Sonography of the Achilles Tendon After Complete Rupture Repair

What the Radiologist Should Know

Salvatore Gitto, MD, Anna Guja Draghi, Chandra Bortolotto, MD, Ferdinando Draghi, MD

This review aims to provide the radiologist with simple and systematic guidelines for evaluation of the Achilles tendon after complete rupture repair. Currently, there is a plethora of nonsurgical and surgical treatments, but sonographic examination has shown no significant differences between them. A systematic analysis of several parameters (morphologic characteristics, structure, color Doppler vascularization, and mobility) should be undertaken. Morphologically, the repaired tendon is larger, wider, or both. The loss of the fibrillary structure, inhomogeneity, and the surgical material in the context of the tendon are "normal" aspects after a repaired rupture. The presence of fluid collections when affecting greater than 50% of the surface of the tendon and extensive calcifications should be considered pathologic aspects. In the immediate postoperative period, there is the absence of vascularization detectable by color Doppler imaging. During the first 3 months, there is an increase in intratendinous vascularization with hypervascularization. From 3 to 6 months, stabilization and regression of the vascularization occur. Beyond the first 6 months, the hypervascularization is pathologic. The pattern of motion is, generally, reduced considerably more often in surgically treated tendons than in non–surgically treated ones. Elastography generally shows a hard appearance, with only a relatively heterogeneous pattern. In conclusion, a treated tendon will never regain a normal sonographic appearance, and the operator must distinguish between normal posttreatment changes and real pathologic characteristics.

Key Words—Achilles tendon; Doppler sonography; musculoskeletal ultrasound; sonography; therapy

The Achilles tendon is the strongest and largest tendon in the human body.[1,2] Its complete rupture is commonly caused by forced and sudden movement at the ankle joint, often occurring in active individuals between 20 and 50 years with no prior history of calf or heel pain.[3–5] The main risk factors include being male and playing recreational sports involving sudden accelerations and jumping.[6–8] Furthermore, even though sports-related injuries represent the most common etiologies, the incidence of non–sports-related ruptures has recently increased.[9,10]

The diagnosis of Achilles tendon rupture relies on the patient history and physical examination. Patients typically refer to a "snap" followed by immediate onset of pain in the back of their lower leg and ankle. A functional limitation is usually experienced while walking and pointing the injured foot downward or while standing on the toes on the affected side.[11,12] Local swelling and a palpable defect proximal to the calcaneal insertion of the Achilles tendon may be detected on physical examination[11,12]; dynamic clinical tests, such as the calf squeeze test, are also helpful.[13–15]

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Address correspondence to Salvatore Gitto, MD, Postgraduation School in Radiodiagnostics, Università Degli Studi di Milano, Via Festa del Perdono 7, 20122 Milan, Italy.

E-mail: sal.gitto@gmail.com

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Considerable controversy exists regarding whether surgical or nonsurgical management should be adopted in the treatment of complete ruptures of the Achilles tendon. Conservative treatment includes rest, pain control, and cast and splint techniques. Because such treatment has a lower rate of infective complications than surgery, it is preferred in older, sedentary patients and those with substantial medical comorbidities.[16,17] Surgical repair, comprising either open or percutaneous approaches, reduces the rate of rerupture and is indicated in younger, active individuals.[16,18–20]

Sonography is used to confirm the location of the injury within the Achilles tendon,[21,22] and it has also been proposed as a pretreatment selection tool for reducing tendon reruptures.[5] At the same time, sonography enables monitoring of the tendon-healing process and follow-up after treatment, as it is valuable in revealing alterations of the tendon echo structure and morphologic characteristics as well as changes in tendon vascularization and gliding.[23–35] Radiologists must be aware of the sonographic appearance of normal and complication-related posttreatment changes in the repaired Achilles tendon. This review aims to provide the radiologist with simple and systematic guidelines for evaluation of the Achilles tendon after complete rupture repair. Such guidelines were generated from our center's experience in combination, as indicated by the references in the text, with a thorough analysis of the last 20 years' literature (Tables 1–4).

Table 1. B-Mode Evaluation of Achilles Tendons After Complete Rupture Repair: Literature Analysis

Authors, y	Treatment	Patients	Follow-up Period	Main Findings
Rupp et al, 1995[33]	Open surgery	60	2–19 y (average, 11 y)	Tendon thickening, inhomogeneous echo structure with hypo/hyperechoic areas, loss of fibrillary pattern, hypoechoic peritendinous ribbons, thickening and poorly defined demarcation of the paratenon, calcifications
Cinotti et al, 1996[24]	Open surgery	62	3–10 y	Tendon thickening, rounded cross-sectional area, inhomogeneous echo structure with hypo/hyperechoic areas, loss of fibrillary structure
Karjalainen et al, 1996[26]	Open surgery	13	1–3 y (average, 18 mo)	Tendon thickening, rounded cross-sectional area, irregular borders, inhomogeneous echo structure with hypo/hyperechoic areas, loss of fibrillary pattern, calcifications
Merk et al, 1997[29]	Open surgery	54	4.4 y (average)	Inhomogeneous echo structure, loss of fibrillary structure
Seddio et al, 1997[34]	Open surgery	10	90 d	Inhomogeneous echo structure, hypoechoic spots around suture threads, loss of fibrillary structure
Rominger et al, 1998[32]	Open surgery	60	6–78 mo	Tendon thickening
Draghi et al, 1999[25]	Various[a]	34[b]	5 y	Tendon thickening, rounded cross-sectional area, inhomogeneous echo structure, loss of fibrillary structure, small hypoechoic spots around suture threads/in perilesional zone, calcifications
Bleakney et al, 2002[23]	Various[c]	70	10–120 mo (average, 63 mo)	Tendon thickening, focal hypoechoic areas, calcifications
Moller et al, 2002[31]	Various[a]	58	24 mo	Tendon thickening, inhomogeneous echo structure with hypo/hyperechoic areas, peritendinous edema
Majewski et al, 2003[27]	Various[c]	73	2.5 y	Tendon thickening
Margetic et al, 2007[28]	Various[a]	100	12 wk	Tendon thickening, inhomogeneous echo structure, paratenon effusion in the first 1–2 mo
Shih et al, 2008[35]	Open surgery	10	2–12 y (average, 6 y)	Tendon thickening, inhomogeneous echo structure with focal hypoechoic areas
Miquel et al, 2009[30]	Percutaneous repair	17	4–37 mo (average, 15 mo)	Tendon thickening, inhomogeneous echo structure with focal hypo/hyperechoic areas, loss of fibrillary structure
Tan et al, 2012[36]	Open surgery	16	4–180 mo (average, 39 mo)	Tendon thickening, inhomogeneous echo structure with hypoechoic areas, loss of fibrillary structure
Busilacchi et al, 2014[37]	Percutaneous repair	25	1 y	Tendon thickening

[a]Open surgical and conservative treatment.
[b]Achilles and patellar tendon injuries grouped together.
[c]Surgical (both open surgery and percutaneous tendon adaptation) and conservative treatment.

B-Mode Evaluation

After repair of a complete rupture, the Achilles tendon shows different morphologic characteristics, structure, and sonographic appearance than a nonoperated tendon. Morphologically, the repaired tendon is larger, wider, or both than a nonoperated tendon (the average anteroposterior maximum diameter of the intact tendon is 5.4 mm [range, 4.0–7.9 mm], whereas the average diameter of a ruptured tendon is 11.7 mm [range, 7.35–19.6 mm]; Figure 1, A and B).[23] The progressive increase in size is observed during the first 3 to 6 months after rupture, and it is irreversible. The extent of the increase may vary according to the surgical technique adopted.[38]

Regarding the structure, "normal" and pathologic aspects should be distinguished. The loss of the fibrillary structure, inhomogeneity (particularly in the first months after intervention), the presence of small hypoechoic areas surrounding the suture threads in the first 6 months, and the surgical material (Figure 1E) within the tendon are normal aspects (Figure 1, C–E).[23,26,30,31,33] Fluid collections (Figure 2A), which are suggestive of a poor prognosis if greater than 50% of the tendon is affected (Figure 2B), as well as extensive intratendinous calcifications (Figure 3A) should be considered pathologic aspects.[23,25,31,38] The contours of the tendon may be irregular, and in this case, sonography may show a hypoechoic peritendinous area, which may persist for up to 3 months.[26,38] Comparing morphologic characteristics after surgical and nonsurgical treatment of complete rupture of the Achilles tendon, there were no significant differences between the treatment groups in any of the evaluated parameters.[23,27,31]

The main complication after surgical or nonsurgical treatment of complete rupture of the Achilles tendon is posttraumatic rerupture (Figure 4).[16,17,39] The clinical presentation is the same as the rupture of a nontreated tendon, but sonographic diagnosis is more difficult for the structural characteristics of the tendon, particularly if large fluid collections are present; a dynamic evaluation during ankle flexion and extension is helpful in revealing discontinuity of the tendon.[33,38]

Table 2. Doppler Evaluation of Achilles Tendons After Complete Rupture Repair: Literature Analysis

Authors, y	Treatment	Patients	Follow-up Period	Main Findings
Draghi et al, 1999[25]	Various[a]	34[b]	5 y	Hypervascularization in 1st 3–4 mo, normal regression thereafter, persistent hypervascularization in symptomatic patients
Shih et al, 2008[35]	Open surgery	10	2–12 y (average, 6 y)	No increased vascularity
Miquel et al, 2009[30]	Percutaneous repair	17	4–37 mo (average, 15 mo)	Intratendinous neovascularization decreasing over time

[a]Open surgical and conservative treatment.
[b]Achilles and patellar tendon injuries grouped together.

Table 3. Sonographic Evaluation of the Mobility of Achilles Tendons After Complete Rupture Repair: Literature Analysis

Authors, y	Treatment	Patients	Follow-up Period	Main Findings
Rupp et al, 1995[33]	Open surgery	60	2–19 y (average, 11 y)	Limited gliding (surrounding tissue moving with the tendon)
Moller et al, 2002[31]	Various[a]	58	24 mo	Limited gliding with peritendinous adhesions, mostly after surgical treatment
Shih et al, 2008[35]	Open surgery	10	2–12 y (average, 6 y)	Limited gliding (surrounding tissue moving with the tendon)

[a]Open surgical and conservative treatment.

Table 4. Elastographic Evaluation of Achilles Tendons After Complete Rupture Repair: Literature Analysis

Authors, y	Treatment	Patients	Follow-up Period	Main Findings
Tan et al, 2012[36]	Open surgery	16	4–180 mo (average, 39 mo)	Hard elastographic pattern, heterogeneous structure
Busilacchi et al, 2014[37]	Percutaneous repair	25	1 y	Progressive stiffening over time

Figure 1. B-Mode evaluation (panoramic images): normal findings in a preinjury Achilles tendon (**A**) and normal findings after tenotomy (**B**–**E**). Seven months after tenotomy, sonography shows a larger and wider tendon, loss of the normal fibrillary appearance, and a homogeneous structure (**B**). Nine months after tenotomy, sonography shows an inhomogeneous structure (**C**). Seven months after tenotomy, sonography shows a homogeneous structure and hyperechoic (arrows), stitches, and calcifications (**D**). Six months after tenotomy, sonography shows a homogeneous structure and surgical material (**E**, arrows). Seven months after tenotomy, elastography shows a stiff tendon (**F**; red is stiff; blue is soft).

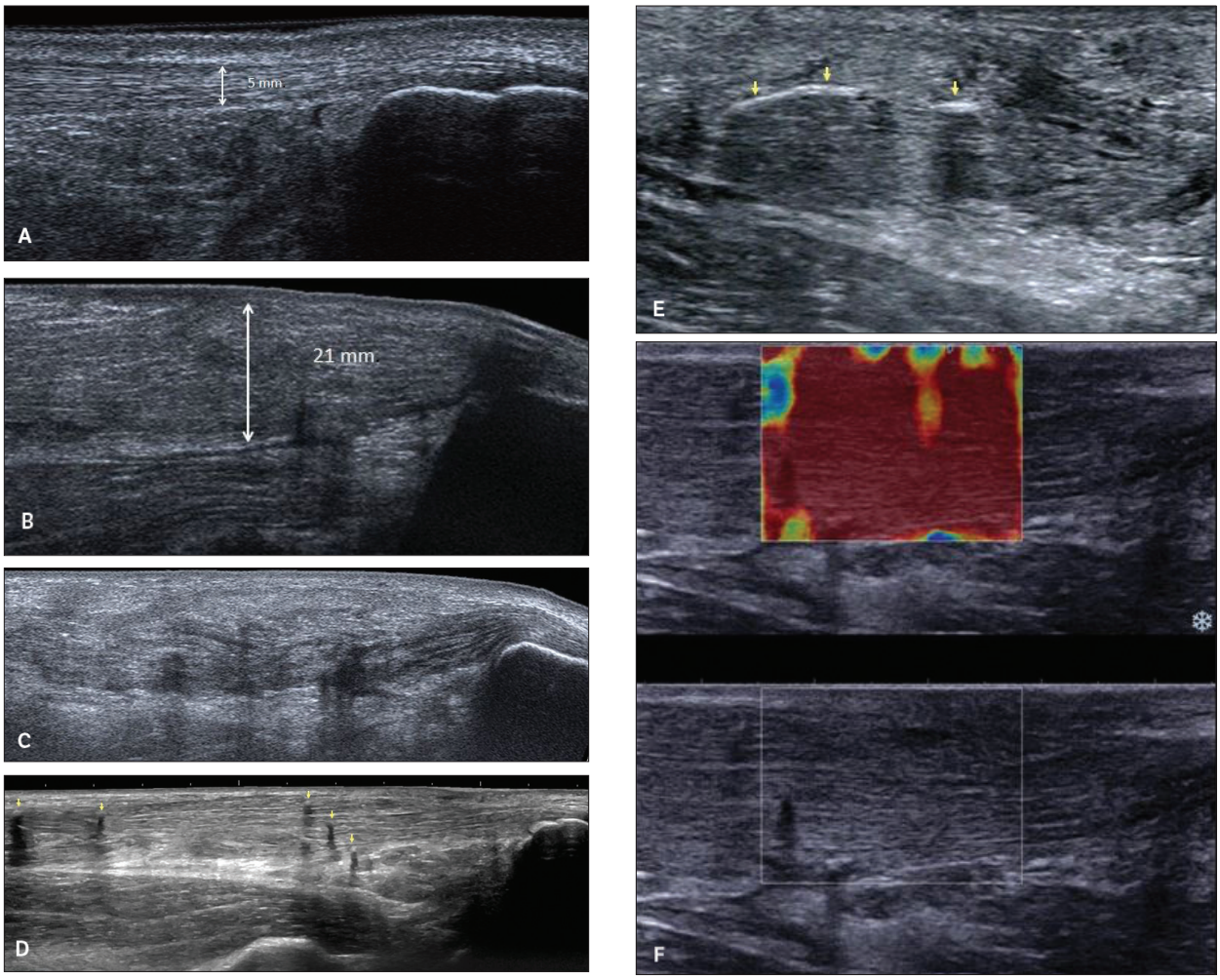
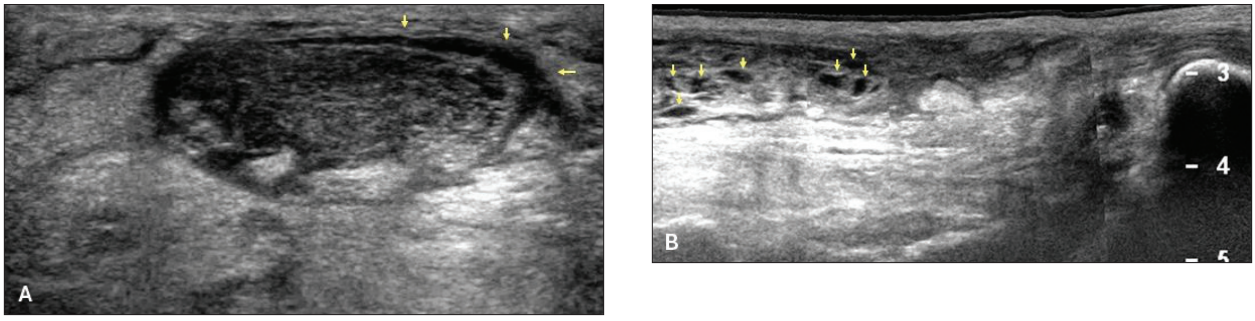


Figure 2. Fluid collections. Two months after percutaneous tenotomy, sonography (axial image) shows a hypoechoic fluid collection surrounding the Achilles tendon (**A**, arrows), which may persist for up to 3 months. Eight months after tenotomy, sonography (panoramic image) shows a larger and wider tendon, loss of the normal fibrillary appearance, and numerous fluid collections (**B**, arrows).



Color Doppler Evaluation: Vascularization

In the immediate postoperative or nonoperative treatment period, there is an absence of vascularization detectable by color Doppler imaging. In the first month after repair, color Doppler imaging shows the appearance of intratendinous vasculature. During the first 3 months, this intratendinous vascularization increases (Figure 3B) and results in hypervascularization. From 3 to 6 months, there is a stabilization and subsequent regression of the vascularization (Figure 3C).[38,40,41] Beyond these first 6 months, persistent hypervascularization (Figure 5) should be considered a marker of pathologic scarring.[25,30] Changes in peritendinous vascularization are less constant and less marked than intratendinous ones (Figure 6).[38]

Mobility Evaluation

In the first few months, there is a physiologic reduction of the tendon's mobility, which is easily assessed if a comparative analysis with the healthy contralateral side is performed.[33,38] Also after 6 months, the mobility of the tendon generally decreases during movement with respect to the surrounding structures, and fatty tissue and paratenon may

Figure 3. Achilles tendon after tenotomy (**A**). After 12 months, sonography (panoramic image) shows a larger and wider tendon, loss of the normal fibrillary appearance, and numerous large calcifications (arrows), suggestive of a poor prognosis. After 4 months, power Doppler imaging (sagittal images) shows discrete hypervascularization (**B**), which regressed 7 months after tenotomy (**C**).

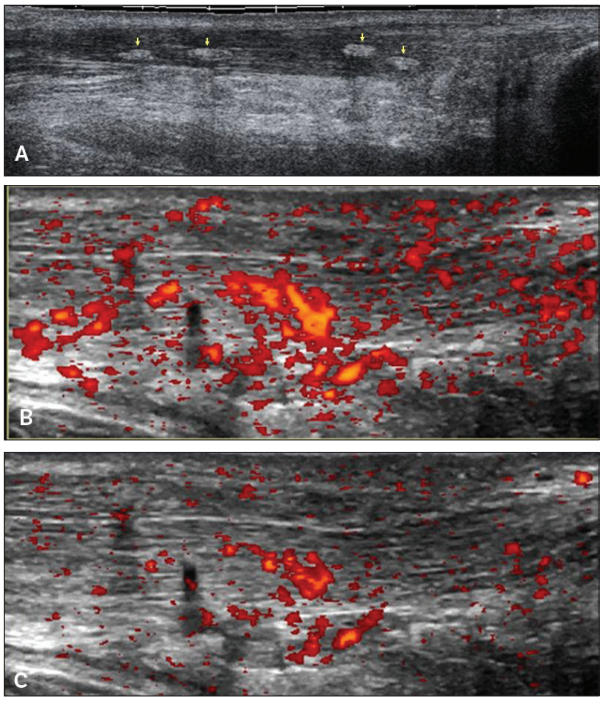


Figure 4. Achilles tendon 1 year after nonsurgical treatment: complete rerupture. Sonography (panoramic image) shows larger and wider fracture stumps (open arrows) separated by hematoma (solid arrows).

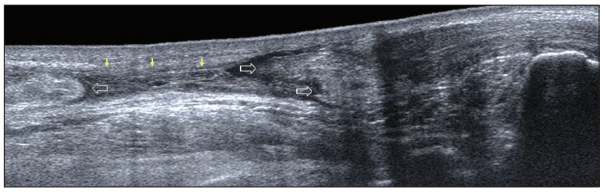
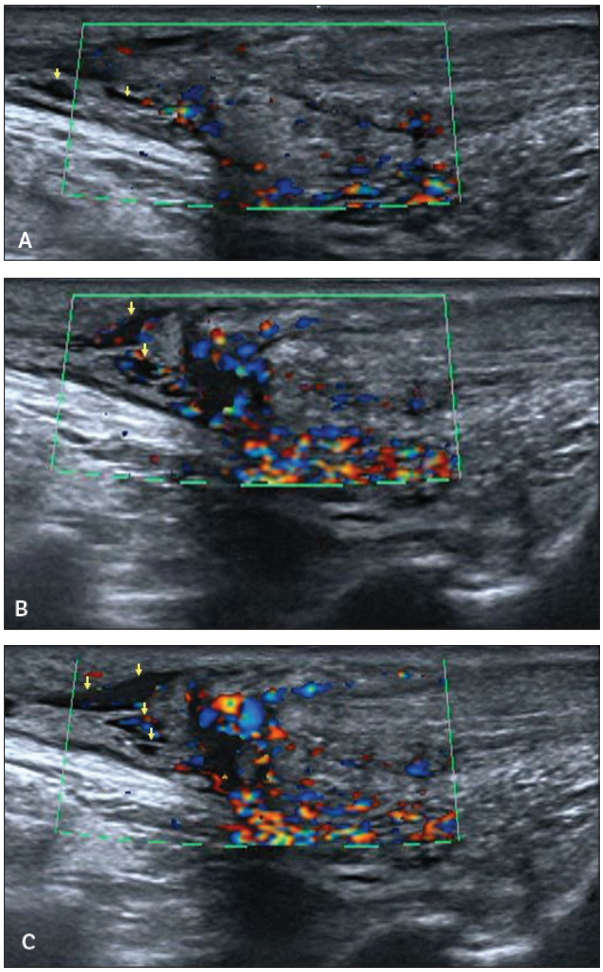


Figure 5. Achilles tendon after tenotomy. Color Doppler imaging (sagittal images) shows a larger and wider tendon, loss of the normal fibrillary appearance, fluid collections (arrows), and hypervascularization at different times after tendon repair. Hypervascularization is modest after 2 months (**A**), increased after 4 months (**B**), and persistent after 7 months (**C**).



be distinctly thickened.[31] The pattern of motion is, generally, reduced considerably more often in surgically treated tendons than in non–surgically treated ones after 1 year.[31]

Elastography

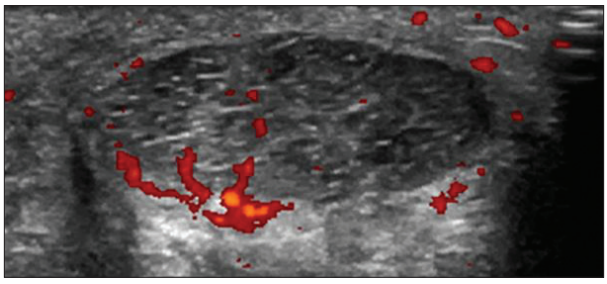
Most studies have been conducted using strain elastography. Healthy Achilles tendons show a hard pattern, whereas pathologic ones have a reduction in stiffness.[42] After surgical treatment of a complete lesion, the tendon returns to a hard appearance, with only a relatively heterogeneous pattern as a natural consequence of healing (Figure 1F).[36] If indirect quantification methods (such as the strain index) are applied, progressive hardening can be observed during the first year of follow-up.[37]

Shear wave elastography seems to be a feasible tool for depicting elasticity changes in tendons after surgical management.[43] This assumption has not yet been confirmed with clinical studies. Therefore, the effectiveness of direct quantification by shear wave elastography cannot be evaluated.

Discussion

The evaluation of an Achilles tendon after complete rupture repair can be performed by combining clinical and imaging data. The imaging technique most frequently used is sonography, whereas magnetic resonance imaging is generally reserved for complex cases and clinical-sonographic discrepancies.[34] Some studies suggest a superior ability of magnetic resonance imaging to detect intratendinous lesions in patients with a surgically repaired complete rupture of the Achilles tendon.[26] Nonetheless, several authors point out that both sonography and magnetic resonance imaging show a very weak correlation with the clinical outcome.[31] In our opinion, mediation between these positions is necessary: the follow-up of the Achilles tendon after complete rupture needs to be realized not only from a clinical perspective but also by an imaging technique such as sonography. At the same time, radiologists should be very careful in their judgment of the Achilles tendon.

Figure 6. Achilles tendon 6 months after tenotomy. Power Doppler imaging (axial image) shows a larger and wider tendon, loss of the normal fibrillary appearance, a homogeneous structure, absence of intratendinous vascularization detectable by Doppler imaging, and peritendinous hypervascularization.



Radiologists should completely change their perspective when evaluating the Achilles tendon after surgical repair (if compared to preoperative ones). In fact, before the rupture of the tendon, sonography is effective in assessing and quantifying its abnormalities (in size, structure, and vascularization), and these abnormalities correlate with the clinical index and give important information about the surgical intervention.[44] After a complete tendon rupture and repair, a correlation between sonography and the clinical presentation is not obvious: posttreatment changes in the sonographic appearance of the Achilles tendon may be poor in patients with only satisfactory clinical results and very marked in those with good clinical performance.[33] This difference means, first, that sonography should be regarded as complementary to clinical assessment, taking advantage of its great value in detecting normal tendon modifications occurring after repair as well as abnormalities suggestive of a poor prognosis. Furthermore, as there are a variety of distinct alterations in the sonographic appearance of the repaired Achilles tendon, either normal or pathologic, radiologists cannot assess and judge the repaired tendon with a preoperative scale. Rather, they must "lower the bar" to correctly distinguish between normal posttreatment changes and real pathologic characteristics.[38]

Although B-mode and Doppler evaluations of an Achilles tendon after complete rupture repair have overcome the first-application phase to enter a "knowledge reorganization" phase, new possibilities and techniques are spreading. In recent years, contrast-enhanced sonography and elastography have been rapidly diffusing even for musculoskeletal applications. The contrast medium has been used mainly as an echo enhancer for Doppler evaluations.[45,46] This application, whereas engaging and useful, seems not to be perspective shifting. Detection of vascularity with new high-end ultrasound equipment has already achieved good results, and further improvement, whereas useful, probably will not modify the work flow.

More hopes are pinned to elastography.[42,43] Only 2 studies have been conducted on Achilles tendons after complete rupture repair.[36,37] Tan et al[36] classified operated tendons both for their elasticity pattern (1–3) and subtypes (homogeneous, relatively homogeneous, and heterogeneous). Generally, operated Achilles tendons seem to show a hard and heterogeneous pattern. Since the

clinical outcome was not specified in the study by Tan et al,[36] further studies are needed to correlate the clinical outcome and elasticity in Achilles tendons after complete rupture repair. Busilacchi et al[37] quantified the elasticity evolution over time with the strain index and found a progressive increase in stiffness during the follow-up. These studies demonstrate that elastography, although very promising, needs further investigation to definitively prove its value.

In conclusion, new techniques are not substantially modifying the actual work flow in the evaluation of Achilles tendons after complete rupture repair. Our experience and the review of the last 20 years' literature suggest that a treated tendon will never regain a normal sonographic appearance. The radiologist must distinguish between normal posttreatment changes, which would be pathologic in a preinjury state, and real pathologic characteristics to aid the clinician in addressing proper treatment.

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