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Value of ultrasound and magnetic resonance imaging in the assessment of Achilles tendon healing following percutaneous repair with the Dresden instrument

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In this article

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Abstract

Background: Percutaneous Achilles tendon (AT) repair with the Dresden instrument is a safe and effective treatment for AT rupture within 15 days after injury. Follow-up includes clinical examination and imaging to assess the healing process and detect possible complications. The findings of each control visit determine the progression of the rehabilitation of each patient.

Methods: We assessed the postoperative findings of all patients who underwent AT with the Dresden technique from May 2022 to September 2023, during a follow-up period of 6 months. The study population included 40 male patients between 18 and 59 years of age. Ultrasound (US) and magnetic resonance imaging (MRI) were performed in all patients at day 15 postoperatively and then monthly for 6 months.

Results: All patients completed 6 months follow-up and 2 (5%) presented with postoperative wound dehiscence. No sural nerve lesions, reruptures, reoperations or other complications were seen. Both imaging methods showed excellent correlation of findings at all time points. Both methods were effective to assess the hematoma and structural changes of the healing process during the first 3 months. The use of US with Doppler was a useful tool to evaluate blood flow to the tendon stumps. After 3 months no significant morphological changes were observed but the US enabled a dynamic functional assessment of the tendon. After 4 months tissues showed homogenization and decrease of volume without further major changes.

Conclusion: Both US and MRI proved to be excellent methods to assess the healing process after percutaneous AT repair. The US performed by an experienced investigator showed advantages over MRI in evaluating the gap between the tendon stumps, the possibility of evaluating the vascularity with Doppler US and assessing the functionality of the healing tendon with dynamic examination, besides being a cheap and easily accessible imaging method.

Keywords
Rehabilitation · Acute · Rupture · Follow-up · Minimally invasive surgical procedures

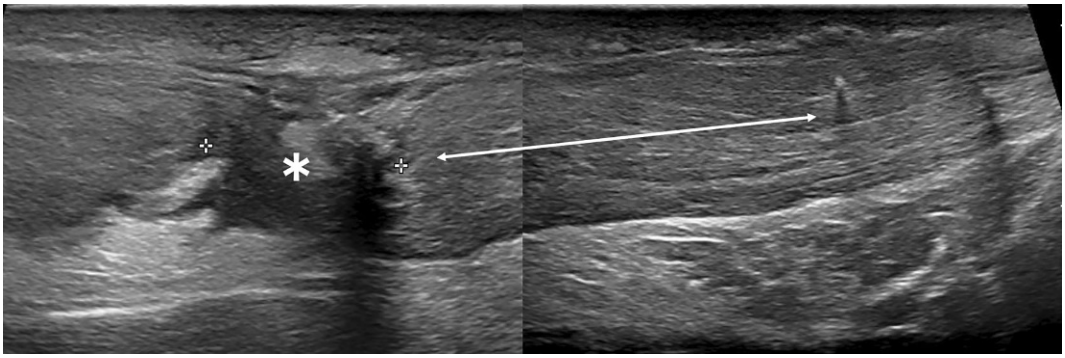

Fig. 1 ◀ Composite ultrasound image in the longitudinal plane 15 days after surgery showing the gap between the tendon margins (*star*) between cursors as a hypoechoic area without interposition of fatty tissue. The *double arrow* delineates the space between the injured tendon margin and the distal suture threads

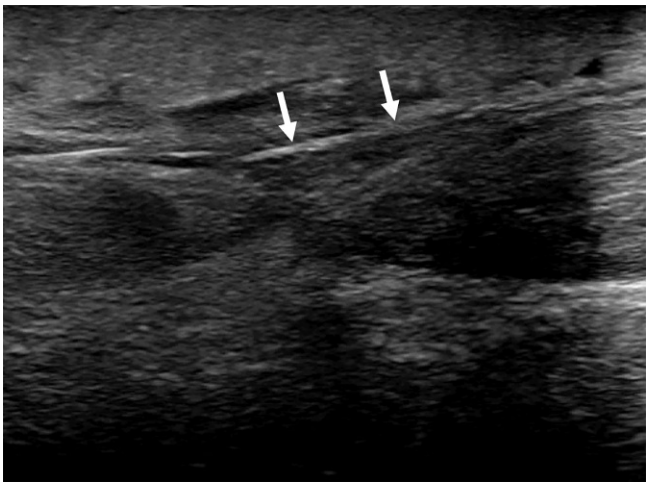

Fig. 2 ◀ Ultrasound image in the longitudinal plante delineating the margins of the gap 15 days post-surgery clearly showing the suture threads (*arrows*) used to approximate the tendon stumps without artifacts

Introduction

Achilles tendon (AT) ruptures represent one of the most frequent tendon lesions in the human body with a steadily rising incidence. It affects men more often than women and between 30 and 50 years of age [1–3]. Management of AT ruptures is still controversial and options include surgical and nonsurgical forms of treatment. Surgical repair showed lower rerupture rates and tended towards better functional outcomes but at the cost of a significantly higher complication rate compared to nonsurgical management [4].

Percutaneous techniques emerged aiming to combine the benefits of operative and nonoperative treatment. Minimally invasive AT repair with the Dresden instrument was first reported in 2005 with excellent outcomes and low complications rates [5, 6]. In particular, sural nerve damage can be completely avoided using the correct percutaneous techniques [5, 6]; however, possible elongation and consequent loss of strength remain a matter of concern [7–9]. Early detection of these complications may be crucial in order to adapt the functional aftertreatment and avoid negative outcomes [10, 11].

Abbreviations

AT	Achilles tendon
MRI	Magnetic resonance imaging
STIR	Short tau inversion recovery
US	Ultrasound

» Percutaneous techniques emerged aiming to combine the benefits of operative and nonoperative treatment

The value of imaging studies, especially ultrasound (US) and magnetic resonance imaging (MRI) in the postoperative assessment of percutaneous AT repair, has been addressed previously [5–7, 12]. We have observed that the progression of tendon healing is a dynamic process that takes approximately 4–6 months, going through different stages that are equally important to achieve an adequate functional adaptation of the tendon, which translates into satisfactory functional outcomes [12].

In the present study, we aimed to describe the imaging findings observed during the 6 months follow-up of patients who underwent AT repair with the Dresden instrument in order to assess local changes and eventual complications. The findings with US and MRI were compared to establish a rational and useful follow-up guide based on the strengths of each method for the different stages of the healing process.

Methods

We present a descriptive study including all patients over 18 years who underwent percutaneous AT repair with the Dresden instrument due to AT rupture in a single institution between May 2022 and September 2023. Demographics and data on the activity triggering the tendon rupture were collected.

The diagnosis of AT rupture was confirmed clinically using the Thompson test, the Matles test and the palpable gap. Surgery was performed within 2 weeks after diagnosis in all patients and by the same senior surgeon. The surgical technique of the percutaneous AT repair using the Dresden instrument was performed according to the technique described previously [5, 12]. All patients were discharged on the day of surgery.

Postoperative follow-up was carried out at days 15 and 30 and then monthly over a period of 6 months. This consisted of clinical evaluation and systematically performed MRI and US. The MRI was performed with a 1.5 T system (Philips, Amsterdam, The Netherlands), following the protocol described in a previous study [6]. The US examinations were performed with a broadband linear 18 MHz transducer (Philips, Amsterdam, The Nether-

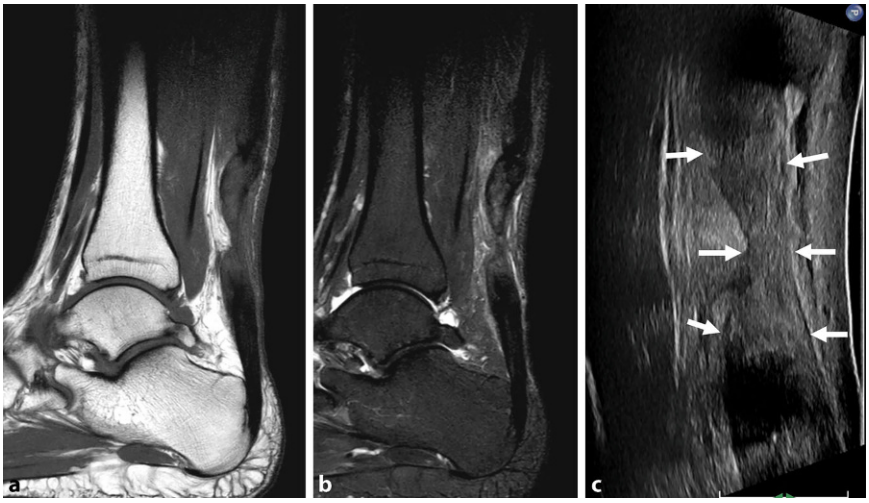

Fig. 3 ▲ The 1-month follow-up with sagittal MRI in T1-weighted (**a**) and STIR (**b**) images showing a normal morphology of the healing tendon with continuity of fibers without a gap or intervening hematoma. The adjacent proximal and distal fibers show signal changes as a normal finding during the reparative process. On US in the longitudinal plane (**c**) the same morphology can be reproduced with high resolution and excellent correlation to the MRI findings (*arrows* delineating the Achilles tendon)

lands) by the same qualified radiologist, trained in the assessment of AT disease. Imaging findings at each stage of the healing process and follow-up were described and a comparison between both methods was carried out. Development of surgical complications, such as wound dehiscence, infection, sural nerve entrapment, reruptures or other conditions resulting in a need for reoperation were evaluated and recorded.

Postsurgical rehabilitation

During the first month after surgery patients were instructed to wear a long walking boot with four heel wedges of 1.5 cm, i.e., a total heel lift of 6 cm. Patients were allowed to walk using crutches and the boot 48 h after surgery. Boot removal was allowed in order to perform active ankle flexion-extension under supervision from the second week onwards. Dorsiflexion did not exceed 90° between the leg and foot axis.

During the second month after surgery patients were instructed to continue the walker boot use with one wedge removed, i.e., a remaining heel lift of 4.5 cm. In order to gain strength of the extensor muscles, active dorsiflexion exercises were performed against the weight of a 5 kg sandbag. Another exercise included pressure against the floor with a tennis ball located under the heel and the knee flexed at 90°.

From the third month onwards patients were instructed to remove the walker boot while avoiding sudden dorsiflexion that might injure the scarring tissue. Patients were instructed to start with controlled and progressive exercises to stretch the AT and strengthen the gastrocnemius muscle. Stationary bike use was allowed at this point. Two of the heel wedges were removed, the remaining wedge with a 1.5 cm lift was worn in the patients' own shoe for another month, which was finally removed 4 months after surgery.

Between months 4–6, rehabilitation exercises were centered on the strengthening of the extensor and flexor muscle groups of the leg. The final goal was to achieve full strength single-leg heel rise. The physiotherapist in charge must have experience handling this process in order not to overexert the muscles, causing pain and inflammation that could delay the recovery. Patients were allowed to run when the single-leg heel rise with the operated leg had equal strength to the nonoperated side. Contact sports and other activities were allowed 6 months after surgery.

Results

During the study period 40 patients with AT rupture underwent percutaneous repair with the Dresden technique. All of them were male. Ages ranged from 19 to 58 years with mean age of 40 years. Of the 40 patients 36 (90%) affirmed that tendon rupture occurred while practicing football, 2 (5%) playing rugby, 1 (2.5%) playing basketball and another 1 (2.5%) while running.

» Only two patients presented with a wound dehiscence, resulting in a total minor complication rate of 5%

All patients completed the 6-month follow-up endpoint. Only two patients presented with a wound dehiscence, resulting in a total minor complication rate of 5%. No other complications were observed, notably no sural nerve entrapment, seroma, or hematoma requiring drainage, rerupture or reoperation for any other reason.

Imaging findings and discussion

The repaired AT goes through three different stages during the healing process: inflammatory, repairing and remodelling stages [13, 14]. In our previous studies we used MRI as the imaging tool to assess the local changes of each stage and described the main findings in the different sequences [6, 12]. We assumed that in the tendon regeneration process ultrasound (US) examination, which is highly valuable in establishing the diagnosis and making decisions [15, 16], could provide additional information to the MRI findings and we aimed to compare both imaging methods [13].

First control: 15 days postoperatively

Evaluation of the surgical area on postoperative day 15 was used as a quality control of the procedure. At that time point the approximation of the tendon stumps and the presence of postoperative fluid collection in the interface that could intervene with the repair process were evaluated. At this early stage a local hematoma, evidenced as a liquid collection adjusted to the gap, is a normal finding but it should not exceed the paratenon or present a proximal or distal extension. One of the advantages of this percutaneous technique is preser-

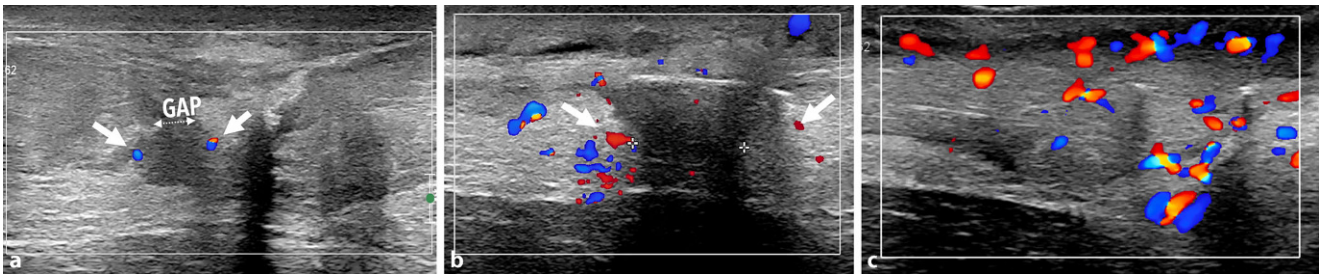

Fig. 4 ▲ Longitudinal view with color-coded Doppler US shows low vascular flow at the margins of the tendon stumps (*arrows*) at 15 days postoperatively (**a**) and a marked increase in vascular flow at the stump margins (*arrows*) at 1 month (**b**) and 2 months (**c**) post-surgery

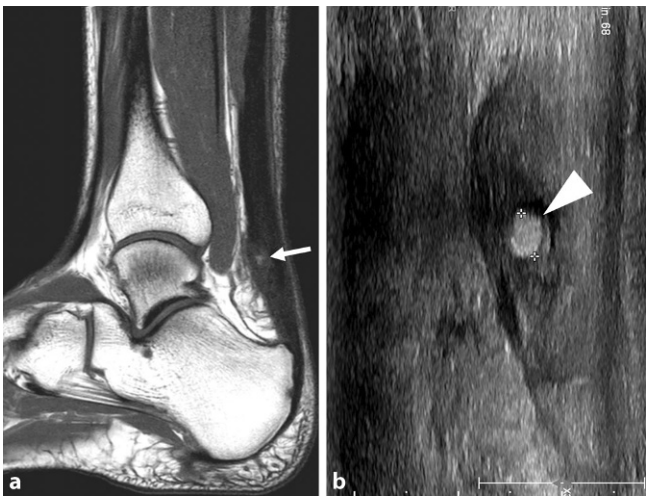

Fig. 5 ▲ MR image in the sagittal plane (**a**) at the 2-month follow-up, showing an internal focal hyperintense area in the repaired AT in the T1-weighted sequence (*arrow*). It could correspond to an intratendinous seroma but US examination (**b**) in the same plane very clearly shows the echogenic focal image of intratendinous residual fatty tissue (*arrowhead*)

vation of the paratenon and the local hematoma rich in growth factors and inflammatory mediators that are beneficial for the healing process. With the paratenon intact, the hematoma is confined to the gap (◘ **Fig. 1**).

» We found US to be a more appropriate alternative in the early postsurgical stages

A problem we encountered at this early stage when using MRI studies was the significant edema in the repaired tissues, including the soleus muscle, the paratenon, tendon margins and gap, evidenced on T2 fat-suppressed sequences. Delimitation of fluid collections is complex and the volume can be overestimated. For this reason, we found US to be a more appropriate alternative in the early postsurgical stages, as tissue delimitation is easier due to its superficial location. The US is particularly useful for this minimally invasive technique as the sutures are located peripherally and not in the tendon stump approximation area and this area can be thoroughly assessed without artifacts that can cause interference (◘ **Fig. 2**; [17]). In the case of a large fluid collection, US can also serve as a guide to drain the liquid in order to reduce the future formation of hypertrophic scars that could weaken the tendon junction area. In our series, however, no patient presented with this finding.

Second control: 1 month postoperatively

After the first month after surgery we noticed that US findings highly correlated with MRI findings regarding the morphology of the repair process: assessment of the suture line was identical with both methods (◘ **Fig. 3**).

Furthermore, areas of fatty tissue in the reparative zone were correctly identified with both methods. The delineation of deep fatty tissue in Kager's triangle near the tendon rupture zone is fundamental as it can affect the evolution of the tendon repair.

» Persistence of hypervascularization beyond 3 months suggests an inflammatory response and poor progression of healing

An adequate blood supply is essential for the healing of an AT rupture because it facilitates the inflow of fibroblasts into the injured area. Fibroblast migration towards the injured area enables the onset of the replacement of reactive granulation tissue with a more mature fibrous scar tissue [14, 18]. During the first, inflammatory stage, there is a relevant migration of leukocytes to the repaired area and stimulation of angiogenesis and tenocyte proliferation to achieve adequate collagen synthesis. This process starts during the immediate postsurgery period and has a maximum activity between 30 and 60 days after tendon repair (◘ **Fig. 4**; [19]). These changes are directly related to the increase in vascular flow, which can be evaluated at the tendon stumps with Doppler US techniques. Therefore, using US as an imaging method at the 1 month control is highly valuable to assess the beginning of vascularization in the repaired area. Intratendinous hypervascularization can be observed up to 3 months postoperatively. Beyond this period, persistence of hypervascularization suggests an inflammatory response and poor progression of healing.

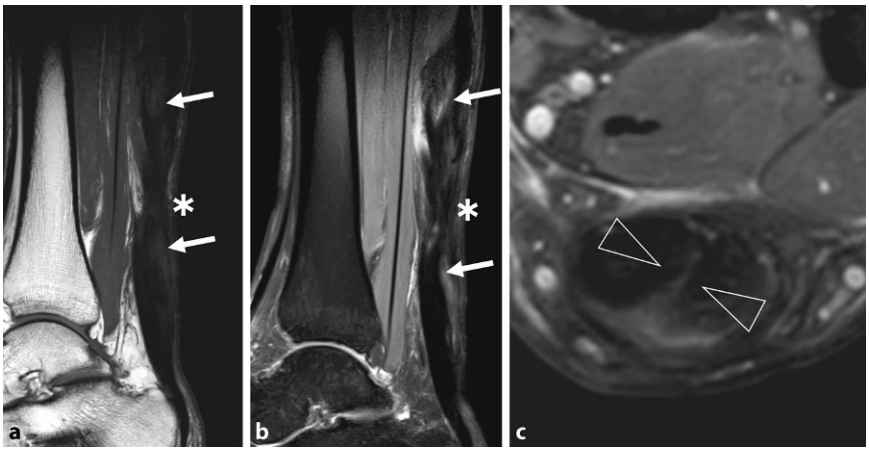

Fig. 6 ▲ At the 3-month follow-up, on MRI in T1-weighted (**a**) and STIR (**b**) sequences the tendon is still heterogeneous and shows areas of intratendinous signal increase (*arrows*) with poor delineation of the former rupture area (*star*). The axial plane with STIR sequences (**c**) is best for identifying the portions of the attached tendon stumps and identifying the remaining interface (*arrowheads*)

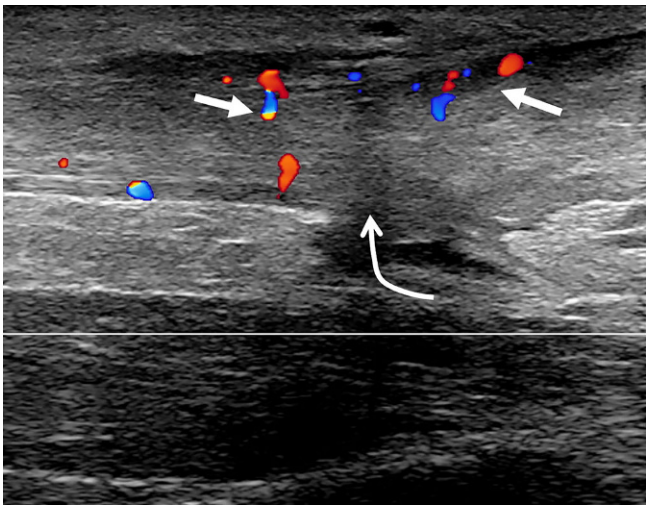

Fig. 7 ◄ Longitudinal plane color-coded Doppler US image at 3 months showing a slightly hypoechoic tissue with a linear appearance in the area where the tendon stumps join (*curved arrow*) with decreasing and peripheral vascular flow (*arrows*)

Third control: 2 months postoperatively

The evaluation 2 months after surgery showed a significant increment in the level of vascular inflow, corresponding to the neovascularization process that reaches its peak at 60 days. At this point, structures were identified with a higher resolution and the repaired area was clearly defined.

As discussed previously, echogenic tissue in the repair zone that can be identified in the US examination may correspond to fibrosis or areas of fatty tissue involved in the repair process. The use of MRI enables the differentiation of this tissue as fat can be identified as a high signal on T1 sequences. At this stage the tendon starts to show a more homogeneous echogenicity and signal in US and MRI (◘ **Fig. 5**).

At this point, the tendon is assessed for the presence of intratendinous calcifications. Even though we found no cases in our series, they are a frequent finding in patients who underwent open surgery, with a reported prevalence between 14% and 26% [20, 21]. They are often associated with pain, increased volume of the tendon and decreased ankle range of motion. A correct diagnosis with US is mandatory and they should not be misinterpreted as hematomas or fibrosis [20].

Fourth control: 3 months postoperatively

Approximately 3 months after surgery, transition from the repair stage to the remodeling stage is expected to begin. The process of granulation tissue becoming fibrous tissue can last 3 more months. Remodeling and collagen accumulation continues for up to 1 year. At this stage, the patient starts with exercises to stretch the AT, which is directly related to the settling of the remodeling stage and the continuous transformation of type III to type I collagen within the fibrous tissue [22, 23].

Another important issue also at this stage is the correct assessment of the true gap between the stumps of the AT following surgery. This gap is frequently overestimated during the repair phase because the granulomatous tissue, rich in vascular flow and inflammatory changes, appears hyperintense on T2 sequences with fat suppression and T1 sequences, which makes it difficult to correctly evaluate the contact area (◘ **Fig. 6**). The US examination enables a more specific assessment of this tissue, displayed as a hypoechoic area between the tendon stumps, which is often difficult to delimitate without a clear cleavage plane and with vascular flow displayed with Doppler US, indicating the presence of reparative tissue and not detritus as might be misinterpreted in MRI (◘ **Fig. 7**). The differential diagnosis must include chronic hematoma or seroma that present as clearly delimited anechoic or heterogeneous collections in US. Also, areas of incipient fibrosis or calcifications, which show increased echogenicity, can be differentiated from granulation tissue more accurately with US than with MRI.

The imaging findings are in line with previous studies suggesting that the tendon healing process can be adequately assessed at the 3rd month following rupture [17, 24]. The US enables the investigator to dynamically evaluate the approximation and movement behavior of the tendon stumps during passive flexion and extension of the foot and determine the exact type of the tissue in the interface area of the suture.

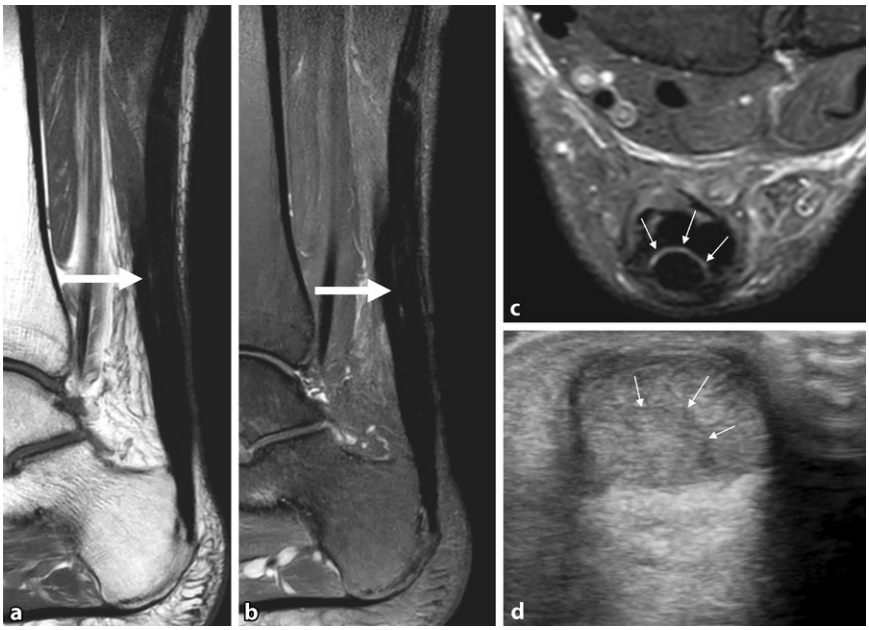

Fig. 8 ▲ MRI at 4 months post-surgery shows a homogeneous tendon in the former rupture zone appearing as a nearly normal finding in the T1-weighted (**a**) and STIR (**b**) sequences in the sagittal plane displaying an intense linear image (*thick arrow*). The latter is easier delineated in the axial plane (**c**) with STIR sequences (*thin arrows*). This finding is very well visualized with US (**d**)

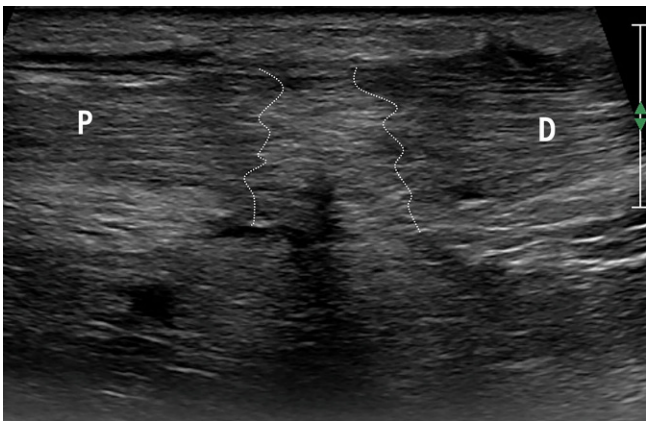

Fig. 9 ◀ Longitudinal US view of the repaired tendon at 5 months showing a focal image with slightly increased echogenicity in the repaired tendon area with a normal fibrillar alignment pattern (*dotted lines*). *P* proximal, *D* distal

Further controls

At 4 months postoperatively no significant structural changes were observed. At this point it was difficult to clearly identify the transition of the repaired area and the intact tissue with both MRI and US (◘ **Fig. 8**). Linear strands of increased signal on T1-weighted and T2-weighted sequences could be observed in some cases. We did not interpret this finding as a complication or an area of weak tendinous tissue. It is important to correlate these images with previous longitudinal studies to define and understand the ideal characteristics of the regenerating tendon.

At 5 months postoperatively, the interface was identified with a signal similar to the normal tendon with MRI while in the US investigations it was still slightly hyperechogenic. As expected, a decrease in the vascular flow in the tendon and adjacent tissue was observed at this point in time indicating the end of the acute repair process (◘ **Fig. 9**).

At 6 months postoperatively, we observed with both imaging methods a residually increased thickness of the tendon in the repaired area with a more homogeneous tendon structure. The tendon structure continues to increase in homogeneity beyond that time, corresponding to the remodeling process that can last up to 1 year [6].

» Knowledge and detection of the described repair stages with the imaging method used are fundamental

Knowledge and detection of the described repair stages with the imaging method used are fundamental as they determine the progression of the physical rehabilitation that goes along with the internal changes of the tendon scar. The internal changes of inflammation, angiogenesis and fibrosis correlate with the different imaging findings, as previously described. Detection of a delayed or disturbed healing process is important in order to modify and adapt the stages of rehabilitation and avoid further complications, particularly tendon elongation or rerupture.

Our study has several limitations. First, the overall number of patients was limited and the lack of relevant complications in this group does not allow definite conclusions to be drawn with respect to their detection with the investigated imaging modalities. Second, because percutaneous suture with the Dresden instrument is the preferred treatment for acute Achilles tendon rupture, we did not investigate tendon healing with other treatment methods, such as non-operative treatment or open suture. On the other hand, this is the first prospective study using both US and MRI for the serial evaluation of AT healing over 6 months post-surgery in a homogeneous patient group with a 100% follow-up.

Practical conclusion

- **Both ultrasound (US) and magnetic resonance imaging (MRI) are excellent methods to assess the healing process after percutaneous Achilles tendon repair and are useful for guiding clinical decisions during the rehabilitation.**
- **US performed by an experienced investigator showed advantages over MRI in evaluating the gap between the tendon stumps, the possibility of evaluating the vascularity with Doppler US and assessing the functionality of the healing tendon with dynamic examination.**
- **Besides that, US is a cheaper and more readily accessible imaging method than MRI and thus may be considered the gold**

standard with respect to imaging of acute Achilles tendon ruptures and monitoring the healing process.

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Declarations

Conflict of interest. G. Joannas, R. Barousse, L. Casola, G. Arrondo, S. Rammelt and M.E. Fratantoni declare that they have no competing interests.
Ethical standards. All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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Zusammenfassung

Bedeutung von Ultraschall und Magnetresonanztomographie bei der Beurteilung der Achillessehnenheilung nach perkutaner Reparatur mit dem Dresdner Instrument

Hintergrund: Die perkutane Naht der Achillessehne (AS) mit dem Dresdner Instrument ist eine sichere und wirksame Behandlung der AS-Ruptur innerhalb von 15 Tagen nach der Verletzung. Die Nachsorge umfasst eine klinische Untersuchung und Bildgebung, um den Heilungsprozess zu beurteilen und mögliche Komplikationen zu erkennen. Die Ergebnisse jeder Kontrolluntersuchung bestimmen den Rehabilitationsverlauf der Patienten.
Methoden: Wir beurteilten die postoperativen Befunde aller Patienten, die sich zwischen Mai 2022 und September 2023 einer AS-Naht mit der Dresdner Technik unterzogen, während einer Nachbeobachtungszeit von 6 Monaten. Die Studienpopulation umfasste 40 männliche Patienten im Alter zwischen 18 und 59 Jahren. Ultraschall (US) und Magnetresonanztomographie (MRT) wurden bei allen Patienten am 15. postoperativen Tag und dann monatlich über 6 Monate durchgeführt.
Ergebnisse: Alle Patienten erreichten eine Nachbeobachtungszeit von 6 Monaten, 2 (5%) Patienten wiesen eine postoperative Wunddehiszenz auf. Es wurden keine Läsionen des N. suralis, Rerupturen, Reoperationen oder andere Komplikationen festgestellt. Beide bildgebenden Verfahren zeigten zu allen Zeitpunkten eine ausgezeichnete Korrelation der Befunde. Mit beiden Methoden ließen sich das Hämatom und die strukturellen Veränderungen des Heilungsprozesses in den ersten 3 Monaten gut beurteilen. Die US-Untersuchung mit Doppler war zudem ein nützliches Instrument zur Bewertung des Blutflusses zu den Sehnenstümpfen. Nach 3 Monaten wurden keine signifikanten morphologischen Veränderungen beobachtet, aber die US-Untersuchung ermöglichte eine dynamische Funktionsbewertung der Sehne. Nach 4 Monaten zeigte sich eine Homogenisierung des Gewebes und eine Volumenabnahme ohne weitere größere Veränderungen.
Schlussfolgerung: Sowohl US als auch MRT erwiesen sich als ausgezeichnete Methoden zur Beurteilung des Heilungsprozesses nach perkutaner AS-Reparatur. Der von einem erfahrenen Untersucher durchgeführte US zeigte gegenüber der MRT Vorteile bei der Beurteilung des Spalts zwischen den Sehnenstümpfen, der Möglichkeit, die Gefäßversorgung mit Dopplersonographie zu beurteilen und die Funktionalität der heilenden Sehne mit einer dynamischen Untersuchung zu bewerten, abgesehen davon, dass es sich um eine kostengünstige und leicht zugängliche Bildgebungsmethode handelt.

Schlüsselwörter
Rehabilitation · Akut · Ruptur · Follow-up · Minimal-invasive Operationen

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