

Ultrasound guided therapeutic injections of the cervical spine and brachial plexus

Abstract

Introduction: Recent applications in ultrasound imaging include ultrasound assessment and ultrasound guided therapeutic injections of the spine and brachial plexus.

Discussion: Ultrasound is an ideal modality for these regions as it allows accurate safe and quick injection of single or multiple sites. It has the added advantages of lack of ionising radiation, and can be done without requiring large expensive radiology equipment.

Conclusion: Brachial plexus pathology may be present in patients presenting for shoulder symptoms where very little is found at imaging the shoulder. It is important to understand the anatomy and normal variants that may exist to be able to recognise when pathology is present. When pathology is demonstrated it is easy to do a trial of therapy with ultrasound guided injection of steroid around the nerve lesion. This review will outline the normal anatomy and variants and common pathology, which can be amenable to ultrasound guided injection of steroid.

Keywords: brachial plexus, injection, neck, nerve, ultrasound.

Introduction

Ultrasound has been used to guide therapeutic injections to almost all accessible parts of the body. Notable exceptions until recently have been the facet joints in the spine, the nerve roots in the spine and the brachial plexus. In our practice we have been doing spinal injection for the last three years and brachial plexus injections for the last two years. Several good references have recently appeared about the spine¹ but there have been very few about the brachial plexus. The current review is an attempt to provide a short overview for the beginner who wishes to start learning how to perform injections to these sites and also diagnose pathology of the brachial plexus. For the brachial plexus, this requires a good understanding of the normal anatomy, variations in anatomy and common pathologies with their ultrasound appearance.

Ultrasound guided facet joint injection in the cervical spine

The clinical indications for doing facet injections and outcomes of injections, is beyond the scope of this review. It will just cover how to perform the procedure when requested by a clinician.

The cervical facets can be easily imaged with ultrasound and safely injected with practice and strict attention to technique.¹ The best way for a beginner to gain this skill is with a home made phantom which can easily be constructed with a plastic model of the cervical spine and gelatin/metamucil mixture.^{2,3} The advantage

of ultrasound over other techniques is that it is quicker to do multiple levels, the patient can be sitting as well as lying prone and for claustrophobic patients, they are not in a CT.⁴ They can be injected from a lateral or posterior approach.⁵ The posterior approach is preferable to avoid an inadvertent intraforaminal injection, because of the well documented potential for vascular trauma or intravascular injection.^{6,7} It has the added advantage that bilateral injection can be done without repositioning the patient.

When using ultrasound it is important to know how to find the landmarks of the cervical spine. A curvilinear transducer has the benefit of a wide field of view, rather than the limited field of view of a linear transducer, unless it has a trapezoid function. There are three standard techniques: the posterior process of C2 is usually bifurcated, you can find the junction of C1 with base of the skull in the sagittal plane and count downwards or you can find the characteristic appearance of the transverse process of C7 and count upwards.^{1,8} The latter will be described below.

The cervical facets are diarthrodial joints where the superior articular process of one vertebra articulates on the inferior articular process of the vertebra above. The angle of each joint increases towards the top, where it is approximately 45° at the top and more vertical at the base of the cervical spine.^{9,10} Each facet has a fibrous synovial capsule and both the joint and capsule probably contribute to pain.¹¹ With active synovitis there

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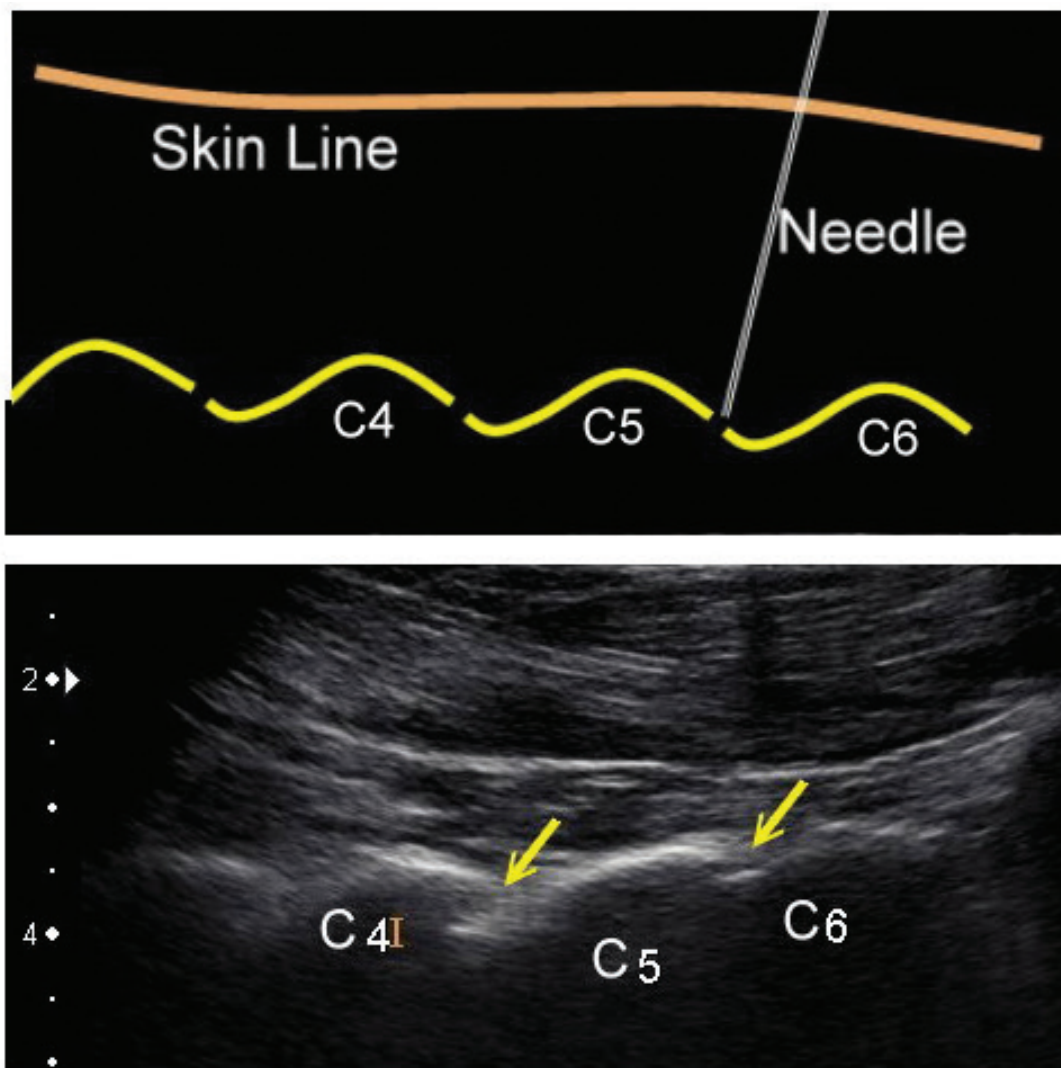


Figure 1: A schematic drawing on the top and corresponding ultrasound image of the 'saw tooth' pattern of the lateral sagittal view of the cervical spine. The small joint gaps are shown which is where the needle is to be positioned.

can be bulging of the capsule and sometimes a small cyst. With advanced osteoarthritis there can be some bony deformity and obliteration of the joint cavity. It is easier to start in the mid cervical spine to properly define the level and then scan laterally where the line of facets make a 'saw tooth' contour. The facet joint cavity makes a small interruption in the bony contour as shown in Figure 1. The colour imaging can be checked to exclude any vessels in the area. Either an 'in plane' or 'out of plane' technique can be used. The advantage of the in plane technique is the entire length of the needle is seen in the field of view. A good example is to use a Terumo 22G 5 cm needle with celestone chondroase and 1% Xylocaine mixed in a 3 mL syringe. This is usually sufficient to do up to six facet joints. When the needle is properly in the joint there should be mild resistance to injection. If there is no appreciable resistance you are probably not properly in the joint. Fastidious technique is needed, no different to injecting small joint spaces in the hand and foot. With practice, several joints can be completed quickly.

Many patients with spine pain may have significant spasm in the overlying muscles (this is especially so in the lumbar spine). These patients notice an increase in pain when the needle punctures the overlying muscles and are often troubled by worsening muscle pain for 1–2 days after the injection. It is suggested these patients use analgesics and heat packs as

required. A slightly oblique approach can avoid passing the needle through the bulk of the muscle and seems to reduce this pain somewhat.

Ultrasound and therapeutic injection of the brachial plexus

When a patient presents for a shoulder ultrasound and has either nothing to find, or presents with some significant component referred down the arm, the brachial plexus should be assessed for possible abnormalities. In many of these cases ultrasound can demonstrate pathology that is amenable to ultrasound guided injection. When our group started doing this technique in our practice, all the patients were originally referred for shoulder ultrasound but clinical suspicion led us to investigate the brachial plexus. Now there are more direct referrals for brachial plexus assessment and/or trial of injection of steroid. Many of the patients that have been injected have derived significant benefit from steroid injection to the involved part of the brachial plexus. Like all steroid injections for neural inflammation or compression it sometimes takes several injections a few months apart to get complete relief. It is usual to find incremental improvement with each subsequent injection.

Assessment of the brachial plexus with ultrasound has been described since 1998.^{12–14} Because of the large number of anatomical variants that occur, it is important to have a sound

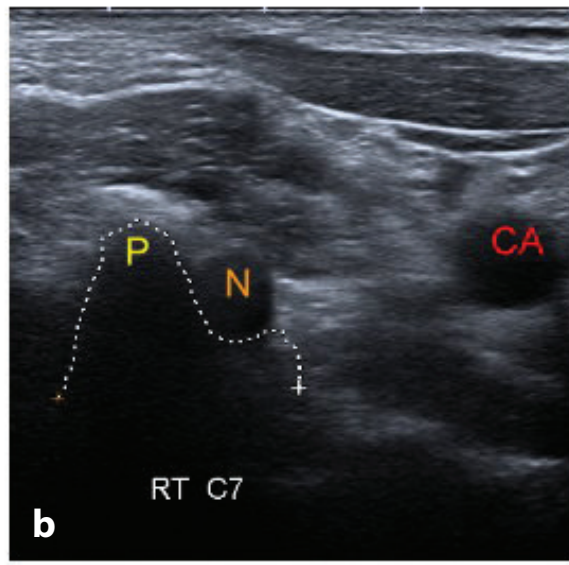
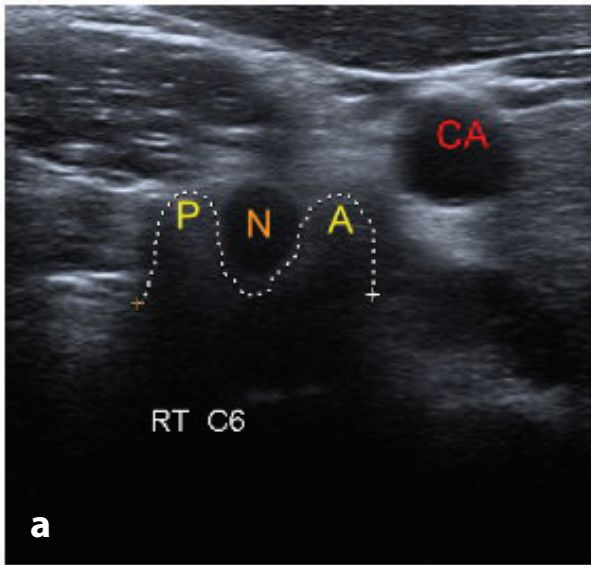


Figure 2a, b: The posterior (P) and anterior (A) tubercles at C6 making the 2 humped camel configuration with the C6 nerve root (N) in the middle. Figure 2b shows the C7 level where there is no anterior pedicle. The carotid artery is shown on both images (CA).

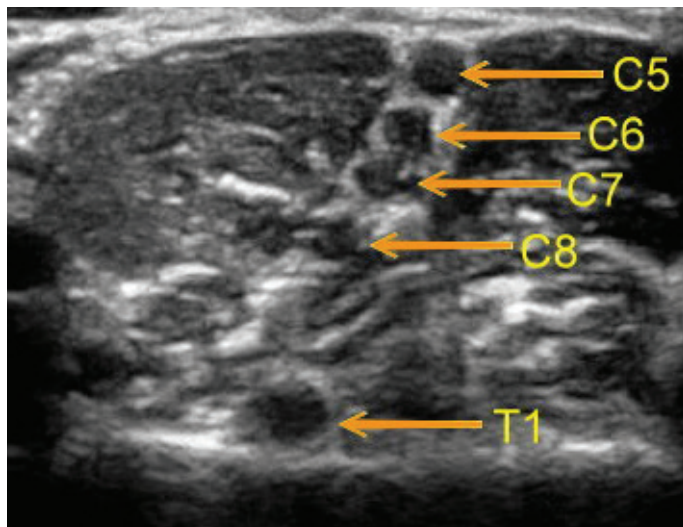


Figure 3: The cervical nerve roots in a line between the anterior and middle scalene muscles.

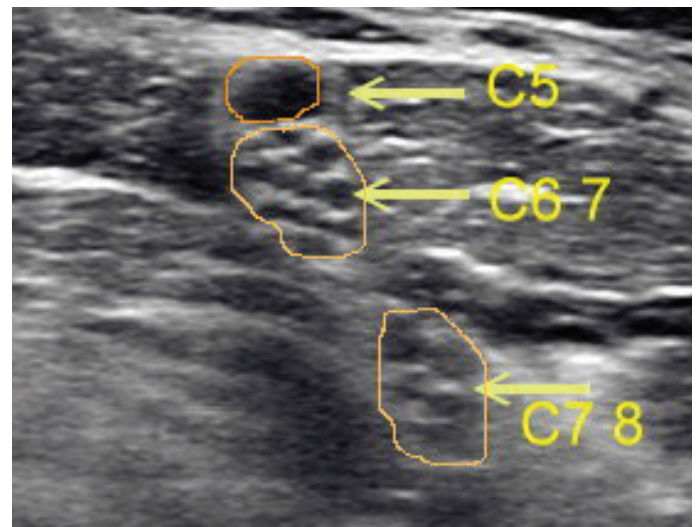


Figure 4: The C5 is a typical monofascicular nerve root while C6&C7 and also C8&T1 have fused into polyfascicular trunks.

understanding of normal anatomy, major variations and the appearance of the common pathologies that might be amenable to therapeutic injection. Again the indications and outcomes of such injections are outside the scope of this review and this article will only describe the technique of ultrasound assessment and injection.

Normal anatomy and variants

The brachial plexus is subdivided into roots, trunks, divisions, cords, and branches. Several mnemonics can be used to remember this architecture (e.g. Really Tired Drink Coffee Black). Typically, the brachial plexus is composed of five roots, three trunks, six divisions, three cords, and terminal branches.

The anatomy of the brachial plexus described in most standard anatomy texts is quite an oversimplification as up to 50% of patients have a major variation.^{15,16} There is often significant difference between left and right sides in a given individual. The usual pattern commences with the nerve roots from C5 to T1. The roots are usually monofascicular and hypoechoic. As the plexus goes distally it becomes polyfascicular and more

echogenic, due to an increasing amount of connective tissue of the epineurium.¹⁵ Ultrasound easily shows the structure of the brachial plexus at most levels,¹⁷ with the major ‘blind spot’ being deep to the clavicle.

The nerve roots emerge from the transverse processes of the cervical vertebrae immediately posterior to the vertebral artery. The transverse process consists of a posterior and anterior tubercle, which join laterally to form a costotransverse bar. This forms a boney cup or groove which the nerve lies in. The spinal nerves that form the brachial plexus run in an inferior and anterior direction.

The C4–C6 transverse processes have a characteristic shape with an anterior and posterior tubercle giving a ‘two humped camel’ sign with transverse ultrasound images. The C7 however usually only has a posterior tubercle which is easily demonstrated with ultrasound,¹⁸ as shown in Figure 2. When injecting nerve roots it is important not to inject too close to the origin as the dura coats the nerve root at its very origin and the injection can inadvertently be intrathecal. The five nerve roots then travel in the interscalene groove between the anterior and middle scalene

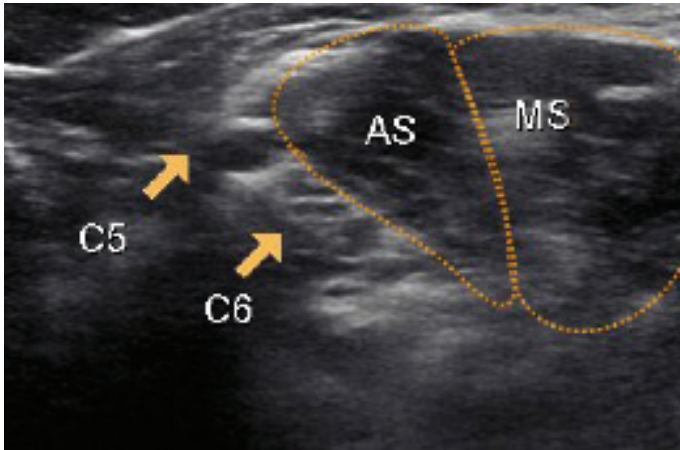


Figure 5: The C5 root and C6 trunk, marked by arrows, lie anterior to the anterior scalene muscle (AS) instead of the more usual position in the interscalene groove. The middle scalene is marked as MS

muscles. The scalene muscles arise from C4–C6 and attach onto the first rib. The subclavian artery lies deep in the interscalene groove and usually lies between C7 and C8. On transverse ultrasound imaging the roots form a straight line of hypoechoic circles as shown in Figure 3.

Many variations of this pattern occur. An example of roots fusing and becoming trunks while still in the interscalene groove is shown in Figure 4. Also there are often aberrant paths with the uppermost two roots going through or around the anterior scalene muscle as shown in Figure 5.^{19,20} We have also seen variants where the roots go thru or around the mid or posterior scalene muscles. While these variants of position can predispose to compression or stretching of the roots and symptoms, they do not necessarily cause a problem. It is important to keep looking for pathology elsewhere when one of these variants is found. Up to 25% of cases have a ‘pre-fixed’ variant where the C4 contributes to the Brachial plexus.¹⁵ This should be considered when the uppermost root seems smaller than the rest. Less commonly, 2.5% of patients have the ‘post-fixed’ variant where the T2 contributes to the plexus.¹⁵ This can be associated with either C5 or C6 as the uppermost root. Injury to the scalene muscles or inflammation can result in neural symptoms. There can be an accessory scalene muscle, the scalene minimus, contributing to compression. This is best demonstrated by scanning up and down through the interscalene space and a small muscle will be seen running obliquely through the space. It is easy to distinguish this muscle from the roots as the direction it takes through the interscalene space is different.

Next the nerve roots form three major trunks. The upper, mid and lower trunks. They often are seen as a single polyfascicular bundle in the supraclavicular fossa – like a bunch of grapes.²¹ Again many variations of the usual pattern are seen. The junction of the trunks and divisions is usually found between the clavicle and the first rib. At this site the plexus and subclavian artery lie just above the first rib.

Inferior to the clavicle, the three cords lie adjacent to the axillary artery. The usual position is lateral, posterior and medial to the artery.²² Many variants of position and number are also found such as two cords or even one cord.^{23–26} The cords then form into the nerve branches over a length of 5 to 10 cm.

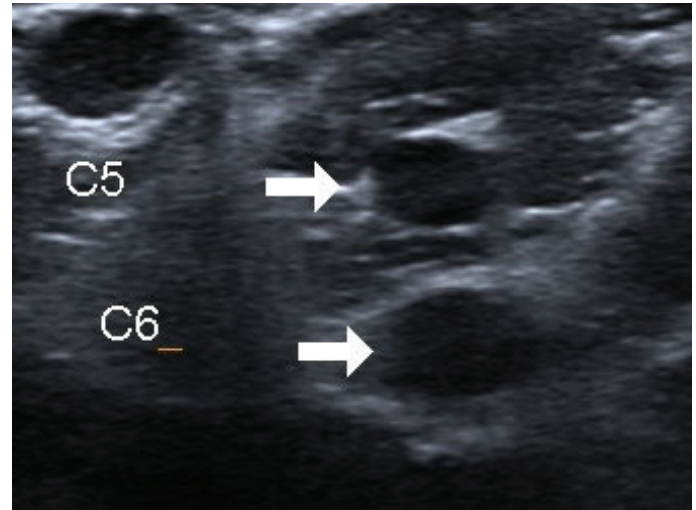


Figure 6: The C6 nerve root is enlarged compared to the normal C5 nerve root.

Pathology of the brachial plexus

With pathology to the brachial plexus, the signs and symptoms may be vague²⁷ and the patient may present for investigation of the neck, shoulder, elbow or wrist. It is important to suspect a brachial plexopathy in those patients where very little is found at the presenting site. Motor symptoms tend to occur in younger patients, post trauma or in neonates; and as a group most are reversible. Sensory symptoms predominate in an elderly and especially post radiotherapy.

Plexopathies can be categorised by site or cause. Anatomical classification is useful as the lesion site affects the incidence, severity, prognosis, and lesion type.²⁸ In general, supraclavicular plexopathies are more common. They are more frequently due to closed traction (which can produce lengthy lesions) and are usually more severe as greater force is required to produce them. These also are typically associated with a worse outcome. The variations of anatomy in the scalene groove may predispose to compression or stretching of the nerve roots. In this region, the usual pathological finding on ultrasound is a swollen hypoechoic nerve root such as is shown in Figure 6. In addition, pathological roots can be very sensitive and produce a ‘Tinnel’s sign’ i.e. give neural symptoms or discomfort with transducer pressure or when a needle is near the site of pathology of the nerve.

The anatomy of the brachial plexus was described by Hippocrates in 400 BC. The earliest recorded account of trauma was recorded in 700 BC in *The Iliad* by Homer where Hector strikes Teucer in the arm “Teucer had just taken an arrow from his quiver and laid it upon the bow-string, but Hector struck him... just where the collar bone divides the neck from the chest, a very delicate place and broke the sinew of his arm so that his wrist was less, and the bow dropped from his hand...”

Traumatic brachial plexopathy

Trauma is the cause in up to 50% of cases and may be associated with a fracture of the cervical spine or clavicle, nerve root avulsion, soft tissue oedema, haematoma or pseudo aneurysm.²⁹ The onset of symptoms may be delayed months or years after the initial injury. With all nerve lesions there is classic dilemma of structure and function. A nerve can be structurally normal

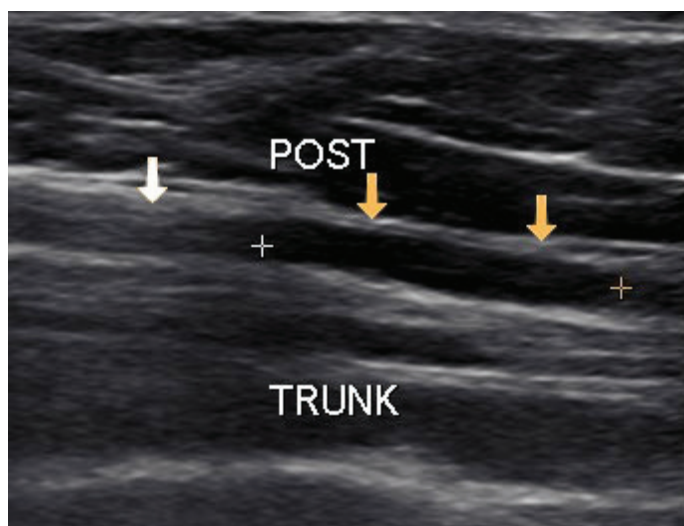


Figure 7: A neuroma in continuity. The abnormal portion marked by the orange arrows is enlarged and hypoechoic compared to the normal portion of the nerve trunk on the left of the image marked by the white arrow.

and still have dysfunction, while some nerves show structural signs of trauma or compression yet have no dysfunction. The pathological classification of nerve injuries is into three groups.

Firstly is a neurotmesis which is a complete anatomical disruption of the both the axon and all of the surrounding connective tissue. This is the most severe type of nerve injury and has no chance of spontaneous recovery. Early surgical treatment is necessary. Secondly is axonotmesis, which is an anatomical interruption of the axon with no or only partial interruption of the connective tissue framework. This type of nerve injury requires regrowth of the axon to the target muscle, which takes a considerable amount of time. This regrowth can be inhibited by scar formation. Whether patients with axonotmesis will require surgical treatment depends on the number of disrupted axons and the extent of scar formation at the site of nerve injury. Lastly is a neuropraxia, which is a physiologic block of nerve conduction within an axon without any anatomical interruption. This is a form of 'nerve shock' where there is normal structure but altered function.

This classification system is only partly useful to the sonologist or sonographer. A more useful classification is: complete disruption, trauma in continuity or structurally normal. Complete disruption shows a complete rupture, often with a swollen proximal nerve, a disruption in the nerve continuity and a retracted nerve distally.³⁰ The distal nerve may develop atrophy over time. There will also be atrophy of the supplied muscles over time.

The features of trauma in continuity may be subtle. They include:

- A distorted course or configuration
- Diffuse nerve enlargement
- Focal nerve enlargement
- A disruption of the fascicular pattern
- Fascicular oedema
- Fibrosis.³¹

Figure 7 shows a neuroma in continuity in the brachial plexus after a traction injury. In the brachial plexus there can be a partial lesion with only some of the fascicles being involved as shown in Figure 8 where the abnormal part of the trunk indicated by



Figure 8: The abnormal part of the trunk indicated by the orange arrow is enlarged and hypoechoic while the rest is normal.

the orange arrow is enlarged and hypoechoic while the rest is normal. Last is a normal nerve with ultrasound. Despite it being normal there may be convincing clinical signs or a 'Tinnels sign' at the site of trauma, and if there is it should be injected with steroid around it because of the clinical suspicion, despite the lack of imaging findings.

There may be secondary clinical features to help localize the site of trauma. If there is a phrenic nerve palsy it suggests trauma at the site of the roots. If there is scapular winging it suggests a proximal C5–C7 lesion (due to long thoracic nerve involvement) and if there is a Horner's syndrome it suggests a lesion at the infraclavicular plexus. Horner's syndrome is due to interruption of the cervical sympathetic chain and results in ptosis, miosis and anhidrosis on the same side of the face. A common anatomical variant that causes brachial plexus pathology is the cervical rib. It occurs in 1% of individuals but only causes symptoms in 10% of affected individuals.³² Cervical ribs may affect the nerves of the brachial plexus in one of two ways. First, the cervical rib may narrow the space between the posterior aspect of the first rib and the anterior scalene muscle. Second, the cervical rib may be situated such that a portion of the brachial plexus must pass over it. In this case the lower plexus trunk rests against the top of the cervical rib and is stretched as it crosses the cervical rib. It is worse if there is a 'post fixed' variant where T2 contributes to the plexus. It tends to present with sensory symptoms more than motor symptoms. The extra rib, with or without a fibrous band, is easily seen at the window where the trunks lie above the first rib. It is seen posterolateral to the brachial plexus and superior to the first rib.

The history of trauma may include stretching, direct impact or compression. In sports these can be common and a neuropraxia of the brachial plexus is called a 'burner' or 'stinger'. They can last from seconds to weeks before they resolve. Injection of these lesions seems to hasten recovery but it is a self-limiting lesion which will usually recover on its own anyway.

Non-traumatic brachial plexopathy

Primary nerve tumors include a schwannoma of the nerve or Pancoasts tumor of the apex of the lung which infiltrates the brachial plexus. A variety of secondary cancers have been

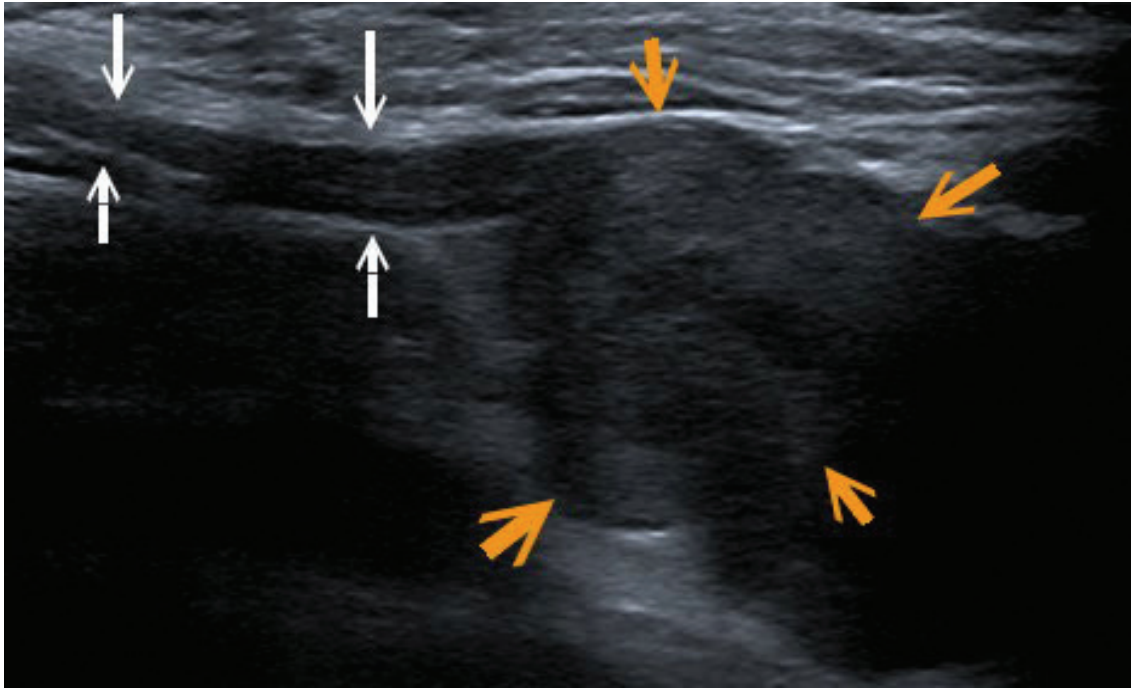


Figure 9: A benign neurofibroma of the brachial plexus with the normal trunk indicated by the white arrows and the tumor by the orange arrows.

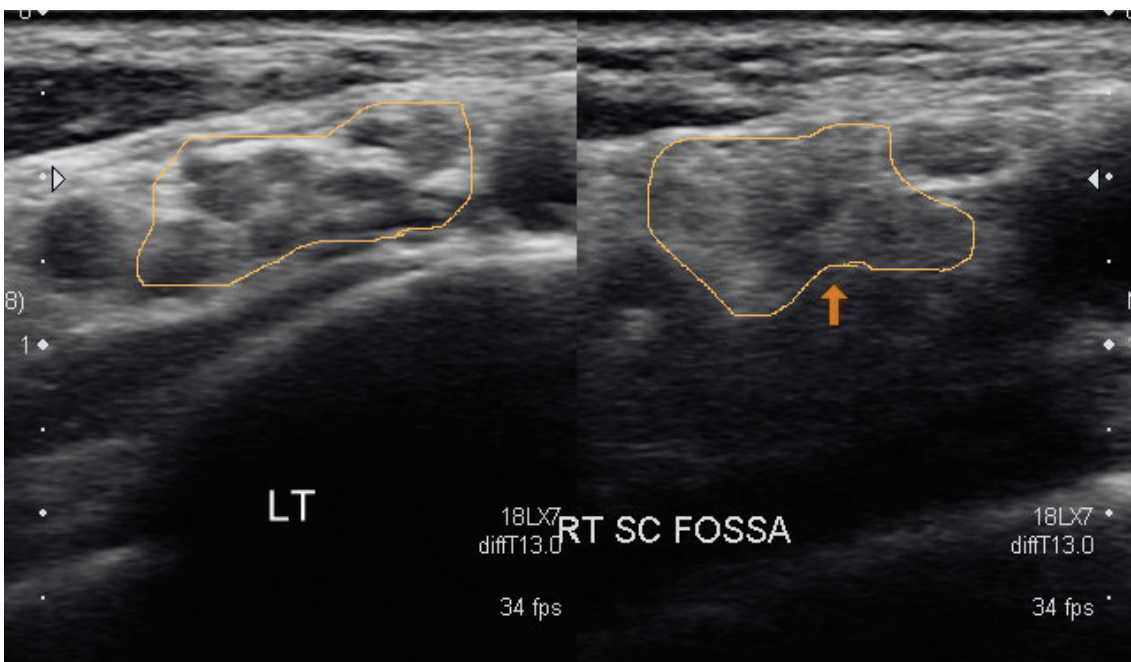


Figure 10: The normal trunk is shown on the left and typical chronic radiotherapy changes are shown on the right with fibrosis and atrophy of tissues and obliteration of the fascicles.

documented and include: breast, lymphoma, leukaemia, and myeloma.^{33,34}

Figure 9 shows a benign neurofibroma of the brachial plexus. Nerves can be damaged by radiotherapy and the brachial plexus can be in the radiotherapy field for breast cancer or cancer to the apex of the lung.^{35,36} It usually involves the divisions, cords or branches. Acute onset of symptoms is less than six months post radiotherapy and is usually irreversible.^{35,36} The nerves are swollen and hypoechoic with adjacent tissue oedema. Chronic onset of symptoms is after six months and is usually reversible. The plexus may show fibrosis and atrophy of tissues with obliteration of the fascicles, demonstrated in Figure 10.

Inflammatory causes of plexopathy include viral, drug and idiopathic. It usually resolves in 6 to 12 weeks and the

ultrasound shows swollen hypoechoic fascicles. Figure 11 shows an acute brachial neuritis. Of cervical radiculopathy secondary to disk disease, 80% to 90% occurs at the C6 and C7 root levels. These patients often present with pain, numbness, and sensory deficit in the upper extremity, and the upper extremity reflexes may be absent or decreased. Coughing, sneezing, or lateral head movement often exacerbates the pain and cause it to radiate into the arm. Also the paraspinal muscles may be tender when palpated.³⁷ At least half of such patients gain relief from ultrasound guided nerve root injection.³⁸ Interestingly, neither the duration of symptoms before treatment or intensity of pain predict the subsequent relief of radicular pain^{39,40} Parsonage Turner syndrome (or acute brachial neuropathy/acute brachial neuritis) is an idiopathic inflammation of the brachial plexus

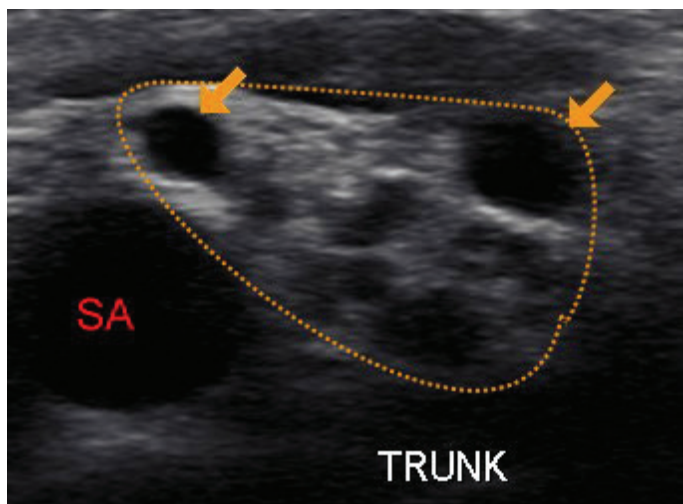


Figure 11: An acute brachial neuritis with enlarged hypoechoic fascicles in the nerve trunk indicated by the arrows.

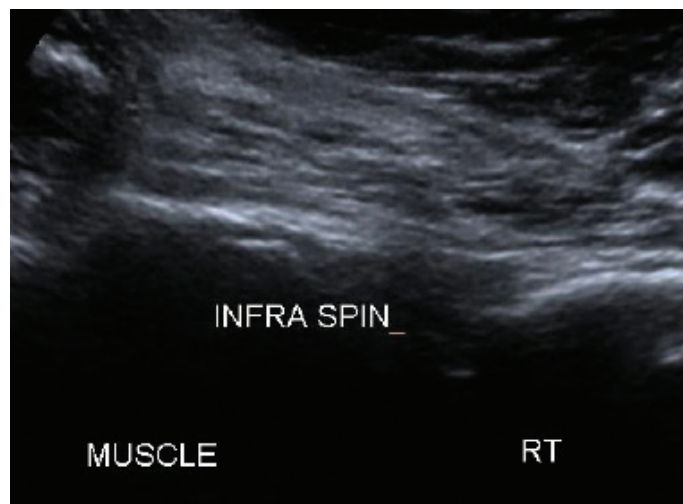


Figure 12: A case of wasting in the infraspinatus muscle from brachial neuritis of several months duration. The muscle is smaller and echogenic from fatty atrophy.

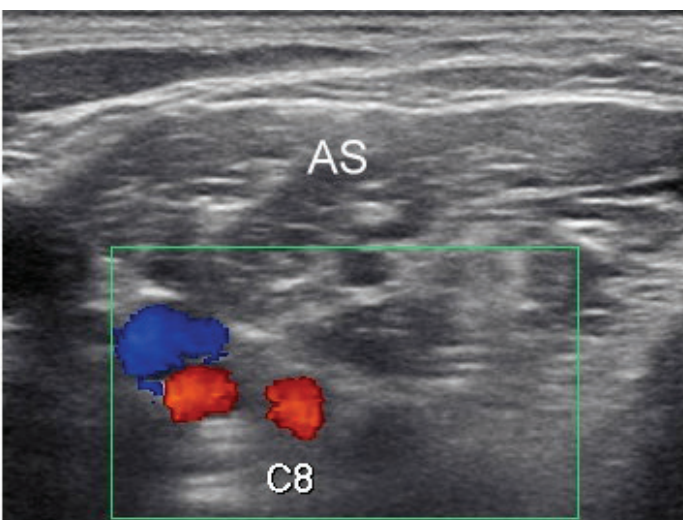
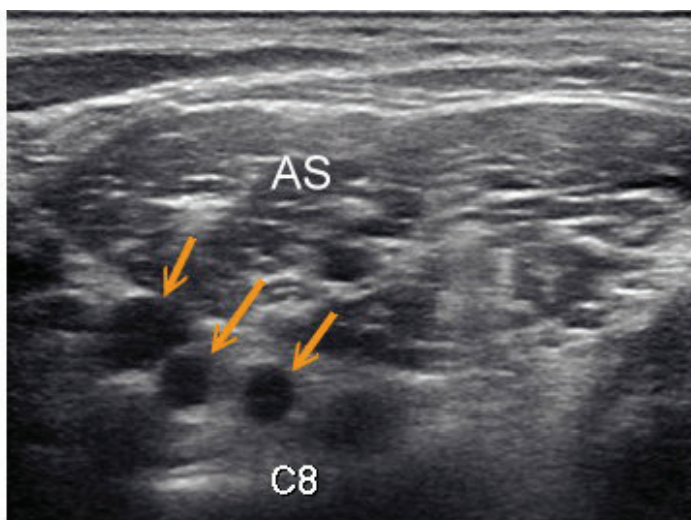


Figure 13: An image of the nerve roots in the interscalene groove with and without color imaging. Without the use of color imaging the vessels can easily be mistaken for nerve roots.

and shows the same findings of swollen hypoechoic nerves. This condition is generally associated with significant pain. Acute, excruciating, unilateral shoulder pain is present, followed by flaccid paralysis of shoulder and parascapular muscles several days later.⁴¹ Due to the extreme pain involved, patients usually present acutely. It varies greatly in manifestation and nerve involvement. Of cases, 97% involve the suprascapular nerve, and 50% involve the axillary nerve and occasionally involve others.⁴² After several weeks of symptoms there may be wasting in the relevant muscles. Figure 12 shows a case of wasting in the infraspinatus muscle from brachial neuritis of several months duration. Injection of steroid around the swollen nerves of these patients seems to help with their pain, but it is uncertain if it actually shortens the duration of the episode.

Ultrasound guided injection

Any patient with symptoms and a structural change to any part of the plexus warrants an injection of steroid. It is best to target the most abnormal portion with the injection. If it is a long segment of pathology one should inject along the whole

abnormal segment. It is important not to traumatise the nerve fascicles when injecting. The brachial plexus does not have a continuous investing sheath but instead has a series of thin compartmented and convoluted fascia that can restrict flow of injection along or around the plexus.^{43,44} It is very important to have a careful technique when injecting and it is often necessary to move the needle to several sites to get a good spread of local anaesthetic and steroid around the plexus while avoiding the accompanying vessels. As the presenting signs and symptoms may be vague the injection is often diagnostic as well as therapeutic. The thinnest needle that is long enough to access the required part is preferable.

It is very easy to inject the nerve roots in the interscalene space. Sometimes it can be a bit elusive to find this site and a helpful hint for beginners is to use a linear transducer and place the transducer so that the carotid artery is on the edge of the field of view. This usually results on the scalene space being in the mid field of view. The sternocleidomastoid muscle usually lies over this and if the head is rotated away it will move out of the way. The needle can easily be inserted along the line of the

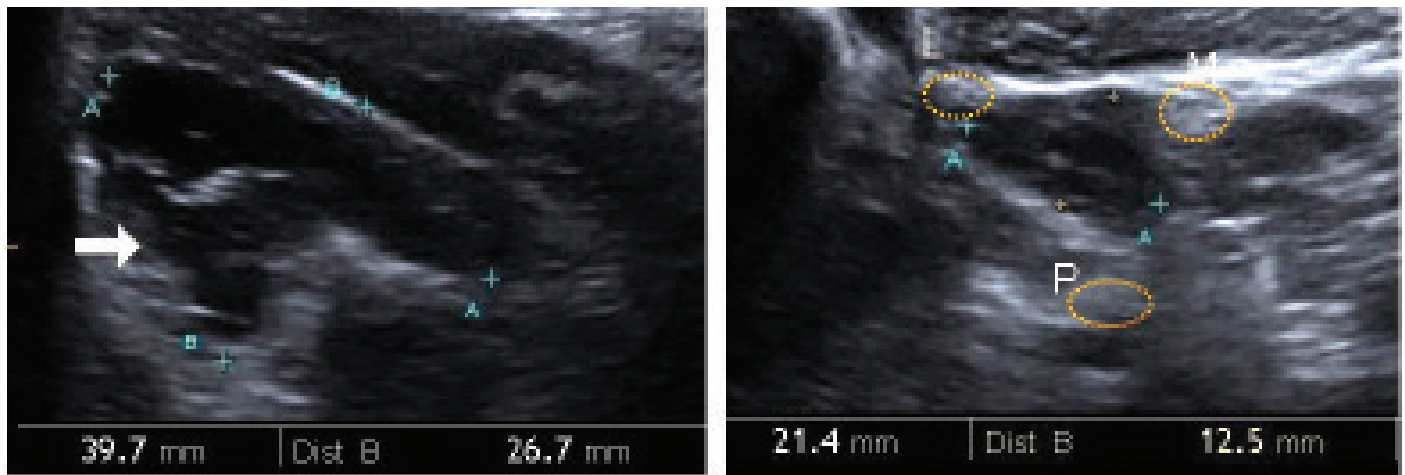


Figure 14: There is a large haematoma indicated by the calipers. It lies deep to the pectoralis minor compressing the nerve cords which cannot be identified on the image on the left. The image on the right was taken post aspiration of the haematoma which shows the collection is smaller and the cords have become more easily seen and are shown outlined by orange dotted lines.

roots till the desired target level is reached. It is preferable to pass the needle posterior to the roots as they travel in an inferior and anterior direction and this avoids nerve damage by the needle. The vessels are somewhat variable in position and it is important to always check with color or power Doppler before needling any part of the plexus. The transverse cervical artery may pass through the interscalene space and it can resemble a nerve trunk in short axis imaging as shown in Figure 13. When imaging without color it is very easy to mistake the vessels for nerve roots. It should be noted that the phrenic nerve, (which innervates the diaphragm), usually lies anterior to the anterior scalene muscle – but can lie within the scalene space.⁴⁵ This means the phrenic nerve can be inadvertently blocked with a nerve root injection. For this reason it is best to only inject one side at a time. An example would be a 22G 5 cm in length or a 22G spinal needle 9 cm in length, depending on the size of the patient. Either celestone kenacort or depomedrol can be used. Most patients will just have lignocaine 1% mixed with the steroid. If however, the request is to perform a diagnostic injection it is preferable to use marcaine as it has a longer duration and allows the patient sufficient time to decide if symptoms have improved or not. Although local anaesthetic is not supposed to affect nerve motor fibres, in clinical practice it does. It is advised that patients do not drive until the local anaesthetic has worn off.

The junction of the trunks and divisions is usually found above the clavicle in the supraclavicular space. At this site the plexus and subclavian artery lie just above the first rib. It is a good site to line up for injection as when properly aligned the needle will bump into the first rib rather than penetrating the pleura if it is advanced too far. Long segment traction neuromas are common in this region as are direct trauma. Injection can be performed in either 'in plane' or 'out of plane', depending on the operator's preference. When the superficial bundles are involved they are easy to inject near, but when the deeper bundles are involved it is more difficult to get good access. It may be necessary to sit the patient up, lie them down and turn the head from side to side to find the best and safest approach to the deeper bundles. It is recommended one does not inject through the plexus to reach the deeper bundles. However with careful technique one can safely inject through the

major vein or artery with a 25G needle 2.5 cm in length. Because of the fibrofatty tissue that surrounds the nerve fascicles there is often a delayed onset of the local anaesthetic effect for 5–10 minutes after the injection. If lignocaine is used, it should have worn off in 30 minutes. Patients should be warned not to drive until the full 30 minutes are up as they can feel fine after the injection and set off in their car only to have the local anaesthetic take effect after they start driving.

In the infraclavicular view the divisions form the three cords that are echogenic in appearance. Because of their depth a lower frequency transducer may be required. They are usually grouped around the artery spaced out, but if the arm is abducted they will bunch together laterally. This is a helpful technique both for imaging and injecting the cords. Ultrasound of the nerve cords is difficult in large patients as the cords are small and echogenic and it can be difficult to distinguish them from the fibrofatty tissue that surrounds the vessels. Lack of lateral cord movement while abducting the shoulder is an abnormal finding suggesting fibrosis or tethering. Fortunately pathology here is less common than the above regions. Figure 14 shows a case of an elderly lady on warfarin who presented for investigation of ulnar nerve symptoms. Assessment of the arm was unremarkable so the examination was extended to assess the brachial plexus. There was a large haematoma deep to the pectoralis minor compressing the nerve cords. Post aspiration of the haematoma, her symptoms resolved. This case highlights the importance of looking at the brachial plexus in patients with suspected peripheral nerve pathology, where no peripheral pathology is found.

Conclusion

Pathology of the cervical spine or brachial plexus can cause significant symptoms and result in pain and/or dysfunction. Ultrasound assessment and injection of the cervical spine and brachial plexus can be easily learned and extends the range of services that ultrasound departments can offer to relieve suffering in patients with chronic pain. Practice will probably show that an experienced ultrasound of the brachial plexus will be superior to MRI for diagnosing pathology and has the added advantage that relief of symptoms may be possible with ultrasound guided injection.

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