c0018

Neuromuscular Ultrasound of Mononeuropathies

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p0180 One of the most common and useful applications of neuromuscular ultrasound is in the evaluation of mononeuropathies. Although mononeuropathies often result from entrapment of isolated peripheral nerves within specific anatomic fibro-osseous canals, there are a variety of other causes, many of which are structural in nature and can be easily visualized on ultrasound. Usually, a combination of clinical examination supplemented by electrodiagnostic (EDX) studies allows one to conclude that a patient's condition is due to a problem with one nerve. If segmental demyelination can be demonstrated, the lesion can be localized to a specific segment of nerve. *However, even with localization to a specific segment of nerve, it is still not known exactly what is causing the problem at that location*. The differential diagnosis might include entrapment from various structural lesions, including narrowing of anatomical tunnels; fibrous bands and aponeuroses; ganglion and synovial cysts; tendon and tendon sheath abnormalities; abscesses, bone spurs, and increased callus; aneurysms; varices; tumors (both benign and malignant); infiltration (e.g., amyloid); and other causes.

p0185 It is not infrequent that EDX studies can localize the problem to one nerve but then cannot localize it to one specific segment of nerve. This occurs classically in axonal loss lesions. If the sensory nerve action potential of a nerve is abnormal, this denotes a lesion of the peripheral nerve at or distal to the dorsal root ganglion. Otherwise, the only other localization that can be determined is that the lesion is at or proximal to the most proximal muscle that is abnormal on needle electromyography (EMG) (see Chapter 16). For example, consider a patient with numbness of the thumb, index, and middle fingers, along with weakness of thumb abduction. One can correctly deduce that there is likely a problem with the median nerve. If the nerve conduction study shows an axonal loss pattern on median motor and sensory nerve conduction studies (low amplitudes, normal or slightly prolonged distal latencies, and normal or slightly reduced conduction velocities), with other nearby nerves being completely normal, a median neuropathy can be confirmed. If one then finds active denervation on needle EMG in the abductor pollicis brevis, flexor pollicis longus, and flexor carpi radialis, but normal findings in the pronator teres and in muscles supplied by the ulnar and radial nerves, the only localization that can be determined is that there is a median neuropathy at or above the takeoff to the flexor carpi radialis. As emphasized in Chapter 16, one might be tempted to place the lesion between the flexor carpi radialis and the pronator teres. However, this is frequently incorrect as it is common in many neuropathies caused by external compression for some fascicles to be affected while others are spared. It is in this very situation that ultrasound can be especially helpful. Ultrasound has the ability to visualize the major upper extremity nerves from the lower brachial plexus down through the upper extremity. In the lower extremity, the sciatic nerve can be followed from the gluteal fold down to the thigh, where it divides into the common peroneal and tibial nerves. Anteriorly, ultrasound can readily visualize the femoral nerve as it travels in the thigh. Below the knee, the peroneal, tibial, sural, and superficial peroneal nerves can be visualized.

p0190 Indeed, one can make a reasonable argument that ultrasound should be employed as a useful complement to EDX studies in all mononeuropathies, since ultrasound can add structural information that EDX studies cannot determine. For example, one might think that ultrasound would add very little to the most common entrapment neuropathy, median neuropathy at the wrist. However, surprisingly, ultrasound can sometimes add very useful information in this situation. Not only can it confirm the lesion and localization, but it can also demonstrate that the median neuropathy is in some cases due to a structural lesion such as tenosynovitis, synovial hypertrophy, a nerve sheath tumor, a fibrolipomatous hamartoma, or anomalous muscles. It is especially important to perform ultrasound of the median nerve when the symptoms are more prominent in the nondominant hand, which might suggest an unusual structural lesion.

p0195 In addition, ultrasound is particularly helpful when looking at unusual mononeuropathies. Because these conditions are rare, and often controversial syndromes, ultrasound can be of particular importance. Among these syndromes are lesions of the tibial nerve at the tarsal tunnel (i.e., tarsal tunnel syndrome), the posterior interosseous nerve at the Arcade of Frohse (i.e., radial tunnel syndrome), the anterior interosseous nerve, the ulnar nerve at the wrist, and the median nerve in the region of the elbow (i.e., pronator syndrome).

p0200 Lastly, ultrasound is especially important in cases of mononeuropathies associated with trauma. Ultrasound can often be helpful in determining if the nerve is in continuity and, given enough time, can discern whether there is a stump neuroma or neuroma in continuity. In addition, especially when examining a nerve for injury after surgery following trauma, ultrasound can be helpful in assessing the possible etiologies. For example, in some cases, the nerve may be damaged by the original trauma. In other cases, the neuropathy may result from external compression, such as from a cast or, rarely, from surgical hardware.

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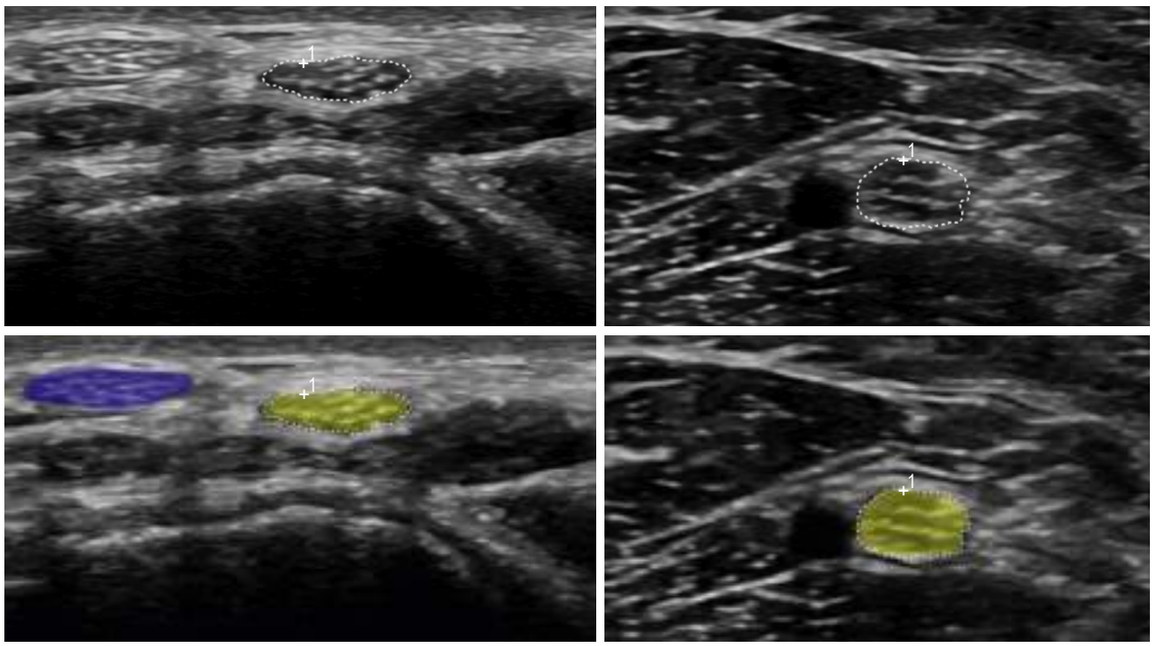

Fig. 18.1 Normal peripheral nerve on short axis ultrasound. *Top Left,* Median nerve at the wrist. *Top Right,* Median nerve in the forearm. *Bottom,* Same images with the median nerves in *yellow* and the tendon to the flexor carpi radialis in *blue*. Peripheral nerves have a "honeycomb" appearance on short axis. The actual fascicles are hypoechoic *(dark)*, whereas the connective tissue (perineurium and epineurium) is hyperechoic *(bright)*. Tendons can sometimes be mistaken for nerves. Note the more compact structure of the tendon compared to the nerve.

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APPEARANCE OF NORMAL NERVE

p0205 Peripheral nerves have a characteristic pattern on ultrasound—on transverse (short axis) sections, they have a "honeycomb" appearance (Fig. 18.1). The actual fascicles are hypoechoic (dark), whereas the connective tissue is hyperechoic (bright). Perineurium surrounds the fascicles and the epineurium surrounds the entire nerve; both are hyperechoic. On longitudinal imaging, the bright epineurium defines the boundary of the nerve with parallel lines running inside, which represent the perineurium (Fig. 18.2). Thus nerves have mixed echogenicity, with the fascicles being dark and the connective tissue being bright. When one applies color or power Doppler ultrasound to nerves, usually no blood flow is seen. The blood vessels that nourish peripheral nerves are usually quite small and beyond the resolution of Doppler. In most nerves, one can make out the normal fascicular architecture. The various fascicles may be slightly different in size.

p0210 Somewhat surprisingly, nerves are actually quite mobile in many areas. This can be easily demonstrated during passive and active motion while viewing the nerve on ultrasound. For instance, one of the most common times this mobility is seen when looking at the median nerve at the wrist while the patient alternatively flexes and extends their fingers. The median nerve normally slides easily among the tendons of the flexor digitorum sublimis.

p0215 Peripheral nerves often run within a neurovascular bundle (Fig. 18.3). This is fortunate but also creates some confusion. It is fortunate because it is fairly easy to identify arteries on ultrasound with color Doppler, and in many cases, the nerve is close by. One classic pattern is to have one artery, one vein, and

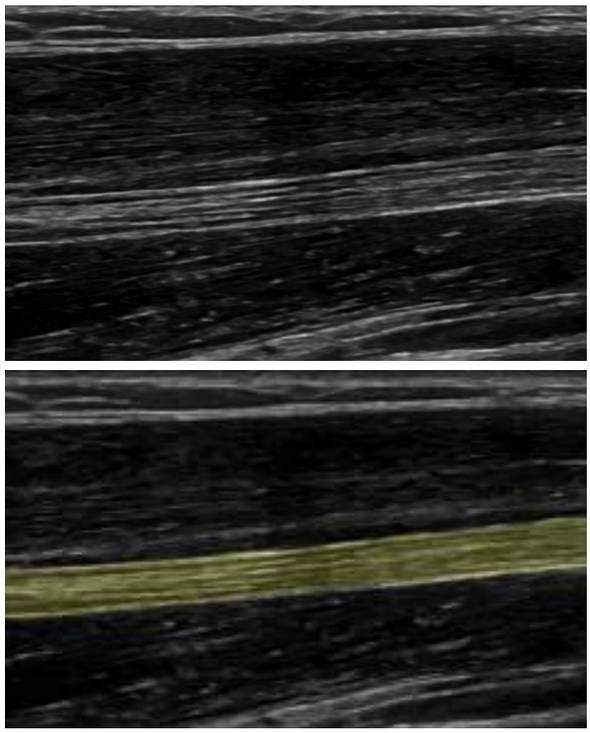

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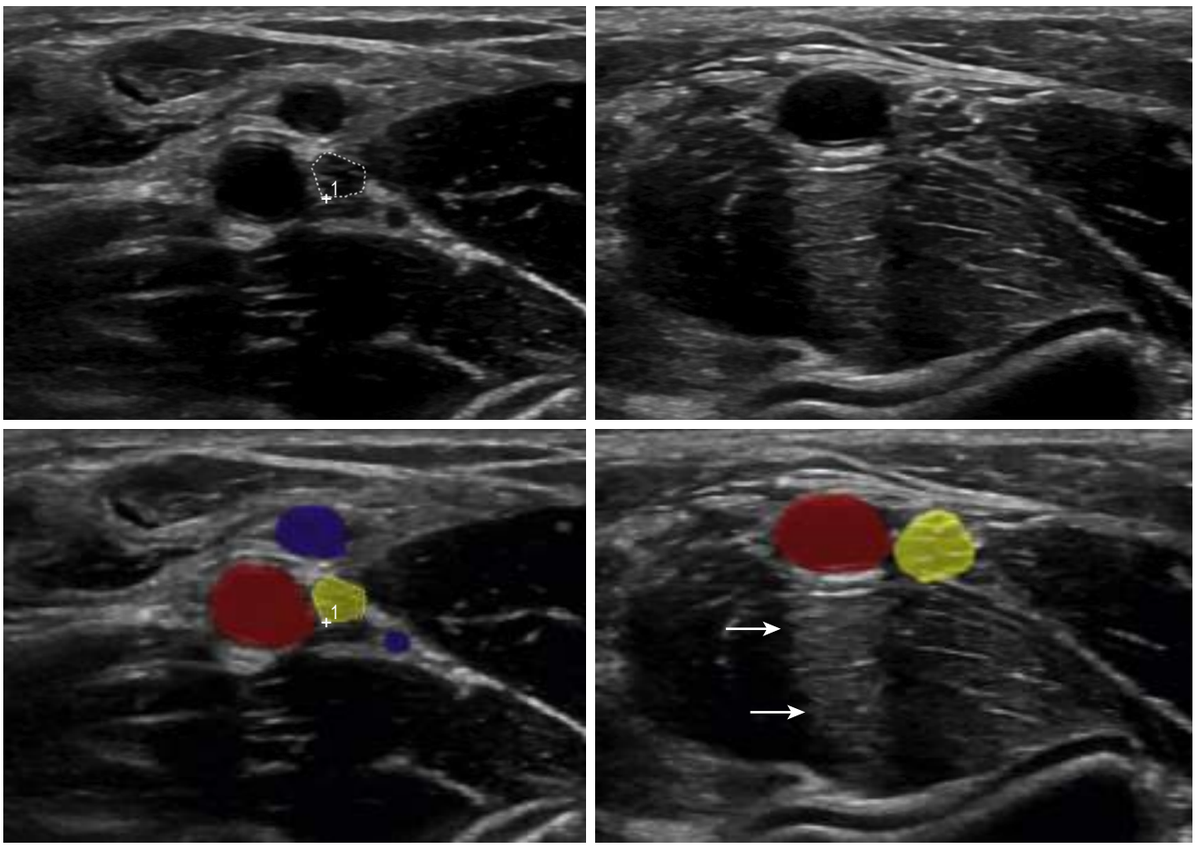
Fig. 18.2 Normal peripheral nerve on long axis ultrasound. *Top,* Median nerve in the forearm. *Bottom,* Same picture with the median nerve colored in *yellow*. On longitudinal imaging, the bright epineurium defines the boundary of the nerve with parallel lines running inside, which represent the perineurium.



f0020 **Fig. 18.3 Neurovascular bundle.** Peripheral nerves often run within a neurovascular bundle containing an artery and vein(s). *Top*, Short axis of the antecubital fossa in two different individuals. *Bottom*, same images but with the median nerve in *yellow*, brachial artery in *red*, and brachial veins in *blue*. Note in the second case, the prominent posterior acoustic enhancement *(arrows)* under the brachial artery, which is a normal finding for fluid filled structures.

one nerve run together in a group. Another common pattern is to have one artery, two veins and one nerve run together in a group. However, it is important not to make the mistake of including blood vessels as part of the nerve when one measures the cross-sectional area (CSA) of the nerve. Veins are fairly easy to identify because slight probe pressure will typically collapse them. In general, arteries are also often easy to identify with the use of color or power Doppler. However, if the artery is small, and/or if the probe is perpendicular to the direction of blood flow, color Doppler may not be positive.

s0015 SCANNING A PERIPHERAL NERVE

p0220 When scanning a peripheral nerve, it is useful to have a standard starting point. By using a standard starting point, one can recognize the usual anatomic pattern of nearby tendons, muscles, blood vessels, and bones, as well as the nerve of interest. For instance, a standard starting point for the median nerve is the short axis view at the distal volar wrist crease. Just radial to the median nerve is the tendon of the flexor carpi radialis; further radial are the radial artery and veins; posteriorly are the tendons of the flexor digitorum sublimis and profundus; and to the ulnar side is the ulnar artery (Fig. 18.4). Good starting locations for other common nerves include (1) the distal volar wrist crease on the ulnar side of the wrist for the ulnar nerve; (2) between the brachioradialis and brachialis muscles at the elbow for the radial nerve; (3) the lateral apex of the popliteal fossa for the sciatic nerve, where it bifurcates into the tibial and common peroneal nerves; (4) in the groove between the medial and lateral gastrocnemius muscles for the sural nerve; and (5) in the groove between the extensor digitorum longus and peroneus longus muscles for the superficial peroneal sensory nerve.

p0225 Once the nerve of interest is found, it can then be traced proximally and/or distally. It is often most helpful to move the probe fairly quickly as one follows the nerve, as the nerve becomes more conspicuous with motion. If one moves the probe too slowly, one can easily lose the nerve within a sea of other echoes. The ability to follow a nerve throughout its course is one of the major advantages of ultrasound in the evaluation of mononeuropathies.

Measurements

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p0230 There are many measurements and other observations that are useful to make when assessing peripheral nerves (Table 18.1). The most important measurement is the size of the nerve,

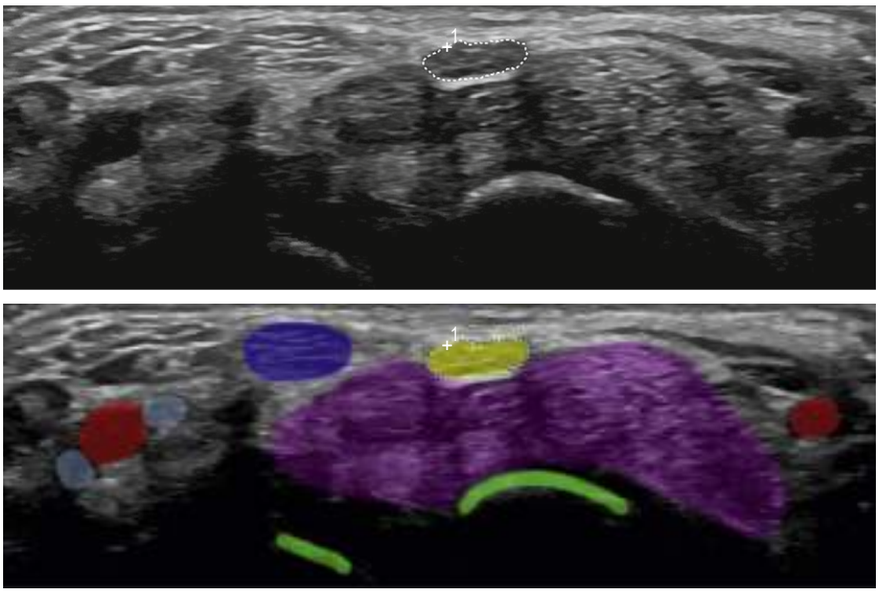

Fig. 18.4 Starting point. When assessing a nerve on ultrasound, it is useful to begin at a standard starting point where one is familiar with the pattern of nearby tendons, arteries, and bone. *Top,* Short axis view of the volar distal wrist crease, with the median nerve outlined. *Bottom,* Same image with the median nerve in *yellow*; the tendon of the flexor carpi radialis in *blue*; further left, the radial artery and veins in *red* and *light blue*; posteriorly, the tendons of the flexor digitorum superficialis and profundus in *purple*; on the right side, the ulnar artery in *red*; and the underlying carpal bones in *green*.

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Table 18.1 Measurement and Other Assessments of Peripheral Nerves on Ultrasound.

Size
Cross-sectional area
AP diameter (small nerves)
Flattening ratio (median nerve)
Ratios of one nerve segment to another
Wrist-forearm ratio (median nerve)
Swelling ratios (ulnar and radial nerves)
Echogenicity
Fascicular Structure
Vascularity
Mobility (median nerve at the wrist and ulnar nerve at the elbow)
Nerve continuity

AP, Anterior-posterior.

specifically the CSA on transverse (short axis) imaging. In general, when nerves are entrapped, they tend to swell proximal to the site of entrapment, causing them to enlarge (Fig. 18.5). There are many valid published normal values for the CSAs of most of the major nerves (Table 18.2). However, recall from Chapter 9 on statistics and the interpretation of test results, all cutoff values result in a small but significant number of false-positives and false-negatives. Having said this, there are clearly cases where the CSA of a nerve is normal and other cases where it is unequivocally abnormal. For example, if the CSA of the ulnar nerve at the wrist is 6 mm^2, it is very clear that the size is normal. Conversely, if the CSA is 25 mm^2 at the wrist, it is unequivocally enlarged. However, there are many borderline cases. For example, if a normal ulnar CSA at the wrist is up to 10 mm^2, one should hesitate to call it abnormal if it is 11 mm^2 at the wrist, with no other findings. From a realistic point of view, 9 mm^2, 10 mm^2, and 11 mm^2 are the same number. Just

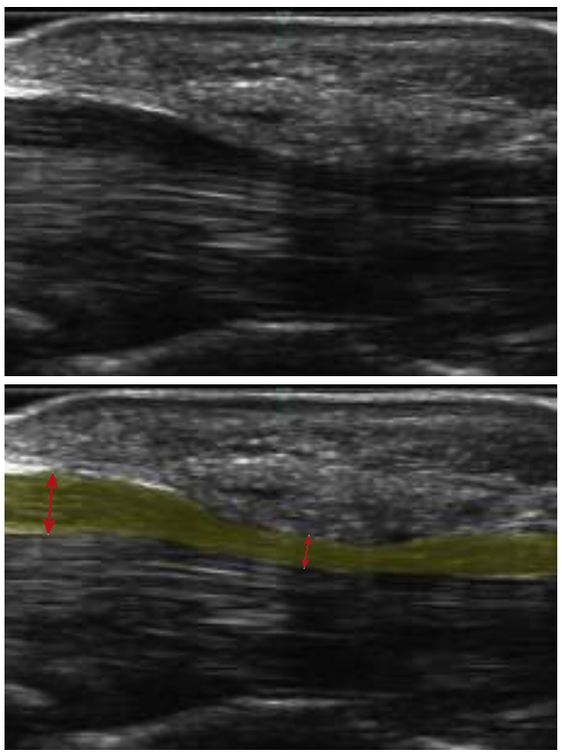

Fig. 18.5 Peripheral nerve swelling. When nerves are entrapped, they tend to swell proximal to the site of entrapment. *Top,* Long axis view of the median nerve at the wrist in a patient with carpal tunnel syndrome. *Bottom,* Same image with the median nerve in *yellow*. Note the swelling of the nerve proximal to the area of narrowing, which is the location of the entrapment. *Red arrow* on the left denotes the width of the nerve at the location where the nerve is swollen, and *red arrow* on the right where the nerve is entrapped.

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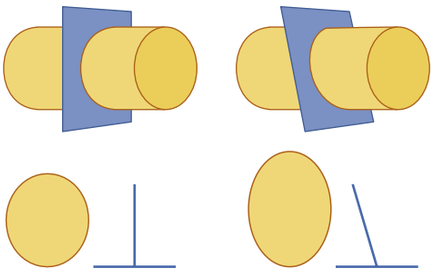
Table 18.2 Nerve Cross-sectional Area Reference Ranges.

Nerve	Site	Upper Limit of Normal (mm^2)	Side-to-Side Upper Limit Difference (mm^2)
Median	Wrist	13.0	3.4
	Forearm	10.7	2.6
	Pronator teres	11.0	2.8
	Antecubital fossa	13.2	4.3
	Mid-arm	13.1	3.0
	Axilla	9.7	3.5
Ulnar	Wrist	8.1	2.6
	Forearm	8.3	2.0
	Distal elbow	8.6	2.0
	Elbow	8.8	2.2
	Proximal below	9.3	1.8
	Mid-arm	8.3	1.6
	Axilla	8.6	1.8
Radial	Antecubital fossa	14.1	5.0
	Spiral groove	13.3	4.5
Musculocutaneous	Axilla	11.9	4.2
Vagus	Carotid bifurcation	9.0	3.1
Brachial plexus	Trunk	11.1	4.5
Sciatic	Distal thigh	80.6	18.9
Peroneal	Popliteal fossa	20.9	9.5
	Fibular head	17.8	4.9
Tibial	Popliteal; fossa	55.9	15.7
	Proximal calf	39.9	10.8
	Ankle	22.3	5.7
Sural	Distal calf	8.9	2.6

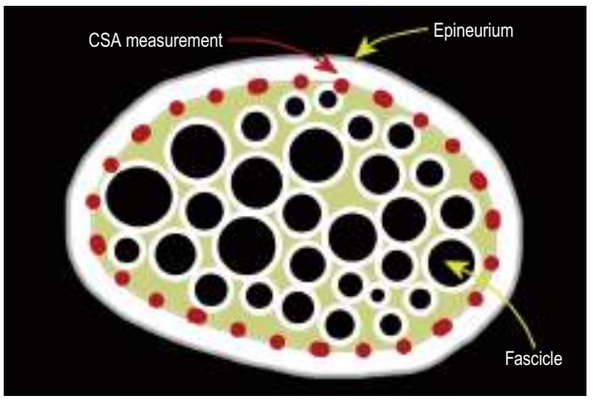
Note: Reference values are based on mean + 2 standard deviations. Nerve area may increase with increased body mass index.
Sources: (1) Cartwright MS, Shin HW, Passmore LV, Walker FO. Ultrasonographic reference values for assessing the normal median nerve in adults. *J Neuroimaging*. 2008;19(1):47–51. (2) Cartwright MS, Shin HW, Passmore LV, Walker FO. Ultrasonographic findings of the normal ulnar nerve in adults. *Arch Phys Med Rehabil*. 2007;88(3):394–396. (3) Cartwright MS, Passmore LV, Yoon JS, Brown ME, Caress JB, Walker FO. Cross-sectional area reference values for nerve ultrasonography. *Muscle Nerve*. 2008;37(5):566–571.

as with using normal values for nerve conduction studies, the authors recommend that the reader not be overly rigid about specific cutoff values for nerve size.

p0235 When measuring the CSA, one must pay attention to a few important points. First, the ultrasound probe must be perpendicular to the nerve (Fig. 18.6). If it is not, it will visualize the nerve at an angle, which artificially increases the measured size of the nerve. The way to avoid this error is to first identify the nerve and then gently tilt the probe back and forth along the probe's long axis (rocking the probe) to the point where the nerve appears to be the smallest. At that point, it is fairly certain that the ultrasound beam is perpendicular to the nerve. One should also assess anisotropy (see Chapter 17) to make sure the ultrasound beam is perpendicular to the nerve. One can assess the anisotropy of the nerve itself or the anisotropy of nearby parallel tendons. When there is marked anisotropy, the image will



f0035 **Fig. 18.6 Measuring cross-sectional area (CSA).** CSA is a sensitive measure of nerve dysfunction. Note, when one measures the CSA, it is essential that the ultrasound probe be perpendicular to the nerve *(left)*. If not, the beam will slice through the nerve at an angle that will artificially increase the measured size of the nerve *(right)*.



f0040 **Fig. 18.7 Manual tracing of the cross-sectional area (CSA).** Cartoon of a nerve in short axis. The thick white border is the epineurium. The *dark circles* are the fascicles. The *thin white borders* around the fascicles are the perineurium. When one traces the nerve to determine its CSA, it is important to place the trace just inside the hyperechoic border of the epineurium *(red dotted line)*.

be darker, indicating that the probe is not perpendicular to the nerve. When anisotropy is minimized, the image will be brighter, indicating that the ultrasound beam is perpendicular to the nerve. The next step is to make the actual measurement. There are two ways to measure the CSA: this can be done electronically by either fitting an elliptical pattern over the nerve or manually tracing the outline of the nerve. The expert consensus is that manually tracing the outline of the nerve is more accurate. As one gets more practice with neuromuscular ultrasound studies, one will see that nerves can take on a variety of shapes and hence the reason that the tracing method is the more accurate. However, for the tracing method, it is important to trace just inside the hyperechoic border of the epineurium (Fig. 18.7). This is key and is extremely important for reliability and for using published normal values.

p0240 In addition to the CSA, other measurements of size can be done. The anterior-posterior (AP) diameter can be measured on short axis imaging. This is most helpful for measuring very small nerves for which accurate measurement of the CSA is difficult or impossible. For instance, the posterior interosseous nerve as it runs between the deep and superficial heads of the

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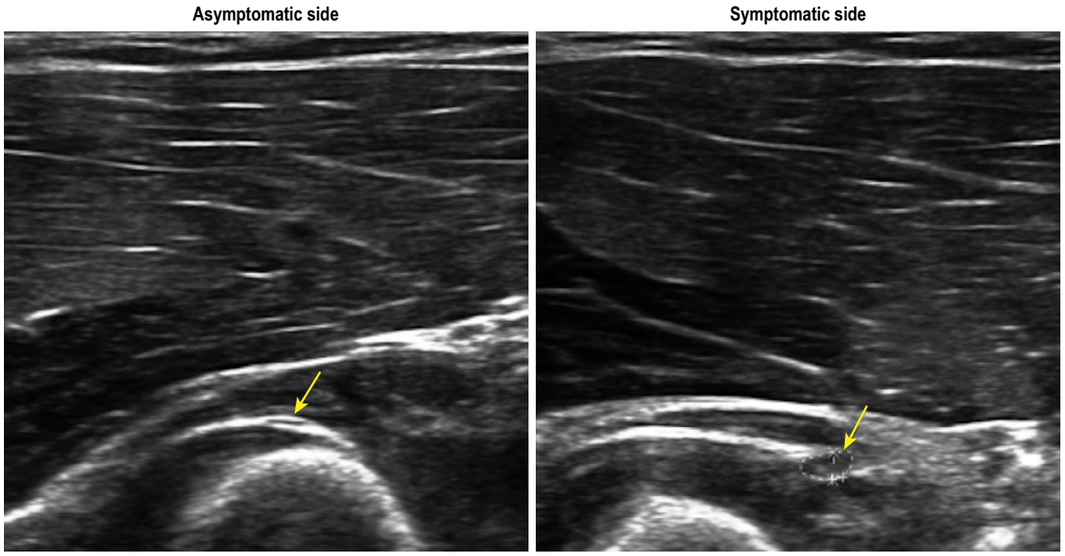

Fig. 18.8 Measuring the anterior-posterior (AP) diameter. Axial view of the posterior interosseous nerve *(yellow arrow)* running between the two heads of the supinator muscle. *Left,* Normal side. *Right,* Abnormal side with an enlarged nerve. The AP diameter is often helpful for very small nerves for which the actual measurement of the cross-sectional area (CSA) is difficult or impossible. In the example here, the CSA of the posterior interosseous nerve on the normal side would be very difficult to measure; thus, the AP diameter would be easier to use.

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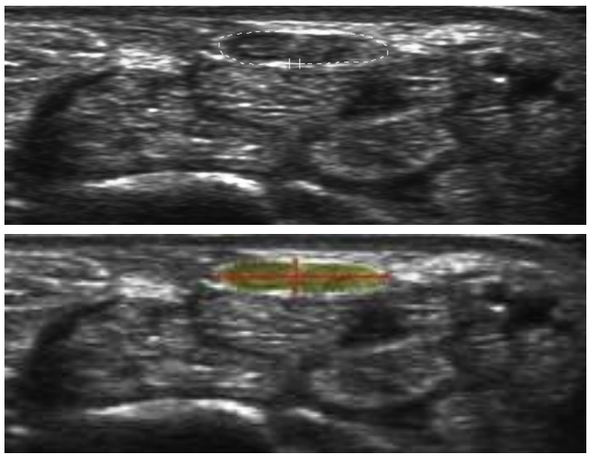

Fig. 18.9 Flattening ratio. The "flattening ratio" is calculated by comparing the width of a nerve with its height on short axis imaging. *Top,* Median nerve on short axis imaging in a patient with carpal tunnel syndrome. *Bottom,* Same image with the nerve in *yellow* and the width and height measured in *red*. A normal median flattening ratio is <3:1. In this case, it was 5:1.

supinator muscle is normally quite small (Fig. 18.8). In this case, taking the AP diameter measurement using a simple electronic caliper can be more easily done than the CSA measurement. Another useful measurement, especially in median neuropathy at the wrist, is the "flattening ratio." This is the ratio of the nerve width to the height on short axis imaging (Fig. 18.9). To calculate the flattening ratio, two lines are drawn, measuring the maximum width and the maximum height. For example, a normal flattening ratio for the median nerve at the wrist is 3:1 or less. Another very helpful measurement for some mononeuropathies is the "swelling ratio," which measures the ratio of the CSA at one location compared with another location on the same peripheral nerve. This measurement is somewhat akin to nerve conduction studies wherein the conduction velocity at one segment of a nerve is compared with the conduction velocity at another segment of the same nerve, either proximally or distally. Since swelling typically occurs just proximal to the site of entrapment, the CSA of the nerve just proximal to the site of entrapment can be compared with the CSA of the same nerve either proximally or distally. This has been studied best in the median nerve using the "wrist-to-forearm ratio" (WFR), wherein the CSA of the median nerve at the wrist is compared with the CSA in the forearm. Ratios greater than 1.4 are considered abnormal. Likewise, ratio measures for the ulnar nerve are commonly used where the maximal CSA at the elbow is compared with the maximal CSA in the forearm and the maximal CSA in the mid-arm. Ratios greater than 1.5 are considered abnormal.

p0245 The next important parameter to assess is echogenicity (Fig. 18.10). When nerves swell adjacent to an entrapment, they also become hypoechoic. The reason that these changes occur is not clear, but may be due to intraneural edema or impaired axoplasmic flow. It is very common for nerves to become enlarged and dark just proximal to the entrapment point. Although assessment of echogenicity is subjective, it is a skill learned over time and an important assessment to make to help determine if the nerve is normal or not. Along with echogenicity is the assessment of fascicular structure (Fig. 18.10). This is also subjective, a skill learned over time, and another important measure. Commonly, when a nerve is entrapped, there is also loss of the normal fascicular architecture (Fig. 18.10). All fascicles become enlarged and hypoechoic. When this occurs, one can no longer discern one fascicle from another. Sometimes, one fascicle within a nerve becomes markedly enlarged (Fig. 18.11). It is very

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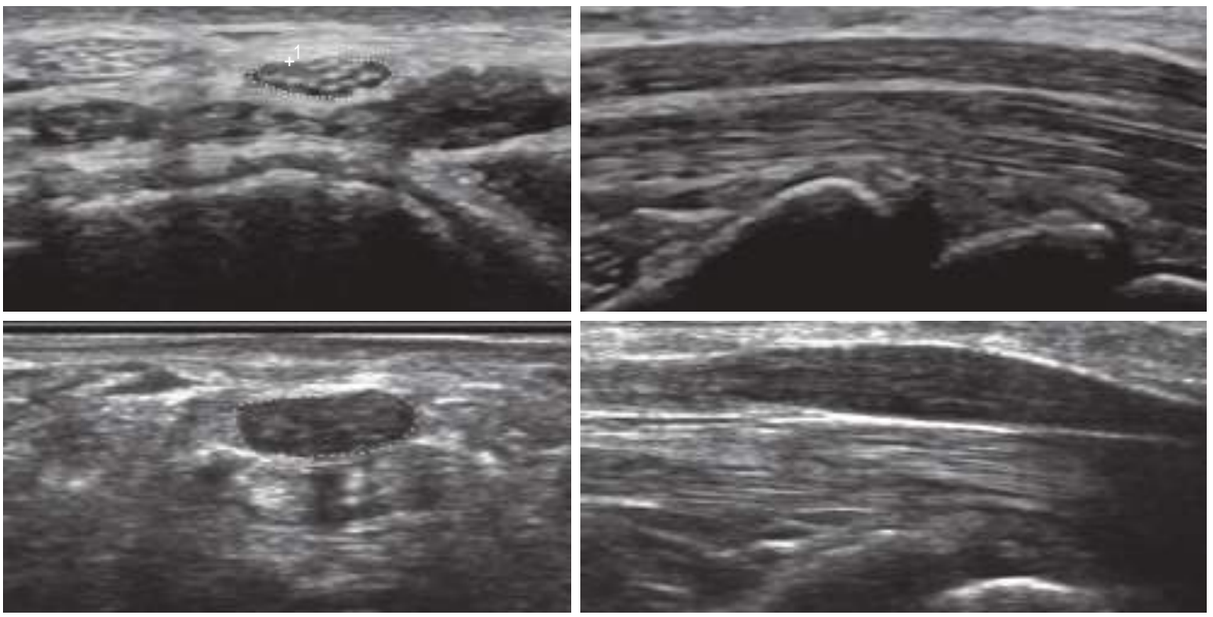

Fig. 18.10 Echogenicity, cross-sectional area, and fascicular structure. *Left*, Median nerve in short axis at the wrist. *Right*, Median nerve in long axis at the wrist. *Top*, Normal patient. *Bottom*, Patient with carpal tunnel syndrome. Note in the bottom pictures that the nerve is enlarged and hypoechoic *(darker)* and that the fascicular architecture has been lost.

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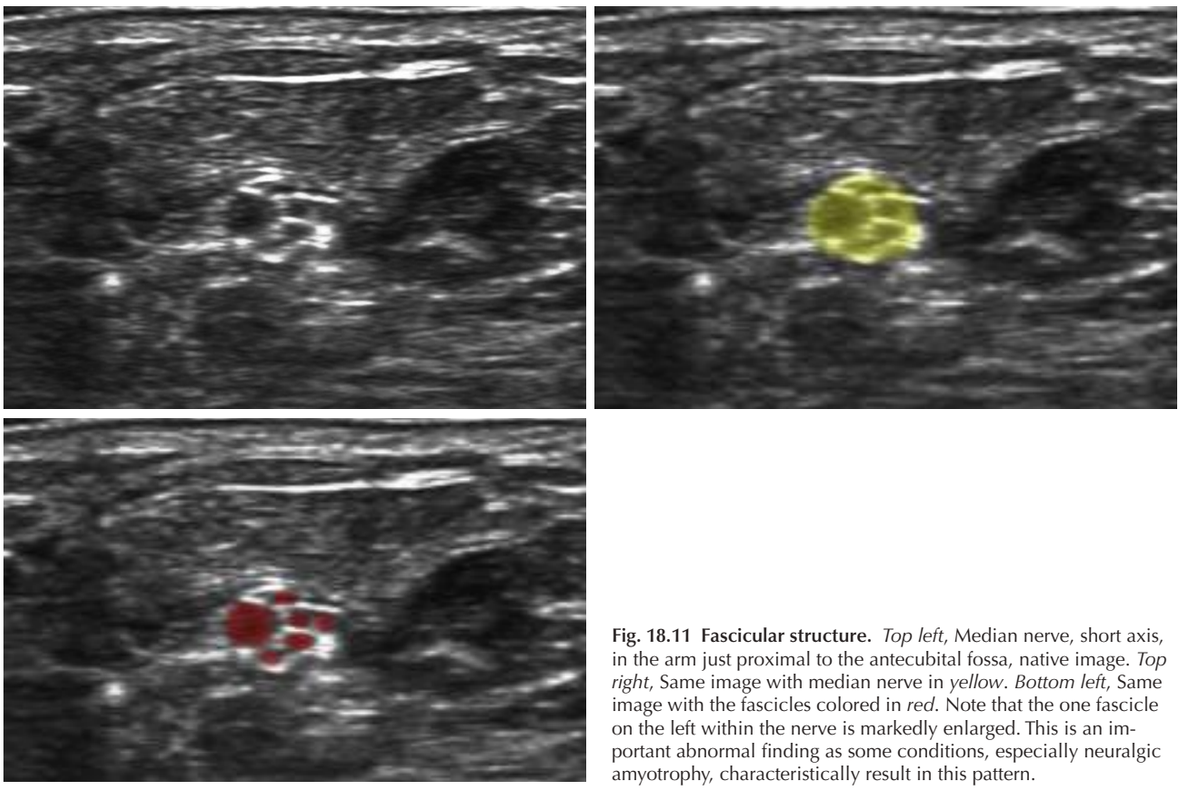


Fig. 18.11 Fascicular structure. *Top left*, Median nerve, short axis, in the arm just proximal to the antecubital fossa, native image. *Top right*, Same image with median nerve in *yellow*. *Bottom left*, Same image with the fascicles colored in *red*. Note that the one fascicle on the left within the nerve is markedly enlarged. This is an important abnormal finding as some conditions, especially neuralgic amyotrophy, characteristically result in this pattern.

important to be able to recognize this abnormal finding, as this pattern is highly characteristic of certain conditions, especially neuralgic amyotrophy (see Chapter 33).

p0250 The last measures commonly made on a peripheral nerve are vascularity and mobility. As noted previously, most nerves are not vascular on Doppler ultrasound. Increased vascularity of nerve is associated most frequently with inflammation, infection, or neoplasia. For instance, in the rare situation where a patient has a malignant nerve sheath tumor, the vascularity may be increased. If there is infection of tissues near or surrounding the nerve, the vascularity is commonly increased. There are also reports of increased vascularity in common entrapment neuropathies. However, in the authors' experience, this is a rare. Mobility of a nerve can also be an important assessment in some neuropathies, especially the median nerve at the wrist and the ulnar nerve at the elbow. One of the significant advantages of neuromuscular ultrasound is its ability to examine structures during movement. In patients with median neuropathy at the wrist, the mobility of the nerve is often diminished with repetitive flexion and extension of the fingers, in contrast to the normal mobility of the median nerve at the wrist in individuals without carpal tunnel syndrome. Obviously, this assessment depends on the patient's ability to cooperate and physically move the fingers. Regarding ulnar neuropathy at the elbow, abnormal mobility of the ulnar nerve can sometimes aid in the diagnosis. In some individuals, flexion of the elbow is associated with subluxation or frank dislocation of the ulnar nerve out of the groove, which can readily be demonstrated on ultrasound (see Chapter 22).

p0255 In cases of trauma, assessment of nerve continuity is key. If there is an acute nerve transection, one can often see the discontinuity and retraction of the two nerve endings. If the discontinuity is chronic, because of the physical transection of the nerve along with hemorrhage and fibrous tissue formation, it is very unlikely that the nerve can successfully grow back. In this case, the nerve will classically end in a hypoechoic ball of tangled nerve fibers, known as a stump neuroma (Fig. 18.12).

p0260 In summary, for every peripheral nerve, one should assess its size, shape, echogenicity, fascicular architecture, and vascularity. In some nerves, the mobility should also be assessed.

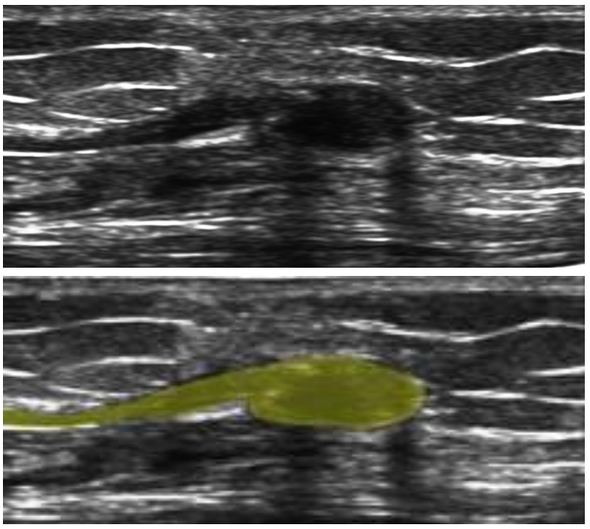
s0025 IMPORTANT STRUCTURAL ABNORMALITIES TO RECOGNIZE

p0265 One of the major advantages of neuromuscular ultrasound in assessing mononeuropathies—beyond evaluating size, shape, echogenicity, fascicular structure, and vascularity—is its ability to look for structural abnormalities that can be the pathologic cause of the mononeuropathy. The ultrasonographer must be able to recognize the most common of these structural abnormalities (Table 18.3).

s0030 Ganglion Cysts

p0270 Cysts may be ganglion cysts or synovial cysts. The walls of ganglion cysts are very thin. Synovial cysts are lined with synovial tissue. From an ultrasound point of view, it is difficult to differentiate between the two. However, from a clinical point of view, whether a cyst is a ganglion cyst or a synovial cyst makes little difference.

p0275 Ganglion cysts are fairly common (Fig. 18.13). They typically arise from a nearby joint or tendon sheath and are filled with synovial fluid. Among the most common sites for ganglion cysts are the dorsal surface of the wrist and the medial knee between the semimembranosus and medial gastrocnemius muscles, the latter known as a Baker's cyst. These particular



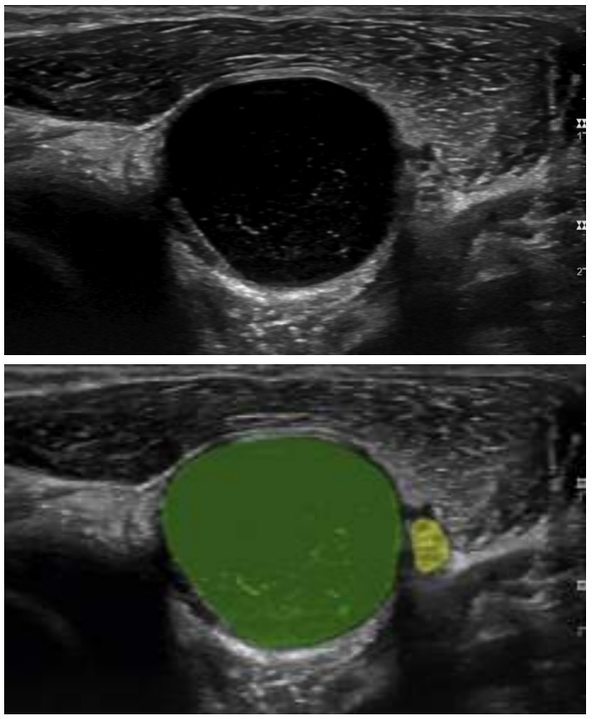
f0065 **Fig. 18.12 Stump neuroma.** *Top,* Superficial radial nerve in the long axis in a patient with a laceration injury to the lateral forearm. *Bottom,* Same image with the nerve in *yellow*. When a nerve is transected, it will classically end in a hypoechoic spherical structure, known as a stump neuroma. This occurs because during attempted nerve regrowth, the nerve grows into a disorganized ball of nerve fibers, the stump neuroma.

t0020 **Table 18.3** Important Structural Lesions to Identify on Ultrasound.

Neuromas (stump neuromas and neuromas in-continuity)
Cysts
Extraneural (ganglion and synovial)
Intraneural ganglion (especially the peroneal nerve)
Bone fragments and callus
Tenosynovitis
Synovial hypertrophy
Tumors
Extrinsic
Benign (e.g., lipoma)
Malignant
Intrinsic
Benign (e.g., neurofibroma, schwannoma)
Malignant (e.g., lymphoma, malignant schwannoma, neurofibrosarcoma)
Scar/fibrous tissue
Hemorrhage and Hematomas
Aneurysms and Pseudoaneurysms
Varix and varices
Anatomic anomalies
Muscles (e.g., reversed palmaris longus; accessory abductor digiti minimi)
Arteries (e.g., persistent median artery)
Nerve (e.g., bifid median nerve)

locations typically do not interfere with peripheral nerves. However, ganglion cysts can occur near other joints and tendons, where they can compress nearby peripheral nerves.

p0280 Ganglion cysts are typically recognized as simple cysts that are usually oval or round in shape. They are negative on Doppler and anechoic and usually have prominent posterior acoustic enhancement. If one looks closely, one can often see a small connection between the cyst and a nearby joint or tendon sheath. These cysts are usually not compressible. The fluid inside is typically anechoic but at times may have punctate bright echoes within the fluid. If they are large enough and near a nerve, they can compress the nerve. Many times, ganglion cysts are multilobular. In this case, they are still anechoic or hypoechoic with posterior acoustic enhancement. Note that if the cyst is just adjacent to bone, it will be difficult to appreciate any posterior acoustic enhancement, as there is already a bright echo originating from the bone.



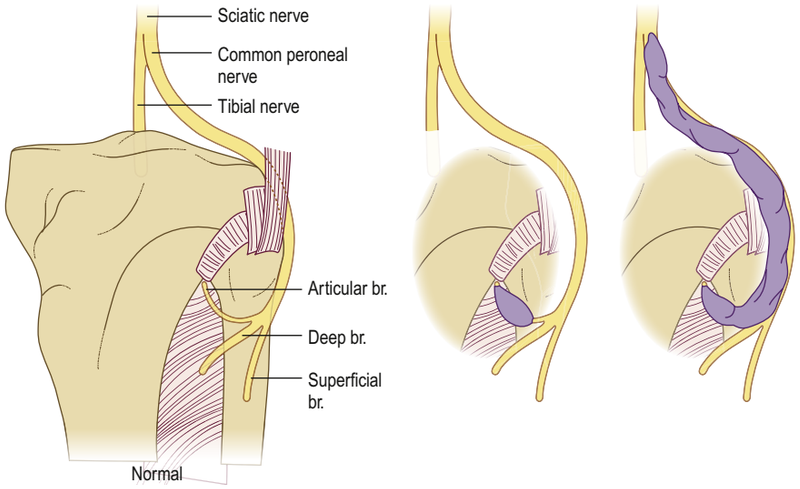
f0070 **Fig. 18.13 Ganglion cyst.** *Top,* Short axis view of the radial nerve just proximal to the elbow, with a large ganglion cyst beside it. *Bottom,* Same image with the radial nerve in *yellow* and a large ganglion cyst in *green*. Ganglion cysts are recognized as hypoechoic or anechoic oval or round structures, sometimes simple and other times multilobular. They have prominent posterior acoustic enhancement. If one looks closely, there is often a small connection between the cyst and a nearby joint or tendon sheath.

Intraneural Ganglia s0035

p0285 Somewhat surprisingly, excessive synovial fluid can sometimes dissect into a nerve and form an intraneural ganglion. This is most often described in cases of peroneal neuropathy at the fibular neck, where there is no obvious clinical etiology (i.e., no history of compression, weight loss, leg crossing, persistent squatting, postsurgical, etc.). In these cases, it is believed that a tear occurs in the articular branch of the common peroneal nerve that supplies the proximal tibiofibular joint. This tear results in synovial fluid entering into the articular branch and travelling retrograde up the articular branch into the deep and common peroneal nerves (Fig. 18.14). The fluid may continue to the sciatic nerve and then sometimes come back down the tibial nerve. With an intraneural ganglion, the nerve becomes hypoechoic and increases in size dramatically (Fig. 18.15). The nerve is often bulbous with a scalloped appearance. Upon close inspection on transverse imaging, the normal nerve fibers within the nerve can sometimes be seen pushed off to one side of the nerve. Intraneural ganglia are important to recognize as they are amenable to surgical decompression and potentially full recovery.

Bone Fragments and Callus s0040

p0290 When trauma involves fracture of bone, it is not uncommon to find small spicules of bone that project from the fracture site. If these spicules push on tissue near a nerve or actually impale a nerve, they can result in a



f0075 **Fig. 18.14 Intraneural ganglion of the peroneal nerve.** *Left,* The common peroneal nerve divides into superficial and deep peroneal branches as well as an articular branch that supplies the proximal tibiofibular joint. *Middle,* If a tear occurs in the articular nerve branch, synovial fluid can enter that branch and travel retrograde in the branch into the deep and common peroneal nerves *(right)*. (Adapted with permission from Spinner RJ, Amrami KK. What's new in the management of benign peripheral nerve lesions? *Neurosurg Clin North Am.* 2008;19(4):517–531.)

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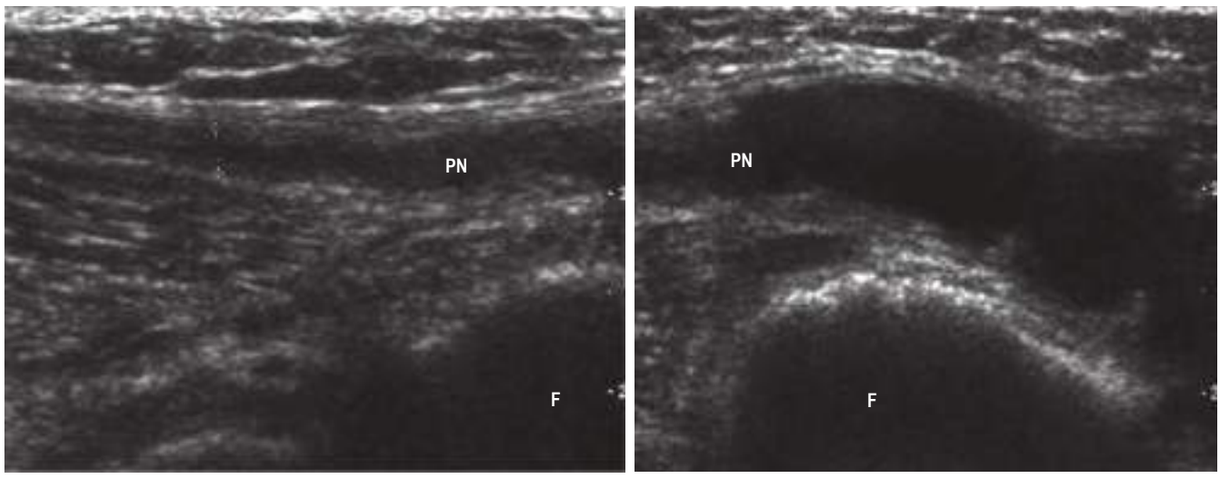

Fig. 18.15 Ultrasound of an intraneural ganglion of the peroneal nerve (PN). Long axis view of the PN at the knee near the fibula *(F)*. *Left*, Normal peroneal nerve. *Right*, Peroneal nerve with an intraneural ganglion. Note that the nerve is enlarged, hypoechoic, and bulbous with a scalloped appearance. (With permission from Visser LH. High-resolution sonography of the common peroneal nerve: detection of intraneural ganglia. *Neurology*. 2006;67:1473–1475.)

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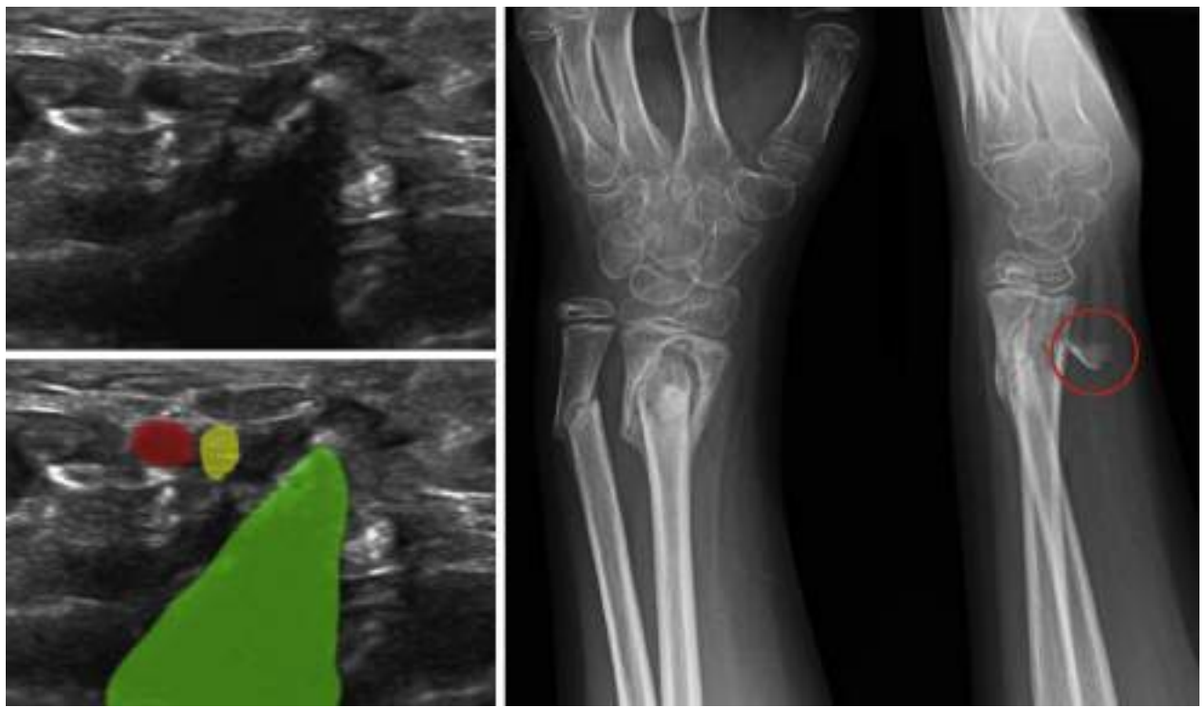
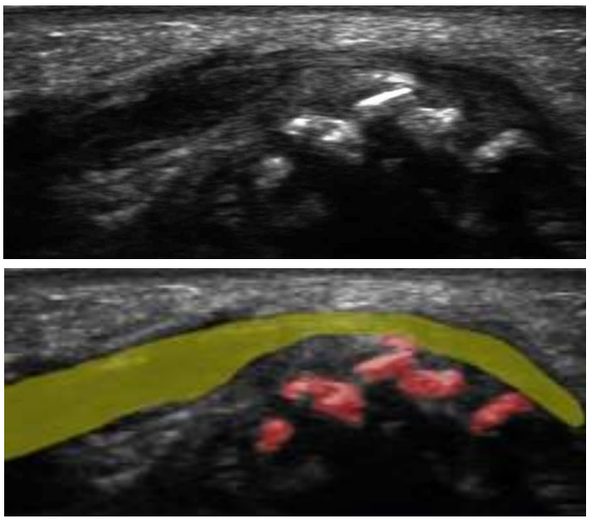


Fig. 18.16 Bone spicule. *Right*, Plain X-rays of the distal forearm showing a significant fracture of the distal radius and ulna. On lateral imaging, bone is seen projecting toward the surface *(red circle)*. *Left Top*, Short axis imaging of the distal ulnar forearm. *Left Bottom*, Same image with the ulnar artery in *red*, ulnar nerve in *yellow*, and bone spur in *green*. Ultrasound has the advantage of being able to demonstrate the proximity of bone fragments to a nerve. In this case, when the ulnar nerve was scanned distally and proximally, it was apparent that the bone spicule was displacing the ulnar nerve and artery laterally.

mononeuropathy (Fig. 18.16). These small spicules are typically seen quite well on plain X-rays. However, plain X-rays are not able to discern whether or not the spicules actually affect the nerve. In this situation, ultrasound can be very helpful. As one scans the course of a nerve, one can make out the unmistakable image of a bone fragment, which is quite hyperechoic with marked posterior acoustic shadowing (Fig. 18.16). If that piece of bone displaces the nerve, dysfunction of the nerve may result.

Likewise, if enough time has elapsed after a fracture for bone repair to occur, this can result in excessive callus formation (Fig. 18.17). As callus is bone, it is recognized on ultrasound as hyperechoic, irregular, and often protuberant in areas where the bone echo should be smooth

p0295



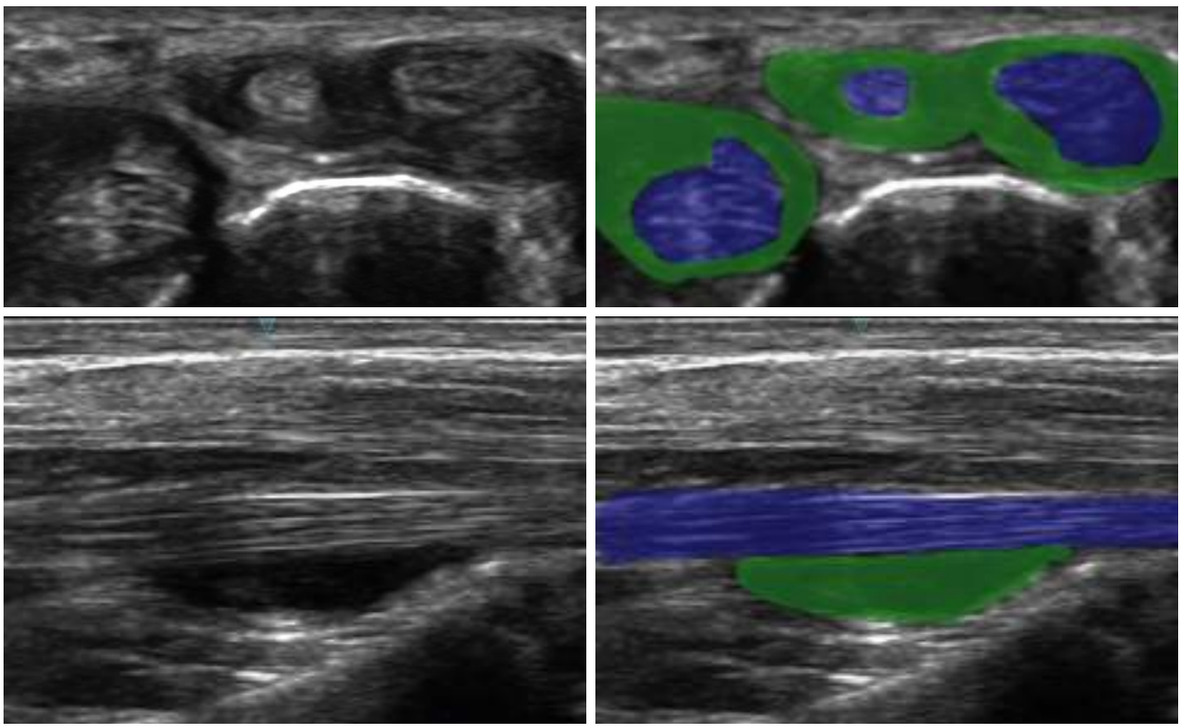
f0090

Fig. 18.17 Bony callus and neuropathy. *Top*, Long axis view of the ulnar nerve at the groove. *Bottom*, Same image with the ulnar nerve in *yellow* and bony callus in *red*. Excessive callus can sometimes occur as a delayed effect of a fracture. If the callus is near a nerve, it can erode into the nerve, especially if the nerve is in a location where it normally slides over the bone. This most classically occurs with the ulnar nerve at the elbow. Note the difference in size of the ulnar nerve proximally and as it travels over the bone.

and bright. If the callus is near a nerve, it can erode into the nerve, especially if the nerve is in a location where it normally slides over the bone. This most classically occurs with the ulnar nerve at the elbow. Indeed, one the most common causes of ulnar neuropathy at the elbow is so-called *"tardy ulnar palsy."* Tardy means delayed. This typically occurs when a patient breaks their elbow, often as a child, and years later develops a progressive ulnar neuropathy, as the ulnar nerve lies adjacent to hypertrophic callus at the elbow. However, since ultrasound cannot pass through bone, any pathology underneath a bone cannot be visualized.

Tenosynovitis and Synovial Hypertrophy s0045

Most tendons are surrounded by a tendon sheath lined by synovium, which creates synovial fluid. The synovial fluid reduces friction and increases the ability of the tendon to glide smoothly. If the tendon is injured or starts to degenerate, the tendon sheath can become inflamed. This inflammation, known as tenosynovitis, leads to pain, swelling, and stiffness. Rarely, the tendon sheath becomes infected. Tenosynovitis leads to increased fluid (which is hypoechoic) within the tendon sheath, thickening of the tendon sheath, and in some cases increased vascularity on Doppler (Fig. 18.18). Tenosynovitis p0300



f0095

Fig. 18.18 Tenosynovitis. *Top*, Short axis imaging of the flexor tendons at the wrist. *Bottom*, Long axis imaging of the flexor tendons at the wrist. *Left*, Native images. *Right*, Same images with the tendons in *blue* and excessive synovial fluid in *green*. With injury and degeneration of the tendon, the tendon sheath can become inflamed. Tenosynovitis is recognized by increased fluid (which is hypoechoic) within the tendon sheath, thickening of the sheath, and, in some cases, increased vascularity on Doppler. Tenosynovitis near a nerve can result in increased pressure on the nerve. Tenosynovitis is important to recognize as additional treatment may be necessary, and its presence may suggest an underlying rheumatologic, degenerative, or infectious condition.

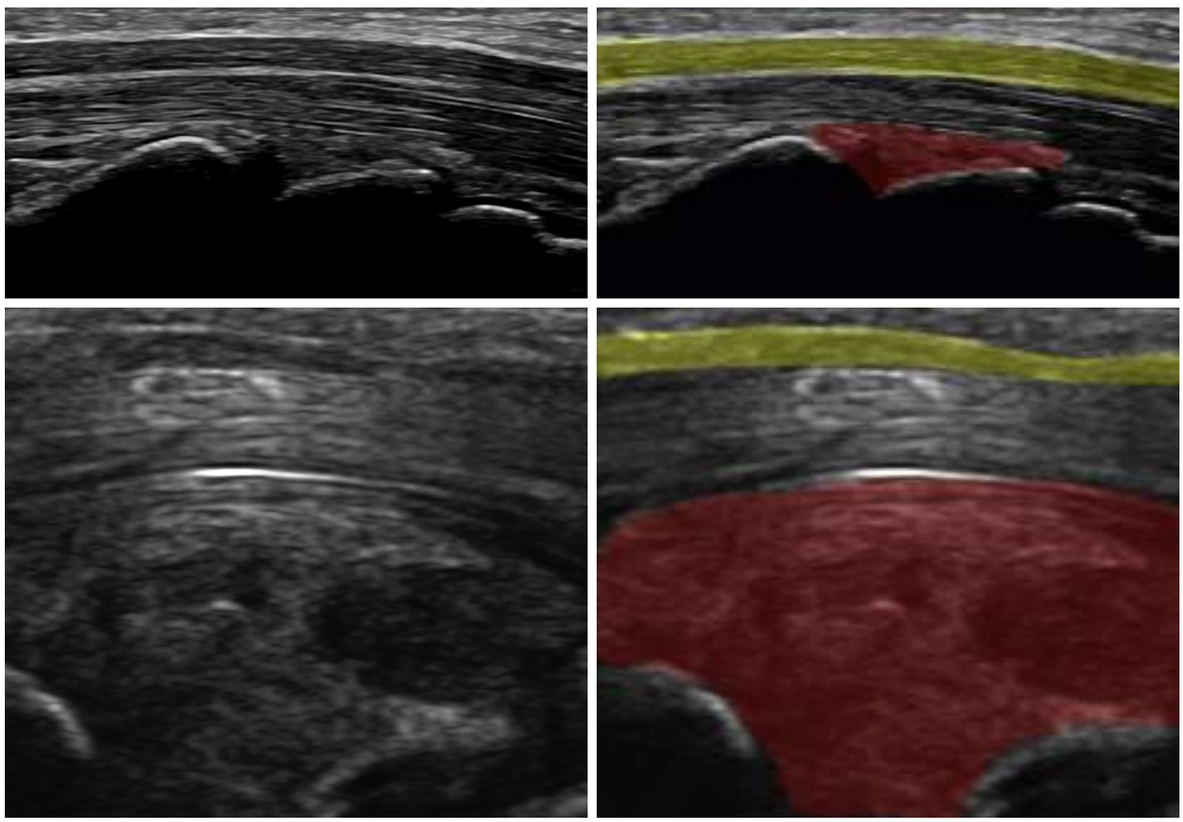
near a nerve can result in increased pressure on the nerve. This is classically seen in some cases of carpal tunnel syndrome. Tenosynovitis is important to recognize as additional treatment may be necessary, and its presence may suggest an underlying rheumatologic, degenerative, or infectious condition.

p0305 Synovial tissue also surrounds most joints and tendon sheaths. Normal synovium is thin and delicate and typically not seen on ultrasound. However, with degenerative and inflammatory disorders, the synovium may become hypertrophied (Fig. 18.19). If there is a large amount of hypertrophy, it may deform the joint capsule, resulting in a bulging outward from the joint. Synovial hypertrophy may be hypoechoic or have mixed echogenicity. If there is active accompanying inflammation, Doppler will show increased vascularity (Fig. 18.20). If the amount of hypertrophy is marked, it may put pressure on nearby nerves (Fig. 18.21).

Tumor

s0050

p0310 A variety of tumors can affect peripheral nerve. Any extrinsic mass, including a tumor, can impinge on nerve. Extrinsic tumors can be benign or malignant. Among benign tumors, lipomas are the most common. Lipomas have a very similar ultrasound appearance to normal fat contained in subcutaneous tissue (Fig. 18.22). Fat is normally hypoechoic with thin, internal undulating connective tissue septa. Indeed, sometimes, the appearance of a lipoma is so similar to fat, it is difficult to separate out a lipoma from the surrounding normal adipose tissue on ultrasound. Lipomas may be slightly more hyperechoic than surrounding fat and rarely will have a thin capsule. However, if they are large enough, lipomas are most often recognized by their compression or distortion of nearby structures, especially the underlying fascia. On Doppler, vascularity is absent or minimal. There



f0100 **Fig. 18.19 Normal and abnormal joint space and synovium.** *Top,* Long axis view of a normal radiocarpal joint. *Bottom,* Long axis view of a diseased radiocarpal joint with massive synovial hypertrophy. *Left,* Native images. *Right,* Same image with the median nerve in *yellow* and the joint space with synovium in *red*. Joints normally have a connective tissue capsule with thin, delicate synovium inside that produces synovial fluid. In this figure, contrast the normal joint on the top with a degenerated joint with massive synovial proliferation on the bottom.

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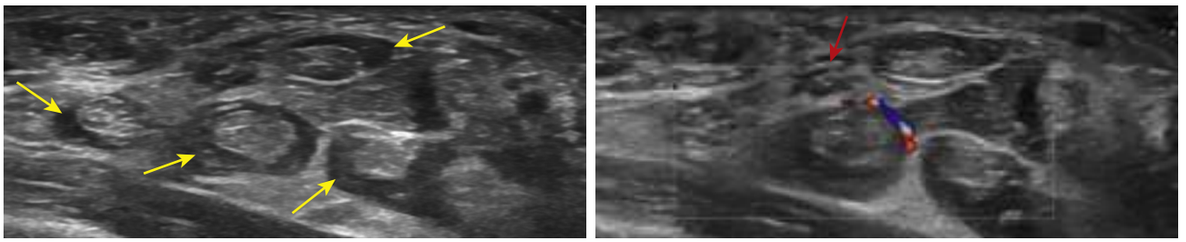

Fig. 18.20 Synovial hypertrophy around tendon sheaths. *Left,* Short axis view of the flexor tendons just proximal to the carpal tunnel. Note that several tendon sheaths are surrounded by tissue with mixed echogenicity *(yellow arrows)*, which is synovial hypertrophy. *Right*, Same image with color Doppler and the *red arrow* pointing to the median nerve. Note the increased vascularity around one of the tendon sheaths. In this case, the tissue surrounding the tendons is synovial hypertrophy. The area that is positive on Doppler indicates active disease.

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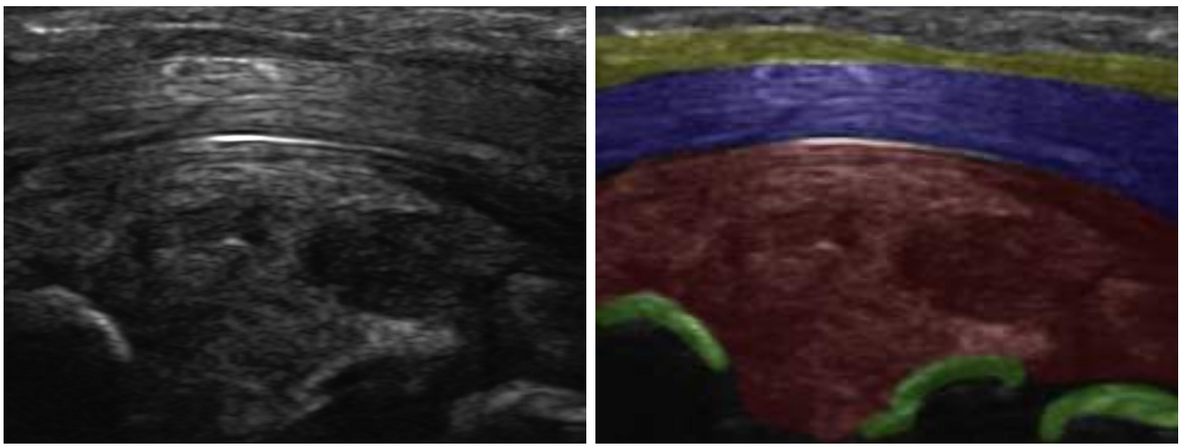

Fig. 18.21 Synovial hypertrophy. Same image as Fig. 18.19, bottom. *Left,* Long axis view of the median nerve at the radial carpal joint. *Right*, Same image with the median nerve in *yellow*, the flexor tendons in *blue*, massive synovial hypertrophy in *red*, and the bony outlines of the radial-carpal and mid-carpal joints in *green*. With degenerative and inflammatory disorders of a joint, the synovium may hypertrophy. If the amount of hypertrophy is large enough, it may deform the joint capsule, resulting in a bulging outward from the joint that can apply upward pressure on nearby nerves. Note the compression and adjacent swelling of the median nerve by the mass at the radiocarpal joint. This mass was surgically excised, with subsequent pathology showing synovial hypertrophy.

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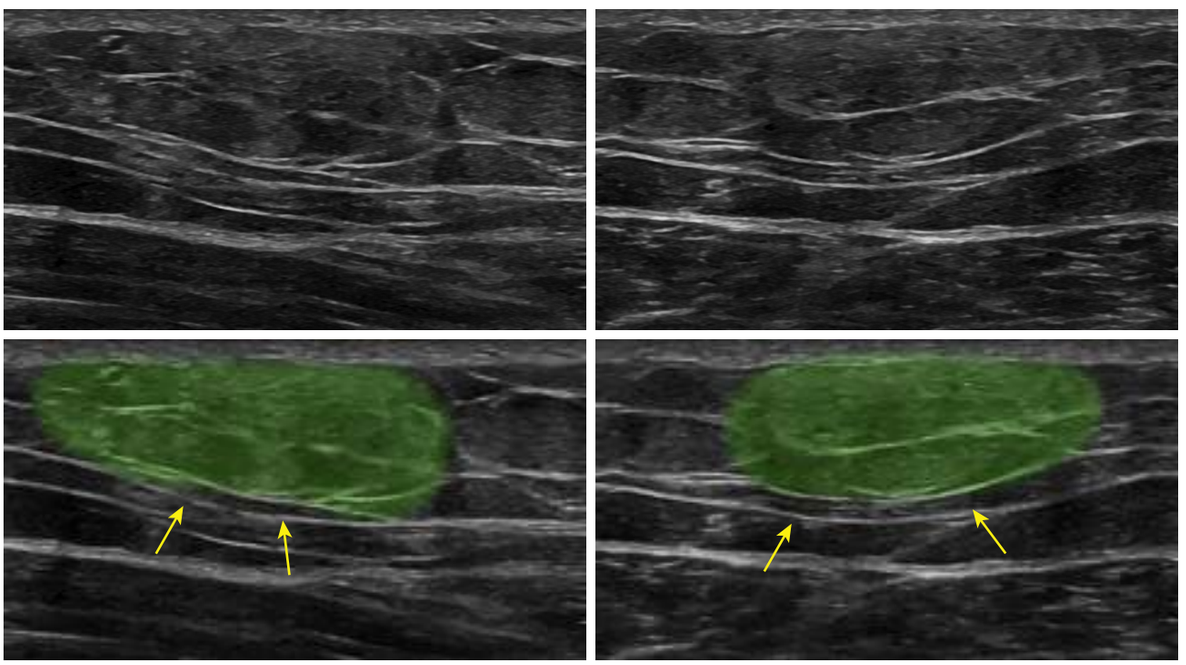

Fig. 18.22 Lipoma. *Top Left,* Long axis view of the proximal thigh. *Top Right,* Short axis view of the proximal thigh. *Bottom,* Same images with the lipoma in *green*. This patient noted a lump under the skin in the proximal thigh. Among benign tumors, lipomas are the most common. Lipomas have a very similar ultrasound appearance to normal fat contained in subcutaneous tissue. Indeed, it is often difficult to separate out the lipoma from the surrounding normal adipose tissue. Note the bowing of the underlying connective tissue *(yellow arrows)*, which helped define the lesion in this case.

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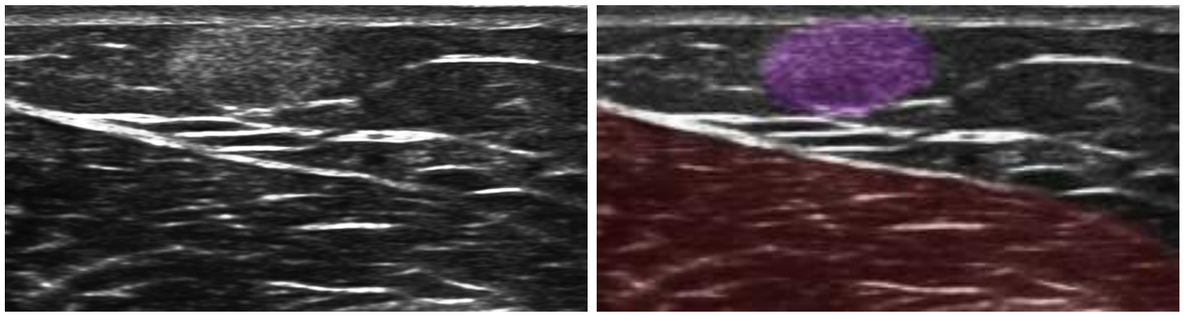

Fig. 18.23 Angiolipoma. There are several types of lipomas, including angiolipomas, which contain many additional small blood vessels. These often create a characteristic speckled, slightly hyperechoic appearance on ultrasound. *Left,* Short axis view of the volar forearm over an area where the patient had noted a lump. *Right,* Same image with the angiolipoma in *purple* and the underlying muscle in *red*.

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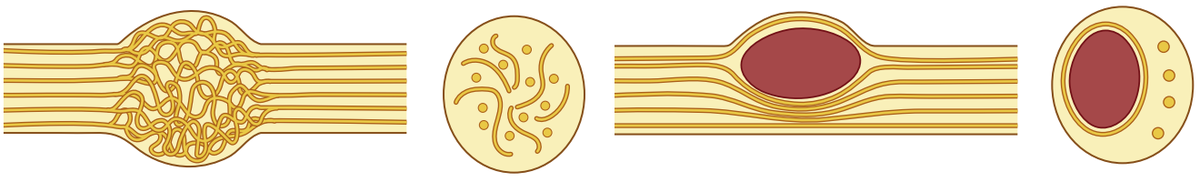

Fig. 18.24 Longitudinal and transverse drawings of a neurofibroma *(left)* and schwannoma *(right)*. Neurofibromas are centrally placed within the nerve and are actually composed of nerve fibers, in contrast to schwannomas, which are eccentrically placed within the nerve and displace the nerve fibers with the nerve.

are several types of lipomas, including angiolipomas in which there may be additional small blood vessels. These often create a characteristic speckled, slightly hyperechoic appearance on ultrasound (Fig. 18.23).

p0315 Malignant extrinsic tumors can also compress nearby peripheral nerves. These are irregular, sometimes associated with cysts, often hypoechoic, and most importantly often positive on Doppler. One always needs to be wary of describing any particular mass as being benign versus malignant based on imaging alone. This is no different than describing findings on plain X-rays, computerized tomography, or magnetic resonance imaging scan. Any abnormal mass identified on ultrasound needs to be biopsied and/or excised.

p0320 In addition, tumors can be intrinsic to the nerve itself. Most intrinsic nerve tumors are benign, either neurofibromas or schwannomas. Neurofibromas are actually tumors of the nerve itself, whereas schwannomas are derived from Schwann cells (Fig. 18.24). As these are both usually benign lesions, vascularity is typically not increased or is minimal. Neurofibromas are usually spindle shaped, with the nerve entering and exiting the mass centrally. In contrast, schwannomas may be somewhat eccentric to the long axis of the nerve (Fig. 18.25). Both neurofibromas and schwannoma are recognized as well-defined circular or oval-shaped masses that are hypoechoic. Both may display some posterior acoustic enhancement. On ultrasound, they are difficult to distinguish from each other. Only when the mass is clearly eccentric to the nerve is the diagnosis of a schwannoma more likely.

p0325 Both schwannomas and neurofibromas can occur by themselves or can be associated with genetic conditions, including neurofibromatosis. Neurofibromatosis can also present with plexiform tumors wherein the peripheral nerve is diffusely increased in size and often has a matted pattern.

p0330 Lastly, nerves can sometimes be infiltrated by malignant neoplasms. Although this is very rare, lymphoma is probably the most common, with a condition known as neurolymphomatosis. This can sometimes start with the infiltration of one specific nerve. The sciatic nerve in the upper thigh is a common location for this rare condition. Again, in this situation, one looks for enlargement of the actual nerve itself. If the mass is vascular on Doppler, the chance that it is malignant increases.

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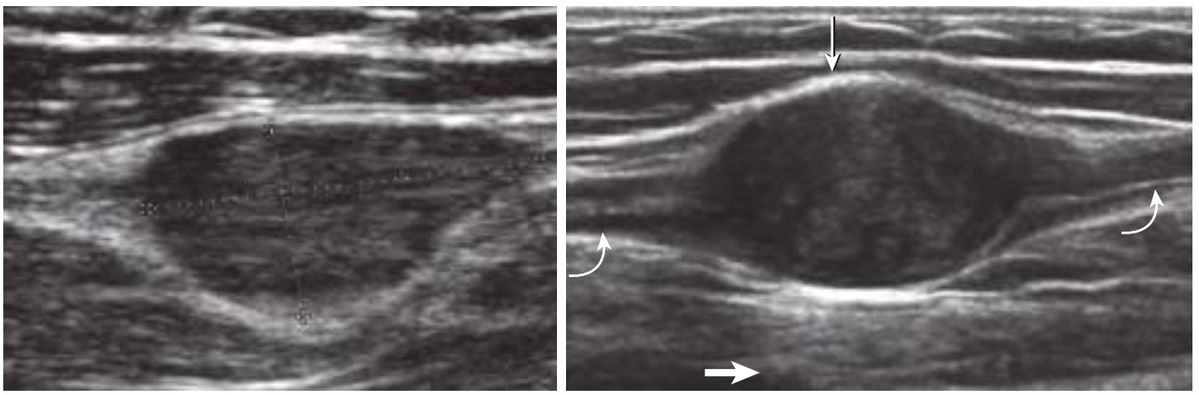

Fig. 18.25 Neurofibroma vs schwannoma. *Left,* Short axis view of a schwannoma. If the tumor is eccentric to the nerve, it is much more likely to be a schwannoma. *Right,* Short axis view of a neurofibroma. Note how the neurofibroma is centrally placed within the nerve *(curved arrows)*. Neurofibromas and other tumors may display posterior acoustic enhancement *(thick arrow),* underscoring that posterior acoustic enhancement occurs in conditions other than cystic lesions. (Adapted with permission from Griffith JF. *Diagnostic Ultrasound: Musculoskeletal*. Elsevier Health Sciences; 2015:II5–10; and Visser LH. High-resolution sonography of the superficial radial nerve with two case reports. *Muscle Nerve*. 2009;39:392–395.)

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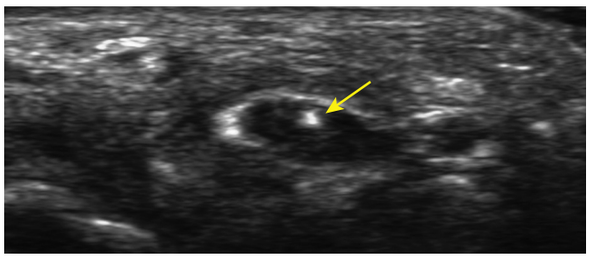

Fig. 18.26 Intraneural scar. Short axis image of the median nerve in a patient s/p carpal tunnel release. Note the hyperechoic spot *(yellow arrow)* within the nerve. This represents intraneural scarring.

s0055

Fibrous Tissue

p0335 Scar formation can occur after trauma or surgery and results from the formation of excessive fibrous tissue. This tissue is usually hyperechoic. Sometimes, scar tissue occurs within the nerve (Fig. 18.26), although most times, excessive scar tissue surrounds peripheral nerves (Fig. 18.27). Other times, scar tissue may put pressure on nerves at a distance.

s0060

Hematomas and Blood Vessel Abnormalities

p0340 Hematomas can result in compression of peripheral nerves. The appearance of a hematoma on ultrasound differs depending on its time course, due to different degrees of blood coagulation, liquefaction, and organization (Fig. 18.28). In the hyperacute setting before the clot has formed, a hematoma (or more properly a hemorrhage) is a well-defined, homogeneous, hypoechoic mass. In the acute setting, hematomas are seen as well-defined heterogeneous masses. They appear somewhat solid, often with a multilaminated whorled appearance. They may have anechoic areas within the hematoma that appear cystic; these represent liquefaction. As time passes and they become more chronic, there may be a more pronounced capsule and varying amounts of internal septation and liquefaction. If followed serially, hematomas slowly decrease in size. Liquefaction may result in posterior acoustic enhancement. If the hematoma calcifies, some posterior acoustic shadowing may be seen. Organizing hematomas can easily be mistaken for tumors on ultrasound. Without a clear history of trauma or prior bleeding/contusion, biopsy is usually needed to differentiate between the two.

p0345 Occasionally, blood vessel abnormalities can directly impinge on a peripheral nerve. Engorged veins or a single large vein known as a varix can rarely affect a peripheral nerve. This is occasionally seen with impingement of the distal tibial nerve in the tarsal tunnel by a varix. On the arterial side, aneurysms or pseudoaneurysms can compress a peripheral nerve. An aneurysm is considered a true aneurysm when all layers of the blood vessel (intima, media, and adventitia) form the outpouching. In contrast, a pseudoaneurysm is often seen following an injury to a blood vessel, wherein the outpouching typically occurs between the media and the adventitia (Fig. 18.29). On ultrasound, both appear as a hypoechoic pulsatile mass adjacent to an artery which is often positive on Doppler with swirling blood flow. However, if the aneurysm or pseudoaneursym is thrombosed, blood flow may not be seen. If large enough, and near a nerve, they can compress a peripheral nerve.

p0350 Lastly, patients can have "extra" blood vessels. As a fetus develops, several blood vessels are present that later become atretic in utero or shortly after birth. However, in some individuals, these vessels persist. The persistent median artery is the best and most common example. In this situation, the persistent median artery runs with the median nerve through the carpal tunnel. When a persistent median artery is present,

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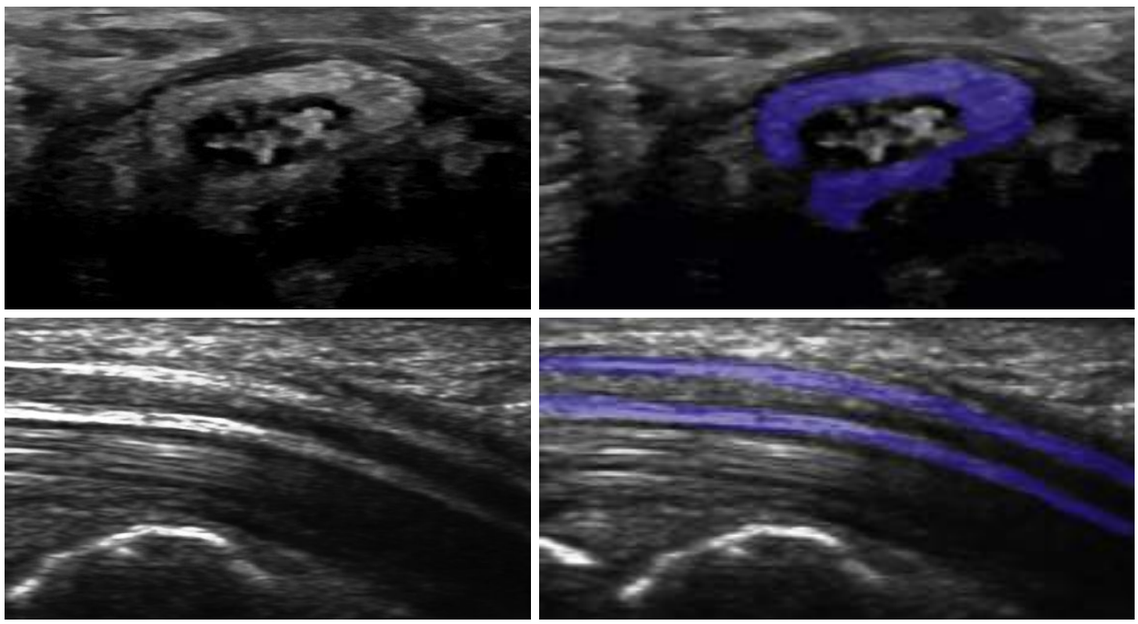

Fig. 18.27 Extraneural scar. *Top,* Short axis image of the median nerve in a patient s/p carpal tunnel release. *Bottom,* Long axis image of the median nerve in the same patient. Note the hyperechoic signal of the scar tissue surrounding the nerve. *Left,* Native images. *Right,* Same images with the extraneural scar in *blue*.

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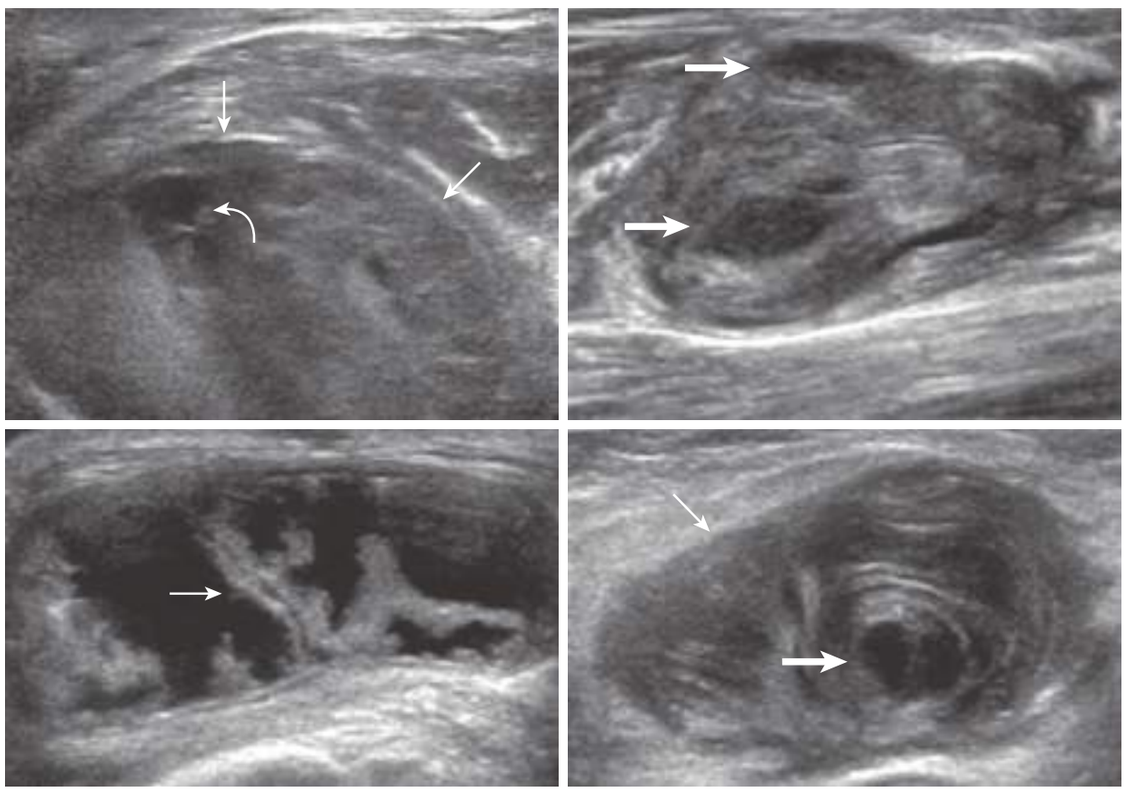

Fig. 18.28 Various ultrasound appearances of a hematoma. *Top Left,* Transverse image of a large, well-defined hematoma *(straight arrows)*. A small anechoic cystic area due to liquefaction is also present within the hematoma *(curved arrow)*. *Top Right,* Longitudinal image of a large hematoma shows a large, well-defined, oval-shaped mass with a multilaminated whorled appearance. Small liquefied areas are seen within the hematoma *(large arrows)*. *Bottom Left,* Transverse image shows liquefaction of a hematoma with a greater cystic component, septae *(arrow)*, and fibrin clots. These features are consistent with a liquefying hematoma. *Bottom Right,* Transverse image of a large hematoma shows a large, well-defined, oval-shaped hematoma *(small arrow)* that is 2 days old. The hematoma shows a typical multilaminated whorled appearance with a central anechoic fluid component *(large arrow)*. (Adapted from Griffith JF. *Diagnostic Ultrasound: Musculoskeletal*. Elsevier: Philadelphia; 2015:II3-21–II3-28.)

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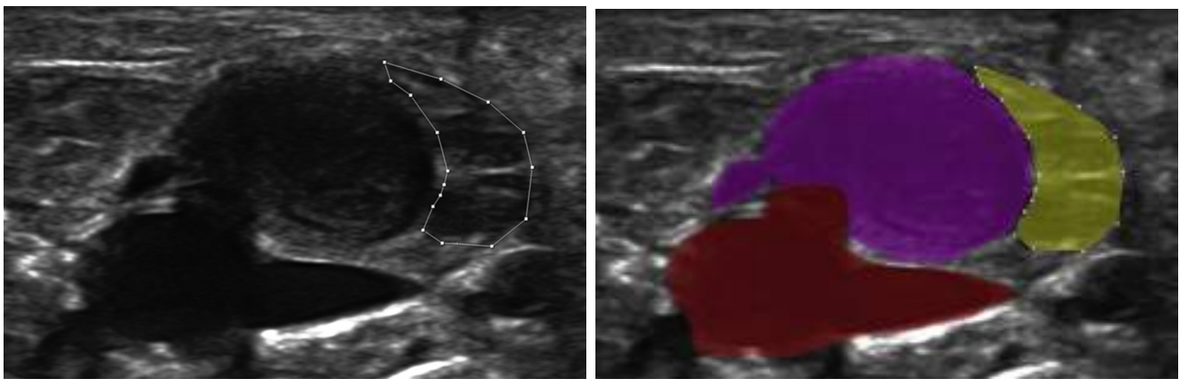

Fig. 18.29 Pseudoaneurysm. *Left*, Long axis view of the median nerve at the antecubital fossa in a patient who developed an acute high median neuropathy after attempted placement of a dialysis catheter in the antecubital fossa. *Right*, Same images with the enlarged median nerve in *yellow*, the pseudoaneurysm in *purple*, and the brachial artery in *red*. Pseudoaneurysms often occur following an injury to a blood vessel. The outpouching occurs when blood enters the potential space between the media and adventitia, causing pressure on the nearby nerve. In this case, the pseudoaneurysm was found to be thrombosed at the time of surgery. Note the massive enlargement, hypoechogenicity, and loss of fascicular structure of the median nerve.

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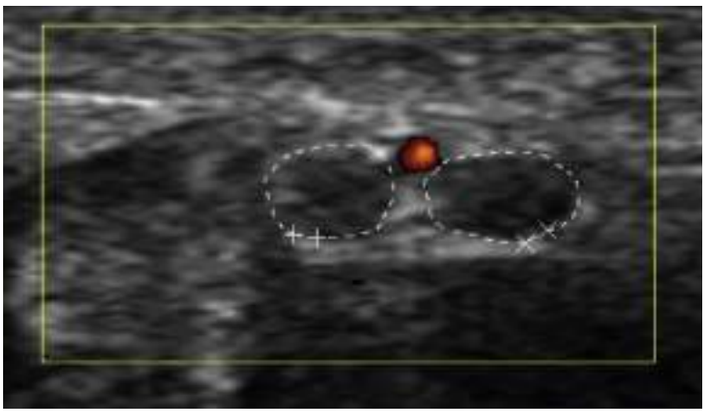


Fig. 18.30 Persistent median artery. Short axis image of the median nerve at the wrist with power Doppler applied. When a persistent median artery is present, it often accompanies an anomaly of the median nerve: instead of being in one bundle, the median nerve is bifid with the artery in between, as in this case.

it often accompanies an anomaly of the median nerve itself: instead of running in one bundle, the median nerve is bifid with the artery in between (Fig. 18.30). If the artery is enlarged or if it thromboses, this can result in increased pressure within the carpal tunnel and compression of the median nerve.

s0065

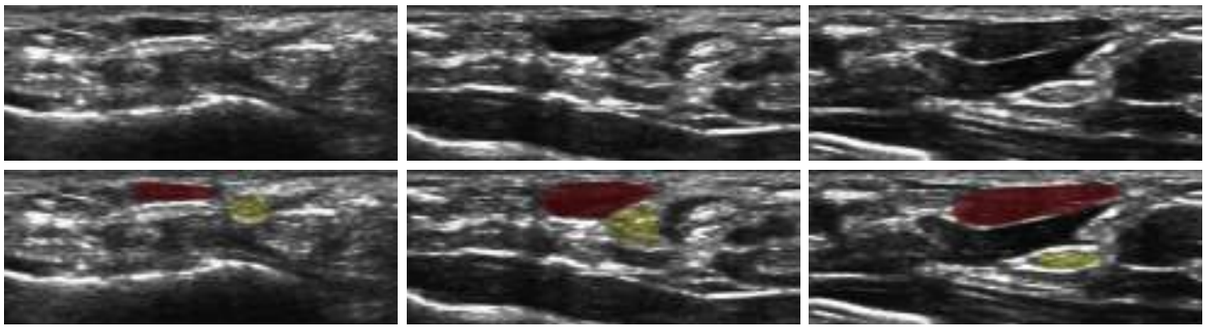
Anomalous Muscles and Other Anatomical Variants

p0355 Accessory muscles are present in many individuals. These muscles can sometimes be hypertrophic and cause an entrapment neuropathy. For example, there is an accessory abductor digiti minimi muscle that can sometimes result in ulnar neuropathy at the wrist. Likewise, an anomalous palmaris longus muscle has been implicated in some cases of median neuropathy at the wrist. This situation occurs with the so-called *"reverse palmaris longus,"* wherein the muscle belly is actually near the wrist with the tendon running to the medial epicondyle, as opposed to the opposite configuration, which is seen in most individuals (Fig. 18.31). In most situations, muscle can be easily identified on ultrasound by its normal hypoechoic "starry night" pattern on transverse imaging.

s0070

Patterns of Muscle Denervation

p0360 As will be discussed in Chapter 19, after a muscle is denervated, it undergoes various changes. It typically shrinks and becomes atrophic. Normal muscle fibers are hypoechoic. As they atrophy or totally disappear, the muscle becomes hyperechoic on ultrasound. This occurs as the ratio of connective tissue to muscle fibers increases. The muscle often develops a so-called *"moth-eaten"* appearance on ultrasound as a consequence of chronic denervation. This pattern of denervation atrophy is readily seen on ultrasound. Looking at the pattern of



f0160

Fig. 18.31 Anomalous muscle. *Top,* Short axis view of the median nerve at the wrist moving proximally. *Bottom,* Same images with the median nerve in *yellow* and a "reversed palmaris longus" in *red*. Anomalous muscles can sometimes become hypertrophied and cause an entrapment neuropathy. A reverse palmaris longus has been implicated in some cases of median neuropathy at the wrist. With a reverse palmaris longus, the muscle belly is distal instead of proximal.

muscles that are denervated can also be helpful in recognizing a peripheral neuropathy. If the pattern of denervation atrophy fits the distribution of muscles supplied by one peripheral nerve, then ultrasound can lend support to a diagnosis of a mononeuropathy.

s0075

Suggested Readings

Bianchi S, Martinoli C. *Ultrasound of the Musculoskeletal System*. Springer; 2007.

Griffith JF. *Diagnostic Ultrasound: Musculoskeletal*. Elsevier Health Sciences; 2015.

Jacobson JA. *Fundamentals of Musculoskeletal Ultrasound*. 3rd ed. Elsevier; 2017.

Spinner RJ, Amrami KK. What's new in the management of benign peripheral nerve lesions? *Neurosurg Clin N Am*. 2008;19(4):517–531.

Strakowski JA. *Ultrasound Evaluation of Focal Neuropathies: Correlation with Electrodiagnosis*. Demos Medical; 2013.

Strakowski JA. *Introduction to Musculoskeletal Ultrasound: Getting Started*. Demos Medical; 2015.

Visser LH. High-resolution sonography of the common peroneal nerve: detection of intraneural ganglia. *Neurology*. 2006;67:1473–1475.

Walker F, Cartwright MS. *Neuromuscular Ultrasound*. Saunders; 2011.

PRESTON: 18

Non-Print Items

Abstract:
One of the most common and useful applications of neuromuscular ultrasound is in the evaluation of mononeuropathies. Although mononeuropathies often result from entrapment of isolated peripheral nerves within specific anatomic fibro-osseous canals, there are a variety of other causes, many of which are structural in nature and can be easily visualized on ultrasound. In addition, it is not infrequent that electrodiagnostic studies can localize the problem to one nerve but cannot localize it to one specific segment of nerve. This occurs classically in axonal loss lesions. Ultrasound often allows localization in this situation along with specific anatomic information that may indicate a specific etiologic diagnosis. When scanning a peripheral nerve, there are several routine measures that can be assessed by ultrasound. These include cross-sectional area, echogenicity, mobility, vascularity, and fascicular structure. Similar to nerve conduction studies, one segment of nerve is often compared with an adjacent segment. Several important pathologic conditions that can affect peripheral nerves may be identified by ultrasound. These include ganglion cysts (both extraneural and intraneural), bone fragments and callus, tenosynovitis and synovial hypertrophy, tumors (neurofibromas, schwannomas, fibrolipomas, lipomas, sarcomas, lymphomas, and other malignancies), hematomas, aneurysms (true and pseudo), and anomalous muscles.

Keywords: Cross-sectional area; Echogenicity; Flattening ratio; Ganglion cyst; Intraneural ganglion; Mononeuropathy; Synovial hypertrophy; Tenosynovitis; Ultrasound; Wrist-to-forearm ratio.