Pudendal nerve and branch neuropathy: magnetic resonance neurography evaluation

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Abstract

Pudendal neuralgia is being increasingly recognized as a cause of chronic pelvic pain, which may be related to nerve injury or entrapment. Due to its complex anatomy and branching patterns, the pudendal nerve abnormalities are challenging to illustrate. High resolution 3 T magnetic resonance neurography is a promising technique for the evaluation of peripheral neuropathies. In this article, the authors discuss the normal pudendal nerve anatomy and its variations, technical considerations of pudendal nerve imaging, and highlight the normal and abnormal appearances of the pudendal nerve and its branches with illustrative case examples.

Keywords

Pudendal nerve, magnetic resonance imaging (MRI), magnetic resonance neurography, pelvic pain, pudendal neuralgia

Introduction

The pudendal nerve is a mixed nerve composed of sensory, motor, and autonomic fibers. It innervates the female and male genitalia in addition to the perineum and rectum. Pudendal neuralgia is reported to have a prevalence of 6.6% among the general population and it is more commonly observed in women (1). It can be caused by a number of etiologies, such as entrapment, blunt or iatrogenic trauma, infection, or tumor compressing or infiltrating the nerve. These etiologies can affect the pudendal nerve or its branches in isolation or it can also involve the contributing sacral and pelvic nerves. Traditionally, the evaluation of pudendal neuralgia is based upon the clinical findings, since electrodiagnostic studies are limited in the evaluation of the pelvic neuropathies (2). Magnetic resonance neurography (MRN) is a high resolution non-invasive imaging technique dedicated to the evaluation of peripheral nerve pathologies and is being increasingly used in the setting of suspected pudendal neuropathy (3–6). It is imperative for the radiologist to become familiar with the normal and abnormal appearances of the pudendal nerve on MRN in the context of different pathologies affecting the sacral nerves, pudendal nerve, and its branches. In this article, the authors provide a review of normal pudendal nerve anatomy, its branching variations, and technical considerations of MRN imaging for its optimal evaluation. Normal and abnormal appearances of the pudendal nerve and its branches are also presented with representative case examples along with pertinent review of the available literature.

Anatomy and variations

The pudendal nerve originates from the sacral nerve roots (S2–S4), and carries sensory, motor, and autonomic fibers. It courses laterally and inferiorly along the anterior border of the piriformis muscle. After it...
passes the antero-inferior margin of the piriformis muscle, it enters the gluteal region. At this level, it accompanies the pudendal artery and vein throughout the remainder of its course (7). It then runs inferiorly and laterally coursing between the sacrospinous ligament (anterior) and the sacrotuberous ligament (posterior). Distal to the inter-ligamentous space, it wraps around the inferior margin of the sacrospinous ligament and runs anteriorly and laterally to enter a confined space under the obturator internus fascia, known as Alcock’s canal (or the pudendal nerve canal) (3). The nerve is usually the posterior-most structure within the canal. Additionally, within the pudendal nerve canal or just before entering it, the pudendal nerve gives rise to inferior rectal branch, which travels horizontally towards the external anal sphincter muscle and distal rectum. The pudendal nerve terminates in the pudendal canal branching into the dorsal nerve of the penis/clitoris and the perineal branches (8) (Fig. 1).

Recently, Furtmüller et al. reported a number of variations during surgical dissections of male and female cadavers (9). These included separate trunks traveling in the inter-ligamentous space or in Alcock’s canal, namely, common rectal-perineal trunk, dorsal-perineal nerve trunk, and rectal-dorsal trunk. In other variations, the inferior rectal nerve(s), perineal branch, or the dorsal nerve originated directly from the sacral plexus. Additionally, the dorsal nerve of penis or clitoris may arise proximal to the inter-ligamentous space and pudendal canal, up to 13 mm proximal to the ischial spine (10). The dorsal nerve then travels an average of 30 mm superior to the plane of the ischial tuberosity and 19 mm inferior to the tendinous arch of the levator ani. It exits by piercing through the inferior fascia of the urogenital diaphragm traversing between the inferior transverse pubic ligament and the pubic arch, on an average 6 mm lateral to the pubic symphysis, to terminate on the dorsum of the penis/clitoris (9).

**Causes of pudendal neuropathy**

Pudendal neuralgia can be caused by a number of etiologies. In a large series of 189 patients diagnosed with pudendal neuralgia, four locations of pudendal nerve entrapment were described (9), namely, the sciatic notch (2.1%), the ischial spine (4.8%), Alcock’s canal (79.9%), and distal branch neuropathy (13%). The etiologies can be further categorized based on location of the lesions along the course of the nerve (11–16):

- Pelvis or sacrum: a tumor or infection can involve sacral nerve or proximal pudendal nerve trunk(s);
- Inter-ligamentous space: nerve injury may be related to fall or the nerve can get entrapped underneath the thickened falciform process of the sacrotuberous ligament;
- Entrance to Alcock’s canal: previous fall or pelvic surgery, e.g. hysterectomy or prior pelvic mesh surgery; under the thickened or tight obturator fascia; prominent varicosities;
- Ischiorectal space: prior hemorrhoidal surgery, ischiorectal abscess or proctocolectomy;
- Alcock’s canal: pubic bone fracture;
- Inside the pubic canal: birth trauma or cycling;
- Pubic symphysis area: trauma, penile fracture, or surgery.

In addition to the above, Tarlov cysts may also compress the nerve roots, or radiation therapy to the pelvis may affect the contributing sacral nerve roots or the nerve itself. In the authors’ experience, the most common cause of pudendal neuralgia appears to be

![Fig. 1. Illustrations (a, b) showing normal pudendal nerve and its branches.](image-url)
Clinical findings

Pudendal neuralgia is a painful condition and the patients commonly present with genital numbness and erectile dysfunction (14,15). The pain is usually unilateral but quite commonly spreads bilaterally involving the deep pelvis, and there is often worsening of the pain during sexual intercourse (18). In a recent article by Prologo et al., patients with pudendal neuralgia described the pain in a variety of ways as burning, pulling, crushing, pressure, and throbbing (19).

On physical examination, the pudendal neuralgia may be elicited by direct pressure on the ischial spine and inferomedial to the sciatic notch (20). Tenderness can be elicited on direct palpation of the obturator internus muscle or by passive internal and external rotation of the hips (3). The Nantes criteria have been proposed for the diagnosis of pudendal neuralgia (2). The inclusion criteria consist of: pain in the area innervated by the pudendal nerve, extending from anus to clitoris (or penis); pain more severe when sitting; pain that does not awaken patient from sleep; pain with no objective sensory impairment; and pain relieved by diagnostic pudendal block. The exclusion criteria include: purely coccygeal, gluteal, or hypogastric pain; exclusively paroxysmal pain; exclusive pruritus; and presence of other non-pudendal imaging abnormalities able to explain the symptoms. To be diagnosed with pudendal neuralgia, a patient must exhibit all five inclusion criteria and also demonstrate absence of all exclusion criteria.

Diagnostic evaluation

Pudendal neuropathy may be overlooked due to many diagnostic confounders, such as pelvic floor dysfunction, chronic prostatitis, interstitial cystitis, vulvodynia, coccydynia, hemorrhoids, ischial bursitis, and orchialgia (18,21). To make an accurate diagnosis, the clinician requires a good clinical history, physical examination, and exclusion of other causes of pelvic pain. This is supplemented by use of different diagnostic modalities, such as pudendal nerve terminal motor latency testing (PNTML), electromyography (EMG), and MRN (4,22,23). PNTML and EMG have questionable value in the diagnosis of pudendal neuropathy. EMGs are not specific for patients with pudendal neuralgia and may give abnormal results in the case of sacral radiculopathy or other upstream pathologies. The PNTML test examines only the motor function and cannot provide any direct evidence of sensory nerve damage (24).

MRN imaging: technical considerations

With the development of new advances in MRI dedicated to evaluation of peripheral nerves, also known as MRN, detailed assessment of anatomy and pathology of sacral nerves, pudendal nerve, and its branches is possible with superior resolution (25–27). MRN as opposed to conventional MRI affords superior resolution for delineation of fascicular detail and encompasses pulse sequences that allow uniform fat suppression, vascular signal suppression, diffusion imaging and three-dimensional (3D) imaging (28–30). MRN can supplement the information gained from clinical and electrodiagnostic findings because it is able to detect the normal and abnormal appearance of the major nerves, as well as the surrounding soft tissue pathologies (31). The pudendal nerve is small and therefore, its evaluation is frequently limited due to poor spatial resolution and signal to noise ratio (SNR) on wide field-of-view imaging, inhomogeneous fat suppression, nerve branching variations, and surrounding vessels, especially in the setting of pelvic venous congestion. Prior imaging techniques were limited to thick slice (5–6 mm with 10–20% interslice gap) T1-weighted (T1W), fat suppressed T2-weighted (T2W), and STIR (short tau inversion recovery pulse sequences) (3). Using MRN, the nerve can be displayed in superior resolution, in multiple planes, and in both anatomic and diffusion contrasts (4). The MRN protocol dedicated to pudendal nerve evaluation in our institute is highlighted in Table 1 (MR scanner: Achieva, Ingenia, Philips, Best, The Netherlands). Generally, 3T MRN provides better SNR as compared with the 1.5T machine and both two-dimensional and 3D imaging evaluation of the pudendal nerve and its branches is accomplished within approximately 25 min. The anterior torso XL coil, preferably multi-transmit coil, is used for imaging. Using 4 mm slice thickness and 10% gap with higher matrix (>256), one can assess the fascicular structure of the nerve. The fat saturation on T2W imaging is accomplished using spectral adiabatic inversion recovery (SPAIR) or modified (m) Dixon technique. T2 SPAIR imaging mitigates pulsation and breathing artifacts, which are common with mDixon imaging.
However, the latter can provide multiple maps, such as in-phase, opposed phase, water, and fat maps (32). Keeping the echo time about 60–65 ms for fat suppressed T2W imaging provides optimal SNR while enhancing the signal of endoneurial fluid in the nerve. Since many of these patients present with non-specific clinical findings and many also have lower back pain, in our institute, we perform complete lumbosacral plexus (LS) examination (total time 45–50 min) in most cases. The LS plexus MRN evaluation in addition includes lumbosacral spine evaluation with axial and sagittal T2W imaging, and axial T1W and T2 SPAIR in the upper abdomen. The 3D imaging field of view extends from the L2 level to the lesser trochanters and from the anterior to posterior skin, while keeping the isotropic resolution of 1.5 mm. This evaluation aids in assessment of the LS spine, LS plexus nerves, sciatic, femoral, ilioinguinal, iliohypogastric, and genitofemoral nerves. Intravenous contrast administration is reserved for patients with an underlying history or suspicion of infection or malignancy.

### Imaging evaluation

Axial T1W and T2 SPAIR (T2mDixon) images are evaluated together for the identification of anatomy and pathology (4). In the initial assessment, the reader should focus on the potential findings of injury or entrapment, such as focal scarring, thickened sacrotuberous or sacrospinous ligaments, thickened obturator fascia, perineal scarring, fracture deformity of the pubic rami or the sacrum, and any mass lesion. Thereafter, the major peripheral nerves of pelvis are evaluated on 3D imaging technique with thick slab maximum intensity projections (MIP) for signal and caliber symmetry. The normal sacral ganglia are twice as bright as the distal nerve root exiting the neural foramina and the bilateral sacral nerves show symmetrical appearance in signal and size (33). The pudendal nerves are best seen on axial images along the distal edge of piriformis muscle entering the interligamentous space at the ischial spine (4,5). The nerve is intermediate signal intensity at this point and shows a fascicular appearance, which helps in differentiation of the nerve from the adjacent vessels in the neurovascular bundle. The nerve usually starts branching distal to this point and can sometimes show different variations as described above.

Filler showed that the presence of pudendal nerve or rectal branch hyperintensity along the medial border of the obturator internus or proximal to its entrance to the Alcock’s canal is a useful indicator of neuropathy (34). In the authors’ experience, as the nerve enters Alcock’s canal under the obturator fascia, minimal hyperintensity on T2W images is not uncommon due to the magic angle artifact. The inferior rectal branch can be seen coursing in a curved manner in the ischiorectal fat plane with or without associated veins. When the axial images are evaluated with diffusion tensor imaging (DTI), the normal and abnormal nerve can be easily identified, as DTI suppresses the venous signal and isolates the nerve in difficult cases. The inferior rectal branch can arise before or after the pudendal nerve enters Alcock’s canal. Within Alcock’s canal, one or multiple nerve trunks can be identified. Distal perineal branches are difficult to identify due to their small size and frequent presence of pelvic venous congestion in affected cases (35). The intermediate signal dorsal nerve of the clitoris or penis is identified immediately under the pubic symphysis on either side following the respective viscera (Fig. 2). 3D imaging is quite useful in evaluation of larger nerves in the lumbosacral plexus (26,36), although in the authors’ experience, it is limited for pudendal nerve evaluation due to small size and adjacent incomplete venous signal suppression despite the use of motion sensitive driven equilibrium pulse. However, in a few cases, it can depict the course and caliber alterations associated with pudendal pathology.

### Table 1. 3 Tesla MRN imaging parameters

<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>Slice (mm)</th>
<th>Matrix</th>
<th>FOV/Other</th>
<th>Time of acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial T2 SPAIR or T2 mDixon</td>
<td>5320</td>
<td>63</td>
<td>4.0</td>
<td>320 × 256</td>
<td>L5–S1 level to lesser trochanters</td>
<td>5 min 30 s</td>
</tr>
<tr>
<td>Axial T1W</td>
<td>710</td>
<td>8.7</td>
<td>4.0</td>
<td>320 × 256</td>
<td>L5–S1 level to lesser trochanters</td>
<td>5 min 10 s</td>
</tr>
<tr>
<td>Axial DTI</td>
<td>7100</td>
<td>83</td>
<td>4.0</td>
<td>128 × 128</td>
<td>L5–S1 level to lesser trochanters</td>
<td>6 min 20 s</td>
</tr>
<tr>
<td>Coronal 3D SPAIR TSE</td>
<td>2000</td>
<td>78</td>
<td>1.5</td>
<td>1.5 mm isotropic voxel</td>
<td>L2–3 to lesser trochanters</td>
<td>8 min</td>
</tr>
</tbody>
</table>

3D, three-dimensional; b, diffusion moment; DTI, diffusion tensor imaging; FOV, field of view; MSDE, motion sensitive driven equilibrium; SPAIR, spectral adiabatic inversion recovery; STIR, short tau inversion recovery; TE, echo time; TR, repetition time.
Combined evaluation on anatomic and diffusion-weighted imaging is useful in the detection of various pathologies related to pudendal neuralgia. Perineural scarring (strand-like hypointensities along the course of the nerve) can be differentiated from vessels, since vessels are bright on T2W images and are suppressed on high b values of DTI. One can differentiate the bright nerve from normally hyperintense vessel as the nerve shows a fascicular appearance and is intermediate in signal unless abnormal. Tortuosity of vessels in the vicinity of the pudendal nerve or Alcock’s canal has been reported as an abnormal finding in patients with pudendal neuralgia (3). However, in the authors’ experience, it is quite common to find pelvis-venous congestion in pelvic pain patients and it is not clear whether this finding is related or unrelated to pudendal neuralgia. The pathologic findings of the pudendal and its branch neuropathy include alterations in signal or contour of the nerve, prominence of fascicles and/or encasement in scarring. Other suggestive findings include perineural pathology, such as thickened obturator fascia, thickening of the sacrotuberous or sacrospinous ligaments from prior injury, and prior intervention related perineural scar tissue and pubic fracture (37).

The sacral nerves and adjacent piriformis muscle should be evaluated when looking for pudendal nerve abnormality. Increased signal or size of the sacral nerves is seen in lumbosacral plexopathy (usually bilateral), injury (bony fracture, trauma history, adjacent muscle strains), or perineural malignancy (nodular

**Fig. 2.** Normal pudendal nerve anatomy. Axial T1W (a, d) and T2 SPAIR (b, c, e, f) images demonstrate the normal appearance of the pudendal nerve (arrows) at the ischial spine (a, b), Alcock’s canal (c, d) and its branches, i.e. inferior hemorrhoidal nerves (e) and perineal branches (f). Notice the intermediate signal of the normal nerves with the main trunks are best seen on T1W images and smaller branches are best seen on T2W images.

**Fig. 3.** Sacral and pudendal neuropathy. A 40-year-old man presents with right pelvic and gluteal pain following a fall. Coronal (a) 3D IR TSE axial image shows abnormal asymmetrical thickening and hyperintensity of the right sacral nerve roots (long arrows) as compared to the left (small arrows). Axial T2 SPAIR images (b, c) show grade I strains in bilateral piriformis muscles (right > left, arrows). The right pudendal nerve is asymmetrically prominent and hyperintense as compared to the left (arrows).
thickening and contrast enhancement), which may cause pudendal symptoms (Fig. 3). Since the most common cause is traction neuropathy, increased signal and prominence of the nerve is seen at the ischial spine (3). It is not uncommonly seen as a bilateral finding. DTI aids in finding the nerve signal alteration as it makes it conspicuous on the trace images due to suppression of the surrounding fat, muscle, and vascular signal. The downstream neuropathy changes could be seen extending into the pudendal canal (Fig. 4). The distal perineal or hemorrhoidal branches when entrapped in the pelvic floor scarring, become prominent and therefore, can be identified on the T2W and DTI images. The dorsal nerve of penis or clitoris can be seen as asymmetrically prominent or hyperintense due to genital inflammation or prior injury (Suppl. Figs. 1–4). These findings should be carefully correlated with the clinical picture and if concordant, image guided injections can be planned and performed to help the patient (3,17). There is limited literature describing imaging evaluation of these small branches of the pudendal nerve. If imaging confirms the neuropathy, pudendal injection is performed as a confirmatory diagnostic test or for therapeutic benefit. If imaging shows a normal nerve, further diagnostic injection can still be attempted if there is persistent strong clinical suspicion of neuropathy (38). However, if the diagnostic injection does not provide the needed pain relief in the latter case, the diagnosis of pudendal neuralgia should be abandoned (3).

Finally, MRN is helpful to find other confounding causes of pelvic pain, such as endometriosis, genitofemoral neuropathy, ilioinguinal neuropathy, and other unsuspected pelvic mass lesions (19).

Fig. 4. Pudendal nerve re-entrapment neuropathy. A 34-year-old man with history of prior multiple surgeries for pudendal neuropathy, complaining of persistent right sided pelvic pain and numbness. Axial T1W images (a, c) and axial T2 SPAIR (b, c) images show postoperative scarring from partial ligament resections on both sides (right > left) and increased signal of the pudendal nerves bilaterally with more prominence on the right (long arrows) as compared to the left (small arrows). The right pudendal nerve abnormality is conspicuous on DTI trace images (e, f; arrows, b value-600) with effective vascular and muscle signal suppression, correlating with patient's symptoms.
Treatment

Pudendal neuralgia is a painful disease and timely treatment is essential before it worsens to peripheral, segmental, or central sensitization stages. Initial treatment is conservative and is primarily physiotherapy (including the use of biofeedback, myofascial release, manual connective tissue techniques, and vaginal dilators), and oral, rectal, and vaginal medications (39). A physician can also consider trigger point injections or botox injections as needed to help address pelvic floor muscular over-activity. Female pelvic pain shows a significant rate of spontaneous symptom remission in women over the years following presentation (40). Integrating physical and psychosocial treatments is likely to produce the best results for both men and women.

As a complement to conservative measures, nerve blocks can be performed as both a diagnostic and therapeutic measure by injection of perineural local anesthetic, hyaluronidase, and steroid (3). These can alleviate the symptoms temporarily and the patient may get enough pain relief to resume normal daily functioning. Image-guided pudendal blocks provide direct visualization of the nerve and can be used to target the nerve at various levels: as it passes between the sacropinous and sacrotuberous ligaments, at the ischial spine, and in Alcock’s canal (8,17). In recalcitrant cases or fading response to conservative treatment, surgery can be performed via transgluteal, perianal, laparoscopic, or transperineal approaches to decompress the nerve (24). Branch nerve resection is performed in the setting of neuroma while neurolysis with ligament resection is performed in the setting of entrapment or perineural scarring (41). Re-entrapment neuropathy can also occur following surgery and imaging plays an important role in the detection of iatrogenic nerve injury or entrapment related to perineural scarring (42,43). Pulsed radio frequency and cryotherapy has also been used as another option for intractable cases or following successful injections as a long-term measure for pain relief (19,44).

In conclusion, pudendal neuralgia can be seen with numerous etiologies and the diagnosis is challenging. High-resolution MRN examination may be used to confirm the diagnosis of pudendal neuropathy, guide perineural injections, and exclude other confounding causes of pelvic pain syndrome.

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