Ultrasound of Peripheral Nerves: Expected features and Shocks!

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Learning objectives

The aims of this presentation are to demonstrate the normal anatomy of peripheral nerves at the wrist, elbow, knee and ankle and to describe ultrasound assessment of the various pathologies and incidental findings that may be encountered when examining these structures. The cases described are by no means exhaustive but aims to give the reader an insight into what may be encountered and further diagnoses to consider.
Background

Imaging of peripheral nerves in patients with symptoms of entrapment neuropathies or polyneuropathy is frequently supplemented with ultrasound after nerve conduction studies. Numerous pathologies producing irritation or entrapment of peripheral nerves may be diagnosed at ultrasound assessment. Neuropathies can be divided into those that result from a structural abnormality in the region of the nerve and those due to an intrinsic abnormality of the nerve, such as a nerve sheath tumour. An appreciation of the usual imaging appearances of peripheral nerves and pathologies occurring along their course is essential. We describe ultrasound techniques such as dynamic assessment of peripheral nerves and imaging features of common pathologies of the extremities that may be identified.
Imaging findings OR Procedure Details

Ultrasound assessment of peripheral nerves is usually conducted using a 10-15MHz hockey stick probe scanned over the nerve in both transverse and longitudinal planes.

Peripheral nerves are hypoechoic structures which are ovoid and multifascicular in transverse section. The fascicles are surrounded by hyperechoic perineurium. No vascularity is demonstrable in peripheral nerves.

Median nerve and pathologies at the hand and wrist

The median nerve originates from the medial and lateral cords of the brachial plexus (C6, C8 and T1) and passes alongside the brachial artery through the arm. At the forearm, it can be identified between the flexor digitorum superficialis and profundus muscles. It has a purely motor anterior interosseous branch and sensory palmar cutaneous branch, both of which arise proximal to the nerve entering the carpal tunnel. The median nerve is identified at the carpal tunnel at the palmar crease using the landmarks of the scaphoid tubercle and pisiform Fig. 1 on page 15. The nerve is scanned in the transverse plane distally to the level of the trapezium tubercle and hook of hamate, and then assessed in the longitudinal plane.

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in the body, affecting 2-4% of the population. Women are affected more than men and it may be bilateral in up to 50% of patients. Any pathology that decreases the size of the carpal tunnel or increases the size of the median nerve may lead to carpal tunnel syndrome.

Ultrasound has been shown to be as effective as nerve conduction studies in the assessment of CTS. Features of CTS include Fig. 2 on page 15:

- Enlarged cross-sectional area of >9mm²
- Difference of the cross-sectional area at the carpal tunnel and level of pronator quadratus of >0.25mm²
- Calibre change of the median nerve at the proximal tunnel: "notch sign" or flattening of the distal median nerve
- Hypoechoegenicity of the nerve
- Bulging of the retinaculum of >2mm anterior to a line across the tubercle of trapezium and hook of hamate

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Many of these secondary signs of nerve entrapment (e.g. focal flattening, proximal distension and hypoechogenicity on ultrasound) can be applied to the examination of any peripheral nerve.

The most common median nerve anomaly is that of a bifid median nerve which occurs in 2.8% of the population\(^3\) Fig. 3 on page 16. This is a result of an early division of the median nerve in the forearm. This appearance is often noted in patients who present with carpal tunnel syndrome. The measurement of the cross-sectional area of the median nerve is not applicable in cases where there is a bifid median nerve.

The presence of a bifid median nerve is often associated with a persistent median artery of the forearm, which is often identified between the two nerve bundles Fig. 4 on page 17. It has been identified in 26% of asymptomatic volunteers\(^4\) but may be a risk factor for the development of carpal tunnel syndrome. Reporting of this finding is crucial when assessing the median nerve on ultrasound as it may be injured during a carpal tunnel release if the operating surgeon is unaware of the finding.

Other abnormalities of the median nerve may include the presence of a fibrolipomatous hamartoma Fig. 5 on page 19, Fig. 6 on page 18. These are benign tumours of the nerve sheath that occur due to proliferation of adipose tissue. They are echogenic on ultrasound and on MRI show identical signal characteristics to fat.

Patients with demyelinating neuropathies (such as chronic inflammatory demyelinating polyneuropathy, Charcot-Marie-Tooth neuropathy or progressive inflammatory neuropathy) will have marked enlargement and hypoechogenicity of peripheral nerves on ultrasound Fig. 7 on page 19.

The space within the carpal tunnel may be reduced by the presence of a ganglion cyst. These are benign, avascular, cystic masses that often occur in the wrist and hand. The ganglion is usually attached to a joint capsule Fig. 8 on page 20, Fig. 9 on page 20 or tendon sheath Fig. 10 on page 21 and filled with mucin\(^5\). They therefore demonstrate posterior acoustic enhancement on ultrasound. Ultrasound is not only useful in the assessment of these masses, but may also be utilized to guide aspiration of these masses if clinically indicated.

Patients with inflammatory arthropathy often develop proliferative joint disease and synovitis which may be demonstrated on ultrasound Fig. 11 on page 22. There is synovial thickening, increasing degrees of vascularity and possibly a joint effusion or erosions demonstrated.
Other incidental findings of the hand and wrist may include:

- De Quervain's tenosynovitis is the second most common tendon entrapment in the hand and wrist Fig. 12 on page 23. It is demonstrated by thickening and possible increased vascularity of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendon sheath in the first dorsal compartment of the wrist.

- Giant cell tumour of the tendon sheath Fig. 13 on page 9 is a form of pigmented villonodular synovitis with identical histological characteristics. They are the second most common tumour of the hand after ganglion cysts with a predilection for the flexor surfaces. The mass is of soft tissue density and may show increased internal vascularity. They often arise from palmar tendons and may cause underlying bony erosion.

**Ulnar nerve and pathologies at the elbow**

The ulna nerve originates from the medial cord of the brachial plexus (C8 and T1) and passes medial to the brachial artery through the arm. It enters the posterior compartment of the arm by piercing the medial intramuscular septum to lie posterior to the medial epicondyle in the cubital tunnel. At the wrist, the ulnar nerve can be identified at Guyon's canal lying medial to the ulnar artery and vein and lateral to the pisiform Fig. 14 on page 9. It divides into superficial sensory and deep muscular branches in the canal.

Compression of the ulna nerve at the elbow is the second most common entrapment neuropathy in the body 21-25 cases per 100,000 Fig. 15 on page 10. Physical labour and recurrent dislocation of the ulna nerve are through to be risk factors for the development of this condition. Snapping, or dislocation, of the ulna nerve often co-insides with dislocation of the medial head of triceps. This can be assessed by dynamic scanning with ultrasound. Recognition of this feature is crucial as surgical translocation of the nerve without correction of the snapping triceps will not relieve the patient's symptoms.

Compression of the ulna nerve at the elbow may be due to the presence of an accessory muscle Fig. 16 on page 10, which may reduce the size of the cubital tunnel. This is the most common structural anomaly in the cubital tunnel and is found in 23% asymptomatic elbows on MRI.

Trauma to the ulna nerve, perhaps following an olecranon fracture or previous surgical intervention, may result in the development of an ulna nerve neuroma Fig. 17 on page 11. This is identified as a hypoechoic bulb-like distention of a segment of the nerve following an injury to the nerve, or end-bulb distension of a previously severed or amputated nerve. Care should be taken to not diagnose these lesions as tumours.
A differential diagnosis for pain over the medial aspect of the elbow is medial epicondylitis, or golfer’s elbow. This is identified on ultrasound by areas of hypoechogenicity of the common flexor tendon origin. Similarly pain over the lateral aspect of the elbow may be due to lateral epicondylitis, or tennis elbow, which involves the common extensor tendon origin. This is 7-10 times more common than medial epicondylitis. Calcification in the tendon, bony irregularity of the insertion of the tendon and increased vascularity may be demonstrated Fig. 18 on page 12. Often these diagnoses are made clinically but ultrasound confirmation is often useful if the diagnosis is in doubt.

Lipomas are commonly identified mass lesions that may cause peripheral nerve compression. They commonly occur in patients over the age of 50 years and can occur in any region of the body. Although these are benign adipose lesions, their size and position may need to be removed depending on their composition. Ultrasound has been show to have low accuracy in the diagnosis therefore MRI is often valuable Fig. 20 on page 14.

Common peroneal (fibular) and tibial nerves and pathologies at the knee and ankle

The sciatic nerve originates from the sacral plexus (L4-S3) and divides proximal to the popliteal fossa into common peroneal and tibial nerve. The common peroneal nerve runs across the lateral head of gastrocnemius and around the fibula head before dividing into deep and superficial branches. The tibial nerve travels along the posterior aspect of the tibia in the calf. At the ankle, it runs posterior to the medial malleolus through the tarsal tunnel.

Neuropathy of the common peroneal or tibial nerves may result from compression in the popliteal fossa from a mass lesion, trauma, joint pathology or intrinsic nerve sheath tumour. Popliteal artery aneurysms may be demonstrated Fig. 21 on page 24 and when large enough may cause compression of the branches of the sciatic nerve to varying degrees. Examination of the common peroneal or tibial nerves at the knee may reveal a concurrent joint effusion Fig. 22 on page 25, Baker’s cyst Fig. 23 on page 26 or ganglion cyst Fig. 24 on page 27.

The common peroneal nerve is often injured following fractures of the fibula neck Fig. 25 on page 27. Less often, the posterior tibial nerve is injured following a medial malleolar fracture Fig. 26 on page 28. The nerve may appear hypoechoic and swollen on ultrasound. Over time a neuroma may develop leading to long term pain and paraesthesia Fig. 27 on page 29.
Nerve sheath tumours are hypoechoic masses along a nerve and may be a cause of neuropathy. Schwannomas and neurofibromas are the most common types of nerve sheath tumours. Schwannomas are hypoechoic, well-defined masses with the nerve identified eccentrically within it. There is often intratumoural cystic change and hypervascularity demonstrated. These lesions are resectable without a resultant neurological deficit Fig. 28 on page 30. Neurofibromas, however, demonstrate a target sign with the nerve centrally located within the mass and no vascularity. These lesions have malignant potential and therefore require resection and grafting\textsuperscript{6}. Giant cell tumours as described above may also present in the lower limbs Fig. 29 on page 31.
Fig. 13: 21mm hypoechoic mass (arrows) on the radial aspect of the 1st MCP joint of the right hand with internal vascularity. The lesion was further assessed with MRI (T1W shown) and is in keeping with a giant cell tumour of the tendon sheath.

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**Fig. 14:** 28 year old male patient with symptoms of ulna neuropathy. There is hypoechogenicity and swelling of the right ulna nerve (circle) seen in Guyon’s canal with a normal appearance of the left ulna nerve.

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**Fig. 15:** 51 year old male patient with symptoms of ulna neuropathy. There is hypoechogenicity and swelling of the right ulna nerve at the cubital tunnel. (medial epicondyle, M)

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Fig. 16: 53 year old male patient with symptoms of ulna neuropathy. There is hypoechogenicity and swelling of the right ulna nerve (circle) at the cubital tunnel and compression from an accessory anconeus epitrochlearis muscle (arrow). (medial epicondyle, M)

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Fig. 17: Neuroma of the ulna nerve (U) identified in a 76 male patient following trauma.

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**Fig. 18:** 5 year old female patient with severe lateral epicondylitis demonstrating calcification in the common extensor tendon origin, hypoechogenicity and marked vascularity.

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**Fig. 19:** 76 year old female with a palpable lump in the antecubital fossa the lump (L) was of mixed echogenicity on ultrasound and low density on CT with a Hounsfield unit of -50, in keeping with a lipoma.

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**Fig. 20:** Male patient with a large lump (L) in the arm. This was echogenic on ultrasound but difficult to characterise therefore an MRI, coronal T1 shown here, was performed to confirm the presence of a lipoma with no adverse features.

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**Fig. 1:** Normal median nerve (M) in transverse section at the level of the hamate and trapezium. The extensor retinaculum (arrows) is seen overlying the median nerve.

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Fig. 2: Transverse (arrows) and longitudinal (arrowheads) of the median nerve in a patient with carpal tunnel syndrome showing enlargement of the nerve and a change in calibre in longitudinal section.

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Fig. 3: Transverse section of a bifid and enlarged median nerve (arrows) in the carpal tunnel on ultrasound and axial fat-sat MRI.

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**Fig. 4:** Persistent median artery of the forearm (arrow) and bifid median nerve (M). The ulnar nerve and artery are seen volar to the extensor retinaculum (U).

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**Fig. 6:** Intraneural lipoma (arrows) of the median nerve which appears more mass-like than fibrolipomatous hamartoma, demonstrated on ultrasound in transverse and longitudinal section and axial T1W and STIR MRI showing identical signal characteristics to fat.

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**Fig. 5:** Fibrolipomatous hamartoma (arrows) of the median nerve seen on ultrasound in transverse section and axial T1W MRI.

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**Fig. 7:** The left median nerve shows markedly thickened epi- and perineurium in the carpal tunnel and through the forearm. The left ulnar nerve also shows marked enlargement. The appearances were in keeping with a chronic demyelinating neuropathy. Normal right median nerve in the forearm.

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**Fig. 8:** 45 year old female patient with a septated ganglion cyst measuring 16 x 9 x 8 mm in the volar aspect of the right wrist, on the radial aspect of the flexor carpi radialis tendon. No internal vascularity was demonstrated.

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**Fig. 9:** 54 year old female patient with chronic ulnar sided right wrist pain and tenderness over the pisiform. Coronal STIR MRI demonstrates a multiloculated ganglion at the piso-ulnar interval extending around the pisiform (arrows). This was then identified on ultrasound and aspirated.

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**Fig. 10:** 41 year old female patient with a ganglion cyst arising from a flexor tendon sheath demonstrating a stalk (arrows).

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**Fig. 11:** Synovitis of the radiocarpal joint demonstrated on greyscale and power Doppler ultrasound in a patient with rheumatoid arthritis.

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Fig. 12: Thickening of the APL and EPB tendon sheath with increased vascularity seen on power Doppler in a patient with De Quervain’s tenosynovitis.

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**Fig. 21:** 58 year old female patient with thrombosis of a saccular pseudoaneurysm (arrows) of the popliteal artery. On ultrasound no colour flow was demonstrable. Axial T1 MRI shows the pseudoaneurysm and marked subcutaneous oedema. (Femur, F).

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**Fig. 22:** Knee joint effusion (arrows) seen at the lateral aspect of the knee joint. (Patella, P; femur, F).

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**Fig. 23:** Ultrasound and axial T2 fat sat MRI showing a Baker's cyst (B) herniating between the medial head of gastrocnemius (G) and semimembranosus (SM) tendon.
Fig. 24: 28 year old male patient with a ganglion cyst (G) found on MRI compressing and displacing the popliteal neurovascular bundle.
**Fig. 25:** Plain film demonstrating a fracture of the fibula neck fracture (arrow). There may be damage to the common peroneal nerve at this site.

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**Fig. 26:** Plain film demonstrating bilateral malleolar fractures (arrows). There may be damage to the posterior tibial nerve posterior to the medial malleolus.

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Fig. 27: Sural nerve neuroma (N) following trauma. The bulb-like dilatation of the nerve is seen at the termination of the nerve. The arrows indicate the normal calibre proximal nerve.

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Fig. 28: 44 year old female patient with focal pain over the lateral aspect of the left thigh. Ultrasound showed a hypoechoic lesion (arrows) with no vascularity. The lesion was of low T1 signal and high T2 signal on MRI and thought to represent a nerve sheath tumour. The lesion was noted to grow over 6 months and was resected confirming the diagnosis of a schwannoma on histology.

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Fig. 29: 29 year old male patient with a lump (arrows) on the anterior aspect of the ankle. The lesion was hypoechoic is moderate vascularity on ultrasound. Sagittal and post-contrast STIR MRI show the well-defined lesion with surrounding oedema and enhancement. The lesion was resected and confirmed to be a giant cell tumour. (Tibia, T; fibula, F).

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Conclusion

Multiple pathologies may be encountered when assessing peripheral nerves, some incidental and others directly resulting in neuropathy. Adequate ultrasound technique and familiarity with the imaging appearances improve confidence in these examinations.