Imaging of the foot in rheumatoid arthritis

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Learning objectives

- To review the imaging findings of rheumatoid arthritis (RA) in the foot, concerning the forefoot, midfoot, hindfoot and ankle, with special emphasis on conventional radiography and magnetic resonance imaging (MRI).

- To review the basics of the mechanics of foot deformities in RA.

Background

Rheumatoid Arthritis

RA is a symmetric polyarticular disease affecting the synovial joints of the appendicular skeleton (proximal interphalangeal joints of the hands, metacarpophalangeal joints, wrist, metatarsophalangeal joints, posterior and plantar aspect of the calcaneus, knee, elbow, glenohumeral joint, acromioclavicular joint, ankle and hip). The cervical spine is also commonly involved.

In most cases, imaging findings are nonspecific, and may also be found in other inflammatory arthropathies. On the other hand, distinguishing RA involvement from degenerative osteoarthritis, post-traumatic or neuropathic changes may be difficult.

The most important issue is the pattern of articular involvement and its distribution, which is very characteristic and typical for RA and allows an adequate diagnosis in most cases.

Findings and procedure details

Imaging Methods

In order to optimize long-term outcome, early aggressive therapy is essential. It is thus necessary to have an early diagnosis and sensitive disease monitoring.

Imaging methods have an important role in the evaluation of RA.
Conventional radiography is still the first imaging study to be performed, because of its low-cost, high availability and reproducibility.

Weight-bearing views are required to evaluate foot deformities: a weight-bearing lateral foot radiograph must include the ankle and may demonstrate involvement of the subtalar, talonavicular or calcaneocuboid joints.

Conventional radiography remains important to differentiate early RA from other joint conditions, and to monitor progression.

Disadvantages:

- Gives little information in the early phase of the disease, as some changes may take months or years to manifest, and then it may be too late for a timely treatment.
- It is relatively insensitive for early osseous damage and completely insensitive for soft tissue changes like synovitis.

Imaging findings on conventional radiography (Fig.1,2):

- Fusiform soft tissue swelling
- Regional or periarticular osteoporosis: regional osteoporosis is common in inflamed joints and is initially periarticular
- Concentric joint space narrowing: progressive destruction results in bony ankylosis
- Bone cysts
- Marginal and central bone erosions

Computed Tomography (CT) is useful in the detection of bone erosions. The projectional superimposition of structures seen on conventional radiography does not occur with CT. Given the advantages of other imaging methods, CT does not seem to be an important tool in the evaluation of RA patients.

Ultrasound is useful in the evaluation of joint, tendons and bursal involvement. It can visualize inflammatory and destructive changes.

Magnetic Resonance Imaging
MRI is very sensitive in the detection of medullary bone marrow edema and permits early detection of bone erosions (up to three years before conventional radiographs). The use of paramagnetic intravenous contrast agent is indicated for the detection of synovial thickening and areas of abnormal enhancement.

MRI findings, such as synovitis, bone edema and erosions, may predict subsequent radiographic erosive disease progression.

MRI in early RA can help identify patients with aggressive disease, thus permitting the use of targeted therapies in these patients.

In the future, MRI may help in the differential diagnosis of an early arthritis, be important in monitoring therapeutic response, and in the prognostication of patients.

**Imaging findings on MRI:**

- **Synovitis**: manifests as synovial hyperemia (which enhances after contrast administration) and an increase in the volume of synovial fluid; it indicates acute inflammation (Fig.3).
- **Fibrotic pannus**: manifests as a relatively hypovascular soft tissue mass in close proximity to an erosion; indicates a latter phase in the inflammatory process (Fig.4).
- **Joint effusion**
- **Bone marrow edema** predominantly periarticular: has been shown to precede erosive damage.
- **Erosions** (Fig.5) and **subchondral cysts**: these constitute osseous defects; it is thought that subchondral cysts in RA may constitute "pre-erosions" and eventually progress to erosions; MRI is much more sensitive to its detection than conventional radiographs, and contrast enhancement permits the distinction between erosions / pre-erosions and degenerative subchondral cysts.
- **Intra-articular loose bodies** (Rice bodies): these are common and characteristic findings in RA and include bone and cartilage fragments.
- **Reduced thickness of the cartilage**

**Para and extra-articular findings:**

- **Tendons**: tendon sheath synovitis, tendinitis and rupture
- **Bursas**: synovitis, erosions of the adjacent bone; the retrocalcaneal bursa is frequently involved
- **Subcutaneous tissues**: rheumatoid nodules (Fig.6)

These are granulomatous lesions with central necrosis and occur in 20% of RA patients. They occur in the subcutaneous soft tissues in areas subject to trauma and overlying
bursas, joints, tendons and ligaments. They are more common in the upper limbs and less frequent in the foot, typically in pressure points (heel, plantar aspect of the metatarsal heads).

- The MRI characteristics are nonspecific and include nodular areas isointense to muscle on T1 and intermediate heterogeneous signal/hyperintense on T2. The enhancement pattern may include homogeneous enhancement or heterogeneous signal with peripheral enhancement in lesions with central necrosis.

  - **Bone**: osteopenia, insufficiency fractures (Fig.7), avascular necrosis
  - **Peripheral neuropathy**
  - **Generalized edema**

**Rheumatoid Arthritis in the foot**

In decreasing order of frequency, RA in the foot affects the forefoot, midfoot, hindfoot and ankle.

**Forefoot**

Forefoot changes are common in RA, affecting 80-90% of patients and may be the initial manifestation in 10-20%. Erosions appear earlier and more frequently in the feet (90%) than in the hands (75%). The metatarsophalangeal joints of the lateral fingers are more commonly involved. Intermittent or persistent pain and soft tissue swelling may be prominent.

- **Location of the erosions and soft tissue swelling:**

  The initial manifestations occur at the **metatarsophalangeal joints**, particularly in the fifth. These changes predominate in the medial and plantar aspect of the metatarsal heads, except the fifth toe, where the soft tissue swelling and erosions predominate in the medial and lateral aspect of the metatarsal head (Fig.8,9,10). This may be a very early and important manifestation of the disease.
The fifth metatarsal head is the most affected and the first is the less affected (Fig.11). Early osseous erosions may also be present in the medial aspect of the distal portion of the proximal phalanx of the hallux.

- **Destruction of metatarsal heads**

As the disease progresses, more metatarsal heads are involved with progressive destruction. Rarely there may be complete destruction of one or more metatarsal heads (Fig.12).

- **Involvement of the hallux**

The metatarsophalangeal joint of the hallux is the less affected. Changes in the hallux occur in the metatarsal head and in the proximal phalanx near the metatarsophalangeal joint and include osteoporosis, joint space narrowing and erosion of the adjacent sesamoids.

The frequency of *hallux valgus* increases with the duration of the disease, with subluxation of the sesamoids between the 1\(^{st}\) and 2\(^{nd}\) metatarsal heads (Fig.13).

Other changes may be present in the hallux, such as the *hallux rigidus*, which manifests as decreased or absent dorsiflexion of the first metatarsophalangeal joint secondary to fibrosis or bony ankylosis (Fig.14).

*Characteristic deformities of the forefoot (Fig.15,16):*

- Metatarsal spreading
- *Hallux valgus*
- Lateral deviation of the toes in the metatarsophalangeal joints

- The frequency of deformities in the second, third, fourth and fifth metatarsophalangeal joints increases with the duration of the disease, and after ten years almost all patients are affected.

- The misalignment of the metatarsophalangeal joints is typical of the more advanced phases, with lateral deviation of the first, second, third and fourth and *quintus varus*, thus defining the **triangular deformity** of the forefoot.
All types of finger deformities may be present

- Hammer toe: flexion deformity of the proximal interphalangeal joint with extension of the distal interphalangeal joint.

- Claw toes: flexion deformity of the proximal interphalangeal joint only (Fig.17).

- Swan-neck deformity: hyperextension of the metatarsophalangeal joint with flexion of the proximal interphalangeal joint (Fig.18).

- Cock-up

Other deformities of the forefoot include:

- Lateral deviation of all toes
- Monoarticular variants (rare)
- Lateral deviation of all toes except the hallux
- Tibial deviation of the toes

Midfoot

Midfoot changes are common and almost always associated with metatarsophalangeal changes. They are less characteristic than the forefoot changes, appear later and are more asymmetric.

Soft tissue swelling is common due to joint effusion, synovial pannus and periarticular edema and may be irreversible.

There may be degenerative changes in the midfoot, sometimes before the inflammatory changes of RA (Fig.19,20).

There is predilection for the talocalcaneonavicular joint, with diffuse joint space narrowing, focal sclerosis and osteophytosis. The erosions are small and infrequent. The tarsal erosions that are not in the posterior and inferior aspect of the calcaneus are uncommon, and less common in RA than in the negative spondyloarthropathies. The cuneonavicular, intercuneiform, cuneocuboid and cuboideonavicular joints are also frequently involved.
The adjacent sesamoid bones may also be affected.

**Osseous or fibrous ankylosis** may occur and exceptionally involve all tarsal bones (Fig.21).

The **talo-crural joint involvement** may be associated with tarsal sinus (Fig.22) and tarsal tunnel syndromes:

- The tarsal tunnel, with the posterior tibial nerve, is often compressed with synovitis.

The most common midfoot deformity in RA is **pes planovalgus** (Fig.23). The transverse arch becomes flatter due to the ligamentous laxity caused by local inflammation. It is initially flexible and subsequently becomes rigid. The incidence of flat foot is higher in the feet affected with tarsitis. The alignment of the forefoot and the hindfoot can be estimated by tracing a line along the longitudinal axis of the first metatarsal which must be aligned with the longitudinal axis of the talus.

- Posterior tibial tendon dysfunction with edema and swelling is common (Fig.24,25): posterior tibial tendon dysfunction is the most common cause of acquired flat foot deformity; inflammatory arthritis is one of the causes of posterior tibial tendon dysfunction; there may be rupture of the inflamed posterior tibial tendon.

- Anterior tibial tendon tenosynovitis (Fig.26), tendinitis and rupture may complicate the process, contributing to joint destabilization.

**Heel**

**Retrocalcaneal bursitis** (Fig.27)

Manifests clinically as a fluctuating mass which extends to both sides of the Achilles tendon.

On conventional radiography, it is a soft tissue mass in the postero-superior aspect of the calcaneus which obliterates the normal radiolucent region between the calcaneus and the Achilles tendon, and projects inferiorly in the pre-Achilles fat pad.
Adjacent erosions in the posterior and superior aspect of the calcaneus are characteristic.

**Tendinosis, peritendinitis and paratenonitis (Fig.28)**

Manifests clinically as pain and swelling of the Achilles tendon. On conventional radiography, Achilles tendinosis leads to enlargement and blurring of the tendon limits.

Changes in the insertion of the plantar aponeurosis and the Achilles tendon may occur. Changes in the Achilles tendon and its insertion on the hindfoot are best visualized on MRI: the tendon becomes thickened and is surrounded by edematous fat; the erosions are visualized as cortical defects, usually with surrounding edema.

**Rupture of the Achilles tendon** is rare.

**Plantar fasciitis (Fig.29)**

Manifests clinically as flushing and swelling of the plantar aspect of the calcaneus, usually in close proximity to its insertion in the antero-medial calcaneal tuberosity.

On MRI, there is thickening of the plantar fascia (hyperintense on T2 and hypointense on T1), soft tissue and adjacent bone marrow edema, and osseous erosions in the plantar aspect of the calcaneal tuberosity.

**Periostitis manifesting as calcaneal spurs (Fig.30)** occurs in the plantar aspect of the calcaneus. It is less common in RA than in the seronegative arthropathies and can occur before or after erosions. They are more irregular and fluffy when compared to the small and well-corticated degenerative spurs.

**Ankle**

Changes in RA are less frequent in the ankle than in other locations.
Talocrural arthritis

Occurs later, and almost always associated with tarsal involvement.

Joint space narrowing occurs more frequently in the lateral aspect of the joint.

A tibial cyst may be present, as well as synovitis, which manifests as soft tissue swelling, limitation of movement and pain.

Accessory bones may also become affected by the inflammatory process, especially the os tibiale, os trigonum (Fig.31) and fibular accessory ossicle.

Foot deformity

Inflammatory synovitis is the initial and predominant factor that leads to weakening of the structures that gives support to the foot (joint capsules, ligaments, tendons and certain muscles).

In this context of fragility, common mechanical stresses predispose to deformity. Mechanical stresses such as footwear may cause stress to the foot or fail to support it. Weight-bearing is particularly harmful during inflammatory crisis. The most affected structures are the metatarsals, subtalar joint complex and the tendon of the tibialis posterior muscle.

In some cases, the healing process with postinflammatory contracture has an important role in the cause of the deformity.

At a later stage, there is osteoarticular destruction with subsequent dislocation or ankylosis.

All these factors increase muscular imbalance between flexor and extensor muscles and abductor and adductor muscles. The eccentric action of these muscles gives rise to deformity.

The toes deformities depend on mechanical factors (Fig.32): the medial arch flattening (that occurs with flat foot) and forefoot spreading increases the tension of the short flexor tendons, which passively flex the proximal interphalangeal joints.
The proximal phalanx is not subject to the action of the flexor muscles, so the extensor tendons perform greater strength in the proximal phalanges.

In the end of this process, the metatarsal heads are located inferiorly to the proximal phalanx (Fig.33).

The other ligamentous supporting structures (capsule and ligaments) are also weakened and the dislocation of the first phalanx is accentuated.

Osseous and cartilaginous destruction worsens the deformities and the healing process with secondary fibrosis can make it fixed.

**Lateral deviation of the toes** is mainly due to the role of the *extensor digitorum brevis* tendons (Fig.34). The medial arch flattening and the forefoot abduction (*pes planovalgus*) deviates the traction axis of this muscle laterally and upwards; the lateral deviation of the toes occurs in this way. The lateral deviation of the toes decreases from the first to the fourth toe.

The fifth toe is not subject to the action of the extensor digitorum brevis, but is particularly subject to footwear injury as well as other factors (Fig.35).

Clawed toes and metatarsophalangeal joint subluxation completes the scenario.

The deformity is initially flexible but soon it becomes fixed.

With the subluxation of the metatarsophalangeal joints, the toes lose their role in the walking process, which is responsible for the formation of callus and bursitis.

**Images for this section:**
Fig. 1: Periarticular osteoporosis
Fig. 2: Erosions and joint space narrowing

Fig. 3: Synovitis (Proton density MRI)
**Fig. 4:** Fibrotic pannus (MRI. Left: T1; right: contrast-enhanced T1)

**Fig. 5:** Erosions (MR images. left: T1; right: top-T1, middle-T2, bottom- contrast-enhanced T1)
Fig. 6: Rheumatoid nodules (MR images. Left: T1; middle and right: contrast-enhanced T1)
Fig. 7: Insufficiency fracture in the 3rd metatarsal bone

Fig. 8: Typical location of the erosions and soft tissue swelling.
Fig. 9: Erosion on the lateral aspect of the left 5th metatarsal head, often the first affected site.
Fig. 10: Erosions
Fig. 11: Erosions on the first metatarsal head.
Fig. 12: Destruction of metatarsal heads
**Fig. 13:** Hallux valgus with subluxation of sesamoid bones
**Fig. 14:** Hallux rigidus

**Fig. 15:** Metatarsal spreading, hallux valgus and triangular deformity of the forefoot.
**Fig. 16:** Lateral deviation of the toes in the metatarsophalangeal joints, metatarsal spreading, hallux valgus, triangular deformity of the forefoot

**Fig. 17:** Claw toes: flexion deformity of the proximal interphalangeal joint only.
**Fig. 18:** Swan-neck deformity: hyperextension of the metatarsophalangeal joint with flexion of the proximal interphalangeal joint.

**Fig. 19:** Degenerative changes in the midfoot
Fig. 20: Degenerative changes in the midfoot (T1-MRI)
**Fig. 21:** Osseous fusion

**Fig. 22:** Tarsal sinus syndrome (MRI. Left: proton density; right: T1)

**Fig. 23:** Pes planovalgus
Fig. 24: Posterior tibial tendon tenosynovitis (T2 MRI)

Fig. 25: Posterior tibial tendon partial tear (Proton density MRI)
Fig. 26: Anterior tibial tendon tenosynovitis (MR images. Left: T1; right: STIR)
Fig. 27: Retrocalcaneal bursitis (Proton density MRI)
Fig. 28: Achilles tendon tendinosis (MRI. Left: T1; right: STIR)
Fig. 29: Plantar fasciitis (STIR MRI)
Fig. 30: Periostitis manifesting as calcaneal spurs

Fig. 31: Erosions in os trigonum
**Fig. 32:** Short flexor tendons (1) passively flex the proximal interphalangeal joints. The extensor tendons (2) perform greater strength in the proximal phalanges.

**Fig. 33:** In the end of this process, the metatarsal heads are located inferiorly to the proximal phalanx.
**Fig. 34:** Lateral deviation of the toes is mainly due to the role of the extensor digitorum brevis tendons (1).
Fig. 35: The fifth toe is not subject to the action of the extensor digitorum brevis, but is particularly subject to footwear injury.
Conclusion

• In decreasing order of frequency, RA in the foot affects the forefoot, midfoot, hindfoot and ankle.

• Changes in the forefoot are common in RA, and may be the initial manifestation of the disease.

• Soft tissue swelling and erosions predominate in the medial and plantar aspect of the metatarsal heads, except the fifth toe, where the changes are in the medial and lateral aspect.

• Characteristic deformities include metatarsal spreading, hallux valgus and lateral deviation of the toes in the metatarsophalangeal joint.

• All types of finger deformities may be present.

• Midfoot changes are common but less characteristic than forefoot changes and erosions are infrequent.

• Pes planovalgus is the most common midfoot deformity in RA.

• Changes in the heel include retrocalcaneal bursitis, tendinosis, peritendinitis and paratenonitis of the Achilles tendon, plantar fasciitis and calcaneal spurs.

• RA changes are less frequent in the ankle than in other locations.

Personal information

References