MRI of the Brachial Plexus : A pictorial review

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Purpose

Magnetic resonance imaging (MRI) is the imaging modality of choice to depict normal anatomy and pathology of the brachial plexus. The anatomy of the brachial plexus roots, trunks, divisions and cords is well demonstrated on MRI due to inherent contrast differences which exist between nerves and adjacent fat. We will discuss the well established MR sequences employed to ensure these contrast differences are exaggerated when imaging the brachial plexus.

In this pictorial review, we will discuss the normal MRI anatomy and present real case images to demonstrate the normal anatomy and pathology of the brachial plexus. The following brachial plexus pathologies have been included: trauma, radiation plexitis, inflammatory plexitis, Pancoast tumour, thoracic outlet syndrome, metastatic infiltration, lymphoma, nerve sheath tumour and iatrogenic injury.

The aim of this review is to provide the reader with insight into the normal brachial plexus anatomy and varied pathological appearances on MRI.
Methods and Materials

Method

In our centre we use the Philips Intera 1.5T MRI scanner. A dedicated protocol is used for imaging of the brachial plexus. Both left and right brachial plexuses are imaged to allow comparison and better detection of abnormalities. We use the following protocol:

<table>
<thead>
<tr>
<th>Protocol Description</th>
<th>FOV (mm)</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>TI (ms)</th>
<th>ST/GAP (mm)</th>
<th>Matrix (252/227)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal STIR (include both shoulders)</td>
<td>250</td>
<td>1750</td>
<td>15</td>
<td>165</td>
<td>3, 1.2</td>
<td>500/245</td>
</tr>
<tr>
<td>Coronal T1 (FOV - 250mm, TR, TE - 593ms, 15ms, ST/GAP - 3mm, 1.2mm Matrix - 400/317)</td>
<td>250</td>
<td>593</td>
<td>15</td>
<td></td>
<td>3, 1.2</td>
<td>400/317</td>
</tr>
<tr>
<td>Axial T2 (C5 to inferior axilla)</td>
<td>280</td>
<td>4832</td>
<td>100</td>
<td></td>
<td>5, 0.5</td>
<td>300/290</td>
</tr>
<tr>
<td>Axial T1 (FOV - 250mm, TR, TE - 650ms, 12ms ST/GAP - 3mm, 1.2mm Matrix - 252/227)</td>
<td>250</td>
<td>650</td>
<td>12</td>
<td></td>
<td>3, 1.2</td>
<td>39</td>
</tr>
<tr>
<td>Sagittal T1 (C-spine to midpoint of arm)</td>
<td>250</td>
<td>650</td>
<td>12</td>
<td></td>
<td>3, 1.2</td>
<td>39</td>
</tr>
</tbody>
</table>

An advanced search was carried out on the Picture Archiving and Communication System (PACS) used at our centre looking at all brachial plexus imaging performed over the past 5 years. Over 100 cases were identified—specific pathology was then sought and examples of the various pathologies are shown in detail here.
Results

Real Case Examples

Basic Anatomy (Fig 1-10)

The brachial plexus is a somatic nerve complex which arises from the ventral rami of C5-T1 of the spinal cord. Sometimes minor branches are contributed by C4 and T2. Anatomically it is divided into 5 segments which can be remembered by the mnemonic-

Radiology (Roots) Technologists (Trunks) Drink (Divisions)

Cold (Cords) Beverages (Branches)

The imaging anatomy is greatly simplified by using easily identifiable anatomical landmarks. The roots are located in the interscalene triangle, trunks at lateral border of middle scalene muscle, divisions in the retroclavicular space, cord and terminal branches in retropectoralis space. On sagittal images, the C8 and T1 are below the proximal part of first rib. Trunks are formed just lateral to the scalene triangle. Divisions are located where the brachial plexus cross the clavicle. Cords are positioned around the axillary artery. On coronal images, the T1 nerve root can be identified as a horizontal linear structure surrounded by fat close to lung apex.

The dorsal scapular artery, a branch of subclavian artery runs between the trunks. The divisions and cords are positioned above and around the subclavian and axillary arteries (1,2,3).

On STIR images, the nerves have a slightly increased signal intensity compared to the surrounding tissues.

With the exception of the trapezius muscle and an area of skin near the axilla which are not supplied by the brachial plexus, the sensory and motor supply to the upper limb comes exclusively from the brachial plexus. Pathology of the brachial plexus can therefore lead to great functional impairment which makes detection of such pathology so important.

Inflammatory plexitis (Fig 11)

Brachial plexus neuritis may be idiopathic, or could be associated with viral or bacterial infection or vaccination. Inflammation of the brachial plexus tends to affect the lower brachial plexus. Inflammatory plexitis commonly presents with acute onset of unilateral
shoulder pain followed by flaccid paralysis of the shoulder and para-scapular muscles. Inflammatory plexitis often runs a self-limiting course. MRI shows diffuse swelling and increased T2W signal in affected nerves. There can be mild oedema of the affected muscles particularly supra and infraspinatus (4).

**Nerve sheath tumour involving the brachial plexus.** *(Fig 12,13)*

The neurogenic tumours involving the brachial plexus include schwannoma, neurofibroma, plexiform neurofibroma and malignant peripheral nerve sheath tumour. Typically, neurogenic tumours have an ovoid form and the nerve can often be seen entering and leaving the tumour. In Schwannoma, the nerve enters or leaves the tumour eccentrically hence can be resected without damaging the nerve, while in neurofibromas the nerve passes through the centre of the tumour hence difficult to resect (5). These tumours are similar in signal intensity to muscle on T1W and show markedly increased signal intensity on T2W. They enhance with IV Gadolinium and may demonstrate cystic areas (2).

**Pancoast Tumour involving the brachial plexus.** *(Fig 14,15)*

Pancoast tumour is the name given to non small cell lung carcinomas which arise in the lung apex and invade the lower brachial plexus, subclavian vessels, upper ribs and vertebral bodies (6). Classically patients with Pancoast tumour present with pain in the shoulder and arm, weakness and atrophy of the muscles of the hand and Horner's syndrome (involvement of the stellate ganglion). MRI is used to examine local extension of the tumour towards the brachial plexus, subclavian vessels, vertebral bodies and intervertebral foramina. Contraindications for surgery include brachial plexus involvement above C8 (2).

**Case 4: Metastatic infiltration of the brachial plexus.** *(Fig 16)*

Breast carcinoma is the most common source of metastatic disease causing brachial plexopathy. Other metastatic sources include lung carcinoma and head and neck cancer (2).

Tumour characteristically is of low signal on T1 weighted images and high signal on T2 weighted images and also shows enhancement post gadolinium (contrast). Signal characteristics of a tumour can vary, however the presence of a focal mass is often a reliable sign in identifying tumour infiltration (7).

**Lymphoma involving the brachial plexus.** *(Fig 17,18)*
Lymphoma can involve the brachial plexus in different ways. The brachial plexus can be compressed or infiltrated by enlarged lymph nodes or a nodal mass. Lymphoma of the paravertebral lymph nodes can extend through the intervertebral foramina and extend to the extradural space. These can be seen as diffuse infiltrative masses.

**Radiation induced brachial plexopathy.** *(Fig 19)*

In patients who have undergone radiotherapy for treatment of their primary breast or lung carcinoma it may be difficult to establish clinically whether their brachial plexus symptoms are due to the primary carcinoma or the result of the radiotherapy though some specific signs and symptoms may be useful to guide the clinician. For example Horner's syndrome, lower brachial plexus involvement, severe pain, hand weakness and a latency period of more than 1 year is more suggestive of tumour involvement, whereas upper brachial plexus involvement with lymphoedema and lack of pain and a latency period of less than 1 year are more in keeping with radiation induced brachial plexopathy.

MR1 allows for accurate differentiation as well: radiation plexopathy is usually low signal on T1 weighted images and of high signal on T2 weighted images and does characteristically not enhance post gadolinium though a small proportion may enhance. Radiation plexopathy often causes architectural distortion and diffuse thickening of the brachial plexus without the presence of a focal mass.

**Thoracic outlet syndrome.** *(Fig 20)*

Congenital presence of bony abnormalities such as a cervical rib or an elongated transverse process of C7 which should not be larger than the transverse process of T1 can cause neurogenic thoracic outlet syndrome. These congenital bony abnormalities can cause compression of the nerve roots C8-T1 or the inferior trunk. This can be due to compression of the neurovascular bundle as it passes through different compartments of the thoracic outlet (Interscalene triangle, costoclavicular space and retropectoralis minor space).

**Surgical ligation involving the brachial plexus.** *(Fig 21)*

Surgical ligation is an example of open traumatic injury of the brachial plexus and as described earlier in case one there will be asymmetry in the appearances of the brachial plexus and differentiation of pre and post ganglionic lesions is important in terms of prognosis and surgical options available.

**Direct traumatic injury to the brachial plexus**
Traumatic injuries of the brachial plexus are often the result of high impact/energy accidents such as road traffic accidents. From a surgical point of view, it is important to divide these trauma patients into pre and post ganglionic injuries which can be difficult to establish clinically and so MRI plays the major role. Post ganglionic injuries have a better prognosis as nerve grafting is possible, whereas in pre-ganglionic injuries where the nerve root is often avulsed direct surgical repair is difficult.

MRI of post ganglionic injuries can show thickened nerves with low signal intensity on T1 weighted images and high signal intensity on T2 weighted images. There may also be discontinuity of the nerve with distal nerve contraction. Pre-ganglionic injuries can often cause nerve root avulsions with or without an associated pseudomeningocele (cerebrospinal fluid collection due to a dural tear). The presence of a pseudomeningocele is highly suggestive, but not pathognomonic of a preganglionic lesion.
Fig. 1: Normal sagittal anatomy Roots (blue arrows) lateral to the intervertebral foramina

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**Fig. 2:** Roots seen in the interscalene triangle between the anterior scalene muscle (ASM) and middle scalene muscle (MSM)

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Fig. 3: Trunks located just lateral to the interscalene triangle

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Fig. 4: Infraclavicular plexus show 3 cords (blue arrows) at level of pectoralis muscles.
**Fig. 5:** C8 nerve root (blue arrow)

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Fig. 6: Slightly bright normal C8 nerve roots (blue arrows)
Fig. 7: A plexus trunk (blue arrow)

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Fig. 8: Horizontal T1 Nerve roots (blue arrow)

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Fig. 9: Cords (blue arrow) seen as linear structures above the axillary artery (AA)

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Fig. 10: Plane of roots and trunks between the scalene muscles

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Fig. 11: Inflammatory plexitis. STIR Coronal shows swollen and hyperintense right sided cords. Compare them with the left sided cords.

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Fig. 12: Nerve sheath tumour Axial T2W image shows a hyperintense lesion with central cyst between the scalene muscles

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Fig. 13: Nerve sheath tumour T1W fat sat post Gadolinium Coronal image shows an enhancing ovoid lesion in region of the right trunks

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Fig. 14: Pancoast Tumour (Superior Sulcus tumour) T1W Coronal shows a lobulated hypointense mass (blue arrows) arising from the right lung apex, involving the 1st and 2nd ribs and the lower roots and trunks.

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**Fig. 15:** Pancoast Tumour (Superior Sulcus tumour) T1W Axial shows a lobulated hypointense mass (blue arrows) arising from the right lung apex, involving the 1st and 2nd ribs and the lower roots and trunks.

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Fig. 16: Metastasis from carcinoma breast Coronal T1W images shows a spiculated focal mass lesion in left axilla involving the left cords (blue arrow) in a case of carcinoma breast.

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**Fig. 17:** Non Hodgkins lymphoma T1W axials show a lobulated hypointense lesion at root of neck involving the roots lateral to the intervertebral foramina

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Fig. 18: Non Hodgkins lymphoma T2W sagittal show a lobulated hyperintense paravertebral lesion involving the roots lateral to the intervertebral foramina (blue arrows)

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Fig. 19: Radiation Plexopathy Coronal T1W image shows architectural distortion of right sided cords with diffuse thickening and hypointense signals on T1W and T2W

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Fig. 20: Neurogenic Thoracic outlet syndrome Sagittal T1W image shows reduction in costoclavicular space with obliteration of fat around the brachial plexus (white arrow)

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Fig. 21: Accidental ligation of Brachial plexus T1W Coronal shows altered course of the right brachial plexus

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Conclusion

The brachial plexus is a complex network of nerves which is responsible for much of the sensory and motor innervation of the upper limb. Pathology of the brachial plexus can therefore cause great psychological and physical dysfunction. MRI is the imaging modality of choice to demonstrate anatomy and pathology of the plexus and we have presented a variety of MRI cases to allow the radiologist to get an insight of what normal and abnormal brachial plexus anatomy should look like to allow them to make the correct diagnosis and aid the clinician in forming a management plan.
References


