Clinical Radiology xxx (xxxx) xxx

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Pictorial review

Imaging of peripheral nerve causes of chronic buttock pain and sciatica

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ARTICLE INFORMATION

Article history:
Received 6 October 2020
Received in revised form
23 January 2021
Accepted 17 February 2021

Chronic buttock pain is a common and debilitating symptom, which severely impacts daily activities, sleep, and may affect athletic performance. Lumbar spine, posterior hip, or hamstring pathology are usually considered as the primary diagnoses; however, pelvic neural pathology may be a significant cause of chronic buttock pain, particularly if there are prolonged (>6 months) buttock and/or radicular symptoms. The subgluteal space is the site of most pelvic causes of neural-mediated buttock pain, primarily relating to entrapment neuropathy of the sciatic nerve (deep gluteal syndrome), although other nerves within the subgluteal space including the gluteal nerves, pudendal nerve, and posterior cutaneous nerve of thigh may also be involved. Additionally, cluneal nerve entrapment at the iliac crest may result in "pseudo-sciatica". Anatomical variants of the pelvic girdle muscles and functional factors, including muscle spasm and pelvic instability, may contribute to development of deep gluteal syndrome, along with neural senescence. Imaging findings primarily relate to the presence of sciatic neuritis and peri-sciatic pathology, including neural compression and peri-neural adhesions or fibrosis. This imaging review describes the causes, magnetic resonance imaging and ultrasound imaging findings and imaging-guided treatment of pelvic neural causes of chronic buttock pain and sciatica.

Introduction

Chronic buttock pain is a debilitating symptom, which severely impacts daily activities and sleep and may affect performance in athletes. Its prevalence is unknown; however, piriformis syndrome, a common cause of buttock pain, may be seen in up to 6% of patients with back and/or sciatica pain.[1]

Although posterior hip or hamstring pathology are often considered as the primary diagnosis, neural pathology may be a significant cause of chronic buttock pain, particularly if there are co-existing radicular symptoms or back pain. In these cases, lumbar disc herniation is usually considered to be the cause of symptoms; however, if lumbar spine pathology has been excluded, pelvic causes of neural pain should be considered, especially if symptoms are present

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https://doi.org/10.1016/j.crad.2021.03.005

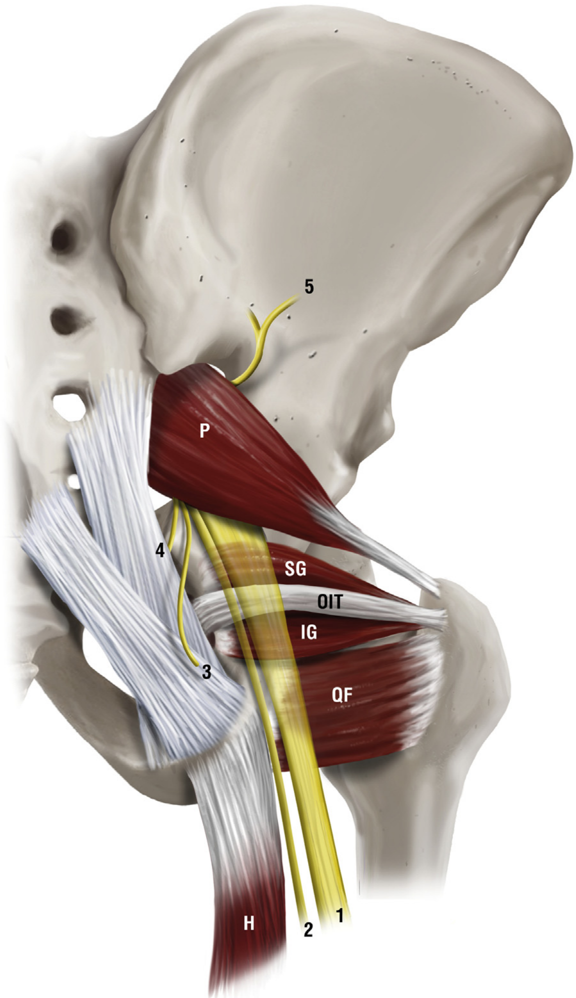

Figure 1 Anatomy of the subgluteal space. Diagram of the deep muscles of the subgluteal space, with the gluteus maximus muscle removed. The sciatic nerve (1) typically emerges from beneath piriformis muscle (P), passing over the obturator internus–gemellus tendon and muscle complex, quadratus femoris (QF) muscle and lateral to the hamstring origin (H). Note that the gemellus muscles lie superior (SG) and inferior (IG) to the obturator internus tendon within the subgluteal space; the obturator internus muscle belly lies deep to the subgluteal space within the pelvis (not drawn). Medial to the sciatic nerve lies the PCNT (2). The inferior gluteal nerve (3) and pudendal nerve (4) emerge from below piriformis further medially within the subgluteal space. The superior gluteal nerve (5) is seen superiorly within the subgluteal space, passing superior to the piriformis muscle and adjacent to the SI joint.

for ≥6 months, when symptoms from an acute disc lesion should typically have resolved.

Along with neural features, such as sharp or shooting pain and pins and needles in the buttock and/or leg, patients with pelvic neural causes of pain may complain of sitting or walking pain and nocturnal pain, with sitting pain being particularly common.[1–3] An antalgic sitting posture and neural sensitisation lateral to the ischial tuberosity may be seen at examination.[2,3]

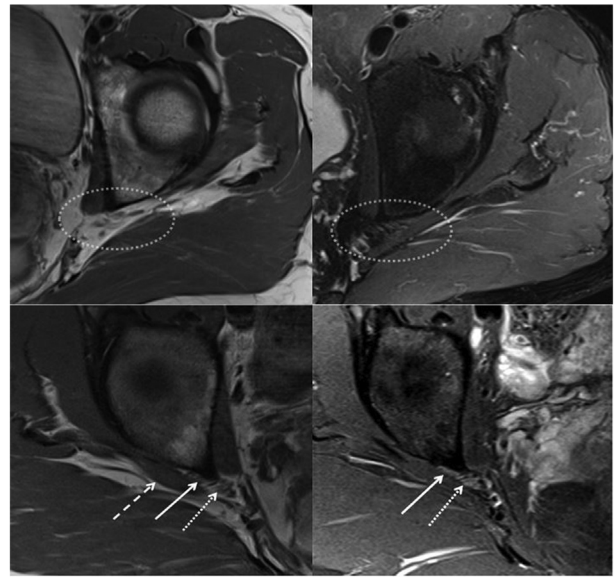

Figure 2 MRI of normal sciatic nerve and sciatic neuritis. Axial PD and T2 FS images of the sciatic nerve within the subgluteal space. Normal sciatic nerve (above) fascicles appear as short lines or dots on axial images and are iso-intense to muscle on T1 imaging and mildly hyperintense to muscle on T2 imaging (dashed circles). Intraneural fat separates fascicles and there is preservation of perineural fat planes. With sciatic neuritis (below) there is increased neural fascicular T2 signal, closer to that of adjacent vessels. With compression or scarring of the sciatic nerve, loss of intra-neural and perineural fat planes may be seen, as in this case where the lower piriformis muscle belly in a type A piriformis MTJ (dashed arrow) compresses the sciatic nerve. (See Fig 4a) Note effacement of intra- and perineural fat planes involving the peroneal nerve (arrow) more than the tibial nerve (dotted arrow).

Anatomical considerations

The subgluteal space is the site of most of the pelvic causes of neural-mediated buttock pain and has been well described in the recent imaging and surgical literature.[2,3] It is enclosed by the middle and deep gluteal aponeuroses, extending from the greater sciatic notch to the lower border of gluteus maximus. These aponeuroses fuse laterally, joining the tensor fascia lata and iliotibial tract superiorly and linea aspera inferiorly. Medial borders include the sacrum, ischial tuberosity/hamstring tendons and ligaments that form the greater and lesser sciatic foramen. Posteriorly it is bound by gluteus maximus, whilst anteriorly there is a “floor” of muscles formed by piriformis, obturator internus tendon and gemelli, and quadratus femoris as well as the hamstring origin and femoral neck[2,3] (Fig 1).

Along with the sciatic nerve, several smaller nerves pass through the subgluteal space, including the gluteal nerves, pudendal nerve, and posterior cutaneous nerve of thigh. Sciatic nerve entrapment in relation to any of the above structures reduces neural glide within the subgluteal space and may trigger the onset of buttock pain and sciatica. Additionally, a number of anatomical variants in relation to

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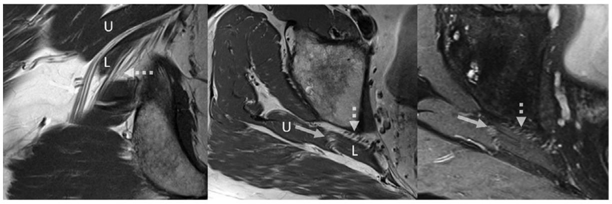

Figure 3 Beaton type II variant in a patient with chronic right buttock, thigh and calf pain. Coronal T1 (left), Axial PD (middle) and Axial T2 FS (right) images show a split sciatic nerve passing through the piriformis muscle with the peroneal nerve (white arrow) dividing the muscle into upper (U) and lower (L) muscle bellies. (See Fig 4b.) There is effacement of intra-neural fat and neural fascicular oedema of the peroneal nerve compared to the tibial nerve (dashed arrow).

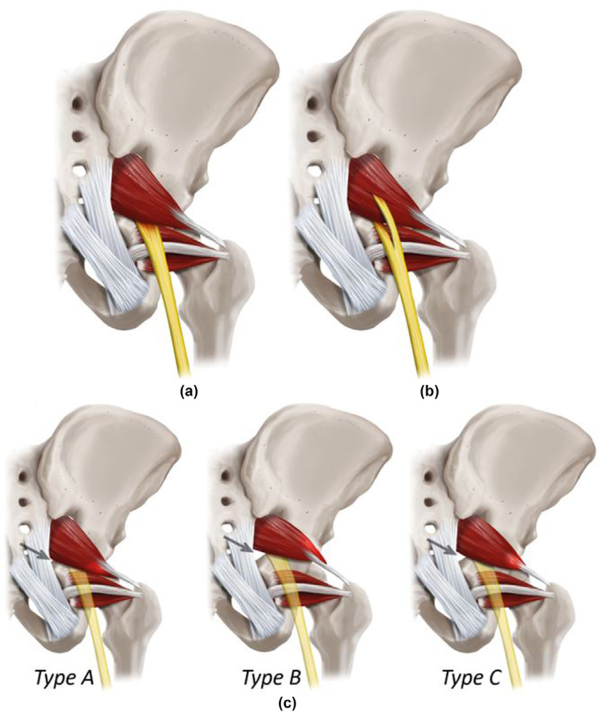

Figure 4 Diagrams showing the common causes and anatomical variants of deep gluteal syndrome. (a) Inflamed and enlarged (compared with Fig 1) piriformis muscle and sciatic nerve and (b) Beaton type II morphology with inflamed sciatic nerve resulting in piriformis syndrome. (c) Three variants of the piriformis musculotendinous junction (MTJ; red highlights) described by Windisch *et al.* Type A MTJs, seen in 70% of cadavers, have a larger lower muscle belly attaching closer to the tendon insertion than the upper belly. Type B MTJs, seen in 20%, have an upper muscle belly that attaches closer to the tendon insertion than the lower belly. In type C MTJs, seen in 10%, the upper and lower piriformis muscle belly MTJs attach at the same distance from the insertion. In the type A MTJ configuration, the lower piriformis muscle belly results in reduction in the infrapiriform fossa compared to the other types B and C, with potential for dynamic sciatic nerve entrapment, especially if piriformis muscle hypertrophy or SI joint counternutation are present.

piriformis and the other short hip rotators described by Beaton and Windisch may compromise the sciatic nerve at piriformis level.[4,5] Finally, at the posterior iliac crest, three

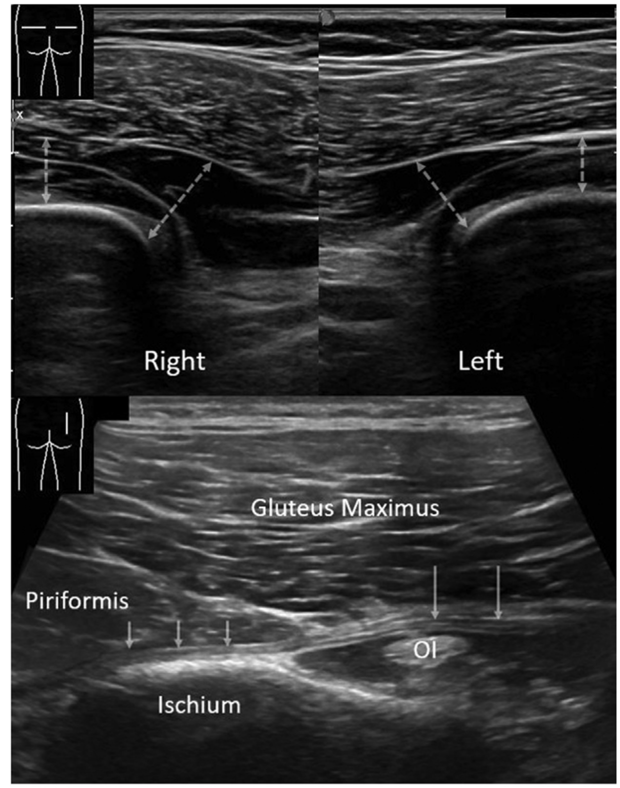

Figure 5 Ultrasound findings in piriformis syndrome. (a) A 14-year-old right-footed junior soccer player with right buttock and posterior knee pain. Transverse ultrasound of the right and left piriformis muscles shows right piriformis muscle enlargement compared to the left (dashed arrows) (see Fig 4a). Note the echogenic intra-muscular line separating the upper and lower muscle bellies. (b) A 21-year-old right-footed Australian-rules footballer with chronic right buttock and radicular leg pain. Longitudinal ultrasound of right piriformis muscle showing type A piriformis MTJ morphology with enlarged lower muscle belly compressing the sciatic nerve against the posterior acetabulum (see Fig 4a). Note effacement of sciatic nerve fascicles deep to piriformis. Piriformis syndrome is seen the dominant leg in kicking sports due to overuse.

superior cluneal nerve branches emerge from deep, passing through the thoracolumbar fascia at fibro-osseous tunnels. Inferomedial to the posterior superior iliac spine middle cluneal nerves also pass from deep to the long posterior sacroiliac ligament to emerge into the superficial buttock. Cluneal nerve entrapment may occur at these fibro-osseous tunnels or the ligament, respectively.

Aetiological considerations

Deep gluteal syndrome (DGS) is a recently described clinical entity encompassing multiple causes of entrapment neuropathy within the subgluteal space that results in chronic buttock pain and/or sciatica.[2,3,6] As with entrapment neuropathies elsewhere (e.g., carpal tunnel syndrome), ischaemia and age-related senescence of peripheral nerves results in susceptibility of the subgluteal space nerves to onset of symptoms in middle age.[7–9] Functional

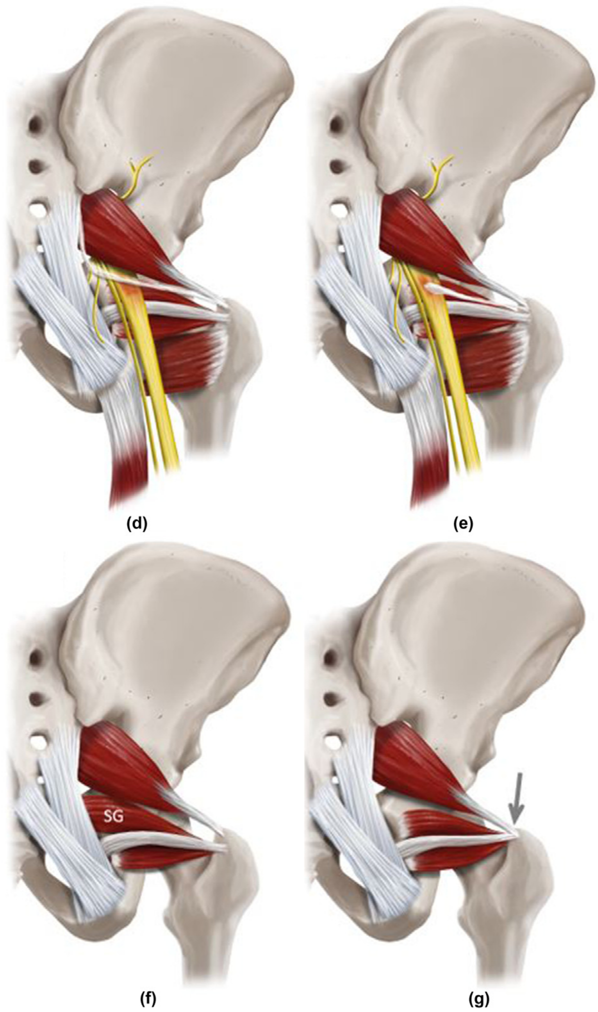

Figure 6 (a) Types 1B and (b) 2A peri-sciatic adhesions resulting in sciatic neuritis. Note the proximity of the posterior cutaneous nerve of thigh, which is commonly involved with adhesive sciatic neuritis. (c,d) Variant morphology of the piriformis and superior gemellus and obturator internus tendon also described by Windisch. (c) An enlarged superior gemellus (SG) muscle takes a more superior origin from the ischial spine and (d) the obturator internus tendon is fused with piriformis tendon (arrow). Both variants result in a closer relationship of the lower piriformis and superior gemellus muscles, reducing the infra-piriform fossa.

factors such as muscle spasm, sporting overload, lumbar spondylolysis, and sacroiliac joint instability may also be significant in the development of pelvic entrapment neuropathy at piriformis and the iliac crest.[1,3,10,11] Additionally, the prevalence of piriformis syndrome and DGS in females (a 6:1 female-to-male ratio) may point to a role for pregnancy-related factors, such as post-partum pelvic instability and/or enthesopathy-related adhesions (particularly around the ischial tuberosity and sacral ligament attachments), contributing to DGS.[1,3,12] Direct trauma, resulting in muscle spasm or peri-neural adhesions, may also precipitate piriformis syndrome and other causes of DGS.[1,3]

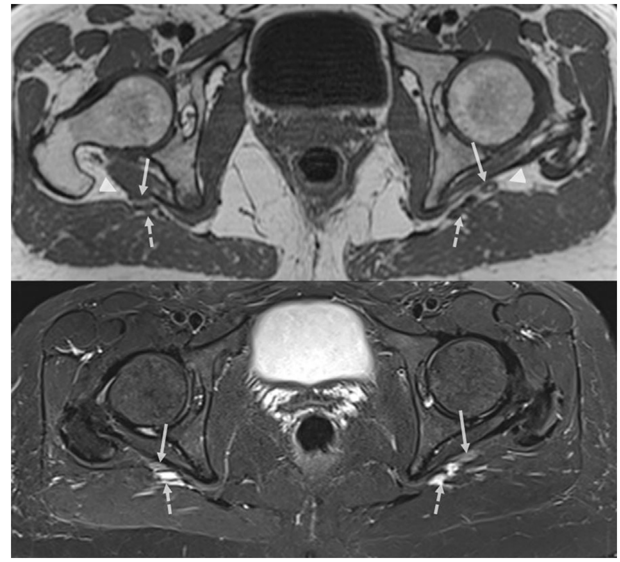

Figure 7 Peri-sciatic vascular band adhesion (compressive or bridge type 1B) in a patient with chronic right buttock pain (see Fig 6a). High-resolution axial T1 and axial T2 FS images of the pelvis showing peri-sciatic vascular band adhesion at the level of the inferior gemellus and obturator internus tendon. Note the vasa vasorum (dashed arrow) on the right is adherent to the posterior aspect of the sciatic nerve (arrow) with reduction in the sub-gluteal space (arrowheads).

Figure 8 Peri-sciatic vascular band adhesions (type 1B) in a patient with chronic right buttock pain (see Fig 6a). Axial T1-weighted bilateral pelvic MRI (above) shows reduction in the subgluteal space on the right compared to left (arrow and dashed line on left). T2-weighted imaging (below) shows asymmetric dilatation of the vasa vasorum on the right, which is closely applied to the posterior aspect of the sciatic nerve at the inferior gemellus when compared with the left (circled). Note the more prominent appearance of the right inferior gluteal vessels, suggesting adhesive involvement of these structures (within circles).

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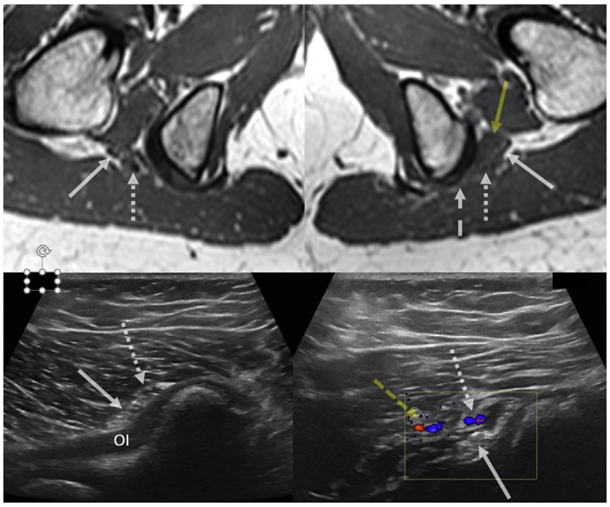

Figure 9 Peri-sciatic band adhesions in a patient with chronic left buttock pain. Axial reformatted T1 SPACE MRI images (above) show low-signal effacement of medial peri-sciatic fat planes (dashed arrow) associated with the sciatic nerve (arrow) and vasa vasorum (dotted arrow) on the left compared to right side. There is inferior displacement of the left inferior gemellus muscle (yellow arrow) due to loss of volume associated with peri-sciatic adhesions. Transverse ultrasound (bottom left) at the inferiorly displaced inferior gemellus (IG) shows adhesion of vessels (dotted arrow) to the posterior left sciatic nerve (arrow). Post-neurolysis image (bottom right) with 60 ml normal saline shows displacement of echogenic adhesions and vessels (dotted arrow) from the sciatic nerve (arrow) by anechoic saline, as well as the inferior gluteal neurovascular bundle (dashed yellow arrow).

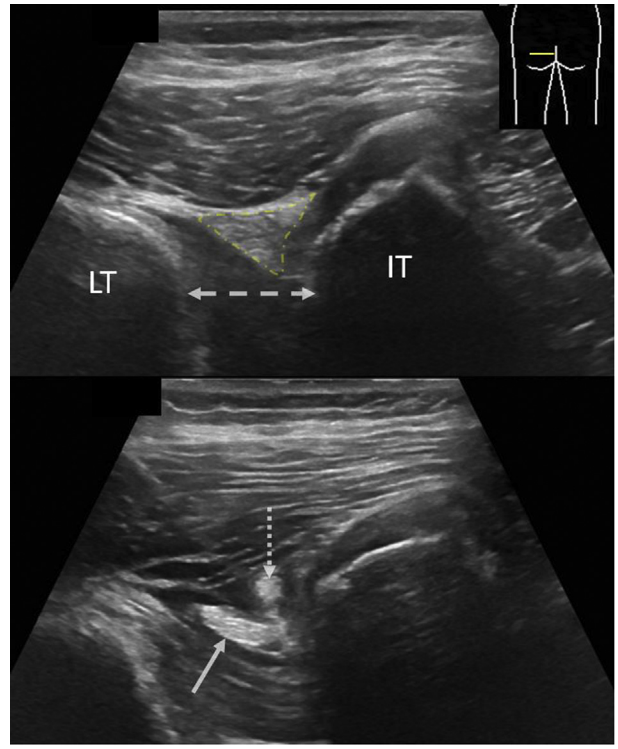

Figure 10 Peri-sciatic adhesions at the ischial tunnel associated with ischiofemoral impingement in a patient with right buttock and posterior thigh pain. Transverse ultrasound scans at the ischial tunnel show a sonographic triangle sign due to the sciatic nerve, peri-sciatic adhesions and the posterior cutaneous nerve of thigh (yellow dotted line). Note reduction in the ischiofemoral space between the lesser trochanter (LT) and ischial tuberosity (IT). In the lower image, the PCNT was dissected from the sciatic nerve during neurolysis, with reproduction of posterior thigh symptoms. Echogenic appearances of the nerves with loss of fascicular architecture are thought to be due to chronic endofibrosis.

Imaging considerations

Imaging plays a significant role in the diagnosis and management of DGS, with findings primarily relating to the presence of sciatic neuritis and peri-sciatic pathology.

Magnetic resonance imaging (MRI) protocols for DGS typically include a combination of conventional sequences and sciatic magnetic resonance neurography (MRN) on high-field strength MRI. Double sagittal-oblique proton density (PD) weighted sequences have been advocated to optimally detect fibrous bands and sciatic neuritis.[2] The author's preferred protocol is to perform bilateral axial and coronal PD and T2 fat-saturated (FS) imaging of the pelvis along with bilateral coronal high resolution (1 mm thickness, contiguous slices) T1-weighted three-dimensional (3D) turbo spin echo (TSE) with variable flip angle ("SPACE") imaging, with reconstructions in the axial plane, in addition to bilateral sciatic 3D short tau inversion recovery (STIR) SPACE MRN. Sagittal and axial T2-weighted imaging of the lumbar spine is also performed in the absence of previous imaging to screen for spinal pathology. This protocol is readily reproducible and allows excellent visualisation of sciatic neuritis and peri-sciatic pathology.

On MRI, sciatic neuritis appears as high T2-signal within the nerve, including oedematous fascicles, and effacement of intra-neural and perineural fat planes due to compression (Fig 2). Spurious high signal within the nerve due to magic angle artefact may be observed and should be interpreted with caution unless compression of the nerve or peri-sciatic pathology is visible.[2,10,13] Chronic neuritis may appear as low rather than high-signal fascicles in addition to intra-neural fat effacement due to endoneural fibrosis. Notably, high-resolution T1-weighted SPACE imaging allows detection of fine adhesions due to the greater contrast resolution for fibrosis and increased spatial resolution compared to conventional PD sequences. MRN helps to mitigate the effect of dilated adherent vasa vasorum, whose signal may overwhelm intra-neural high T2-signal changes associated with neuritis, especially in older patients where ectasia of peri-sciatic vessels is common. Bilateral imaging is important as it allows comparison with the contralateral side, including identification of subtle adhesions, volume loss of the asymmetric subgluteal space, and intra- and perineural fat plane effacement, as well as dilated vessels associated with adhesions.

Ultrasound has a more limited role in the assessment of deep gluteal syndrome due to the depth, obliquity, and size of the nerves, beam attenuation associated with fatty

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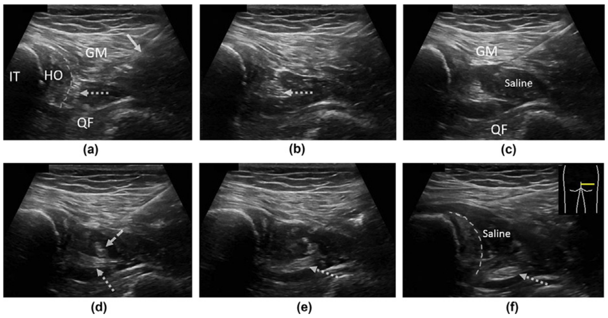

Figure 11 Sciatic neurolysis at the ischial tunnel in a patient with "hamstring syndrome". Transverse ultrasound images showing progressive peri-sciatic hydrodilatation (a–f) at the level of the ischial tuberosity (IT) and hamstring origin (HO). Note initial needle (arrow) position lateral to the sciatic nerve (dotted arrow) with separation of quadratus femoris (QF) from gluteus maximus (GM) in (a–c). The sciatic nerve is adherent to the hamstring origin (dashed line) in these images. The posterior cutaneous nerve of thigh with adhesions is dissected off the sciatic nerve, with thigh referral of symptoms occurring during neurolysis in images (d) and (e). The sciatic nerve has been dissected from the hamstring origin with some fine residual web-like adhesions between the nerve and hamstring origin as well as dorsolaterally in (f). Typically, 20–80 ml normal saline is used to perform neurolysis, depending on the extent of adhesions.

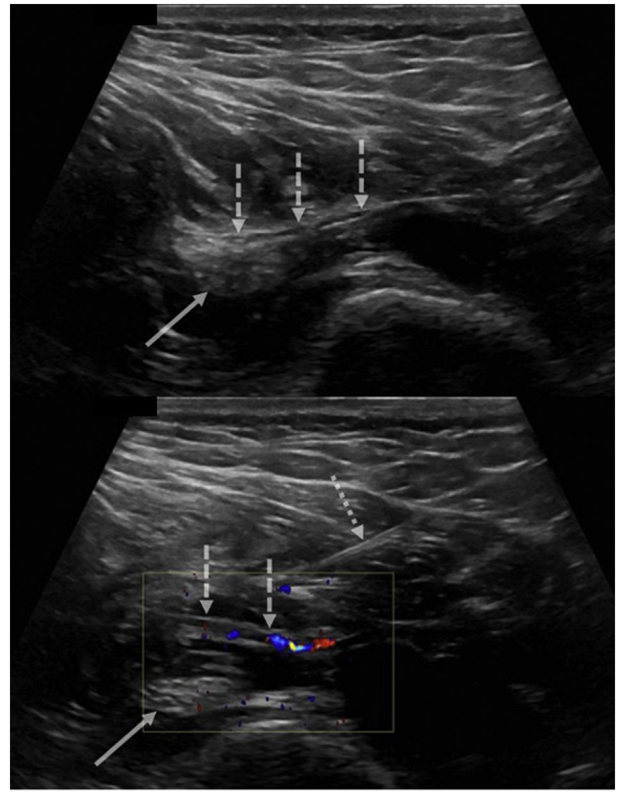

Figure 12 Peri-sciatic vascular band adhesion (adhesive or horse-strap type 2A) at the ischial tunnel in a patient with chronic right buttock pain (see Fig 6b). Note the vessel (dashed arrows) adherent to the posterior sciatic nerve (arrow) in the image above. During neurolysis, the adherent vascular band is dissected from the sciatic nerve (arrow) with anechoic saline (needle shown by dotted arrow), in the image below. Doppler trace in the vascular adhesion (dashed arrows, lower image), is visible due to the shallow depth and absence of gluteus maximus fatty infiltration.

infiltration of gluteus maximus, and significant operator dependency; however, neural fascicular oedema, echogenic perineural adhesions, and/or sciatic nerve compression by variant anatomy may be observed in sonographically friendly patients.[10,13] Compression and reduced mobility of the sciatic nerve may also be seen dynamically.[14]

Piriformis syndrome

Piriformis syndrome (PS) is the best known cause of deep gluteal syndrome, thought by some to be as common as lumbar disc herniation as a cause of chronic sciatica.[1,15,16] It may be divided into somatic and neuropathic PS presentations, with somatic causes resulting in buttock pain due to piriformis muscle spasm, and neuropathic causes resulting in buttock pain and sciatica due to compressive sciatic neuropathy.[10,17] There has been some doubt as to the role of anatomical variants, such as those described by Beaton[4,5,18]; however, when sciatic neuritis is present in the setting of neural compression by piriformis variants and appropriate symptoms, imaging is supportive of the diagnosis of PS and is confirmed with a local anaesthetic infiltration test[2,10,19] (Figs 3 and 4). Dynamic sciatic nerve entrapment is a common variant of PS usually diagnosed endoscopically; however, the presence of an enlarged lower muscle belly associated with a type A piriformis musculotendinous junction may visibly compromise the infrapiriform fossa and result in compressive sciatic neuritis[4,10] (Figs 2, 4 and 5). Mass lesions and haematomas in and around piriformis are rare causes of chronic PS outside of the tertiary medical setting.[20]

Comprehensive evaluation of PS is best performed with MRI, which may demonstrate anatomical variants of piriformis muscle and the sciatic nerve and muscle hypertrophy in addition to sciatic neuritis.[13,19] Ultrasound is limited in its assessment of PS due to beam attenuation, especially caused by age-related fatty replacement of gluteus maximus and non-visualisation of the upper and medial muscle belly; however, sciatic nerve compression and oedema, a prominent lower piriformis muscle belly or asymmetrically enlarged muscle with tenderness on sono-palpation over the piriformis may be seen[10,21] (Fig 5). Ultrasound-guided injection may also confirm the diagnosis with positive response to local anaesthetic and when combined with cortisone injection may successfully augment rehabilitation in refractory cases of PS.[9,11,17,22] Botulinum toxin A injection is also increasingly used as a primary treatment or when cortisone injection has failed.[10,11,22,23]

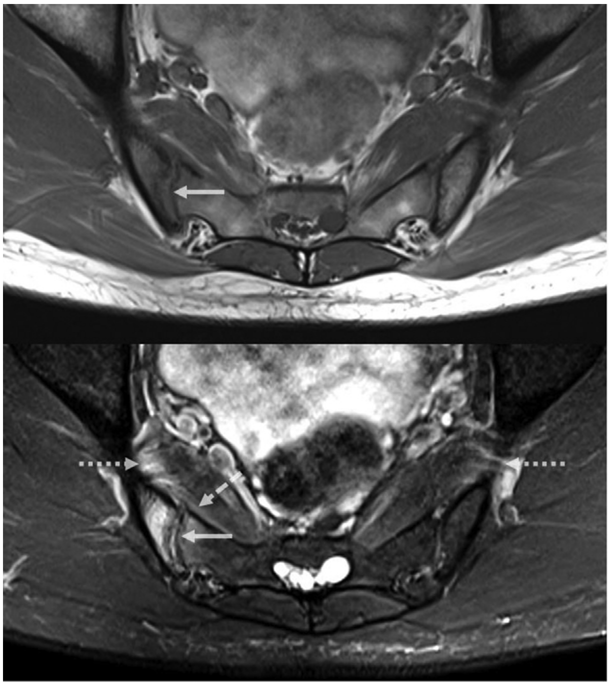

Figure 13 Right sacroiliitis and superior gluteal neuritis in a patient with chronic right buttock pain. Axial T1 and T2 FS images of the SI joints show widening of the right SI joint and subchondral oedema due to sacroiliitis (arrows). There is piriformis muscle oedema (dashed arrow) adjacent to the joint and oedema associated with the right superior gluteal neurovascular bundle (dotted arrow), as compared to the left.

Peri-sciatic band adhesions

Peri-sciatic band adhesions have been more recently described in the clinical and imaging literature and have been classified into three types by endoscopists.[2,3] Compressive or bridge-type bands (type 1) limit movement and cause anterior to posterior (1A) or posterior to anterior (1B) compression of the sciatic nerve and are commonest posteriorly. Adhesive or horse-strap bands (type 2) tether the sciatic nerve laterally (2A) or medially (2B) and are commonest laterally (Fig 6a and b). Undefined bands (type 3) have an erratic distribution, anchoring the sciatic nerve in multiple directions.[2,3] Adhesions may occur at any level, tethering the sciatic nerve to the greater trochanter, sacrotuberous ligament, gluteus maximus muscle, and/or deeper muscles. They are classified as proximal bands when at the greater sciatic notch, distal when at the ischial tunnel (quadratus femoris and hamstring origin) and middle when located at piriformis and the obturator internus–gemellus complex.[2,3]

Sciatic neuritis may be seen on routine T2-weighted or MRN sequences[2,13,16,19]; however, bilateral high-resolution imaging of the subgluteal space is required to optimally assess the presence of peri-sciatic band adhesions. Findings include visible adhesive bands or effacement of perineural fat planes. Asymmetric dilatation of peri-sciatic vessels may also indicate the presence of vascular band adhesions, reported endoscopically as a large vessel or leash of vessels, that may require ligation.[3] Adhesion-related displacement of tissues including the sciatic nerve or inferior gemellus muscle may also be seen (Fig 6a and b, 7–9). Ultrasound may demonstrate echogenic perineural scar tissue, which results in reduced glide of the sciatic nerve on dynamic ultrasound (Figs 9 and 10). It plays a more significant role in treatment, which includes peri-sciatic hydro-dilatation (sciatic neurolysis) with saline.[2,6] Adherent nerves and vessels may also be seen (Figs 7–12).

Sacro-iliac joint pathology and superior gluteal neuropathy

Sacro-iliac joint (SIJ) pathology may contribute to deep gluteal syndrome due to structural or functional causes. SIJ arthropathy with synovitis or osteophyte formation may result in neuropathy of the superior gluteal nerve as it exits above piriformis[13,19] (Fig 13). SIJ counternutation, associated with lumbar spondylolisthesis and pelvic instability, may result in functional compromise of the greater sciatic notch and infra-piriform fossa due to anterior rotation of the sacrum, thereby exacerbating piriformis syndrome[10] (Fig 14). Compression of the superior gluteal nerve by superior intramuscular tendons of piriformis has also been described as a cause of superior gluteal neuropathy, although superior gluteal nerve entrapment may be difficult to assess at imaging due to its out-of-plane orientation.[13,19,24] MRI is the best modality for evaluation of the sacrum and SI joints, however, imaging of pathological SI joints may be normal and SI joint counternutation is also best assessed clinically.[10]

Gemelli–obturator internus syndrome

Gemelli–obturator internus syndrome is an uncommon cause of DGS, caused by compression of the sciatic nerve between the lower piriformis muscle belly and gemellus–obturator internus tendon muscle complex.[2,3] Fusion of piriformis and obturator internus tendons, described by Windisch *et al.*, or variant origin of the superior gemellus from above the ischial spine, may also predispose to this syndrome[4] (Fig 15). Hypertrophy of the gemelli and/or piriformis muscles and variant superior gemellus anatomy may be seen on MRI. Ultrasound may also demonstrate sciatic nerve compression dynamically with resisted internal hip rotation. Treatment is similar to PS and may ultimately require surgical release of the muscle.[2,3]

Pudendal neuropathy

Pudendal neuropathy is not typically recognised as cause of buttock pain, more commonly presenting with groin pain; however, subgluteal space entrapment at the sacrotuberous ligament or ischial spine may result in buttock

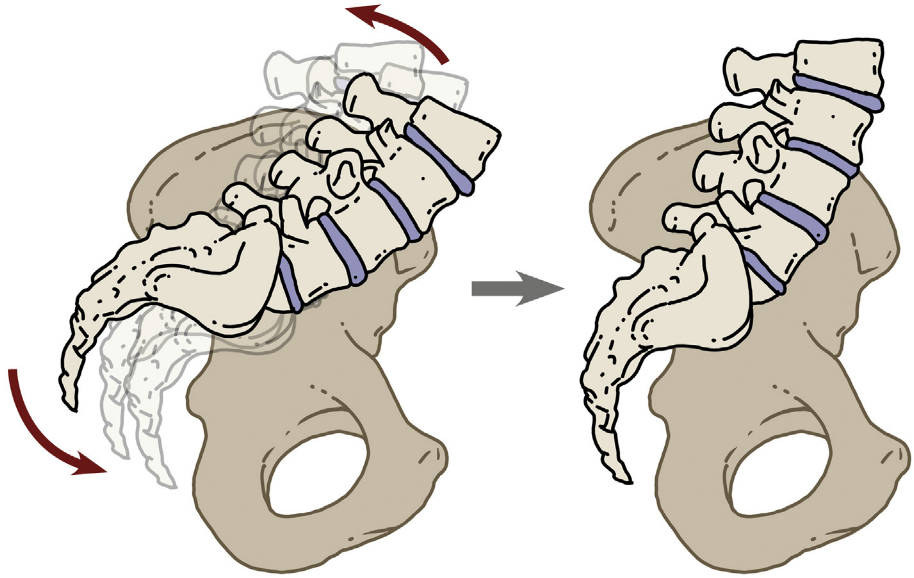

Figure 14 Diagram showing the effects of sacroiliac joint counternutation on the infrapiriform fossa. There is anterior rotation of the sacrum and posterior rotation of the ischium due to laxity in SI joint counternutation, resulting in narrowing of the greater sciatic foramen (see ghosted images of sacral movement). These changes are common in women post-partum and result in reduction of the infrapiriform fossa. Along with piriformis muscle functional or structural changes including spasm, hypertrophy or oedema, counternutation increases the potential for compromise of the sciatic nerve as it exits the pelvis. Additionally, functional or structural changes in the sciatic nerve due to aging or diseases of myelination such as Charcot–Marie–Tooth, further increase susceptibility of the sciatic nerve to compromise and the development of sciatic neuritis in middle age.

and/or groin pain. Shearing of gluteus maximus on the sacrotuberous ligament has been described as a potential cause of pudendal nerve entrapment.[13] Focal scarring and adhesions of the pudendal neurovascular bundle and enlargement of the pudendal nerve may be seen on MRI and ultrasound of suitable patients, often in association with a prominent ischial spine that superficially displaces the nerve (Fig 16). "Lobster claw" entrapment due to impingement of the nerve between the sacrotuberous and sacrospinous ligaments may cause proximal Alcock's canal entrapment and "medial hamstring" pain.[13] Perineural infiltration of local anaesthetic and cortisone may be diagnostic and therapeutic.[13]

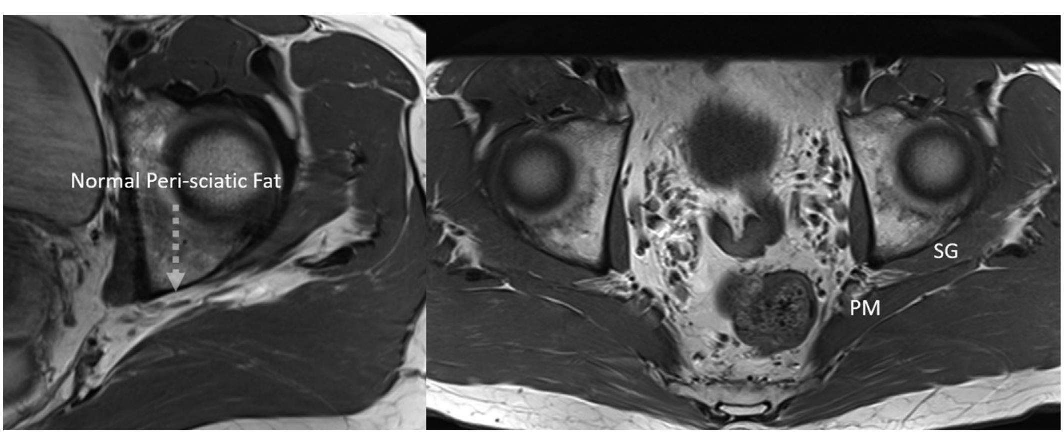

Figure 15 Gemelli–obturator internus syndrome in the author, who presents with intermittent bilateral buttock pain and heel numbness. Axial PD image of the normal subgluteal space above obturator internus tendon (left) showing the normal appearance of the sciatic nerve at the posterior acetabulum. Axial T1 image showing enlarged superior gemellus muscles arising from the posterior acetabulum bilaterally (right), superior to their usual origin from the ischial spine. An aberrant muscle origin of superior gemellus compromises the infra-piriformis fossa and causes compression of the sciatic nerve between the piriformis muscle and superior gemellus (see Fig 6c). Along with variant superior gemellus origin, lateral fusion of the piriformis and obturator internus tendons and a type 1 piriformis MTJ were also present, further compromising the infra-piriform fossa (schematic diagram inset; see Fig 6d). Piriformis and obturator internus tendon fusion was also described by Windisch *et al.*, along with the type 1 piriformis MTJ.

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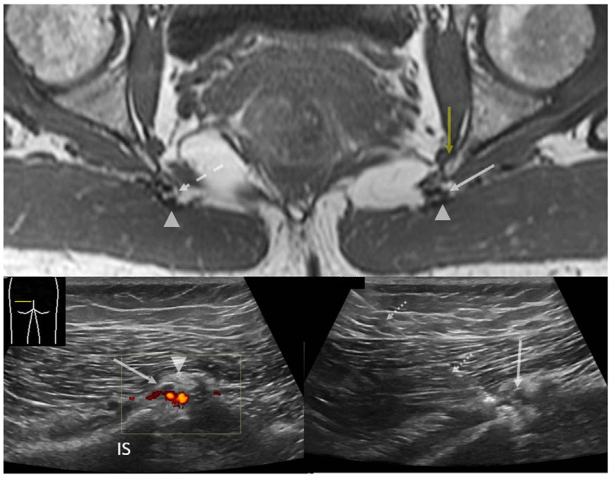

Figure 16 Pudendal neuralgia in a patient with chronic left buttock and groin pain. Note the enlarged left pudendal nerve (arrow) on axial T1-weighted MRI and transverse ultrasound of the buttock lying between the sacrotuberous ligament posteriorly (arrowhead) and low-signal pudendal vessels and ischial spine (yellow arrow) anteriorly, compared to the normal right nerve (dashed arrow) which appears as subtle grey “dots” in the fatty tissue between these structures. At ultrasound, the enlarged pudendal nerve (arrow) lies posterolateral to the pudendal vessels, which are readily visible on power Doppler, and is adherent to the sacrotuberous ligament (arrowhead, bottom left). The ischial spine (IS) is prominent and may contribute to ligament related impingement of the pudendal neurovascular bundle. Ultrasound-guided injection (needle shown with dotted arrows) may be diagnostic and therapeutic by hydrodilatation of adhesions (bottom right).

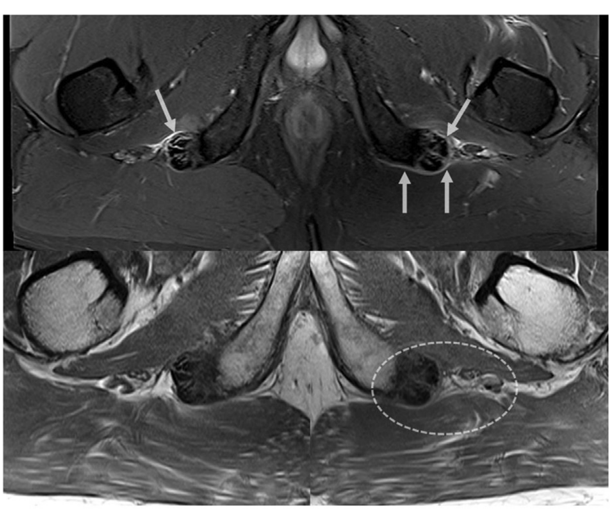

Figure 17 Hamstring syndrome in a patient with chronic left buttock pain due to peri-sciatic adhesions (undefined type 3) associated with hamstring tendinopathy and ischial bursitis. Axial T2-fat saturated (above) and PD (below) images show loss of volume and web-like adhesions within the ischial tunnel at the left hamstring origin (dashed oval) associated with hamstring tendinosis, including paratenonitis and ischial bursitis (arrows).

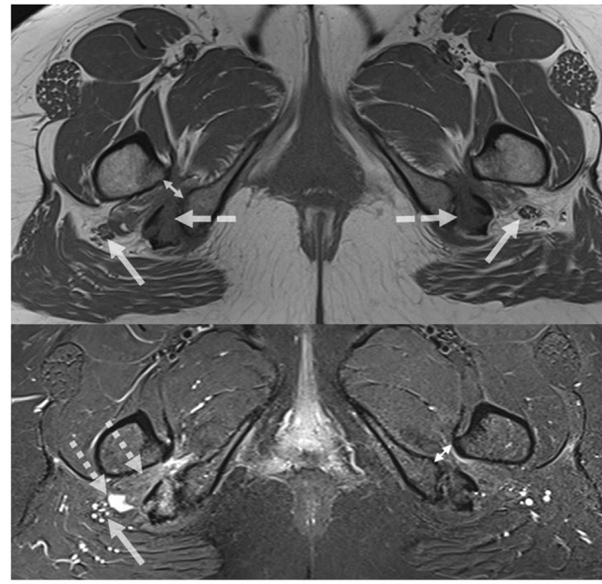

Figure 18 Ischiofemoral impingement and deep peri-sciatic adhesions in a patient with chronic right buttock and leg pain. Axial T1 and T2 FS of the pelvis showing bilateral IFI with reduced ischiofemoral space (double-headed arrow). Note the right quadratus femoris oedema and atrophy with associated bursitis (dotted arrows) extending to the sciatic nerve. There is fascicular swelling and loss of intra-neural fat compared to the left sciatic nerve (arrows). There is also advanced bilateral degenerative hamstring tendinopathy (dashed arrows).

Hamstring (ischial tunnel) syndrome, posterior cutaneous nerve of thigh neuropathy, and ischiofemoral impingement

Hamstring or ischial tunnel syndrome, caused by peri-sciatic adhesions at the hamstring origin, may follow high-hamstring strains, chronic hamstring origin tendinopathy, or ischial bursitis. Hamstring syndrome results in sciatic neuritis with neural sensitisation at the lateral aspect of the ischial tuberosity.[2,3,25] Imaging findings and treatment are as for sciatic neuritis associated with peri-sciatic band adhesions[2,25] (Figs 9, 10 and 17) Additionally, the posterior cutaneous nerve of the thigh (PCNT) may be visualised during neurolysis in this region. A “triangle sign” due to the presence of echogenic adhesions that involve the PCNT within the ischial tunnel may be seen, frequently in association with chronic ischial bursitis. Posterior thigh pain in the distribution of the PCNT, or groin pain due to perineal branch involvement, may be experienced during neurolysis (Fig 10). Ischiofemoral impingement may also result in sciatic neuritis due to bony impingement of quadratus femoris, resulting in bursitis and peri-sciatic adhesions[3,26] (Figs 10 and 18).

Ischial bursitis and inferior gluteal neuropathy

Gluteal nerve injury may follow pelvic surgery or trauma, including prosthetic or bony impingement around the

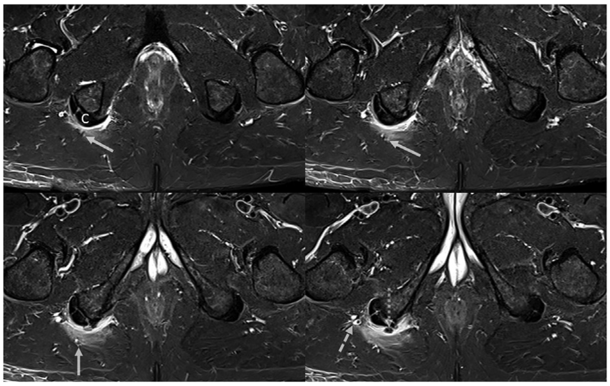

Figure 19 Inferior gluteal neuritis secondary to pseudogout-related ischial bursitis. Transverse T2 FS MRI of the hamstrings showing florid right ischial bursitis overlying the conjoint (C) and semimembranosus tendon origins associated with calcium crystal deposition disease, including a focal calcific deposit (dotted arrow). There is adjacent gluteus maximus muscle oedema and oedema of inferior gluteal nerve (arrows) within the muscle. Note extension of bursitis to the vasa vasorum of the right sciatic nerve (dashed arrow), with potential for the development of subsequent peri-sciatic adhesions.

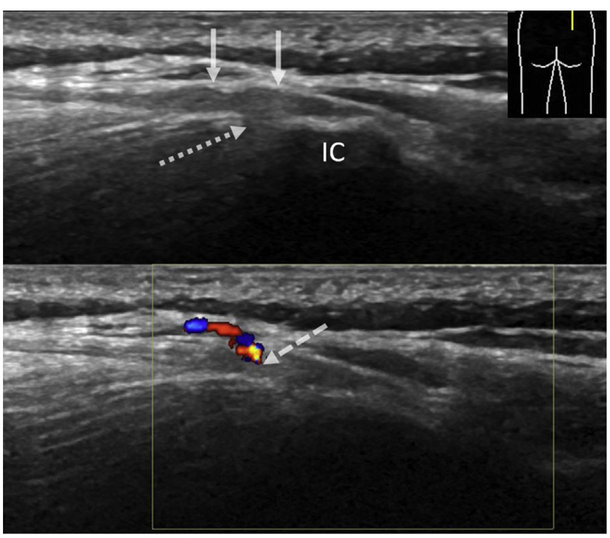

Figure 20 Superior cluneal neuropathy in patient with buttock and iliac crest pain. Longitudinal ultrasound at the medial right superior iliac crest (IC) shows a focal area of lumbar fascia thickening (arrows) and a defect in the deep fascia at the iliac crest (dotted arrow) corresponding to a fibro-osseous tunnel. The nerve was not clearly resolved; however, the medial branch of the superior cluneal nerve was identified by the presence of vessels extending to the fibro-osseous tunnel and trigger point pain. Diagnostic local anaesthetic injection of all three cluneal branches provided complete pain relief, confirming the diagnosis.

sciatic notch[13,19]; however, the inferior gluteal nerve also passes in close proximity to the hamstring origin, and consequently, hamstring enthesopathy and/or ischial bursitis may also result in adhesive neuritis of the inferior gluteal nerve that may mimic hamstring syndrome. In inferior gluteal neuritis, the nerve may be traced into a thickened, high-signal (MRI), or echogenic (US) ischial bursa due to acute or chronic bursitis. The nerve is identified by accompanying vessels that pass distally into the gluteus maximus muscle (Fig 19). Inferior gluteal neuropathy may co-exist with conventional hamstring syndrome and symptoms may not improve following neurolysis unless bursal hydro-dilatation and neurolysis of the inferior gluteal nerve is performed (Fig 9).

Cluneal neuropathy

Cluneal neuropathy (“clunealalgia” or “pseudo-sciatica”) is a frequently overlooked cause of buttock pain, usually due to superior cluneal nerve entrapment at the posterior iliac crest.[27,28] Upper buttock pain identified at the iliac crest is characteristic. Focal “trigger points” may be evident on sono-palpation at one or more sites across the iliac crest corresponding to the medial and middle, or less frequently, the lateral branches. Diagnosis is usually made clinically and confirmed with trigger point injection.[27] The superior cluneal nerves are fine and orientation is unfavourable for imaging unless conditions are optimal, e.g. young, slim patient; however, these small nerves may be identified at fibro-osseous tunnels at the lumbar fascia iliac crest attachment, where fascial thickening may be observed (Fig 20). Middle cluneal neuropathy is considerably less common but may result in triggering as the nerves emerge deep to the long posterior sacroiliac ligament, where they may also be injected under ultrasound guidance.[28] Trigger point injection may be therapeutic for cluneal neuropathy and augment rehabilitation.[27,28]

Conclusion

Pelvic peripheral nerves are under-diagnosed causes of chronic buttock and sciatica, despite more recent awareness of deep gluteal syndrome in the clinical and imaging literature. Anatomical variants are also under-recognised in the pathophysiology of chronic buttock pain but may become clinically significant with senescence of the peripheral nerves in middle age as well as development of other functional changes such as muscle spasm or overload, and lumbar or pelvic instability. In addition to sciatic neuritis, entrapment neuropathies of the superior and inferior gluteal nerves, pudendal nerves, PCNT, and cluneal nerves may cause chronic buttock and sciatica symptoms. Although MRI is the technique of choice for evaluating most causes of chronic buttock pain in appropriate patients, ultrasound may also show neural and peri-neural pathology and may be used for therapeutic purposes.

Conflict of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Eamon Koh is employed by Envision Medical Imaging.

Please cite this article as: Koh E, Imaging of peripheral nerve causes of chronic buttock pain and sciatica, Clinical Radiology, https://doi.org/10.1016/j.crad.2021.03.005

Acknowledgements

The author thanks Phil Watson for MRI protocol development.

References

1. Hicks BL, Varacallo M. *Piriformis syndrome*. Treasure Island, FL: StatPearls Publishing; 2020.
2. Hernando M, Cerezal L, Pérez-Carro L, *et al.* Deep gluteal syndrome: anatomy, imaging, and management of sciatic nerve entrapments in the subgluteal space. *Skelet Radiol* 2015;**44**(7):919–34.
3. Perez Carro L. Deep gluteal space problems: piriformis syndrome, ischiofemoral impingement and sciatic nerve release. *Muscles Ligaments Tendons J* 2016 Dec 21;**6**(3):384–96.
4. Windisch G, Braun EM, Anderhuber F. Piriformis muscle: clinical anatomy and consideration of the piriformis Syndrome. *Surg Radiol Anat* 2007;**29**(1):37–45.
5. Beaton Anson BJ. The relation of the sciatic nerve and of its subdivisions to the piriformis muscle. *Anat Rec* 1937;**70**(1):1–5. https://doi.org/10.1002/ar.1090700102.
6. Rosales J, García N, Rafols C, *et al.* Perisciatic Ultrasound-guided infiltration for treatment of deep gluteal syndrome. *J Ultrasound Med* 2015;**34**(11):2093–7.
7. Latinovich R, Gulliford MC, Hughes RA. Incidence of common compressive neuropathies in primary care. *J Neurol Neurosurg Psychiatry* 2006 Feb;**77**(2):263–5.
8. Verdú E, Ceballos D, Vilches JJ. Navarro X Influence of aging on peripheral nerve function and regeneration. *J Peripher Nerv Syst* 2000 Dec;**5**(4):191–208.
9. Fishman LM, Anderson C, Rosner B. BOTOX and physical therapy in the treatment of piriformis syndrome. *Am J Phys Med Rehabil* 2002;**81**(12):936–42. https://doi.org/10.1097/01.PHM.0000034956.35609.5E.
10. Koh E, Webster D, Boyle J. Case report and review of the potential role of the type A piriformis muscle in dynamic sciatic nerve entrapment variant of piriformis syndrome. *Surg Radiol Anat* 2020 Oct;**42**(10):1237–42.
11. Kirschner JS, Foye PM, Cole JL. Piriformis syndrome, diagnosis and treatment. *Muscle Nerve* 2009;**40**(1):10–8. https://doi.org/10.1002/mus.21318.
12. PhD thesis *Sjodahl J Pregnancy related pelvic girdle pain and its relation to muscle function*. Linkoping, Sweden: Linkoping University; 2010, https://www.diva-portal.org/smash/get/diva2:355620/FULLTEXT01.pdf.
13. Martinoli C, Miguel-Perez M, Padua L, *et al.* Imaging of neuropathies about the hip. *Eur J Radiol* 2013;**82**(1):17–26.
14. Coppieters MW, Andersen LS, Johansen R, *et al.* Excursion of the sciatic nerve during nerve mobilization exercises: an in vivo cross-sectional study using dynamic ultrasound imaging. *J Orthop Sports Phys Ther* 2015;**45**(10):731-737.
15. Fishman LM, Schaefer LP. The piriformis syndrome is underdiagnosed. *Muscle Nerve* 2003;**28**(3):646–9. https://doi.org/10.1002/mus.10482.
16. Filler AG. Piriformis and related entrapment syndromes: diagnosis & management. *Neurosurg Clin N Am* 2008;**19**(4):609–22. https://doi.org/10.1016/j.nec.2008.07.029. vii.
17. Jankovic D, Peng P, van Zundert A. Piriformis syndrome: etiology, diagnosis and management. *Can J Anesth* 2013;**60**:1003–12. https://doi.org/10.1007/s12630-013-0009-5.
18. Smoll NR. Variations of the piriformis and sciatic nerve with clinical consequence: a review. *Clin Anat* 2010 Jan;**23**(1):8–17.
19. Petchprapa C, Rosenberg Z, Sconfienza L, *et al.* MR Imaging of entrapment neuropathies of the lower extremity. *RadioGraphics* 2010;**30**(4):983–1000.
20. Vassalou E, Katonis P, Karantanas A. Piriformis muscle syndrome: a cross-sectional imaging study in 116 patients and evaluation of therapeutic outcome. *Eur Radiol* 2017;**28**:447–58.
21. Zhang W, Luo F, Sun H, *et al.* Ultrasound appears to be a reliable technique for the diagnosis of piriformis syndrome. *Muscle Nerve* 2019;**59**(4):411–6.
22. Filler AG, Haynes, Jordan SE, *et al.* 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 Feb;**2**:99–115.
23. Fishman L, Dombi G, Michaelsen C, *et al.* Piriformis syndrome: diagnosis, treatment, and outcome—a 10-year study. *Arch Phys Med Rehab* 2002;**83**(3):295–301.
24. Rask M. Superior gluteal nerve entrapment syndrome. *Muscle Nerve* 1980;**3**(4):304–7.
25. Puranen J, Orava S. The hamstring syndrome. *Am J Sports Med* 1988;**16**(5):517–21.
26. Torriani M, Souto S, Thomas B, *et al.* Ischiofemoral impingement syndrome: an entity with hip pain and abnormalities of the quadratus femoris muscle. *AJR Am J Roentgenol* 2009;**193**(1):186–90.
27. Isu T, Kim K, Morimoto D, *et al.* Superior and middle cluneal nerve entrapment as a cause of low back pain. *Neurospine* 2018;**15**(1):25–32.
28. Aota Y. Entrapment of middle cluneal nerves as an unknown cause of low back pain. *World J Orthoped* 2016;**7**(3):167.