MRI of tumours of the soft tissues of the foot.

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Authors: T. Robba\textsuperscript{1}, G. Regis\textsuperscript{2}, A. Gallo\textsuperscript{2}, M. I. Stefanica\textsuperscript{1}, V. Ciccone\textsuperscript{3}, A. Linari\textsuperscript{1}, E. Brach del Prever\textsuperscript{1}, A. COMANDONE\textsuperscript{1}, C. Faletti\textsuperscript{2}; \textsuperscript{1}Turin/IT, \textsuperscript{2}TORINO/IT, \textsuperscript{3}Torino (TO)/IT
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Learning objectives

To illustrate the MR features of both benign and malignant lesions of the soft tissues of the foot.
Lesions of the soft tissues of the foot represents about 8% of benign and 5% of malignant tumors of the whole body (Woertler, 2005) with a ratio of benign / malignant 4:1 (Mercury, 2002). In our experience the mortality of these tumors is 27% of all malignants. The latter value of the mortality is significantly higher than other districts (10.3%), probably due to the higher frequency of highly aggressive histological types such as synovial sarcoma (22% of all malignant tumors of the foot versus 4% in other districts). Because of the limited thickness of the soft parts, the tumor becomes symptomatic and detected at physical examination at an early stage, when the imaging can't demonstrate yet the specific characteristics of different histological types (Baert, 2009).
Imaging findings OR Procedure details

We reviewed MR examinations in our electronic archive of 44 patients from January 2005 to June 2010 and correlated our results with histology (23 F and 21 M, average age 45.88 years - range 11 -78, SD 14.09 years).

The 44 cases of tumors of the soft parts of the foot in our series are listed in Table 1.

Lesions should be classified as:

A) TUMOUR-LIKE LESIONS

- Cystic tumor-like lesions

  - **Soft-tissue ganglia**: it is mixoid lesion that occurs around joints or tendon sheaths. It is usually a well defined cystic structure, often multiloculated.

  - **Synovial cyst**: it is a juxta-articular fluid collection communicating with a degenerate joint.

  - **Advential bursa**: it is usually associated with allux valgus and allux rigidus; if inflamed, it results in bursitis subjacent to the first metatarsophalangeal joint.

- Noncystic tumor-like lesions

  - **Neuromas**: they are not true soft tissue neoplasms, but represent lesions of nerve caused by reactive hyperplasia.

**Traumatic neuroma**: it represents an insufficient, reparative proliferation of an injured nerve often due to amputation; at histologic analysis they are non-neoplastic, non-encapsulated tangled masses of axons, Schwann cells, endoneurial and perineurial cells in a dense collagenous matrix with surrounding fibroblasts.

**Morton neuroma**: it represents perineural fibrosis with high collagen content and loss of the myelinated fibers about the plantar digital nerve, likely related to chronic injury. Morton neuroma is most frequently located between the third and fourth metatarsal heads.

The lesion is typically centered on the vascular nervous bundle in intercapitometatarsal space, on the plantar side of the transverse metatarsal ligament and has hypointense signal on T1 and T2. (Fig 1 2,3).
- **Rheumatoid nodules**: they occur in 20-30% of rheumatoid patients in advanced stage; these are granulomatous foci with central area of necrosis along subcutaneous tissues and may be associated with active inflammatory marrow signs, joint effusion and synovitis.

- **Hyperkeratosis**: it is a superficial thickening in response to mechanical pressure, typically within the submetatarsal soft tissues of the forefoot. We illustrate a rare case of diffuse hyperkeratosis of distal phalanges. *(Fig 4,5,6,7,8).*

  - **Synovial-Based Processes**

- **Synovial chondromatosis**: it is an uncommon disorder in which multiple hyaline cartilage nodules are formed within a joint, tendon sheath or bursa. Calcifications occur in 70-95% of cases, consequently the signal depends on the degree of mineralization of the osteochondral bodies. Contrast-enhancement is typically peripheral. Remember that the imaging finding of chondromatosis is comparable to the more rare synovial chondrosarcoma *(Fig 9,10,11,12,13).*

- **Pigmented villonodular synovitis (PVNS)**: it is a proliferation of extra or articular synovia. The predominance is in the young individuals. The lesions are not calcificated and the erosion of the joint is frequent, with recurrent hemarthrosis. The MR could demonstrate the hemosiderin deposits within the inflamed synovia *(Fig 14,15,16,17,18).*

- **Gout**: the manifestation consists in focal urate deposits often associated with well-marginated bone erosions; calcifications are rare; they presents heterogeneous and predominantly peripheral gadolinium enhancement *(Bancroft, 2008).*

B) **TUMOUR LESIONS**

Some tumor lesions are characterized by their place of origin: juxta-articular, juxta-tendon, neurogenic and of plantar fascia.

  - **Juxta-articular lesions**

- **Synovial sarcoma**: it is the most common malignant tumor of the ankle-foot district. It is juxta-articular and localized in 60-70% of lower limb. It occurs in patients between the ages of 15 and 35 years. Although included in the synovial lesions, it does not originate from synovial tissue but from undifferentiated mesenchymal cells. It appears as a slowly growing juxta-articular swelling and is typically polymorphous at the MRI examination, generally characterized by the coexistence of solid and cystic tissue *(Fig 19,20)*, with fluid-fluid levels ("triple signal"), clearly evident in T2. It presents discrete contrast-enhancement *(Fig 21,22).* On the radiography and CT subtle and irregular
calcifications (mostly represented at the periphery of the lesion), when present, are better appreciated.

- **Synovial chondrosarcoma**: extremely rare, it can originate from a pre-existing or new chondromatosis, which imaging is superimposable.
  
  - **Juxta-tendon lesions**
  
- **Giant cell tumor of tendon sheath or nodular tenosynovitis**: it is the most common and represents about 5-15% of all tumour lesions of the district ankle-foot (Fig 23,24,25).
  
  - **Neurogenic lesions**

**Benign**

- The **benign peripheral nerve sheath tumors (BPNSTs)** are divided into two groups: neurilemmoma (Schwannoma) and neurofibroma.

**Schwannoma**: it contain cells that are closely related to the normal Schwann cell. It appears as nodular/spindle mass along the course of a nervous branch that can be observed at the periphery of the lesion, which typically has a target appearance (Fig 26,27,28). Histologically there are Antoni A (hypercellular areas composed of spindle cells arranged in short bundles or interlacing fascicles) and Antoni B regions (hypocellular and less organized areas with myxoid tissue). The Schwannoma in which Antoni A areas are predominant are often called cellular Schwannoma. Ancient Schwannoma, rare at level of the foot, are large Schwannoma with degenerative changes, calcification, hemorrhage and fibrosis.

**Neurofibroma**: less frequent, it is composed by Schwann cells and interlacing fascicles of wavy fibroblasts, that often contain abundant amounts of collagen.

- **Granular cell tumour (granular cell Schwannoma)** is a rare large cells tumor with granular cytoplasm related to Schwann cells

**Malignant**

- **Malignant peripheral nerve sheath tumours (MPNSTs)**: they are fusiform, with the epineurium and perineurium becoming thickened proximally and distally to the mass. The tumors cells are arranged in fascicles and areas of hemorrhage and necrosis are frequent. The lesions are often similar in appearance to the benign ones, which
apparently can give rise to. MRI signs of malignancy are size > 5 cm, intralesional necrosis, inhomogeneous signal and contrast-enhancement. Moreover the MPNSTs may appear as inhomogeneous masses, with irregular margins and infiltrating attitude.

- **Plantar fascia lesions**

The level of the plantar fascia is the typical localization of the fibroblastic lesions such as nodular fasciitis and fibromatosis.

- **Nodular fasciitis:** it is localized in 16% of cases at the foot, most frequently along the plantar fascia. It can be placed in the subcutaneous tissues or in the thickness of the fascia. The matrix of the lesion is usually fibrous but sometimes presents myxoid, degenerative cystic and calcified areas; accordingly it will also change the MRI signal of the lesion (Fig 29, 30, 31).

- **Plantar fibromatosis** or disease of Ledderhose: it appears as a fusiform thickening with multiple nodules, most often on the medial side and rarely causes the retraction of the fascia, in contrast to the palmar localization. It presents a typical iso-or hypointense signal on T1 and T2 compared to skeletal muscle.

- **Extra-abdominal aggressive fibromatosis:** it appears along the fascia (“fascia tail sign”) but can be located in other sites, especially in the diffuse forms; it shows also a typical clear hypointensity signal on T1 and T2, for the high hemosiderin content (Fig 32, 33, 34, 35).

The other lesions have signal characteristics and morphology that may be indicative of their histotype:

- **Adipose line lesions**

- **Lipoma:** it is a benign tumour comprised of mature adipocytes; it is the most common mesenchymal soft tissue tumour in adults but is only infrequently found in the ankle and foot. Like in other districts, some elements (size, branches intralesional fibrosis, calcification) may be suspect for a lipoma-like liposarcoma, which must still be confirmed histologically. If present, fibrous septations within the lesion are usually thin, hypointense on T2-weighted or STIR images, and do not enhance following contrast administration. The presence of non-adipose tissue components, thick septa with hyperintense T2-weighted signal or contrast-enhancement should raise suspicion of a liposarcoma. Furthermore, liposarcomas of the foot are very rare. (Fig 36, 37, 38, 39, 40).

- **Neural fibrolipoma:** hypertrophy of mature fat and fibroblast in the epineurium.
- **Muscular line lesions**

  It is a heterogeneous group of lesions, which in a few cases (vascular leiomyoma, alveolar rhabdomyosarcoma) have a privileged place in the district ankle-foot.

  - **Benign tumors of smooth muscle:** they are the *vascular leiomyoma* (it origins from the tunica media of vessels with vascular channels and proliferation of smooth muscle cells) and the *hemangioma* (it typically contains fat, smooth muscle, fibrous tissue, calcification, hemosiderin).

  - **Malignant neoplasms of smooth muscle:** it is the *leiomyosarcoma* (infiltrative and aggressive mass with heterogeneous signal, due to the intralesional hemorrhage and necrosis).

  - Among the *malignant striated muscle neoplasms*, the alveolar and pleomorphic variants of *rhabdomyosarcoma* are the most represented variant at the ankle and foot.

- **Fibrohistiocytic lesions**

  - **Malignant fibrous histiocytoma (MFH):** it origins from a primitive mesenchymal cell, with markers of histiocytoid differentiation. It is the most common sarcoma of the foot after synovial sarcoma. MR imaging are not specific: solid soft tissue mass with characteristics of signal intensity dependent upon the variable amount of collagen, necrosis and hemorrhage.

  - Particular attention is given to mixofibrosarcoma and fibromixoid sarcoma. In absence of contrast media, when the *myxofibrosarcoma* is small, it can mimic a simple bursitis for the myxoid component (as well as sinovialsarcoma for cystic component), *(Fig 41,42)*. In *(Fig 43,44,45,46)* we illustrate a *fibromyxoid sarcoma* which, being low-grade, has remodeled the bone without a true aggressive osteolysis.

- **Chondro-osseus lesions**

  - **Chondroma:** benign extraosseous and extrasynovial soft tissue tumor, composed primarily of mature hyaline cartilage.

  - **Extraskeletal osteosarcoma**

    - **Extraskeletal chondrosarcoma:** also called extraskeletal myxoid chondrosarcoma. The main types include convenzional (medullary), clear cell, mesenchymal and dedifferentiated chondrosarcoma.

    - **Others**
- **Lymphoma**: primary lymphoma of soft tissue is extremely rare; patients with lymphoma may present with a palpable mass, simulating a soft tissue sarcoma. They have no tendency to intralesional necrosis (Fig 47,48,49,50).

- **Extraskeletal Ewing sarcoma**: it is a very aggressive PNET tumour.

- **Myopericytoma**: it is a rare perivascular neoplasm with intermediate aggressiveness that arises from pericytes, contractile spindle cells, surrounding capillaries and postcapillary venules (Fig 51,52,53,54).

- **Clear cell sarcoma**: it is a rare malignant tumour of uncertain differentiation, called also malignant melanoma of soft parts because 50% of these lesions produces melanin (Fig 55,56).

- **Phosphaturic mesenchymal tumour**: this is a rare mesenchymal tumor whose cells produce a humoral factor (phosphatonin) that reduces renal tubular resorption of phosphate, resulting in osteomalacia (oncogenic osteomalacia) (Fig 57,58,59).

**Table n.1**

<table>
<thead>
<tr>
<th>Histology</th>
<th>N° cases</th>
<th>Median age (years)</th>
<th>Site</th>
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<tr>
<td>TUMOR LIKE-CONDITIONS</td>
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<td>50</td>
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<tr>
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<td>Hyperkeratosis</td>
<td>70</td>
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<td>27</td>
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<td>Pigmented villo nodular synovitis (PVNS)</td>
<td>47</td>
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<td>1 tarsal region</td>
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<td><strong>Phosphaturic mesenchymal tumor</strong></td>
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Fig. 0: Morton neuroma Coronal, short-axis T1 weighted demonstrates two localization (III and IV intermetatarsal space) of rounded nodules, plantar to the transverse metatarsal ligament, with hypointense signal.

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Fig. 0: Morton neuroma The Coronal, short-axis T2 weighted images better demonstrates the nodule (rounded hypointense signal) localized on the IV intermetatarsal space than the other one, small, on the III intermetatarsal space.
Fig. 0: Morton neuroma Coronal, short-axis STIR image demonstrate a moderate hyperintensity of the nodules.
**Fig. 0:** Hyperkeratosis Coronal long-axis T1 weighted image shows extended solid formation in the subcutaneous tissue of distal phalanges of all fingers except the first, with low-intermediate signal intensity.

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**Fig. 0:** Hyperkeratosis Coronal short-axis T1-weighted image shows extended solid formation in the subcutaneous tissue of distal phalanges of all fingers except the first, with low-intermediate signal intensity

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**Fig. 0:** Hyperkeratosis Coronal short-axis T2 weighted image shows inhomogeneous hypointensity signal

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Fig. 0: Hyperkeratosis STIR image shows inhomogeneous hypointensity signal.

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**Fig. 0:** Hyperkeratosis Contrast-enhanced Coronal short-axis T1 weighted shows diffuse heterogeneous enhancement.

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Fig. 0: Synovial chondromatosis Axial T2 weighted image of the ankle shows multiple rounded hypointense formations referable to calcifications and hyaline cartilage.

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**Fig. 0:** Synovial chondromatosis Axial STIR shows hypointense multiple chondromatosis nodules in the anterior recess of the ankle joint.

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**Fig. 0:** Synovial chondromatosis Axial STIR shows two small calcified formations close to the anterior talar-fibular ligament.

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**Fig. 0:** Synovial chondromatosis Sagittal T1 weighted image shows multiple hyaline cartilage nodules in the anterior recess of the tibial-tarsal joint.

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**Fig. 0:** Synovial chondromatosis Sagittal STIR image confirms the hypointense chondromatosis nodules surrounded by a thin effusion in the anterior recess.

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Fig. 0: Pigmented villonodular synovitis (PVNS) or diffuse type of giant cell tumor Axial T2 weighted image shows low signal intensity areas (corresponding to deposits of hemosiderin) from subtalar joint to lateral compartment.

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**Fig. 0:** Pigmented villonodular synovitis (PVNS) or diffuse type of giant cell tumor. Axial STIR image shows a hypointense soft tissue from subtalar joint to lateral compartment.

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**Fig. 0:** Pigmented villonodular synovitis (PVNS) or diffuse type of giant cell tumor Coronal Gradient-echo image shows low signal intensity soft tissue involving subtalar joint, with bone erosions on both sides of the joint.

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Fig. 0: Pigmented villonodular synovitis (PVNS) or diffuse type of giant cell tumor Sagittal T1 weighted image shows mixed intermediate to low signal intensity soft tissue in the ankle. The lesions cause a erosion of calcaneous and astragalus.

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**Fig. 0:** Pigmented villonodular synovitis (PVNS) or diffuse type of giant cell tumor. Contrast-enhanced sagittal T1 weighted image shows the focal persistent low signal intensity because of the hemosiderin deposits within the inflamed enhanced synovial.

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**Fig. 0:** Synovial sarcoma Axial TSE T2 weighted image shows deep, lobulated, large soft tissue mass that is in close relationship with joint capsule and invade anterior and lateral compartments. The mass is inhomogenous hypointense relative to subcutaneous fat.

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**Fig. 0:** Synovial sarcoma Axial TSE T2 weighted image demonstrate also the coexistence of solid and fluid tissue.

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**Fig. 0:** Synovial sarcoma Sagittal SE T1 weighted image shows two round intrarticular lobulated lesions with inhomogeneous low signal intensity.

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**Fig. 0:** Synovial sarcoma Sagittal SE T1 weighted image after gadolinium contrast injection. Discrete contrast enhancement is seen within the lesion.

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**Fig. 0:** Giant Cell Tumor of the extensor tendon sheath Axial T2 weighted image shows a solid nodule, with typical heterogeneous hypointensity compared to adipose tissue (for the presence of hemosiderin) and with a characteristics rim of low signal intensity around the nodule.

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Fig. 0: Giant Cell Tumor of the extensor tendon sheath Sagittal STIR image shows a subtle hyperintensity

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**Fig. 0:** Giant Cell Tumor of the extensor tendon sheath In Sagittal T1 weighted image show a well circumscribed mass, isointense to muscle.

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**Fig. 0:** Schwannomas Axial T2 weighted image shows a well defined bordered little mass around the course of a nervous branch that can be observed at the periphery of the lesion, which typically has a target appearance.

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**Fig. 0:** Schwannomas In Coronal GE image the schwannoma is hyperintense

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**Fig. 0:** Schwannomas Sagittal STIR image shows the alignment along the nerve and the hyperintensity at the periferic area

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Fig. 0: Nodular fasciitis Coronal short-axis T2 weighted image shows a delimited nodule in the subcutaneous tissue inseparable from the plantar fascia, slightly hyperintense compared with muscle. The nodule is surrounded by a hypointense rim.

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Fig. 0: Nodular fasciitis Sagittal T1 weighted image shows the fibrous nodule in the subcutaneous tissue on the external side of the plantar fascia, isointense with the muscle.

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**Fig. 0:** Nodular fasciitis. In Sagittal STIR the nodule appear slightly hyperintense compared with muscle.

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Fig. 0: Extra-abdominal aggressive fibromatosis Coronal, short-axis T2 weighted shows solid well-defined mass at the level of the plantar region (at the II and III metatarsal), with low signal intensity within correspond to deposits of hemosiderin.

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**Fig. 0:** Extra-abdominal aggressive fibromatosis Coronal short-axis STIR image demonstrates a hypointensity of the lesion.

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Fig. 0: Extra-abdominal aggressive fibromatosis Sagittal T1 weighted image shows hypointensity of the lesion; multiple images of similar appearance are also welcome within soft tissue of the ankle and tarsus region.

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**Fig. 0:** Extra-abdominal aggressive fibromatosis Contrast-enhanced sagittal T1 weighted image shows a moderate heterogeneous contrast enhancement of all lesions

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Fig. 0: Lipoma Axial T2 weighted image of the ankle shows a voluminous well encapsulated lesion in relationship with the tendons of the flexors; the tibial nerve is "pluckers" in lipoma itself. It is present the signal intensity similar to subcutaneous fat.

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**Fig. 0:** Lipoma Axial STIR weighted image shows complete suppression of the signal.

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Fig. 0: Lipoma Sagittal T1 weighted image: the lesion is isointense to subcutaneous adipose tissue

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**Fig. 0:** Lipoma Sagittal STIR weighted image shows complete suppression of the signal.
**Fig. 0:** Lipoma Coronal Gradient-echo weighted image of the ankle shows longitudinal extension of the lipoma, medial to the flexor hallucis longus tendon

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Fig. 0: Mixofibrosarcoma Coronal short-axis STIR image: the third metatarsal space is employed by a hyperintense lesion which, in the absence of contrast medium and small size, can mimic a simple bursitis for the myxoid.

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Fig. 0: Mixofibrosarcoma Coronal short-axis TSE T2 shows high signal intensity of soft tissue in the third metatarsal space
**Fig. 0:** Fibromixoide sarcoma AP radiograph of the forefoot shows remodeling of the distal phalanx of II finger

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Fig. 0: Fibromixoide sarcoma Sagittal T1 weighted image shows a lesion of low-intermediate signal

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Fig. 0: Fibromixoide sarcoma Sagittal STIR weighted image shows subtle and inhomogeneous iperintensity

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Fig. 0: Fibromixoide sarcoma Contrast-enhanced sagittal T1 weighted image shows a moderate heterogeneous contrast enhancement of the lesion.

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Fig. 0: Lymphoma Axial T1 weighted image of ankle shows a lesion with homogeneous signal hypointense compared with muscle.

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**Fig. 0:** Lmphoma Sagittal T1 weighted image shows a mass infiltrating fibers of the plantar muscle.

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**Fig. 0:** Lymphoma Sagittal STIR image demonstrates the lesion with signal intensity, with slightly hyperintense signal intensity for the high cellularity.

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**Fig. 0:** Lymphoma Coronal STIR image of ankle shows a large mass with slightly high signal intensity than the adjacent muscles. There are no signs of necrosis or hemorrhage.

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Fig. 0: Miopericitoma Coronal T2 weighted image of ankle demonstrates in medial side, a well-defined, oval-shaped lesion with inhomogeneous signal hyperintense to muscle. Irregular high intensity areas are seen within these lesion.

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**Fig. 0:** Miopericitoma Axial STIR image of ankle shows inhomogenous appearance of the ovoid soft tissue mass, nearly hyperintense with adjacent structures. The mass causes distortion of the soft tissue.

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**Fig. 0:** Miopericitoma Axial T1 weighted image of ankle shows well delineated, ovoid, nearly homogeneous mass lesion medial to the talus. The mass has low signal intensity, with punctate zones with signal void in the posterior side of lesion.

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Fig. 0: Miopericitoma Contrast-enhanced axial T1 weighted of ankle. The pattern of enhancement is inhomogeneous: the strongest enhancement is observed at the periphery of the tumor.

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**Fig. 0:** Clear cell sarcoma Sagittal T1 weighted image of a rounded mass, in plantar aspect of fist finger, demonstrates nearly dishomogeneous appearance with low signal intensity in major portions of the tumor.

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Fig. 0: Clear cell sarcoma On the sagittal STIR image the lesion appears homogeneous well-defined borders, lacks perilesional edema, bone invasion or intratumoral necrosis. The tumor tissue can demonstrate a wide spectrum of signal intensities.

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**Fig. 0:** Phosphaturic mesenchymal tumor Coronal short-axis T1 weighted image. Presence of a mass nearly dishomogeneous appearance with low signal intensity in major portions of the tumor.

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**Fig. 0:** Phosphaturic mesenchymal tumor Coronal short-axis T2 weighted image shows within the subcutaneous fat layer of medial plantar area a mass hypointense.

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**Fig. 0:** Phosphaturic mesenchymal tumor Coronal short-axis STIR image. The gross appearance of the tumour is much more outlined and presents low signal intensity.

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Conclusion

Some benign (e.g. giant cells tumor) and malignant (e.g. synovial sarcoma) histological types of soft tissue tumours of the foot are more represented than others. Their appearance does not have typical MRI characteristics because sometimes the lesions become apparent earlier than in other districts, because of the small thickness of the superficial tissues. Therefore, their location (juxta-articular, juxta-tendon) is crucial for the differential diagnosis.
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