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Review

Value of magnetic resonance imaging in monitoring Achilles tendon healing after percutaneous suture using the Dresden technique

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Abstract

Purpose: Tendon healing is a complex process taking place in several stages. There is a paucity of data on tendon morphology after percutaneous repair for acute Achilles tendon rupture.
Materials and methods: We used high field MRI (1.5 Tesla to 3 Tesla) with T1 and T2-weighted sequences including fat suppression to assess the healing process after percutaneous Achilles tendon repair using the Dresden technique. MRI was performed at 3, 6, 8 and 12 months postoperatively.
Results: During tendon repair a gradual transition from an irregular and hyperintense signal toward a more homogeneous and hypointense signal was observed inside the Achilles tendon after percutaneous repair. These changes took place centripetally. During the early and late remodeling phase at 6 and 12 months, respectively, the tendons look thickened and homogeneous in both sequences.
Conclusions: MRI represents an excellent means of monitoring the healing process after percutaneous Achilles tendon repair. The results of the present study confirm that the percutaneous, peritendineum preserving technique with the Dresden instrument results in a near physiologic centripetal tendon healing.

Introduction

The use of minimally invasive surgical techniques for Achilles tendon repair has lead to a redefinition of radiographic findings when using mainly magnetic resonance imaging (MRI) to monitor the repair process and tendon regeneration with more sensitivity and specificity.

Publications in the medical literature mostly describe repair-related changes associated with the use of open suture techniques. To learn about the technique described in this report is important to

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understand the imaging findings in later controls and to learn which data to look at for adequate recovery of tendon function.

MRI has excellent contrast resolution for the assessment of both the normal and repaired Achilles tendon.

Imaging techniques

We used high field MRI (1.5 Tesla to 3 Tesla) mainly with the use of basic sequences to assess the anatomy and different tissues found during repair. T1 weighted sequences are used most widely. The continuity of the normal tendon can be seen with low signal intensity (black) contrasting very well with the high intensity (light) of the fat layers of the paratenon and Kager's fat pad as well as the musculotendinous junction with the soleus.

T2 weighted sequences with either fat suppression or fat saturation acquisition depict fat tissue and the healthy tendon as black or hypointense, with a clear contrast to the disrupted areas, edema, residual fluid collections, hematoma or areas of chronic mucoid degeneration which are light or hyperintense.

It is also useful to assess the edematous changes in the paratenon and Kager's fat pad as well as soleus muscle edema which typically changes due to the advancement of needles when using this technique. The insertion of the calcaneus may also be studied in these cases to define insertional changes which might be pre-existing or occur during recovery (Fig. 1).

Intravenous contrast media (gadolinium DTPA) is used only when suspecting a severe complication such as surgical wound dehiscence, intra-tendinous abscess formation, tendon, soft tissue, or muscle infection. In general, as these complications are uncommon, gadolinium injection is rarely used.

Several planes are obtained when performing an MRI scan. The sagittal and the axial plane provide most information on the Achilles tendon and its insertion while the coronal plane does not provide any relevant additional information. It is important to use a wide FOV (field of view) mainly in the cranio-caudal direction in order to include the muscular structures of the triceps surae, especially the soleus and the distal insertion of the tendon.

Ultrasound (US) imaging is an excellent technique for an early assessment of pre- and post-surgical changes providing a dynamic, real-time examination [1]. However, it is operator-dependent and therefore an examiner with adequate training in US imaging must be in charge of the pre- and post-surgical assessment as this method is not reproducible for inter-physician consultation. It is therefore most useful if the physician designing the treatment approach based on the US findings is the one performing the US imaging. In many countries this is not feasible and surgeons must refer patients to a radiologist and rely on the written report.

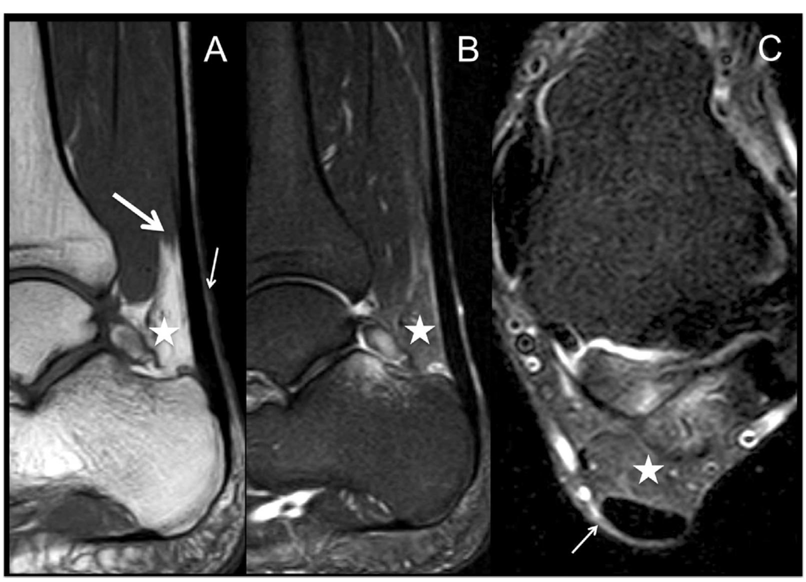

Fig. 1. MRI of a healthy Achilles tendon. (A) T1 weighted sagittal sequence displaying a normal signal of the tendon and the musculotendinous junction of the soleus (big arrow), the paratenon (small arrow) and Kager's fat (asterisk). T2 weighted sequences with fat suppression in the sagittal (B) and axial (C) plane. The tendon, paratenon and Kager's fat are identified as normal. Note the bone marrow edema in the os trigonum and adjacent calcaneus as a sign of local irritation by the accessory bone.

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In contrast, MRI scans are recorded or shared in a Digital Imaging and Communications in Medicine (DICOM) format and may be analyzed together with other health care professionals for easier interpretation. For this reason, in many instances, MRI is the best option for postoperative controls.

Early stages of tendon healing

The available literature typically describes changes seen in the MRI at one year after surgery [2]. However, the sutured tendon undergoes several stages during healing, such as the inflammatory stage, repair stage and remodeling stage. It is therefore reasonable to use imaging throughout this process to obtain more detailed information about tendon healing.

Twenty-four hours after surgery, the inflammatory stage begins with migration of white blood cells to the repaired area followed by angiogenesis and tenocyte proliferation for adequate collagen synthesis. Maximum levels of activity will occur in the following weeks (1—2 months) during the repair stage. Approximately 3 months after surgery, transition between repair and remodeling occurs, when the repairing cell tissue turns into fibrous tissue. This process starts at three months, plateaus at about 6 months, and persists for about one year after surgery. It is important to effectively identify complications during the first, vulnerable stages in order to achieve good final remodeling for good tendon function and to prevent rerupture [3].

An MRI scan one month after surgery might seem too early and therefore unnecessary due to the inflammation resulting in a diffuse edema around the rupture site. However, it is a useful tool to assess surgical aspects, correct mistakes and make improvements, determine the early residual gap as compared with the previous study and verify

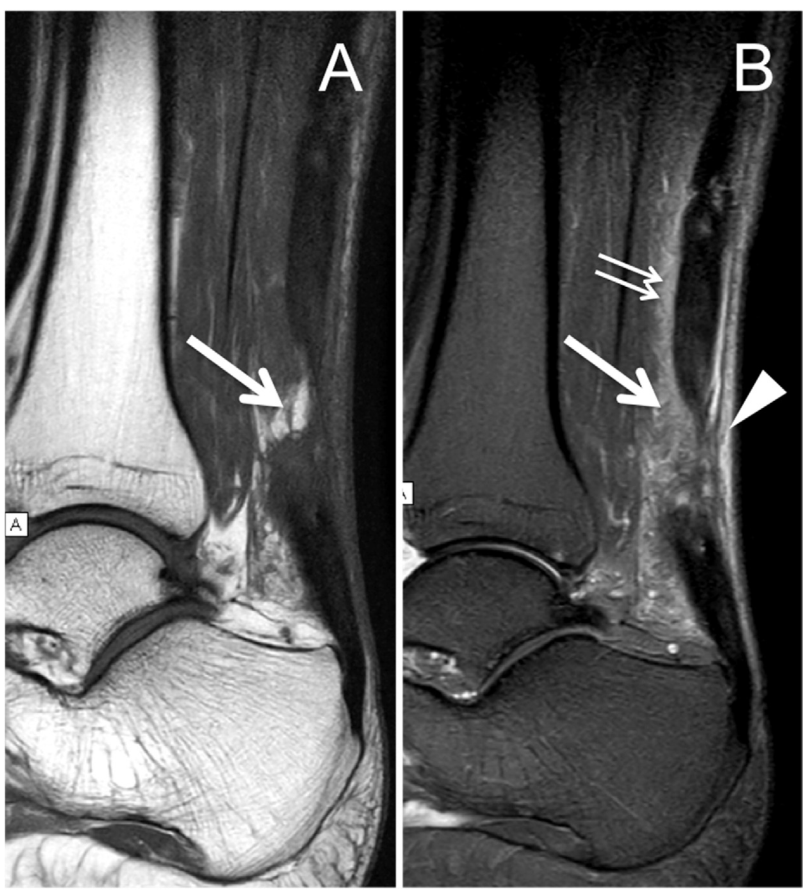

Fig. 2. MRI control at one month postoperatively showing the different sequences, signal changes in the gap without dehiscence or fiber retraction. (A) T1 weighted sequences shows an area of hyperintense signal (arrow). (B) T2 weighted sequences show a slight hyperintense signal in the same area (arrow) corresponding to a postoperative edema. No fluid collections are observed in the paratenon, only edema in the anterior paratenon (double arrow in B) and in the soft tissue posterior to the Achilles tendon (arrowhead in B).

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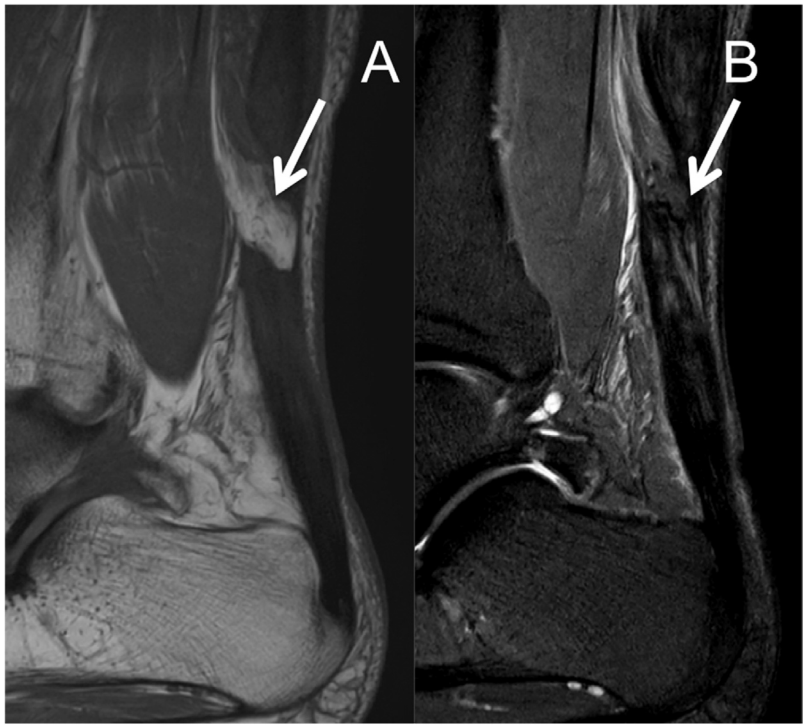

Fig. 3. (A) T1 weighted sequence showing hyperintense soft tissue interposition in the tendon at the level of the suture (arrow). (B) The T2 weighted sequence with fat suppression shows a decreased signal in the corresponding area (arrow).

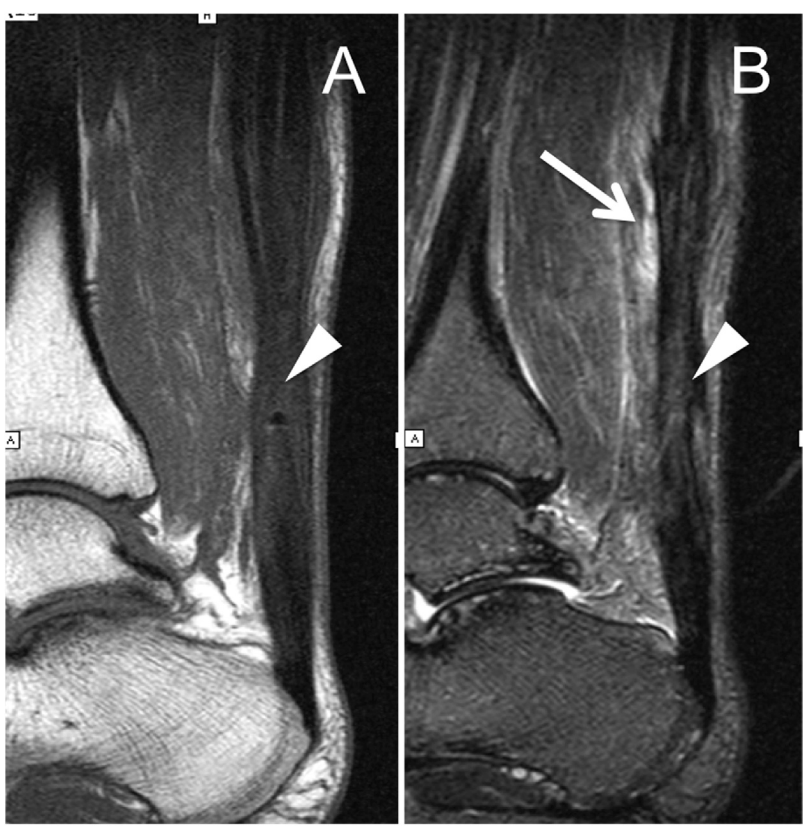

Fig. 4. (A) T1-weighted sequences show internal signal changes in the repaired tendon proximally and at the level of the middle third. The signal is heterogeneous without dehiscence or disruption of fibers corresponding to normal in the early repair phase (arrowhead). (B) T2 weighted image showing a heterogeneous signal in the same area (arrowhead) and soft tissue edema in the paratenon which is a typical finding secondary to the rupture and surgical procedure (arrow).

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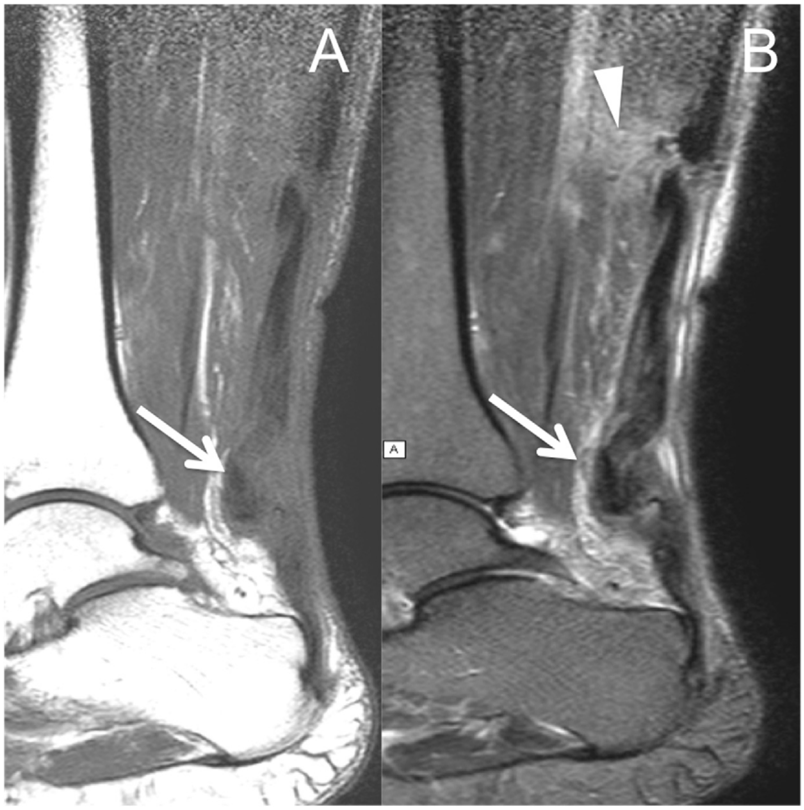

Fig. 5. (A, B) During the repair phase, edematous changes (arrowhead in B) are seen along with signs of distal tendon fiber retraction in the soleus at the point of entry of the needle as well as normal tendon healing at the former rupture site (arrows).

adaption of the tendon stumps. These findings are helpful to predict short term outcome, adjust frequency and loading for physical activity, assess soleus edema and Kager fat pad changes, and rule out the presence of any postoperative hematoma. MRI at this stag is also able to verify and quantify the presence of fat tissue in the gap, which is a common finding in patients with high soleus insertions because fat tissue might interpose between the sutures leading to prolonged healing in the repair stage (Figs. 2 and 3) [4].

The findings seen on MRI should always be interpreted together with the clinical findings because of the nonspecific posttraumatic and postoperative inflammatory changes in the soft tissues at the hindfoot that persist for several weeks (Fig. 4).

The size of the postoperative gap might be overestimated during the repair phase due to physiological signal changes within the tendon stumps during regeneration with granulomatous tissue showing high signal intensity in T2 sequences with fat suppression acquisition, with the gap frequently appearing largerlarger than preoperatively. The morphological aspects of the tendon must be then carefully studied for each particular phase. A true dehiscence with hyperintense T1 high signal must be differentiated from a hematoma or fat tissue interposition- with edema displaying low T1 signal intensity (Fig. 5). Ultrasound examination might help in these cases with dynamic maneuvers to check gap width [5].

Occasionally, expected changes are not visualized and regeneration tissue is not identified correctly. The physiological process of tendon healing is delayed and in the presence of edematous changes in the paratenon and Kager fat pad the gap might persist and be suggestive of poor apposition of the tendon stumps. This might be due to a poor surgical technique or inadequate post-surgical management with increased tension on the tendon during rehabilitation leading to re-rupture (Fig. 6).

Late stages of tendon healing

Three months after surgery, the primary repair tissue consisting predominately of type III collagen (elastin) has been gradually replaced by mature fibrous tissue consisting of type I collagen under the physiological influence of tendon stretching.

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Fig. 6. T1-weighted (A) and T2-weighted images (B) of an MRI at 3 months postoperatively. The patient complains about pain associated with rehabilitation. MRI reveals substantial edematous changes in the muscular planes of the soleus and Kager's fat pad (arrowheads in B). In both T1 and T2 weighted images there is visualization of sutures (arrow) suggestive of tendon re-rupture or instability.

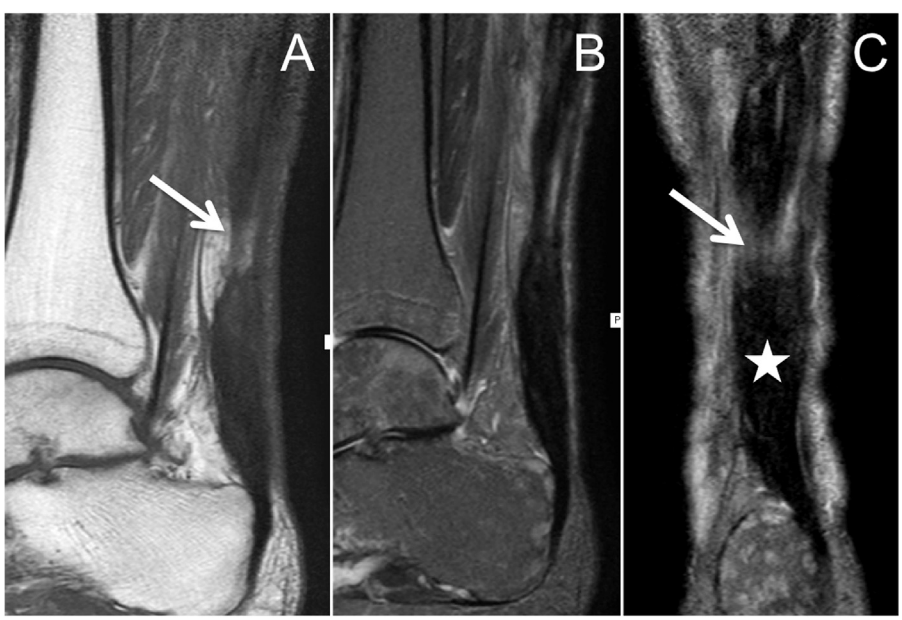

Fig. 7. T1-weighted (A) and T2-weighted (B—C) MRI sequences at 10 months postoperatively. The physiologic late repair phase is characterized by recovery of the tendon shape and evidence of diffuse thickening (asterisk in C). Signal changes may persist in the suture area. They appear mostly homogeneous with some tendon bridges (arrows in A and C).

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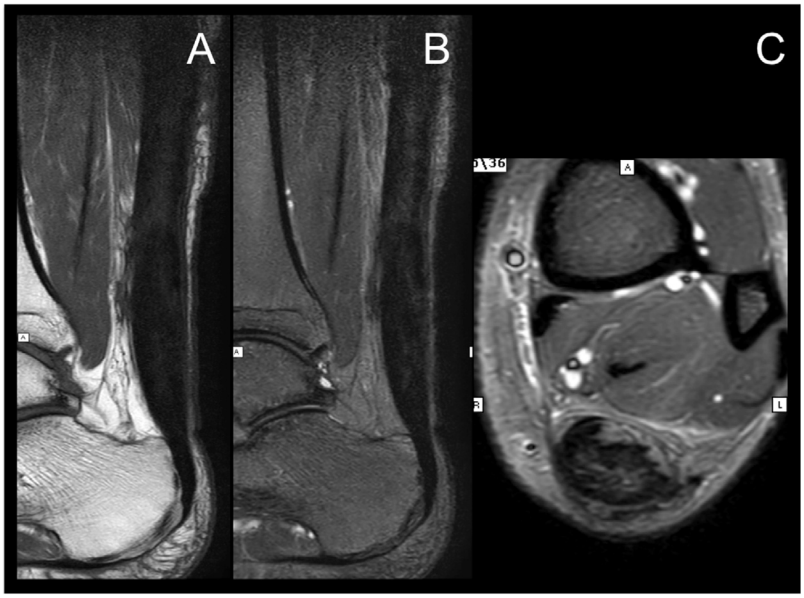

Fig. 8. Sagittal T1 (A), T2 (B) and axial T2-weighted images (C) demonstrating physiologic tendon healing at 6 months postoperatively. The images show almost complete recovery as evidenced by diffuse thickening of the Achilles tendon and slight heterogeneity in the central area.

Fig. 9. Sagittal T1 (A), T2 (B) and axial T2-weighted MR images (C) at 8 months postoperatively, showing diffuse tendon thickening and a central area of residual mucoid degeneration.

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The mature tissue displays a low signal intensity in all MRI sequences. The area appears darker and becomes similar to the original tendon. This is also associated with an increased tendon volume which is often larger than the area of the original rupture (Figs. 7 and 8) [6].

When using the percutaneous, peritendineum preserving Dresden technique for Achilles tendon repair there is a low to zero incidence of common complications such as wound healing problems, re-rupture, or infection. [1,4,7,8]. Consequently, MRI scans show a mostly homogeneous signal during the repair and remodeling stages. However, like after open surgical repair the tendon will look diffusely thickened with some internal heterogeneous signals mainly high T1 and T2 signal intensity with fat suppression representing focal intra-substance degeneration or chronic myxoid material up to one year postoperatively (Fig. 9) [9].

Summary and conclusions

Repair-associated changes occurring inside the Achilles tendon after percutaneous repair represent a typical signal alteration toward diffuse hypointense homogeneity over time. During the repair stage these changes are centripetal, i.e. occurring from the peripheral to the central areas. During the early and late remodeling phase at 6 and 12 months, respectively, the tendons look thickened and homogeneous in both sequences.

At 3 months postoperatively, central areas with high signal intensity in T1 and T2 weighted sequences are often detected with fat suppression representing granulomatous tissue and transformation from type III to type I collagen without alterations in the scar tissue. These physiological repair dynamics demonstrate that physical therapy actually promotes recovery of normal tendon function thus supporting the concept of functional after treatment irrespective of the primary treatment [1].

Based on our experience, a control MRI scan at one month with or without ultrasound complement is important to detect early failure of the repair and prevent long-term complications by early intervention if needed, e.g. evacuation of seroma or hematoma, repeat suture, etc. Another control at 3 months will demonstrate the transition from the repair to the remodeling phase including centripetal reorganization of the collagen and gap reduction, and rule out late complications occurring as a result of poor tendon healing or inadequate physical therapy. Ultrasound-guided PRP (platelet rich plasma) injection might improve healing and reduce repair times at this stage. However, MRI findings must always be interpreted together with the clinical findings at follow up.

In conclusion, MRI represents an excellent means of monitoring the healing process after percutaneous Achilles tendon repair. The results of the present study confirm that the percutaneous, peritendineum preserving technique with the Dresden instrument results in a near physiologic centripetal tendon healing starting at the peritendineum. Future studies should assess if diffusion MRI techniques and T2 mapping provide additional prognostic information for follow up. It would also be interesting to assess whether the tendon is getting more homogeneous and thinner in the late remodeling phase beyond one year postoperatively. Selected focal heterogeneous signals with potential mucoid degeneration or calcifications should be assessed with CT scanning or plain X-rays to define outcome in the following controls.

Conflict of interest

The authors confirm that there is no conflict of interest.

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