ORIGINAL PAPER

Validity and Reliability of Mini-Invasive Surgery Assisted by Ultrasound in Achilles Tendon Rupture

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doi: 10.5455/aim.2019.27.40-44

ACTA INFORM MED. 2019 MAR 27(1): 40-44

Received: Nov 05, 2018 • Accepted: Nov 30, 2018

ABSTRACT

Introduction: The surgical treatment for Achilles tendon rupture has become very popular in the last years, because of the good outcomes and the low re-rupture rate. **Aim:** The aim of this study is to compare the results between open surgery and percutaneous ultrasound-assisted surgery. **Methods:** All patients who underwent an Achilles tendon surgical repair in the last 3 years were included, resulting in a total of 56 patients (40 M and 16 F) with an average age of 53 years. Of these patients, 36 were treated with an open suture, while 20 with a mini invasive ultrasound assisted suture. At a minimum follow-up of one year, patients were evaluated echografically, using both the Achilles Tendon Rupture Total score (ATRS) and the McComis score, and performing the ultrasounds bilaterally to assess both the structure and the diameter of tendons. **Results:** Both groups of patients showed an average ATRS score >80. The McComis score was 54.18 vs. 56.25 ($p>0.05$). Plantar flexion and dorsal flexion work were not similar ($p>0.05$). On average, the calf circumference of the operated side was decreased compared to the healthy side between the groups ($p>0.05$). The thickness of the operated tendons evaluated with ultrasound measurement compared to the average tendon, ($p <0.05$). **Conclusion:** The ultrasound-assisted tenorrhaphy is a reliable treatment with good clinical and functional outcomes; anyway, the percutaneous technique and the open surgery show similar results.

Keywords: Achilles, Ultrasound-assisted, Percutaneous, Tenorrhaphy, Suture.

1. INTRODUCTION

The Achilles tendon is the strongest tendon of the human body. Its tensile strength is 50 to 100N/mm^2 (1, 2). Unfortunately, this tendon frequently undergoes a spontaneous rupture, 2-6 cm proximally to the insertion on the calcaneous area because of the poor vascularization of this area.

Subcutaneous Achilles tendon ruptures occur by an indirect trauma. A correlation between this lesion and highly competitive sports has been demonstrated (3). Some sports can cause the weakening of the tendon (by micro-trauma or ischemia). There is an increased interest in this pathology because of its correlation with the increasing practice of non-competitive sports, especially among middle-aged individuals, usually without an adequate training.

Several methods have been proposed for the treatment of this rupture, but there is no evidence about the superiority of one of them (4-7). Non operative treatments consist in immobilizing the ankle in plantar flexion for 8-10 weeks using plaster cast (8). Non-operative management avoids surgery risks, but may result in a decreased tendon resistance and a mean re-rupture rate of 20% (9). The indication for this treatment is for patients with low functional activity.

The surgical treatment has become very popular in the last years, also for the low re-rupture rate. The purpose of surgery is to restore the continuity of the tendon, retrieve the strength of plantar flexion, avoid retraction, and allow earlier return to pre-injury activity. Traditional open surgical technique has been associated with a high rate (11% to 29%) of wound complications (i.e. necrosis, infections, adhesions etc.) (10, 11).

Percutaneous methods described firstly by Ma and Griffith (12) avoids most of disadvantages of open surgical treatment.

2. AIM

The aims of this study were: to evaluate the safety and effectiveness of mini-invasive ultrasound-assisted surgery; and to compare the results between open surgery and mini-invasive ultrasound-assisted surgery.

3. METHODS

In our study, a series of consecutive patients who underwent an Achilles tendon suture consequently to an acute tear, from 2012 to 2015, were included. We excluded all the patients who had a tear more than two weeks before, an open injury or a distal tendon stump of less than 3 cm from the insertion.

The diagnosis was made in all cases with both clinical and ultrasound evaluations. The study population consisted in 56 patients (40 M and 16 F) with an average age of 53 years (34-68). The right tendon was involved in 30 cases, while the left tendon in 26 cases. The average follow-up was at least 12 months from surgery. The patients were divided into 2 groups, based on the different treatment performed:

Total amount of 36 patients were treated with a traditional open surgery, with an "end to end" pull-out suture and 20 patients were treated with a Ma and Griffith percutaneous ultrasound-assisted suture technique. The patients' randomization principle was based on their decision of which treatment they decided to choose.

All patients were fully informed about the 2 types of surgical treatment with their pros and cons and the corresponding surgical and conservative alternatives. Patients were treated according to the ethical standards of the Helsinki Declaration and were invited to read, understand and sign the informed consent form.

Both treatments were performed with the patient in prone position and without the use of tourniquet, under local regional anesthesia. The end-to-end pull out suture was made Approximating the ruptured ends of the tendon with No. 5 nonabsorbable tension suture, using a modified Kessler stitch through the stump 2.5 cm from the rupture. The Ma and Griffith percutaneous suture technique consisted first in the palpation of the tendineous gap. Ultrasonography was used to determine the location of the stumps and disappearance of the gap upon flexion of the foot was checked on the ultrasound images. In all cases we used the ACUSON Sequoia Ultrasound System by Siemens (Figure 1). The sural nerve was identified too. Then, six small skin incisions, 3 medially and 3 laterally, were performed at a distance of 2 cm one from each other. The proximal and distal incisions were determined based on the location of the tear. If required by the level of the intersection with the sural nerve, the lateral entry point was shifted medially to avoid injuring the sural nerve during insertion of the needle. Then, under ultrasound control, the tendon was sutured with a FiberWire 2 (Arthrex®), inserting the needle through one of the incisions, exiting from the opposite one, re-entering to the near one, and repeating this passage for 2-3 times (Figure 2). Progression of each needle was monitored on the transverse ultrasound image to allow proper positioning within the tendon. After tensioning and tightening of the sutures, ultrasonography was used to check that the two tendon stumps were in close contact with each other.

Postoperative treatment and Rehabilitation

A below-leg plaster cast was applied with the ankle in plantar flexion for 30 days; during this period, patients cannot remove the plaster cast and cannot start the rehabilitation. Patients must use two crutches with no weight-bearing, and start an antithrombotic prophylaxis (Enoxaparin 4000 U.I 1fl/day for 30 days).

After the first month, we stopped the antithrombotic therapy, and the leg plaster was replaced by a Walker brace with partial weight. After 2 months, a full unsupported weight-bearing was permitted. All patients who underwent minimally invasive surgery were evaluated during the operation using ultrasounds, and at 1, 2 month and 6 months, with a final visualization of the sutured tendon (Figure 3).

All patients followed the same physiotherapy protocol as the patients treated with classical open tendon suture. The first step was to restore the ankle ROM with active and passive mobilization; the second step was to restore the strength of the tendon performing isometric and eccentric exercises in order to improve the vascularization of the tendon and increase the healing process.

The patients were evaluated retrospectively with a questionnaire on the Achilles tendon rupture and scored using the Achilles Tendon Rupture Total score (ATRS) (13).

The anatomical and functional features of all patients were evaluated using the simplified McComis score (14) (Table 1) that considered the results as: very good (score from 80 to 70), good (from 69 to 60), fair (from 59 to 50), and poor (<50). An ultrasound evaluation of the affected tendon was made to assess its structure and diameter, and to compare it with the contralateral healthy one.

Statistical analysis was performed with the Fisher's exact test for categorical variables and the Student's t test for comparisons between the groups. The data were recorded in a Microsoft Excel sheet (Microsoft Corporation, USA), and analyzed using SPSS 23.0 statistical software (SPSS Inc., Chicago, IL, USA). A p value <0.05 was considered significant.

4. RESULTS

All the 56 patients were evaluated with a minimum follow-up of 12 months. Clinical evaluation included functional assessment of the ability to perform 5x10 repetitive single affected-side heel rises and surgery-related complications. Ultrasound control was made to evaluate both the structure and the diameter of the tendon.

Table 1 reports the average values for the ATRS questionnaire and McComis score. Both groups reached high scores (>85) in ATRS questionnaire, with no statistical difference between open and percutaneous repair. The McComis score for the percutaneous and open surgical technique (56.25 vs 54.18, respectively) were not statistically significant differences either.

Regarding the joint balance measurements obtained, no statistically significant differences were found between the two groups in plantar and dorsal flexion (30 °

Tab.1	ATRS	Mc Comis	Pl.flex	Dors.flex	Diamcalf	Diamtend	ATRS	McComis	Pl.flex	Dors. Flex	Diam-calf	Diam. Tend.
Mean	87.67	56.25	30,06	27.6	36.16	12.39	85.21	54.18	33.16	25	34,7	5
Std. Deviation	2.32	3.62	2,13	2.05	2.74	2.30	1.93	2.81	2.68	2.90	2.47	1,74
Std. Error of Mean	0.38	0.60	0,35	0,33	0,45	0.38	0.43	0.62	0,59	0.64	0.55	0.39
Lower 95% CI of Mean	86.8	55.11	29,33	26.74	35,13	11.61	85.15	52.68	31.6	23.64	33.54	4.18
Upper 95% CI of Mean	88.37	57.56	30,78	28.1	36,98	13.17	86.95	55.32	34.1	26.36	35.86	5.81

Table 1. Resume of the clinical and echographic outcomes.

vs 33.16 ° and 27.6 ° vs 25 °, respectively).

The mean calf diameter was 36.1 cm in open surgery, and 34.7 in the ultrasound group. The calf circumference of the treated leg was decreased compared to the healthy side.

Statistically significant differences were observed in the average thickness in the frontal plane of the tendons ($p < 0.05$), because the operated patients had an average thickness of 12 mm and 15 mm in comparison with the non-operated tendons whose average diameter it was 5 and 6 mm respectively.

Figure 1. ACUSON Sequoia Ultrasound System by Siemens

We found a greater increase in the diameter of the tendons treated with open surgery than the ones treated with the percutaneous technique. The echographic structure of tendons treated with open surgery showed an increased fibrillar degeneration and disparity compared to tendons treated percutaneous not operated of 1.5 cm and between the groups treated with different techniques the difference was not significant (36.1 Vs 34.7).

Figure 2.Intraoperative photo of final result of percutaneous treatment ultrasound assisted

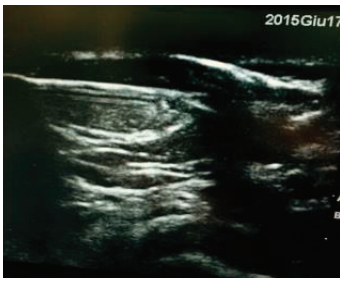

Figure 3.The restored continuity of the tendon, ultrasound control

There was no statistically significant difference in surgery time in the two groups. This result was probably due to a longer time in tendon suture and shorter time in skin suture in U.S. assisted technique.

The clinical examination showed satisfactory results in 40 patients who reported a significant improvement in pain symptoms; only 3 patients had a dorsiflexion limitation less than 10 °.

During follow-up, complications related to surgery were not observed, such as wounds or deep infections, sural nerve injuries or re-ruptures.

5. DISCUSSION

The treatment of Achilles tendon rupture remains controversial; surgery resulted in a lower re-rupture rate and earlier return to activity than conservative treatment (2-3). The surgical techniques, percutaneous or open, showed similar results in both clinical and functional evaluations (8-16).

Our study shows that tendons treated with open surgery had an increased diameter compared to those treated by percutaneous surgery, but with a greater dishomogeneity of the tendon. Moreover, the literature has clearly demonstrated that open traditional repair is associated with a high risk of wound complication, such as infections, non-healing of the skin or sural nerve injuries.

In 1977, Ma and Griffith (12) were the first to describe a percutaneous technique for the repair of this rupture, but this technique became very popular with ultrasound control as described by Blankstein (17). Ultrasound is used for diagnosis, to confirm the localization of the sural nerve, allows an accurate detection of the tendon ends, and ensures that the ends of the tendon are brought on passive plantar flexion.

From 2008 to 2010, Maffulli et al (18) enrolled 28 consecutive patients (21 men and 7 women; median age, 46 years) with chronic closed ruptures of the Achilles tendon who had undergone reconstruction with a free semitendinosus tendon graft. They assessed the Achilles tendon Total Rupture Score (ATRS), maximum calf circumference, and isometric plantar flexion strength before surgery and at the last follow-up. Outcome of surgery and rate of complications were also recorded. The median follow-up after surgery was 31.4 months.

Their overall results of surgery were: excellent/good in 26 (93%) of 28 patients. The ATRS improved from 42 (range, 29-55) to 86 (range, 78-95) ($P < .0001$). In the operated leg, the maximum calf circumference and isometric plantar flexion strength were significantly improved after surgery ($P < .0001$); however, their values remained significantly lower than those of the opposite side ($P < .0001$). All patients were able to walk on tiptoes and returned to

their pre-injury working occupation. No infections were recorded (18). Their conclusion were (18): mini-invasive reconstruction of the Achilles tendon, with a gap lesion larger than 6 cm, using the ipsilateral free semitendinosus tendon graft provides a significant improvement of symptoms and function, although calf circumference and ankle plantarflexion strength do not fully recover (18).

In 2015, Maffulli et al (19) published the paper about 21 patients undergoing minimally invasive reconstruction using a transfer of the ipsilateral peroneus brevis (PB) (five patients) or the free ipsilateral semitendinosus tendon (ST) graft with or without interference screw fixation (ten and six patients, respectively). We assessed the maximum calf circumference and isometric plantar flexion strength before surgery and at the last follow up (19). The Achilles tendon total rupture score (ATRS) and number of single-leg heel lifts on the affected leg were evaluated at the last follow up. The median follow up was 39 months. The outcome of surgery was excellent/good in 17 (81 %) of 21 patients. In the operated leg, the maximum calf circumference and isometric plantar flexion strength were significantly improved after surgery ($P<0.0001$). The average ATRS was 86 (range 79-92), and the average number of single-legged heel lifts was 33 (range 11-48). No further re-ruptures were recorded (19).The conclusions were: minimally invasive ipsilateral PB transfer and free ipsilateral ST graft with or without interference screw fixation are safe and effective procedures to reconstruct the Achilles tendon after a re-rupture, providing a significant improvement of the symptoms and function in the midterm (19).Kosanovic et al. (20) performed a modified Bunnel's percutaneous technique to suture the Achille's tendon. The authors only dealt with the early diagnosis of chronic rupture(< 8 weeks). The authors reported a patient with tendon non-union, which would normally be considered a re-rupture. This technique may have some merits in the early stages of chronic rupture, but larger numbers required. In another study (21), with a modified percutaneous technique in larger gaps, a total of 10 mini-incisions were made on either side of the tendon. Sutures were passed proximally and distally in a figure-of-eight fashion, and the ends delivered and tied in the two middle stab incisions. A validated outcome measure, greater detail in methodology and results would help interpret future series of this promising technique (22). Most tears and tendinopathy lesions occur approximately two to six centimeters from the insertion of the Achilles tendon on the calcaneus (23). In this area, complete tears are easily differentiated from partial tears, but the nearby plantaris tendon, lying medially, can be mistaken for an intact Achilles tendon (23). When diagnosis is doubtful, US examination may provide dynamic imaging, and ankle dorsiflexion may be helpful to detect tendon discontinuity (23). Therefore, baseline US appearance is not able to predict clinical outcome. In Achilles tendinopathy, grey-scale ultrasonography is a cost-effective method to examine the Achilles tendon (23). As grey scale sonography is operator dependent, and relies on the detection of hypoechoic lesion and assessment of tendon thickening and widening, it was hoped that the addition of color or power Doppler assessment would add objective evidence of pathology.

Instead the ultrasound assisted tenorrafia is an easy procedure, with a short learning curve, and it useful to preserve the blood supplies of the paratenon and soft tissues, suggesting a better healing of the wound and the tendon. The intra-operative use of ultrasonography does not significantly increase the operating time. Ultrasonography improves the reliability of suture positioning by providing real-time images of the boundaries of the tendon and their relationships with the sural nerve. The learning curve for ultrasound evaluation of the Achilles tendon was extremely short. Evaluation of the sural nerve proved more challenging but was facilitated by the clear visibility of the external saphenous vein traveling alongside the nerve.

In 2011 Saxena et al. showed the importance of the ability to perform 5 sets of 25 single-legged heel raises in post operative patients. We usually reduce the number of repetitions according to a low average training level of our population (24).

6. CONCLUSION

The ultrasound assisted tenorrhaphy is a feasible treatment with a good clinical and functional outcome, low rate of complication. The authors conclude that this technique should be the golden standard, due to lower risk of wound dehiscence, infections or sural nerve injuries in comparison to open surgery. Ultrasound assistance is very important confirm the localization of the sural nerve, the accurate detection of the tendon ends, and ensures that the ends of the tendon are brought on passive plantar flexion.

- **Author's contribution:** M.B., G.R, O.B, P.C., G.R., C.I.V.,A.R.I., and A.C. gave substantial contribution to the conception or design of the work and in the acquisition, analysis and interpretation of data for the work, L.M., J.C.I, F.S.S. and D.G.G. had role in drafting the work and revising it critically for important intellectual content. Each author gave final approval of the version to be published and they are agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
- **Conflict of interest**: All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honorarium, paid expert testimony, patent applications/registrations, and grants or other funding.
- **Human and animal rights:** For this type of study any statement relating to studies on humans and animals is not required. Patients gave their informed consent prior to being included in the study. All procedures involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments.

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