Follow-up study with sonoelastography after open surgery repair on Achilles tendon in professional athletes and balet dancers in comparance to non-sport related persons

Poster No.: B-1173
Congress: ECR 2017
Type: Scientific Paper
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Keywords: Musculoskeletal soft tissue, Extremities, Trauma, Ultrasound, Elastography, Ultrasound-Power Doppler, Comparative studies, Diagnostic procedure, Treatment effects, Athletic injuries, Outcomes, Tissue characterisation
DOI: 10.1594/ecr2017/B-1173

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Purpose

The Achilles tendon is the most commonly ruptured tendon in the body [1]. Rupture of the Achilles tendon often requires surgical repair and extended immobilization, which may lead to prolonged rehabilitation [2]. In addition, the ruptured Achilles tendon heals slowly due to the limited blood supply and slow cell turnover [3]. Biomechanical properties and viscoelasticity of the repaired Achilles tendon are different from non damaged, and it is of great value for sport-related persons and ballet dancers. If repaired tendons are too stiff and hence not being able to absorb sufficient energy during the motion, they are more likely to be injured again Fig. 1 on page 3 [4]. Postsurgical late complications include infection, development of adhesions, decreased ankle range of motion, muscle atrophy and weakness, nerve injury, blood clots (deep venous thrombosis, pulmonary embolism), skin sloughs, heel ulcers, hematoma formation, and re-rupture of the tendon. Therefore, it is important to evaluate the tendon stiffness following repair of Achilles tendon.

Sonoelastography (SE) is a non-invasive ultrasonographic imaging technique [5]. The best report assessing the mechanical properties of a repaired Achilles tendon after surgery was performed by Zhang et al [6]. Recently, it was reported that reabilitation period of sport-related persons is different from non-sport-related, this is due to different motional activities during reabilitation [7].

The purpose of the study was to compare sonoelastography features and Strain Ratio (SR) of the Achilles tendon after open surgery in different sport activity persons.
Fig. 1: Physiologic and pathologic elongation of Achilles tendon under physical activity (Novach#k N., 1998)

© Physiologic and pathologic elongation of Achilles tendon under physical activity (Novach#k N., 1998)
Methods and materials

Patient population

39 patients (24 - non sport related persons, without permanent sports activity and 15 athletes and balet dancers) with acute Achilles rupture after open surgical repair were included in the follow-up US with sonoelastography study.

The patients were 8 females and 31 males.

With a median age of the whole group 38.1±10.6 years (range 18-65).

First group (non athletes) with median age 39.9 +/- 6.7 years, second group (athletes) - 35.6 +/- 9.7 years.

In all cases, the rupture was located in the middle third of the tendon and was treated with open surgery.

28 had ruptures on the right side and 11 on the left side. All patients: (Non athletes and athletes) had no diabetes mellitus, cancer, lung and heart diseases, rheumatoid arthritis, spondyloarthropathy, and hypercholesterolemia due to the association between these factors and tendon abnormalities [8].

Rehabilitation programm

All patients received rehabilitation treatment in recommended amount according to time after surgery [9,10] supervised by the physiotherapist at our hospital's center. The rehabilitation program included non-weight-bearing cast immobilization with reduced equinus and toe motion for 6 weeks and a short leg cast with neutral ankle dorsiflexion from 6 to 8 weeks postoperatively. After fitting with a partial weight-bearing, removable cast boot or night splint from 8 to 12 weeks postoperatively, patients completed a physical therapy program, including proprioceptive and functional ankle recovery, and cross-training. The cast boot was discontinued at 12 weeks postoperatively. Then patients sustained full weight-bearing followed by a physical therapy program, including return to sport, road running, and cross-training.

Ultrasound examination

Each tendon was scanned in a prone position with the foot hanging over the edge of the examination bed in a neutral position to avoid tendon stress [11].
US examination with Sonoelastography with US-angiography was performed using MyLab Class-C (ESAOTE) with a linear probe BL433 (3-18MHz).

US examination protocol performed with a standard technique in longitudinal plane. SE examination results were represented in color over the conventional B-mode image using the standardized settings, recommended by manufacturer. The SE images were obtained using mild compression; based on the quality factor. The SE images are composed of 256 degrees color map, which is configured such that the soft tissue is shown in yellow, green and red and the hard tissue in blue.

An ROI was selected in the repaired part of the Achilles tendon, and quantitative data (SR index) were determined. SE scans were repeated at least 4 times to obtain a mean value of the SR. Sonoelastography Mean Strain Ratio values (SR1, SR2 values) of the regenerated Achilles tendon were measured in the longitudinal plane predominantly in the repaired region during the follow-up period (1 week, 3, 6, 12, 36-40 weeks after surgery) in comparison to the fat tissue. The total number of SE studies were 225.

**Functional outcomes**

Functional outcomes were assessed with the American Orthopedic Foot and Ankle Society (AOFAS) rating system [12].

**Statistical analysis**

Student’s t-test were used to consider statistical significance with p<0.05. Continuous variables are expressed as means±standard deviations (SD). STATA software (version11.0; Stata Corp., TX) was used for data analysis. General linear regression analysis and correlation coefficients were used to investigate the relationship between elasticity and functional scores. Differences were considered statistically significant when P<0.05.
Results

The average time from injury to surgery was 5.8 (range, 1.0-15) days. Postoperatively, none of the patients developed postoperative infections, deep venous thrombosis, recurrences, or pulmonary embolisms. The average follow-up time was 40 weeks (9 months). The mean time to return to sport was 14.3 weeks (range, 9 weeks to 21 weeks).

There were significant differences with respect to the mean SR values and functional scores of the repaired Achilles tendon at 6, 12, and 24 weeks postoperatively between 2 groups (all t<0.05) Fig. 2 on page 8

Tendon function was positively correlated with increase in SR values of the repaired Achilles tendon. Unfortunatelly no correlation was found between tendon function and grey scale or color Doppler images in both groups.

Achilles tendons at different time points postoperatively showed significant increase during the process of healing.

Our results suggest that the stiffness of the surgically repaired Achilles tendon immeadeatelly postoperative decreased gradually and after 12 weeks began gradually increase as the wound-healing process continues Fig. 3 on page 8, Fig. 4 on page 8.

We also found significant differences with respect to the AOFAS scores at different time points postoperatively (after surgery, 6 weeks, 12, 36-40 weeks).

In addition, a significant positive correlation between AOFAS scores and the elasticity of healing tendons was noted.

This finding suggests that lower elastic modulus values might predict poor mechanical properties, functional outcomes, and healing of repaired tendons as noted during 12 weeks after surgery.

Sport related patients showed more prominent and quick appearance of increase in stiffness of the regenerated tendon and more prominent decrease in elasticity 3 weeks after surgery than non athlets. The SE images reflects the qualitative part Fig. 5 on page 9 , Fig. 6 on page 10.

Mean values of SR for athlets 3 weeks after surgical repair was 2.5+/-0.6, for non-sport-related persons 4.1+/-1.4, p<0.001;
Mean values of SR for athletes 6 weeks after surgical repair was 1.7+/-0.5, for non sport-related persons 3.6+/-1.7, p<0.005;

Mean values of SR for athletes 12 weeks after surgical repair was 1.9+/-1.1, for non sport-related persons 3.8+/-1.3, p<0.007.

Non-sport related patients showed prolongation in time for increase in tendon stiffness that result in longer rehabilitation time Fig. 7 on page 11, Fig. 8 on page 12
Fig. 2: Mean SR values of the repaired Achilles tendon after surgery, at 3 weeks, 6, 12, and 36-40 weeks postoperatively between 2 groups

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<table>
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<th></th>
<th>Athletes</th>
<th>Non-athletes</th>
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<tr>
<td>After surgery</td>
<td>5,1 +/- 2,3</td>
<td>5,4 +/- 2,7</td>
<td>p=0</td>
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<tr>
<td></td>
<td>p&lt;0,01***</td>
<td>p&lt;0,5</td>
<td></td>
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<tr>
<td>3 weeks AS</td>
<td>2,5 +/- 0,6</td>
<td>4,1 +/- 1,4</td>
<td>p&lt;0,01***</td>
</tr>
<tr>
<td>6 weeks AS</td>
<td>1,7 +/- 0,5</td>
<td>3,6 +/- 1,7</td>
<td>p&lt;0,005***</td>
</tr>
<tr>
<td>12 WAS</td>
<td>1,9 +/- 1,1</td>
<td>3,8 +/- 1,3</td>
<td>p&lt;0,01***</td>
</tr>
<tr>
<td>36-40 WAS</td>
<td>4,6 +/- 2,2</td>
<td>5,7 +/- 2,5</td>
<td>p&lt;0,5</td>
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Fig. 3: Changes in SR in the Achilles tendon during rehabilitation period in Athlets and ballet dancers.

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**Fig. 4:** Changes in SR in Achilles tendon in non-sport related persons during rehabilitation period.

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Fig. 5: SE images obtained in different patients 3 weeks after surgery repair in 2 athletes and a ballet dancer. Total decrease in elasticity of the Achilles noted.

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Fig. 6: SE images of non athletes 3 weeks after surgery repair. Multiple zones of increased stiffness present in the Achilles tendons.

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**Fig. 7**: SE image of the Achilles tendon 3 weeks postoperatively in non-sport related person.

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**Fig. 8**: SE image of the Achilles tendon 24 months postoperatively showed a appearance of the fibrillar structure and increase in stiffness. Note a red coloured paratenon appeared clearly (The same patient non sport related)

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Conclusion

Sonoelastography is an effective method for monitoring regenerative processes of the Achilles tendon after operation, reflecting the elasticity of the collagen fibers which can be used for individual rehabilitation programs for sport related and non-sport related patients.
Personal information

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References


