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FULL PAPER

Anatomical and MR correlative study of the proximal sciatic nerve vasculature

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Objective: The aim of our study is to demonstrate that increased T_2 signal on MRI could be due to intraneural vessels in asymptomatic individuals, and may therefore be a normal finding.

Methods: An initial anatomic cadaveric study was undertaken to gain a better understanding of the vascular supply of the proximal sciatic nerve. Secondly, a retrospective study of MR imaging of patients without sciatic symptoms was performed to assess the prevalence of intraneural vessels, defined as hyperintensity on at least three consecutive slices on both T_2 and gadolinium enhanced T_1 weighted imaging, visible on routine MSK pelvic imaging.

Results: The anatomical study demonstrated a relatively abundant blood supply in the peri-ischiatic region. In the MR study, 20/76 (26%) patients showed visible intraneural vessels. More than one intraneural vessel was depicted in two of the sciatic nerves. Direct branching between the extrinsic and intrinsic systems was seen in only five cases.

Conclusion: Normal intraneural vessels can frequently be seen within the sciatic nerve on routine musculoskeletal pelvic imaging.

Advances in knowledge: T_2 hyperintensity in the proximal sciatic nerve can be due to intraneural vessels and should not necessarily be reported as abnormal.

INTRODUCTION

Sciatica is a common clinical condition.¹ The causes can be divided into intraspinal and extraspinal. Most cases will be intraspinal related to degenerative disc disease. However, extraspinal causes such as extrinsic compression by adjacent masses (tumour, infection, haematoma), piriformis syndrome and intraneural tumours are increasingly recognized^{2–5} as both spatial and contrast resolution have improved, particularly in cross-sectional imaging.

In routine musculoskeletal pelvic imaging, the use of fat suppression techniques and improving signal-to-noise ratio demonstrate the proximal sciatic nerve with increasing resolution. In our own institution, we have noticed a rise in the number of questions posed regarding sciatic intraneural hyperintensity on T_2 weighted images in the proximal sciatic nerve from both radiological and clinical colleagues on these routine studies. This feature might be consistent with normal vessels within the nerve but to the best of our knowledge no scientific study of normal internal vasculature in this region has been conducted. Moreover, there is neither available information in the frequency of such a feature in asymptomatic patients nor correlation

between anatomic and imaging studies. This is important as abnormal intraneural T_2 hyperintensity involving individual fascicle bundles can be demonstrated within the sciatic nerve.⁴ Consequently, knowledge concerning normal imaging features of the sciatic nerve is required.

The aim of our study is to demonstrate that increased T_2 signal on MRI could be due to intraneural vessels in asymptomatic individuals, and may therefore be a normal finding.

METHODS AND MATERIALS

Two separate studies—one anatomical single cadaver study with no MR imaging performed on the specimen and an MRI study in patients with no histopathological analysis.

Anatomical study in cadavers

A study was initially undertaken on a cadaver to gain a better understanding of the vascular supply of the sciatic nerve in the ischiatic region.

The embalmed cadaver (male, 70 years) was injected via the infrarenal aorta by hand pump with red epoxy resin to better differentiate arterial from venous vessels. Macrodissection

and microdissection of the right sciatic nerve was undertaken. The left side was sectioned into contiguous 3 mm axial slices. The location, course and relationships to the adjacent vascular structures of the sciatic nerve were analysed simultaneously and in consensus by a musculoskeletal radiologist and an anatomist. All the specimens were photographed using a digital camera. No MR imaging was performed on this specimen.

The sciatic nerves in the peritrochanteric region were then sent for histological assessment (coronal and axial sections). Haematoxylin and eosin stain and orcein stain were used to demonstrate elastic fibres and differentiate arterioles from venules.

MR study in patients

This study was conducted in accordance with our local ethics committee review board. Information was delivered prior to the examination, and written consent was obtained from each patient.

Clinical and imaging features of the patients who were referred to our musculoskeletal imaging department for MR imaging of the pelvis within the previous year (1 January to 31 December 2015) were reviewed. Imaging was performed on a 3T MRI scanner (Ingenia, Philips Healthcare, Eindhoven, Netherlands) using Torso and posterior integrated coil components.

The inclusion criteria included both fat suppressed fluid sensitive axial sequences and fat suppressed T_1 post gadolinium axial imaging (TR 643 ms, TE 10 ms, FOV 240×380 , acquisition matrix 380×182 , slice thickness 4 mm, interval gap 1.2 mm, NSA 1.4).

The primary exclusion criteria included the presence of bone or soft tissue mass in the sciatic region, clinical details in the referral of lower limb motor, sensory or reflex changes and pain radiating below the knee and any imaging artefacts significantly reducing image quality.

MR images were reviewed independently by two radiologists (with 1 and 3 years experience in MSK radiology) aiming for consensus. A further second read with both radiologists was performed for cases where there was not consensus from the independent first read. The nerve was analysed from cranially at the inferior border of the piriformis to caudally at the musculotendinous junction of the proximal hamstrings. If a hyperintense structure within the nerve was visible on three consecutive axial slices of the fluid sensitive sequences and visible on the gadolinium enhanced T_1 sequence it was considered positive for an intraneural vessel. The position of the adjacent extrinsic vascular system and presence of more than one intraneural vessel were also included.

The fluid sensitive sequences included T_2 Dixon (TR 4739 ms, TE 30 ms, FOV 300×373 , acquisition matrix 380×182 , slice thickness 4 mm, gap 1.2 mm, NSA 1) for 46 sciatic nerves and T_2 FS for 30 nerves (TR 5600 ms, TE 86 ms, FOV 400×375 , acquisition matrix 384×250 , slice thickness, 4 mm gap 1.2 mm, NSA 2).

Figure 1. (a) Posterior view of the sciatic nerve. Black asterisks demonstrate the sciatic nerve. Black circles from superior to inferior show the most superior intraneural vessel which arose from the inferior gluteal artery, the middle intraneural vessel which arose from a branch from the inferior gluteal artery and the most inferior of the three a branch of the the medial circumflex. (b) A diagram from TeachMeAnatomy (<http://teachmeanatomy.info>) which highlights the local relations of vessels and piriformis to the sciatic nerve.

The course of the sciatic nerve and its potential pathway variants in relation to the piriformis muscle were assessed on the fat suppressed T_2/T_2 Dixon images and T_1 axial images in consensus by both readers. The Beaton and Anson classification was used to describe these variants.⁶

RESULTS

Anatomical study in cadavers

Dissection of the right sciatic nerve demonstrated a normal course below the piriformis muscle through the greater sciatic foramen. The piriformis was then released and reflected. Microdissection demonstrated three regions of vessels piercing the sciatic nerve sheath (Figure 1a,b). The most superior vessel was a branch of the inferior gluteal artery which entered the posterior sheath of the nerve immediately distal to the piriformis muscle (Figure 2a). The middle vessel arose at the medial aspect of the nerve from the inferior gluteal artery (Figure 2b). The most inferior vessel arose from a branch of the medial circumflex artery (Figure 2c). The 3-mm axial sections of the left sciatic nerve clearly demonstrated epoxy resin within intraneural arterioles (Figure 3a,b). The vessels entering the nerve sheath measured a maximum of 2 mm in diameter.

Histological analysis of the two sciatic nerves showed the intraneural vascular anatomy consisting of longitudinal anastomosing chains within the epineurium and perineurium as well as capillaries in the endoneurium (Figure 4a–c).

MR study in patients

40 patients (18 males, 22 females, mean age: 46 years, range: 10–75) were included. Unsuitable imaging quality excluded 2 patients. In total, 76 sciatic nerves were available for review. Twenty four out of 76 sciatic nerves (32%) showed intraneural hyperintense structures on three contiguous slices on fluid sensitive sequences, as agreed by both radiologists. Twenty out of 76 (26%) also enhanced after gadolinium administration and were read as intraneural vessels visible on routine pelvic MSK imaging. Four nerves in three patients demonstrated equivocally high signal on T_2 weighted images.

Figure 2. Magnified view of superior intraneural artery post microdissection. (a) The full black arrows highlight the edge of the nerve. The dotted black arrows shows the vessel. (b) Magnified view of two middle intraneural vessels post microdissection. (c) Magnified view of distal intraneural artery post microdissection.

As the sciatic nerve exited the greater sciatic foramen below the piriformis, the adjacent extrinsic sciatic vascular system was seen passing posterior to the nerve from medial to lateral (Figure 5). Intraneural vessels were frequently detected at this level but direct branching between the extrinsic and intrinsic systems was seen in only five cases (Figure 6). We also noted more than one intraneural vessel in 2 (10%) of the sciatic nerves (Figure 7).

Subjectively both readers noted that intraneural vessels demonstrated a tortuous and predominantly peripheral route within the nerve sheath. An objective assessment of this was not performed.

We found 10 out of 76 sciatic nerves (12%) demonstrated variant course consistent with Beaton and Anson most common Type 2 variant (Figure 8 and 9). Of these, 3 (30%) showed intraneural vessels.

We recognize several limitations to our study:

- (1) Our anatomic study was based on only one cadaver and the MR study performed on living patients, therefore firm conclusions between the studies cannot be made. The cadaveric study was only performed to gain a better understanding of the usual vascular supply of the sciatic nerve to aid interpretation of the MRI.
- (2) The second part of the study was based on only 38 patients. Larger studies might demonstrate different frequency of intraneural vessels or sciatic variations.
- (3) We did not perform histological study of the sciatic nerves in our patients for ethical reasons and we did not add MR

Figure 3. (a) Axial section with the left sciatic nerve highlighted by the dotted black oval. (b) Magnified axial section: white arrows show larger intraneural arterioles within the epineurium and black arrows demonstrate smaller arterioles within the perineurium.

neurography sequences, as this study was based on the analysis of routine MSK studies.

- (4) Due to the very small calibre of the vessels, we used qualitative assessment of intraneural hyperintensity only. Quantitative measurements as described in other studies⁷ could not be accurately applied.

In conclusion, the presence of sciatic intraneural hyperintensity on T_2 weighted images in the proximal sciatic nerve should be assessed with caution as normal intraneural vessels are a potential cause of this appearance.

Figure 4. (a) Axial section through the proximal nerve. The two white dashed line ovals highlight intraneural vessels deep to the epineurium. The black dashed line highlights nerve fascicles. (b) Magnified microscopic view of the intraneural anatomy of the proximal nerve. Grey arrow demonstrates an artery, the black arrow demonstrates a thrombus within a vein and the blue arrow shows an adjacent nerve fascicle. (c) Coronal section of the proximal specimen with dotted black arrows highlighting the vasculature running longitudinal with adjacent nerve fascicles (black solid arrows).

Figure 5. Three axial images taken from the same level: superior image T_2 Dixon water phase, middle image T_2 Dixon fat phase, bottom image T_1 fat suppressed gadolinium enhanced image. The pink rings outline the sciatic nerve and the blue arrows the adjacent extrinsic vessels.

DISCUSSION

Our study showed that on routine MRI, increased T_2 signal without symptoms was found in 32% of examined nerves. This was shown to be due to intraneural vessels in 26% of nerves based on the criteria we chose. The sciatic nerve is the largest branch of the sacral plexus and the broadest nerve in the body. It has an abundant extrinsic and intrinsic blood supply.^{8,9} The extrinsic arterial supply usually originates from branches of the inferior gluteal artery and medial circumflex artery. As described in the anatomic literature^{10,11} and also showed in our cadaver study, the sciatic nerve receives multiple branches from the inferior gluteal artery. The proximity and abundance of adjacent feeding vessels may explain the high frequency of the vessels that can be depicted within the nerve in this region on routine MRI examinations.

The exclusion of patients with hyperintense intraneural structures on T_2 weighted images seen on less than three adjacent

Figure 6. T_1 Fat suppressed, gadolinium enhanced axial images of a left sciatic nerve. The left image is cranial and the right most image caudal. Red dashed line outlines the sciatic nerve and blue arrows show the extrinsic vessels passing posterior to the nerve. The black arrow shows an arising intraneural vessel.

Figure 7. Axial T_2 FS images of a left sciatic nerve (left superior, right inferior). The red dashed line outlines the sciatic nerve and the blue arrow demonstrates an intraneural vessel. The yellow arrow demonstrates a further intraneural vessel.

slices or that did not enhance after gadolinium administration was arbitrary. It was chosen to increase depiction of longitudinal structures and to improve delineation of enhancing intraneural structures and therefore the incidence would change based on minor changes to these exclusion criteria.

The frequency of intraneural vessels in our study is directly influenced by the MR protocol used in our Department and it can be different in other studies with different protocols. However, our goal was only to demonstrate that intraneural vessels can be frequently depicted on routine MR protocols. The improvement in the contrast and spatial resolution of routine MR sequences increases the likelihood of depiction of this normal feature in the sciatic nerve. The knowledge that such intraneural structures can

Figure 8. Coronal T_1 MPR demonstrating an example of a left-sided sciatic variant. The red arrows show the branching of the sciatic nerve with the superior branch passing through the piriformis muscle and the inferior branch passing below. This is in keeping with the most common variant Type 2. The white arrows demonstrate the left piriformis muscle.

Figure 9. Beaton and Anson's schematic of the variant proximal sciatic anatomy. (a) Normal passage of the whole sciatic nerve below and behind the piriformis, (b) most common variant a bifurcation of the sciatic branch passes between the piriformis, (c) variant in which nerve bifurcates and passes above and below piriformis, (d) the whole nerve passes through the piriformis, (e) and (f) further hypothetical variant routes.

be frequently seen in this region can be useful to avoid potential false positive reports, particularly in patients with sciatic symptoms.

To the best of our knowledge, this study is the first to demonstrate that normal intraneural vascular structures are frequently detected using usual sequences and should not be read as abnormal fascicles. This is important as abnormal intraneural T_2 hyperintensity, sometimes involving individual fascicle

bundles have been identified.⁴ The vessels winding path within the nerve and close relationship to the adjacent extrinsic vessels can be useful to differentiate from nerves fascicles which have been shown to have an ordered somatopic distribution.¹²

The use of a specific three-dimensional (3D) diffusion-weighted reversed specific fast imaging with steady state precession (3D DW-PSIF) MR sequence which has the potential to create nerve-specific images with suppression of vessels

in MR neurography, might be particularly useful to confirm the vascular nature of the intraneural high signal intensity. However, suppression is not uniformly effective in small vessels (3–5 mm).¹³ Moreover, at least at present, this technique is not included in the routine pelvic musculoskeletal MRI setting. Magic angle effect has been described as a cause of false positives in peripheral nerve imaging at 1.5 T^{14,15} although less relevant at 3 T.¹⁶ However, in our study, the increased signal intensities seen in the nerves had the appearance of dots on axial images and did not involve the whole surface. Moreover, the use of both T_1 and T_2 weighted imaging for our inclusion criteria should reduce this problem.

The intraneural vessels demonstrated on MR images appeared deep to the epineurium most probably lying within the

perineurium. The vessels seen entering the nerve sheaths were difficult to identify in all patients due to their thin diameter but the images used in our study were not optimized for a targeted analysis of the sciatic nerve. Endoneural capillaries are probably too small to be depicted.

Our study did find several patients with the most common type of sciatic nerve anatomical variation as described by classified by Beaton and Anson. Intraneural vessels could also be detected in this variation with a similar frequency.

In conclusion, the presence of sciatic intraneural hyperintensity on T_2 weighted images in the proximal sciatic nerve should be assessed with caution as normal intraneural vessels are a potential cause of this appearance.

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