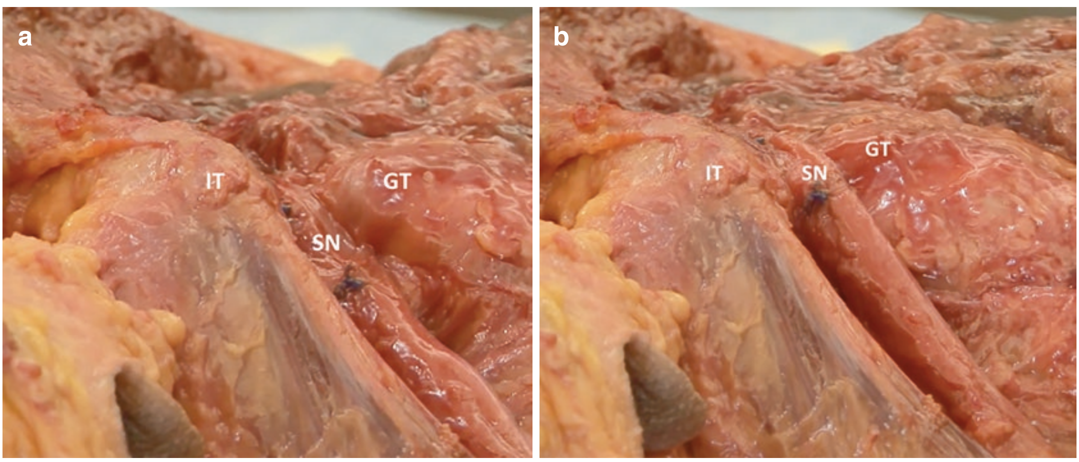


**Fig. 8.10** Posterior view of the sciatic nerve (SN) excursion between the greater trochanter (GT) and ischial tuberosity (IT) in a cadaveric specimen, right hip. The sciatic nerve is forced posterior to the GT and ischium during increasing hip flexion and external rotation (**a**, **b**). This pattern of excursion of the sciatic nerve may change according to the bone morphology, adjacent soft tissue restriction, and knee position (flexion or extension)

of the space between the inferior border of the piriformis, the superior gemellus, and the sacrotuberous ligament [40].

## Etiology

The piriformis muscle and tendon are the most common source of extra-pelvic sciatic nerve impingement. Yeoman first described the possibility of sciatic nerve entrapment by the piriformis muscle in 1928 [41]. The introduction of the term "piriformis syndrome" has been credited to Robinson, in 1947 [42]. The diagnostic resources have improved last decades, and a number of structures have been associated with sciatic nerve entrapment within the deep gluteal space: the piriformis muscle [2, 3, 11, 12, 43–49], fibrous bands containing blood vessels [2, 3, 43] (Fig. 8.11), gluteal muscles [1], gemelli-obturator internus complex [6, 7], hamstring muscles [4, 5], ischial

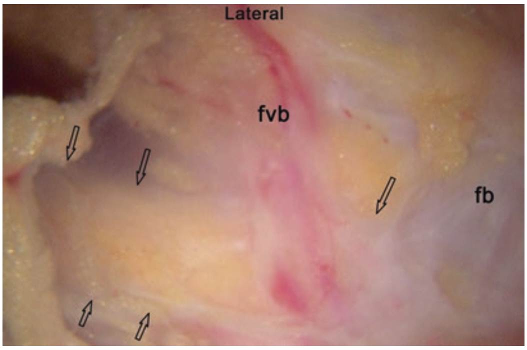


**Fig. 8.11** Entrapment of the sciatic nerve by fibrovascular scar band, endoscopic visualization. The sciatic nerve is indicated by the open arrows and is anterior to a fibrovascular band (fvb) and another fibrous band (fb)

tuberosity [8, 50], and space-occupying lesions [11, 12]. Additionally, vascular abnormalities [10, 47], prolonged surgery in the seated position [51], acetabular reconstruction surgery [52], and total hip replacement [53] have been reported to cause compression of the sciatic nerve. Considering the variation of anatomical structures causing the entrapment, the term "deep gluteal syndrome" [1] seems to be a more accurate description of this non-discogenic sciatica.

The piriformis muscle is the most common source of sciatic nerve entrapment [2, 3, 11, 12, 43–49]. The risk of nerve compressive symptoms is increased by the existence of variation in the relationship between the piriformis muscle and the sciatic nerve. Six categories of piriformis-sciatic nerve variations have been reported [35] (Fig. 8.12). However, other sciatic nerve variants have been identified. For instance, the authors of this chapter incidentally found a bifid sciatic nerve that runs below the piriformis muscle in a male cadaver during a routine anatomic dissection (Fig. 8.13). The prevalence of anomalies was 16.9% in a meta-analysis of cadaveric studies [36] and 16.2% in a review of published surgical case series [36]. It is important to mention that the anomaly itself may not be the etiology of the DGS symptoms. Martin et al. [2] reported on 35 patients endoscopically treated for deep gluteal syndrome. Eighteen patients involved the piriformis muscle as etiology, including the sciatic nerve passing through the piriformis muscle or a portion of piriformis muscle/tendon passing through or anterior to the sciatic nerve [2]. A thick piriformis tendon hidden under the piriformis belly can also be identified causing sciatic nerve compression (Fig. 8.13). Hypertrophy of the piriformis muscle has also been associated with sciatic nerve compression [12, 46, 47, 56]. However, of 14 patients with posttraumatic piriformis syndrome, Benson and Schutzer found that only two had larger piriformis muscles on the symptomatic side and seven appeared smaller than the unaffected side [44].

Atypical fibrovascular scar bands and hypertrophy of the greater trochanteric bursae have been reported in many cases of sciatic nerve entrapment [2, 3] (Fig. 8.14). In 27 of the 35 patients previously described by Martin et al., the greater trochanteric bursa was found to be excessively thickened, and large fibrovascular scar bands were present in many patients [2]. The fibrovascular bands extended from the posterior border of the greater trochanter to the gluteus maximus onto the sciatic nerve and then proximally to the greater sciatic notch [2]. The obturator internus/gemelli complex is commonly overlooked in association with sciatica-like pain [6, 7, 15]. As the sciatic nerve passes under the belly of the piriformis and over the superior gemelli-obturator internus, a scissor effect between the two muscles can be the source of entrapment. In one case, Martin et al. found the obturator internus penetrating the sciatic nerve.

The sciatic nerve courses close to the hamstrings origin at the most lateral aspect of the ischium tuberosity (Fig. 8.4). Avulsions of the hamstring tendons or congenital fibrotic bands can affect the sciatic nerve causing symptoms of entrapment [4, 5, 57–59]. Other sources of sciatic nerve entrapment within the deep gluteal space include malunion of the ischium or healed avulsions, greater trochanter ischium impingement (Fig. 8.14), tumor, sciatic nerve venous varicosities [9] (Fig. 8.15), and gluteus maximus (from a prior iliotibial band release). Intra-

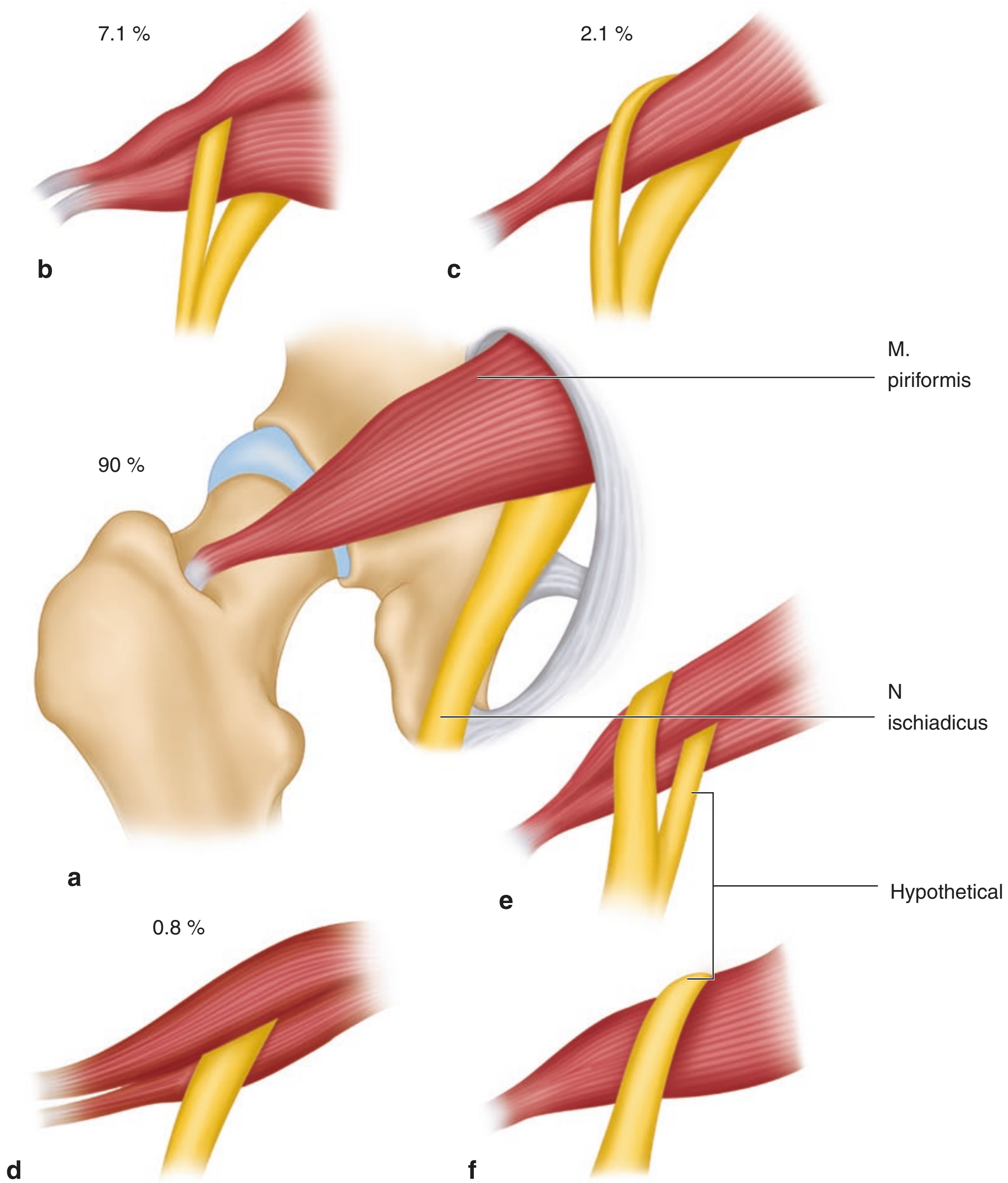


**Fig. 8.12** Schematic of piriformis-sciatic nerve variants. Six types of arrangement of the sciatic nerve, or of its subdivisions in relation to the piriformis muscle, arranged in the order of frequency [35]. Gluteal (external) view. The percentage incidence in 240 examples is indicated. Figures (**e**) and (**f**) were hypothetical in 1938 [35]. (**a**) Nerve undivided passes out of greater sciatic foramen, below piriformis muscle, (**b**) divisions of nerve pass through and below heads of muscle, (**c**) divisions above and below undivided muscle, (**d**) nerve undivided between the heads of muscle, (**e**) divisions of nerve between and above heads, and (**f**) undivided nerve above undivided muscle [35]

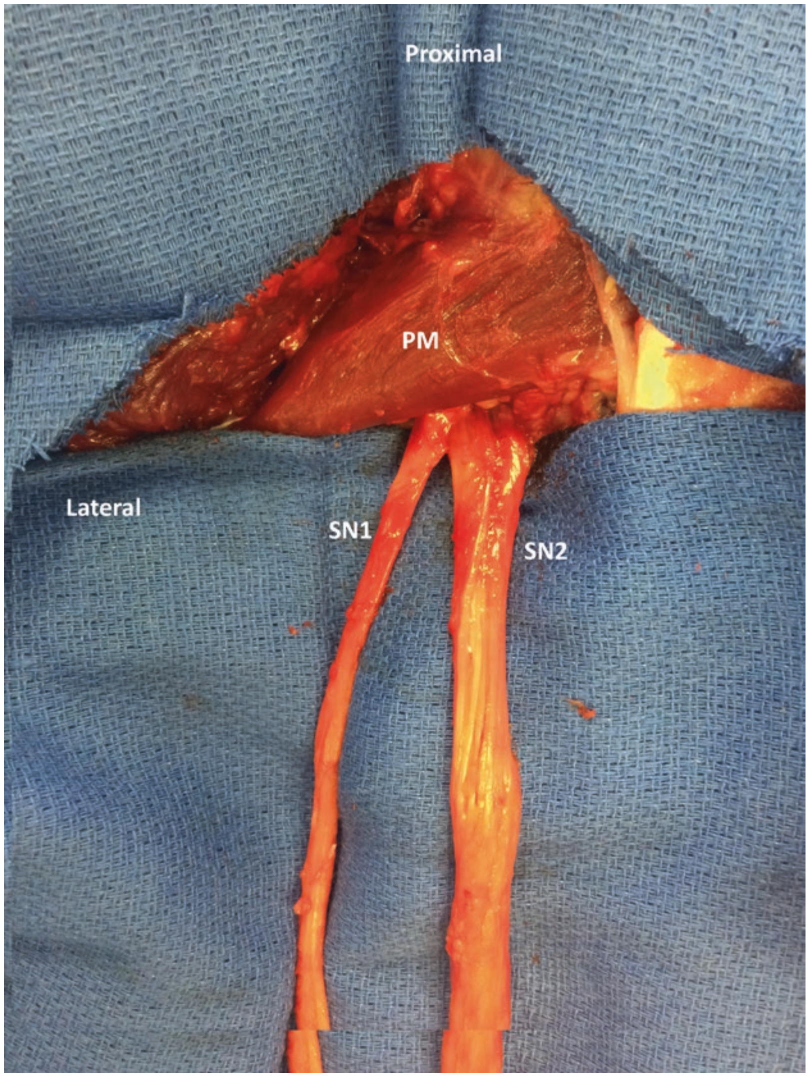


**Fig. 8.13** Posterior hip dissection in a 58 years-old male cadaver. Observe a bifid sciatic nerve (SN1 and SN2) running below the piriformis muscle (PM)

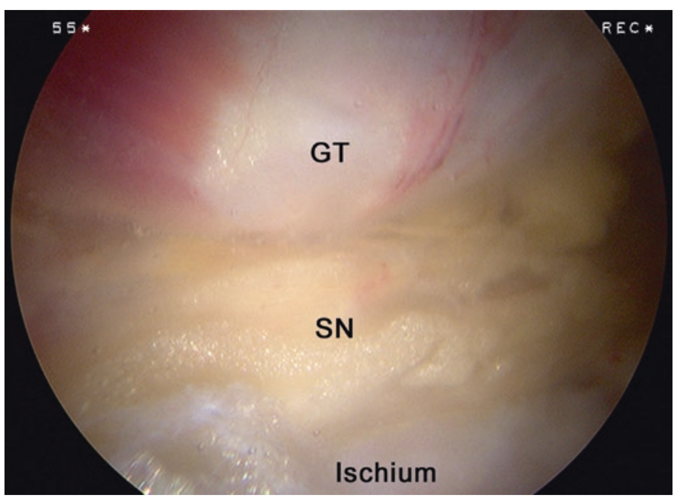


**Fig. 8.14** Endoscopic view of sciatic nerve (SN) compression between the greater trochanter (GT) and ischial tuberosity. With hip flexion and external rotation, the sciatic nerve was not able to move due to the ischial outgrowth of the bone

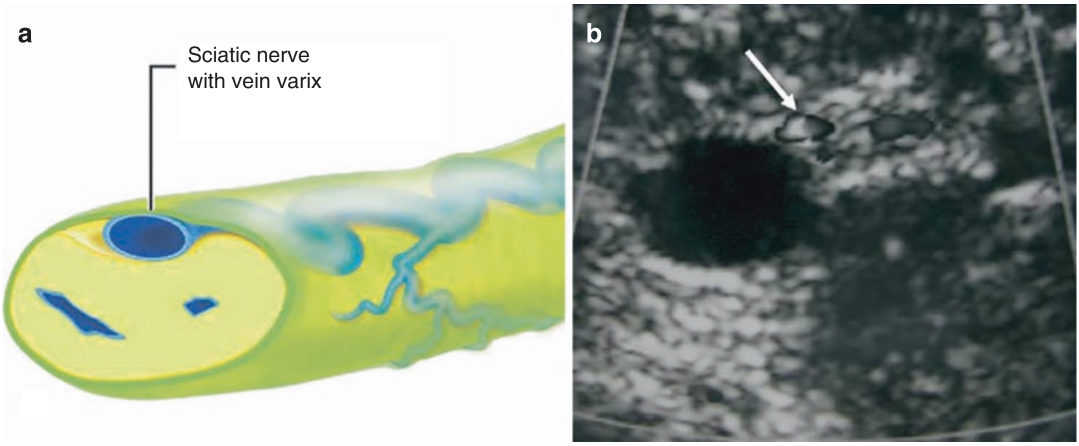


**Fig. 8.15** Varicose veins around the sciatic nerve. (**a**) Schematic drawing of varicose veins within the perineurium and the sciatic nerve. (**b**) Sciatic nerve at the midthigh with varicose veins within the nerve (arrow) in a patient who presented with pain and swelling. A larger refluxing vein is also seen in adhesion with the nerve. Reprinted with permission from Labropoulos et al. [9]

**Table 8.2** Entrapments of the sciatic nerve within the deep gluteal space in key publications

| | |
|---|---|
| Piriformis muscle | Martin et al. [2], Guvencer et al. [40], Papadopoulos and Kahn [55], Adams [43], Beauchesne and Schutzer [11], Benson and Schutzer [44], Chen [12], Dezawa et al. [45], Filler et al. [46], Hughes et al. [47], Mayrand et al. [48], Sayson et al. [49], Vandertop and Bosma [3], McCrory and Bell [1] |
| Hamstring muscles | Martin et al. [2]; Puranen and Orava [4], Young et al. [5] |
| Gemelli-obturator internus complex | Martin et al. [2]; Meknas et al. [7, 15], Cox and Bakkum [6] |
| Fibrous bands containing blood vessels | Martin et al. [2]; Adams [43], Vandertop and Bosma [3] |
| Ischial tuberosity | Miller et al. [8], Patti et al. (2008), Torriani et al. (2009) |
| Sciatic varicosities and vascular abnormalities | Martin et al. [2], Papadopoulos and Kahn [55], Hughes et al. [47], Papadopoulos et al. [10], Labropoulos et al. [9] |
| Gluteal muscles | Martin et al. [2]; McCrory and Bell [1] |
| Acetabular reconstruction surgery | Issack et al. [52] |
| Prolonged surgery in the seated position | Brown et al. [51] |
| After total hip replacement | Uchio et al. [53] |
| Secondary to space-occupying lesions intra-pelvic | Beauchesne and Schutzer [11], Chen [12] |
| Gynecologic and vascular abnormalities | Possover [13], Possover et al. [34] |

articular hip disorders may also be involved with sciatic nerve symptoms. Patients submitted to surgical treatment of femoroacetabular impingement often recovery hip mobility or can move the hip without having intra-articular pain. Considering that neural structures are sensitive to strain [39], increases in mobility can cause strain greater than habitual in the sciatic nerve, triggering the sciatic nerve entrapment symptoms in patients with variations in the piriformis-sciatic nerve relationship. This factor may be even more important in patients with capsular laxity and bone abnormal morphologies, as increased femoral version or retroversion.

The fibers of the sciatic nerve can be also entrapped in the lumbar spine, pelvis, and thigh. A discussion regarding intra-pelvic etiologies of sciatic nerve entrapment will be provided in the differential diagnoses section. Table 8.2 summarizes the etiologies of sciatic nerve entrapment reported in the main publications.

## Clinical Presentation and Ancillary Testing

### History and Physical Examination

A comprehensive physical examination, a detailed history, and standardized radiographic interpretation are paramount in evaluating hip pain [2, 60, 61]. When assessing posterior hip pain, the physical examination will allow for an assessment of osseous, capsular labral, musculotendinous, and neurovascular etiologies. Additionally, it is important to recognize the coexistence of many of these pathologies. The lumbar spine, abdominal, genitourinary problems are ruled out by history, physical examination, and ancillary testing. It is important to consider intra-pelvic causes of sciatic nerve entrapment, particularly in patients with previous gynecologic surgical procedures and menses-related pain [13, 34]. In all cases of suspected sciatic nerve entrapment, the spine must first be ruled out by MRI and history/physical examination.

Patients presenting with sciatic nerve entrapment often have a history of trauma and symptoms of sit pain (inability to sit for more than 30 min), radicular pain of the lower back or hip, and paresthesias of the affected leg [2, 44]. Patients may present with neurological symptoms of abnormal reflexes or motor weakness [55]. Some symptoms may mimic a hamstring tear or intra-articular hip pathology such as aching, burning sensation, or cramping in the buttock or posterior thigh. Symptoms of sit pain can also be caused by pudendal nerve entrapment, in which the pain is medial to the ischium and will be discussed later in this chapter. Upon palpation of the piriformis, Robinson described a tender sausage-shaped mass as a key feature of what he termed "piriformis syndrome" [42]. Physical examination tests that have been used for the clinical diagnosis of sciatic nerve entrapment include passive stretching tests and active contraction tests. The space between the piriformis and obturator internus muscles narrows with flexion, adduction, and internal rotation [40].

The seated piriformis stretch test (Fig. 8.16a) is a flexion, adduction with internal rotation test performed with the patient in the seated position [60]. The examiner extends the knee (engaging the sciatic nerve) and passively moves the flexed hip into adduction with internal rotation while palpating 1 cm lateral to the ischium (middle finger) and proximally at the sciatic notch (index finger). A positive test is the recreation of the posterior pain at the level of the piriformis or external rotators. An active piriformis test (Fig. 8.16b) is performed by the patient pushing the heel down into the table, abducting and externally rotating the leg against resistance, while the examiner monitors the piriformis. In a recent published study, the combination of the seated piriformis stretch test with the piriformis active test presented a sensitivity of 91% and specificity of 80% for the endoscopic finding of sciatic nerve entrapment [62].

The palpation of the gluteal structures is fundamental for the diagnosis of gluteal and sit pain. Patient is seated with the pelvis square to the examination table, and the ischial tuberosity (IT) serves as the reference point for palpation (Fig. 8.17a–c). Pain superolateral to the IT at the sciatic notch is characteristic of deep gluteal syndrome [2]; pain lateral to the IT, ischial tunnel syndrome or ischiofemoral impingement is considered; pain at the IT, hamstring tendon pathologies are possible; and pain medial to the IT, pudendal nerve entrapment is considered. An active knee flexion test against resistance, with 30° versus 90° of knee flexion, can help evaluate the proximal hamstring tendons [5].


**Fig. 8.16** (**a**) Seated piriformis stretch test. The patient is in the seated position with knee extension. The examiner passively moves the flexed hip into adduction with internal rotation while palpating 1 cm lateral to the ischium (middle finger) and proximally at the sciatic notch (index finger). (**b**) Active piriformis test. With the patient in the lateral position, the examiner palpates the piriformis. The patient drives the heel into the examining table thus initiating external hip rotation while actively abducting and externally rotating against resistance

Ischial tunnel syndrome or hamstring syndrome is described as pain in the lower buttock region that radiates down the posterior thigh to the popliteal fossa and is commonly associated with hamstring weakness [4]. This syndrome is related to sciatic nerve entrapment by scarring or a fibrotic band at the lateral insertion of the hamstring tendons to the ischial tuberosity [4, 5]. Patients experience pain with sitting, stretching, and with exercise, primarily running (sprinting and acceleration) [5, 63]. Palpable tenderness is located around the ischial tuberosity in the proximal hamstring region. Clinically, Young et al. reported that the straight leg raise test (Lasègue test) is slightly positive without neurological deficit. Marked weakness of the hamstring muscle at 30° knee flexion yet normal strength at 90° knee flexion is a suggestive finding in diagnosis [5].

Symptoms related to other nerves may be observed in cases of sciatic nerve entrapment, such as weakness of the gluteus medius and minimus muscles (superior gluteal nerve), weakness of the gluteus maximus (inferior gluteal nerve), perineal sensory loss (pudendal nerve) [64], or loss of posterior cutaneous sensation (posterior femoral cutaneous nerve) (Table 8.1) (Fig. 8.18).

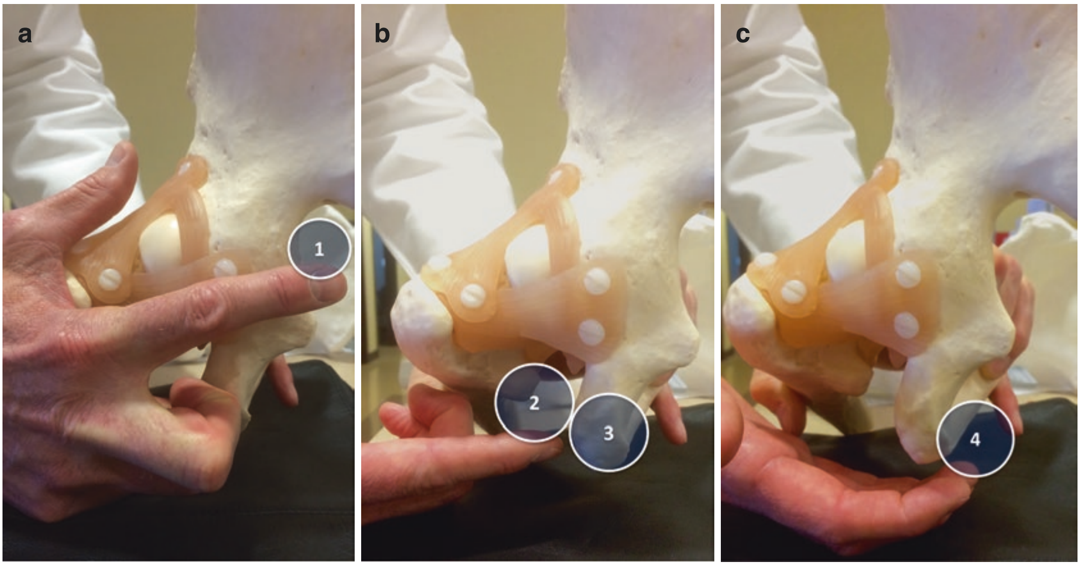


**Fig. 8.17** Palpation of the deep gluteal space. The examiner palpates the gluteal area using the ischial tuberosity (IT) as reference: (1) superolateral at the piriformis muscle/sciatic nerve (index finger); (2) moving the index finger to palpate lateral to the IT, ischiofemoral impingement and ischial tunnel syndrome; (3) at the IT, hamstring origin tendinopathy and avulsion (middle finger); (4) medial at the obturator internus/pudendal nerve (ring finger)

## Ancillary Testing

Guided injections are useful to support the diagnosis of DGS, mainly when the piriformis is involved. Computed tomography, fluoroscopy, ultrasonography, electroneuromyography, or magnetic resonance imaging is useful to obtain more precise injections [46]. The results and techniques for injections in deep gluteal space will be discussed in more detail in the treatment section. The association of physical examination and injection is also utilized to rule out intra-articular hip pathologies, nerve root compression at lumbar spine, and pudendal nerve entrapment.

Electromyography and nerve conduction studies may assist with the diagnosis of deep gluteal syndrome. Piriformis entrapment of the sciatic nerve is often indicated by H-reflex disturbances of the tibial and/or fibular nerves [65, 66]. It is important to compare side to side and perform a dynamic test with the knee in extension and hip in adduction with internal rotation. This position will tighten the piriformis muscle compressing the sciatic nerve sufficiently to disturb nerve conduction distally. Patients presenting with symptoms of sciatic nerve entrapment may fail to

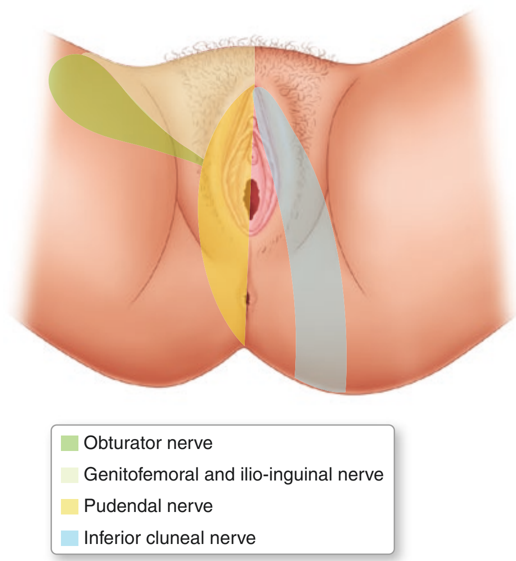


**Fig. 8.18** Sensory zones of the perineum in female. The sensitive innervation territory is marked according to the nerve. The dotted area represents the obturator nerve territory. The vertical lines represent the genitofemoral and ilioinguinal nerves. The oblique lines represent the pudendal nerve. The crossed lines denote the inferior cluneal nerve innervation. Although the figure illustrates well-defined areas of innervation, it is important to remember that an overlap in dermatomes is frequent [64]

exhibit paraspinal denervation even when radiculopathy coexists [65]. Although electrodiagnostic assessment can be useful when associated with adequate physical examination and injection tests, obesity, edema, and age can impair the acquisition of sensory nerve action potentials in the lower limb, principally for the proximally located nerves [67]. Moreover, asymptomatic patients (usually elderly) often present neurogenic changes in electrodiagnostic studies [67]. These features may be problematic for the differential diagnosis between lumbosacral and peripheral entrapment [67].

Magnetic resonance imaging (MRI) is the most useful imaging method for evaluation of sciatic nerve entrapment. The sciatic nerve anatomy and potential sources of compression can be assessed through this imaging method, including anomalies of the piriformis muscle, scar from proximal hamstring avulsion, osseous compression, and intra-pelvic abnormalities (Fig. 8.19). The MRI is also helpful in detecting direct and indirect signs of nerve injury [68].

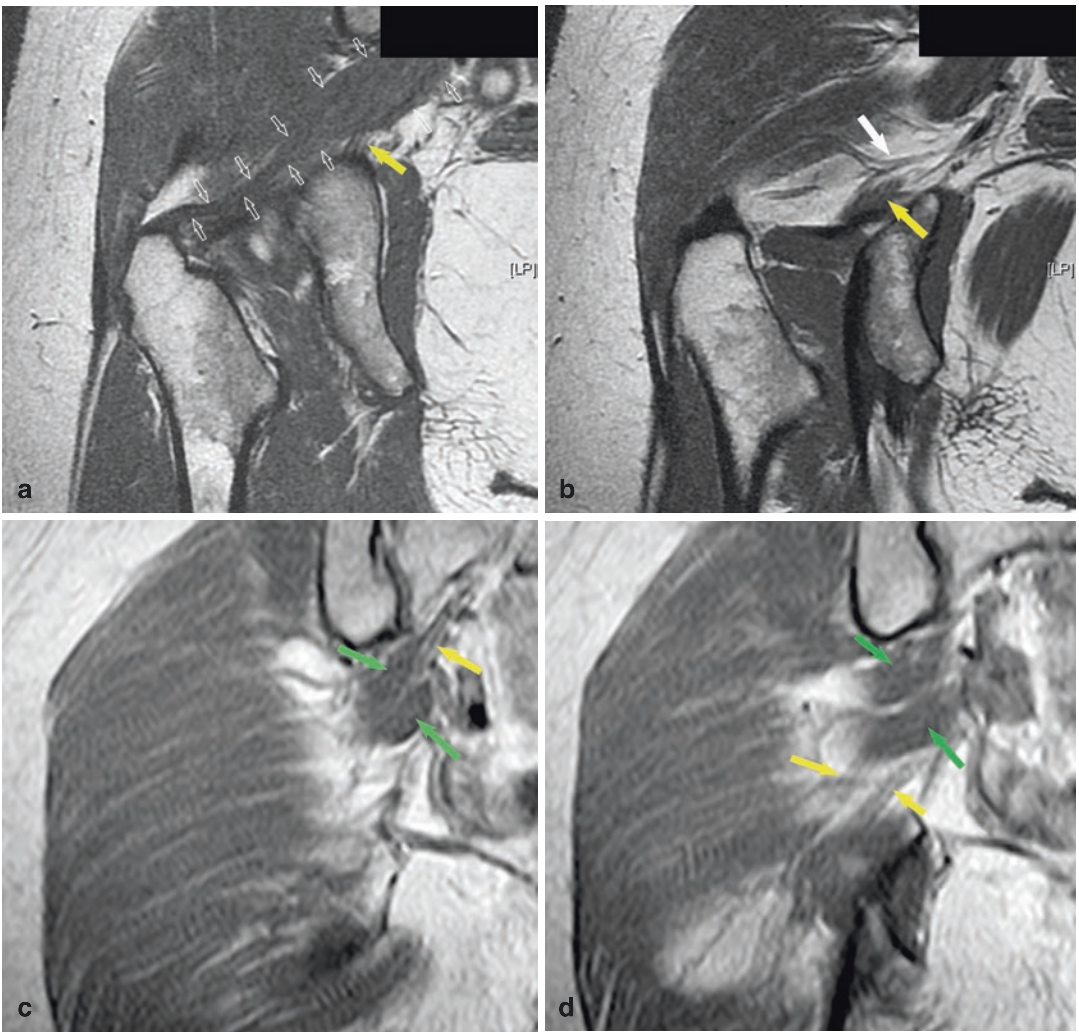


**Fig. 8.19** Magnetic resonance images of deep gluteal space, coronal view of the right hip. (**a**) Normal relationship between the piriformis muscle (open arrows) and the sciatic nerve (yellow arrow). (**b**) More posterior cut of the same hip demonstrating the inferior gluteal artery (white arrow) leaving the sciatic notch close to the sciatic nerve (yellow arrow). (**c**) and (**d**) Variation of the sciatic nerve/piriformis relationship in a patient with deep gluteal syndrome. The superior division of the sciatic nerve (yellow arrow in **c**) is demonstrated crossing between the two piriformis muscle portions (green arrows)

**Table 8.3** Main differential diagnosis of deep gluteal syndrome

| Diagnosis | History | Physical examination | Ancillary tests |
|---|---|---|---|
| Pudendal nerve entrapment | Pain in the anatomical territory of the pudendal nerve, worsened by sitting, does not wake the patient at night<br>Numbness | Tenderness at the medial ischium | Injection guided by imaging<br>Intra-pelvic tests |
| Ischiofemoral impingement | Sciatic nerve complaints<br>Lower back pain<br>Limping | Long-stride walking reproduces the pain during terminal hip extension<br>Tenderness at the lateral ischium<br>Positive ischiofemoral impingement test | MRI showing decreased ischiofemoral and quadratus femoris space and quadratus femoris muscle edema |
| Greater trochanter ischial impingement | Sciatic nerve complaints<br>Laxity?<br>Limping | Tenderness at posterior aspect of the greater trochanter<br>Pain in deep flexion, abduction, and external rotation | Injection guided by imaging |
| Ischial tunnel syndrome | Sciatic nerve complaints<br>Limping<br>Pain increased by flexion of the hip and extension of the knee | Tenderness at lateral ischium<br>Positive hamstring active test | Injection guided by imaging<br>MRI showing hamstring origin avulsion with edema around the sciatic nerve |

Hyperintensity on fluid-sensitive images that is focal or similar to that of adjacent vessels is more likely to be significant [68]. However, hyperintensity in peripheral nerves may be seen in normal nerves due to the artifact known as magic angle effect [69]. Abnormalities in nerve size, fascicular pattern, or blurring of the perineural fat tissue are suggestive of neural injury, although those features are difficult to be noted in small diameter nerves [68]. The main indirect sign of nerve entrapment injury is the muscular denervation edema [70]. In addition to sciatic nerve compression assessment, the MRI is important to rule out spine issues, intra-articular hip pathology, and other differential diagnoses. Despite the usefulness of MRI in the diagnosis of deep gluteal pain, the potential false-positive and false-negative results reinforce the importance of a proficient physical examination. Ultrasonography is a valuable method to guide nerve blocks and has been increasingly utilized for nerve assessment, with the advantages of dynamic evaluation and Doppler assessment of the vascular nerve supply [9].

The differential diagnosis of sciatic nerve entrapment is established through the combination of physical examination, imaging studies, and piriformis injection test (Table 8.3).

## Treatment

### Nonoperative Treatment

The nonoperative treatment for deep gluteal syndrome begins addressing the suspected site of entrapment. Compression from a hypertrophied, contracted, or inflamed muscle (piriformis, quadratus femoris, obturator internus, superior/inferior gemellus) is initially treated with rest, anti-inflammatories, muscle relaxants, and physical therapy. The physical therapy program should include stretching maneuvers aimed at the external rotators. The piriformis stretch, or FAIR, involves placing the hip in flexion, adduction, and internal rotation (Fig. 8.20a). Patients with CAM impingement, anterior pincer impingement, or acetabular retroversion may not be able to stretch adequately into this position and should be evaluated and treated primarily for the intra-articular pathology, as most will resolve with appropriate surgical intervention. In a seated position, the patient brings the knee into the


**Fig. 8.20** Piriformis stretch, sciatic nerve glides, and hip circumduction. (**a**) The piriformis stretch is performed in a seated position. The patient brings the knee toward the opposite shoulder. (**b**) For the sciatic nerve glides, the patient first performs cervical extension and plantar flexion of the ankle, (**c**) followed by cervical flexion with ankle dorsiflexion. (**d**) Circumduction performed in supine position with gentle circular passive movements in the following sequence: abduction, external rotation, flexion, internal rotation, extension

chest and across midline and pulls the knee to the opposite shoulder during 20 s. Gradually progress the stretching by increasing duration and intensity until a maximal stretch is obtained. Sciatic nerve glides and hip circumduction exercises are useful to maintain the sciatic nerve excursion and should be gently performed (Fig. 8.20b–d). Additional physical therapy techniques that may be helpful include ultrasound and electrical stimulation. Patients with more intense or acute symptoms may not tolerate positions of hip flexion associated with knee extension. In this situation, a knee brace to avoid knee extension and maintain the sciatic nerve without tension may be helpful for some patients. The brace is adjusted according to the straight leg raise test, and gradual extension of the knee is performed toward full extension during 4–6 weeks.

Guided injections of anesthetic or corticosteroid into the piriformis muscle can provide pain relief in patients not responding to physical therapy. It is important to administer the injection to the correct site, and different techniques can be utilized for guidance, including fluoroscopy, CT, ultrasound, electromyography, and MRI. A trial of three injections has been recommended before opting for more aggressive therapy, taken on a case by case basis [46, 55, 71]. The literature has reported variable results for piriformis injection [46, 72, 73]. Pace and Nagle reported a double-injection technique of Kenalog and Xylocaine toward the piriformis muscle which relieved the pain in 41 out of 45 patients [73]. Filler et al. reported lasting pain relief in 37 out of 162 patients following 1 or 2 injections of Marcaine and Celestone [46]. The piriformis muscle may be also injected with botulinum toxin [54]. Another alternative is the perisciatic nerve injection of anesthetic and corticosteroid instead of the intra-piriformis muscle [74]. Most cases of deep gluteal syndrome/sciatic nerve entrapment will respond to nonoperative measures.

## Operative Treatment

As a general guideline, only patients who have failed conservative measures are considered for operative treatment. The type of surgical procedure depends on the clinical and imaging diagnosis. The response to targeted injections is helpful to predict the treatment success.

Effective open and endoscopic techniques have been described for a number of posterior hip pathologies including sciatic nerve decompression (Fig. 8.13). Innovative surgical techniques as car-

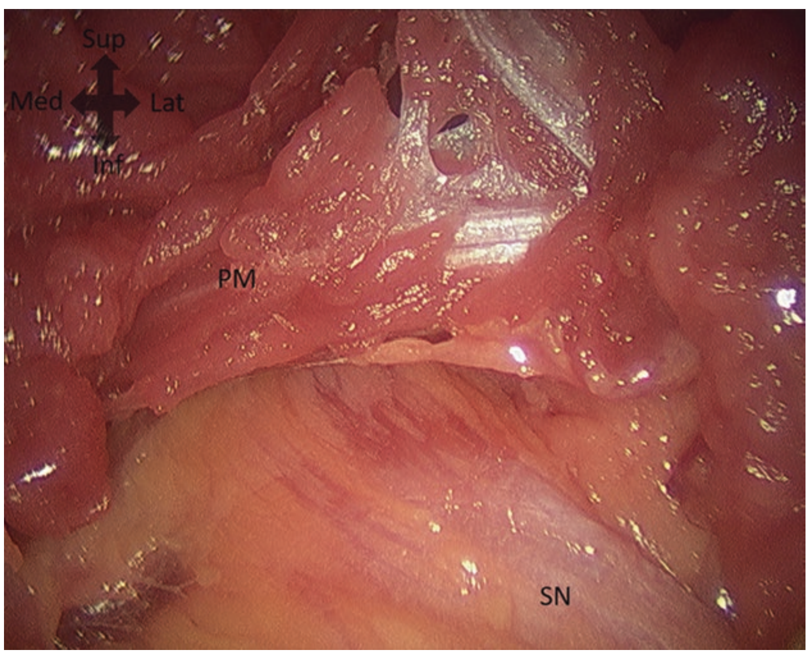


**Fig. 8.21** Deep gluteal space exploration by using carbon dioxide ($CO_2$) gas as an insufflation medium. *PM* piriformis muscle, *SN* sciatic nerve

bon dioxide gas insufflation as a medium for deep gluteal endoscopy are being developed in order to simplify the technical aspects of the procedure while decreasing complications (Fig. 8.21).

A comprehensive and illustrative description of both open and endoscopic techniques for treating deep gluteal syndrome is presented in this book describing surgical approaches to the posterior hip.

## References


1. McCrory P, Bell S. Nerve entrapment syndromes as a cause of pain in the hip, groin and buttock. Sports Med. 1999;27:261–74.
2. Martin HD, Shears SA, Johnson JC, Smathers AM, Palmer IJ. The endoscopic treatment of sciatic nerve entrapment/deep gluteal syndrome. Arthroscopy. 2011;27:172–81.
3. Vandertop WP, Bosma NJ. The piriformis syndrome. A case report. J Bone Joint Surg Am. 1991;73:1095–7.
4. Puranen J, Orava S. The hamstring syndrome. A new diagnosis of gluteal sciatic pain. Am J Sports Med. 1988;16:517–21.
5. Young IJ, van Riet RP, Bell SN. Surgical release for proximal hamstring syndrome. Am J Sports Med. 2008;36:2372–8.
6. Cox JM, Bakkum BW. Possible generators of retrotrochanteric gluteal and thigh pain: the gemelli-obturator internus complex. J Manip Physiol Ther. 2005;28:534–8.
7. Meknas K, Kartus J, Letto JI, Christensen A, Johansen O. Surgical release of the internal obturator tendon for the treatment of retro-trochanteric pain syndrome: a prospective randomized study, with long-term follow-up. Knee Surg Sports Traumatol Arthrosc. 2009;17:1249–56.
8. Miller A, Stedman GH, Beisaw NE, Gross PT. Sciatica caused by an avulsion fracture of the ischial tuberosity. A case report. J Bone Joint Surg Am. 1987;69:143–5.
9. Labropoulos N, Tassiopoulos AK, Gasparis AP, Phillips B, Pappas PJ. Veins along the course of the sciatic nerve. J Vasc Surg. 2009;49:690–6.
10. Papadopoulos SM, McGillicuddy JE, Albers JW. Unusual cause of 'piriformis muscle syndrome'. Arch Neurol. 1990;47:1144–6.
11. Beauchesne RP, Schutzer SF. Myositis ossificans of the piriformis muscle: an unusual cause of piriformis syndrome. A case report. J Bone Joint Surg Am. 1997;79:906–10.
12. Chen WS. Sciatica due to piriformis pyomyositis. Report of a case. J Bone Joint Surg Am. 1992;74:1546–8.
13. Possover M. Laparoscopic management of endopelvic etiologies of pudendal pain in 134 consecutive patients. J Urol. 2009;181:1732–6.
14. Loukas M, Louis RG Jr, Hallner B, Gupta AA, White D. Anatomical and surgical considerations of the sacrotuberous ligament and its relevance in pudendal nerve entrapment syndrome. Surg Radiol Anat. 2006;28:163–9.
15. Meknas K, Christensen A, Johansen O. The internal obturator muscle may cause sciatic pain. Pain. 2003;104:375–80.
16. Solomon LB, Lee YC, Callary SA, Beck M, Howie DW. Anatomy of piriformis, obturator internus and obturator externus: implications for the posterior surgical approach to the hip. J Bone Joint Surg Br. 2010;92:1317–24.
17. Standring S. Grays anatomy the anatomical basis of clinical practice. London: Elsevier; 2008.
18. Miller SL, Gill J, Webb GR. The proximal origin of the hamstrings and surrounding anatomy encountered during repair. A cadaveric study. J Bone Joint Surg Am. 2007;89:44–8.
19. Filler AG. Diagnosis and treatment of pudendal nerve entrapment syndrome subtypes: imaging, injections, and minimal access surgery. Neurosurg Focus. 2009;26:E9.
20. Moore K, Dalley A. Essential clinical anatomy. Philadelphia: Lippincott Williams and Wilkins; 1999.
21. Windhofer C, Brenner E, Moriggl B, Papp C. Relationship between the descending branch of the inferior gluteal artery and the posterior femoral cutaneous nerve applicable to flap surgery. Surg Radiol Anat. 2002;24:253–7.
22. Kalhor M, Beck M, Huff TW, Ganz R. Capsular and pericapsular contributions to acetabular and femoral head perfusion. J Bone Joint Surg Am. 2009;91:409–18.
23. Gautier E, Ganz K, Krugel N, Gill T, Ganz R. Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg Br. 2000;82:679–83.
24. Sunderland S, Hughes ES. Metrical and non-metrical features of the muscular branches of the sciatic nerve and its medial and lateral popliteal divisions. J Comp Neurol. 1946;85:205–22.
25. Sunderland S, Ray LJ. The intraneural topography of the sciatic nerve and its popliteal divisions in man. Brain. 1948;71:242–73.
26. Seidel PM, Seidel GK, Gans BM, Dijkers M. Precise localization of the motor nerve branches to the hamstring muscles: an aid to the conduct of neurolytic procedures. Arch Phys Med Rehabil. 1996;77:1157–60.
27. Moayeri N, Groen GJ. Differences in quantitative architecture of sciatic nerve may explain differences in potential vulnerability to nerve injury, onset time, and minimum effective anesthetic volume. Anesthesiology. 2009;111:1128–34.
28. Sladjana UZ, Ivan JD, Bratislav SD. Microanatomical structure of the human sciatic nerve. Surg Radiol Anat. 2008;30:619–26.
29. Georgakis E, Soames R. Arterial supply to the sciatic nerve in the gluteal region. Clin Anat. 2008;21:62–5.

30. Karmanska W, Mikusek J, Karmanski A. Nutrient arteries of the human sciatic nerve. Folia Morphol (Warsz). 1993;52:209–15.
31. Ugrenovic SZ, Jovanovic ID, Vasovic LP, Stefanovic BD. Extraneural arterial blood vessels of human fetal sciatic nerve. Cells Tissues Organs. 2007;186:147–53.
32. Del Pinal F, Taylor GI. The venous drainage of nerves; anatomical study and clinical implications. Br J Plast Surg. 1990;43:511–20.
33. Testut L, Latarjet A. Traite d'anatomie humaine. Paris: G. Doin & Cie; 1949.
34. Possover M, Schneider T, Henle KP. Laparoscopic therapy for endometriosis and vascular entrapment of sacral plexus. Fertil Steril. 2011;95:756–8.
35. Beaton L, Anson B. The sciatic nerve and the piriformis muscle: their interrelation and possible cause of coccygodynia. J Bone Joint Surg Am. 1938;20:686–8.
36. Smoll NR. Variations of the piriformis and sciatic nerve with clinical consequence: a review. Clin Anat. 2010;23:8–17.
37. Coppieters MW, Alshami AM, Babri AS, Souvlis T, Kippers V, Hodges PW. Strain and excursion of the sciatic, tibial, and plantar nerves during a modified straight leg raising test. J Orthop Res. 2006;24:1883–9.
38. Fleming P, Lenehan B, O'Rourke S, McHugh P, Kaar K, McCabe JP. Strain on the human sciatic nerve in vivo during movement of the hip and knee. J Bone Joint Surg Br. 2003;85:363–5.
39. Wall EJ, Massie JB, Kwan MK, Rydevik BL, Myers RR, Garfin SR. Experimental stretch neuropathy. Changes in nerve conduction under tension. J Bone Joint Surg Br. 1992;74:126–9.
40. Guvencer M, Akyer P, Iyem C, Tetik S, Naderi S. Anatomic considerations and the relationship between the piriformis muscle and the sciatic nerve. Surg Radiol Anat. 2008;30:467–74.
41. Yeoman W. The relation of arthritis of the sacro-iliac joint to sciatica, with an analysis of 100 cases. Lancet. 1928;2:1119–22.
42. Robinson DR. Pyriformis syndrome in relation to sciatic pain. Am J Surg. 1947;73:355–8.
43. Adams JA. The pyriformis syndrome – report of four cases and review of the literature. S Afr J Surg. 1980;18:13–8.
44. Benson ER, Schutzer SF. Posttraumatic piriformis syndrome: diagnosis and results of operative treatment. J Bone Joint Surg Am. 1999;81:941–9.
45. Dezawa A, Kusano S, Miki H. Arthroscopic release of the piriformis muscle under local anesthesia for piriformis syndrome. Arthroscopy. 2003;19:554–7.
46. Filler AG, Haynes J, Jordan SE, Prager J, Villablanca JP, Farahani K, McBride DQ, Tsuruda JS, Morisoli B, Batzdorf U, Johnson JP. Sciatica of nondisc origin and piriformis syndrome: diagnosis by magnetic resonance neurography and interventional magnetic resonance imaging with outcome study of resulting treatment. J Neurosurg Spine. 2005;2:99–115.
47. Hughes SS, Goldstein MN, Hicks DG, Pellegrini VD Jr. Extrapelvic compression of the sciatic nerve. An unusual cause of pain about the hip: report of five cases. J Bone Joint Surg Am. 1992;74:1553–9.
48. Mayrand N, Fortin J, Descarreaux M, Normand MC. Diagnosis and management of posttraumatic piriformis syndrome: a case study. J Manip Physiol Ther. 2006;29:486–91.
49. Sayson SC, Ducey JP, Maybrey JB, Wesley RL, Vermilion D. Sciatic entrapment neuropathy associated with an anomalous piriformis muscle. Pain. 1994;59:149–52.
50. Bano A, Karantanas A, Pasku D, Datseris G, Tzanakakis G, Katonis P. Persistent sciatica induced by quadratus femoris muscle tear and treated by surgical decompression: a case report. J Med Case Rep. 2010;4:236.
51. Brown JA, Braun MA, Namey TC. Pyriformis syndrome in a 10-year-old boy as a complication of operation with the patient in the sitting position. Neurosurgery. 1988;23:117–9.
52. Issack PS, Kreshak J, Klinger CE, Toro JB, Buly RL, Helfet DL. Sciatic nerve release following fracture or reconstructive surgery of the acetabulum. Surgical technique. J Bone Joint Surg Am. 2008;90(Suppl 2 Pt 2):227–37.
53. Uchio Y, Nishikawa U, Ochi M, Shu N, Takata K. Bilateral piriformis syndrome after total hip arthroplasty. Arch Orthop Trauma Surg. 1998;117:177–9.
54. Porta M. A comparative trial of botulinum toxin type A and methylprednisolone for the treatment of myofascial pain syndrome and pain from chronic muscle spasm. Pain. 2000;85:101–5.
55. Papadopoulos EC, Khan SN. Piriformis syndrome and low back pain: a new classification and review of the literature. Orthop Clin North Am. 2004;35:65–71.
56. Filler AG. Piriformis and related entrapment syndromes: diagnosis & management. Neurosurg Clin N Am. 2008;19:609–622, vii.
57. Chakravarthy J, Ramisetty N, Pimpalnerkar A, Mohtadi N. Surgical repair of complete proximal hamstring tendon ruptures in water skiers and bull riders: a report of four cases and review of the literature. Br J Sports Med. 2005;39:569–72.
58. Orava S. Hamstring syndrome. Oper Tech Sports Med. 1997;5:143–9.
59. Wood DG, Packham I, Trikha SP, Linklater J. Avulsion of the proximal hamstring origin. J Bone Joint Surg Am. 2008;90:2365–74.
60. Martin H. Clinical examination and imaging of the hip. In: Byrd J, Guanche C, editors. AANA advanced arthroscopy: the hip. Philadelphia: Saunders; 2010.
61. Martin HD, Kelly BT, Leunig M, Philippon MJ, Clohisy JC, Martin RL, Sekiya JK, Pietrobon R, Mohtadi NG, Sampson TG, Safran MR. The pattern and technique in the clinical evaluation of the adult hip: the common physical examination tests of hip specialists. Arthroscopy. 2010;26:161–72.

62. Martin HD, Kivlan BR, Palmer IJ, Martin RL, Hatem M. Diagnostic accuray of clinical tests for sciatic nerve entrapent in the gluteal region. Knee Surg Sports Traumatol Arthrosc. 2013;22(4):882–8.
63. Migliorini S, Merlo M. The hamstring syndrome in endurance athletes. Br J Sports Med. 2011;45:363.
64. Labat JJ, Riant T, Robert R, Amarenco G, Lefaucheur JP, Rigaud J. Diagnostic criteria for pudendal neuralgia by pudendal nerve entrapment (Nantes criteria). Neurourol Urodyn. 2008;27:306–10.
65. Fishman LM, Wilkins AN. Piriformis syndrome: electrophysiology vs. anatomical assumption. In: Fishman LM, Wilkins AN, editors. Functional electromyography. New York: Springer; 2011.
66. Jawish RM, Assoum HA, Khamis CF. Anatomical, clinical and electrical observations in piriformis syndrome. J Orthop Surg Res. 2010;5:3.
67. Katirji B. Electrodiagnostic approach to the patient with suspected mononeuropathy of the lower extremity. Neurol Clin. 2002;20:479–501, vii.
68. Petchprapa CN, Rosenberg ZS, Sconfienza LM, Cavalcanti CF, Vieira RL, Zember JS. MR imaging of entrapment neuropathies of the lower extremity. Part 1. The pelvis and hip. Radiographics. 2010;30:983–1000.
69. Chappell KE, Robson MD, Stonebridge-Foster A, Glover A, Allsop JM, Williams AD, Herlihy AH, Moss J, Gishen P, Bydder GM. Magic angle effects in MR neurography. AJNR Am J Neuroradiol. 2004;25:431–40.
70. Kim SJ, Hong SH, Jun WS, Choi JY, Myung JS, Jacobson JA, Lee JW, Choi JA, Kang HS. MR imaging mapping of skeletal muscle denervation in entrapment and compressive neuropathies. Radiographics. 2011;31:319–32.
71. Barton PM. Piriformis syndrome: a rational approach to management. Pain. 1991;47:345–52.
72. Benzon HT, Katz JA, Benzon HA, Iqbal MS. Piriformis syndrome: anatomic considerations, a new injection technique, and a review of the literature. Anesthesiology. 2003;98:1442–8.
73. Pace JB, Nagle D. Piriform syndrome. West J Med. 1976;124:435–9.
74. Hanania M, Kitain E. Perisciatic injection of steroid for the treatment of sciatica due to piriformis syndrome. Reg Anesth Pain Med. 1998;23:223–8.