PICTORIAL REVIEW

MRI of soft tissue masses of the hand and wrist

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The vast majority of soft tissue mass lesions of the wrist and hand are benign [1, 2]. In practice, the most common lesions encountered are ganglia. The most frequently seen solid masses include giant cell tumours of tendon sheath (GCTTS), lipomas, Dupuytrens contractures, nerve sheath tumours, glomus tumours, haemangioma/vascular malformations and synovial pathology. In general MRI is unable to differentiate between benignity and malignancy, but in many circumstances a specific diagnosis may be achieved by taking into account the location of the lesion within the hand or wrist and its signal characteristics [2–4]. Plain films and CT may detect calcification and allow assessment of adjacent bony structures but unlike MRI do not offer much in the way of tissue characterization. Ultrasound has an extremely useful role in localizing lesions and determining if the lesion is cystic or solid [5, 6], but further tissue characterization is limited.

This pictorial review covers the MRI appearances of the most commonly encountered soft tissue masses of the wrist and hand, and describes the main features, specifically the signal characteristics and location, that help differentiate them.

Imaging technique

Ideally the patient should be scanned supine with the arm by the side and the dorsum of the hand parallel to the coronal plane of the magnet. However some patients may need to be scanned prone with the arm above their head in the so-called “Superman” position. The disadvantage of this position is that it may be uncomfortable and therefore prone to increased motion artefact.

A dedicated wrist coil is advised and to achieve high resolution a small field of view (FOV) in the order of 8–12 cm, with a matrix of at least 256 by 512 and slice thickness of 1.5–3 mm. A number of pulse sequences and image planes can be used. At the authors’ institution a routine examination for a mass would include coronal or sagittal $T_1$ and $T_2$ weighted sequences with axial short tau inversion recovery (STIR) and $T_1$ weighted images. Intravenous gadolinium may be administered to help differentiate solid from cystic lesions.

Ganglion

Ganglia are the most common cause for a palpable mass in the wrist and hand. They most commonly occur in young women. Approximately 10% of patients have a history of trauma. Ganglia were described by Hippocrates as “knots of tissue containing mucoid flesh”. Histologically ganglia have a thin connective tissue capsule, but no true synovial lining, and contain mucinous material. Synovial cysts, which have a synovial lining, are histologically distinct from ganglia but are indistinguishable on imaging [7]. The terms “ganglion” and “synovial cyst” are therefore often used interchangeably. The aetiology of ganglia is unclear; they may represent a synovial herniation or coalescence of small degenerative cysts arising from the tendon sheath, joint capsule or bursae [8].

On MRI a unilocular or multilocular rounded or lobular fluid signal mass is seen adjacent to a joint or tendon sheath. Very small cysts may simulate a small effusion but a clue to the diagnosis is the paucity of fluid in the remainder of the joint and the focal nature of the fluid. Typically ganglia are low signal on $T_1$ weighted images and high signal on $T_2$ weighted images, but high proteinaceous content or haemorrhage can result in lesions appearing isointense or hyperintense on $T_1$ weighted images.

Mild enhancement of the capsule or of septae may be seen following post intravenous gadolinium (Figure 1) [9]. A ganglion is considered occult when it is not clinically palpable, usually because it lies deep to tendons. Ganglia occur in four main areas (Figure 2) [8, 10]:

1. Dorsum of the wrist (around 60%). These usually originate from the scapholunate joint or ligament. A
small synovial pedicle frequently extends through the fibres of the scapholunate ligament and dissects through overlying structures proximally or distally. Erosion of the dorsal lunate is occasionally associated.

2. Volar aspect of the wrist (20%). These arise from the radio-scaphoid, scapho-trapezial, or metacarpo-trapezial joint. They can extend around the flexor carpi radialis tendon and/or radial artery. Ulnar ganglia are associated with tears in the triangular fibrocartilage complex.

3. Flexor tendon sheath (10%). Typically these occur at the metacarpo-phalangeal joint.

4. Distal interphalangeal joint, located on the dorsum of the fingers between the nail and distal interphalangeal joint (10%). These are commonly associated.

Figure 1. (a) Dorsal ganglion. Axial $T_2$ weighted image demonstrating a well defined fluid signal lobulated mass arising from the region of the dorsal scapho-lunate ligament (arrow). The lunate (Lu) and scaphoid (Sc) are labelled. (b) Axial $T_1$ weighted image demonstrating an intermediate signal mass.

Figure 2. (a) Occult dorsal ganglion. Coronal short tau inversion recovery (STIR) image demonstrating a fluid signal mass (arrows) arising from the dorsum of the wrist. (b) Axial $T_2$ weighted image demonstrating a high signal mass (arrows) lying deep to the extensor tendons.
referred to as “mucous cysts” and are usually associated with osteoarthritis [11]. They may cause pain and nail distortion and may discharge.

**Giant cell tumour of the tendon sheath**

Giant cell tumours of the tendon sheath (GCTTS) are common benign synovial masses of unknown aetiology arising from the tendon sheath, often referred to as focal pigmented villonodular synovitis (PVNS). There is a slight female predominance. These lesions usually affect the volar aspect of the first three digits [12], much less commonly affecting the wrist.

MRI typically shows a well defined mass adjacent to or enveloping a tendon [13]. Characteristically the mass is hypointense on $T_1$ weighted images, approximately equal to skeletal muscle. On $T_2$ weighted images there is usually low signal due to chronic haemorrhage with haemosiderin deposition [14]. Blooming artefact may occur with gradient echo sequences. There may be areas of low signal and high signal on $T_2$ weighted images due to the presence of haemosiderin and fluid respectively. Uniform enhancement can be seen post intravenous gadolinium (Figure 3) [13].

**Fibromatosis**

Fibromatosis refers to group of benign but sometimes locally aggressive proliferative lesions comprised of myofibroblasts [15]. These are characterized by infiltrative growth, and may therefore mimic a malignant lesion. Lesions may be superficial, resulting in Dupuytren’s contracture or deep.

**Dupuytren’s contracture**

Proliferation of fibrous tissue within the palmar aponeurosis of the hand results in Dupuytren’s contracture [16]. Patients present with subcutaneous nodules on the palmar surface of the distal crease of the hand which progresses to cords and bands and finally the characteristic flexion contracture secondary to fibrous attachments to the underlying tendon sheath. Up to 25% of patients over 65 years are affected with a male predominance. Most commonly the fourth ray is involved.

MRI demonstrates focal nodules or cords arising from the palmar aponeurosis extending distally and superficially parallel to the flexor tendons. The lesions terminate in fine strands extending into the subcutaneous tissues at the level of the distal metacarpals [17]. Lesions of high cellularity tend to be of higher signal on $T_2$ weighted images than those with a large collagenous component [15, 16] (Figure 4).

**Deep musculoaponeurotic fibromatosis**

Deep musculoaponeurotic fibromatosis typically occurs between the ages of 10 years and 40 years. There is equal sex predominance. Usually solitary lesions occur but synchronous multicentric lesions have been reported [18]. Plain films may reveal evidence of bone erosion without invasion or destruction. The lesions may have poorly defined margins and appear infiltrative. Great variability in appearance is seen on MRI depending on the degree of cellularity and collagen content [19]. Generally lesions are of low signal on $T_1$ weighted images, with areas of low and high signal on $T_2$ weighted images representing collagen and cellularity, respectively.

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Figure 3. (a) Giant cell tumours of tendon sheath (GCTTS) of index finger. Axial $T_1$ weighted image demonstrating a well defined intermediate/low signal mass (arrow) adjacent to the flexor tendon (arrowhead). (b) Axial $T_2$ weighted image demonstrating a low signal mass indicating the presence of haemosiderin, surrounded by a rim of high signal (arrowheads).
Fibroma of the tendon sheath

This is a rare benign tumour of the tendon sheath which may be confused with GCTTS. It is usually a firm well defined mass attached to the tendon sheath. The MRI appearance is variable but usually the presence of fibrous tissue results in low signal on both $T_1$ and $T_2$ weighted images [20].

Lipoma

Although simple benign lipomata are the most common soft tissue tumour, they are uncommon in the hand [21]. They are lesions of mature adipose tissue which may occur in a subcutaneous or deep location, presenting as a slow growing painless mass. 80% of lesions measure less than 5 cm [17]. Pressure effects can result on neighbouring structures such as nerves and vessels in locations where there is confined space, e.g. Carpal tunnel and Guyon’s canal. Typically they occur at the thenar or hypothenar eminence.

Superficial lipomata may be inconspicuous on MRI particularly when they blend in with normal subcutaneous fat. They demonstrate typical fatty signal with homogeneous high signal on $T_1$ weighted and low signal on STIR or $T_2$ fat saturated images [22] (Figure 5). Septations may be seen but nodules or solid components suggest a liposarcoma. Complications such as haemorrhage or infarction can result in a more complex appearance which may simulate liposarcoma. Intramuscular lipomata may infiltrate between muscle fibres resulting in a more heterogeneous appearance on MRI.

Fibrolipomatous hamartoma

The aetiology of fibrolipomatous hamartoma may be related to hypertrophy of mature fat and fibroblasts in the epineurium [23]. It presents in young adulthood with a slow growing mass on the volar aspect of the hand or wrist or forearm and may be associated with macrodactyly. It has a marked predilection for the median nerve with up to 85% occurring at this location and may give rise to symptoms of pain or paresthesia [24]. The MRI appearances are pathognomonic with longitudinally orientated cylindrical foci of low signal intensity surrounded by fatty signal intensity representing nerve fascicles, giving a spaghetti-like appearance on coronal planes and co-axial cable appearance on axial images [25, 26] (Figure 6). On MRI areas of low and high signal are seen on both $T_1$ and $T_2$ weighted images representing the fatty and fibrous contributions of the tumour.

Haemangioma/vascular malformations

Mulliken and Golwacki’s classification of vascular anomalies defines a haemangioma as a tumour characterized by increased cell turnover of endothelium, mast cells, fibroblasts and macrophages [27]. This tumour is not usually present at birth (except in the congenital haemangioma) but becomes apparent during the first few weeks of life as a firm non-compressible mass within the soft tissues after which there is rapid growth (the proliferative phase) followed 6–10 months later by an involuting phase. Complete resolution occurs in 70% by 7 years and the remainder continue to diminish until the age of 12 years. Some lesions persist into adulthood, and may present incidentally or following trauma. In the proliferative phase these appear as a soft tissue mass isointense or hypointense to muscle on $T_1$ weighted images and high signal on $T_2$ weighted images. Serpentine vascular flow voids may be evident on both sequences and there is uniform enhancement with intravenous gadolinium. With involution there is decrease in size of the mass with replacement by variable and increasing amounts of fat, loss of the high flow signal voids and absence of enhancement (Figure 7a,b).

Vascular malformations on the other hand are not neoplastic lesions but are errors of vascular morphogenesis with a normal rate of endothelial turnover, and hence grow commensurately with the child [27].
Figure 5. (a) Lipoma. Coronal $T_1$ weighted image demonstrating a well defined homogeneously high signal mass (arrowheads) in the thenar eminence. (b) Coronal short tau inversion recovery (STIR) image demonstrating a low signal mass (arrowheads) in the thenar eminence.

Figure 6. (a) Fibrolipomatous hamartoma of the median nerve. Axial $T_1$ weighted image demonstrating a mass (arrows) comprised of low signal foci surrounded by fatty signal, the “co-axial cable” sign. (b) Coronal $T_1$ weighted image demonstrating separation of nerve fascicles by fatty tissue (arrows), the “spaghetti” sign.
Occasionally they can suddenly enlarge due to haemorrhage, infection or hormonal influence at puberty. They are present at birth although they may not become apparent until adolescence or early adulthood. The lesions can be subdivided according to vessel type into the following groups: capillary, venous, arterial and lymphatic. Often these occur in combination. It is clinically important to separate them into low flow (capillary, venous, lymphatic or a combination) or high flow (arteriovenous) [28]:

Capillary malformations are the equivalent of the port wine stain. A clinical diagnosis may be made in most instances. On imaging skin thickening is seen with no vascular channels apparent.

Venous malformations are comprised of dilated slow flowing vascular spaces and channels with no solid tissue component aside from septations. They appear on MRI as septated high signal soft tissue masses on T2 weighted images with no evidence of high flow velocity signal voids. On T1 weighted images they are isointense to muscle. The presence of phleboliths results in foci of signal void. Gradient echo imaging is useful to document slow flow and exclude the presence of any high flow. With contrast, there is uniform or inhomogeneous enhancement of the vascular spaces.

Lymphatic malformations consist of multiple lymphatic fluid containing spaces with intervening septa. On MRI they are comprised of septated cysts of variable size. Fluid–fluid levels may be seen. Stranding of the adjacent subcutaneous tissue may be seen due to associated lymphatic obstruction and may simulate cellulites [29] (Figure 7c–e).

Arteriovenous malformations (AVMs) are high flow vascular anomalies with abnormal connections between arteries and veins. AVMs have an intervening central nidus whereas arteriovenous fistulae do not. On MRI they appear as enlarged vascular channels without a discrete soft tissue mass which on spin echo imaging appear as signal voids with corresponding bright signal on flow-enhanced GE sequences [30]. MR angiography or ultrasound can be used to confirm the high flow state and assess arterial supply. Skin thickening and fat deposition may be seen in association as well as perilesional oedema [29] (Figure 8).

**Figure 7.** (a) Haemangioma. Coronal T1 weighted image demonstrating a lobulated mass (arrowheads) with extension into the thumb (arrow), which is slightly hyperintense to skeletal muscle. (b) Haemangioma. Coronal short tau inversion recovery (STIR) image demonstrating a lobulated hyperintense mass. (c) Venous malformation. Axial T2 fat-saturated image demonstrating a lobulated, serpentine lesion in the thenar eminence. (d) Venous malformation. Coronal T1 weighted image demonstrating a mass with well defined, low signal margin (arrowheads). (e) Venous malformation. Coronal STIR image demonstrating a lobulated high signal mass.

**Figure 8.** (a) Small arteriovenous malformation. Coronal short tau inversion recovery (STIR) image demonstrating a small serpiginous high signal mass on the radial aspect of the wrist (arrow), confirmed as a vascular structure on ultrasound. (b) Axial T2 fat-saturated image demonstrating a high signal serpiginous mass (arrow) on the radial aspect of the wrist. There is also a ganglion (arrowhead) on the ulnar aspect of the wrist.
Benign peripheral nerve sheath tumours

Benign peripheral nerve sheath tumours (PNST) are common masses of the forearm and hand. Schwannomas arise from the schwann cells surrounding the nerve whereas neurofibromas arise from the central nerve fascicles [31]. In the hand and wrist, schwannomas arise from deeper and larger nerves (particularly the ulnar nerve) and often occur along the flexor surfaces whereas neurofibromas tend to involve smaller cutaneous nerves. Both tend to present in young adulthood and are small, solitary and slow growing. The vast majority of these are not associated with neurofibromatosis [21].

The most important imaging feature of neurogenic tumours is recognition of a fusiform mass with a “dural-tail”, representing the entering and exiting nerve at a typical nerve location [31]. This is usually straightforward where the nerve is large or deep but with superficial small PNSTs this feature may not be seen (Figure 9a,b). The eccentric nature of the schwannoma in relation to the nerve may allow its differentiation from a neurofibroma [32] (Figure 9c).

The signal intensity of these tumours is fairly non-specific demonstrating isointensity or slight hyperintensity to muscle on T₁-weighted images and marked hyperintensity on T₂-weighted images. There may be areas of heterogeneity but this finding is more commonly seen with malignant PNST. A target sign with hyperintense periphery and central hypointensity on T₂-weighted is most commonly seen with neurofibroma but occurs with other PNST. This corresponds to central fibromatosis and surrounding myxomatosis tissue [33] (Figure 10a,b). The “split fat” sign is often seen around neurogenic tumours and relates to the fact that the neurovascular bundle is surrounded by fat so masses arising from this location maintain a rim of fat around them. The “fascicular” sign describes small ring-like structures on T₂-weighted images corresponding to the fascicular bundles within the nerve [31] (Figure 10c). Muscular atrophy with concomitant increased fat content may be appreciated but can be quite subtle particularly with the small muscles of the forearm and hand. This is best appreciated on T₁-weighted images and may require the contralateral side for comparison [32]. Most PNSTs enhance vividly with contrast but the pattern of enhancement is variable with foci of heterogeneity not uncommonly seen. Features suggestive of malignancy include large size (greater than 5 cm), prominent enhancement, infiltrative margins, marked heterogeneity and rapid growth [31].

Glomus tumour

Glomus bodies are responsible for thermoregulation and are present throughout the dermis of the body but are particularly concentrated in the digits of the hand and foot. Glomus tumours are small hamartomas of the neuromyoarterial apparatus within the glomus body and are responsible for up to 5% of soft tissue tumours of the hand [34]. They are most commonly found at the fingertips, either in the pulp or beneath the fingernail, and typically present in the fourth and fifth decades as exquisitely painful lesions exacerbated by temperature changes [35]. Clinically, disappearance of pain after application of a tourniquet proximally on the arm is pathognomonic of the tumour and is known as the Hildreth sign [36]. On plain films, smooth extrinsic bone erosions adjacent to the lesion may be seen if the lesion is large enough.

With the use of surface coils lesions as small as 2 mm may be detected with MRI. They are typically of low or intermediate signal on T₁ weighted images and homogenously high intensity on T₂ weighted images. They enhance uniformly following gadolinium [34, 37] (Figure 11).

Soft tissue chondroma

Soft tissue chondromas are small nodules of cartilage not attached to bone. They represent 6% of all hand and wrist soft tissue tumours [31]. There is a wide range of ages at presentation. Patients present with a slow growing mass less than 2 cm in size. They may be attached or associated with tendons or tendon sheaths, joint capsule or periosteum [17]. Plain film shows a well defined soft tissue mass with most lesions showing foci of calcification which may be central or peripherally located. Typical rings and arcs of mineralization may be seen and adjacent bony remodelling or extrinsic erosion may be evident (Figure 12a).

On MRI the lesions are intermediate signal on T₁ weighted images and high on T₂ weighted images. If calcification is present foci of low signal may be seen on both sequences (Figure 12b,c).

Malignant masses

Malignant soft tissue tumours of the hand are uncommon [1, 2]. The lesions most often encountered are malignant fibrous histiocytoma in the older population, synovial sarcoma, rhabdomyosarcoma, malignant nerve sheath tumours, liposarcomas and extraskeletal chondrosarcomas. Because of non-specific morphological features, these tumours can be confused with benign lesions such as aggressive fibromatosis or ganglion cysts, particularly when they are small. The possibility of a malignant lesion needs to be considered when the mass does not have an unequivocal benign diagnosis on MRI [38].

The MRI features that should raise the possibility of malignancy are a large lesion with poorly defined margins, inhomogeneity on T₂-weighted images, irregular enhancement following intravenous contrast and the presence of necrosis (Figure 13).

Pseudomasses

Synovial pathology

Synovial hyperplasia and tenosynovitis can present as a focal masses around joints and tendons. This may occur as an isolated abnormality or in the setting of an arthropathy, particularly rheumatoid arthritis.

MRI is extremely useful for defining the extent of disease. Inflamed, hypertrophied pannus demonstrates
Figure 9. (a) Schwannoma. Sagittal $T_1$ weighted image demonstrating an ovoid intermediate signal mass (arrowheads) on the volar aspect of the wrist. (b) Sagittal $T_2$ fat saturated image demonstrating dural tail at both ends of a high signal mass (arrows), strongly suggesting a neurogenic lesion. (c) Schwannoma. Coronal short tau inversion recovery (STIR) sequence demonstrating an ovoid high signal mass in the palm with a clearly defined dural tail (arrow).
Figure 10. (a) Neurofibroma. Coronal $T_1$ weighted image demonstrating an ovoid intermediate signal mass (arrowheads). (b) Axial $T_2$ fat saturated image demonstrating the “target” sign, with a mass of central low signal intensity (arrowheads) with surrounding high signal. (c) Fascicular sign. Sagittal $T_2$ weighted image demonstrating a small low signal ring like structure within a small neurofibroma (arrows). Note the presence of a dural tail (arrowhead).
Figure 11. (a) Nail-bed glomus tumour. Coronal $T_1$ weighted image demonstrating a small intermediate signal mass (arrow) in the nail-bed. (b) Coronal short tau inversion recovery (STIR) image demonstrating a high signal mass in the nail-bed (arrow).
Figure 12. (a) Periosteal chondroma. Lateral plain radiograph of the ring finger showing a soft tissue mass with scalloping of the underlying bone (arrowheads) and an arc of peripheral calcification (arrow). (b) Sagittal $T_1$ weighted image showing an intermediate signal mass (arrowheads). The underlying bone is scalloped. (Continued)
intermediate signal on $T_1$ weighted images and high signal on $T_2$ weighted and STIR images [39] (Figure 14). Intravenous gadolinium can help differentiate pannus from fluid because pannus demonstrates diffuse enhancement on $T_1$ weighted images whereas the fluid remains low signal. With tenosynovitis, fluid is seen around tendons as high signal on $T_2$ weighted images.

**Anomalous muscles**

Anatomic variants of the muscles of the wrist and hand are common [40, 41]. These can be clinically significant when they cause compressive symptoms or appear mass-like. Often lesions are not recognized on imaging as the signal characteristics are identical to normal muscle.

The accessory abductor digiti minimi muscle is present in up to 24% of all wrists [40]. On axial images a fusiform mass is present with the signal characteristics of muscle lateral and anterior to the pisiform bone at the level of the origin of the abductor digiti minimi muscle. This may cause an ulnar or median neuropathy [42] (Figure 15).

The extensor digitorum brevis manus muscle occurs in 1–3% of the population [43]. Clinically this may be mistaken for a dorsal ganglion. This arises from the distal radius and inserts on the index finger. Normally the extensor tendons are unaccompanied by their muscle bellies at the level of the carpus. However, in the presence of an extensor digitorum brevis manus muscle, it is noted that there is a muscle medial to the tendon of the index finger at or distal to the level of the carpus [44].

Palmaris longus muscle variants may compress the ulnar and median nerves. The normal muscle arises from the medial epicondyle and inserts into the palmar aponeurosis. MRI may demonstrate a midline mass superficial to the flexor retinaculum at the wrist but diagnosis may require more proximal imaging of the forearm [45] (Figure 16).

Proximal origin of the lumbrical muscles occurs when the origin of these muscles is within the carpal tunnel rather than just distal to it (diagnosed with the fingers in extension) and is seen in up to 22% of individuals [40]. It may be the cause of carpal tunnel syndrome [46].

**Soft tissue infection**

Soft tissue infection with abscess formation may mimic a soft tissue mass. MRI not only allows demonstration of the extent of soft tissue involvement but can help determine the presence of osteomyelitis [47]. On MRI an abscess is typically demonstrated as fluid signal, with intermediate/low signal on $T_1$ weighted images and high signal on $T_2$ weighted and STIR images, and an enhancing wall following intravenous gadolinium (Figure 17).

**Conclusion**

The vast majority of soft tissue mass lesions of the wrist and hand are benign. By noting the signal characteristics and determining lesion location, a specific diagnosis of the mass can often be made (Figure 18). Certain lesions such as lipomata, ganglia, fibrolipomatous hamartoma and GCTTS have characteristic appearances. Unfortunately, where the lesion does not exhibit
Figure 13. (a) Synovial sarcoma. Axial T₁ weighted image demonstrating an intermediate signal mass on the palmar aspect of the hand. (b) Axial T₂ fat-saturated image demonstrating a predominantly hyperintense mass with central hypointense areas. The features are non-specific.

Figure 14. (a) Seronegative arthropathy with synovitis. Coronal short tau inversion recovery (STIR) image demonstrating diffuse synovitis of the carpus with fluid at the distal radioulnar joint (arrowhead) and at the scapho-trapezoid joint (arrow). There is diffuse peri-articular bone marrow oedema. (b) Axial T₂ weighted image demonstrating synovial fluid and hypertrophy (arrowheads) arising from between the scaphoid and capitate (arrow).
Figure 15. (a) Accessory abductor digiti minimi. Coronal $T_1$ weighted image demonstrating an accessory muscle belly (arrowheads). (b) Axial $T_1$ weighted image demonstrating the accessory muscle belly (arrowheads) in Guyon’s canal compressing the neurovascular bundle (arrow). The patient had ulnar neuropathy.
Figure 16. Accessory palmaris longus muscle. Sagittal $T_1$ weighted image demonstrating an accessory muscle belly at the level of the wrist (arrows).
typical features, differentiation from malignancy cannot be categorically made.

References

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