The Hitchhikers Guide to the Lumbosacral Plexus

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2016-2017 UCSD MSK Fellow

Objectives

- Review the anatomy of the lumbosacral plexus and relevant lower extremity nerves.
- Better understand the sometimes complex pelvic courses of nerves.
- Familiarize with lumbosacral MR neurography (LS MRN) protocols and approaches to interpretation.
- Explore samples of potential pathological processes in the lumbosacral plexus.

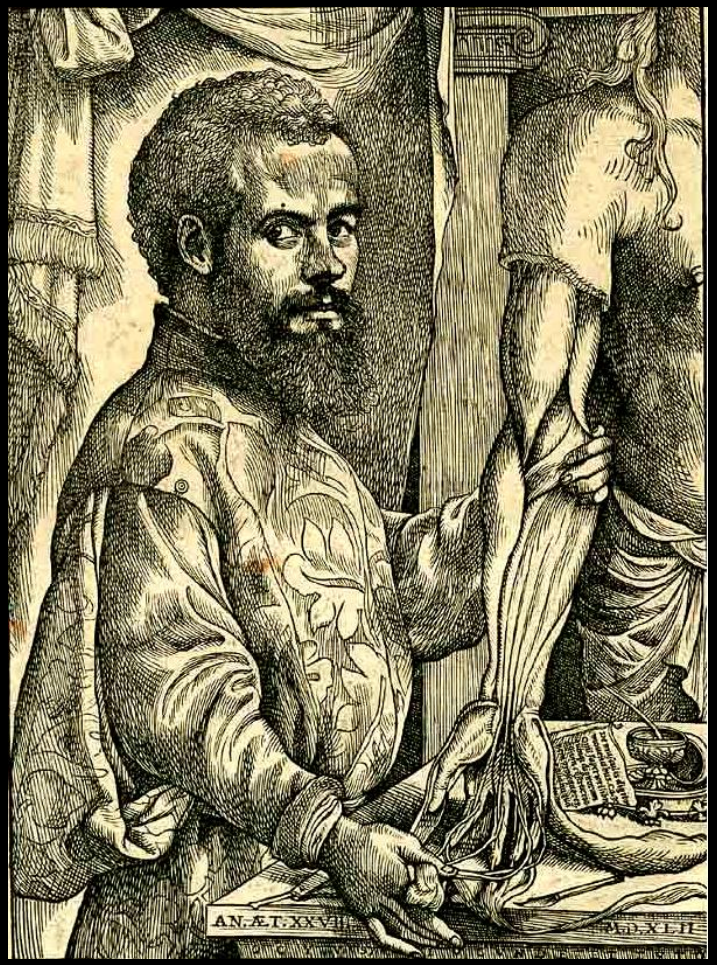
Quote

“All you really need to know for the moment is that the universe is a lot more complicated than you might think, even if you start from a position of thinking it’s pretty damn complicated in the first place.”

Some might say the same about the LS plexus, but as we will see, there is nothing to panic about.

Brief History of Nerves

- Etymology:
  - Latin nervus "sinew, tendon; cord, bowstring." (1)
- 4th Century BC, Aristotle (Greek) believed that nerves were controlled by and originated in the heart.
- 2nd Century AD, Galen (Roman) concluded that the brain was the most important organ of the body, with the nerves emanating from it. Came to this conclusion via dissection. Also thought soft and hard nerves for sensation and motion and that nerves must be hollow.



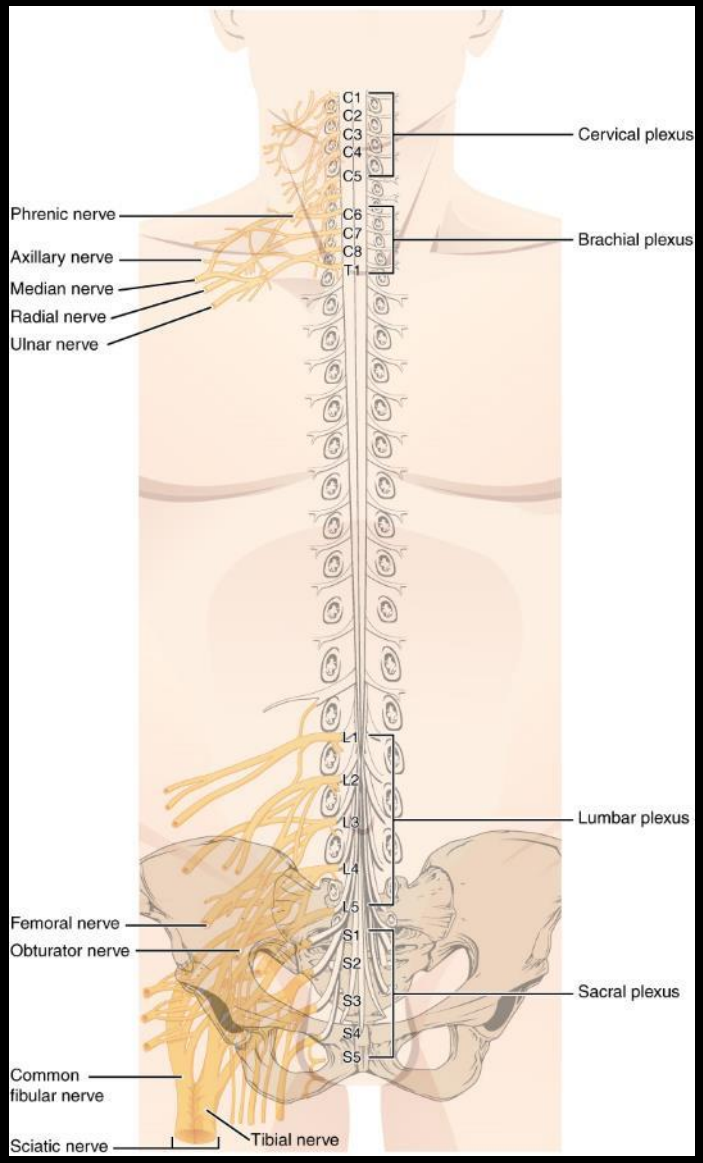
Andreas Vesalius

Nerve Plexuses

Latin for “braid”

4 major plexuses in the body:

- Cervical
- Brachial
- Lumbar
- Sacral

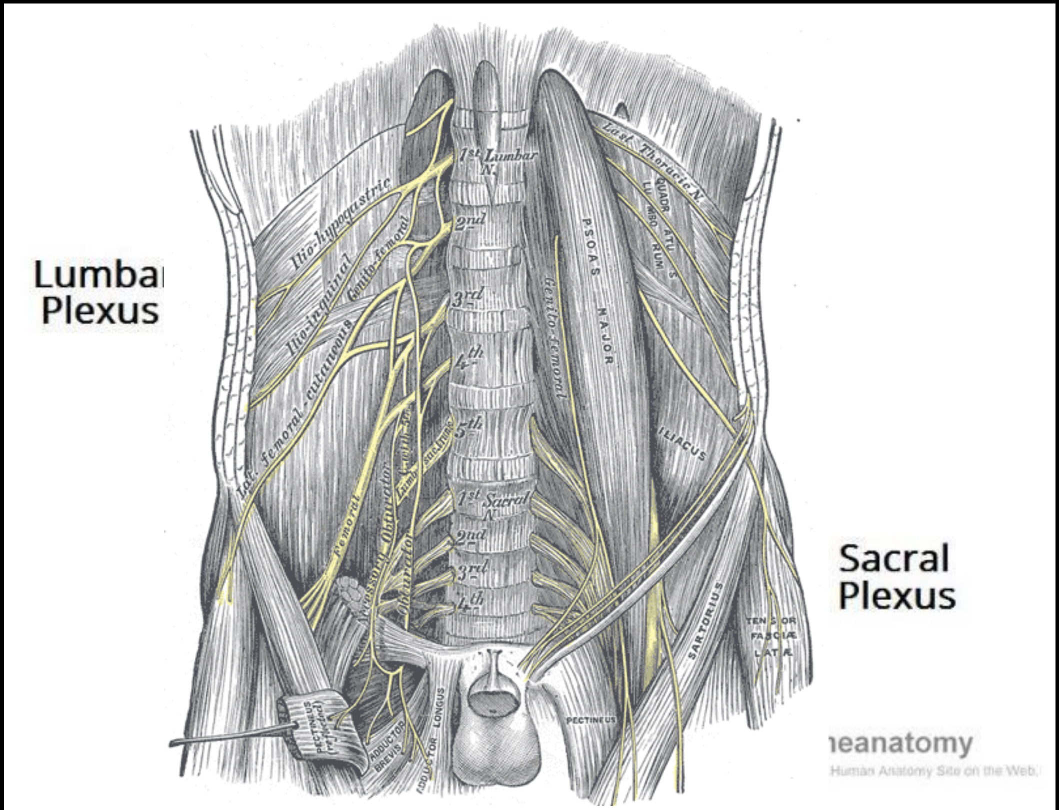


https://upload.wikimedia.org/wikipedia/commons/thumb/f/f3/1321_Spinal_Nerve_Plexuses.jpg/320px-1321_Spinal_Nerve_Plexuses.jpg

Anatomy

"Lumbosacral" Plexus

- Lumbar Plexus
- Sacral Plexus
  - Lumbosacral Trunk
  - Pudendal Plexus



http://accessphysiotherapy.mhmedical.com/data/Multimedia/grandRounds/lumbar/media/lumbar_print.html

Anatomy

Lumbar Plexus (T12)L1-L4

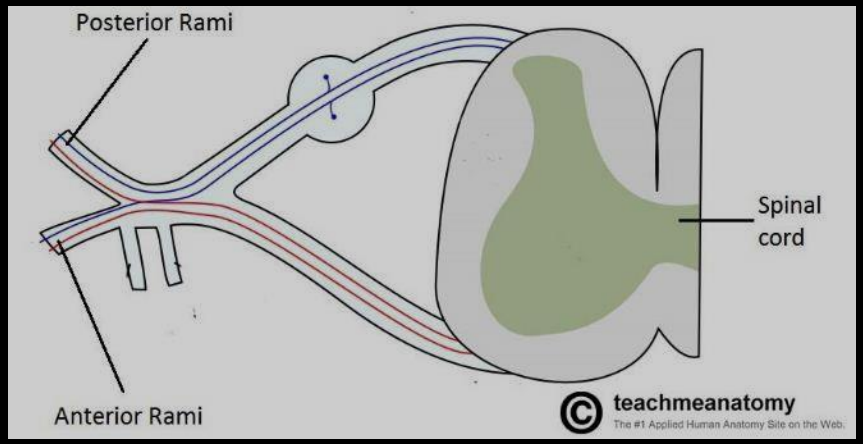
- Branches
  - Iliohypogastric
  - Ilioinguinal
  - Genitofemoral
  - Lateral femoral cutaneous
  - Femoral
  - Obturator
    - Accessory obturator (8-29%)

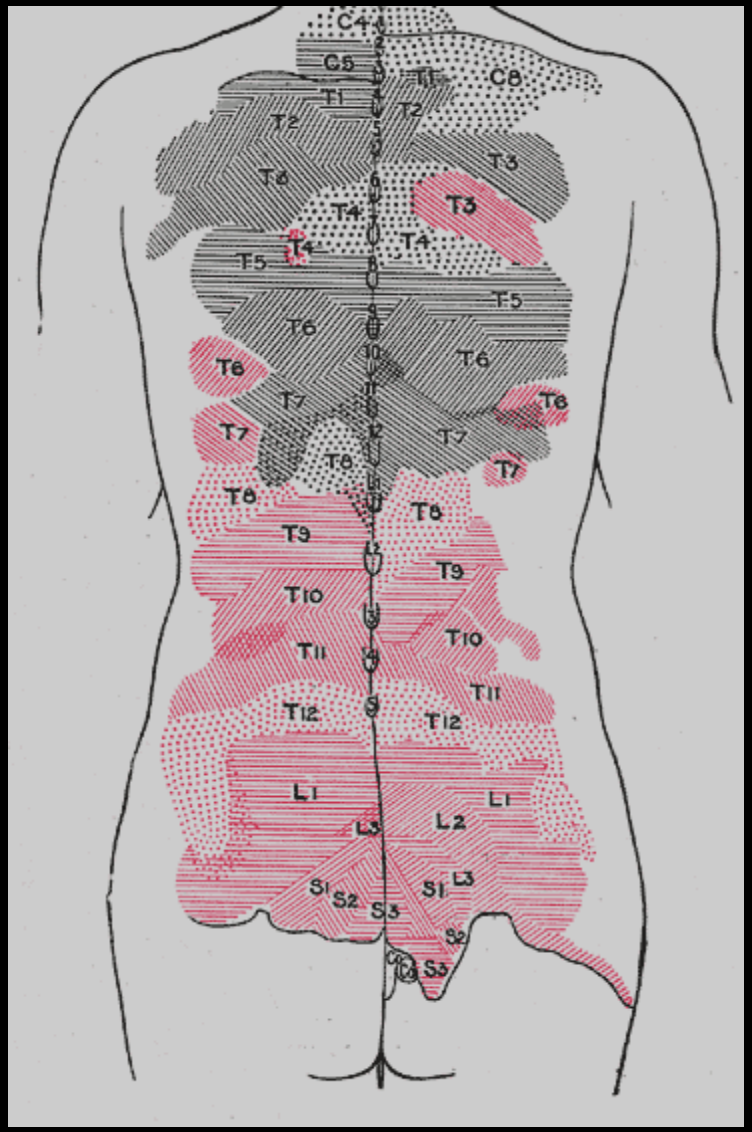
Sacral Plexus (L4-S4)

- Branches
  - Superior Gluteal
  - Inferior Gluteal
  - Sciatic
    - Tibial
    - Common Peroneal
  - Posterior Femoral Cutaneous
  - Pudendal

Anatomy

- The lumbar and sacral plexuses arise from the ventral rami of the spinal nerves L1-L4 and L4-S4, respectively.



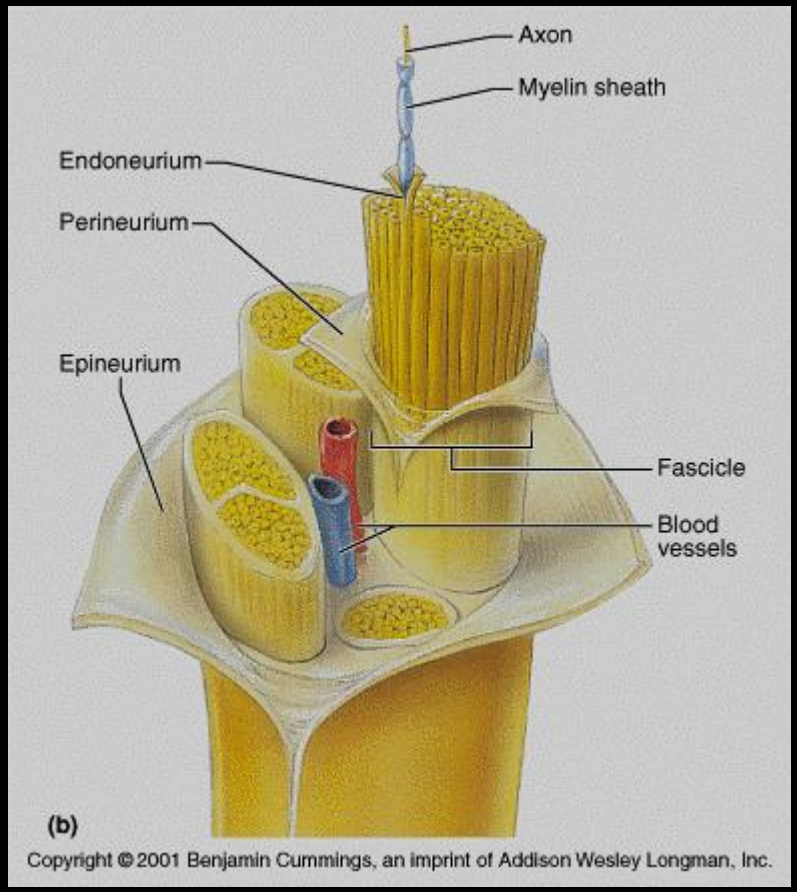


http://teachmeanatomy.info/lower-limb/nerves/lumbar-plexus/

https://upload.wikimedia.org/wikipedia/commons/d/d1/Gray802.png

Anatomy

- Neuron
  - Axon
  - Myelin
- Connective tissues
  - Endoneurium
  - Perineurium (surrounds fascicles)
  - Epineurium (also surrounds blood vessels)



http://www.lrn.org/Popup/Nervous/figure7_10.html

Anatomy

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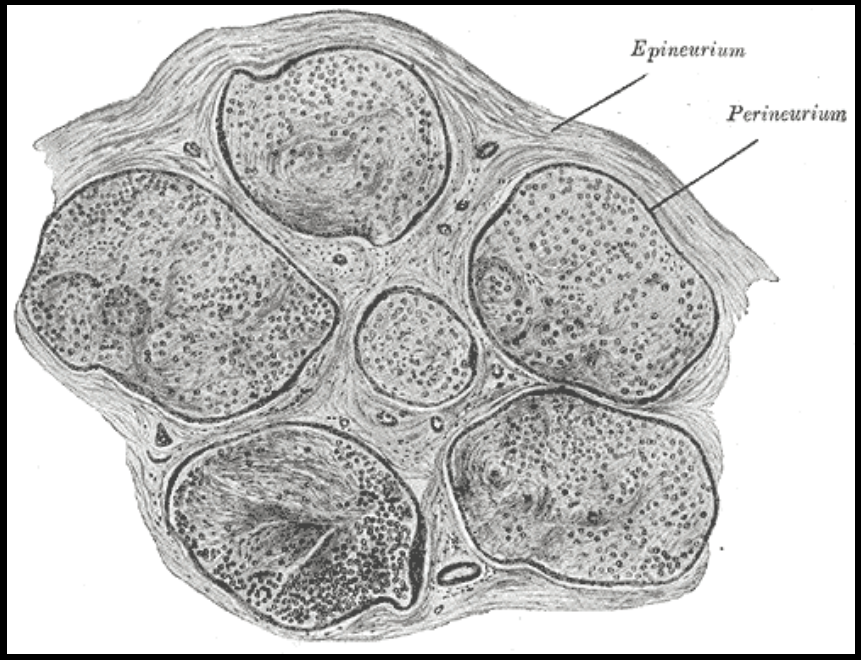

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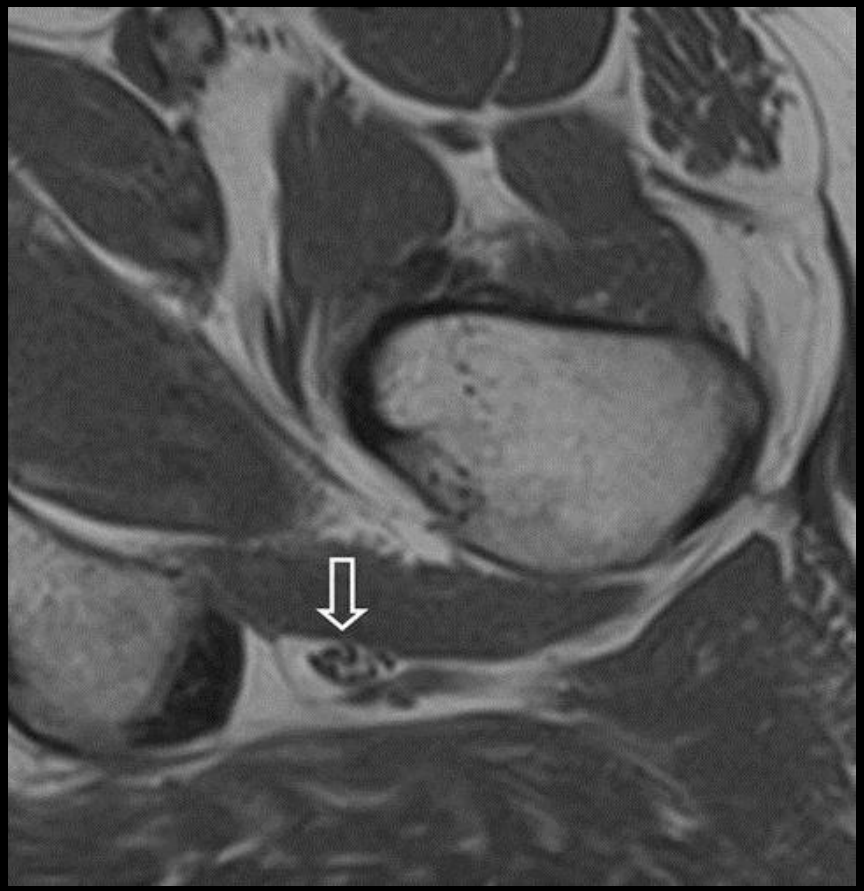
Anatomy



Catherine N. Petchprapa, Zehava Sadka Rosenberg, Luca Maria Sconfienza, Conrado Furtado A. Cavalcanti, Renata La Rocca Vieira, and Jonathan S. Zember. MR Imaging of Entrapment Neuropathies of the Lower Extremity. RadioGraphics 2010 30:4, 983-1000

Anatomy

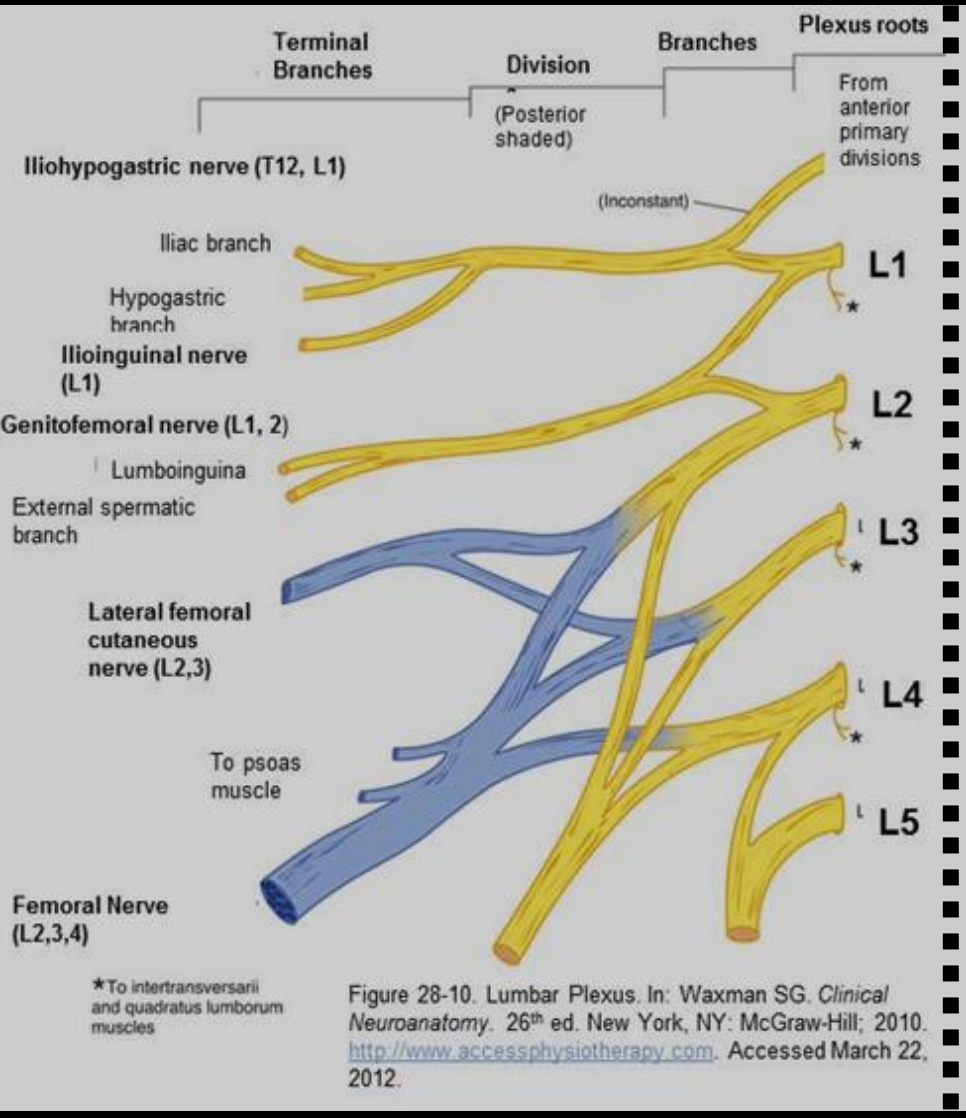
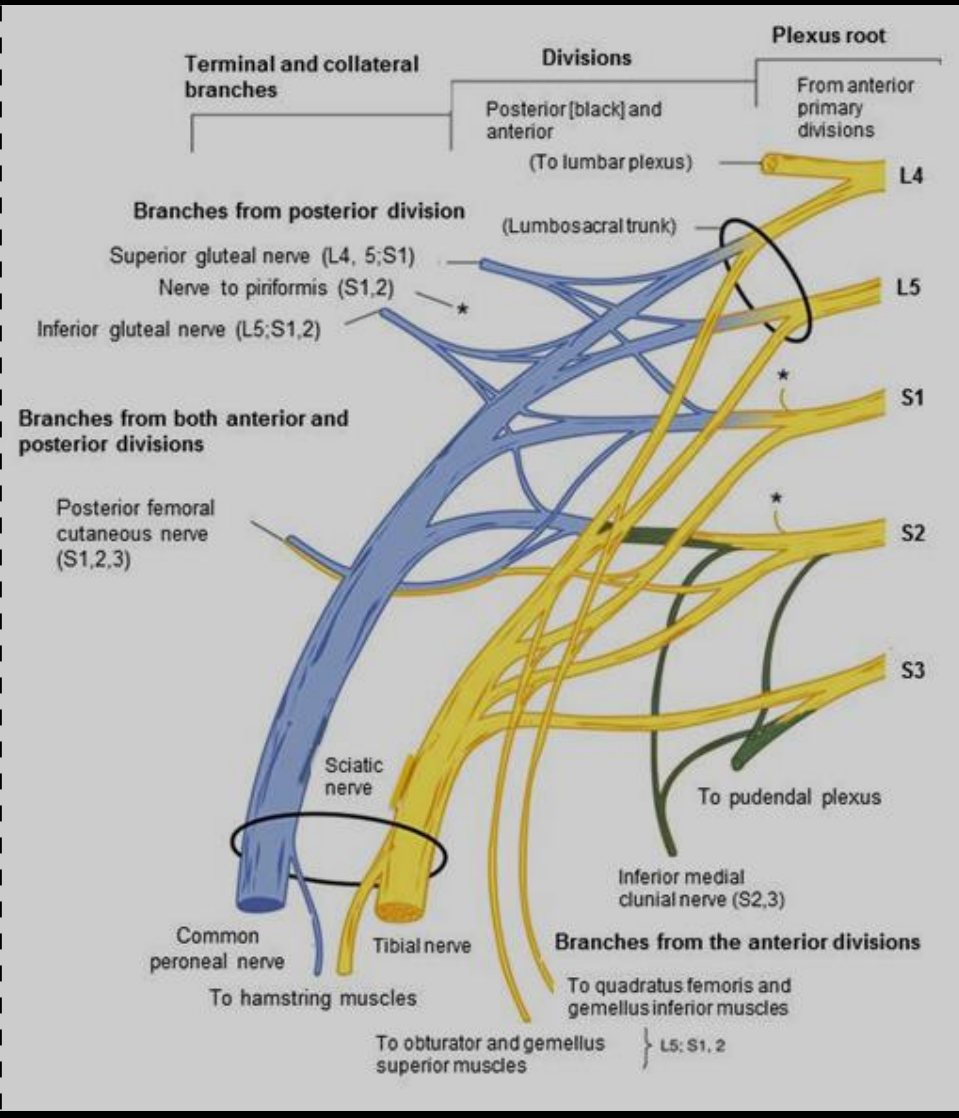


Figure 28-10. Lumbar Plexus. In: Waxman SG. *Clinical Neuroanatomy*. 26th ed. New York, NY: McGraw-Hill; 2010. http://www.accessphysiotherapy.com. Accessed March 22, 2012.



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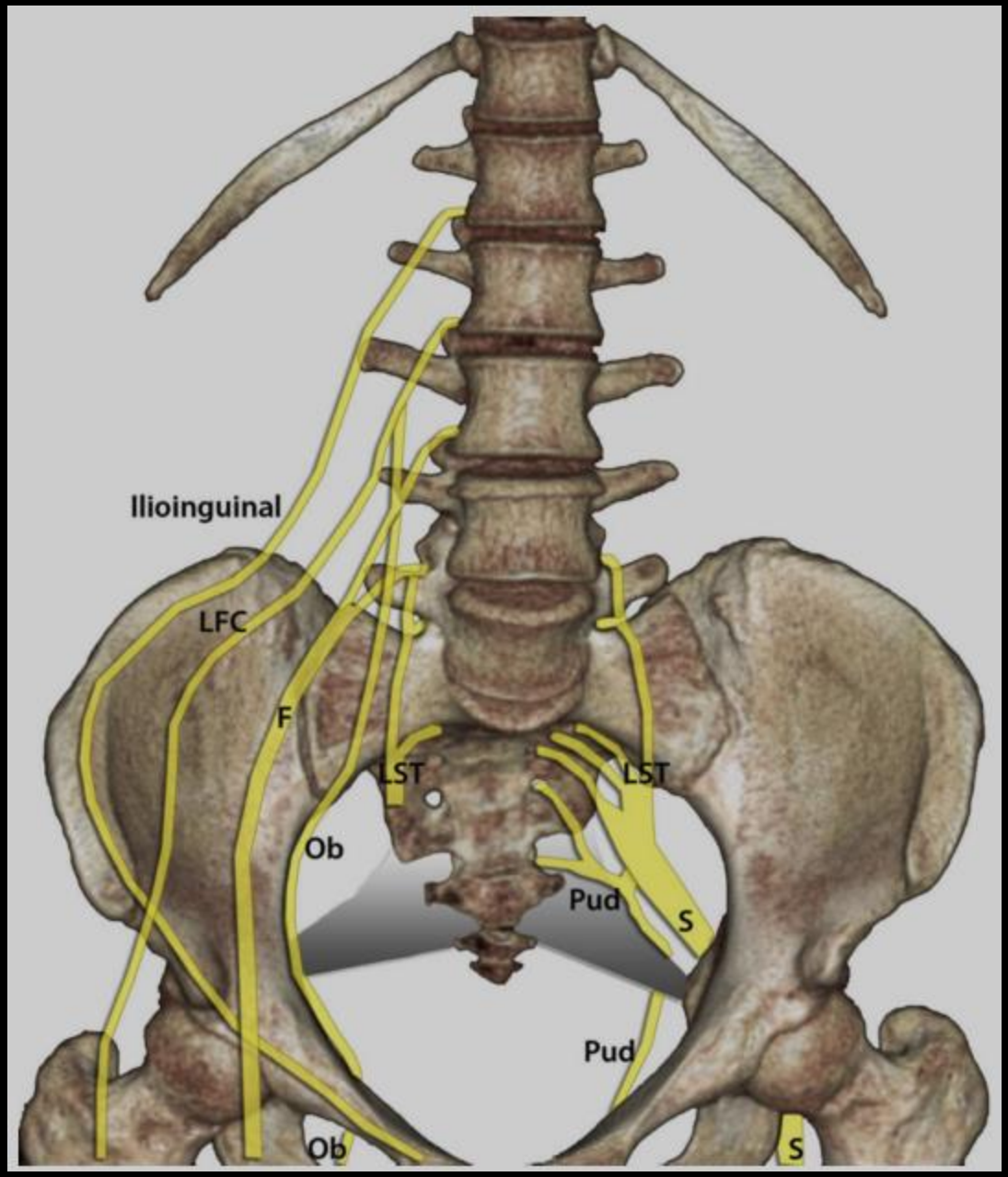

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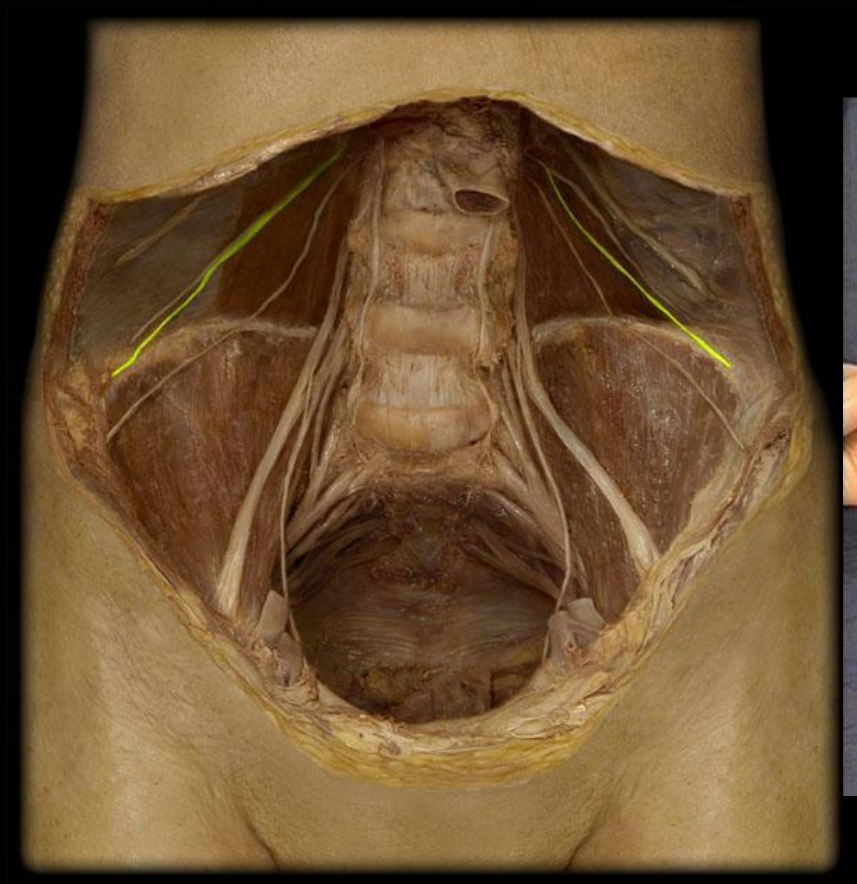
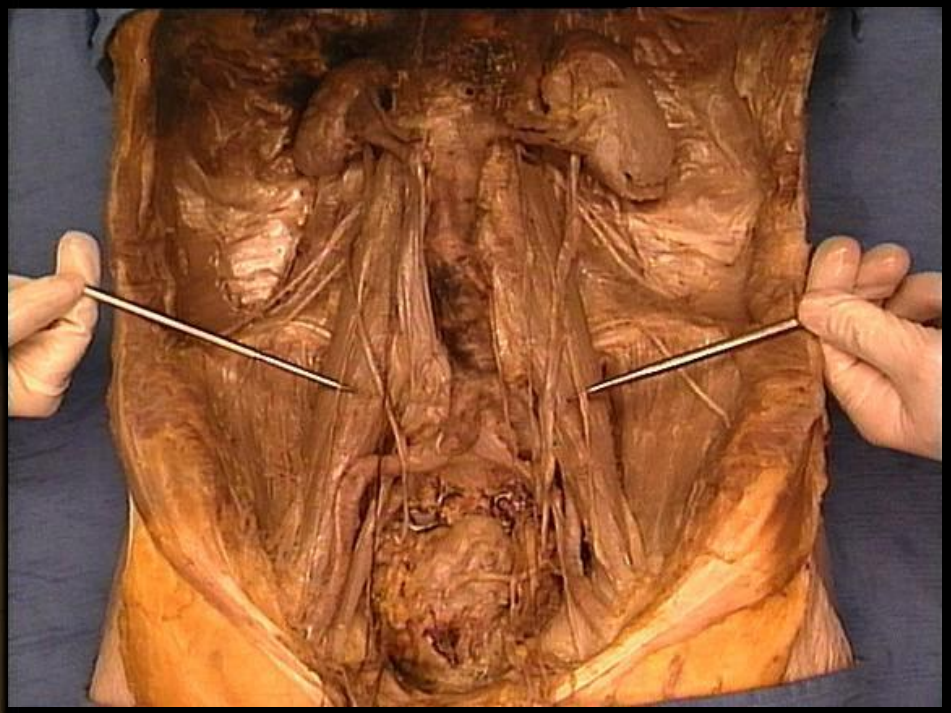
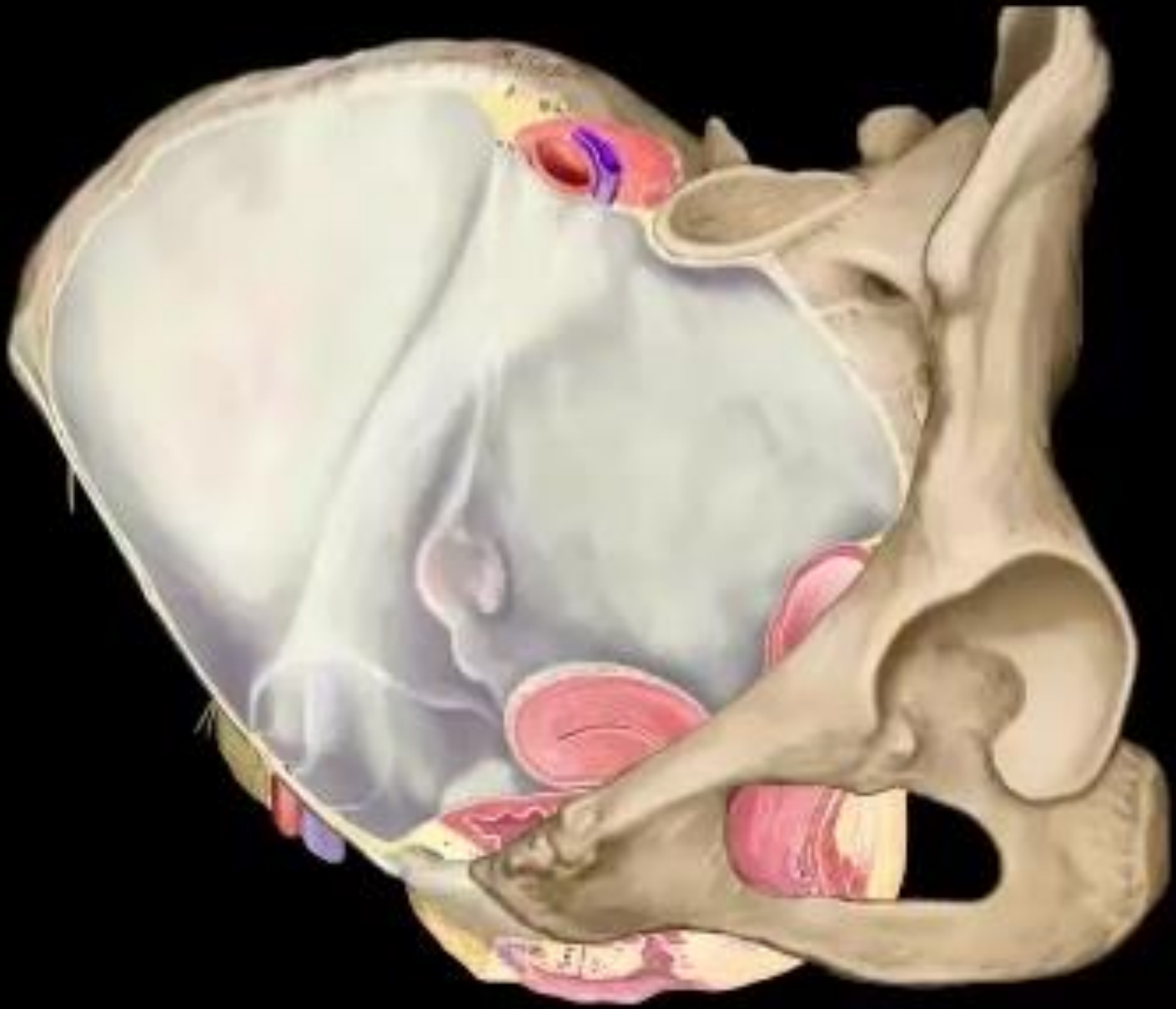
Anatomy

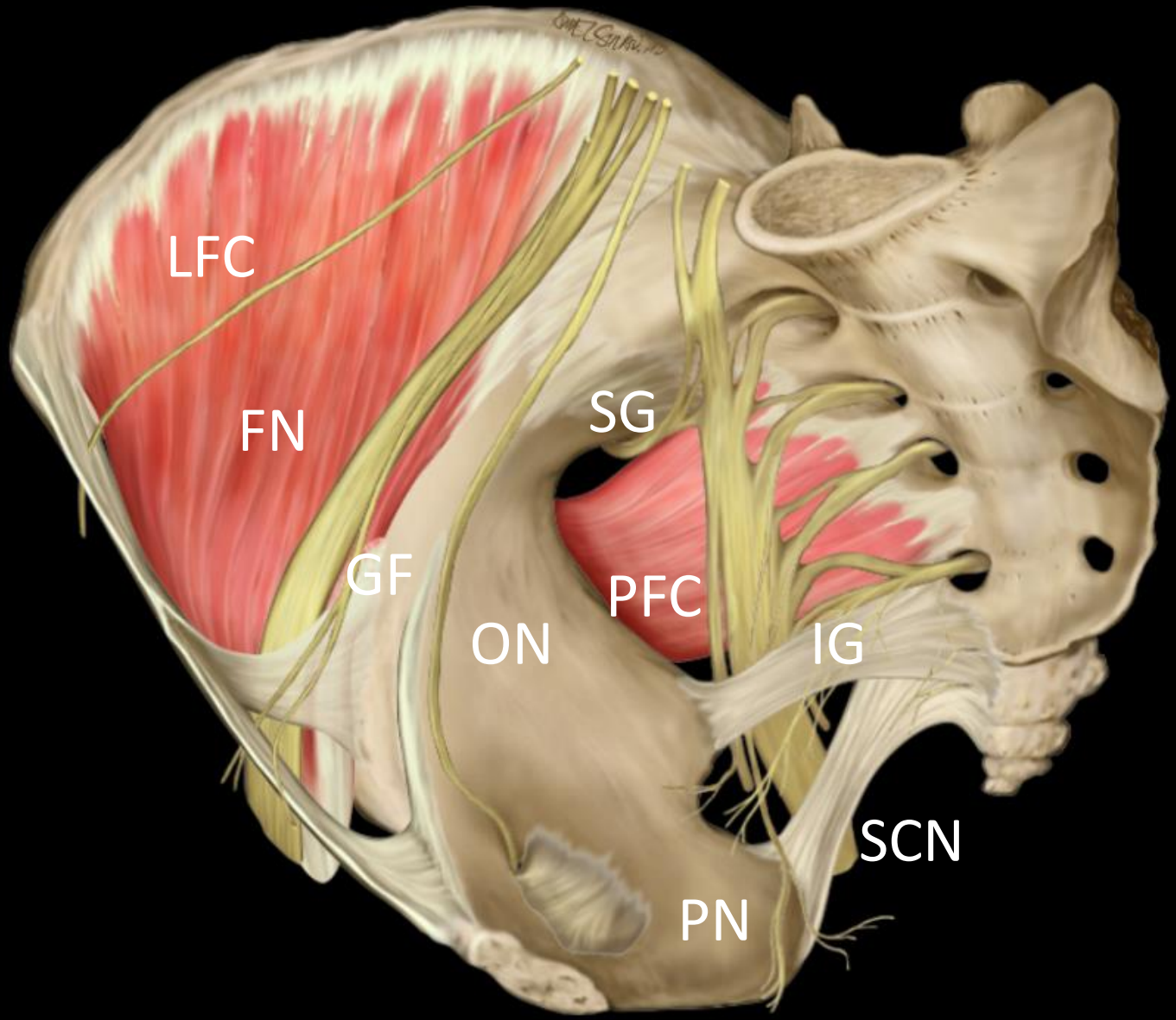




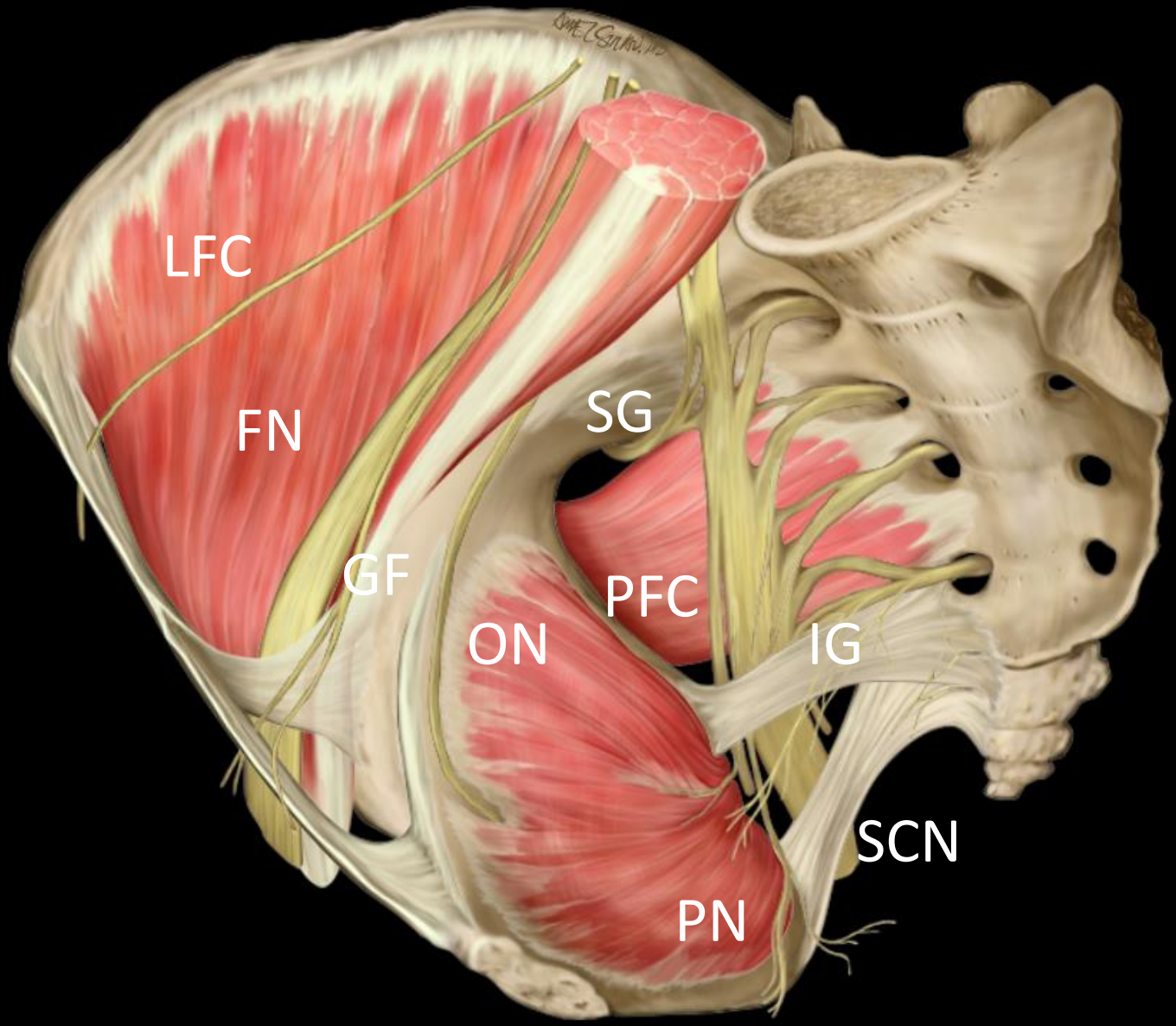
https://www.studyblue.com/notes/note/n/nervous-system/deck/2659341

http://act.downstate.edu/courseware/haonline/labs/l40/170203.htm





https://www1.columbia.edu/sec/itc/hs/medical/anatomy_resources/anatomy/pelvis/index.html



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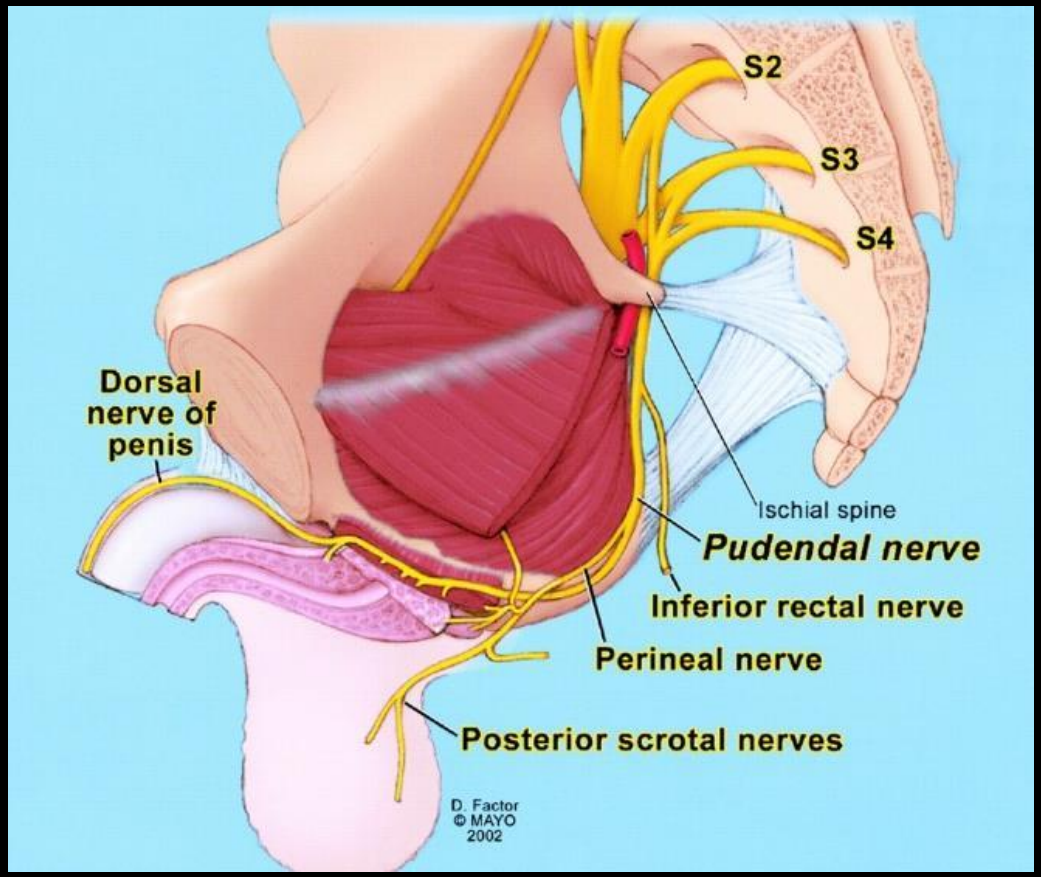
Anatomy

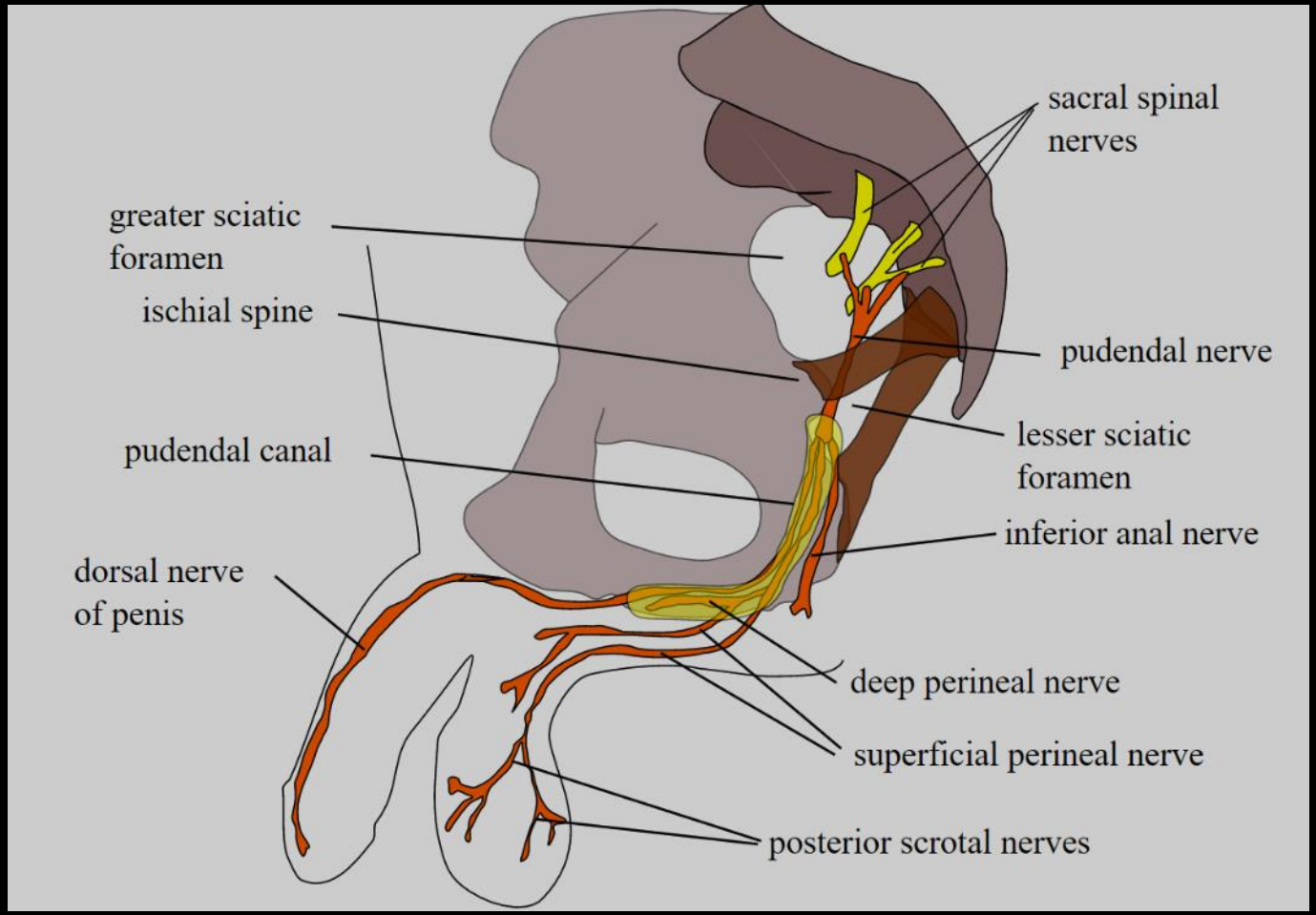
Pudendal Plexus (S2-S4)

- Perforating cutaneous
- Pudendal
- Visceral
- Muscular
- Anococcygeal*



http://www.pudendalhope.info/node/13

Pudendal (Alcocks) Canal



https://en.wikipedia.org/wiki/Pudendal_canal

Pudendal (Alcocks) Canal

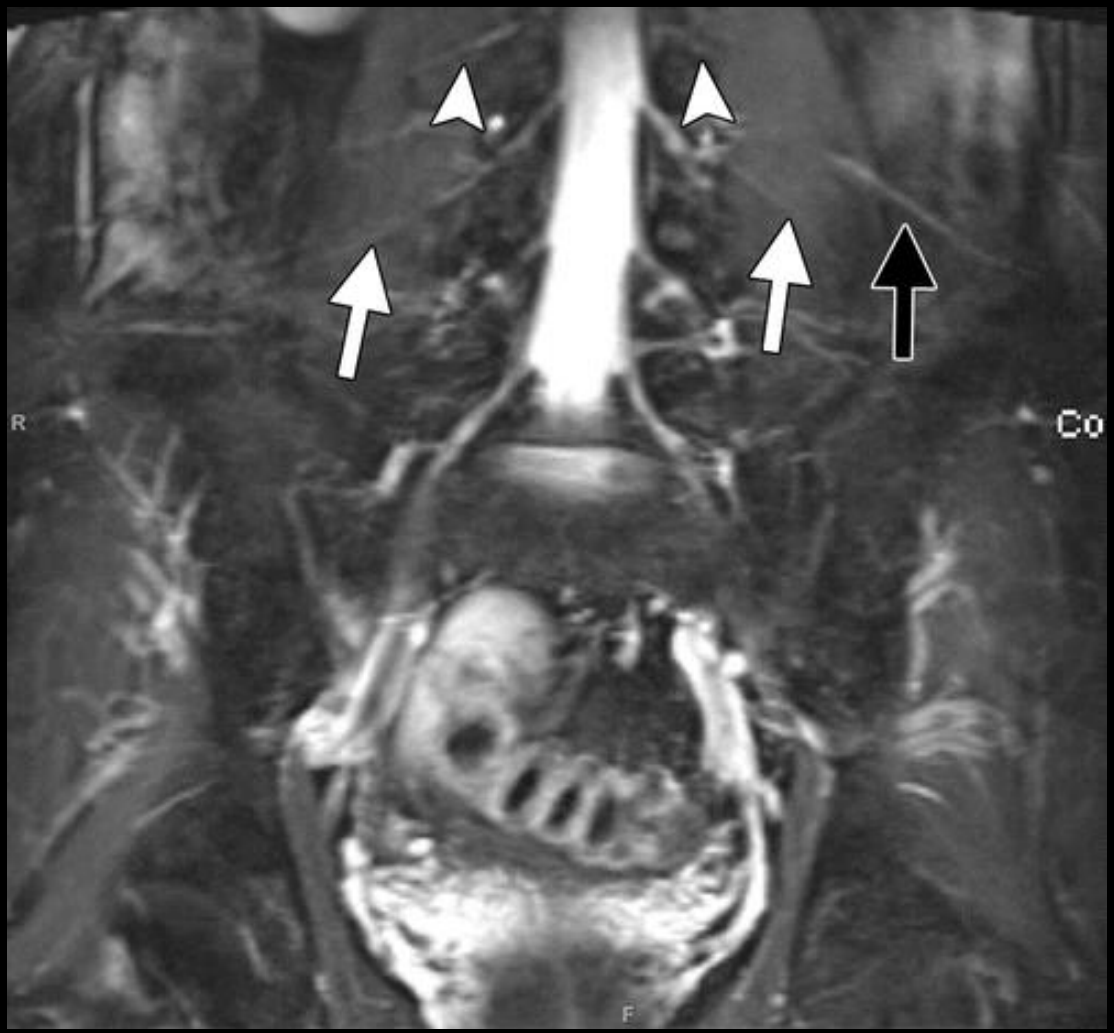
Reference for images

Normal

Iliohypogastric

Ilioinguinal

Lateral Femoral Cutaneous



Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

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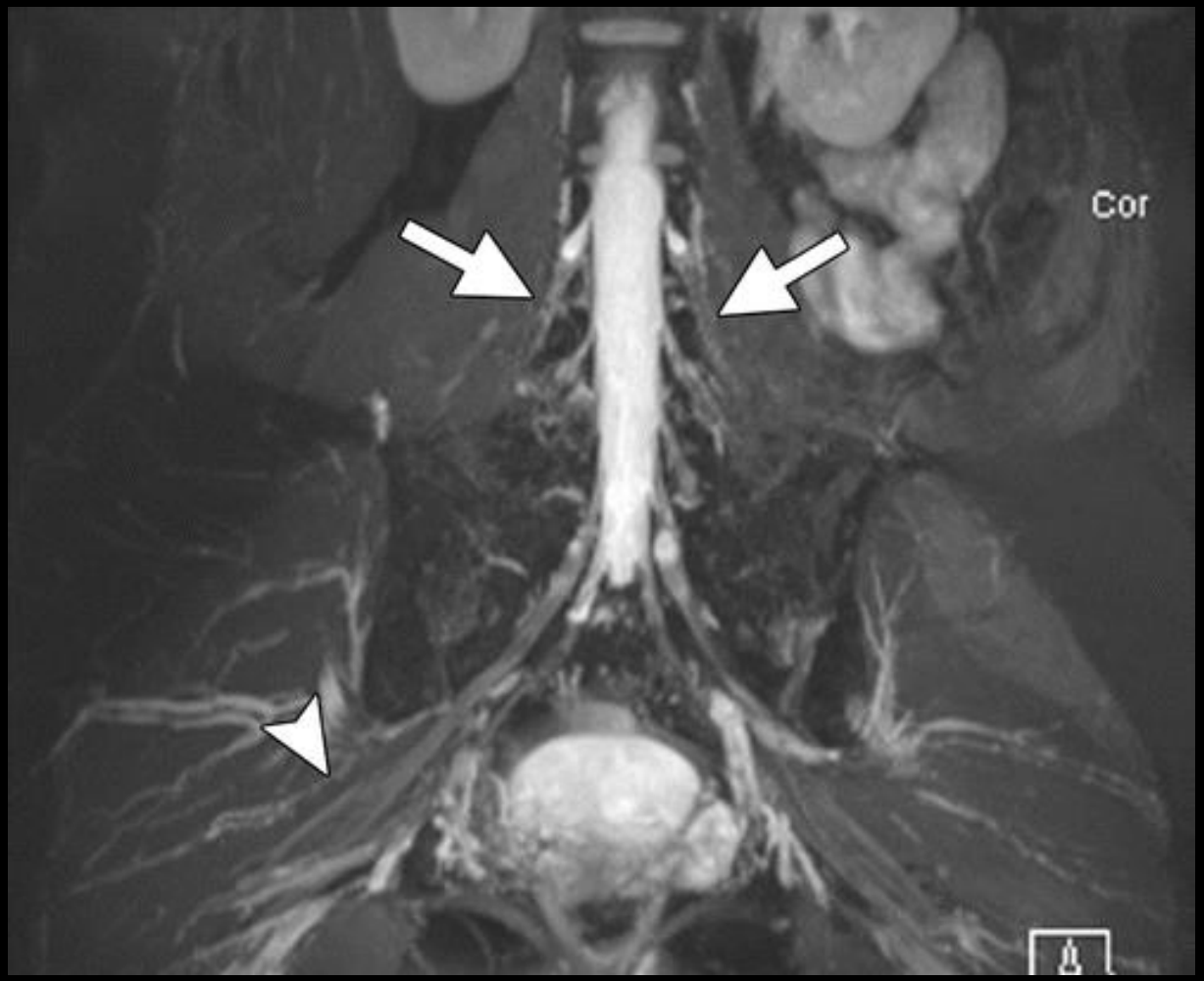

Genitofemoral

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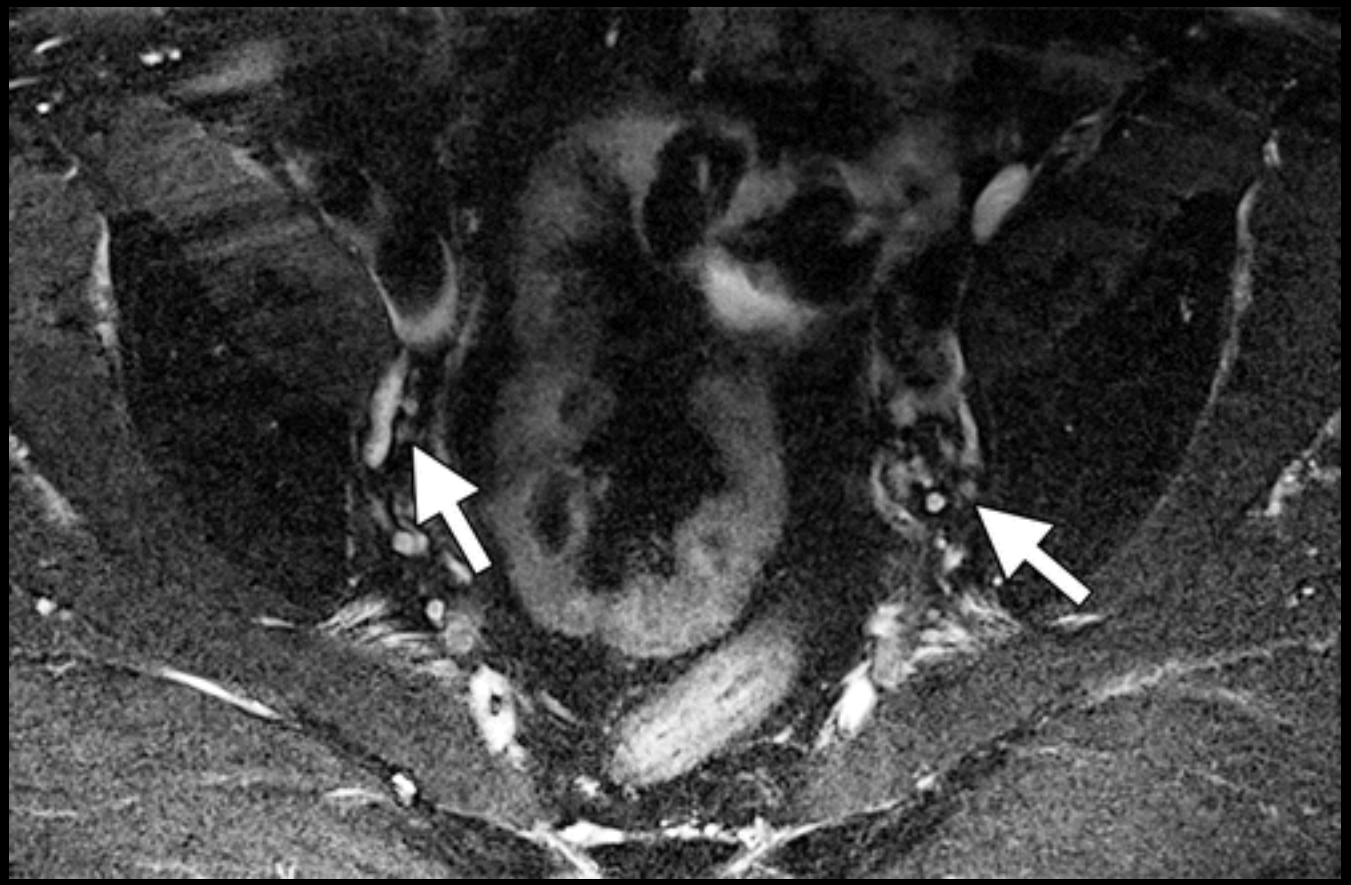

Obturator

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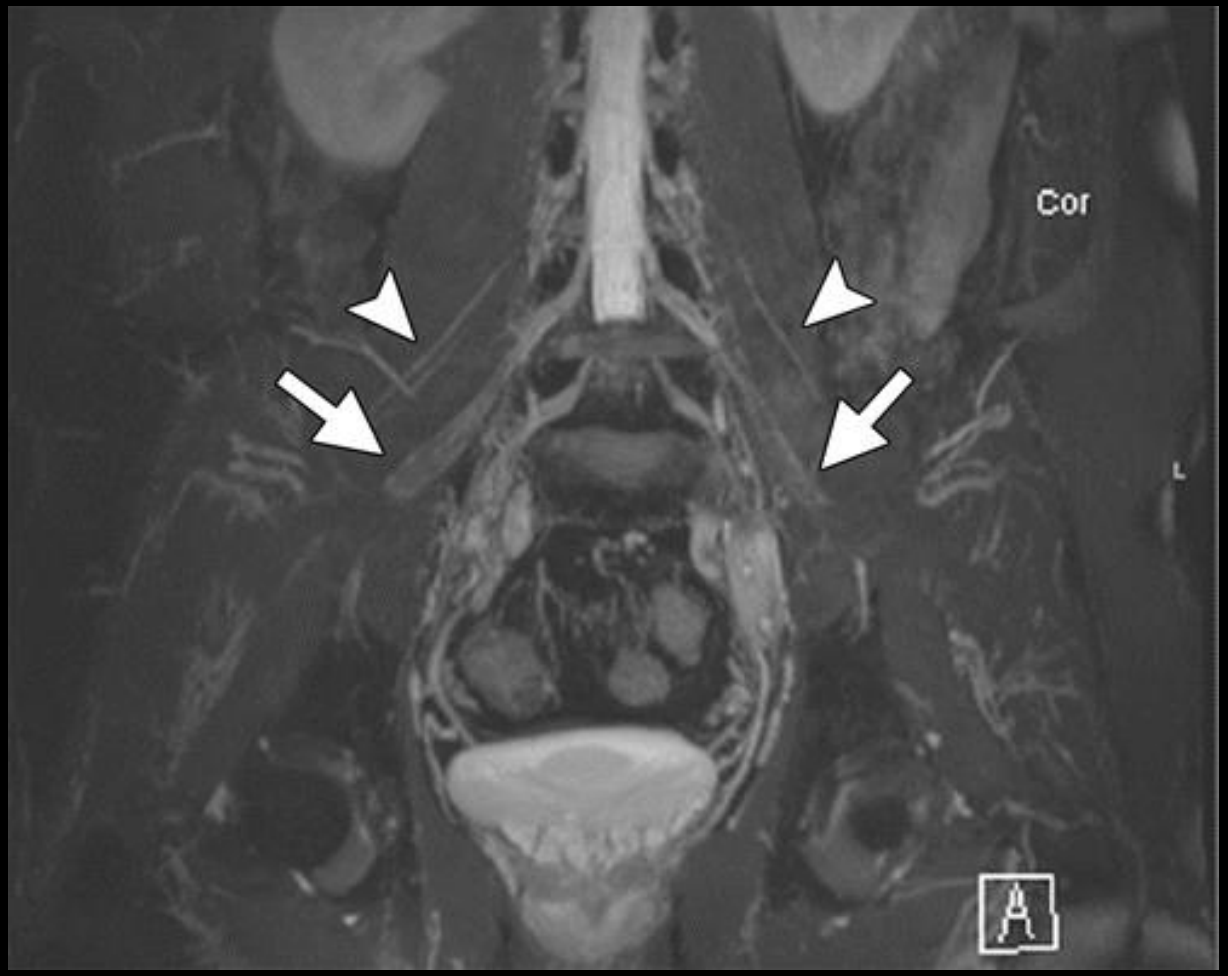

Ilioinguinal

Femoral

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Lateral Femoral Cutaneous

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Normal

Sciatic

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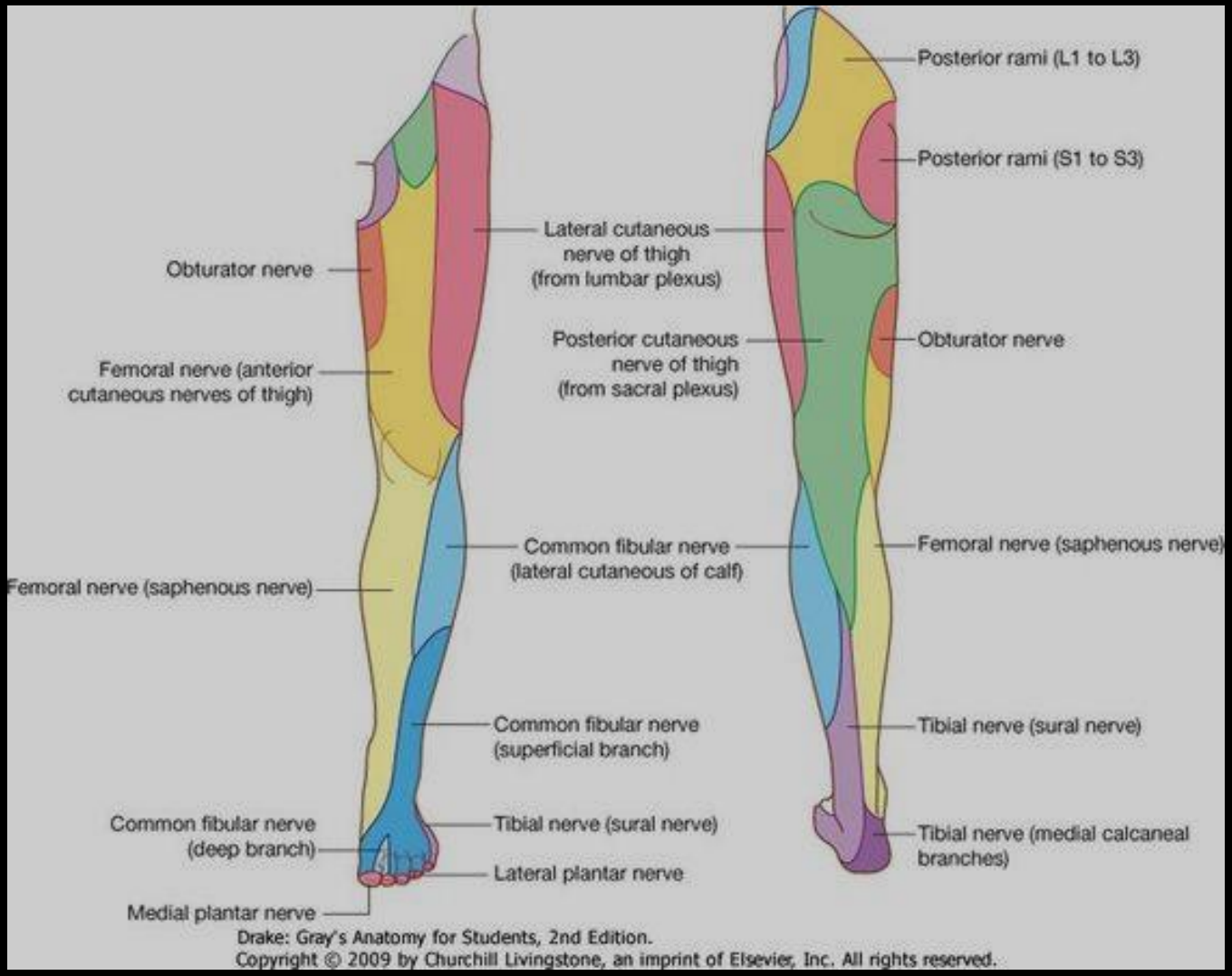
REVIEW OF NERVES INDIVIDUALLY

Upper Lumbar Plexus

- Iliohypogastric (T12 and L1) and Ilioinguinal Nerves (L1)
  - Internal oblique and transversus abdominis muscles.
- Genitofemoral Nerve (L1, L2)
  - Genital branch innervates the cremasteric muscle.
- Lateral Femoral Cutaneous Nerve (L2, L3)
  - No motor contribution.

IH, II, GF, and LFC Sensory



Cesmebasi, A., Yadav, A., Gielecki, J., Tubbs, R. S. and Loukas, M. (2015), Genitofemoral neuralgia: A review. Clin. Anat., 28: 128–135.
http://accessphysiotherapy.mhmedical.com/data/Multimedia/grandRounds/lumbar/media/lumbar_print.html

Femoral Nerve (L2, L3, L4)

- Illiacus
- Pectineus*
- Sartorius
- All the muscles of quadriceps femoris
  - Rectus femoris
  - Vastus medialis
  - Vastus lateralis
  - Vastus intermedius

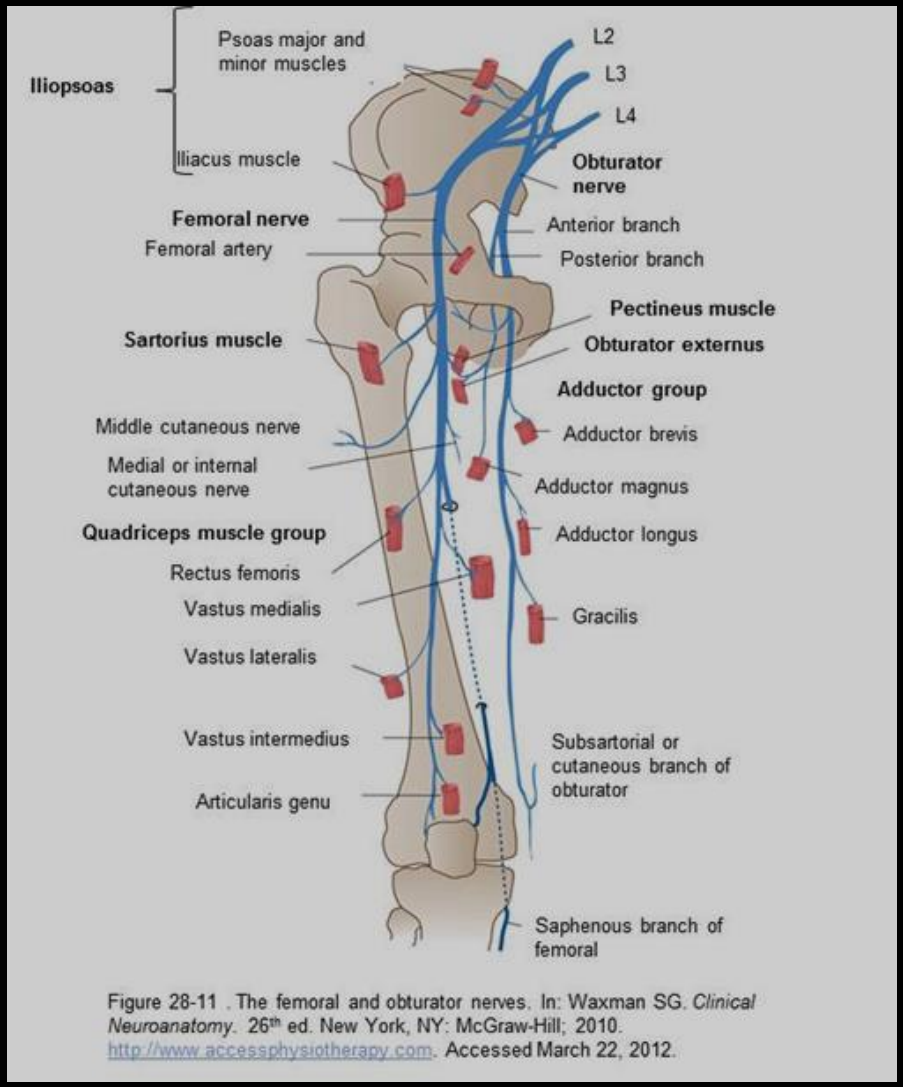


Figure 28-11 . The femoral and obturator nerves. In: Waxman SG. *Clinical Neuroanatomy*. 26th ed. New York, NY: McGraw-Hill; 2010. http://www.accessphysiotherapy.com. Accessed March 22, 2012.

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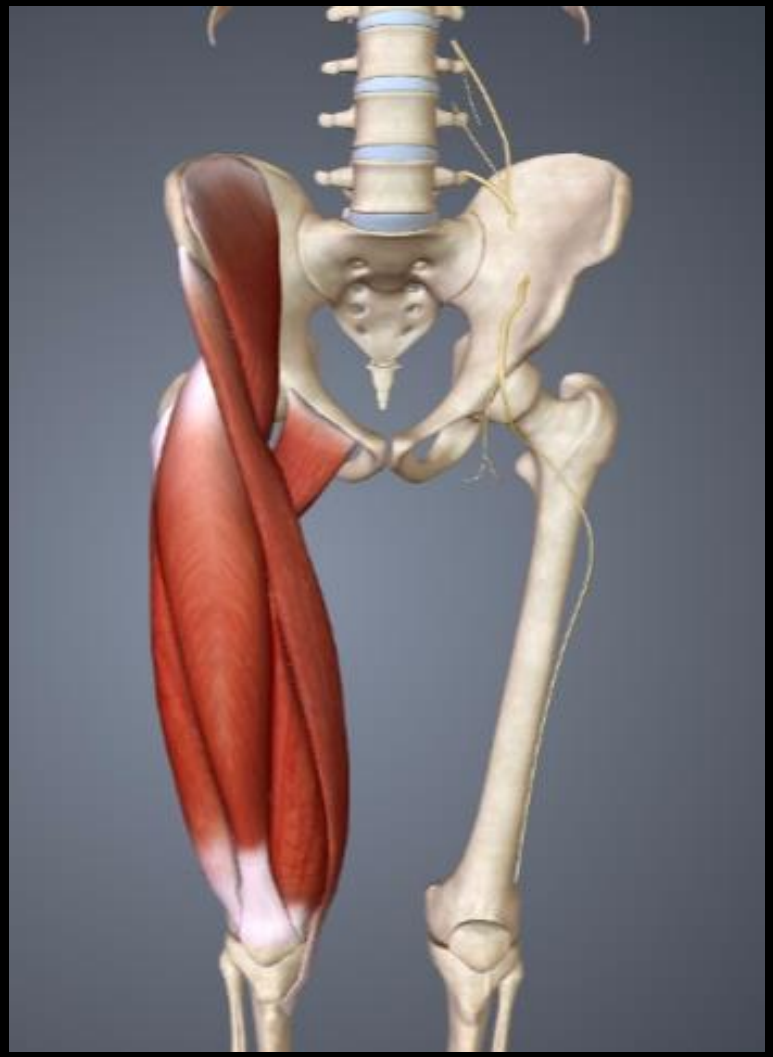
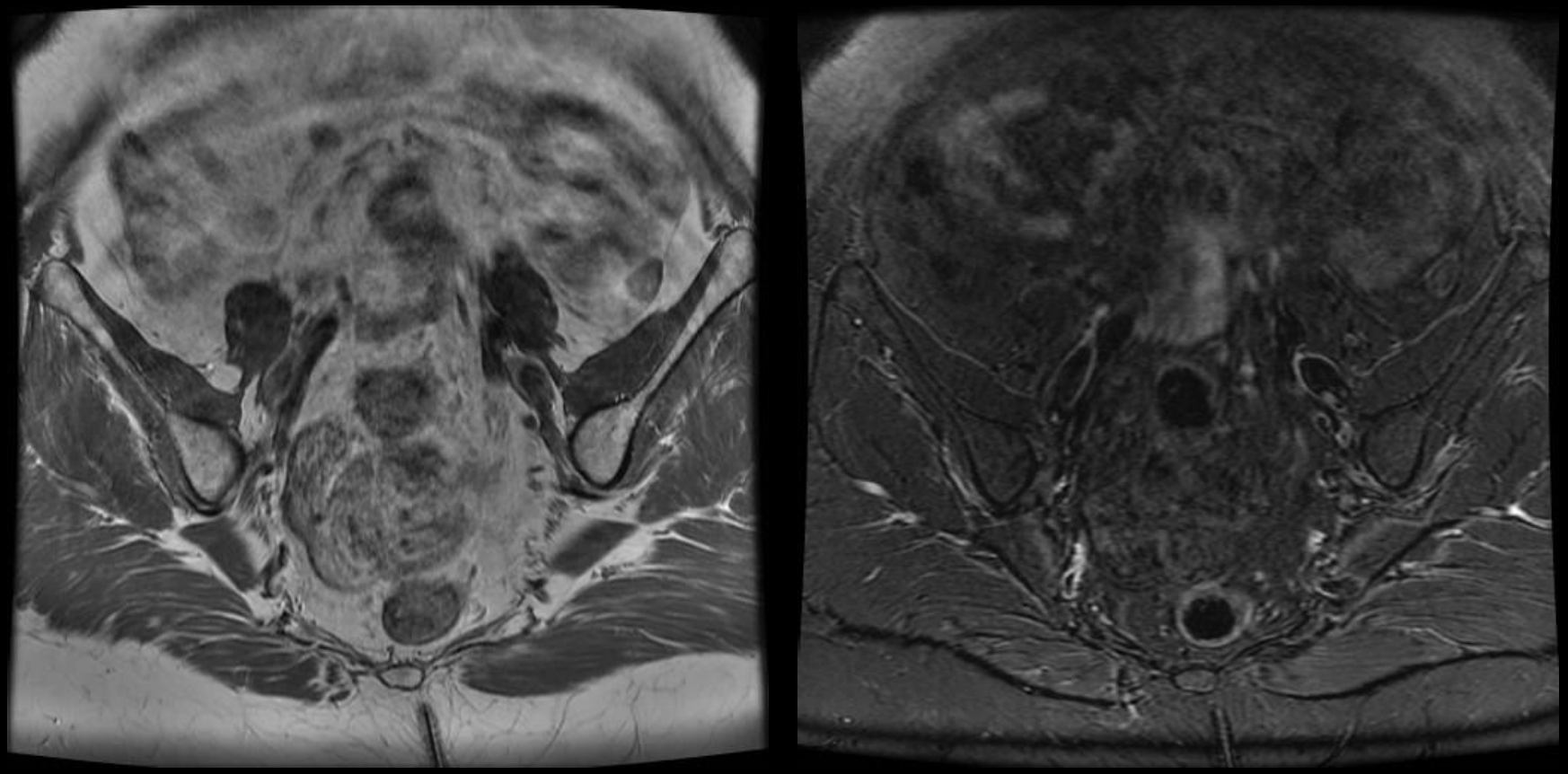


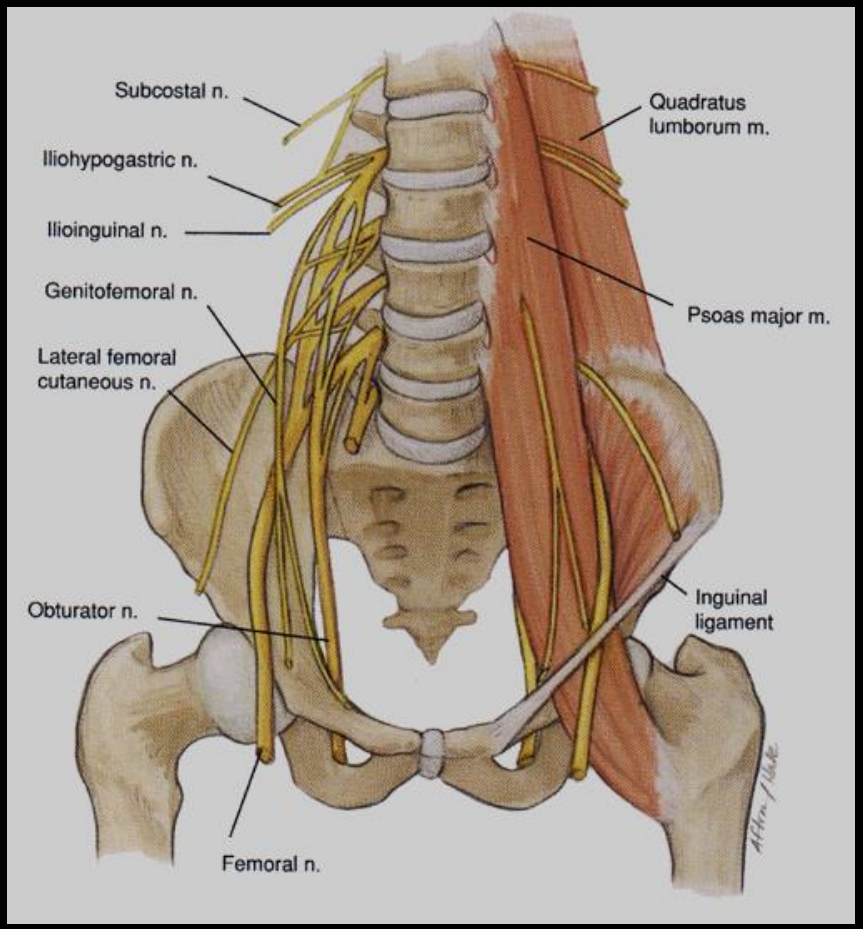
https://human.biodigital.com/

Femoral Nerve (L2, L3, L4)



Psoas Exception

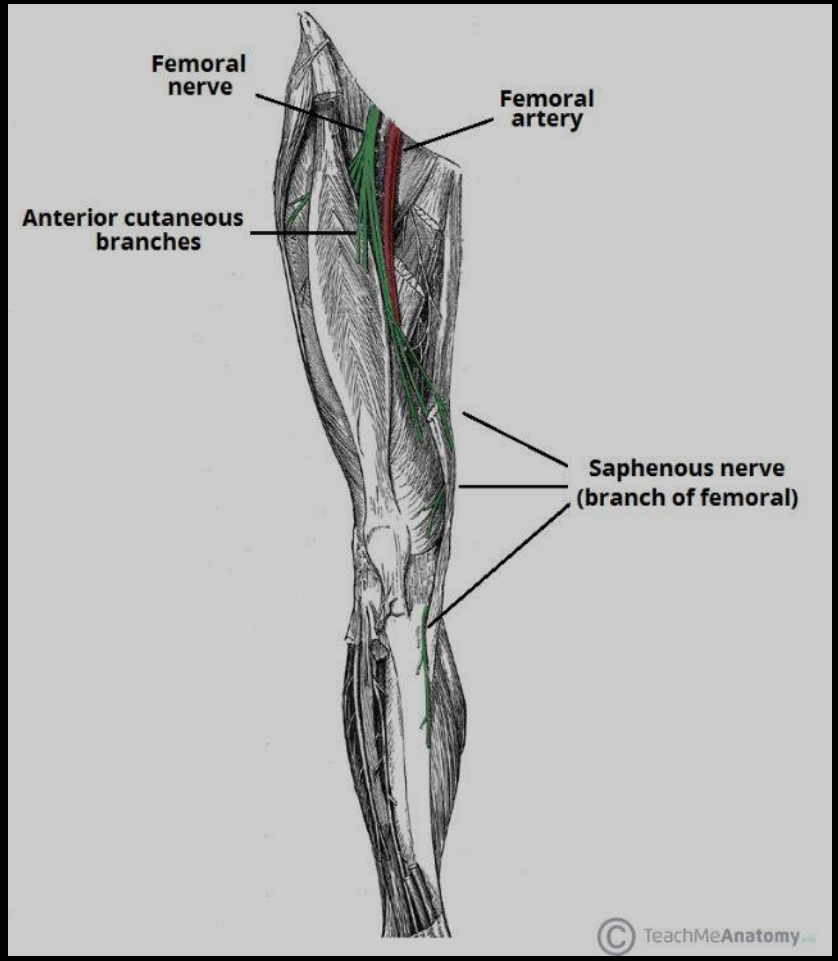
- **Psoas** major is **innervated** by direct branches of the anterior rami off the lumbar plexus at the levels of L1-L3
- Iliacus is **innervated** by the femoral nerve



http://www.drdooleynoted.com/anatomy-angel-psoas-connections/

Femoral Nerve (L2, L3, L4)

- Femoral nerve splits into anterior and posterior branches below the inguinal ligament
- Anterior
  - Anterior femoral cutaneous
  - Muscular (Sartorius, Pectineus)
- Posterior
  - Muscular (Quadriceps)
  - Saphenous nerve*
  - Articular (Knee)



http://teachmeanatomy.info/lower-limb/nerves/femoral-nerve/

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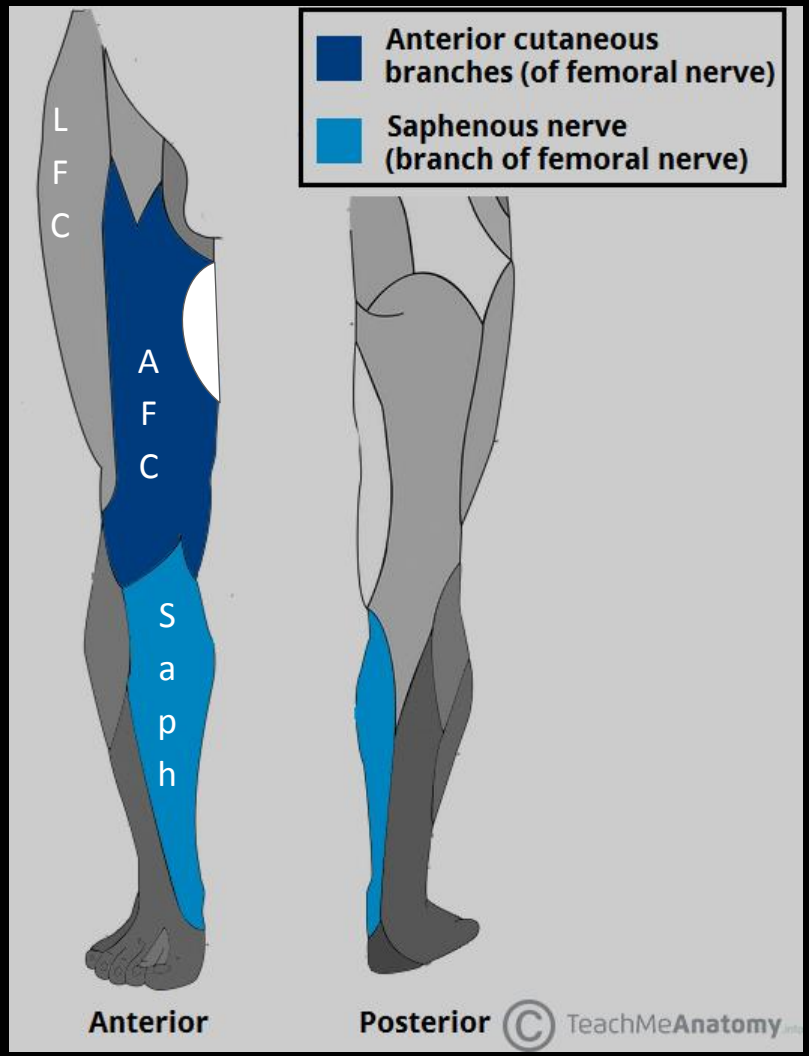

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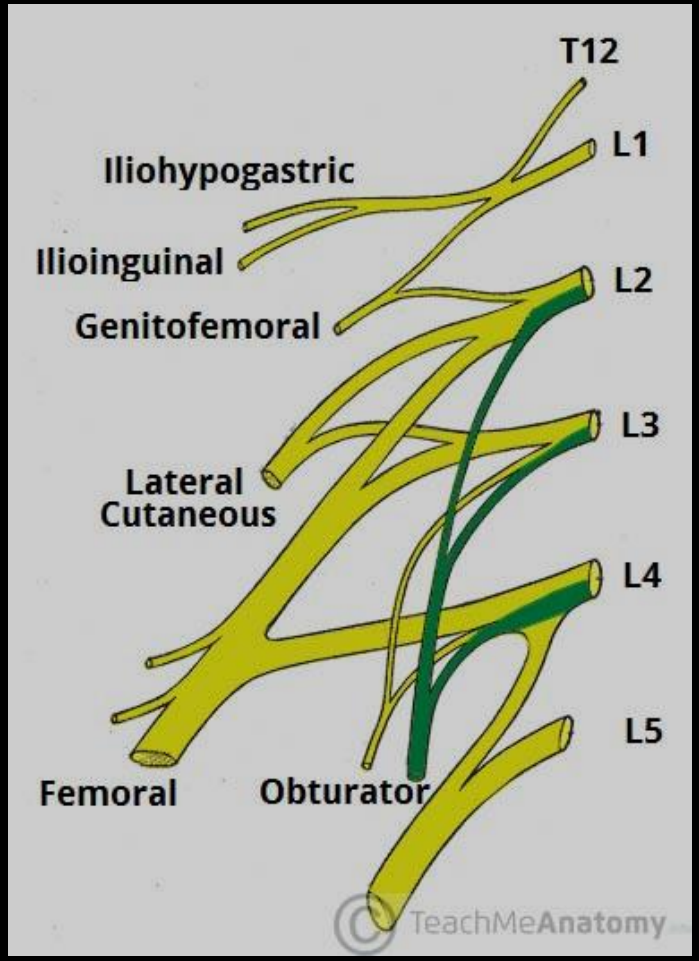
Obturator Nerve (L2, L3, L4)

- Obturator externus
- Pectineus*
- Adductor longus
- Adductor brevis
- Adductor magnus
- Gracilis



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- Adductor magnus
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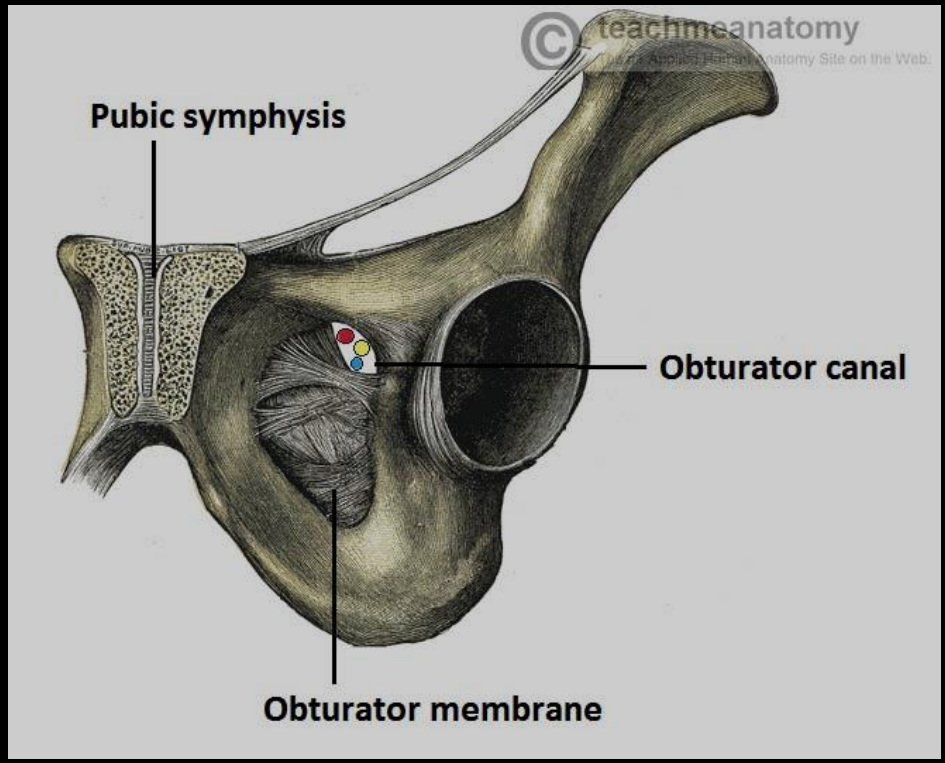
https://human.biodigital.com/

Obturator Nerve (L2, L3, L4)

Obturator Nerve (L2, L3, L4)

- Obturator nerve courses through obturator canal and splits into anterior and posterior branches
- Anterior
  - Gracilis, adductor brevis and longus
  - Rarely pectineus
  - Sensory to medial upper thigh
- Posterior
  - Obturator externus, adductor magnus, occasionally Adductor brevis
  - Sensory to medial knee



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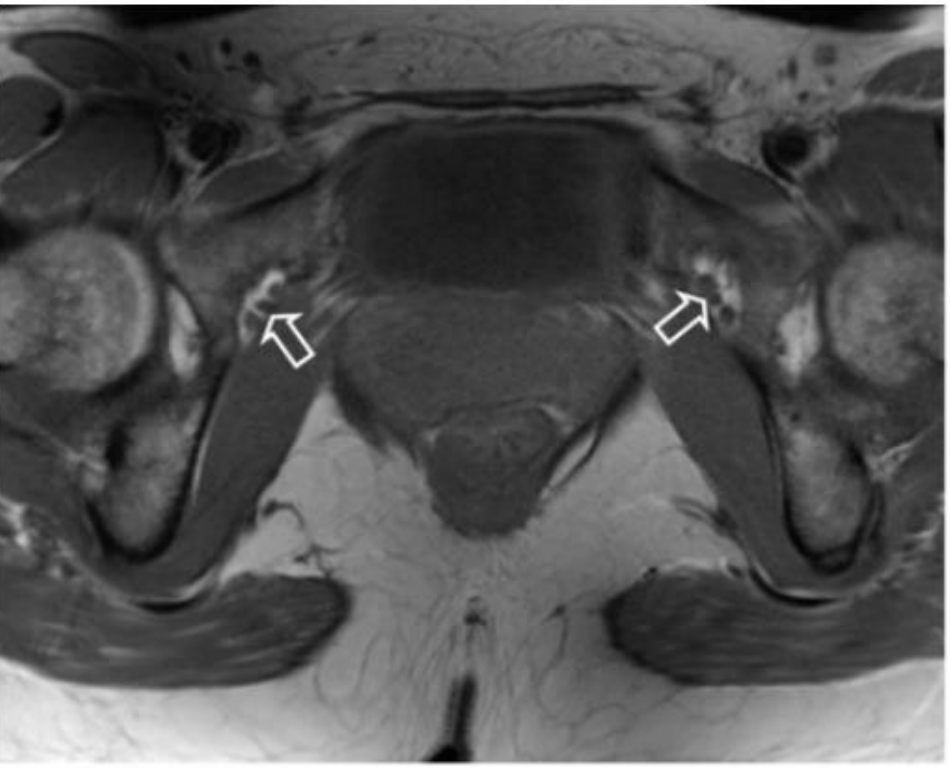

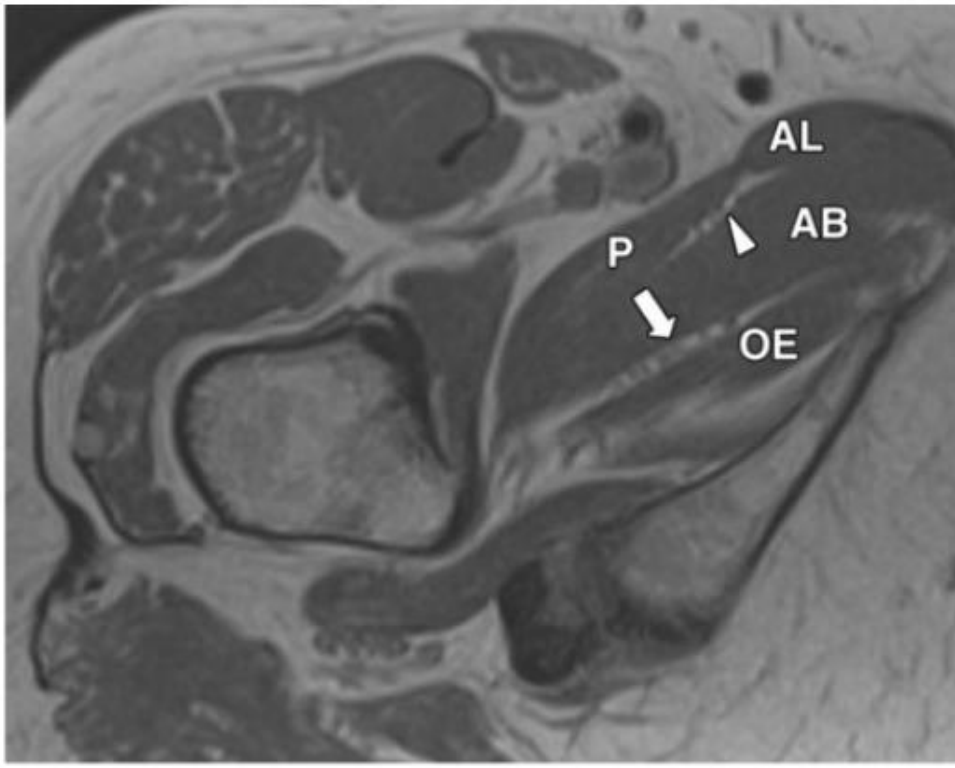

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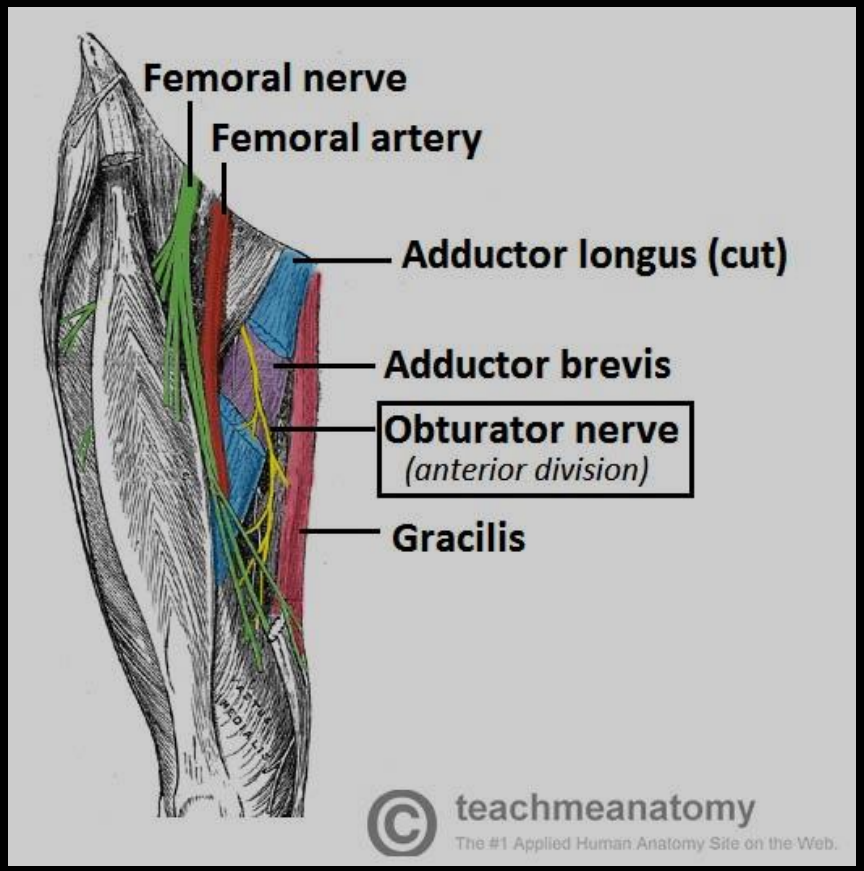
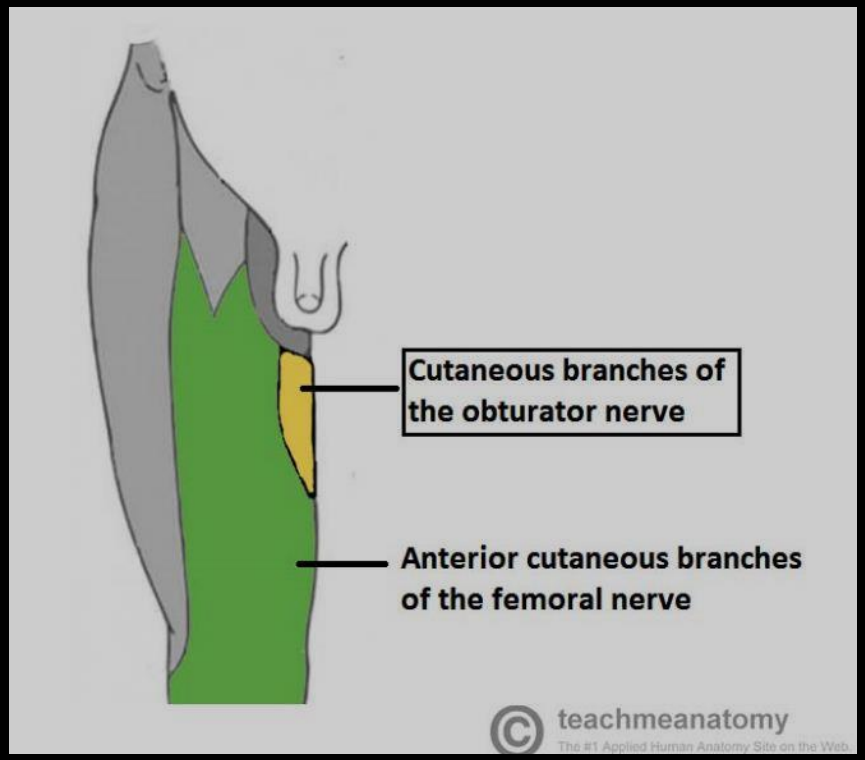
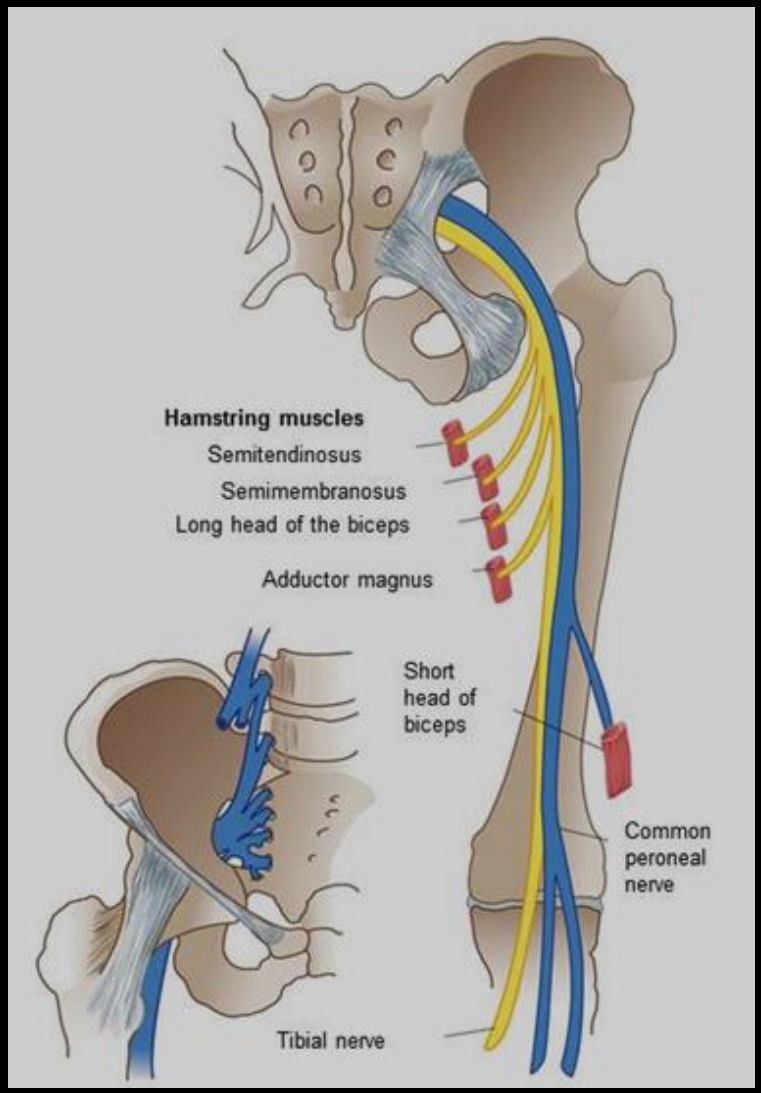




http://teachmeanatomy.info/lower-limb/nerves/obturator-nerve/

Sciatic Nerve (L4-S3)

- Muscles of the posterior thigh and the hamstring portion of the adductor magnus
- Indirectly innervates (via terminal branches) the muscles of the leg and foot



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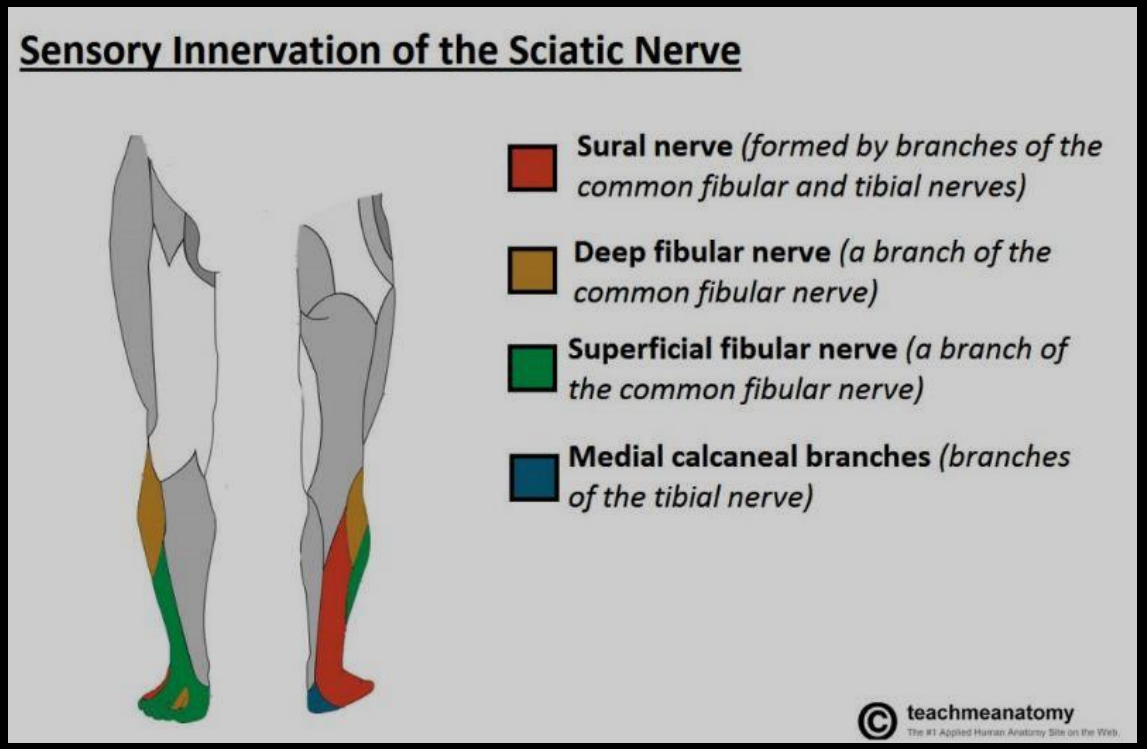
https://human.biodigital.com/

Sciatic Nerve (L4-S3)

- No direct sensory supply.
- Indirectly supplies much of the lower leg via common peroneal and tibial branches.



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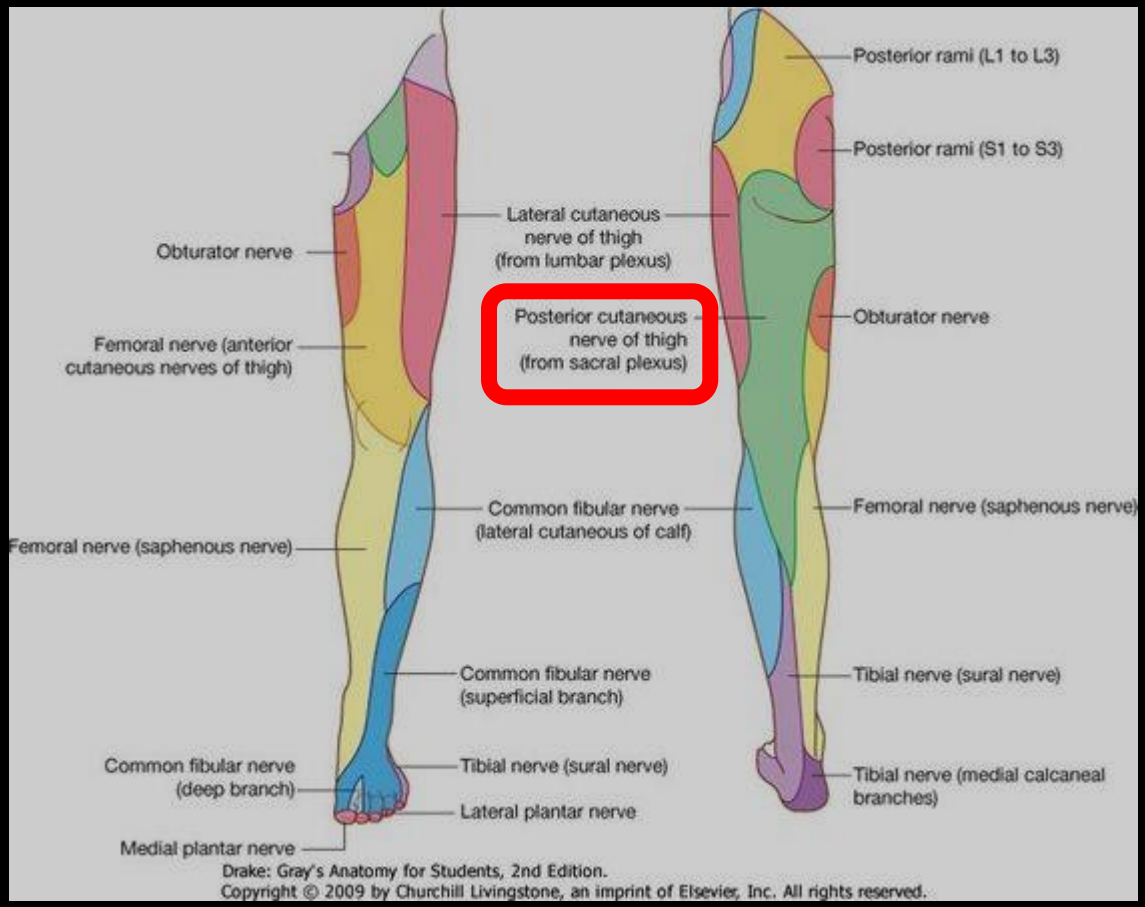
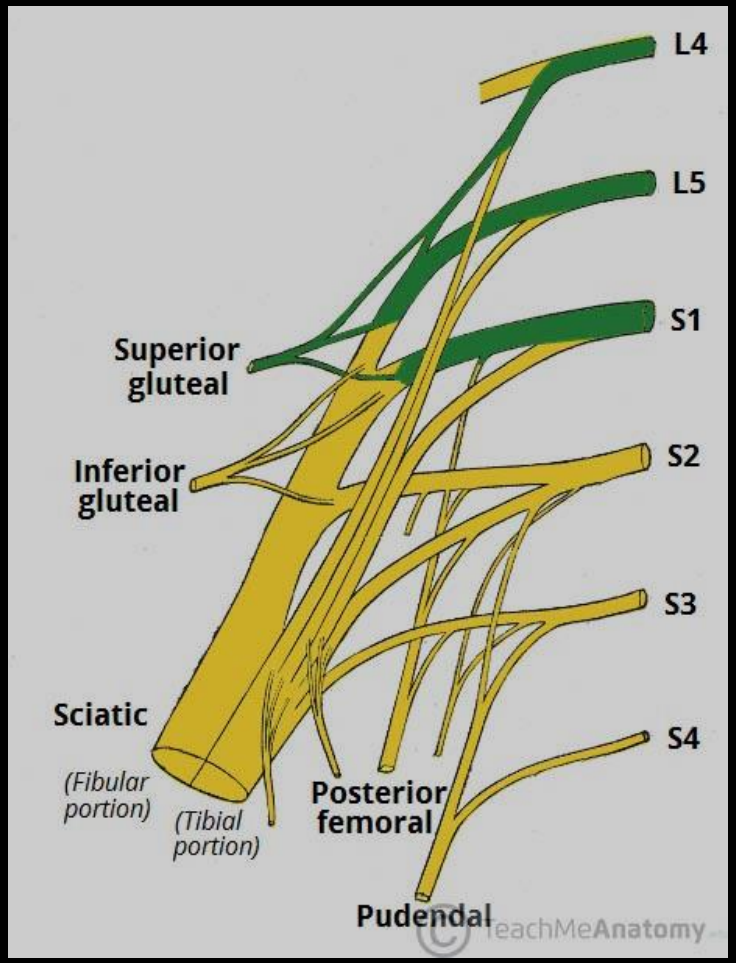
Posterior Femoral Cutaneous (S1-3)

- No muscle contribution



Superior Gluteal (L4, L5, S1)

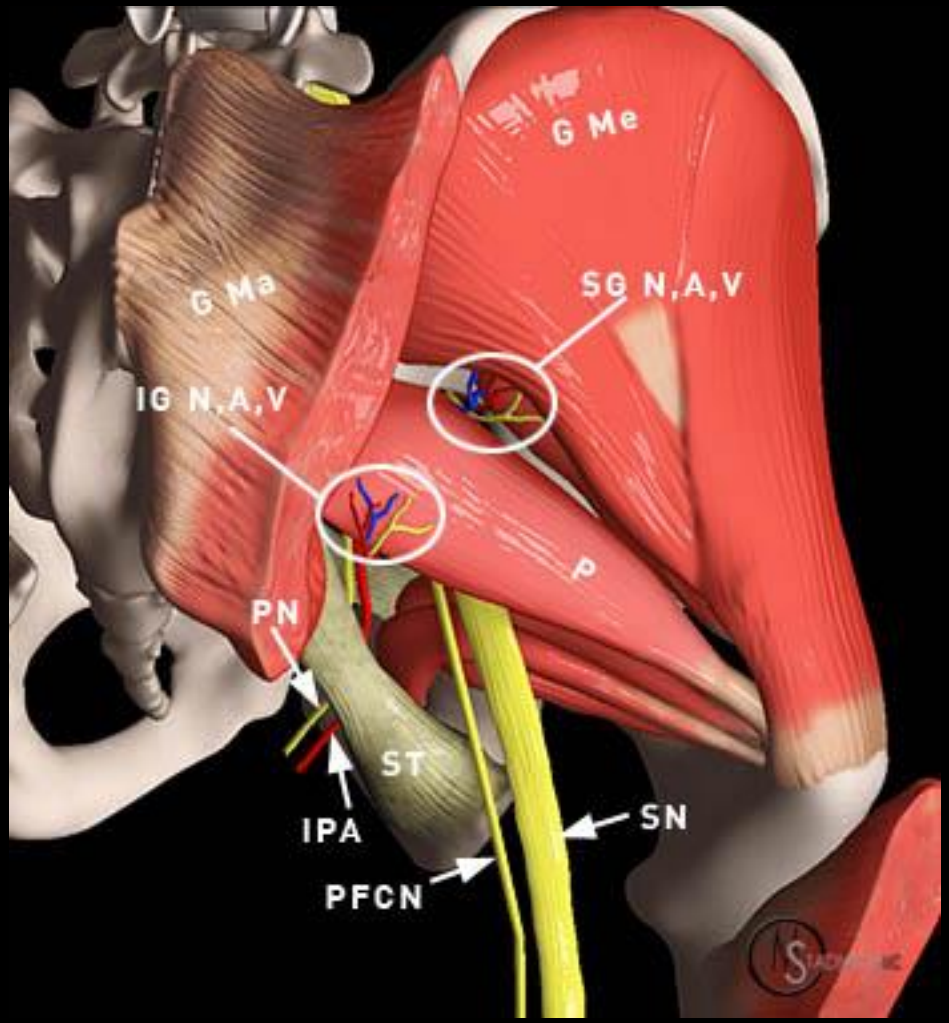
- Gluteus minimus
- Gluteus medius
- Tensor fascia lata



https://human.biodigital.com/

http://teachmeanatomy.info/lower-limb/nerves/sacral-plexus/

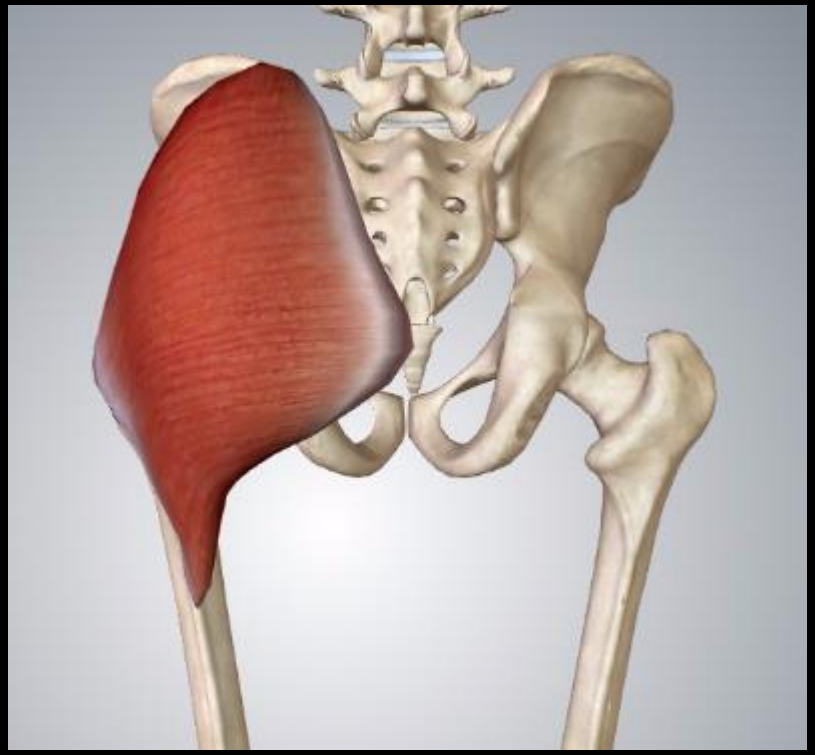
Superior and Inferior Gluteal Nerves

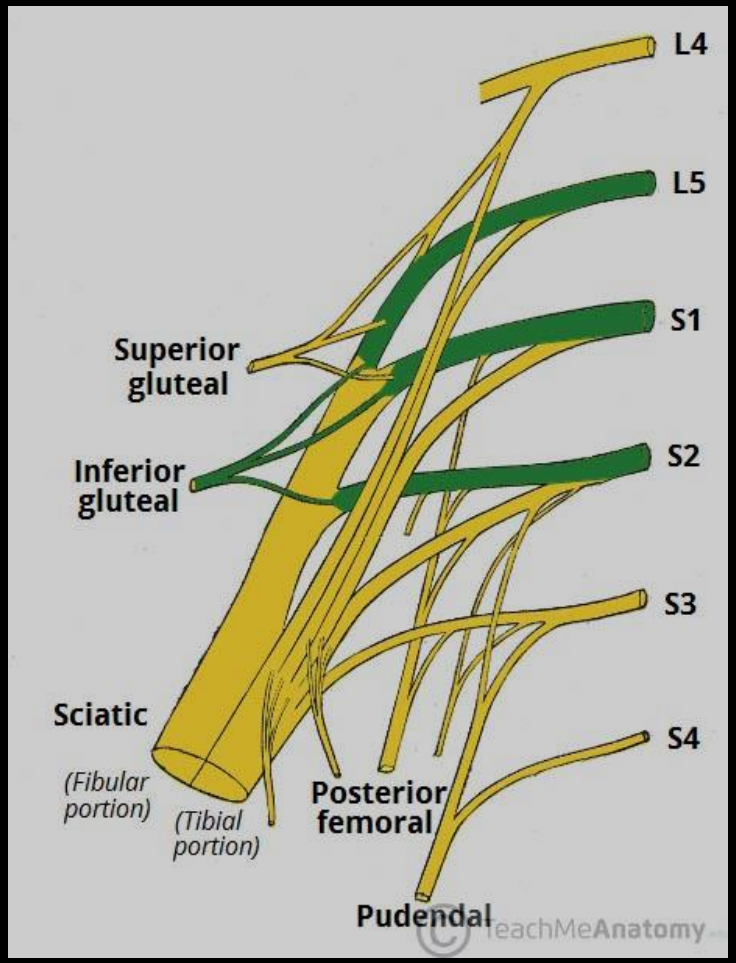


http://radsource.us/piriformis-syndrome/

Inferior Gluteal Nerve (L5, S1, S2)

- Gluteus maximus



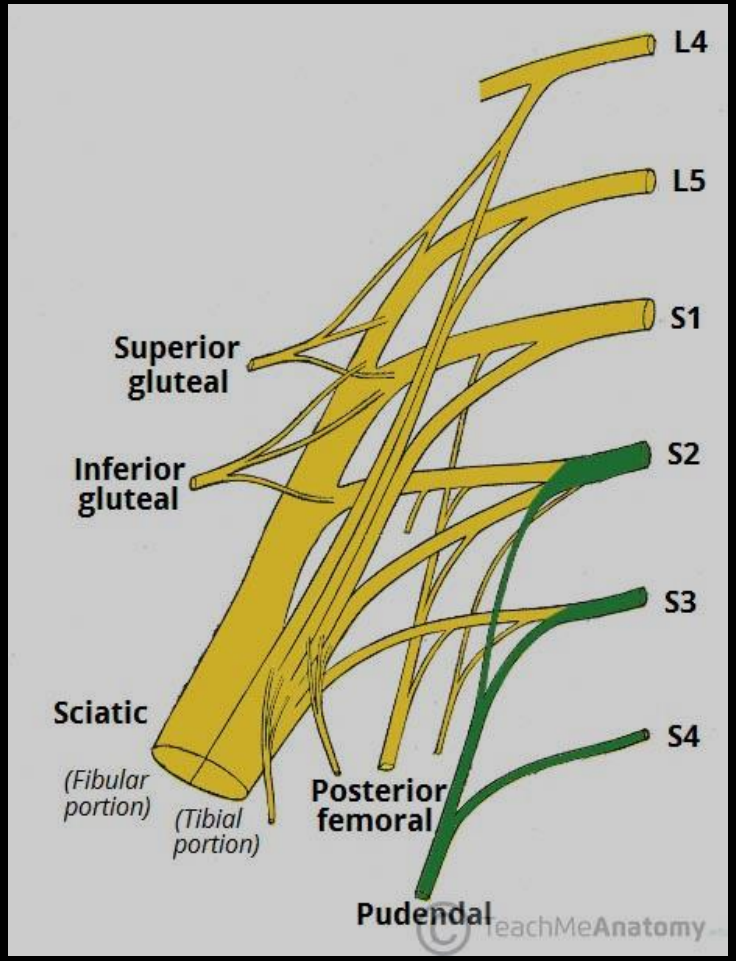


https://human.biodigital.com/

http://teachmeanatomy.info/lower-limb/nerves/sacral-plexus/

Pudendal Nerve (S2, S3, S4)

- Skeletal muscles in the perineum
  - External urethral sphincter
  - External anal sphincter
  - Levator ani.

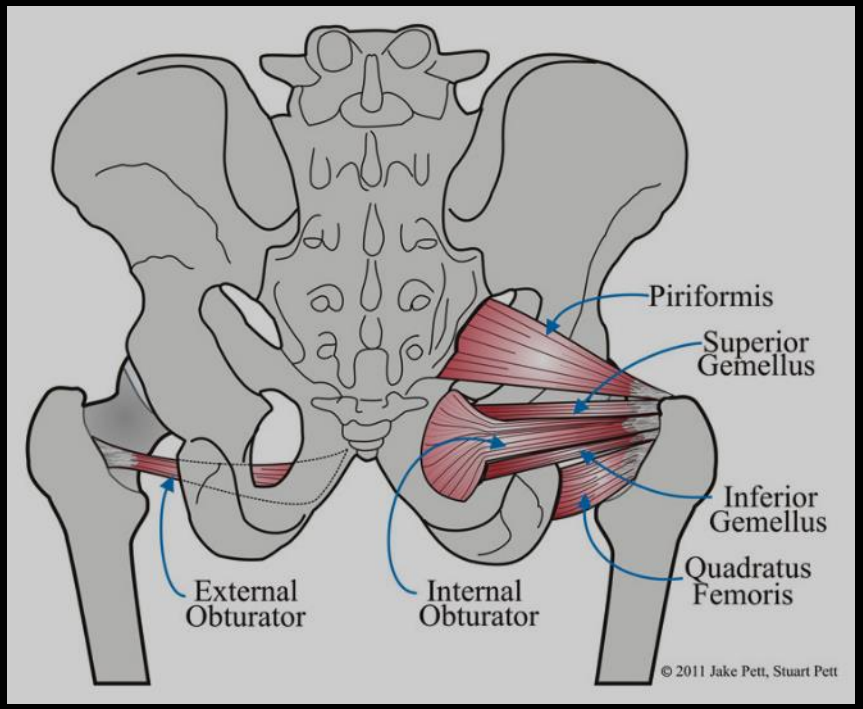


http://teachmeanatomy.info/lower-limb/nerves/sacral-plexus/

Other Muscle Branches Not Already Discussed

In addition to the five major nerves of the sacral plexus:

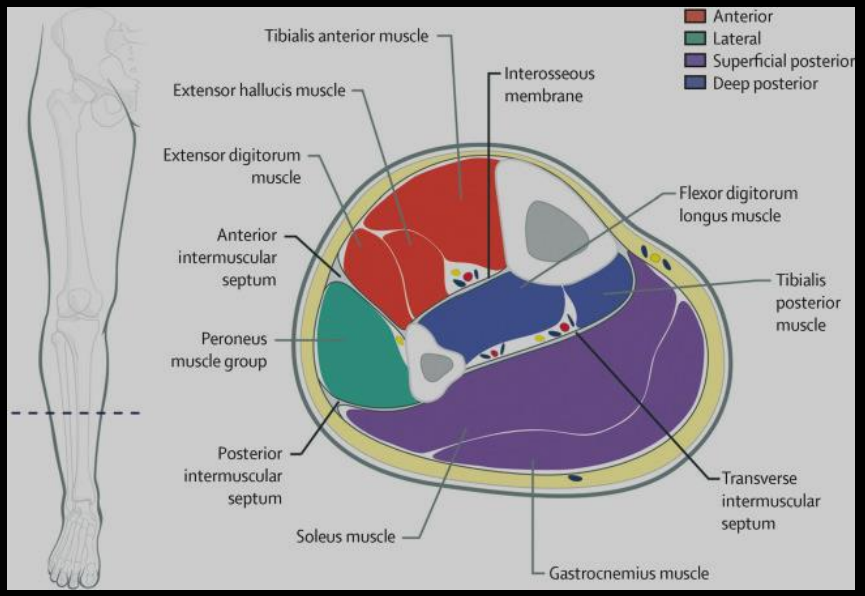
- Nerve to piriformis
- Nerve to obturator internus (also innervates superior gemelllus)
- Nerve to quadratus femoris (also innervates inferior gemelllus)



https://www.iadms.org/page/324

Tibial vs Common Peroneal

- 4 Compartment approach, 3 nerve branches
- Posterior Compartments:
  - Deep:
    - TIBIAL NERVE
  - Superficial:
    - TIBIAL NERVE
- Lateral compartment:
    - SUPERFICIAL PERONEAL N.
- Anterior compartment:
    - DEEP PERONEAL N.



von Keudell, Arvind G et al., Diagnosis and treatment of acute extremity compartment syndrome. The Lancet , Volume 386 , Issue 10000 , 1299 - 1310

Tibial Nerve (L4-S3)

<u>Deep Compartment</u>

- Popliteus
- Flexor Hallucis Longus
- Flexor Digitorum Longus
- Tibialis Posterior

<u>Superficial Compartment</u>

- Plantaris
- Soleus
- Gastrocnemius

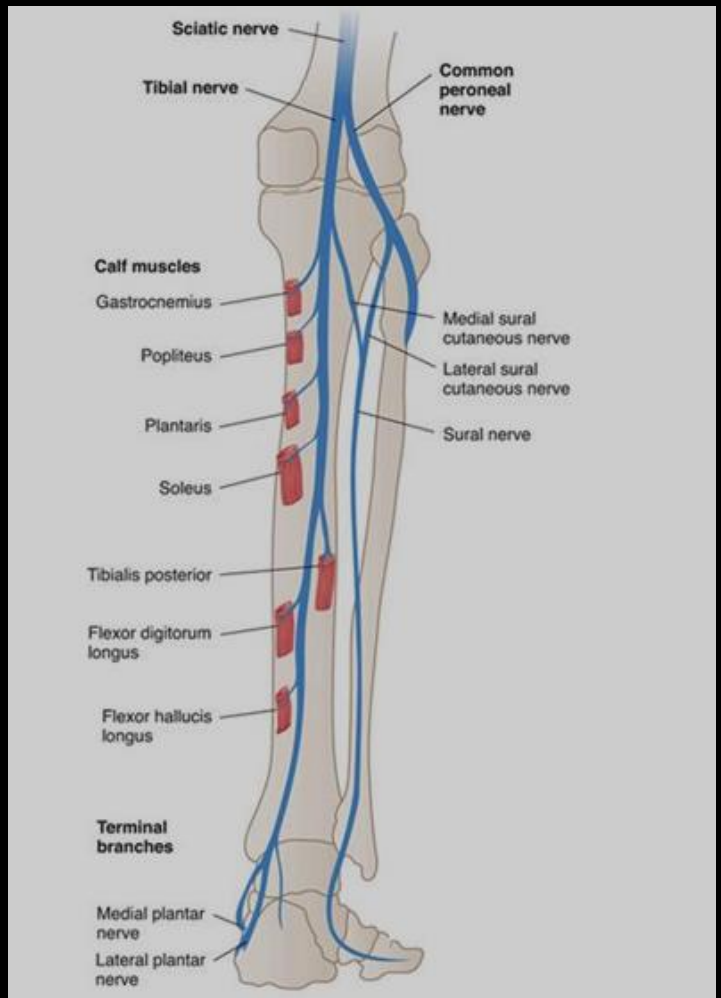


Figure 28-17 . The tibial nerve (L4, 5; S1 –3). In: Waxman SG. *Clinical Neuroanatomy*. 26th ed. New York, NY: McGraw-Hill; 2010. http://www.accessphysiotherapy.com. Accessed March 22, 2012.

http://accessphysiotherapy.mhmedical.com/data/Multimedia/grandRounds/lumbar/media/lumbar_print.html

Tibial Nerve (L4-S3)

<u>Deep Compartment</u>

- Popliteus
- Flexor Hallucis Longus
- Flexor Digitorum Longus
- Tibialis Posterior

<u>Superficial Compartment</u>

- Plantaris
- Soleus
- Gastrocnemius

https://human.biodigital.com/

Common Peroneal Nerve (L4-S3)

Superficial fibular nerve:
(Lateral compartment)

- Peroneus longus
- Peroneus brevis

Deep fibular nerve:

(Anterior compartment)

- Tibialis anterior
- Extensor digitorum longus
- Extensor hallucis longus
- Peroneus Tertius

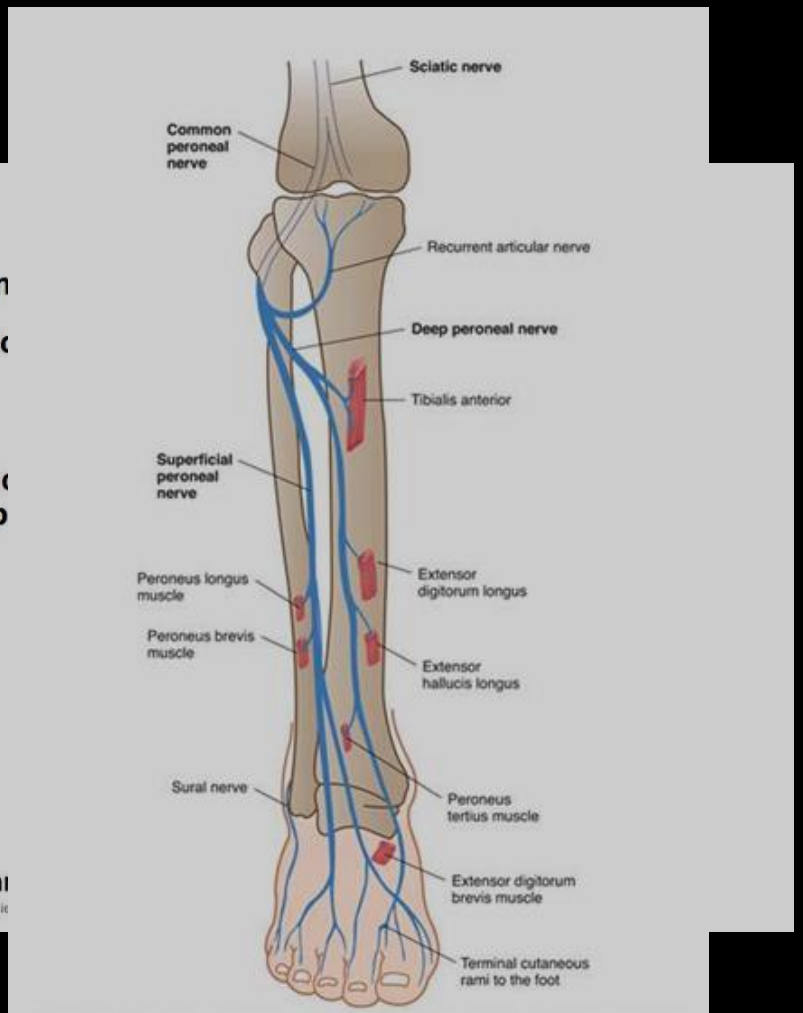


Figure 28-16 . The common peroneal nerve (L4, 5; S1, S2). In: Waxman SG. *Clinical Neuroanatomy*. 26th ed. New York, NY: McGraw-Hill; 2010. http://www.accessphysiotherapy.com. Accessed March 22, 2012.

Common Peroneal Nerve (L4-S3)

Superficial fibular nerve:
(Lateral compartment)

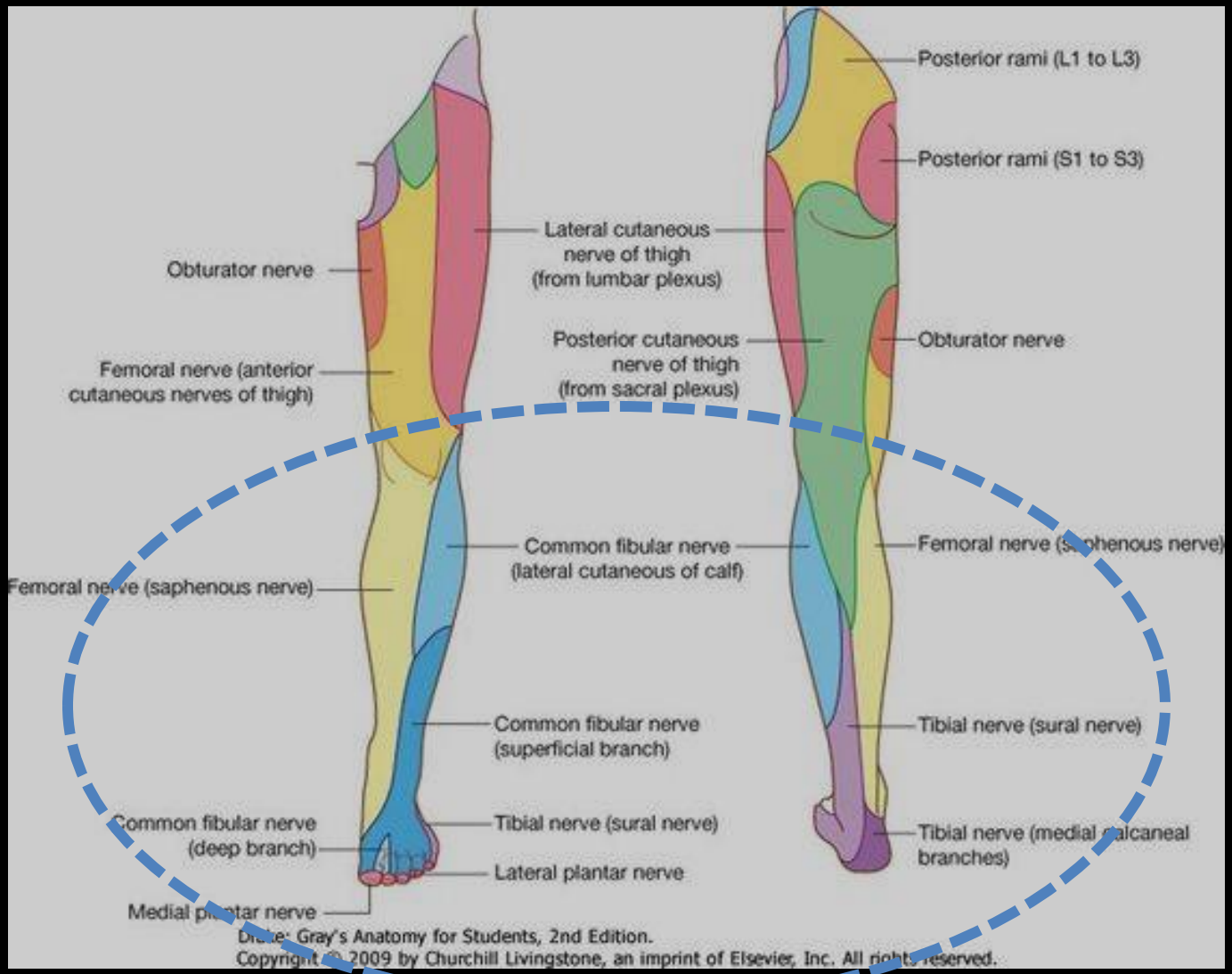
- Peroneus longus
- Peroneus brevis

Deep fibular nerve:

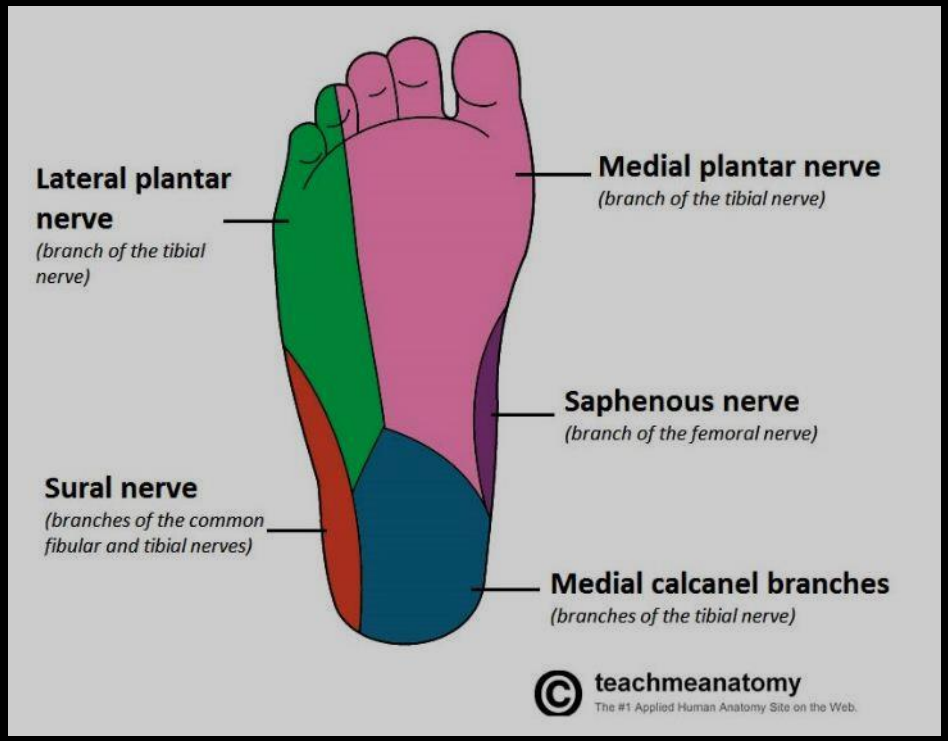
(Anterior compartment)

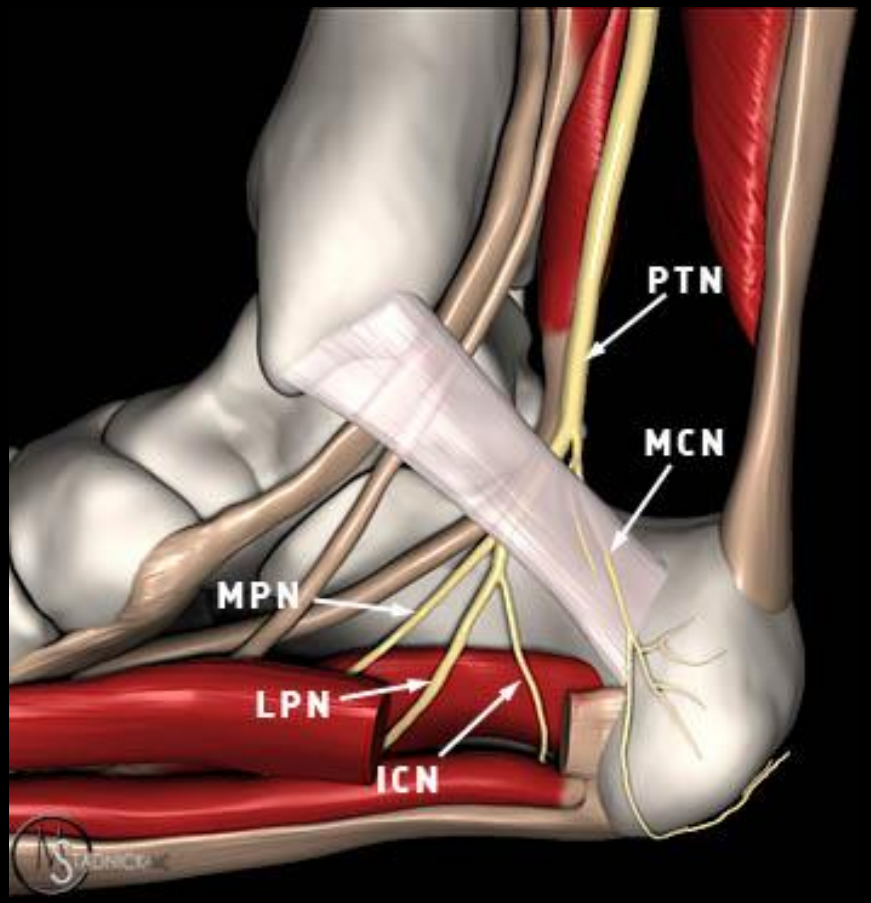
- Tibialis anterior
- Extensor digitorum longus
- Extensor hallucis longus
- Peroneus Tertius

Sensory Innervation



Sensory Innervation





http://accessphysiotherapy.mhmedical.com/data/Multimedia/grandRounds/lumbar/media/lumbar_print.html

http://radsource.us/baxters-nerve/

Quote

“There is an art, or rather, a knack to flying. The knack lies in learning how to throw yourself at the ground and miss.”

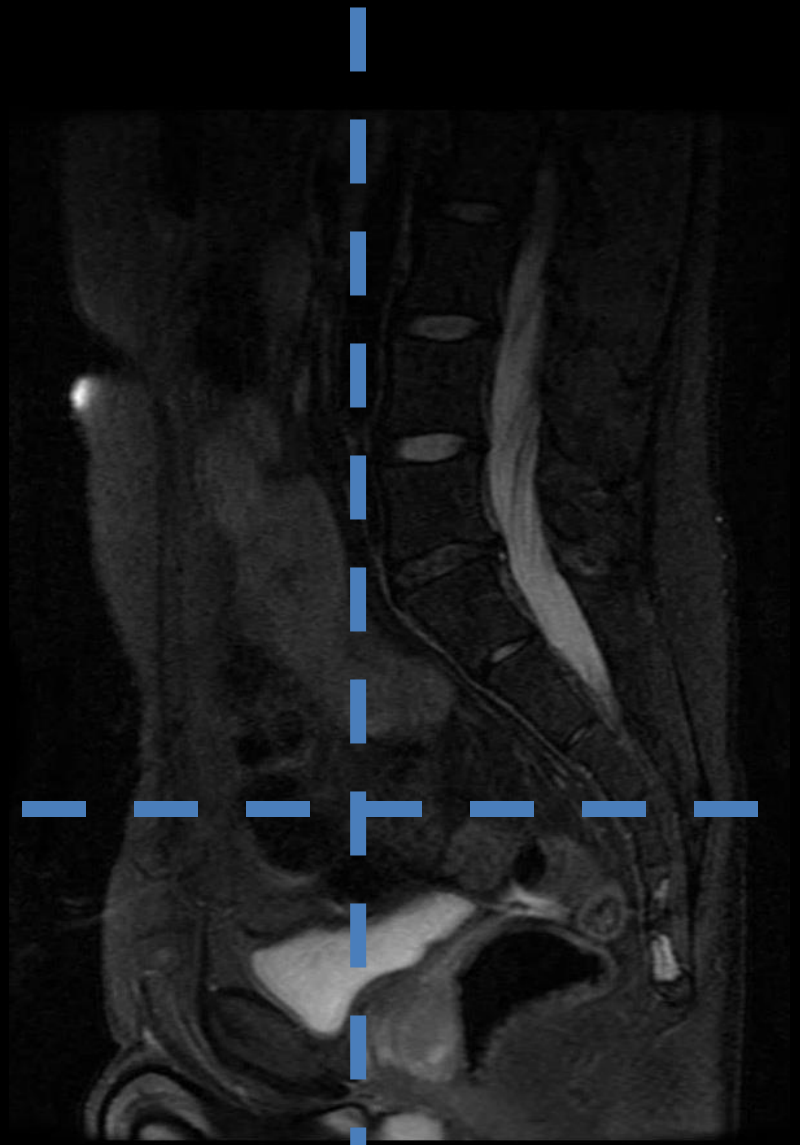
Performing MR LSP Neurography

At UCSD:
Strong preference for 3 Tesla magnet (allows 3D sequences)

- Obl Axial T1
- Obl Axial T2 FS
- Obl Cor T1
- Obl Cor STIR
- Cor PD Cube (reformat to sag and axial)
- Cor T2 Cube FS (reformat to sag and axial)

- Obl Ax T1 FS PRE and POST Contrast
- Ax (straight) DWI

Planes



Possible Protocols

SPAIR- Selectively suppresses fat (similar to STIR)

SPACE- ***isotropic*** 3D TSE

VIBE- ***isotropic*** 3D GRE

Phased-array body coils +/- phased-array spinal coils

Table 1
Our 3-T MR Neurographic Protocol for Evaluating the Lumbosacral Plexus

Sequence	Area	Field of view (cm)	Voxel size (mm^3)	TR/TE (msec)	Turbo factor
Axial T1-weighted turbo spin-echo	Bilateral	33	0.64	800/12	6
Axial T2-weighted SPAIR	Bilateral	33	1.00	4500/80	17
Coronal proton-density SPAIR	Bilateral	36–38	0.6	4980/38	7
Coronal T1-weighted turbo spin-echo	Bilateral	36–38	0.5	550/10	3
Coronal 3D STIR SPACE	Bilateral	36–38	1.45	1500/103	61
Sagittal T2-weighted 3D SPACE	Lumbar spine	28	1.45	1000/99	69
Coronal 3D VIBE*	Bilateral	36–38	0.58	4.39/2.01	…

Note.—Reprinted, with permission, from reference 2. SPACE = sampling perfection with application of optimized contrasts using varying flip angles, SPAIR = spectral adiabatic inversion recovery, STIR = short inversion time inversion recovery, TE = echo time, 3D = three dimensional, TR = repetition time, VIBE = volume interpolated breath-hold examination.
*This sequence is optional.

Table 1 Magnetic resonance neurography protocol on 3 Tesla scanner

Pulse sequence	2D/3D	TR (ms)	TE (ms)	Slice thickness (mm)	Coverage
Axial T1W	2D	700	8	4	T12-L1 to lesser trochanters
Axial T2 SPAIR	2D	4800	65	4	T12-L1 to lesser trochanters
Coronal STIR SPACE	3D	2000	78	1.5 isotropic	T12-L1 to lesser trochanters
Sagittal T2 SPACE	3D	2000	120	0.9 isotropic	T12-L1 to sacrum
Axial DTI	2D	6000	65	4	T12-L1 to lesser trochanters

T: Tesla; 2D/3D: 2 dimensional/3 dimensional; DTI: Diffusion tensor imaging; SPACE: Sampling perfection with application optimized contrasts using variable flip angle evolutions; SPAIR: Spectral adiabatic inversion recovery; STIR: Short tau inversion recovery; TR: Repetition time; TE: Echo time.

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987.
Chhabra A, Farahani SJ, Thawait GK, Wadhwa V, Belzberg AJ, Carrino JA. Incremental value of magnetic resonance neurography of Lumbosacral plexus over non-contributory lumbar spine magnetic resonance imaging in radiculopathy: A prospective study Prospective Study. *World J Radiol*. 2016;8(1):109-116

Possible Protocols

SPAIR- Selectively suppresses fat (similar to STIR)

SPACE- ***isotropic*** 3D TSE

VIBE- ***isotropic*** 3D GRE

Phased-array body coils +/- phased-array spinal coils

Use XL Torso Coil

	Localizer (REF scan)	Mode	Slice	Gap	FAT SAT	FOV	Scan Range
AXIAL OBL	T1	TSE	3mm	1mm	None	25cm	See below
AXIAL OBL	Mid TE (50-60) T2 Fat Sat	TSE	3mm	1mm	SPAIR	25cm	See below
COR OBL	T1	TSE	3mm	1mm	None	25cm	See below
COR OBL	Mid TE (50-60) T2 Fat Sat	TSE	3mm	1mm	SPAIR	25cm	See below
Contrast Injection (OPTIONAL)							
AXIAL OBL	T1 Fat Sat	TSE	3mm	1mm	SPIR	25cm	See below
COR OBL	T1 Fat Sat	TSE	3mm	1mm	SPIR	25cm	See below

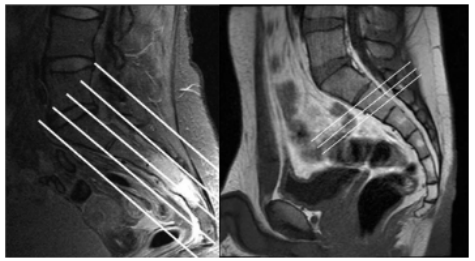
Notes: Angle OBLIQUE to sacrum

FOV:

Craniocaudad = L5 thru lesser trochanters
AP = sacrum thru pubic symphysis
Transverse = greater trochanter to greater trochanter

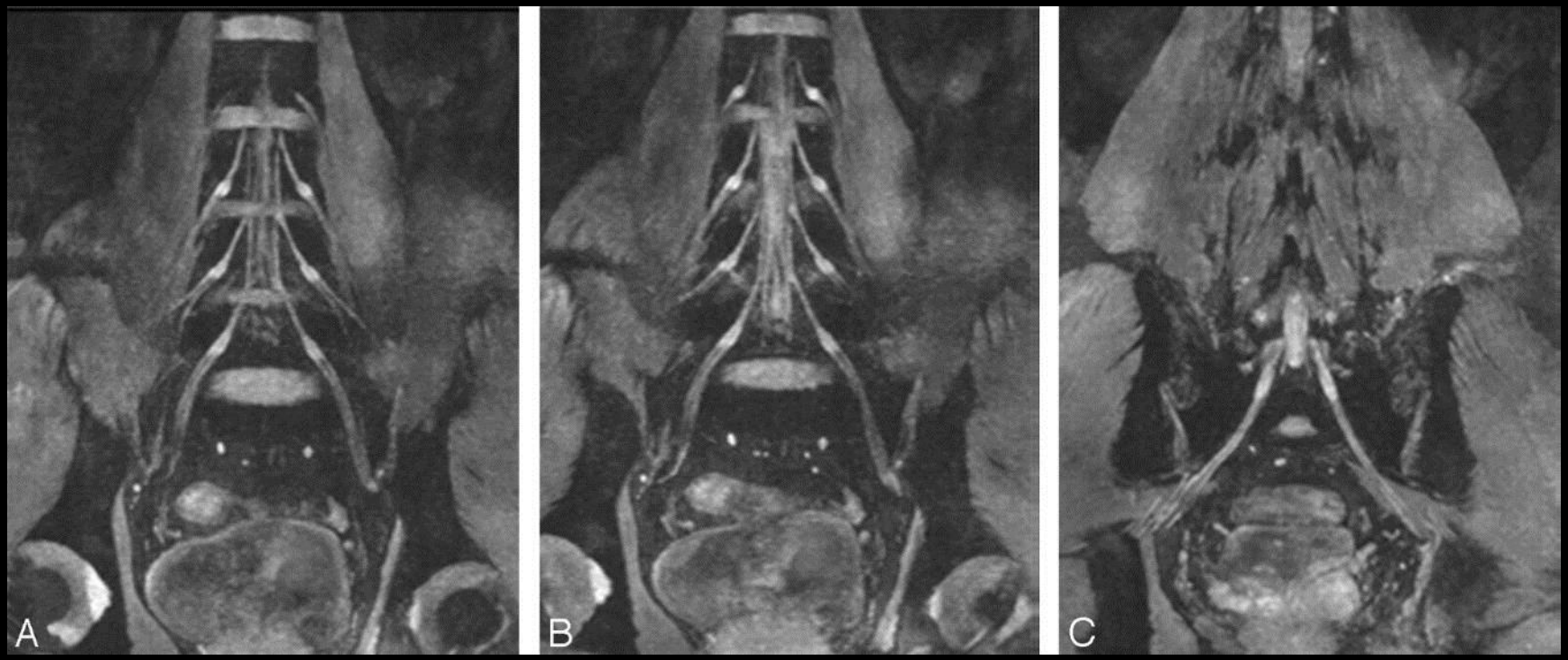
If hardware is present:

- Do Axial and Coronal STIR instead of fat-sat mid-TE
- If with Contrast, do non-fat-sat T1 post-contrast



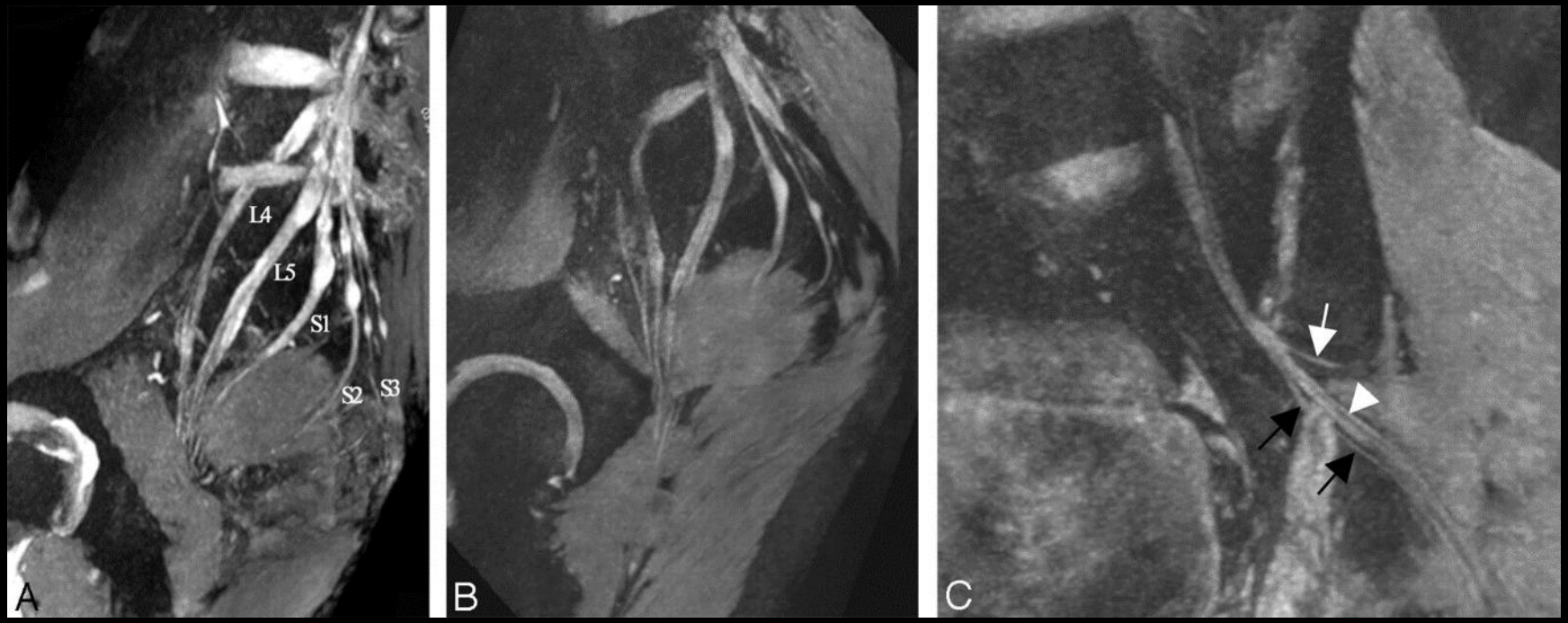
http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/diagnostic-radiology/administration/mri-protocols/mr-adult-lumbosacral-plexus.cfm

3D DW-SSFP



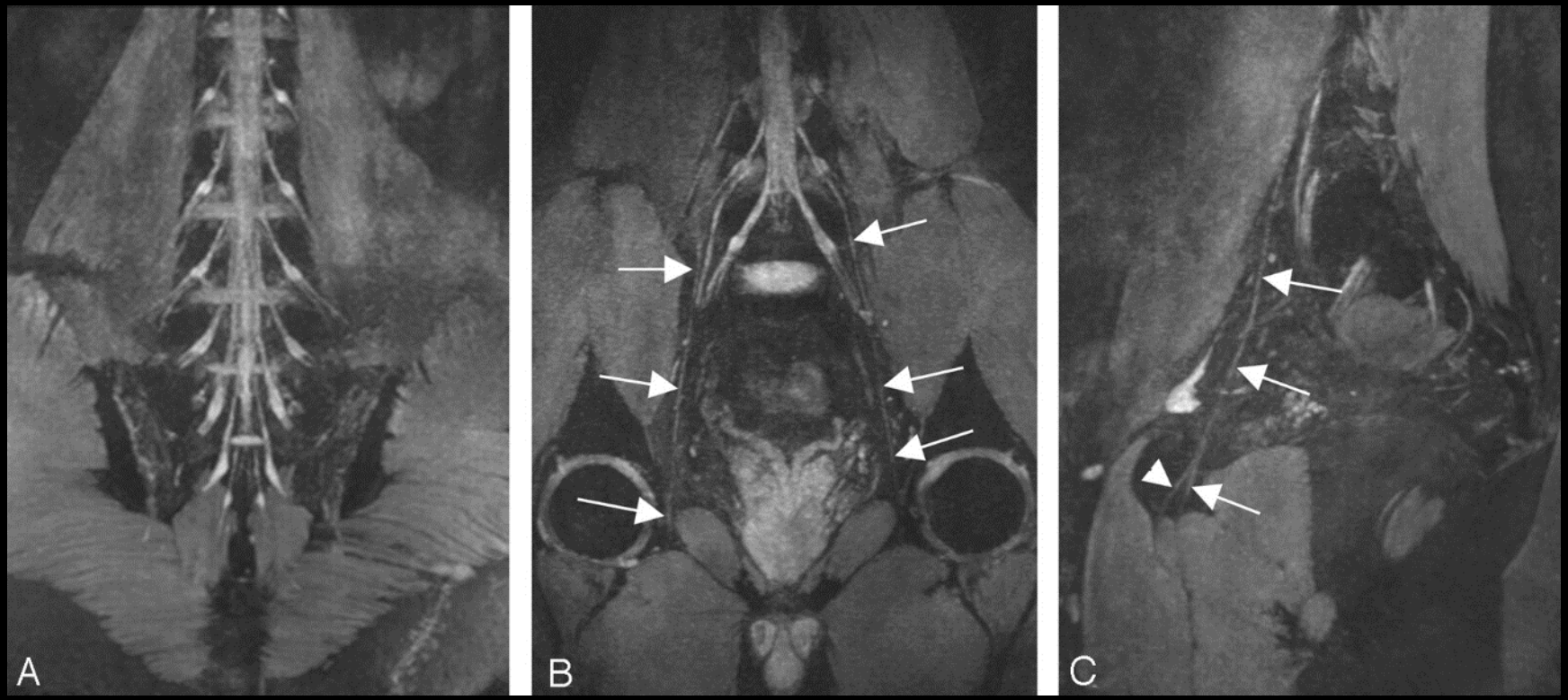
Zhang ZW, Song LJ, Meng QF, et al. High-resolution diffusion-weighted MR imaging of the human lumbosacral plexus and its branches based on a steady-state free precession imaging technique at 3T. AJNR Am J Neuroradiol. 2008;29(6):1092-1094.

3D DW-SSFP



Zhang ZW, Song LJ, Meng QF, et al. High-resolution diffusion-weighted MR imaging of the human lumbosacral plexus and its branches based on a steady-state free precession imaging technique at 3T. AJNR Am J Neuroradiol. 2008;29(6):1092-1094.

3D DW-SSFP



Zhang ZW, Song LJ, Meng QF, et al. High-resolution diffusion-weighted MR imaging of the human lumbosacral plexus and its branches based on a steady-state free precession imaging technique at 3T. AJNR Am J Neuroradiol. 2008;29(6):1092-1094.

Reading MR Neurography/Plexography

- Things to have on hand:
  - History including motor and sensory deficits and laterality
  - Any relevant prior imaging
  - EMG results
  - Reference material

Sensory Dermatomes

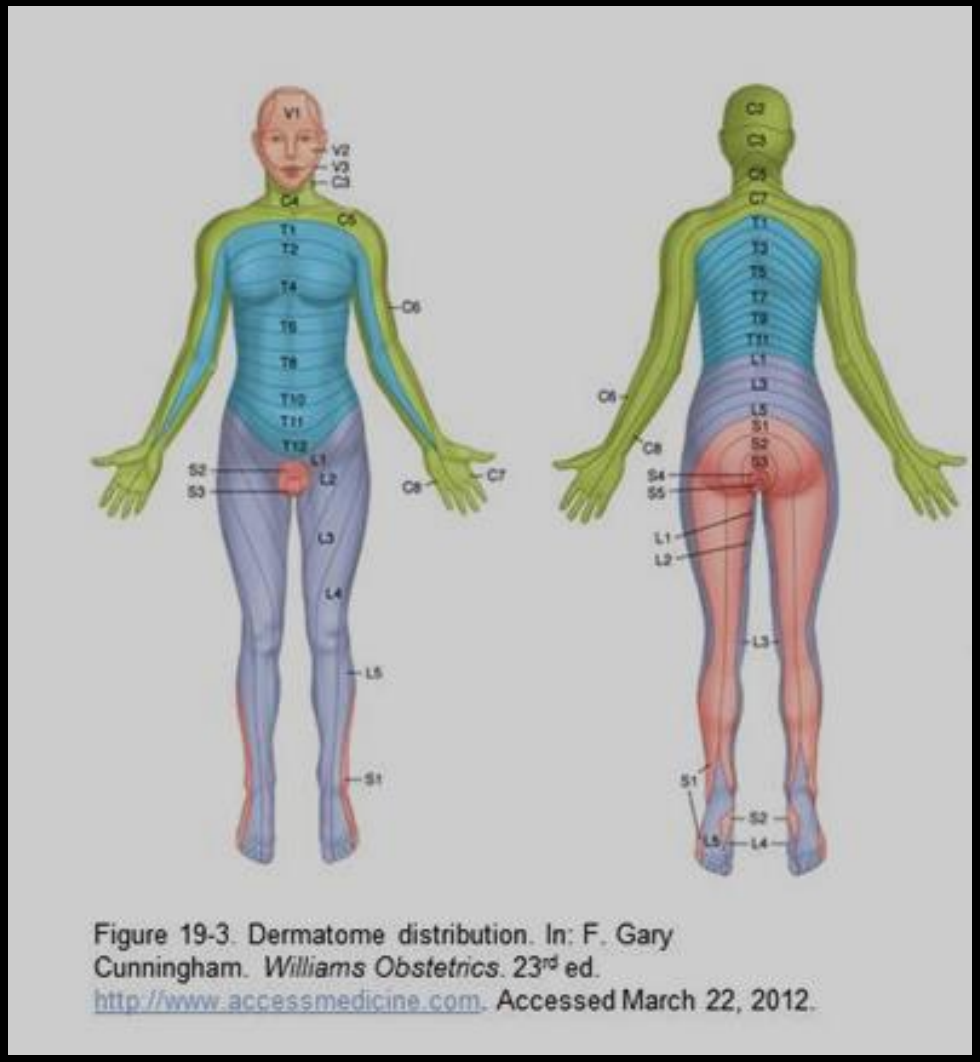
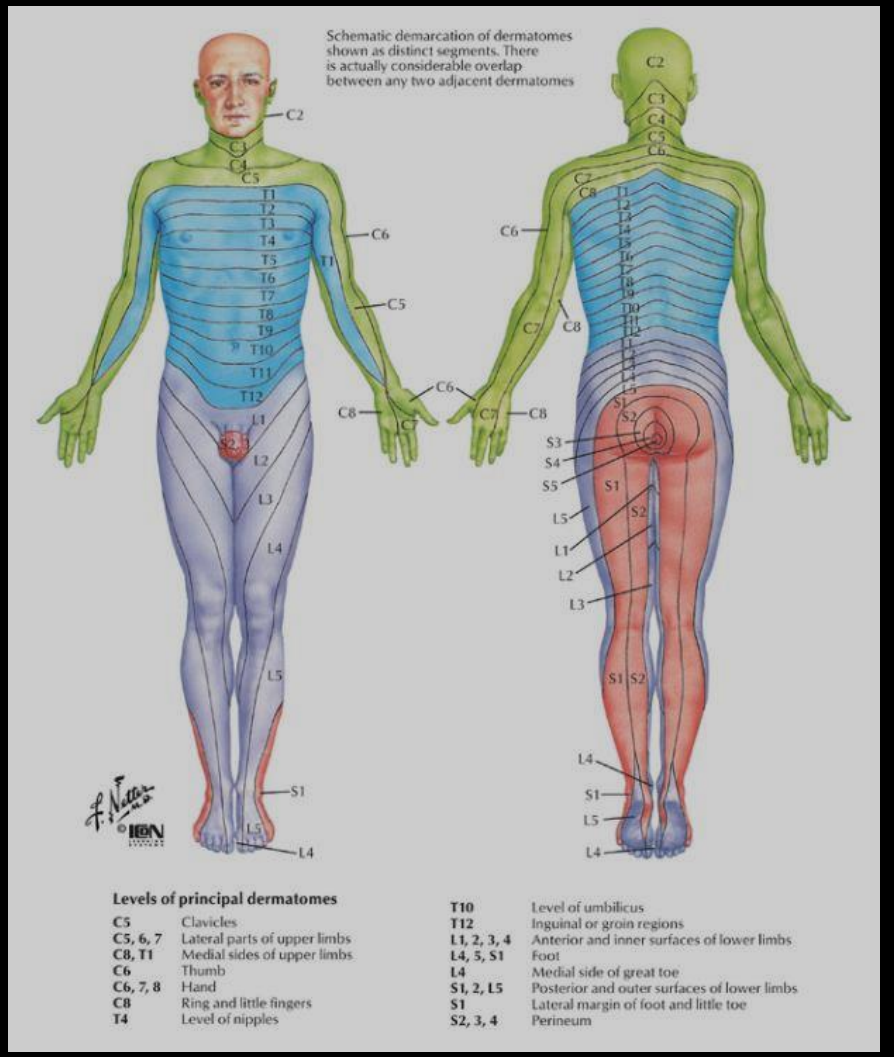


Figure 19-3. Dermatome distribution. In: F. Gary Cunningham. *Williams Obstetrics*. 23rd ed. http://www.accessmedicine.com. Accessed March 22, 2012.



Levels of principal dermatomes

C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
T12	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

http://accessphysiotherapy.mhmedical.com/data/Multimedia/grandRounds/lumbar/media/lumbar_print.html
http://www.backpain-guide.com/Chapter_Fig_folders/Ch06_Path_Folder/4Radiculopathy.html

What Do You Mean by Numb?

- Anesthesia - Loss of sensitivity
- Paresthesia - abnormal sensation such as tingling, tickling, pricking, numbness or burning of a person's skin with no apparent physical cause.
- Dysesthesia – unpleasant sensation, ranging from a mild tingling to incapacitating pain, from touch to the skin by normal stimuli (e.g. clothing)
- Allodynia - perception of innocuous stimuli as being painful*

Clinical Indications of MR Neurography

1. Confirmation of lumbrosacral plexus involvement and definition of the extent of disease in patients with a tumor or tumor-like condition.
2. Assessment of the extent of injury.
3. Evaluation of the lumbrosacral plexus in patients with indeterminate results at MR imaging of the lumbar spine.
4. Exclusion of a mass lesion in patients with unilateral abnormalities at EMG.
5. Exclusion of lesions in patients with normal or indeterminate findings at EMG and persistent symptoms.
6. Confirmation of lumbar plexitis or plexopathy in patients with clinically confusing findings and underlying known systemic conditions.
7. Evaluation of peripheral branch nerve abnormalities and associated lesions, such as piriformis syndrome, pudendal neuralgia, meralgia paresthetica, and nerve entrapments after hernia repair.
8. Planning for MR imaging–guided administration of pain medication.

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Categories of Disease

- Localized
  - Trauma, stretch injuries, extrinsic compression or infiltration
- Systemic conditions
  - Metabolic, autoimmune, ischemic, and inflammatory disorders and vasculitis

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Localized

- Neoplasms
  - Benign and malignant peripheral nerve sheath tumors; lymphoma; malignancies, such as cervical cancer, uterine cancer, colorectal cancer, mesenchymal tumors, and metastatic infiltration; fibrolipomatous hamartoma.
- Tumor-like
  - Perineurioma, amyloid
  - Intra- and extraneural ganglion cysts
  - Neuroma
- Entities related to the psoas major muscle or greater sciatic notch, such as hematoma, abscess, and phlegmon
- Endometriosis
- Trauma*

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Systemic and Inflammatory

- Diabetes mellitus (diabetic amyotrophy)
- Inflammatory neuritis (eg, Guillain-Barré syndrome)
- Ischemic or vasculitic conditions
- Chronic inflammatory demyelinating polyneuropathy,
- Hereditary neuropathies (eg, Charcot-Marie-Tooth disease)
- Radiation neuropathy
- Sarcoidosis
- Connective tissue disorders
- Idiopathic (primary) lumbrosacral plexopathy (analogous to idiopathic brachial plexopathy or Parsonage Turner)

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Characteristics of Nerve Disease

Direct imaging Features

Changes in:

- Nerve size
- Fascicular morphologic characteristics
- Signal intensity
- Nerve course

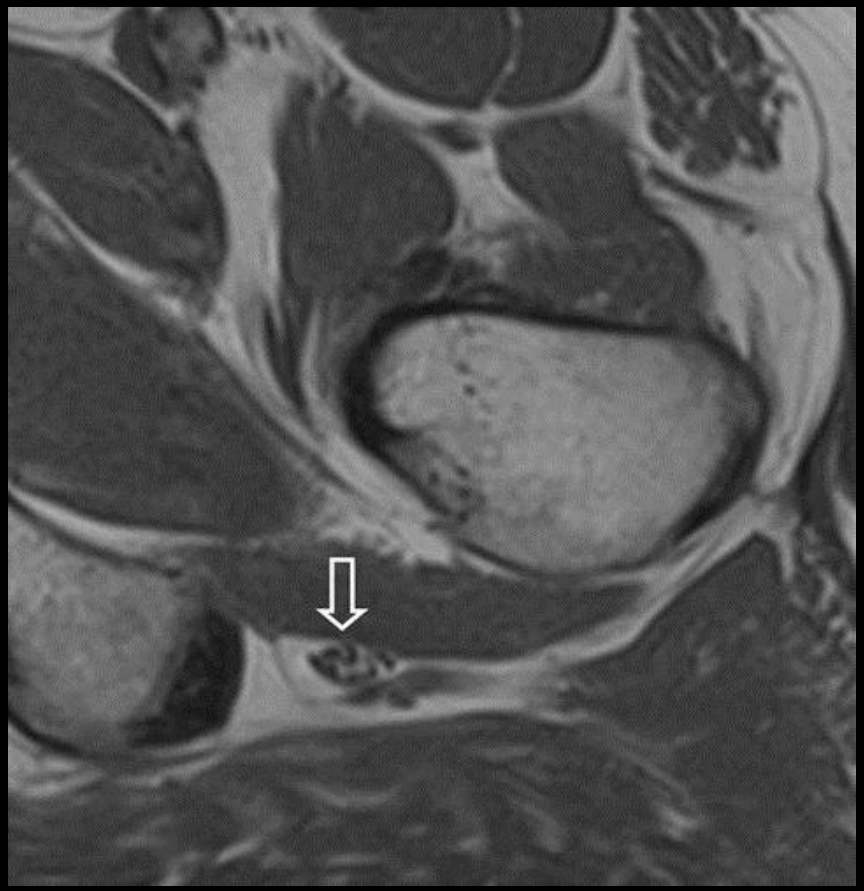
Indirect imaging Features

Changes of:

- Effacement of perineural fat planes as a result of focal fibrosis or mass lesions
- Regional muscle denervation*

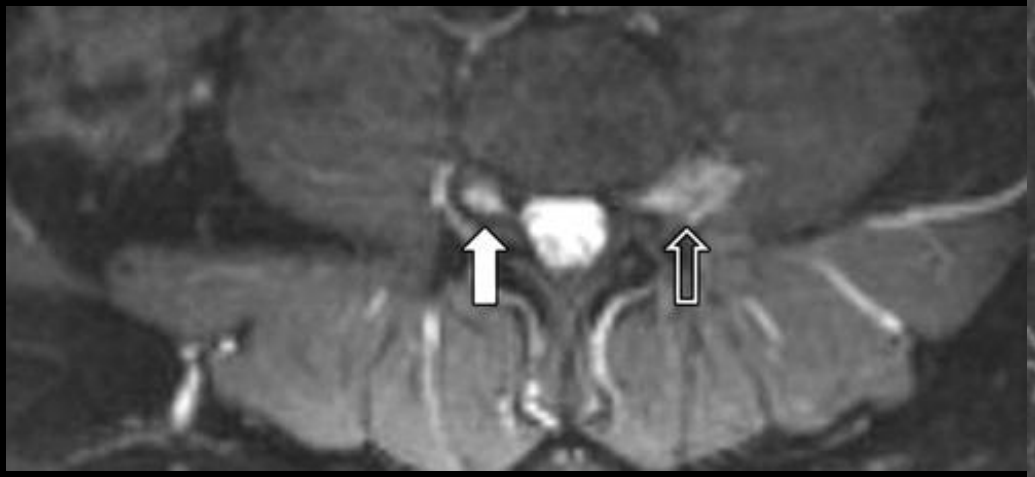
Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Normal



Catherine N. Petchprapa, Zehava Sadka Rosenberg, Luca Maria Sconfienza, Conrado Furtado A. Cavalcanti, Renata La Rocca Vieira, and Jonathan S. Zember. MR Imaging of Entrapment Neuropathies of the Lower Extremity. RadioGraphics 2010 30:4, 983-1000

Abnormal



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Muscle Edema DDx

- Trauma
  - Effects of direct injury or tear
  - Denervation injury: denervation changes in muscles
- Early myositis ossificans
- Inflammatory myopathies
  - Dermatomyositis
  - Polymyositis
  - Inclusion body myositis
  - Eosinophilic myositis
  - Proliferative myositis
  - Myositis associated with connective tissue diseases
    - Systemic lupus erythematosus (SLE)
    - Sjögren syndrome
    - Overlap syndrome
    - Scleroderma
    - Mixed connective tissue disease
- Infective myositis including pyomyositis and viral myositis
- Infiltrating neoplasm, e.g. muscle lymphoma
- Acute or subacute phase of autoimmune neuropathy, e.g. Parsonage-Turner syndrome (in the shoulder)
- Rhabdomyolysis
  - Drug-induced
  - Intravenous heparin therapy
  - Trauma
  - Burns
  - Toxins
  - Autoimmune inflammation
- Vascular causes
  - Muscle infarction
    - Microvascular disease, e.G. Diabetes
  - Behcet disease
  - Sickle cell crisis
- Overuse
  - delayed onset muscle soreness (DOMS)

https://radiopaedia.org/articles/skeletal-muscle-oedema-on-mri-differential

Denervation Changes

Duration	Imaging Findings
Acute (<1 month)	Areas of hyperintensity on T2-weighted images **(indicative of edema)**
Subacute (1–3 months)	Areas of hyperintensity on T2- **(indicative of edema)** and T1-weighted images **(indicative of fatty infiltration)**
Chronic (>3 months)	Areas of hyperintensity on T1-weighted images **(indicative of fatty infiltration**) and reduced muscle volume **(indicative of atrophy)**

Table Adapted from: Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987.

Nerve Signal Intensity

- Similar to the brachial plexus, the signal intensity of the lumbrosacral nerves at T2- weighted imaging is considered abnormal when it approaches that of adjacent vessels and is asymmetric to that in the contralateral side.

- Minimally increased signal intensity at T2-weighted MR imaging should be approached with caution because “magic angle” artifact is a well-recognized occurrence at MR imaging of the lumbrosacral plexus.

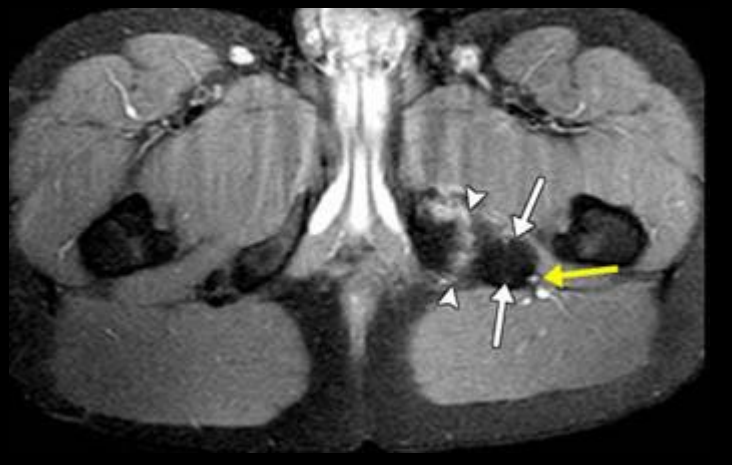
Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

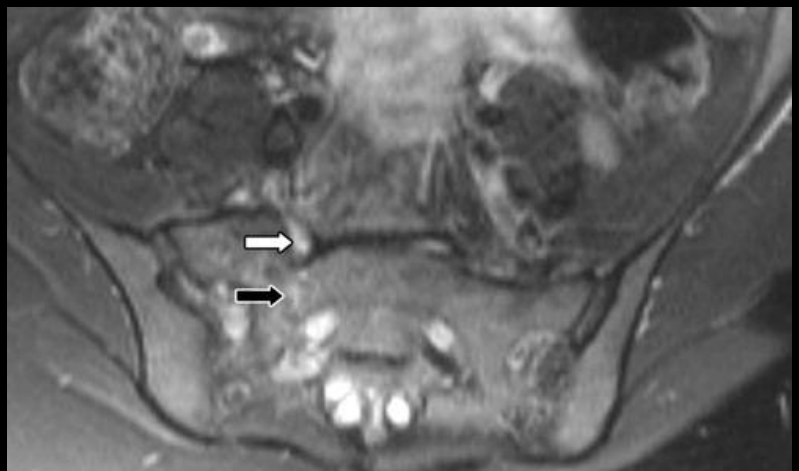
LOCALIZED CASES

Nerve Trauma

- Mechanisms:
  1. Nerve sectioning
  2. Stretching
  3. Compression (intrisic or extrinsic)

- May result from fractures, dislocations, or hematoma.





Petchprapa CN, Rosenberg ZS, Sconfienza LM, Cavalcanti CFA, La Rocca Vieira R, Zember JS. MR Imaging of Entrapment Neuropathies of the Lower Extremity. *RadioGraphics*. 2010;30(4):983-1000.

http://radsource.us/hamstring-tears/

Seddon Classification of Nerve Injury

Neurapraxia

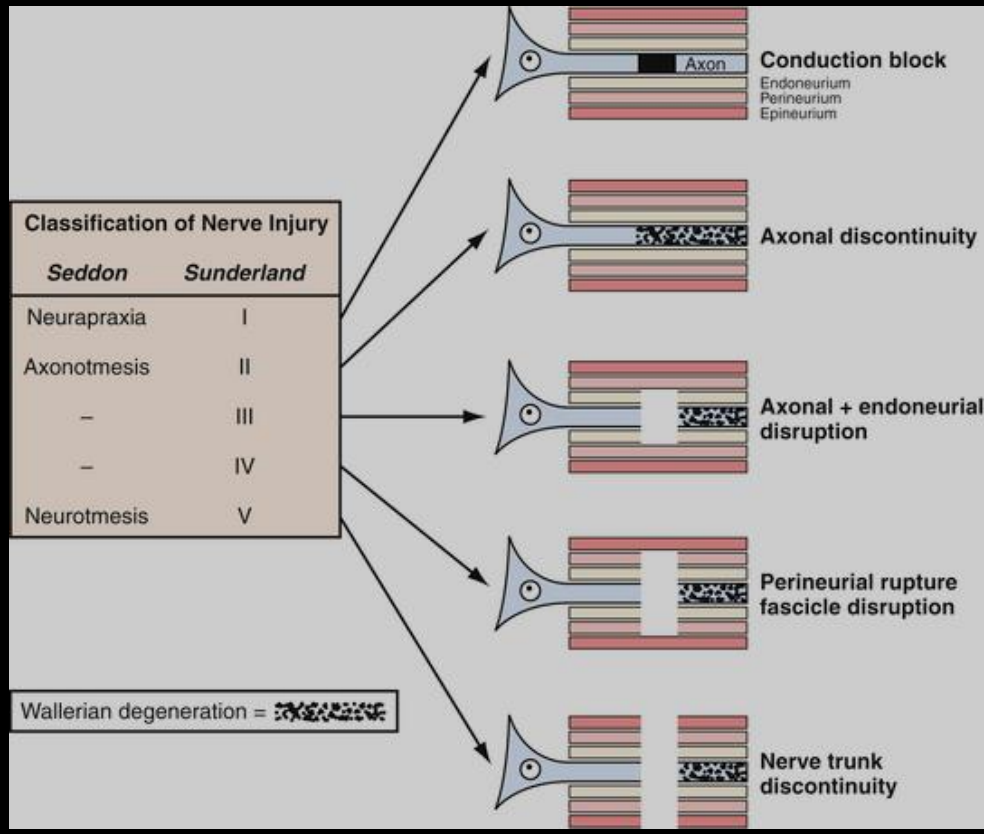
- Axonal dysfunction without interruption of axons or nervous sheath
- Increased signal intensity in the involved nerve or nerves on T2-weighted images and **no associated muscle denervation changes.**

Axonotmesis

- Discontinuity of axons preserving the integrity of connective tissue (perineurium, endoneurium, and epineurium)
- **Wallerian degeneration** distal to the site of insult.
- **Muscle denervation changes** and nerve enlargement as well as disruption or effacement of nerve fascicles.

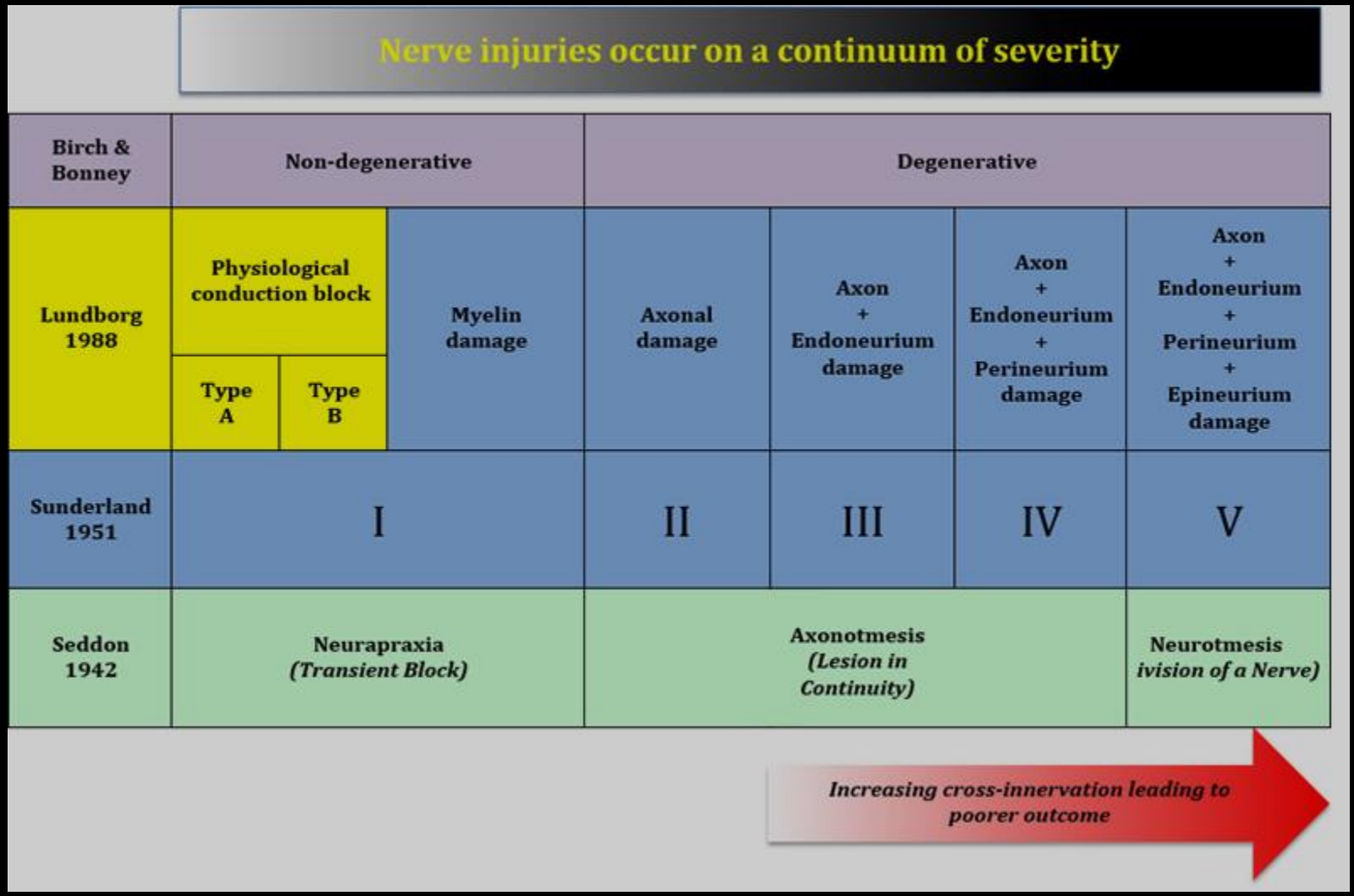
Neurotmesis

- Axonal injury and disruption of the surrounding perineurium and epineurial layers are seen
- Development of a neuroma in continuity or complete transection of the nerve with formation of an end-bulb (stump) neuroma.



http://clinicalgate.com/acute-nerve-injuries/

Severity of Traumatic Nerve Injury

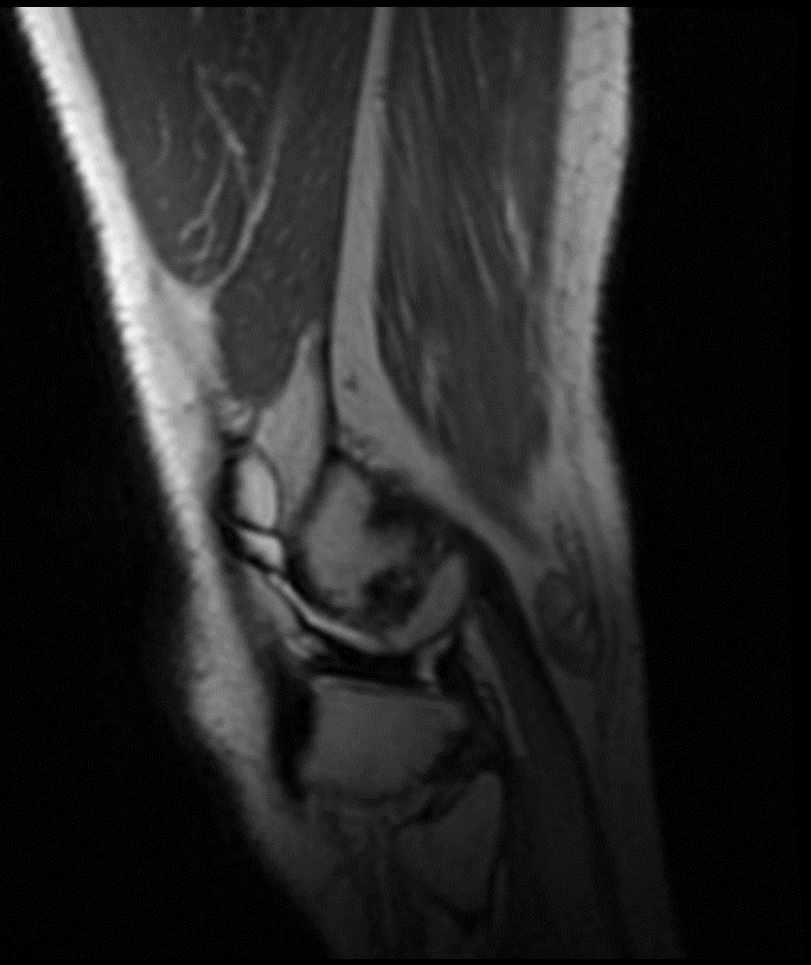


http://www.nerveclinic.co.uk/nerve-injuries/classification

Terminal Neuroma

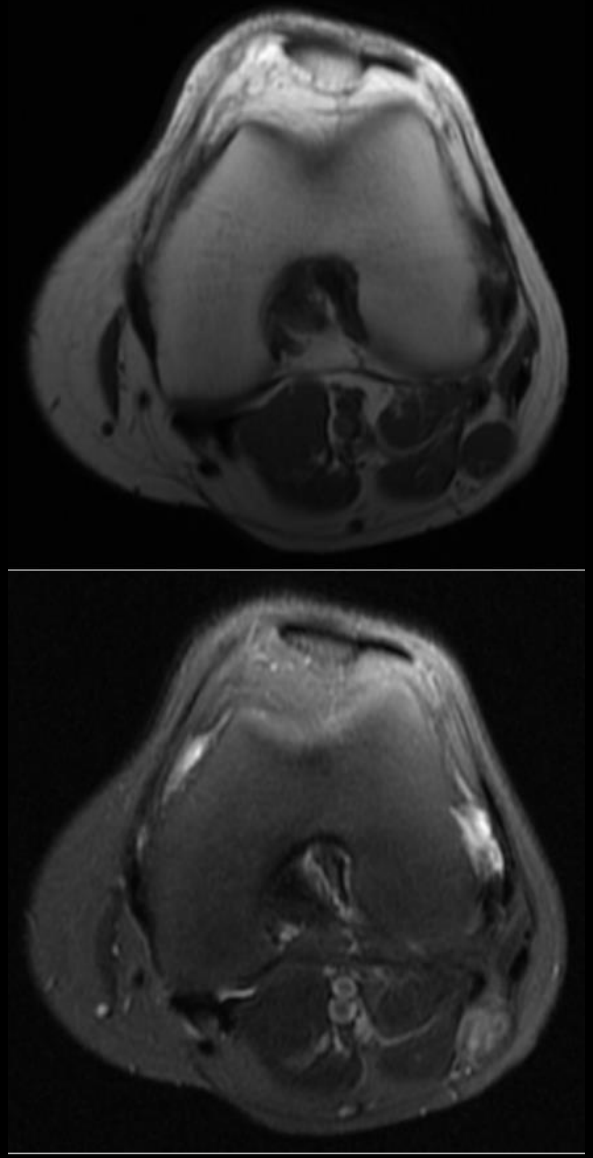
- Any nerve that is lacerated, avulsed, or traumatized may form a neuroma. Neuroma is not a neoplasm.

- *Neuroma-in-continuity*
  - Spindle neuroma
  - Lateral neuroma
  - Neuroma after nerve repair
- *Neuromas in completely severed nerves*
  - Terminal neuroma (end-bulb neuroma)
- *Amputation stump neuroma*



Terminal Neuroma

- Neuroma:
  - Develops a few months after nerve trauma
  - Fusiform enlargement of the nerve of variable length
  - T1 iso- to muscle
  - T2 iso- to hyper-
  - Typically does not enhance



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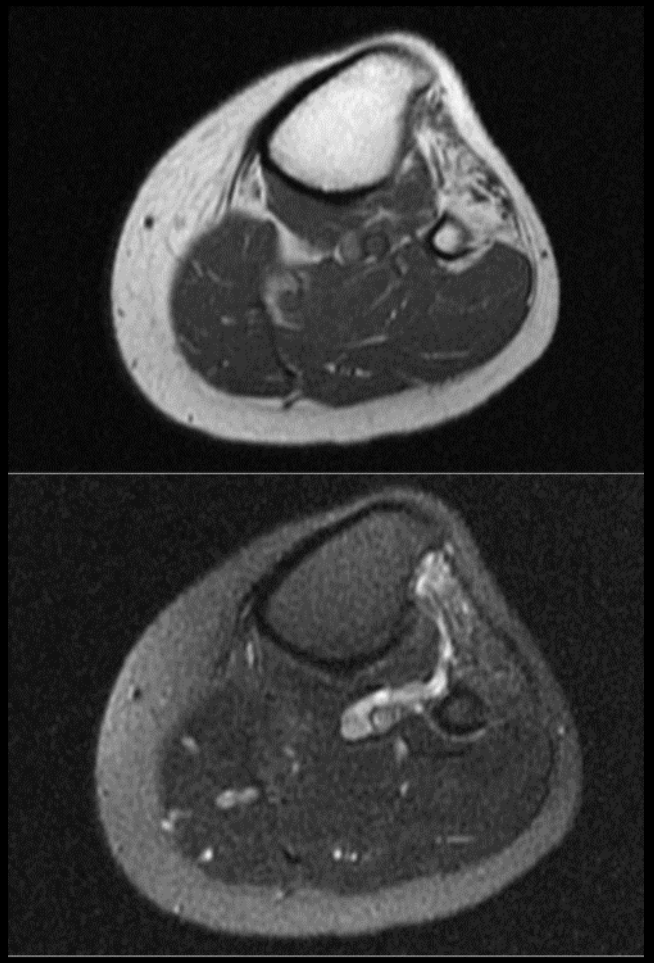
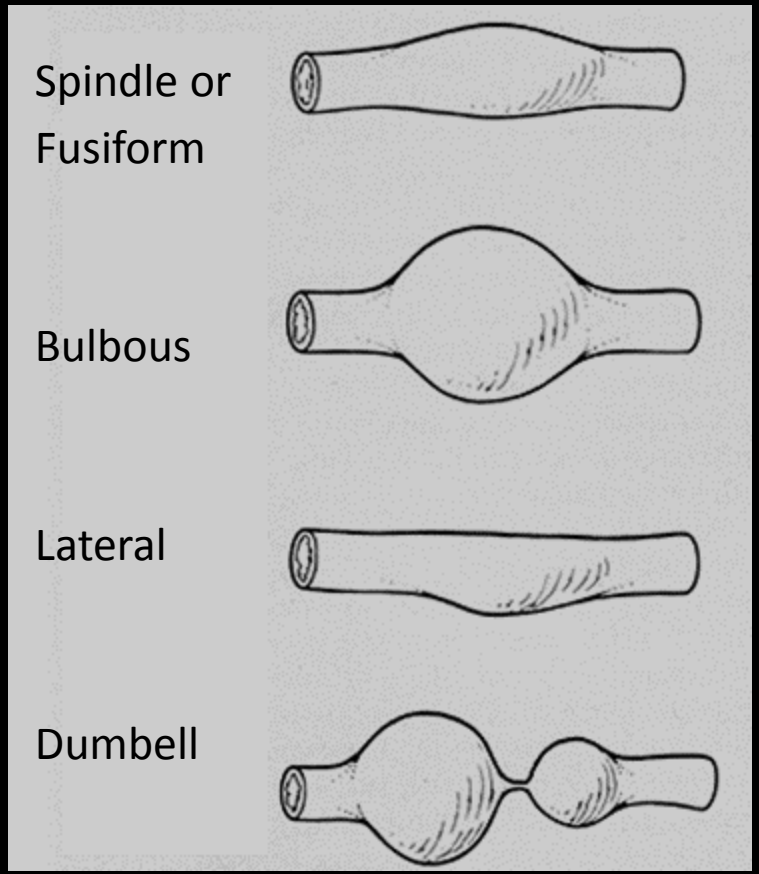
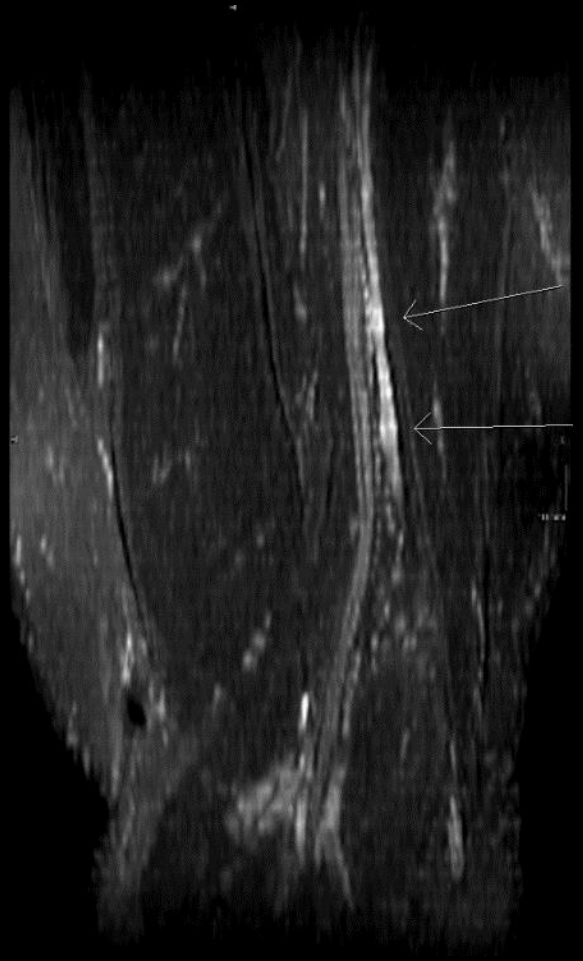


Neuroma in Continuity





http://cal.vet.upenn.edu/projects/saortho/chapter_65/65f10.jpg

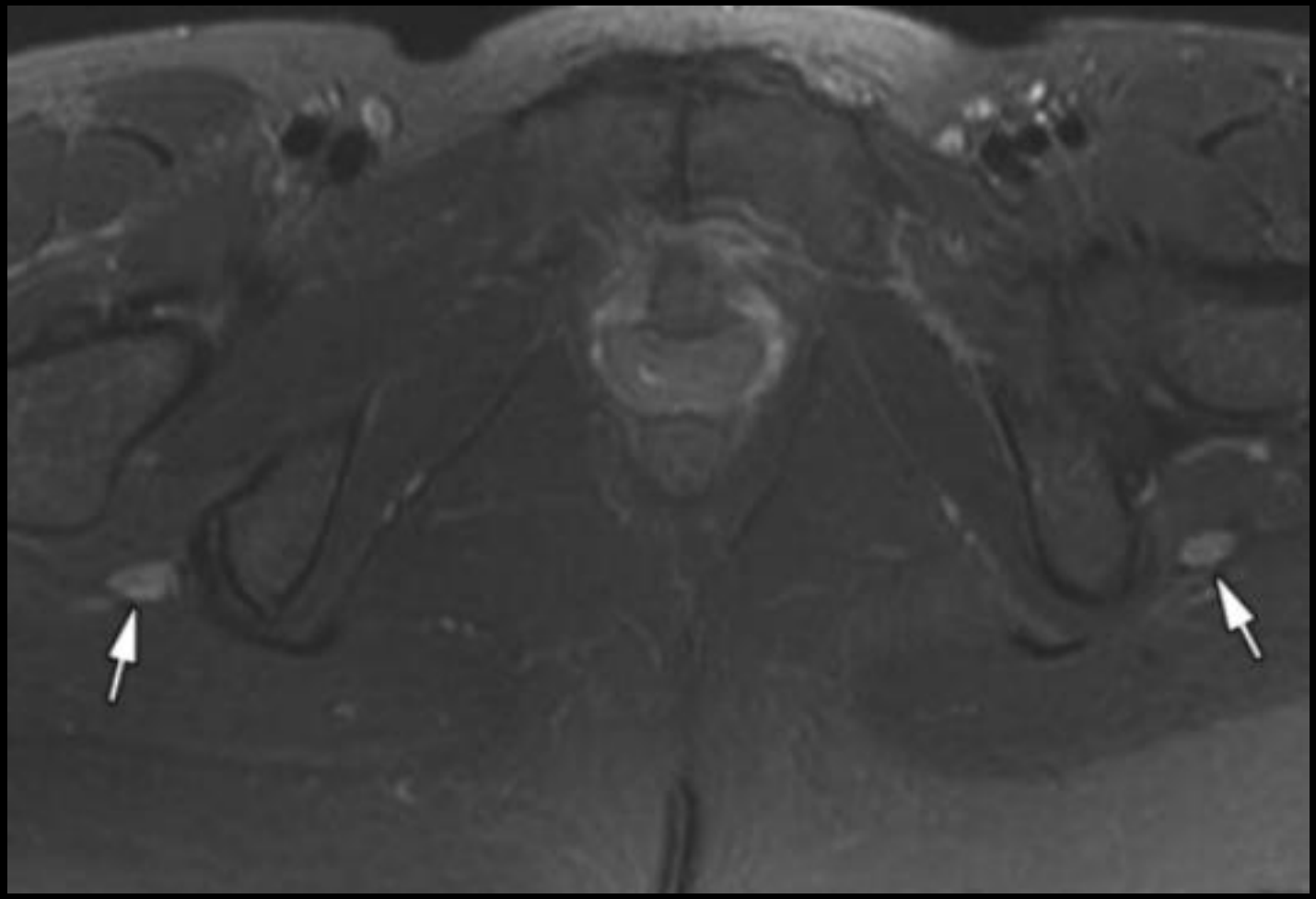
Amputation Stump Neuroma

http://radsource.us/traumatic-neuroma

Sciatic Stretch Injury

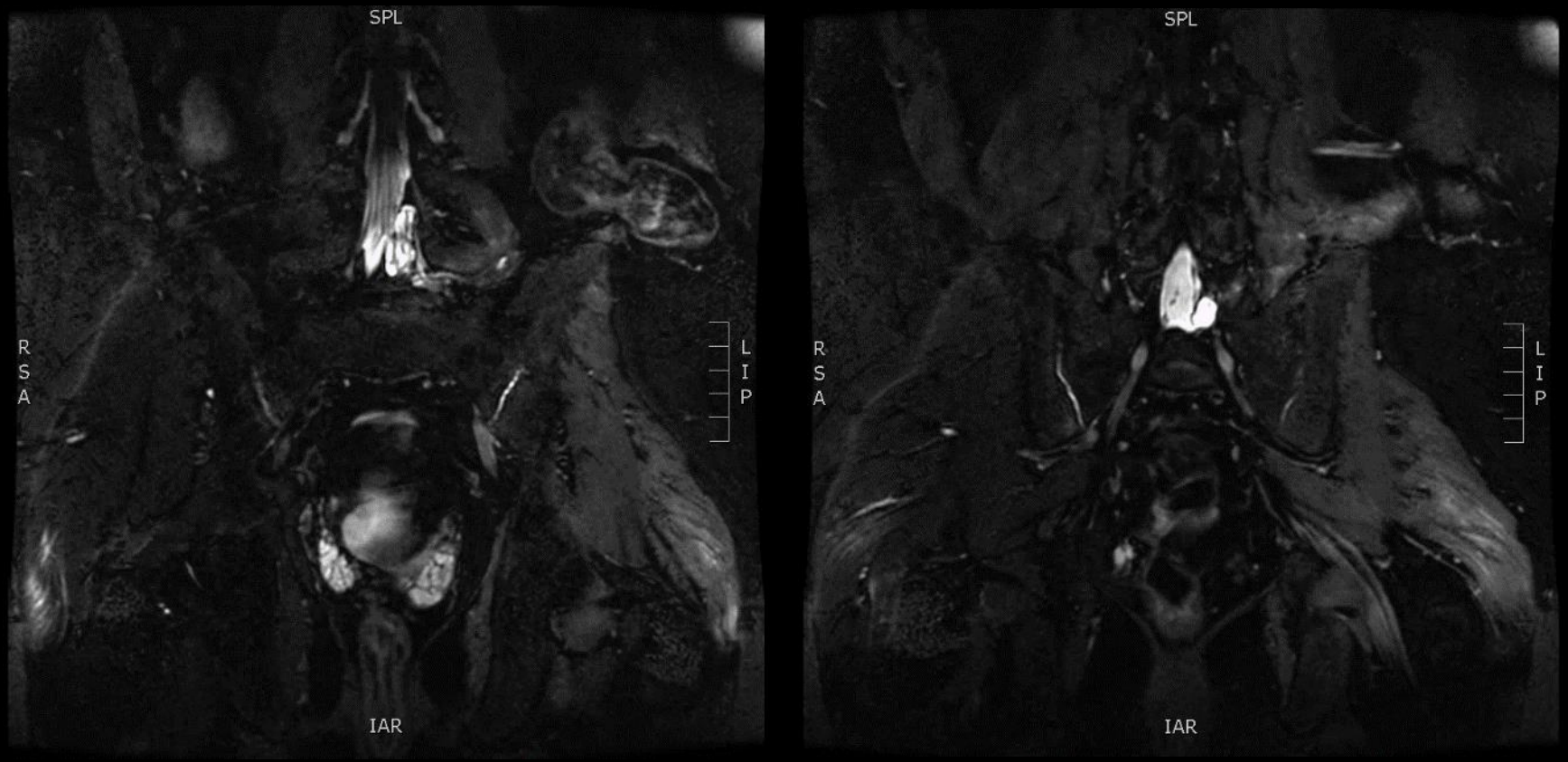
Courtesy of Brady Huang

Prolonged Lithotomy Position



Petchprapa CN, Rosenberg ZS, Sconfienza LM, Cavalcanti CFA, La Rocca Vieira R, Zember JS. MR Imaging of Entrapment Neuropathies of the Lower Extremity. *RadioGraphics*. 2010;30(4):983-1000. doi:10.1148/rg.304095135.

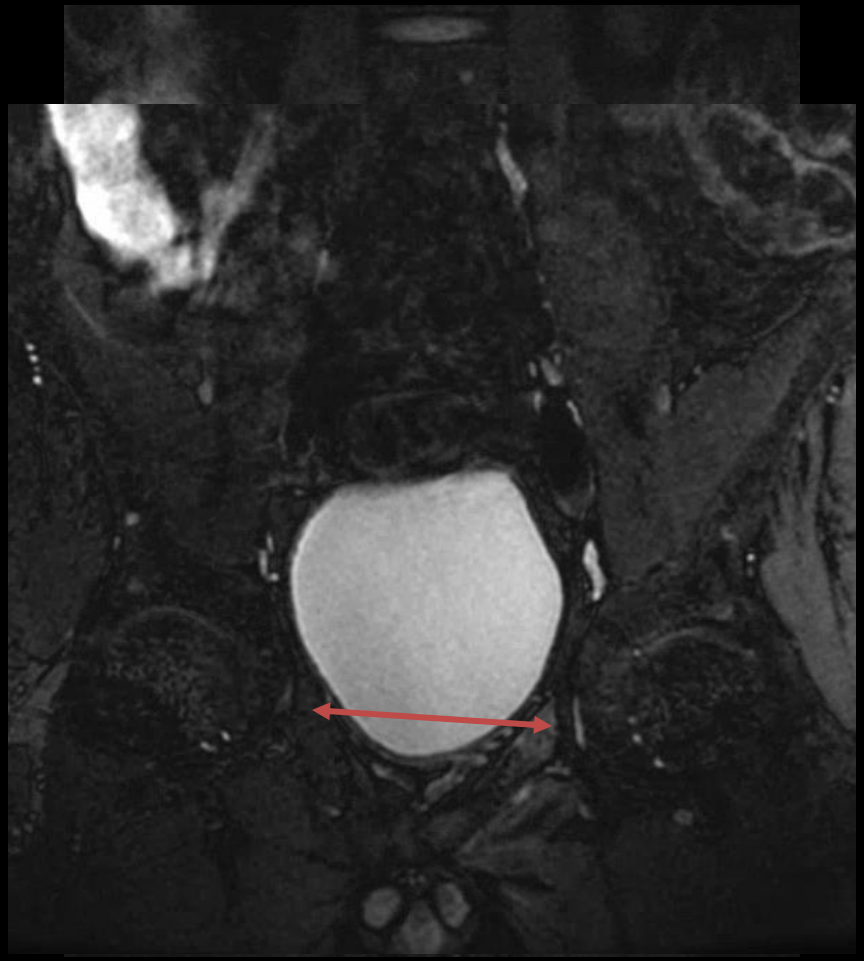
Traumatic Avulsion and Pseudomeningocele



L5 and S1 root avulsions and traumatic pseudomeningoeceles

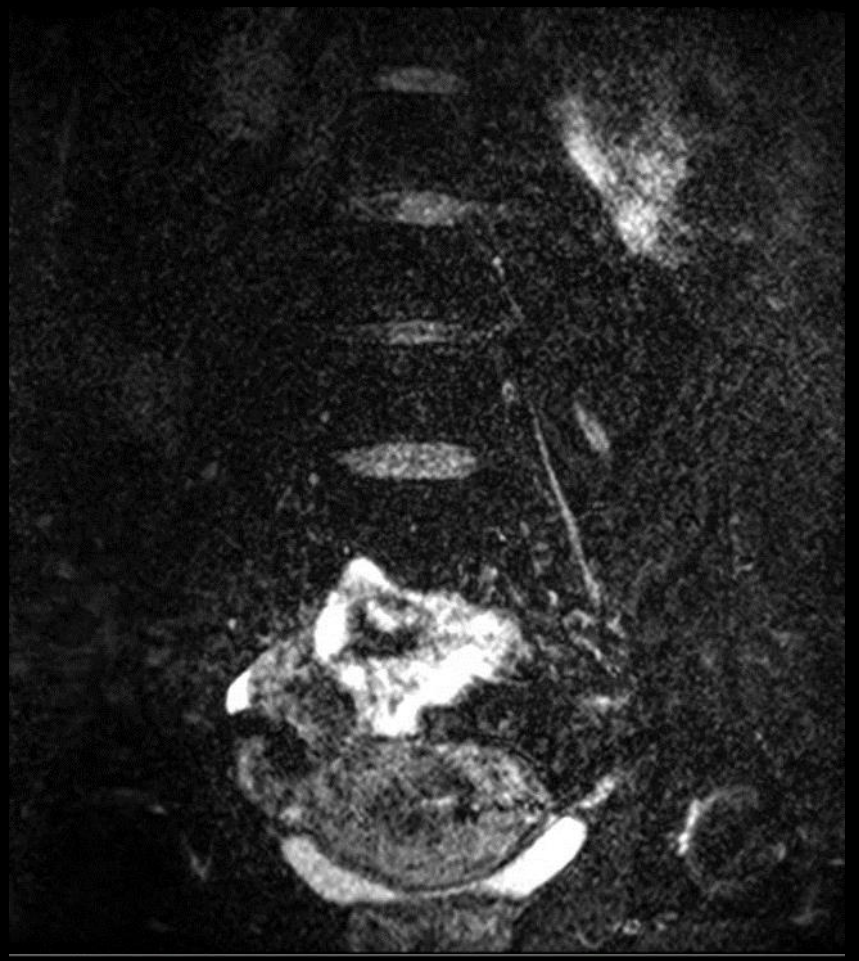
Traumatic Avulsion and Pseudomeningocele

Obturator Nerve Injury



Femoral and Obturator Neuropathy

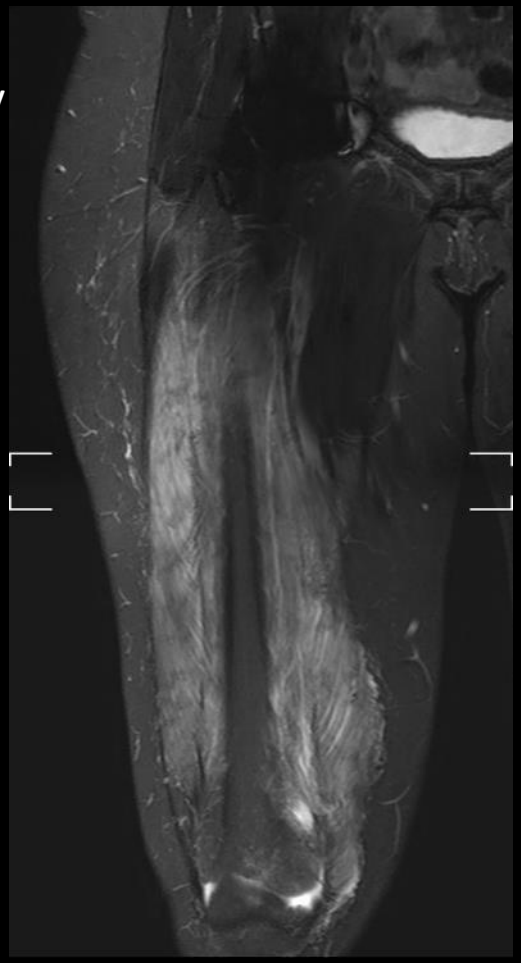
Cube PD

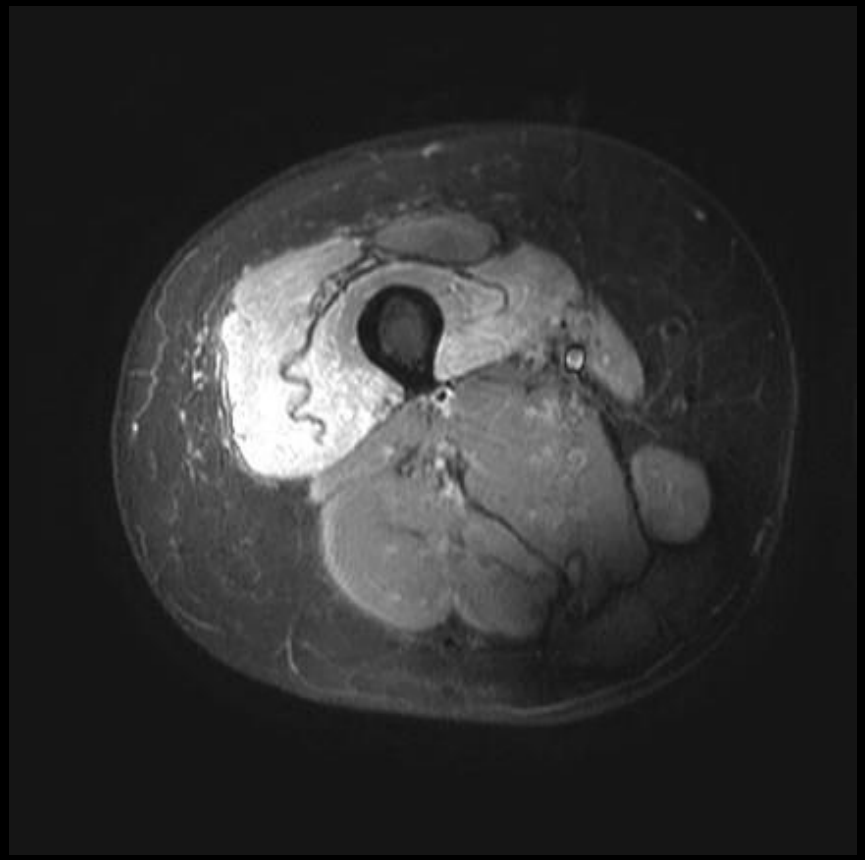


Cube T2 FS

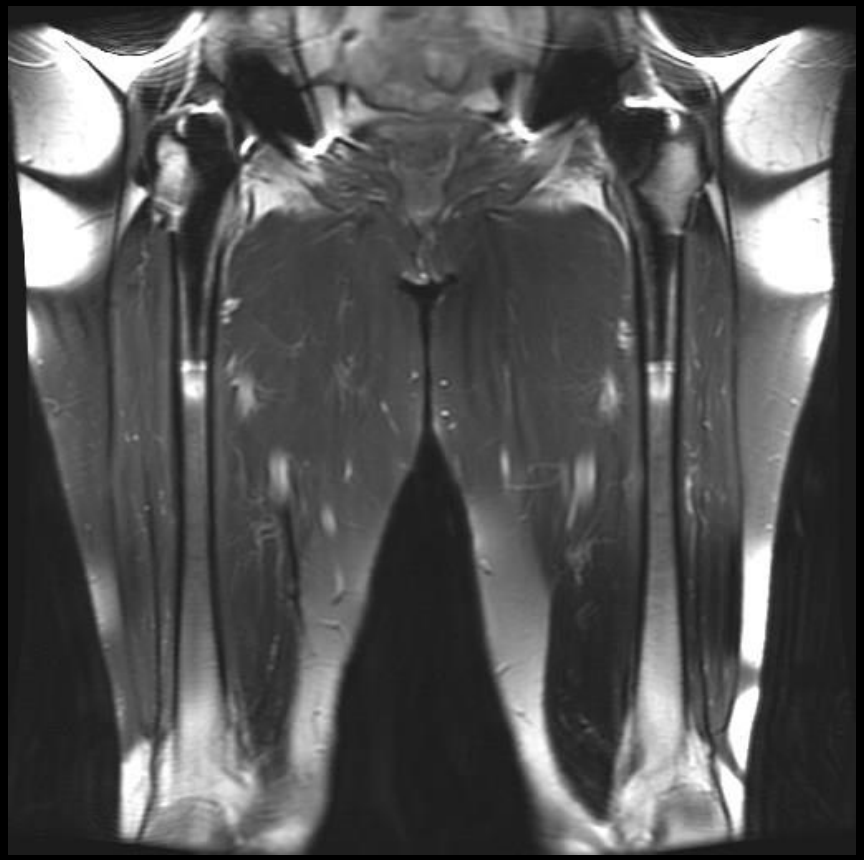
Femoral Nerve Injury

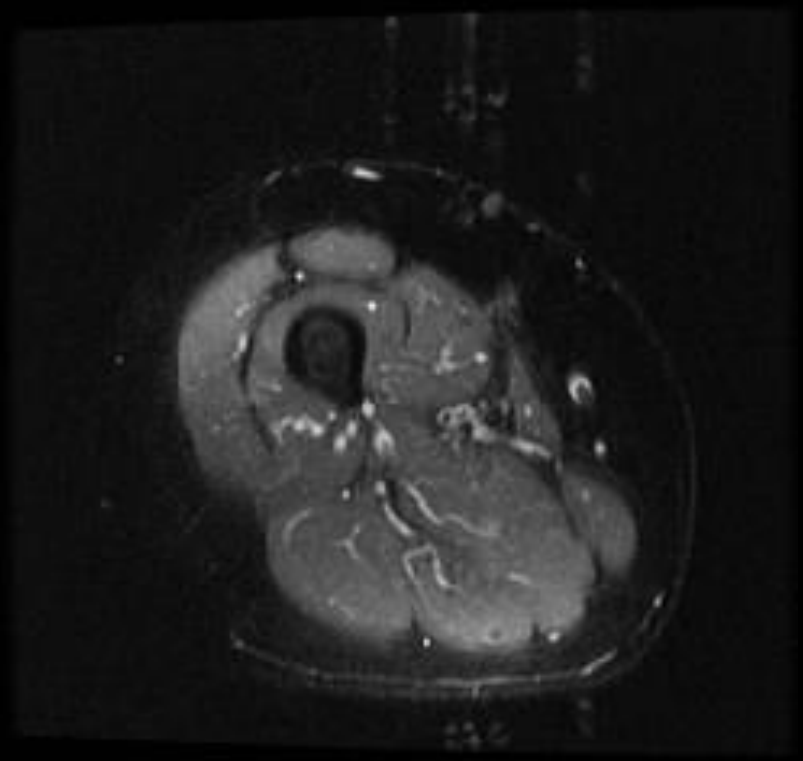
Arthroplasty





Femoral Nerve Injury





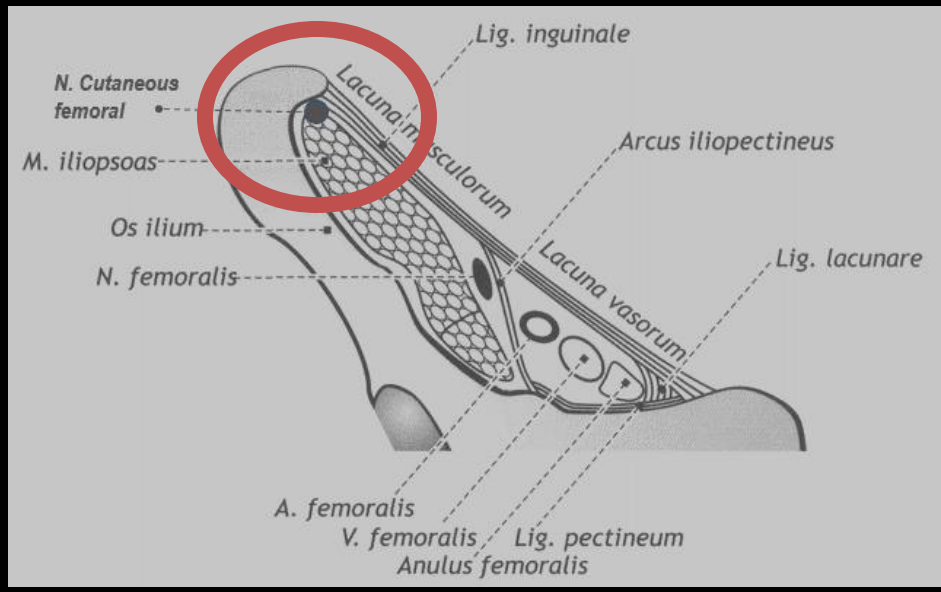
Obturator Nerve Compression

Kim S-H, Seok H, Lee SY, Park SW. Acetabular Paralabral Cyst as a Rare Cause of Obturator Neuropathy: A Case Report. Annals of Rehabilitation Medicine. 2014;38(3):427-432.

Meralgia Parasthetica (LFC)

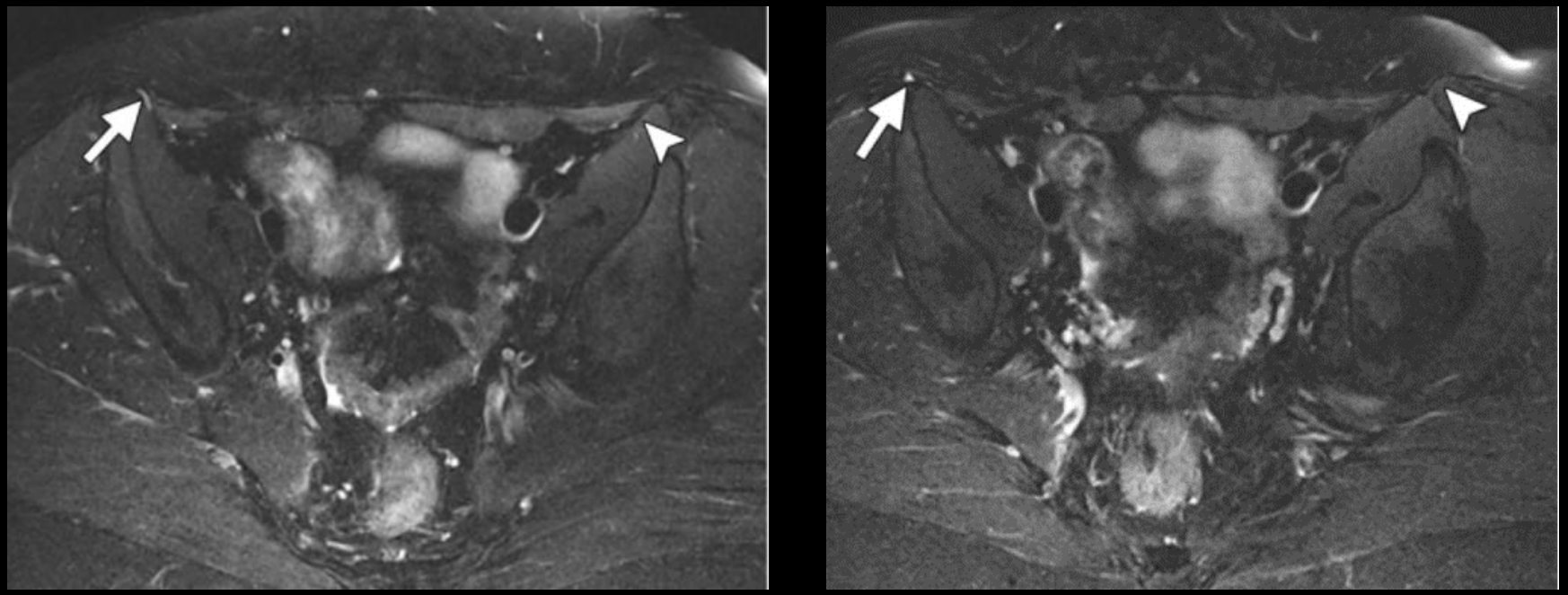
- Entrapment usually occurs in patients who are middle-aged and is bilateral in 10% of patients.

- Common causes:
  - Seat belt injury from motor vehicle accidents
  - Compression by tight garments
  - Anomalous pelvic positioning resulting from a leg length discrepancy
  - Abdominal (eg, ovarian and uterine) masses
  - Diabetes



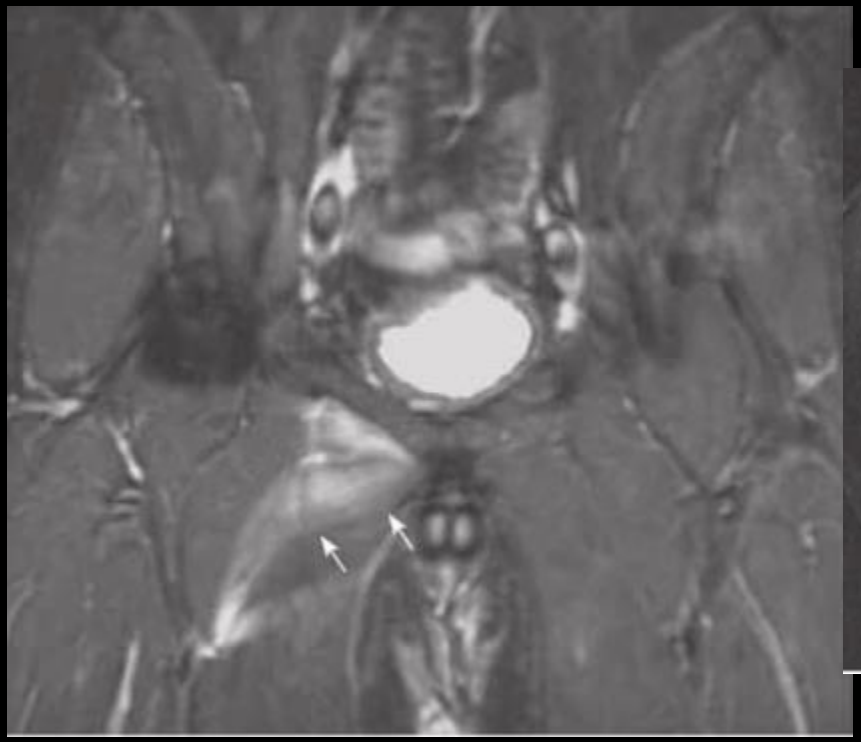
http://epomedicine.com/medical-students/lumbosacral-plexus-simplified/

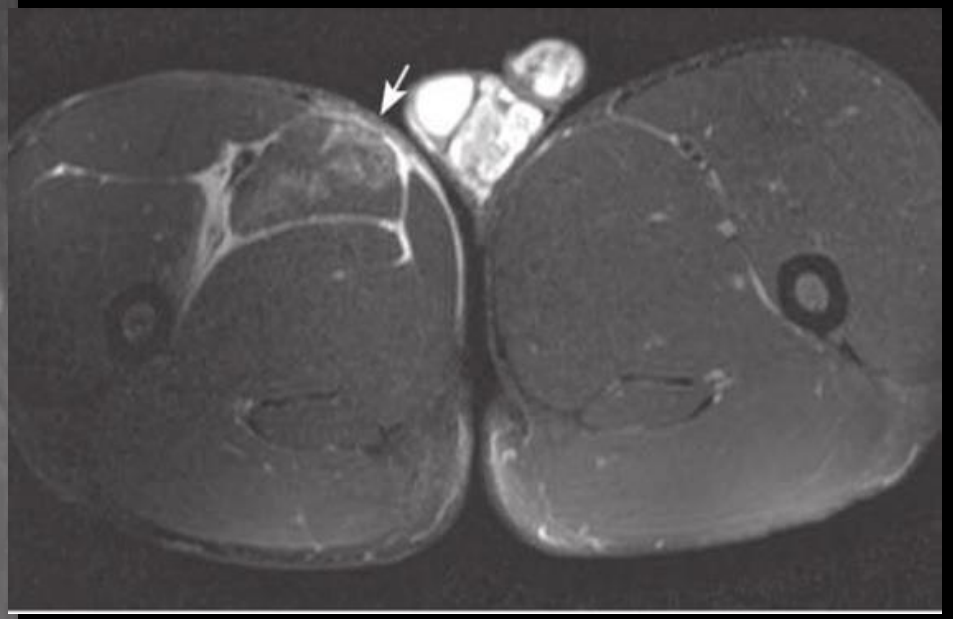
Meralgia Parathetica with a Focal Neuroma



Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987.

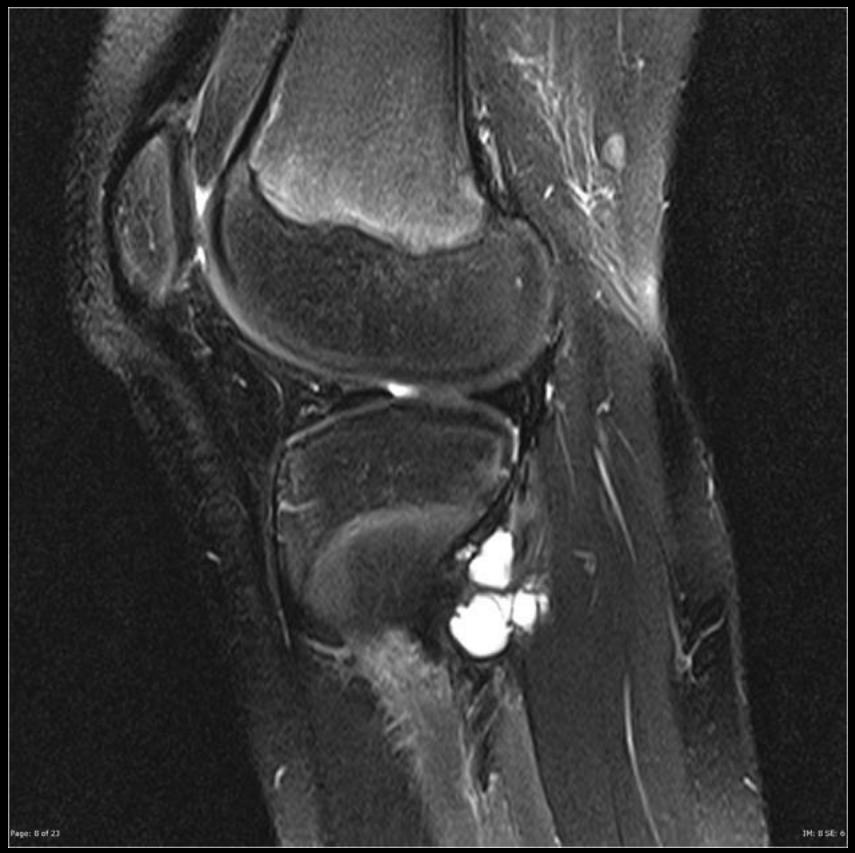
Hockey Goalie–Baseball Pitcher Syndrome





Omar IM, Zoga AC, Kavanagh EC, et al. Athletic Pubalgia and “Sports Hernia”: Optimal MR Imaging Technique and Findings. *RadioGraphics*. 2008;28(5):1415-1438.

Intraneural Ganglion Cyst



Case courtesy of Dr Jeremy Jones, Radiopaedia.org, rID: 24071

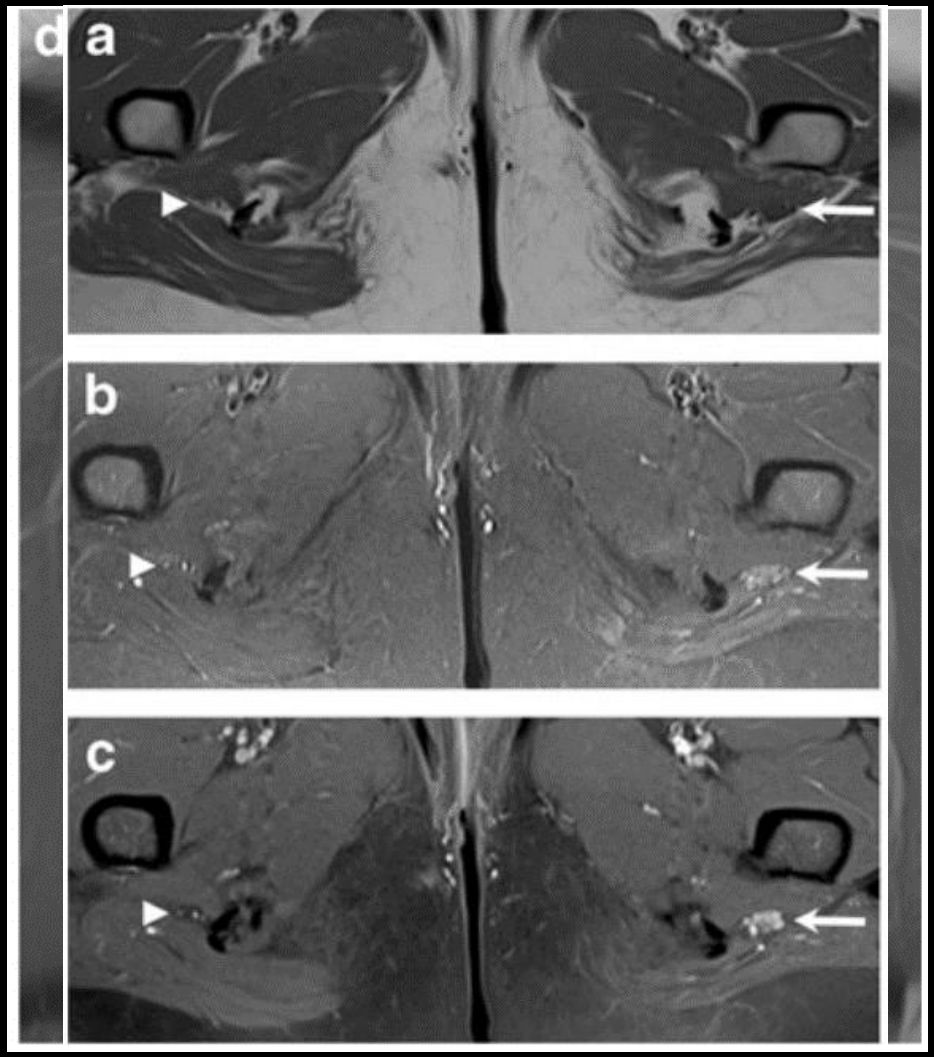
Intraneural Ganglion Cyst

- Cyst formation arising from an articular branch, usually of the peroneal nerve and less commonly the tibial nerve.

Mayo Clinic Animation https://www.youtube.com/watch?v=4QbXBhWomOc

Intraneural Perineurioma

- Not a traumatic lesion like neuroma
- Rare benign peripheral nerve neoplasm
- Most commonly affects teenagers and young adults
- Features:
  - Fascicles involved invidually
  - T1 hypo- to isointense
  - T2 hyperintense
  - Avid enhancement post gadolinium.
  - Atrophy may be present within the muscles innervated by the affected nerve



Nacey NC, Almira Suarez MI, Mandell JW, Anderson MW, Gaskin CM. Intraneural perineurioma of the sciatic nerve: An under-recognized nerve neoplasm with characteristic MRI findings. *Skeletal Radiol*. 2014;43(3):375-379.

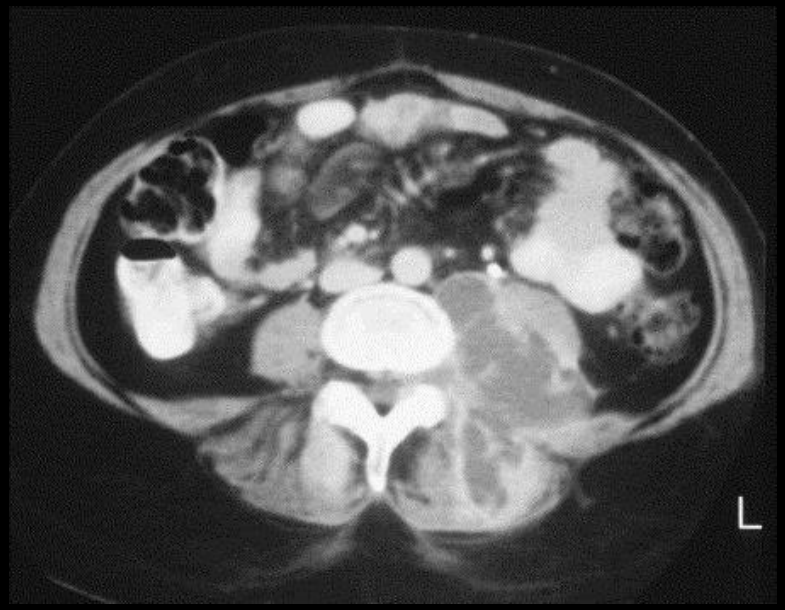
Nerve Lipomatosis

- Most commonly affects median nerve
- Sciatic nerve involvement quite rare.
- Also known as:
  - Neural Fibrolipoma
  - Intraneural Lipoma
  - Perineural Lipoma
  - Fibrolipomatous Hamartoma

Sarp AF, Pekcevik Y. Giant Lipomatosis of the Sciatic Nerve: Unique Magnetic Resonance Imaging Findings. Iran J Radiol. 2016;13(2):e20963.

Malignant Psoas Syndrome

- Patients present with:
  - Proximal lumbosacral plexopathy
  - Painful fixed flexion of the ipsilateral hip
  - Imaging evidence of ipsilateral psoas major muscle malignant involvement.

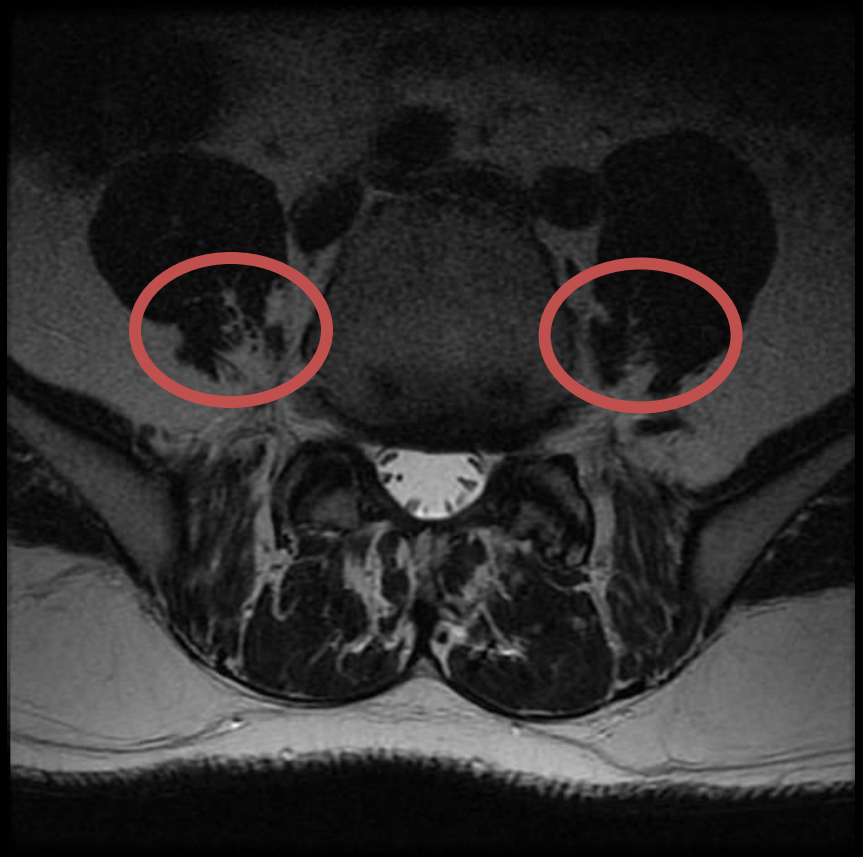


Agar M, Broadbent A, Chye R. The management of malignant psoas syndrome: Case reports and literature review. *J Pain Symptom Manage*. 2004;28(3):282-293. doi:10.1016/j.jpainsymman.2003.12.018.

Relationship of Lumbar Plexus and Psoas

In one study:

- 61 of 63 cadaveric specicmesn showed the lumbar plexus within the psoas major muscle.
  - completely posterior to the psoas major muscle in only 2 of 63.
- In nearly all cases the femoral nerve as well as the obturator were located within the psoas major muscle at the L4-L5 level.



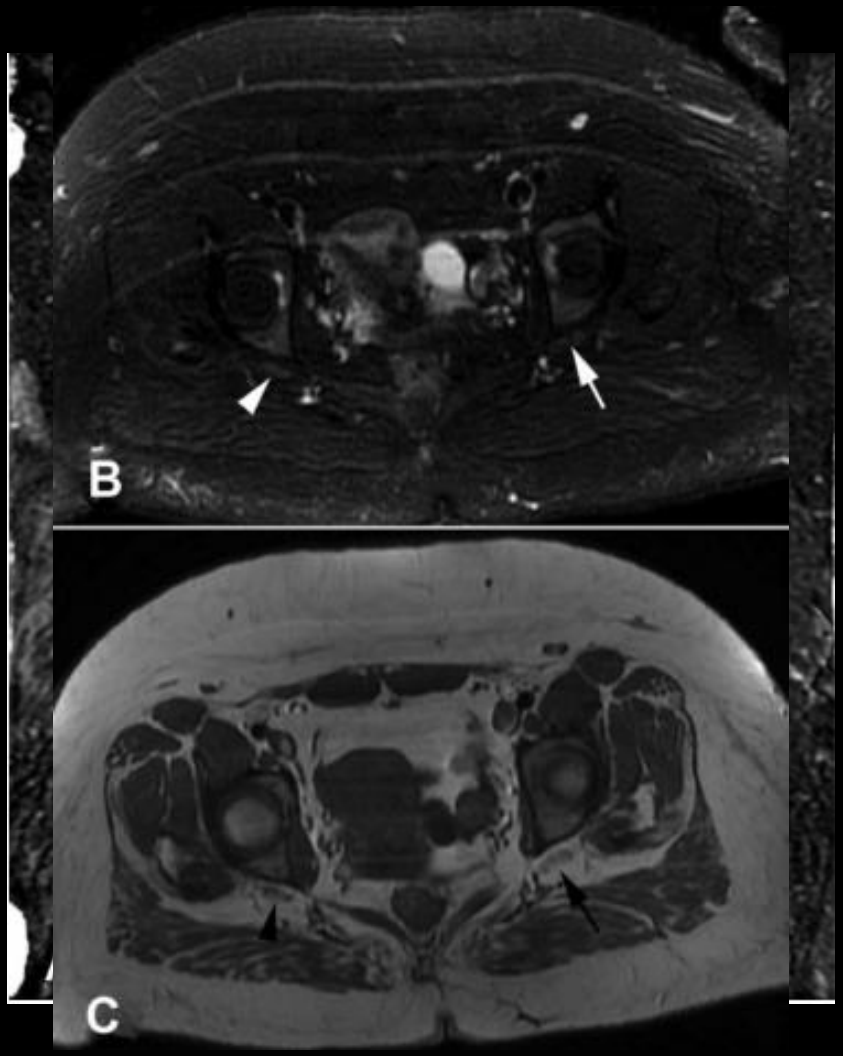
Kirchmair L, Lirk P, Colvin J, Mitterschiffthaler G, Moriggl B. Lumbar Plexus and Psoas Major Muscle: Not Always as Expected. *Reg Anesth Pain Med*. 2008;33(2):109-114.

Courtesy of Brady Huang

Piriformis Syndrome

- Hypertrophy, spasm, contracture, or inflammation/scarring of the piriformis muscle can compress the sciatic nerve and lead to piriformis syndrome.

- Syndrome characterized by isolated sciatic pain limited to the buttock with radiation down the thigh, no sensory deficits, and for which no other discernable cause can be found.



Neufeld EA, Shen PY, Nidecker AE, et al. MR Imaging of the Lumbosacral Plexus: A Review of Techniques and Pathologies. *J Neuroimaging*. 2015;95817(Cc).

Piriformis Syndrome

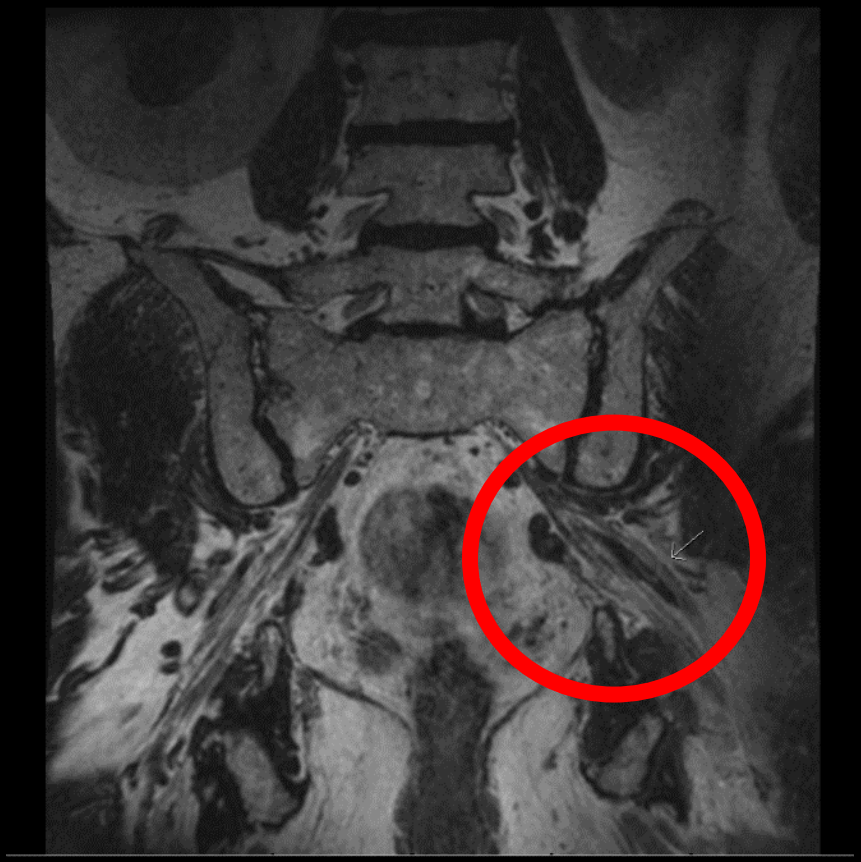
- In one study of patients who responded well to piriformis surgery, 38.5% had ipsilateral muscle hypertrophy and 15% had muscle atrophy.
- Muscle asymmetry alone had a specificity of 66% and sensitivity of 46% in identification of patients with muscle-based piriformis syndrome.
- Ipsilateral nerve edema was associated with reproducible symptoms of piriformis syndrome (during adduction or abduction of the flexed internally rotated thigh) in 88% of patients.
- Use of both asymmetry of the piriformis muscle and increased nerve signal intensity improved the diagnostic ability of MR neurography to 93% specificity and 64% sensitivity in predicting the outcome of piriformis surgery.

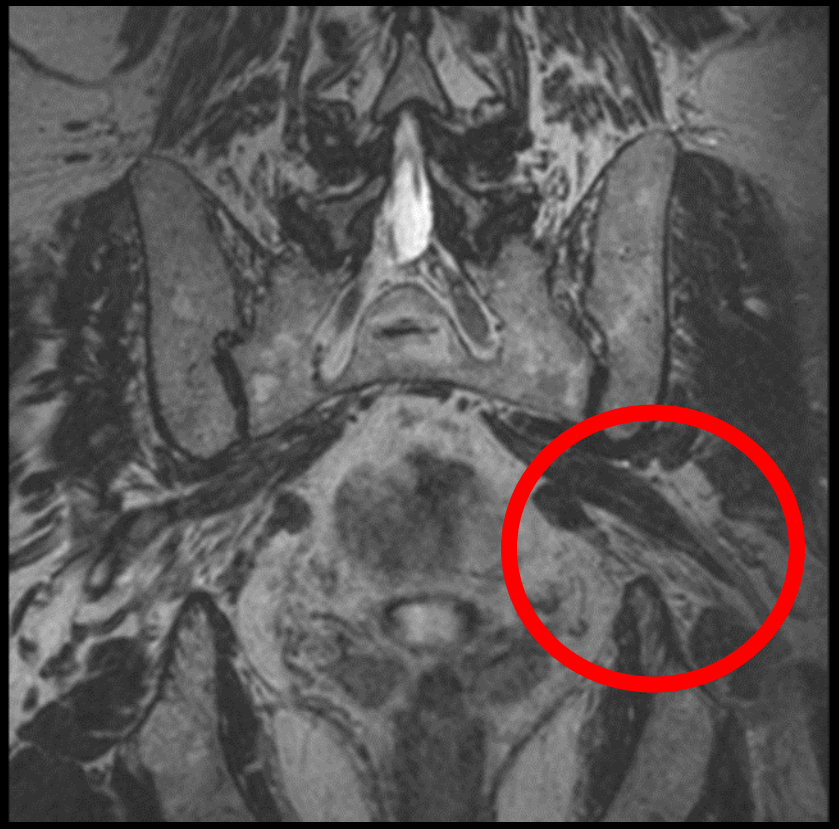
Petchprapa CN, Rosenberg ZS, Sconfienza LM, Cavalcanti CFA, La Rocca Vieira R, Zember JS. MR Imaging of Entrapment Neuropathies of the Lower Extremity. *RadioGraphics*. 2010;30(4):983-1000.

Piriformis Syndrome

- Overall, the syndrome is somewhat controversial.
- Treatment of piriformis syndrome
  - Initially conservative: NSAIDS, PT, and image-guided CS muscle injection.
  - Botulinum toxin has been explored with promising results.
  - Surgical release of the sciatic nerve and sectioning of the piriformis muscle may be considered in refractory cases.

Split Sciatic Nerve





Beaton and Anson

A – Normal, inferior sciatic relative to piriformis

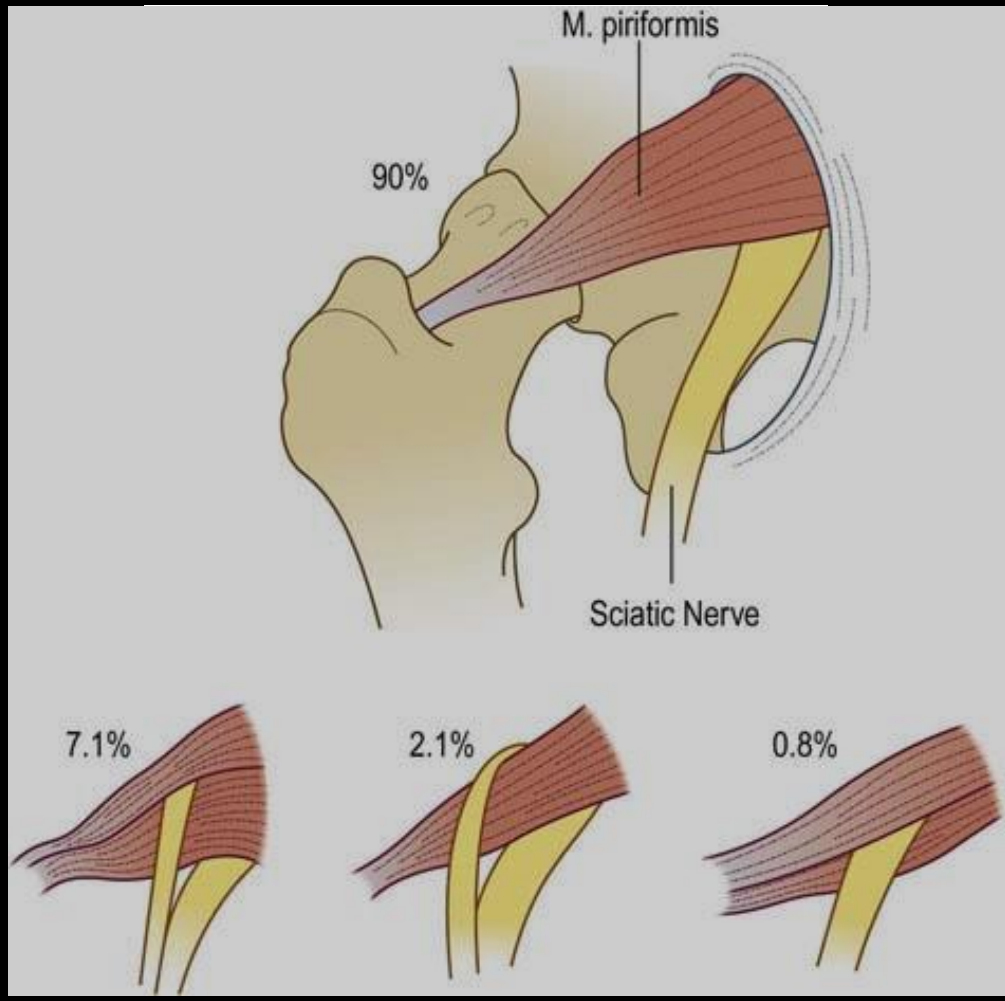
B – Sciatic nerve divisions pass through and below piriformis

C – Nerve above and below piriformis

D – Emerges through the piriformis

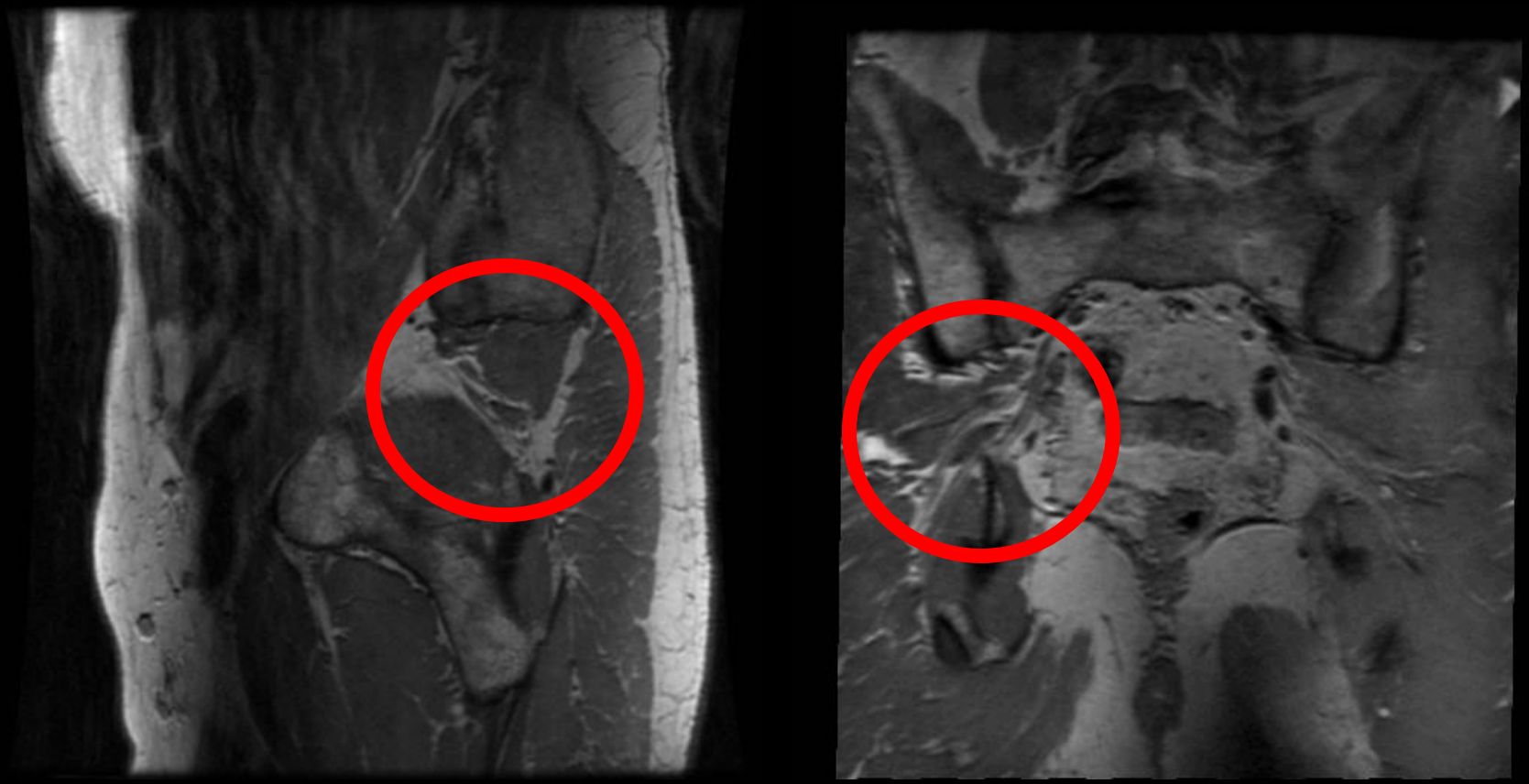
*E – Above and through piriformis

*F – Above piriformis



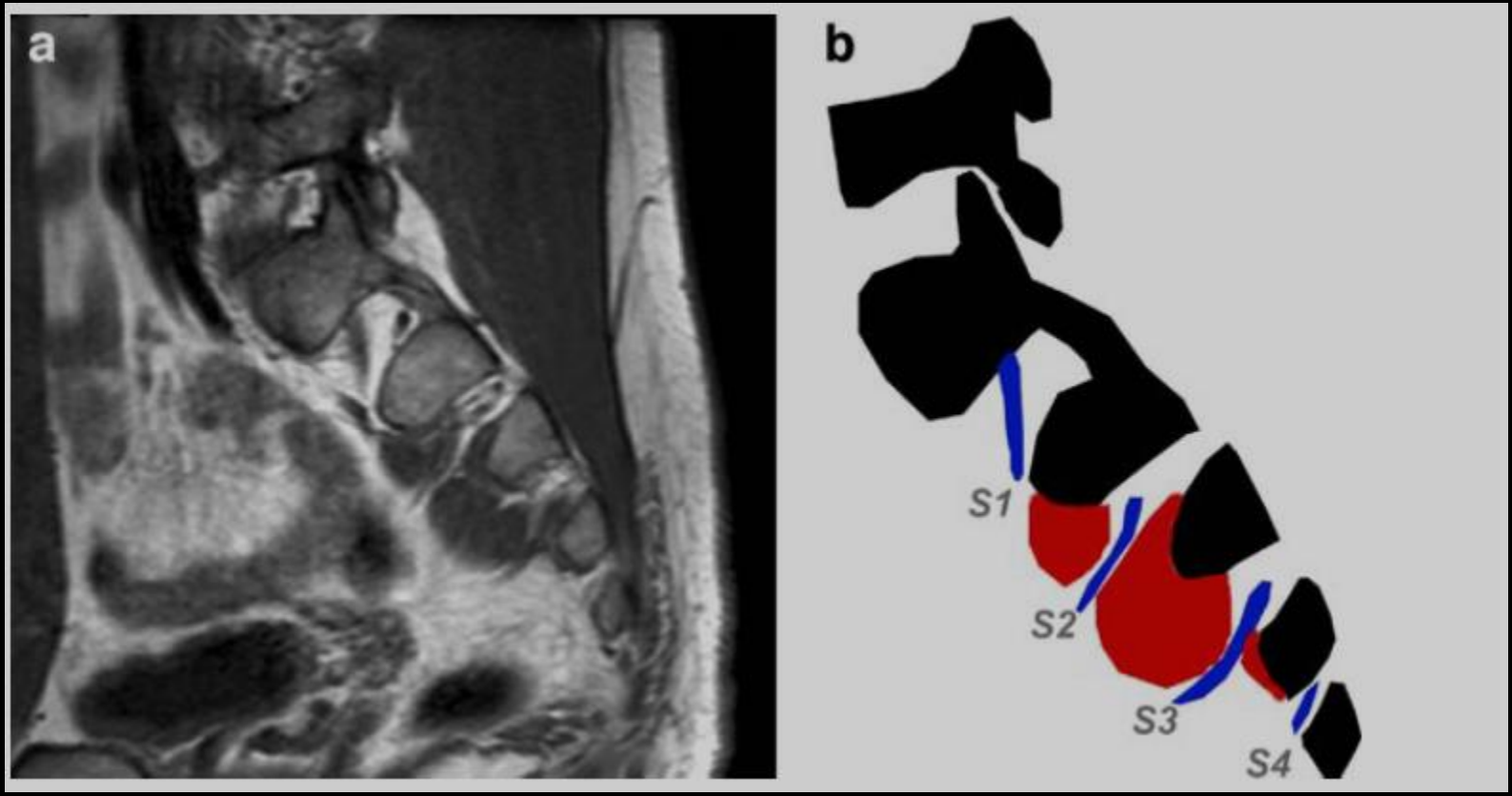
Beaton L, Anson B. The sciatic nerve and the piriformis muscle: their interrelation a possible cause of coccygodynia. *J Bone Jt Surg Am*. 1938;20:686-688.
http://clinicalgate.com/sciatic-neuropathy/

Split Sciatic Nerve



Courtesy of Brady Huang

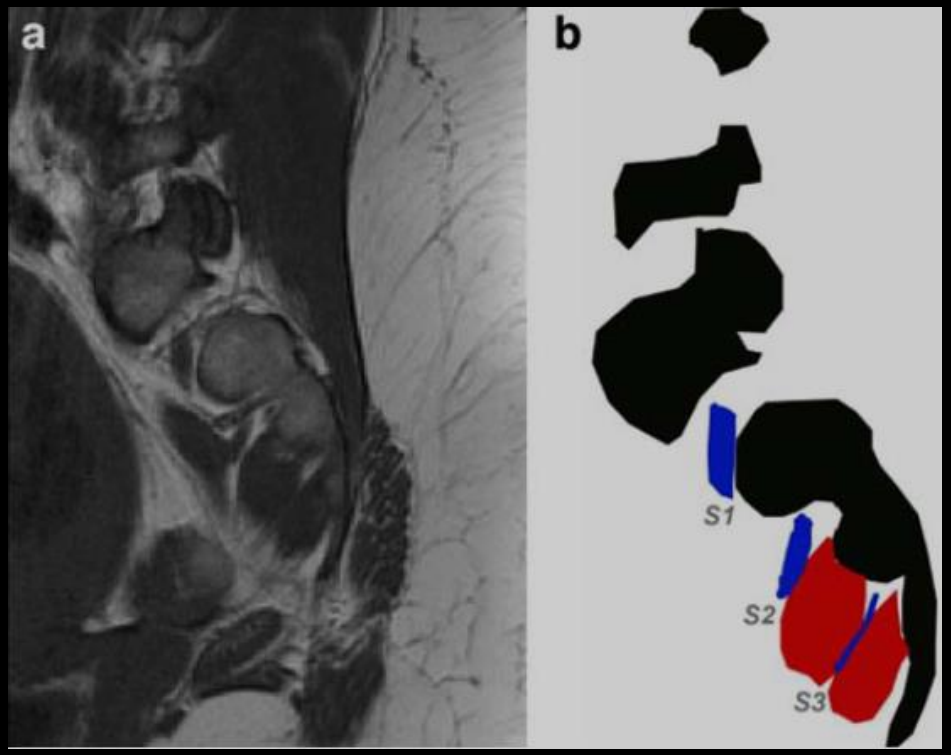
Course of the Proximal Sciatic Nerve Roots



Russell JM, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Bridges MD. Magnetic resonance imaging of the sacral plexus and piriformis muscles. Skeletal Radiol. 2008;37(8):709-713.

Course of the Proximal Sciatic Nerve Roots

- The S1 nerve roots were located above the piriformis muscle in 99.5% of cases (n=199).
- The S2 nerve roots were located above the piriformis muscle in 25% of cases (n=50) and traversed the muscle in the remaining 75% (n=150); 46% were in the top quarter (n=92), 22.5% were in the second quarter (n=45), and 6.5% were in the third quarter (n=13).
- The S3 nerve roots were located above the piriformis muscle in 0.5% of cases (n=1), below the muscle in 2.5% (n=5), and traversed the muscle in the remaining 97% (n=194); 1% were in the top quarter (n=2), 7% in the second quarter (n=14), 42.5% in the third quarter (n=85), and 46.5% in the bottom quarter (n=93).
- The S4 nerve roots were located above the piriformis in 0.5% of cases (n=1) and below the muscle in 95% (n=190); 4.5% were located within the piriformis muscle (n=9), all in the bottom quarter.



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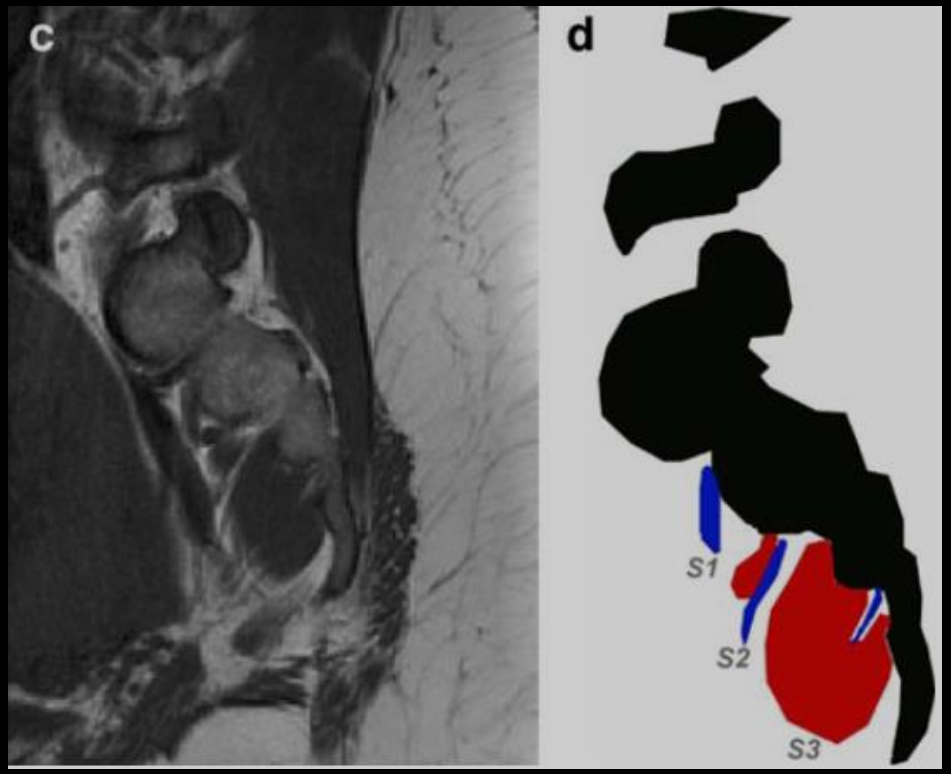

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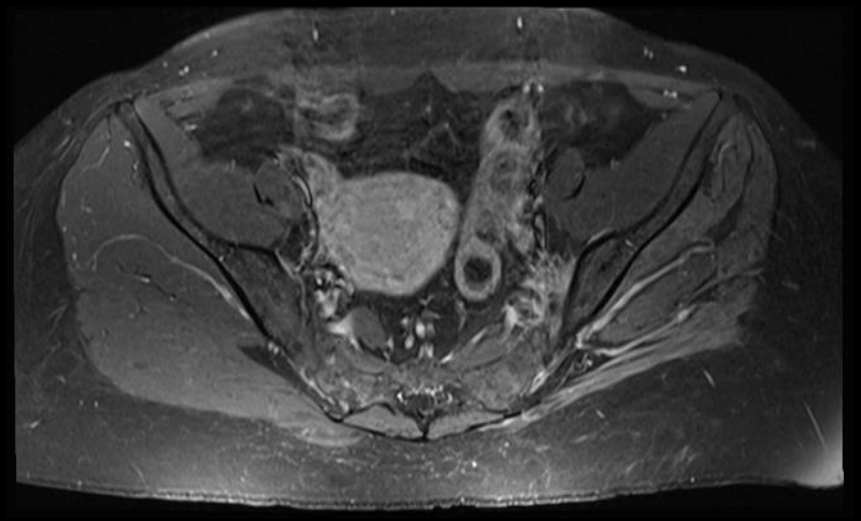
Lumbar Disc Disease

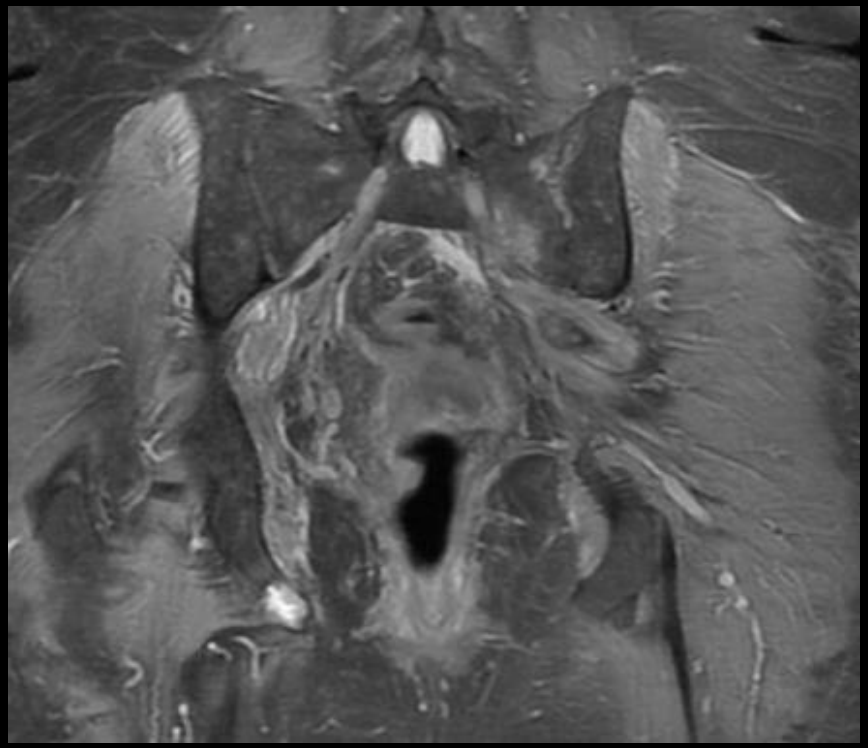
Courtesy of Brady Huang

Endometriosis

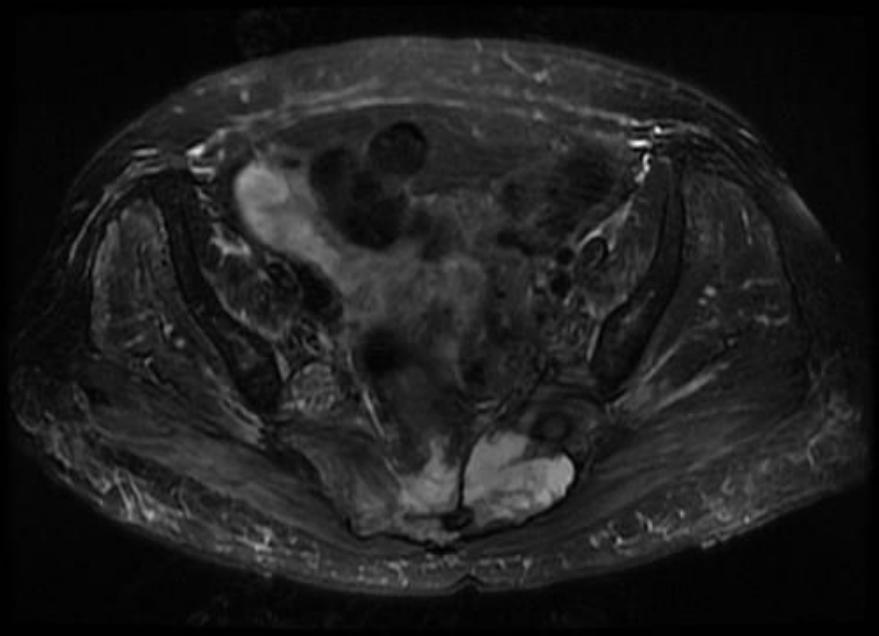


Courtesy of Brady Huang

Endometrial Carcinoma



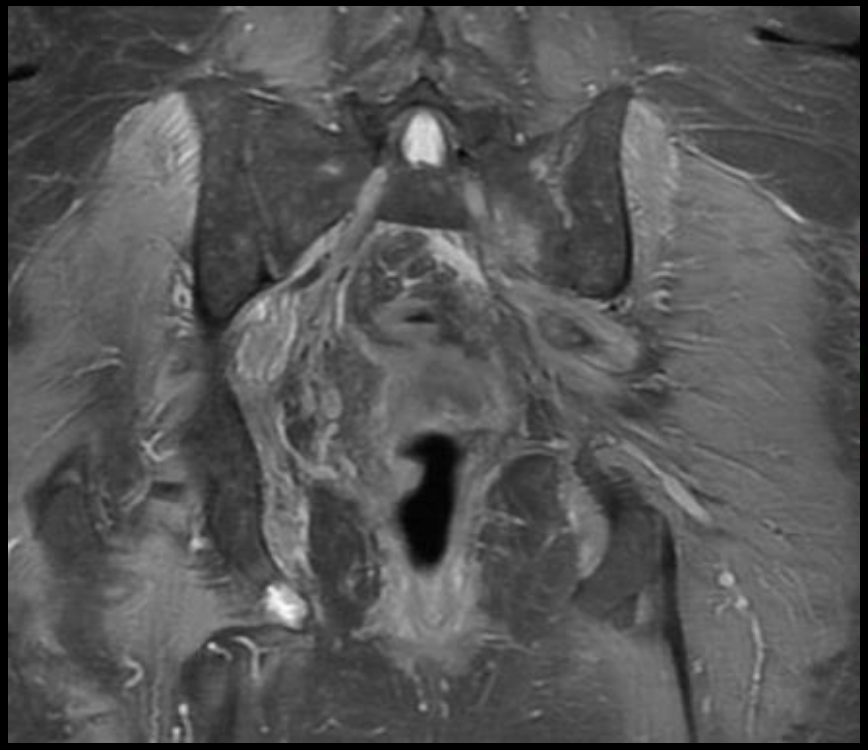
T1 FS Post



T2 FS

Courtesy of Brady Huang

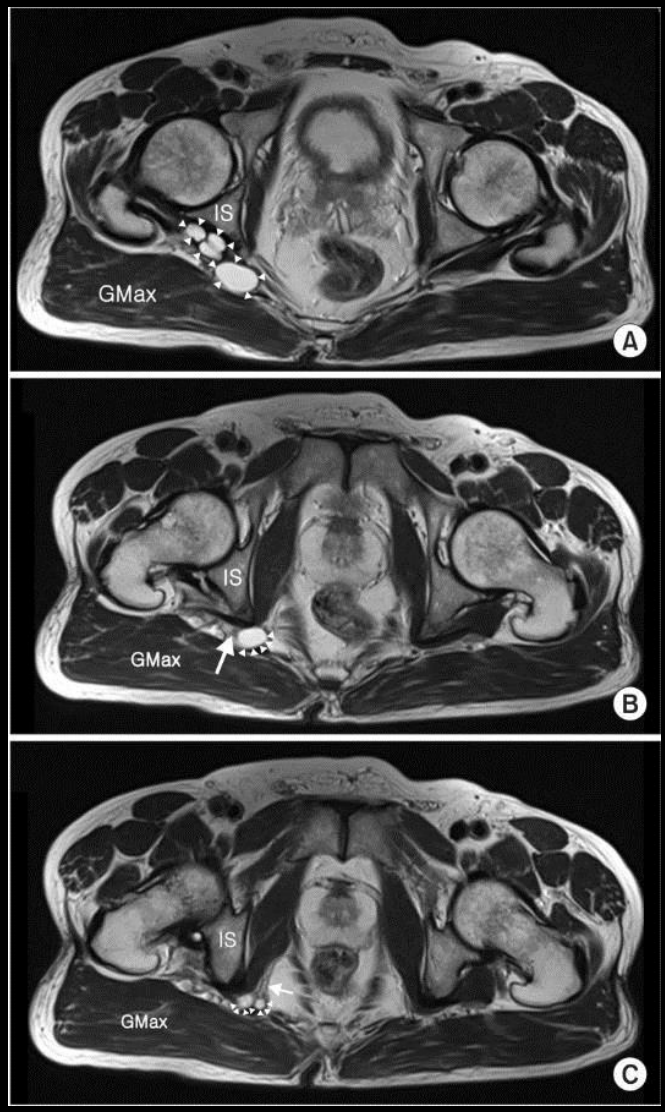
Endometrial Carcinoma



Courtesy of Brady Huang

Pudendal Nerve Compression

- 60-year-old male patient with a tingling sensation and burning pain in the right buttock and perineal area.
- Symptoms improved after aspiration of the cyst.

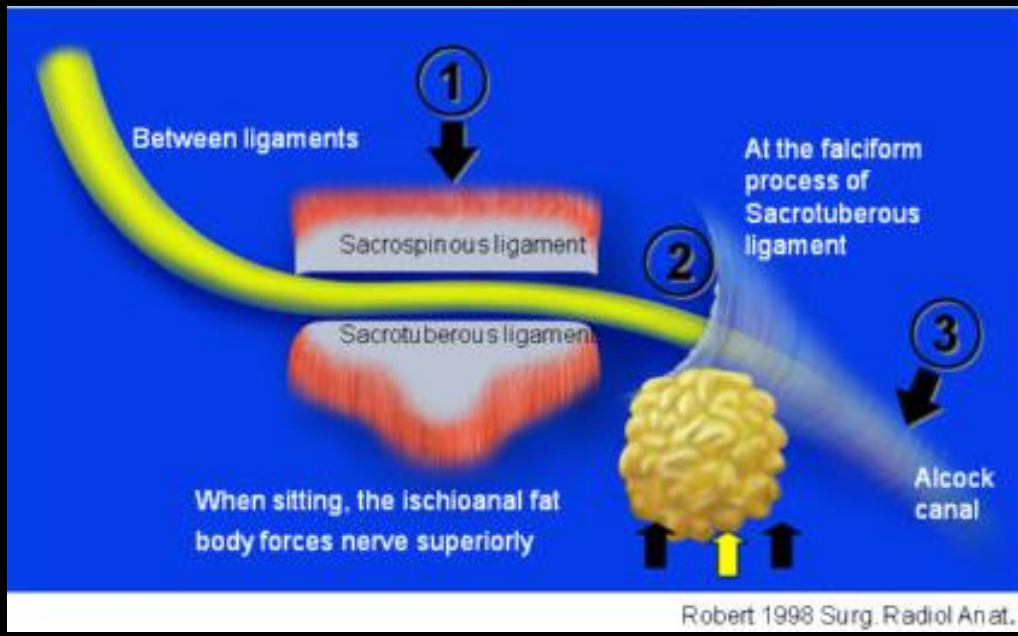


Lee JW, Lee S-M, Lee DG. Pudendal Nerve Entrapment Syndrome due to a Ganglion Cyst: A Case Report. Ann Rehabil Med. 2016;40(4):741-744.

Pudendal (Alcocks) Canal

Sites of Entrapment:

- At the levels of the SS and ST ligaments
- At the entrance to or within Alcocks canal due to the falciform process of the sacrotuberous ligament or a thickened obturator fascia.



http://www.pudendalhope.info/forum/viewtopic.php?f=69&t=1023

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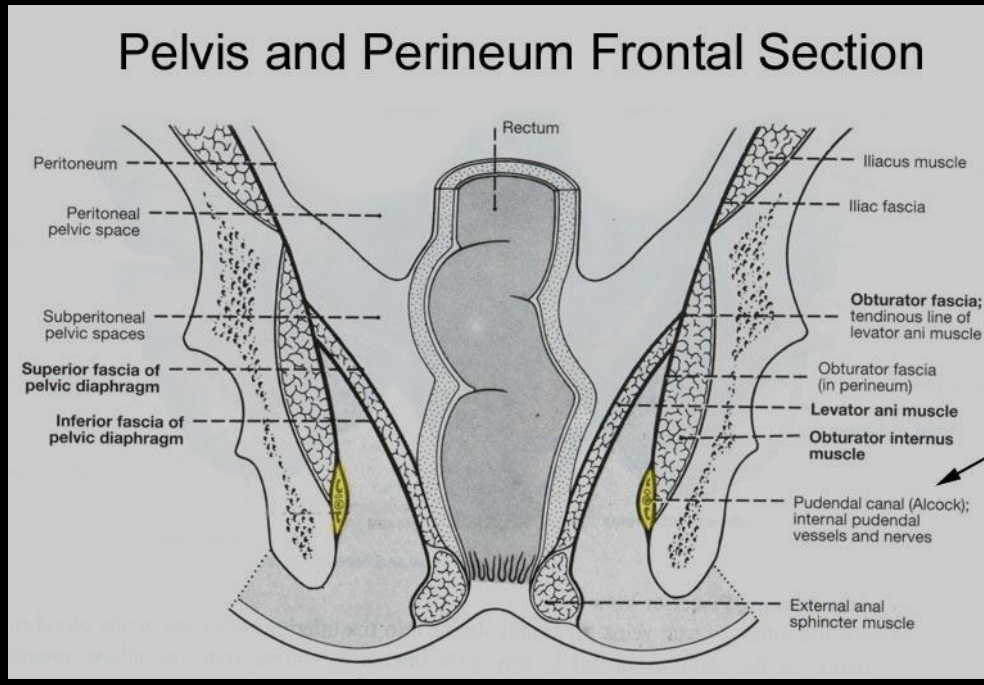


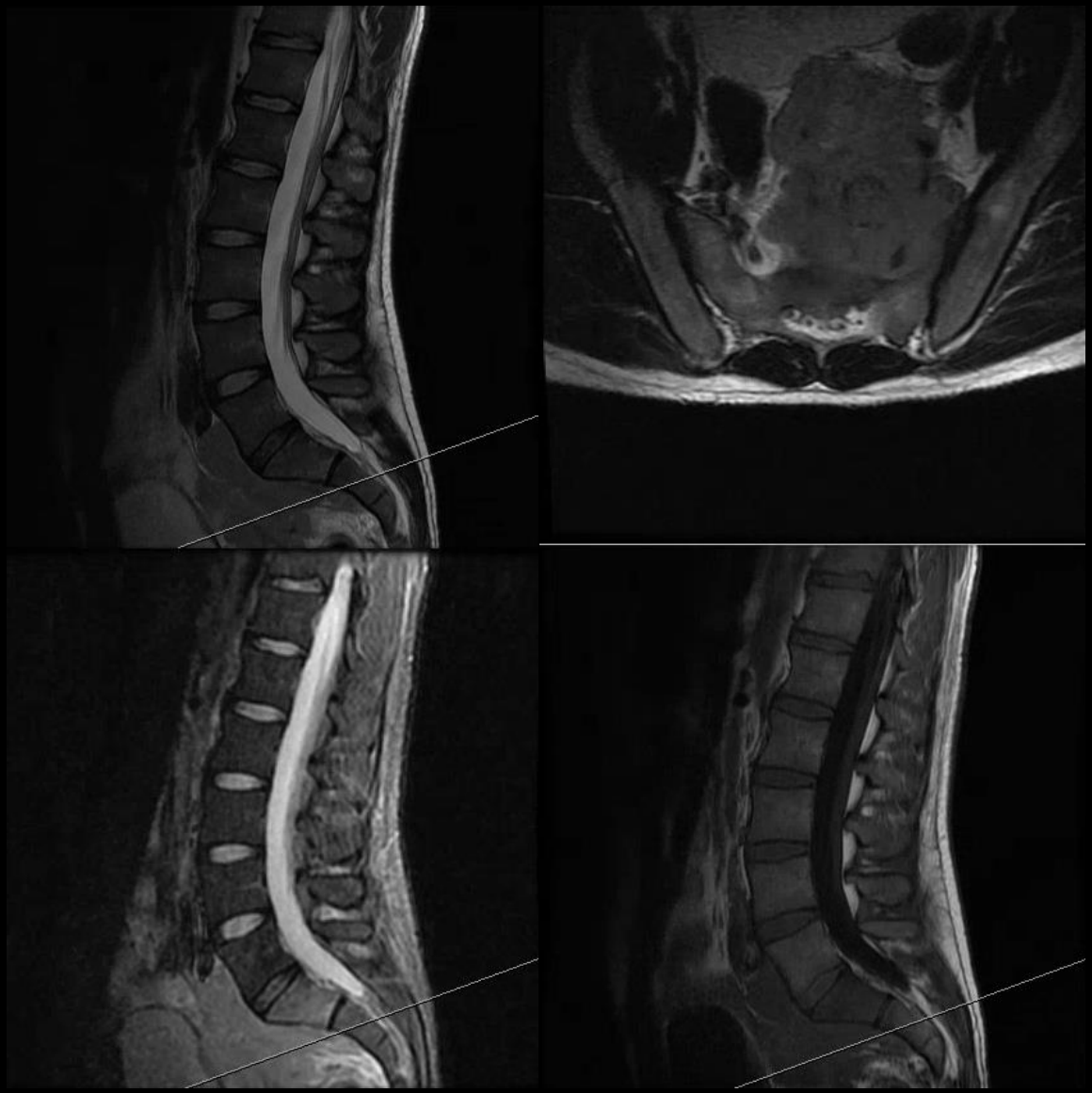
http://www.pudendalhope.info/node/13

Pudendal Nerve Compression (Cyclist)

http://radiologycases.blogspot.com/2012_09_01_archive.html

SYSTEMIC DISEASES

Radiation Induced Plexopathy



Radiation Induced Plexopathy

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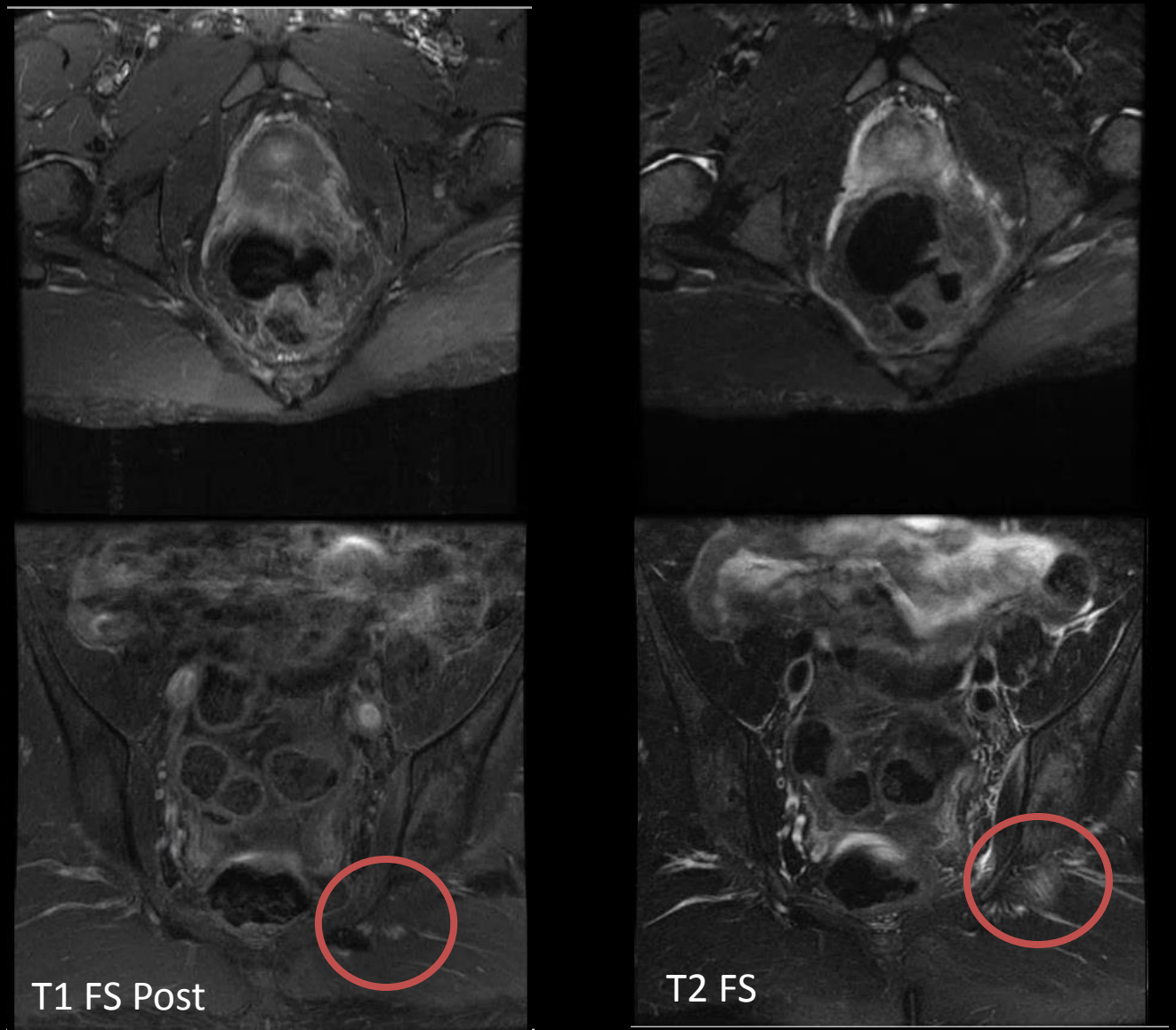
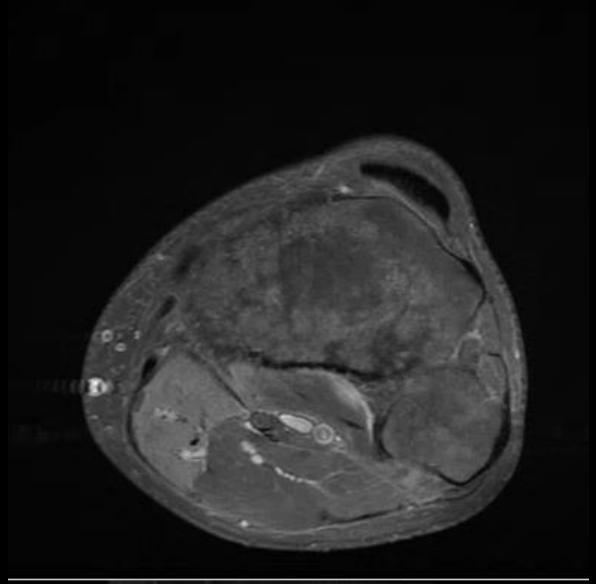
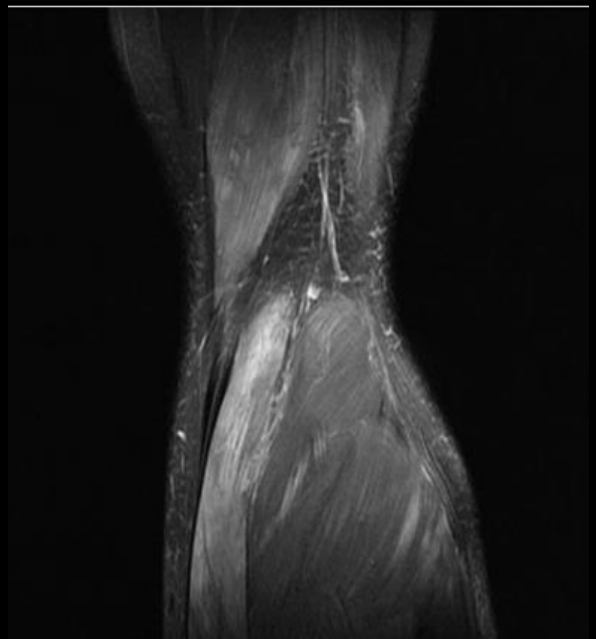
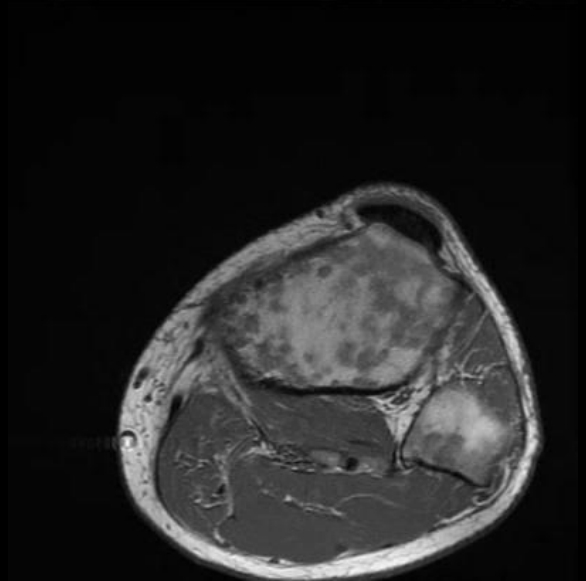


Radiation Induced Plexopathy







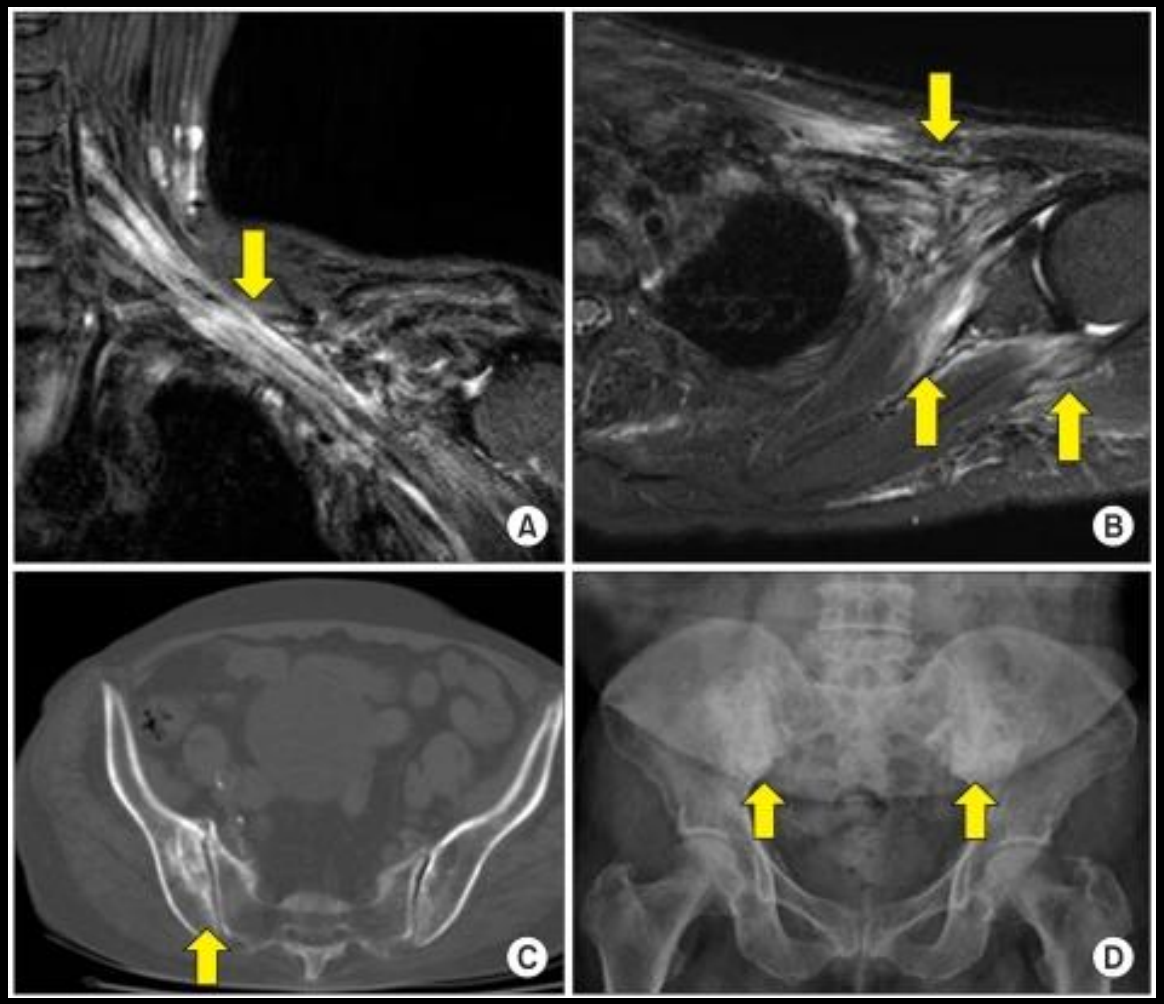
Radiation Induced Plexopathy

- Patients with a history of cancer and radiation therapy may have recurrent tumor or radiation-induced plexopathy.

- Features that favor postradiation plexopathy:
  - Absence of focal or eccentric enhancing mass.
  - Diffuse, uniform, symmetric swelling and T2 hyperintensity of the plexus within the radiation field and soft tissues changes.
  - Diffuse, uniform postcontrast enhancement for months to years after treatment may also result from radiation injury.

Efrat Saraf-Lavi. Imaging of the brachial and sacral plexus. *Appl Radiol*. 2014. http:/.

Radiation Induced Plexopathy



Ko K, Sung DH, Kang MJ, et al. Clinical, Electrophysiological Findings in Adult Patients with Non-traumatic Plexopathies. *Ann Rehabil Med*. 2011;35(6):807.

Charcot Marie Tooth

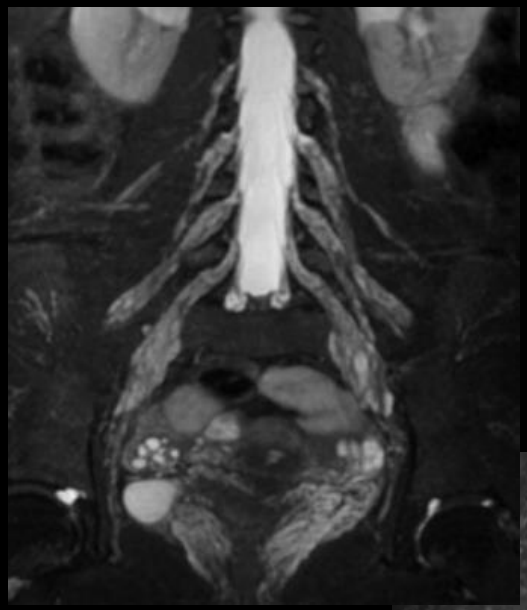
Neufeld EA, Shen PY, Nidecker AE, et al. MR Imaging of the Lumbosacral Plexus: A Review of Techniques and Pathologies. *J Neuroimaging*. 2015;95817(Cc).

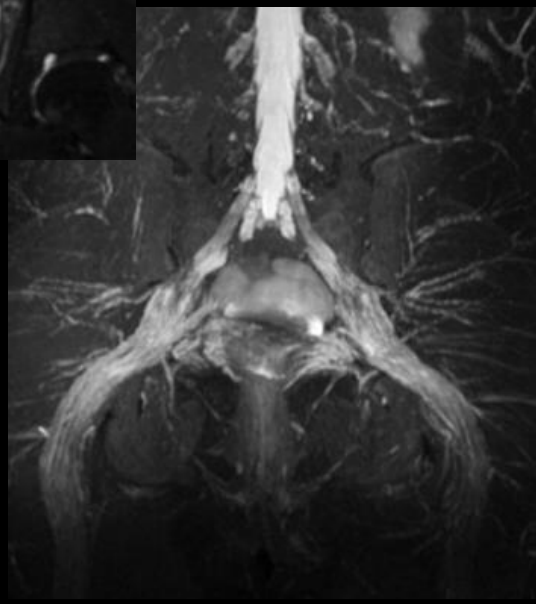
Hypertrophic LS Plexopathies

- Hypertrophy and diffuse hyper-intensity on T2W images of the plexus components have been described in:
  - Chronic Inflammatory Demyelinating Polyneuropathy (CIDP)
  - Multifocal Motor Neuropathy (MMN)
  - Hereditary Hypertrophic Motor And Sensoryneuropathy (HMSN or CMT)

Chronic Inflammatory Demyelinating Polyneuropathy (CIDP)

- Immune mediated neurological disorder causing damage to the myelin sheath of the peripheral nerves.
- Radiologic characteristics include diffuse marked enlargement of peripheral nerves.
- Gadolinium enhancement may be present in active disease.



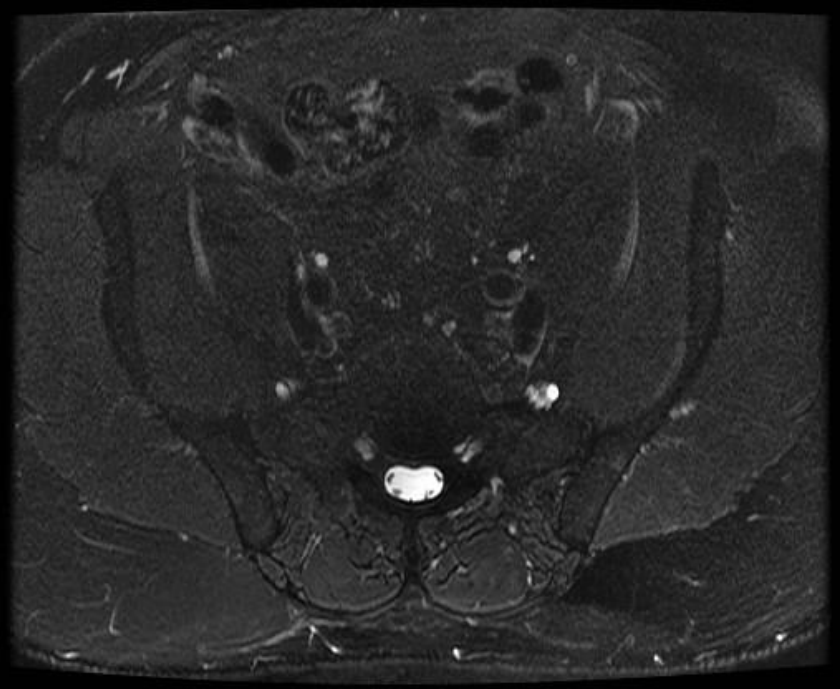


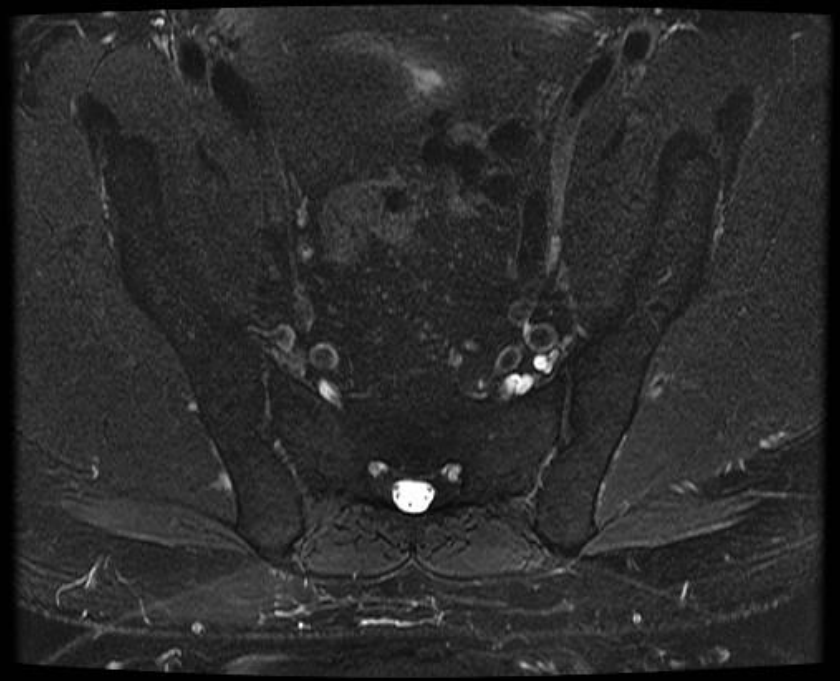
Cejas C, Escobar I, Serra M, Barroso F. High resolution neurography of the lumbosacral plexus on 3T magnetic resonance imaging. *Radiol (English Ed*. 2015;57(1):22-34.

Chronic Inflammatory Demyelinating Polyneuropathy (CIDP)

Courtesy of Brady Huang

Chronic Inflammatory Demyelinating Polyneuropathy (CIDP)





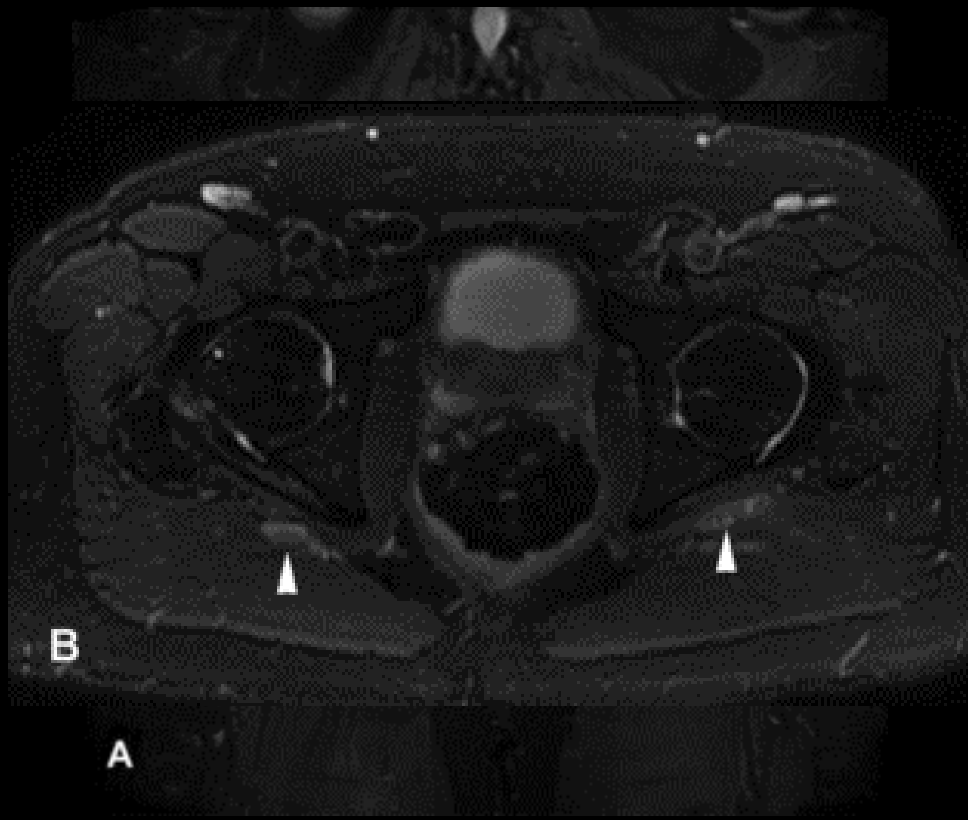
Courtesy of Brady Huang

Chronic Inflammatory Demyelinating Polyneuropathy (CIDP)

Efrat Saraf-Lavi. Imaging of the brachial and sacral plexus. *Appl Radiol*. 2014. http://appliedradiology.com/articles/imaging-of-the-brachial-and-sacral-plexus.

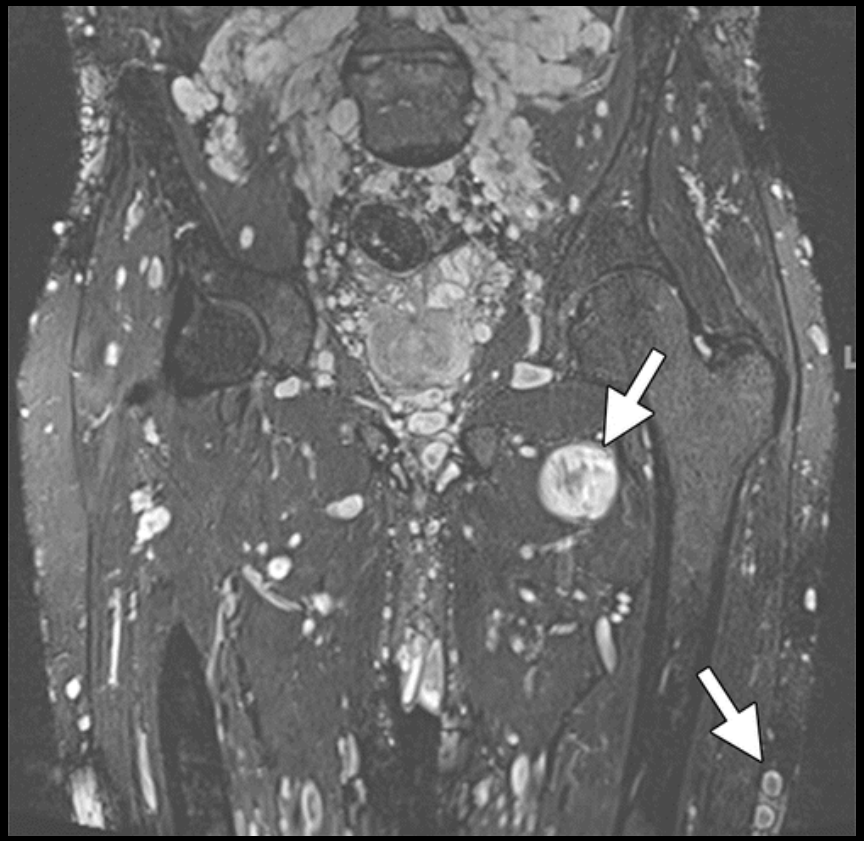
Acute Inflammatory Demyelinating Polyneuropathy (AIDP or Guillain-Barre)

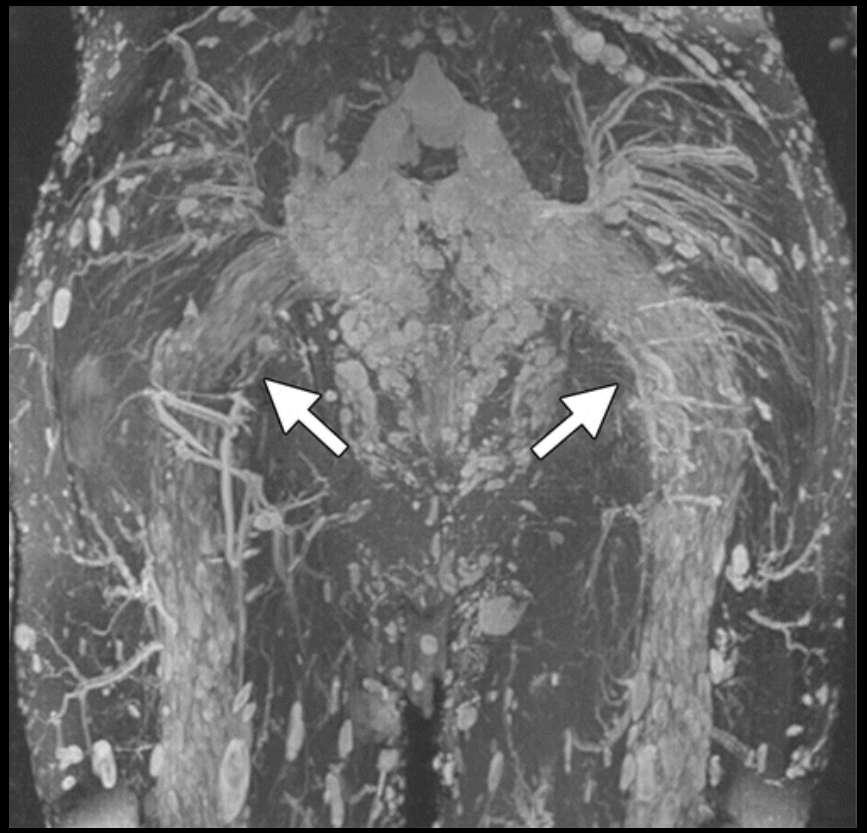
- MRI findings of the lumbosacral plexus for both AIDP and CIDP overlap and the distinction is therefore based on clinical features and time course.



Neufeld EA, Shen PY, Nidecker AE, et al. MR Imaging of the Lumbosacral Plexus: A Review of Techniques and Pathologies. *J Neuroimaging*. 2015;95817(Cc).

Neurofibromatosis Type 1

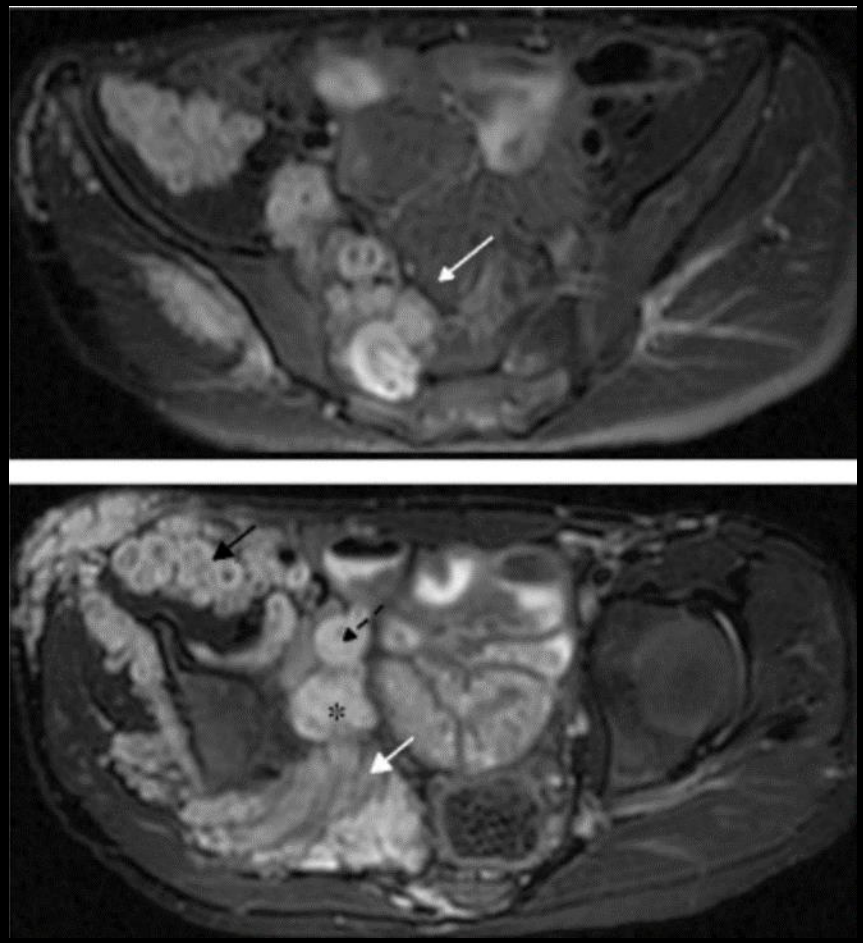




Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987. doi:10.1148/rg.334115761.

Plexiform Neurofibroma

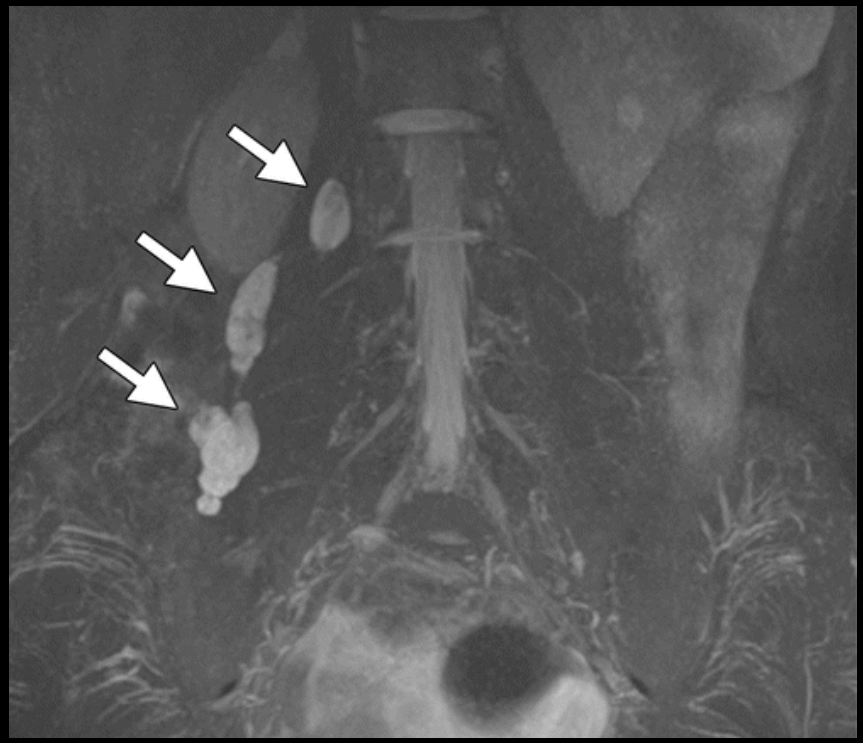
- Multiple expansive heterogeneous images located in the right lumbosacral plexus region with involvement of the femoral nerve, lumbosacral trunk, sciatic nerve, internal obturator, and pudendal nerve



Cejas C, Escobar I, Serra M, Barroso F. High resolution neurography of the lumbosacral plexus on 3T magnetic resonance imaging. *Radiol (English Ed*. 2015;57(1):22-34.

Isolated Peripheral Nerve Sheath Tumors

- Multiple peripheral nerve sheath tumors which demonstrate the target and tail signs involving the right Ilioinguinal nerve.



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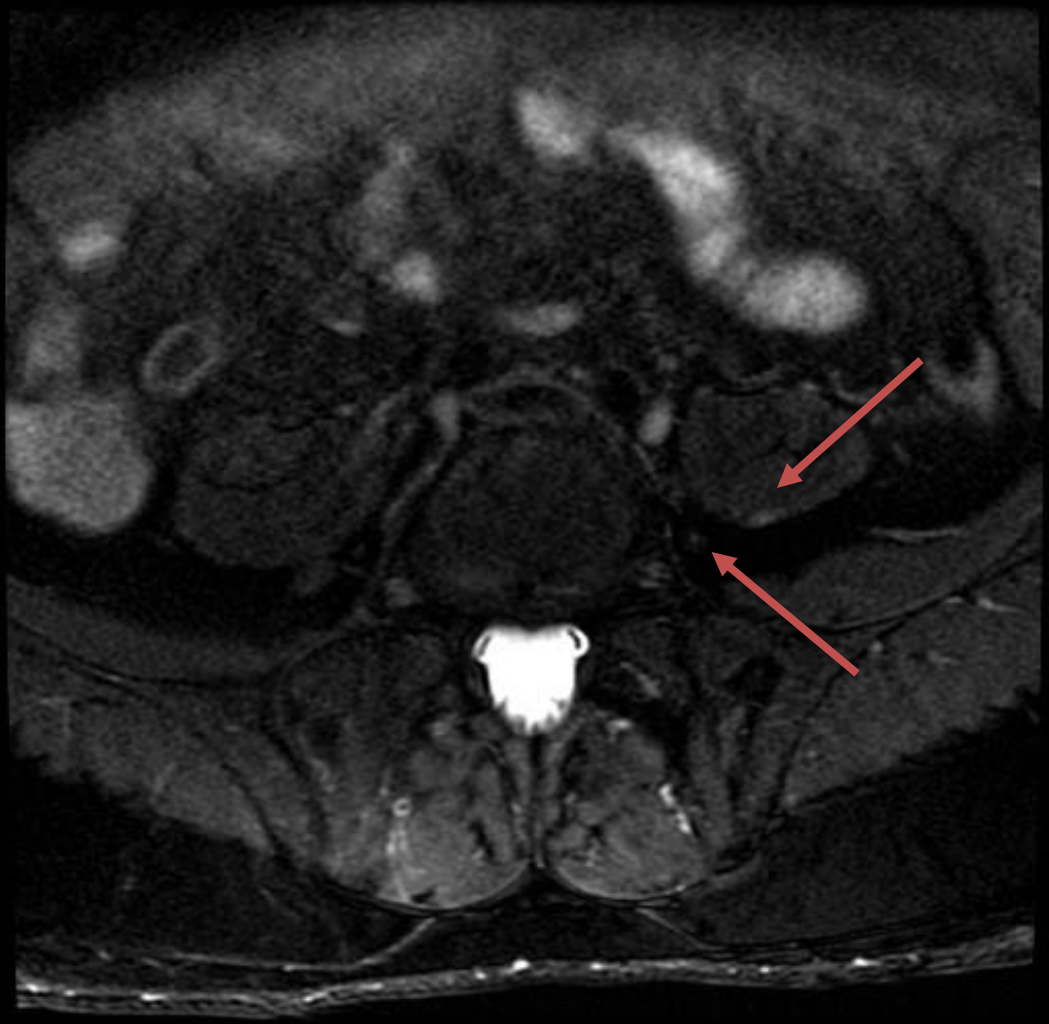
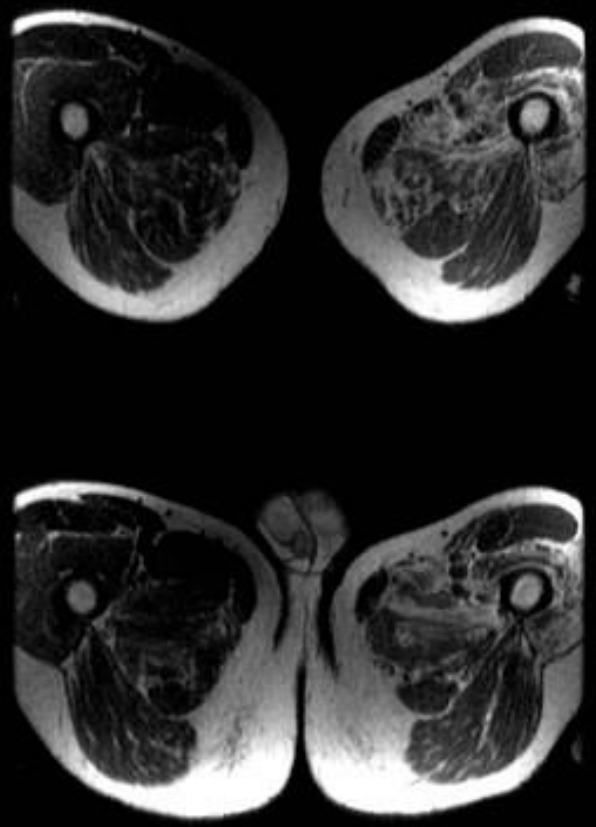
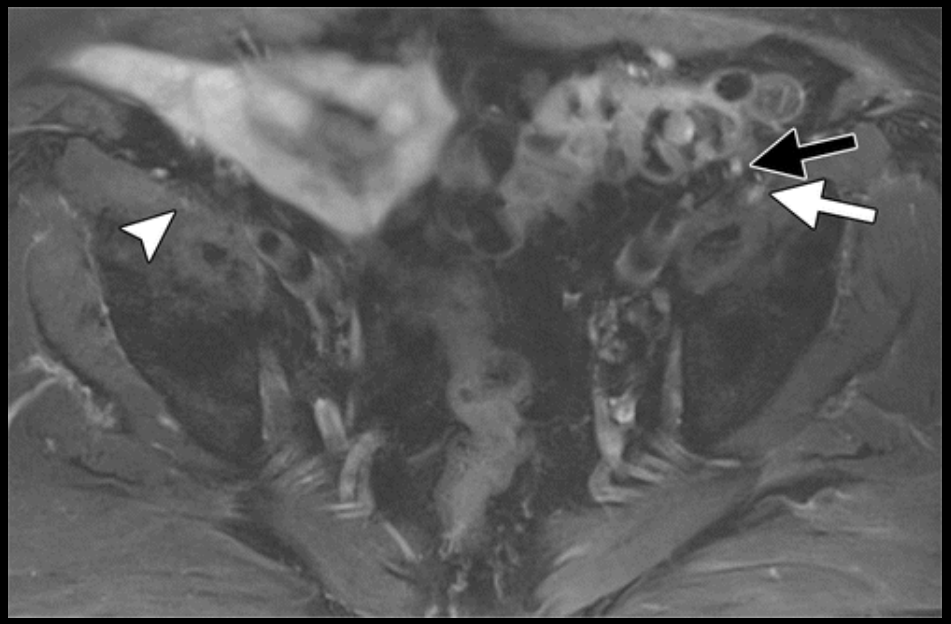
HIV Associated Amyotrophy vs Mononeuropathy Multiplex





Diabetic Amyotrophy

- AKA- Diabetic lumbosacral radiculoplexus neuropathy (DLRPN)
- Usual history of poorly controlled diabetes
- Perivascular inflammation and secondary nerve infarction involving L2,L3 and L4 roots
- Severe proximal leg and hip pain.
- Progressive proximal weakness of the affected extremity.



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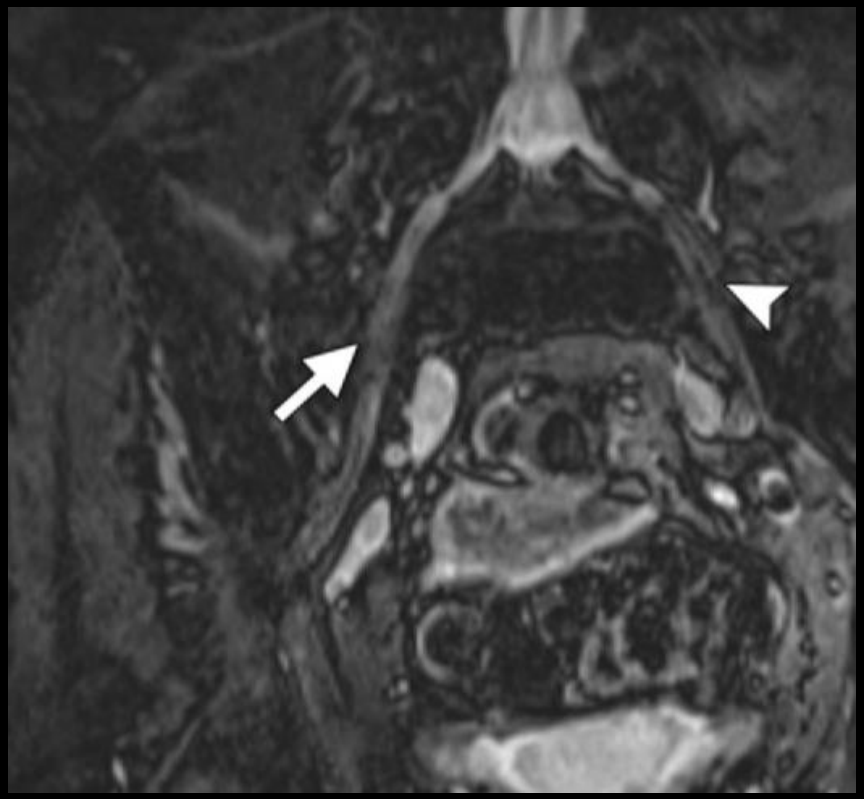
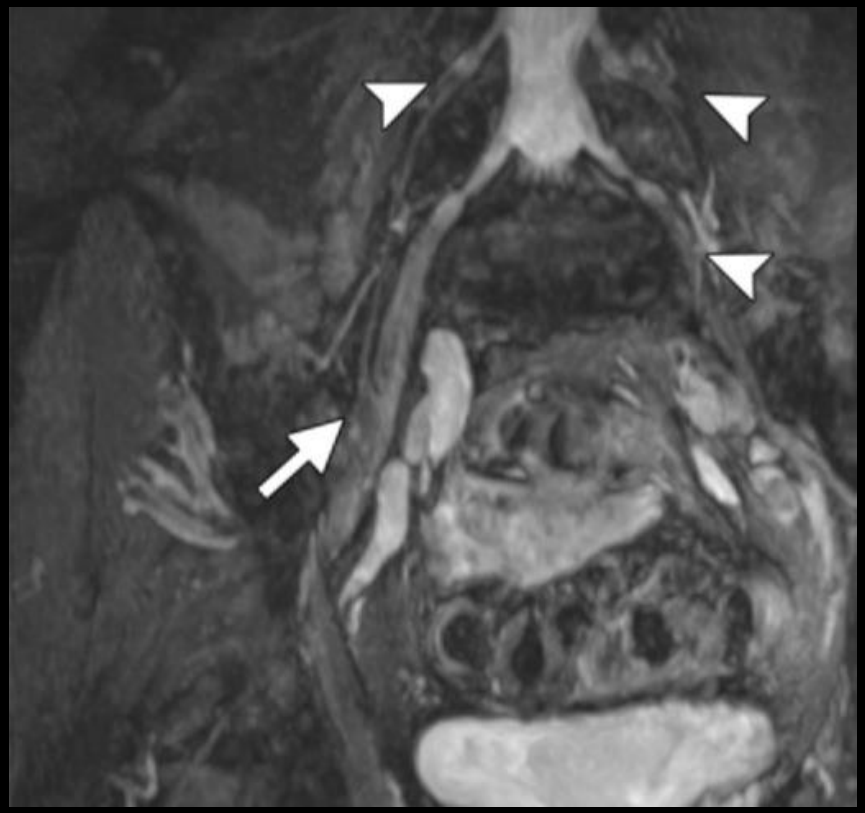
Idiopathic Lumbrosacral Plexopathy

- AKA- non-diabetic lumbosacral radiculoplexus neuropathy (LRPN).
- Usually unilateral LSP hyperintensity on T2-weighted images, with or without contrast enhancement.
- Painful idiopathic LSP afflicts lumbar plexus predominantly, although sacral plexopathy or complete LSP might also occur.
- Monophasic disease, with relapses and continuous progression unusual.

Idiopathic Lumbrosacral Plexopathy



3D STIR SPACE



MIP 3D STIR SPACE

Soldatos T, Andreisek G, Thawait GK, et al. High-Resolution 3-T MR Neurography of the Lumbosacral Plexus. *RadioGraphics*. 2013;33(4):967-987.

Summary

…There's a lot to know…

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End of Year Lecture: Mission Accomplished!