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Demandante: Gonzalo Gómez y otro
Demandados: EPS Sanitas S.A.S. y otros
Radicado: 63001310300220220009800
Asunto: Respuesta requerimiento de información

Reciban un cordial saludo,
En atención a la prueba solicitada por el despacho con relación al **protocolo institucional para la atención de la patología presentada por el señor GÓMEZ**, nos permitimos informarle que de acuerdo a la normatividad vigente, este tipo de patologías son tratadas de conformidad a la literatura científica y especialidad de los médicos tratantes, en contraste con el cuadro diagnóstico que presente el paciente, dado que no son patologías de incidencia en el país, por lo que de acuerdo a la regulación del ministerio de salud, no requiere de protocolos de atención especiales.

Por lo anterior, remitimos para que obre en el expediente, la literatura científica utilizada por los especialistas tratantes de este tipo de patologías, en cinco (05) archivos PDF.

Cordialmente,

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Acute Achilles Tendon Ruptures: Efficacy of Conservative and Surgical (Percutaneous, Open) Treatment—A Randomized, Controlled, Clinical Trial

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ABSTRACT

There is controversy regarding the best treatment for acute ruptures of the Achilles tendon. Multiple treatments present good results in the short and long term, none being superior to the other if a protocol of rehabilitation with full early weightbearing rehabilitation is followed. The objective of this study was to provide evidence on the efficacy and safety of conservative or surgical (percutaneous or open) treatment for acute Achilles tendon rupture. A randomized, controlled, parallel-groups, pilot clinical trial was performed in patients aged ≥18 years who arrived at the emergency room of our center experiencing acute Achilles tendon rupture. Patients were randomized via a computer-generated list to receive 1 of 3 treatments (conservative, percutaneous surgery, or open surgery). All patients followed the same protocol of rehabilitation with early weightbearing. A responder (i.e., successful treatment) was defined as capable of standing heelrise mono- and bipodally for 3 seconds, having a pain score ≤2 (verbal numerical rating scale) after walking, and having returned to active previous life (sport) at 1-year follow-up. From 2014 to 2017, 34 consecutive patients (median age, 41 years [range 18 to 59]; 32 male [94%]) were included: 11 conservative treatment, 11 percutaneous surgery, and 12 open surgery. At 1-year follow-up, the proportion of responders was 100% (11/11, 95% confidence interval [CI] 74% to 100%), 82% (9/11, 95% CI 52% to 95%), and 83% (10/12, 95% CI 55% to 95%), respectively. There was no case of total rerupture. Similar efficacy was found for conservative, percutaneous, and open surgery treatments for acute Achilles tendon rupture at 1-year follow-up with an early weightbearing rehabilitation program.

Acute Achilles tendon rupture is one of the most common tendon injuries: 11 to 37 of every 100,000 middle-aged people suffer this injury every year. There has been an increase in incidence in recent years, especially in older people. It is usually more frequent in males (ratio 2.9:1 to 5.7:1) and at 30 to 46 years of age (1–5). An area of the Achilles tendon 2 to 6 cm from the insertion on the calcaneus has relatively high avascularization (6), and it is this area where acute ruptures of the Achilles tendon occur most frequently.

There is controversy regarding the optimal treatment for acute ruptures of the Achilles tendon (7). Both conservative and surgical treatments present good results in the short and long term, none being superior to the other. In the past, surgical treatment was more often recommended for young, active patients and athletes, since conservative treatment led to a loss of muscle strength and a higher rate of reruptures. In recent times, it has become clear that with a rehabilitation protocol that includes early weightbearing (in some studies, at 10 days postinjury), similar rerupture rates are achieved in both treatments, with a similar return to daily life. However, more complications after surgical treatments (infections, intolerance, tendinitis) have been reported, even though this last difference was not statistically significant (5,8–17). Studies have demonstrated that early weightbearing of an injured tendon stimulates collagen and the healing process (18).

Our working hypothesis was that conservative treatment involving a rehabilitation protocol with early weightbearing is effective and safe for the treatment of acute Achilles tendon rupture.

Financial Disclosure: None reported.
Conflict of Interest: None reported.
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Therefore, the primary objective of this clinical trial was to provide evidence on the efficacy of conservative or surgical (percutaneous or open) treatment for acute Achilles tendon rupture with an early weightbearing rehabilitation protocol. Secondary objectives were to assess the safety of all treatments and the subsequent quality of life of patients.

Patients and Methods

This was a randomized, controlled, parallel-group, unicenter, pilot clinical trial. The study recruited patients with acute Achilles tendon rupture. The ethics committee of the center approved the study protocol. The study was conducted in agreement with the updated Declaration of Helsinki, the guidelines for Good Clinical Practice, and applicable Spanish regulatory requirements. All male and female patients aged 18 to 70 years who arrived at the emergency room of our center experiencing acute Achilles tendon rupture were eligible for the study. All patients provided informed written consent.

The clinical diagnosis of acute Achilles tendon rupture was made when the patient arrived at the emergency room of 1 of the 2 referring hospitals with acute severe pain at the level of the tendon, presenting with hematoma, depression, and discontinuity at the level of the tendon; loss of physiological equinus; inability to perform plantarflexion; and positive Thompson and Matles tests (19,20). For the final diagnosis, an ultrasonography of the tendon was performed where the rupture was identified, revealing the distance to the calcaneal insertion, the distance of the tendon gap, and the existence of signs of tendinosis or chronic tendinopathy. Exclusion criteria were a history of known tendinopathy, chronic ruptures, >10 days since the acute Achilles tendon rupture (21), calcaneal avulsion, myotendinous union lesions, other ipsilateral lesions, open sections of the tendon, or an injury <2 cm or >8 cm from the calcaneal insertion by ultrasound.

A computer-generated randomization schedule was prepared at the start of the study with stratification by 4 variables (to minimize possible bias) according to age (>40 years); whether the patient was a professional athlete or performed regular sports (>4 times per week for 30 min); whether the patient had a previous pathology such as diabetes mellitus, rheumatic diseases, or collagen diseases; and whether the patient had been treated with quinolones or systemic/local corticosteroids, as shown in Table 1. Access to this schedule was limited to the staff who generated it and the staff in charge of assigning the randomization. The investigator who evaluated efficacy was not involved in the treatment assignment, the treatment performed, or the follow-up visits of the patients.

The study comprised 6 on-site, postoperative/postinjury follow-up visits: randomization and treatment (visit 1); first control at day 10 (visit 2); following controls at 6 weeks (visit 3), 12 weeks (visit 4), and 24 weeks (visit 5); and final examination at 52 weeks (last visit or visit 6). All following control visits were performed at outpatient facilities.

Randomized patients were treated with 1 of the following 3 treatments:

1) Conservative treatment (orthopedic treatment): A cast was placed in 30° plantarflexion in the emergency department, and patients were discharged home with analgesic, antithrombotic treatment and no weightbearing of the injured limb. All patients were referred to the Foot and Ankle Unit to proceed with the rehabilitation protocol and the follow-up visits.
2) Percutaneous surgical treatment: Surgery was performed under sedation and local anesthesia and without ischemia cuff. Following the technique described by Ma and Griffith (22), 7 incisions were made in total: 1 transversal at the level of the rupture of the tendon and 3 on each side (2 proximal and 1 distal to the rupture). The proximal incisions were made 2 and 3 cm from the transverse incision, and the distal incision at 2 cm from the transversal incision. (When making the proximal incisions, the surgeon must take into account that the sural nerve crosses from posterior to lateral ~8 to 10 cm from the calcaneal insertion of the Achilles.) With a straight needle, a PDS 1 suture was passed from the proximal incisions crosswise to the proximal end, and similarly at the distal incision. The sutures were then knotted through the transverse incision with the foot in maximum plantarflexion to approximate the ends of the tendon as much as possible. The contralateral extremity was used as a guide for the restoration of proper tendon length. Closure of the incisions was performed with 3-0 prolene suture, and a cast was placed in 30° plantarflexion. Patients stayed for 24 h in the hospital and were discharged home with analgesic, antithrombotic treatment and no weightbearing of the operated limb. Patients were referred to the Foot and Ankle Unit to proceed with the rehabilitation protocol and follow-up visits.
3) Open surgical treatment: Surgery was performed under spinal anesthesia or femoropopliteal block and with ischemia cuff at the level of the thigh raised to 250 mmHg. A vertical posteromedial incision was made. The hematoma and the tendon ends were cleaned, and a double Bunnel suture was performed with a PDS suture of 1 mm (reabsorbable 1-mm braided polydioxanon) (23) with the foot in maximum plantarflexion to approximate the ends of the tendon as much as possible. The contralateral extremity was used as a guide for the restoration of proper tendon length. Suture of the paratendon and subsequent skin closure were performed with 3/0 prolene points, and a cast was placed in 30° plantarflexion. All patients stayed for 24 h in the hospital and were discharged home with analgesic, antithrombotic treatment and no weightbearing of the operated limb. Patients were referred to the Foot and Ankle Unit to proceed with the rehabilitation protocol and follow-up visits.

Table 1
Randomization: 8 strata groups

Group	Age (yr)	Sports?*	PB?†
A	<40	Y	N
B	<40	Y	Y
C	<40	N	N
D	<40	N	Y
E	>40	Y	N
F	>40	Y	Y
G	>40	N	N
H	>40	N	Y

* Athletes or usual sport (>4 times per week/>30 min)

† PB, pathological background: diabetes, rheumatic diseases, collagenopathies, gout; use of chronic glucocorticoids (systemic and/or local current or previous weeks) or fluroquinolones; other diseases not taken into account when stratifying.

Later Protocol for All Patients

All patients remained in the cast for 10 days with no weightbearing of the injured limb. After 10 days, at visit 2, the cast was removed; in the case of surgical treatments, the wound was checked for healing and sutures were removed. Then, a walker-type orthopedic boot below the knee was placed, adding some wedges to gain equine position. All patients followed a strict protocol with early weightbearing, starting load with the boot and wedges immediately, and remaining for 8 days with all the wedges. Subsequently, wedges were removed every 4 days (days 18, 22, 26, and 30), and finally patients remained 8 days more without wedges (from days 30 to 38), walking plantigrade with the boot (Table 2).

At 6 weeks (visit 3), all patients had started active rehabilitation, and the walker boot had been removed. At 12 weeks (visit 4), 24 weeks (visit 5), and 52 weeks (visit 6, final examination at 1-year follow-up), pain intensity, scar evaluation (in patients of the surgical groups), active articular balance, and ability to stand bi- or monopodal heelrise and hold for 3 seconds (form of validation of these patients) (24,25) was assessed. Magnetic resonance imaging was performed if the patient had pain during the posttreatment period. The following specific quality-of-life questionnaires were completed: Achilles tendon total rupture score (ATRS) and Victorian Institute of Sport Assessment (VISA); as well as less specific questionnaires such as the American Orthopaedic Foot and Ankle Society (AOFAS) score for the hindfoot. Also at visit 6, an ultrasound was performed; comparisons were made with the healthy extremity of calf circumference (with measure tape in cm, 10 cm distal from the anterior tibia tuberosity) (26,27); measurement of the physiological plantarflexion at rest and plantarflexion muscle strength were calculated with dynamometry (in Newtons); pain intensity after walking was assessed (verbal numeric rating scale [VNRS]; 0, no pain; 10, the worst pain); and the patient made an overall assessment (Patients' Global Impression) of the study treatment using a verbal rating scale (excellent, very good, good, fair, poor). The patient was then discharged.

Study Outcomes

The primary efficacy endpoint was the proportion of responders (i.e., successful treatment) at 1-year follow-up. A responder was defined as capable of standing heelrise mono- and bipodally for 3 seconds, having a pain score ≤2 (VNRS) after walking, and having returned to active previous life (sport). Secondary efficacy endpoints were the questionnaires, muscular strength for plantarflexion, calf circumference, physiological

Table 2
Rehabilitation protocol with early weightbearing

Postoperative/Postinjury	Plaster in Equine Position (30° PF)
Day 10 (first visit)	- Remove cast - Place orthopedic walker boot and 4 wedges (22° PF) - Weightbearing
Days 11 to 34	
Day 18	- Take off first wedge (16° PF) - Can take off boot at night and start ROM/passive exercises (assisted eversion, inversion and flexion, extension of the foot)
Day 22	- Take off second wedge (10° PF) - Start active exercises
Day 26	- Take off third and fourth wedges (0° PF)
Day 34 and onward	- Start active rehabilitation
Day 40	- Take off the walker boot completely

PF, plantarflexion; ROM, range of motion.

plantarflexion at rest (equinus), and the integrity of the Achilles tendon evaluated by ultrasound at 1-year follow-up, assessing the diameter and length of the tendon and signs of tendinopathy and hypervascularization.

Statistical Analysis

In line with the study protocol, for the primary efficacy analysis, 10 patients per treatment group was considered the minimum sample size necessary to properly evaluate the results of the study. The primary population for efficacy analysis was the whole analysis set (all randomized and treated patients). Baseline characteristics were summarized using standard descriptive statistics, and a descriptive analysis was carried out. Continuous variables were described as mean (standard deviation) or median (range), and categorical data was summarized as absolute frequency and percentages. The proportion of responders was estimated, and its 95% confidence interval (95% CI) was calculated. An exploratory analysis was done among the different groups of treatment. A P value of ≤ 0.05 was considered statistically significant. Data analysis was carried out using Stata/IC 15.0 for Mac (64-bit Intel, revision 25 set 2017).

Results

From February 2014 to February 2017, 34 patients came to the emergency department of our hospital experiencing acute Achilles tendon rupture. All of them were included in the study and were randomized and treated: 11 in the conservative treatment group, 11 in the percutaneous surgery treatment group, and 12 in the open surgery treatment group. Patient baseline characteristics are shown in Table 3. Values for demographic variables were not markedly different among treatment groups. Patients were predominantly young (median age 41 years), Caucasian (100%), and male (94%), and the lesion occurred in the left extremity in 76% (26 patients). Fig. 1 shows the study's flow chart.

Primary Objective: Proportion of Responders at 1-Year Follow-Up

At 1-year follow-up, the proportion of responders was 100% (11 of 11, 95% CI 74% to 100%) in the conservative group, 82% (9 of 11, 95% CI 52% to 95%) in the percutaneous surgery group, and 83% (10 of 12, 95% CI 55% to 95%) in the open surgery group. Four patients (2 in the percutaneous surgical group and 2 in the open surgical group) scored pain intensity >2, which is usually related to scar induration, or could not stand heelrise for 3 seconds.

Table 3
Patient baseline characteristics

	Conservative (n = 11)	Percutaneous Surgery (n = 11)	Open Surgery (n = 12)
Sex			
Female	1 (10)	1 (10)	1 (8)
Male	10 (90)	10 (90)	11 (91.2)
Age (years)	42 (26 to 51)	41 (18 to 50)	40.5 (28 to 51)
Achilles tendon rupture			
Right	2 (18)	1 (10)	4 (33)
Left	9 (82)	10 (90)	8 (66)

Data are n (%) or median (range).

Secondary Efficacy Objectives

Standing heelrise: Four patients (2 in percutaneous surgical group and 2 in open surgical group) could not stand heelrise for 3 seconds at 52 weeks. Therefore, 85.2% (30 of 34) of the patients could bipodally and monopodally stand heelrise and hold for 3 seconds. Fig. 2 shows the progress at 12, 24, and 52 weeks based on the number of patients who could stand heelrise bipodally and monopodally or only bipodally in each treatment group.

Pain: Pain intensity ≤2 by VNRS at 52 weeks was 100% (11 of 11, 95% CI 74% to 100%) in the conservative group, 82% (9 of 11, 95% CI 52% to 95%) in the percutaneous surgery group, and 83% (10 of 12, 95% CI 55% to 95%) in the open surgery group. Pain was related to scar indurations.

Return to sports: At 52 weeks of follow-up, 30 of 34 (88.2%) patients had returned to their active previous life (sports activity: paddle, soccer, climbing, etc.): 1 case in the conservative treatment group, 2 in the

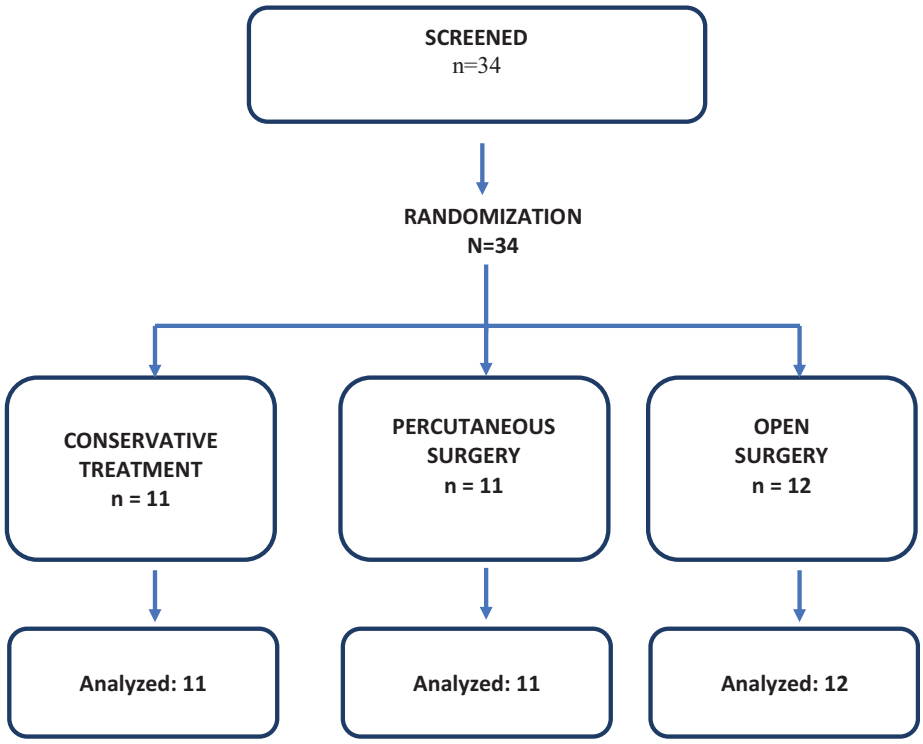

Fig. 1. Study flow chart.

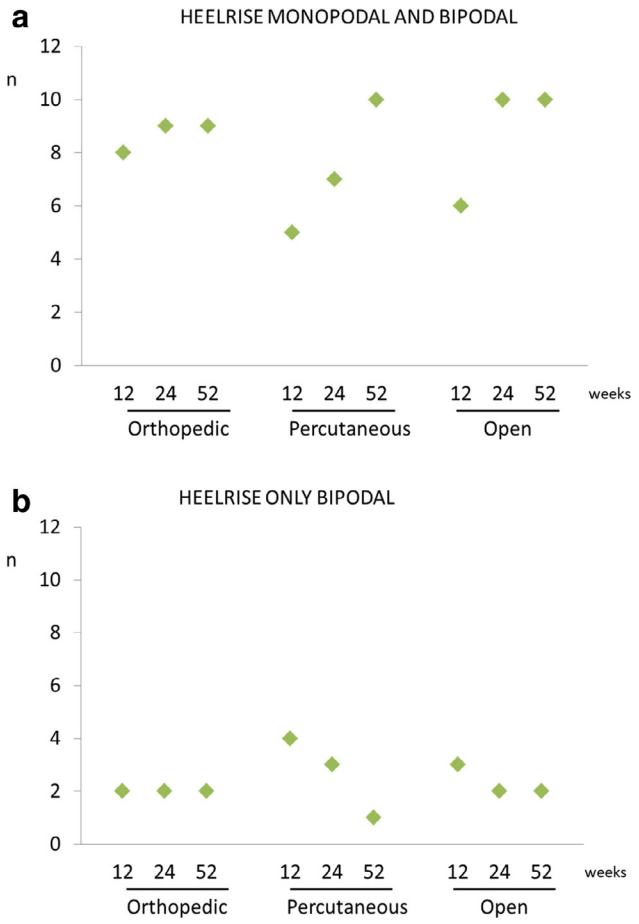

Fig. 2. Number of patients who could stand healrise, bipodal and monopodal (*a*) or bipodal only (*b*), holding for 3 seconds at 12, 24, and 52 weeks of each treatment group.

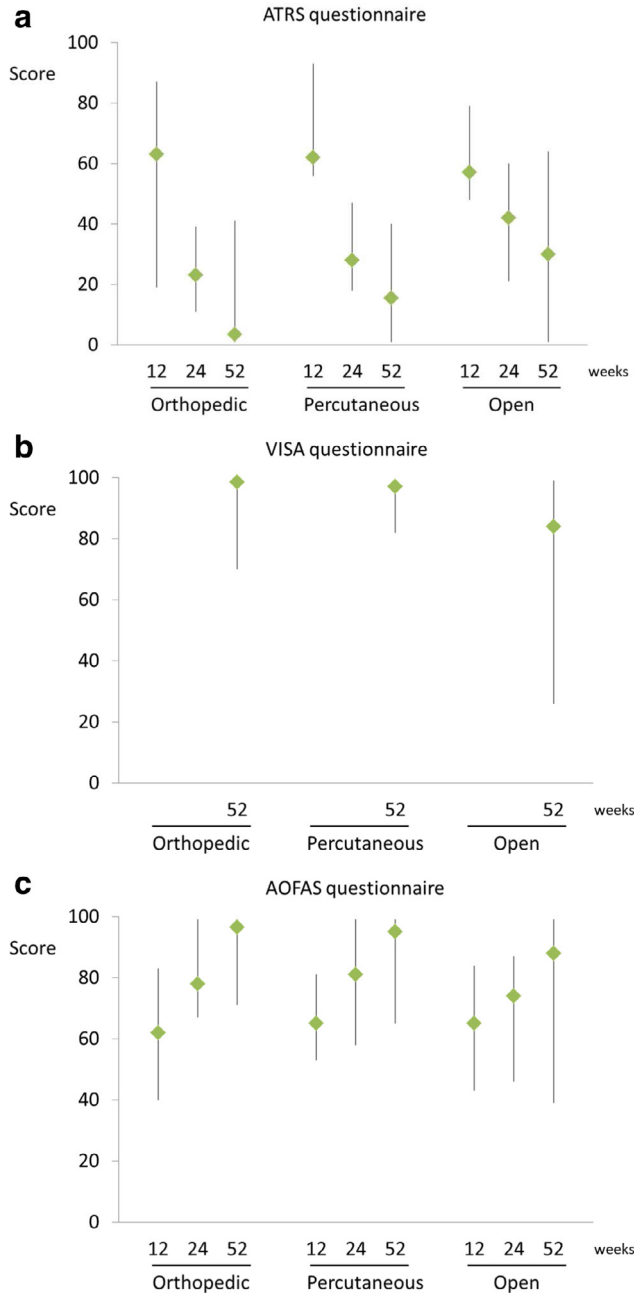

Fig. 3. Median (range) scores of Achilles tendon total rupture (*a*), Victorian Institute of Sport Assessment (*b*), and American Orthopaedic Foot and Ankle Society (*c*) questionnaires by treatment group: orthopedic (n = 11), percutaneous surgery (n = 11), and open surgery (n = 12).

percutaneous group, and 1 in the open surgery group did not perform their usual sports. One patient at baseline (belonging to the open surgery group) did not practice sports; this patient had returned to an active life at 52 weeks.

Questionnaires: Fig. 3*a* shows the median (range) ATRS questionnaire score at 12, 24, and 52 weeks by treatment group; Fig. 3*b*, the VISA questionnaire score; and Fig. 3*c*, the AOFAS questionnaire score. The open surgery group showed a different evolution in the ARTR (lower scores at 24 and 52 weeks) and AOFAS (greater scores at 52 weeks) questionnaires in comparison with the conservative and percutaneous treatment groups. Likewise, the open surgical group showed a lower score in the VISA questionnaire at 52 weeks.

Muscular strength: Fig. 4 depicts the median (range) of the muscle strength (in Newtons) of the sural triceps in the injured and contralateral (healthy) leg by treatment group at 52 weeks. All patients in the conservative group held with maximum strength for 10 seconds in the orthopedic group; in contrast, the strength of 1 patient in the percutaneous surgical group and 2 patients in the open surgery group decreased by 20 N.

Calf circumference: The median (range) of calf circumference at 52 weeks in the conservative group was of 35 cm (range 32 to 43) in the injured limb and 40 cm (range 33 to 43) in the healthy limb; in the percutaneous surgery group, 38 cm (37 to 39) in the injured limb and 41 cm (39 to 43) in the healthy limb; and in the open surgical group, 39 cm (30 to 45) in the injured limb and 41 cm (31 to 45) in the healthy limb.

Plantarflexion: The median (range) plantarflexion at rest (equine) at 52 weeks in the orthopedic group was 26° (range 20° to 30°) in the injured limb and 30° (range 28° to 30°) in the healthy limb; in the percutaneous surgery group, 20° (10° to 30°) in the injured limb and 30° (20° to 30°) in the healthy limb; and in the open surgical group, 15° (10° to 30°) in the injured limb and 30° (15° to 30°) in the healthy limb.

Ultrasound: Table 4 presents the median (range) of ultrasound results (depth and tendon elongation in injured and healthy limbs, heterogeneity, and vascularization) at 52 weeks. Hypervascularization of the tendon was visualized in 3 patients (27%) in the percutaneous surgical group and 4 (33%) in the open surgical group, without any signs of tendinosis or tendinitis in any patient.

Patients' global impression (excellent, very good, good, fair, poor): At 1-year follow-up, 10 patients (91%) in the conserative treatment

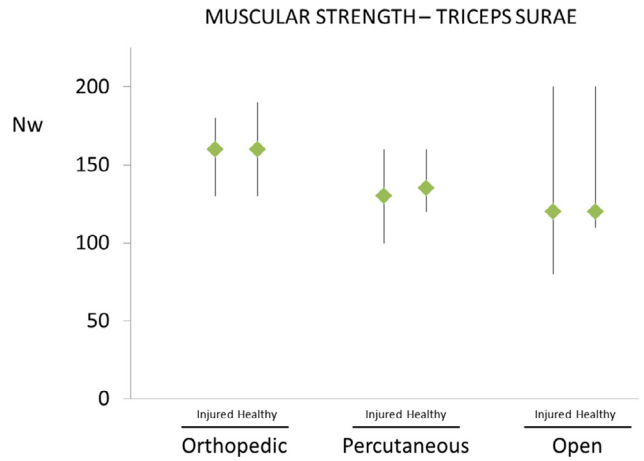

Fig. 4. Median (range) of the muscle strength (in Newtons) of the sural triceps in the injured and contralateral (healthy) leg by treatment group: orthopedic (n = 11), percutaneous surgery (n = 11), and open surgery (n = 12).

group reported excellent impressions of the treatment, and 1 patient (9%) reported very good. In the percutaneous surgery group 8 patients (72%) reported excellent impressions, 2 (18%) very good, and 1 (9%) good. In the open surgery group, 10 patients (83%) reported excellent impressions, and 2 (17%) reported very good.

Complications and Safety

No serious adverse events were reported during the follow-up, and no case of total rerupture. Magnetic resonance imaging was performed in 3 patients (1 of each group) who had pain at 24 weeks after injury. The images showed partial microtears at the level of the Achilles tendon and also in the musculotendinous union, which normally appear after starting more intensive exercises at 6 months. All patients improved with new rehabilitation sessions.

In the percutaneous surgery group, 2 patients had hyperalgesia in the territory of the sural nerve, which disappeared after a year. In the surgical groups, there was no infection of the wounds during the follow-up. At 1 year of follow-up, 5 patients (3 percutaneous surgery and 2 open surgery) had a fibrous and indurated scar. In both patients of the open surgery group, the hypertrophic and indurated scar prevented them from advancing in muscular potentiation because of pain, decreasing scores on quality-of-life questionnaires, and increasing pain (VNRS 3).

Discussion

There is a lot of controversy regarding the treatment of acute Achilles tendon ruptures, without clear advantages of any treatment. Surgical treatment is preferable in active patients, who require an early return to active life, although this treatment is more expensive and presents more complications than conservative treatment (16,22,28). Percutaneous surgery reduces many of the complications presented by open surgery (15,22), with fewer infections and the same incidence of rerupture. One study, however, showed the incidence of sural nerve injury to be higher in percutaneous surgery (5.5% in percutaneous vs 1.2% in open surgery) (29).

We did not find differences in terms of age, degree of previous sport (>4 times/30 minutes of exercise per week), or other antecedents. It should be emphasized that only 9 patients out of 34 performed regular sports at a high-intensity level (more than 4 times a week), none at a professional level.

We observed that patients who followed conservative treatment obtained better results at 1-year follow-up in the different questionnaires (ATRS, VISA, AOFAs), although in the first weeks, the assessment was lower. Although the differences in the results obtained were not statistically significant, we observed that patients who underwent surgical treatments, predominantly in those of the open surgical group, had problems with wound healing, such as keloids and adhesions, diminishing their final satisfaction. These good results of the different treatments are due to the rehabilitation protocol with early weightbearing that our patients followed, as shown by several studies (4,30–32). In recent studies, it has been seen that orthopedic treatment followed by early weightbearing rehabilitation reduces the incidence of rerupture, almost equaling to surgical treatment (1,2,4,5,9–12,33,34). Our study had no cases of rerupture.

Soroceanu el al. (1) compared the results of surgical treatment with conservative treatment, concluding that in those studies in which a rehabilitation protocol was performed with loading and early mobilization, the rate of reoperations was equalized between the 2 treatments. In contrast, 15.8% more complications (deep vein thrombosis, wound infections, necrosis of the skin and tendon, sural nerve injury, tendon elongation, decreased ankle mobility) occurred in patients who underwent surgical treatment.

In another prospective study of 60 patients (35), comparing surgery and orthopedic treatment, the authors observed that the results were similar with both treatments in terms of the questionnaires, but having surgery allowed better and faster recovery of the muscle strength of the triceps surae. However, neither treatment restored the same muscle strength as on the contralateral (healthy) side, similar to what we observed in our study, although we didn't find any differences between the treatments in terms of muscle strength. In our study, we observed that those patients who had scar problems showed inferior results in both the questionnaires and the recovery of the strength of the triceps surae.

We had 2 cases in the percutaneous surgery group of hyperalgesia in the territory of the sural nerve, with resolution before the first year after the injury. As described (36), because the percutaneous incisions are made longitudinally, if the sural nerve is injured, it is most often a result of longitudinal neurotomy instead of an axonotmesis or transverse neurotmesis, allowing the nerve to regenerate over time. As in other studies, we found a decrease in the calf circumference, an increase in the length of the tendon (elongation), and a decrease in the strength of the triceps sural compared with the healthy

Table 4
Results of ultrasound 1 year after injury

Surgery	Depth of tendon (cm)		Length of tendon (cm)		Heterogeneity	Hypervascularization
	Injured	Healthy	Injured	Healthy		
Orthopaedic (n = 11)	1.45 (1.09 to 2.23)	1.20 (0.40 to 1.47)	10.81 (10.69 to 12. 66)	10.98 (10.11 to 11.72)	0	0
Percutaneous surgery (n = 11)	1.72 (1.49 to 1.96)	1.31 (0.88 to 1.42)	12.27 (11.46 to 13.77)	11.02 (10.05 to 13.62)	11	3
Open surgery (n = 11)	1.71 (1.22 to 2.33)	1.42 (0.47 to 1.81)	11.76 (10.17 to 12.77)	10.96 (10.03 to 12.14)	12	4

Data are median (range) or n.

contralateral limb, without these differences being clinically significant (1,25,37,38).

Although we clinically found that patients who underwent conservative treatment had less elongation, these results were not very relevant for the patients, since 88.23% of them returned to their previous sports activity (paddle, soccer, climbing, etc.). Compared with other studies (39,40) that showed a 30% decrease in the muscle strength of the triceps surae at 1-year follow-up, we obtained better results, with only 8% in those who followed open surgical treatment, 6% in the percutaneous group, and 2% in conservative group, without statistically significant differences. We found no correlation between elongation and heelrise, as some studies have described (41).

Our study is subject to some limitations. Its small sample size (pilot clinical trial) and that it only involved 1 center might underestimate or overestimate the generalizability of the results beyond the population and conditions studied.

In conclusion, our results suggest that conservative treatment is just as effective as surgical treatments in the majority of patients, as long as a protocol of rehabilitation with early weightbearing is performed. It would be necessary to perform randomized clinical trials with a larger size to validate these results.

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To Dr. Jorge Muriano, who was the soul of this study (deceased 2017). Dr. Andrea Manent is a PhD candidate at the University of Barcelona, Spain.

References

1. Soroceanu A, Sidhwa F, Aarabi S, Kaufman A, Glazebrook M. Surgical versus nonsurgical treatment of acute achilles tendon rupture. A meta-analysis of randomized trials. J Bone Joint Surg Am 2012;94:2136–2143.
2. Ganestam A, Kallemose T, Troelsen A. Increasing incidence of acute Achilles tendon rupture and a noticeable decline in surgical treatment from 1994 to 2013. A nationwide registry study of 33,160 patients. Knee Surg Sports Traumatol Arthrosc 2016;24(12):3730–3737.
3. McCoy BW, Haddad SL. The strength of Achilles tendon repair: a comparison of three suture techniques in human cadaver tendons. Foot Ankle Int 2010;31(8):701–705.
4. Khan JK, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute Achilles tendon ruptures, a meta-analysis of randomized, controlled trials. J Bone Joint Surg Am 2005;87(10):2202–2210.
5. Wu Y, Lin L, Li H, Zhao Y, Liu L, Jia Z, Wang D, He Q, Ruan D. Is surgical intervention more effective than non-surgical treatment for acute Achilles tendon rupture? A systematic review of overlapping meta-analyses. Int J Surg 2016;36(Pt A):305–311.
6. Pajala A, Kangas J, Siira P, Ohtonen P, Leppilahti J. Augmented compared with non-augmented surgical repair of a fresh total Achilles tendon rupture: a prospective randomized study. J Bone Joint Surg Am 2009;91:1092–1100.
7. Carr AJ, Norris SH. The blood supply of the calcaneal tendon. J Bone Joint Surg Br 1989;71(1):100–101.
8. Crolla RMPH, van Leeuwen DM, van Ramshorst B. Acute rupture of the tendo calcaneus. Surgical repair with functional after treatment. Acta Orthop Belg 1987;53:492–494.
9. van der Eng DM, Schepers T, Goslings JC, Schep NWL. Rerupture rate after early weightbearing in operative versus conservative treatment of Achilles tendon ruptures: a meta-analysis. J Foot Ankle Surg 2013;52:622–628.
10. Jackson G, Sinclair VF, McLaughlin C, Barrie J. Outcomes of functional weight-bearing rehabilitation of Achilles tendon ruptures. Orthopedics 2013;36(8):e1053–e1059.
11. Willits K, Amendola A, Bryant D, Mohtadi NG, Giffin JR, Fowler P, Kean KO, Kirkley A. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am 2010;92:2767–2775.
12. El-Akkawi A, Joanroy R, Weisskirchner Barfod K, Kallemose T, Kristensen S S, Viberg B. Effect of early versus late weightbearing in conservatively treated acute Achilles tendon rupture: a meta-analysis. J Foot Ankle Surg 2018;57(2):346–352.
13. Lill H, Moor C, Schmidt A. Current status of treatment of Achilles tendon ruptures. Results of a nationwide survey in Germany. Chirurg 1996;67:1160–1165.
14. Shaieb MD, Singer DI. Tensile strengths of various suture techniques. Hand Surg 1997;22B(6):764–767.
15. Carmont MR, Heaver C, Pradhan A, Mei-Dan O, Gravare Silbernagel K. Surgical repair of the ruptured Achilles tendon: the cost-effectiveness of open versus percutaneous repair. Knee Surg Sports Traumatol Arthrosc 2013;21:1361–1368.
16. Maffulli N. Rupture of the Achilles tendon. J Bone Joint Surg Am 1999;81:1019–1036.
17. Maffulli N, Waterson SW, Squair J, Reaper J, Douglas AS. Changing incidence of Achilles tendon rupture in Scotland: a 15- year study. Clin J Sport Med 1999;9(3):157–160.
18. Stehno-Bittel L, Reddy GK, Gum S, Enwemeka CS. Biochemistry and biomechanics of healing tendon: Part I. Effects of rigid plaster casts and functional casts. Med Sci Sports Exerc 1998;30(6):788–793.
19. Simmonds FA. The diagnosis of the ruptured Achilles tendon. Practitioner 1957;179:56–58.
20. Matles AL. Rupture of the tendo Achilles. Another diagnostic sign. Bull Hosp Joint Dis 1975;36:48–51.
21. Hwan Y, Min S, Won G, Jun K. How early must an acute Achilles tendon rupture be repaired. J Injury Int 2017;48:776–780.
22. Ma GWC, Griffith TG. Percutaneous repair of acute closed ruptured Achilles tendon. A new technique. Clin Orthop 1977;128:247–255.
23. Manent A, Lopez L, Vilanova J, Mota T, Alvarez J, Santamaría A, Martí Oliva X. Assessment of the resistance of several suture techniques in human cadaver Achilles tendon. J Foot Ankle Surg 2017;56:954–959.
24. Möller M, Lind K, Styf J, Karlsson J. The reliability of isokinetic testing of the ankle joint and a heel-raise test for endurance. Knee Surg Sports Traumatol Arthrosc 2005;13:60–71.
25. Silbernagel KG, Gustavsson A, Thomeé R, et al. Evaluation of lower leg function in patients with Achilles tendinopathy. Knee Surg Sports Traumatol Arthrosc 2006;14:1207–1217.
26. Carmont MR, Silbernagel KG, Mathy A, Mulji Y, Karlsson J, Maffulli N. Achilles tendon resting angle and calf circumference measurement techniques. Foot Ankle Surg 2013;19:245–249.
27. Leppilahti J, Lähde S, Forsman K, et al. Relationship between calf muscle size and strength after Achilles rupture repair. Foot Ankle Int 2000;21:330–335.
28. Westin O, Svensson M, Nilsson Helander K, Samuelsson K, Grävare Silbernagel K, Olsson N, Karlsson J, Hansson Olofsson E. Cost-effectiveness analysis of surgical versus non-surgical management of acute Achilles tendon ruptures. Knee Surg Sports Traumatol Arthrosc 2018;26:3074–3082.
29. Yang B, Liu Y, Kan S, Zhang D, Xu H, Liu F, Ning G, Feng S. Outcomes and complications of percutaneaous versus open repair of acute Achilles tendon rupture: a meta-analysis. Int J Surg 2017;40:178–186.
30. Maffulli G, Del Bueno A, Richards P, Oliva F, Maffulli N. Conservative, minimally invasive and open surgical repair for management of acute ruptures of the Achilles tendon: a clinical and functional retrospective study. Muscles Ligaments Tendons J 2017;7(1):46–52.
31. Frankewycz B, Krutsch W, Weber J, Ernstberger A, Nerlich M, Pfeifer CG. Rehabilitation of Achilles tendon ruptures: is early functional rehabilitation daily routine? Arch Orthop Trauma Surg 2017;137(3):333–340.
32. Suchak AA, Spooner C, Reid DC, Jomha NM. Postoperative rehabilitation protocols for Achilles tendon ruptures: a metaanalysis. Clin Orthop Relat Res 2006;445:216–221.
33. Wallace RG, Heyes GJ, Michael AL. The non-operative functional management of patients with a rupture of the tendo Achillis leads to low rates of re-rupture. J Bone Joint Surg Br 2011;93(10):1362–1366.
34. Lim CS, Lees D, Gwynne-Jones DP. Functional outcome of acute Achilles tendon rupture with and without operative treatment using identical functional bracing protocol. Foot Ankle Int 2017;38(12):1331–1336.
35. Lantto L, Heikkinen J, Flinkkila T, Ohtonen P, Siira P, Laie V, Leppilahti J. A prospective randomized trial comparing surgical and nonsurgical treatment of acute Achilles tendon ruptures. Am J Sports Med 2016;44(9):2406–2414.
36. Carmont MR, Maffulli N. Modified percutaneous repair of ruptured Achilles tendon. Knee Surg Sports Traumatol Arthrosc 2008;16:199–203.
37. Bradley JP, Tibone JE. Percutaneous and open surgical repairs of Achilles tendon ruptures. A comparative study. Am J Sports Med 1990;18:188–195.
38. Heikkinen J, Lantto I, Flinkkila T, Ohtonen P, Niinimaki J, Siira P, Laine V, Leppilahti J. Soleus atrophy is common after the nonsurgical treatment of acute Achilles tendon ruptures: a randomized clinical trial comparing surgical and nonsurgical functional treatments. Am J Sports Med 2017;45(6):1395–1404.
39. Möller M, Lind K, Movin T, et al. Calf muscle function after Achilles tendon rupture. A prospective, randomized study comparing surgical and non-surgical treatment. Scand J Med Sci Sports 2002;12:9–16.
40. Nilsson-Helander K, silbernagel KG, Thomeé R, et al. Acute Achilles tendon rupture: a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. Am J Sports Med 2010;38:2186–2193.
41. Silbernagel KG, Steele R, Manal K. Deficits in heel-rise height and Achilles tendon elongation occur in patients recovering from an Achilles tendon rupture. Am J Sports Med 2012;40:1564–1571.

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Review Articles

Surgical Treatment Versus Conservative Management for Acute Achilles Tendon Rupture: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

Acute Achilles tendon ruptures can be treated with surgical and nonsurgical treatment. However, the optimal intervention for acute Achilles tendon rupture remains controversial. The aim of the present study was to compare the clinical outcomes of surgical treatment versus conservative management for acute Achilles tendon rupture. Eight randomized controlled studies involving 762 patients were included in the meta-analysis. In general, re-rupture occurred in 14 of 381 surgically treated patients (3.7%) and 37 of 377 nonsurgically treated patients (9.8%). Pooled results showed that the total re-rupture rate was significantly lower in surgical group than that in the nonsurgical group (risk ratio 0.38, 95% confidence interval 0.21 to 0.68; $p = .001$). No significant differences were found between the 2 treatment groups in the incidence of deep venous thrombosis, the number who returned to sport, ankle range of motion (dorsiflexion, plantarflexion), Achilles tendon total rupture score, or physical activity scale. Surgical treatment can effectively reduce the re-rupture rate and might be a better choice for the treatment of acute Achilles tendon rupture. Multicenter, double-blind randomized controlled trials with stratification and long-term follow-up are needed to obtain a higher level of evidence and to guide clinical practice, especially in the comparison and selection of different treatments.

Acute Achilles tendon rupture is one of the most common disabling injuries in the male population, largely occurring in those participating in high-impact sports, especially ball games (1–3). According to an epidemiologic study in Denmark, the incidence of Achilles tendon rupture increased from $26.95/10^5$ persons in 1994 to $31.17/10^5$ person in 2013 and is still increasing (4). The current evidence has suggested that multiple risk factors are related to Achilles tendon rupture, including tendon degeneration, poor tendon vascularity, corticosteroid use, fluoroquinolone use, and previous rupture on the contralateral side (2,5–7). Although the ruptured tendon can be treated with surgical and nonsurgical therapies, no consensus has yet been reached regarding the optimal treatment protocol (8–13).

Surgical treatment has become the mainstay of therapy for acute Achilles tendon rupture in the past decades, mainly because of the reported greater risk of re-rupture after nonoperative treatment (14,15). Previously reported meta-analyses (16–18) concluded that the rate of re-rupture ranged from 3.5% to 4.3% in the surgical group and 8.8% to 9.7% in the nonsurgical group. They also found that the re-rupture rate was greater after conservative treatment and complications other than re-rupture occurred significantly more often with surgical treatment. Therefore, orthopedic surgeons have preferred surgical repair for acute Achilles tendon rupture.

Recently, many studies have shown similar functional outcomes and re-rupture rates between operative and nonoperative groups with accelerated rehabilitation, including early weightbearing and protected range of motion (ROM), instead of rigid cast immobilization (11,13). Early cast immobilization without ankle mobilization and weightbearing could increase the risk of re-rupture (14,19). Thus, a rationale exists for the rapid shift toward an accelerated rehabilitation protocol, which appears to stimulate tendon healing and achieve more favorable outcomes (11,13,20–23). Furthermore, conservative treatment could avoid the complications related to surgery, such as wound infection, scar adhesion, tendon necrosis, and nerve injury (11,12). However, large groups of surgeons continue to treat every rupture surgically, even in the obese population. Many reasons exist

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Table 1
Modified Jadad quality scale (27) for each included study

Scale Item	Response Option	Möller et al (14)	Costa et al (23)	Twaddle et al (28)	Metz et al (19)	Nilsson-Helander et al (10)	Willits et al (11)	Keating et al (12)	Olsson et al (13)
1. Was the study described as randomized?	Yes, appropriate (2)		X	X	X	X	X		X
	Yes, unclear (1)	X						X	
	No, inappropriate (0)								
2. Was the study described as double-blind?	Yes, appropriate (2)								
	Yes, unclear (1)								
	No, inappropriate (0)	X	X	X	X	X	X	X	X
3. Was there a description of withdrawals and dropouts?	Yes (1)	X	X	X	X	X	X	X	X
	No (0)								
4. Was there a clear description of the inclusion or exclusion criteria?	Yes (1)	X		X	X	X	X	X	X
	No (0)		X						
5. Was the method used to assess adverse effects described?	Yes (1)	X	X	X	X	X	X	X	X
	No (0)								
6. Were the methods of statistical analysis described?	Yes (1)	X	X	X	X	X	X	X	X
	No (0)								
Total score		5	5	6	6	6	6	5	6

for this, including surgeon experience and patient expectations, and so forth. However, a lack of the latest cogent and recognized clinical evidence might be the main reason.

The current studies and meta-analyses have shown discordant findings, making it difficult to select the best procedure for acute Achilles tendon rupture. Therefore, we need strong evidence from the

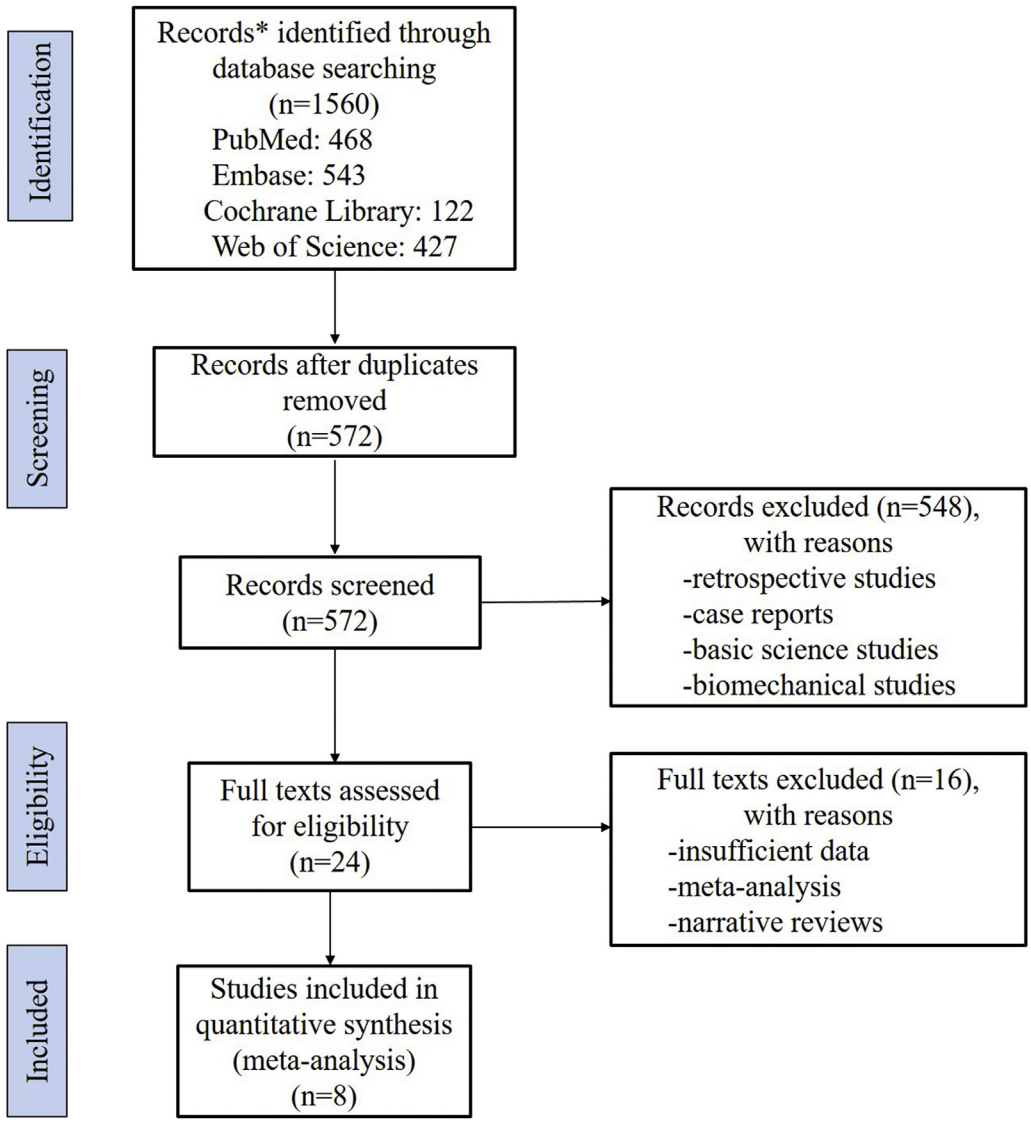

Fig. 1. Flow chart showing method of article selection. *Records were searched and reviewed according to the titles and abstracts.

Table 2
Characteristics of included randomized controlled studies

Study	Patients (% Male)	Mean Age (y)	Effective Follow-Up (%)	Follow-Up Period* (mo)	Level of Evidence
Möller et al (14), 2001	S, 59 (86) NS, 53 (91)	S, 39.6 ± 10.05† NS, 38.5 ± 8.25†	99	24	I
Costa et al (23), 2006	S, 48 (83) NS, 48 (67)	S, 43.3 ± 8.25† NS, 45.5 ± 10.0†	86	12	I
Twaddle et al (28), 2007	S, 25 (70) NS, 25 (64)	S, 41.8 (NR) NS, 40.3 (NR)	84	12	I
Metz et al (19), 2008	S, 42 (74) NS, 41 (85)	S, 41.5 ± 10.0† NS, 42.25 ± 9.25†	100	12	II
Nilsson-Helander et al (10), 2010	S, 49 (81.6) NS, 48 (81.3)	S, 40.9 ± 8.8 NS, 41.2 ± 9.5	100	12	I
Willits et al (11), 2010	S, 72 (82) NS, 72 (82)	S, 39.7 ± 11.0 NS, 41.1 ± 8.0	88	24	I
Keating et al (12), 2011	S, 39 (72) NS, 41 (78)	S, 41.2 ± 8.0† NS, 39.5 ± 9.25†	95	12	I
Olsson et al (13), 2013	S, 49 (80) NS, 51 (92)	S, 39.8 ± 8.9 NS, 39.5 ± 9.7	88	12	I
Total	762 (80.4) S, 383 (79.5) NS, 379 (81.5)	40.97 ± 8.17† S, 40.85 ± 7.67† NS, 41.08 ± 8.17†	NA	12	I, 7; II, 1

Abbreviations: NA, not applicable; NS, nonsurgical group; NR, standard deviation not reported; S, surgical group.
Data presented as mean ± standard deviation.
* Minimum follow-up period listed.
† Data estimated using the method introduced by Hozo et al (29).

latest level I and II prospective randomized studies to reexamine the conclusions given in the previous paragraph and offer intervention recommendations in accordance with the highest level of evidence. We hypothesized that surgical treatment could effectively reduce the risk of re-rupture compared with conservative management but that similar functional outcomes would be found between surgically and nonsurgically treated patients.

Materials and Methods

Search Strategy

The present meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (24). Two of us (S.D., Z.S.) independently searched the most commonly used medical databases, including PubMed (available at: https://www.ncbi.nlm.nih.gov/pubmed/; from 1978 to March 2017), Embase (available at: http://www.embase.com/; from 1974 to March 2017), Cochrane Central Register of Controlled Trials (available at: http://www.cochranelibrary.com/about/central-landing-page.html; up to March 2017), and Web of Science (available at: http://apps.webofknowledge.com/; from 1978 to March 2017) to identify all relevant published studies that had compared the clinical outcomes of surgical treatment with nonsurgical treatment of acute Achilles tendon rupture. We did not search for unpublished studies, and none were included in the present review.

A systematic and comprehensive search was performed using the following search terms: (Achilles tendon OR Achilles OR tendoachilles OR tendocalcaneus) AND (surgical OR nonsurgical OR operative OR nonoperative OR conservative) AND (rupture OR tear OR lesion). The titles were screened and the abstracts carefully reviewed for any potentially eligible studies. The references of each included study were also reviewed to find additional studies that met our inclusion criteria. When necessary, the authors were contacted for the complete manuscript or data confirmation.

Inclusion and Exclusion Criteria

The inclusion criteria for our study were level I and II evidence randomized controlled trials; a target population of acute Achilles tendon rupture; studies comparing the clinical outcomes of surgical treatment and nonsurgical treatment; treatment initiated within 14 days after rupture; and ≥1 outcome measurements postoperatively (e.g., re-rupture rate, functional scores, complications). Retrospective studies, case reports, basic science studies, insufficient data, and biomechanical studies were excluded.

Study Selection

Two reviewers (S.D., Z.S.) independently reviewed the titles and abstracts of all studies generated from the literature search to exclude irrelevant studies and identify potentially relevant articles. For potentially eligible studies, 2 reviewers (S.D., Z.S.) independently reviewed the full text of articles (March 2017) using the inclusion criteria. The references of the retrieved articles were also searched manually. Inconsistencies were resolved by discussion and consensus or by a third author (J.L.). The reviewers were not blinded to the authors, journals, or sources of financial support.

Data Extraction and Quality Assessment

The data were extracted independently by 2 of us (S.D., C.Z.). Any discrepancies in the extracted data were resolved by discussion and consensus. Data extraction mainly included study characteristics, patient demographics, injured side, interval from injury to treatment, surgical technique, functional outcomes, rehabilitation protocols, and complications. Our primary outcome was the re-rupture rate, with re-ruptures occurring within 14 days of initial treatment. The secondary outcomes included deep venous thrombosis (DVT), wound infection, nerve injury, number of patients returning to sports activities, functional scores, including the Achilles tendon total rupture score (ATRS) (25) and physical activity scale (PAS) (26), and ankle ROM, including dorsiflexion and plantarflexion, which were measured using a goniometer (12) and Biodex Multi-Joint System 2 or 3 dynamometer (Biodex Medical, Shirley, NY) in accordance with the manufacture's operating manual (11,12). Other clinical outcomes, determined using different scales, including isokinetic strength, functional index for the leg and ankle, Leppilahti score, short musculoskeletal function assessment score, or Foot and Ankle Outcome Score, were not included in the present meta-analysis, because either the data could not be pooled or significant comparisons could not be made because the outcomes used varied in the different studies.

Two of us (S.D., G.C.) independently assessed the methodologic quality of the studies using the modified Jadad quality scale (Table 1) (10–14,19,23,27,28). The modified Jadad quality scale is a 6-item scale designed to assess randomization, blinding method, withdrawals and dropouts, inclusion and exclusion criteria, adverse effects, and statistical analysis. Scores of 0 to 3 points indicate poor to low quality, and scores of 4 to 8 points denote good to excellent quality. Disagreement was resolved by discussion and consultation with the senior author (J.L.).

Statistical Analysis

If the standard error was not reported, it was estimated using the method introduced by Hozo et al (29). For dichotomous variables, including the re-rupture rate, incidence of DVT, and number of patients returning to sport, the relative treatment effect was reported as the risk ratio (RR) and 95% confidence interval (CI). For continuous data, including dorsiflexion, plantarflexion, ATRS, and PAS, the effect of treatment was quantified by calculating the mean difference with the 95% CI. Heterogeneity across the pooled data was formally tested using the Cochrane χ^2 test and quantified using the I^2 test. An I^2 of <50% was the cutoff for homogeneity of the data using the fixed effects model, justifying pooling. The random effects model was applied if the I^2 was >50% and heterogeneity was significant. Differences were considered significant if $p < .05$. Statistical analysis of all the extracted data was performed using Review Manager software, version 5.3 (Cochrane Collaboration, London, UK, 2014).

Results

Studies and Assessment of Study Quality

We searched a total of 1560 studies according to their titles and abstracts from the abovementioned databases and found 572

Table 3
Summary of results from included randomized controlled trials

Investigator	Injured Side (% Left)	Interval From Injury to Treatment (days)	Surgical Technique	Outcomes
Möler et al (14), 2001	S, 34 (58); NS, 30 (57)	≤7	End to end, modified Kessler	DF, PF, calf circumference, isokinetic strength, heel-raise test, VAS for subjective results of treatment, FIL, satisfaction, time to return to work
Costa et al (23), 2006	S, 28 (58); NS, 27 (56)	≤7	End to end, augmented repair	Time to return to activities, EuroQol health status questionnaire, deficit in calf diameter, loss of DF and PF, muscle dynamometry
Twaddle et al (28), 2007	S, 10 (50); NS, 12 (55)	≤2	End to end, Krackow-type stitch	MFAI, DF, PF, calf circumference
Metz et al (19), 2008	S, 28 (67); NS, 21 (51)	≤3	Bunnell-type suture in proximal tendon, through lateral aspect of calcaneus distally	Time to work resumption, sports after rupture, VAS for satisfaction and pain, Leppilahti score
Nilsson-Helander et al (10), 2010	S, 26 (53); NS, 27 (56)	≤3	End to end, modified Kessler	ATRS, PAS, jump test, strength test, muscular endurance test
Willits et al (11), 2010	NR	≤14	End to end, Krackow-type stitch	Leppilahti score, ROM and isokinetic strength (DF, PF), calf circumference
Keating et al (12), 2011	NR	≤10	End to end, Kessler stitch, interrupted circumferential stitch	SMFA, ROM, and muscle function dynamometry (DF, PF)
Olsson et al (13), 2013	S, 24 (49); NS, 16 (31)	≤4	End to end, modified Kessler, epitendinous cross-stitch	ATRS, PAS, FAOS, EQ-5D, jump test, strength test, muscular endurance test

Abbreviations: ATRS, Achilles tendon total rupture score; DF, dorsiflexion; EQ-5D, EuroQol group questionnaire; FAOS, Foot and Ankle Outcome Score; FIL, functional index for the leg and ankle; MFAI, musculoskeletal functional assessment index; NR, not reported; NS, nonsurgical group; PAS, physical activity scale; PF, plantarflexion; ROM, range of motion; S, surgical group; SMFA, short musculoskeletal function assessment; VAS, visual analog scale.

individual studies after excluding the duplicates. After examining the titles and abstracts of numerous studies, 24 met our inclusion criteria and were included. Finally, 8 published randomized controlled studies met the quality requirements and were the basis of our meta-analysis (10–14,19,23,28). The process of the search strategy is shown in Fig. 1.

The overall methodologic quality of the included studies was relatively high, with a mean modified Jadad score of 5.6 ± 0.5. Seven of

Table 4
Rehabilitation protocols and complications for each included study

Investigator	Rehabilitation Protocol		Complications (n)			
	Surgical	Nonsurgical	Re-Rupture (%)	DVT (%)	Infection (%)	NI (%)
Möller et al (14), 2001	Immobilized with cast for 12 days; followed by a brace for next 8 wk; AROM with FWB at 3 to 8 wk	Immobilized with cast for 8 wk; PWB at 8 wk	S, 1 (1.7); NS, 11 (20.8)	S, 0 (0); NS, 1 (1.9)	S, 1 (1.7); NS, 0 (0)	S, 1 (1.7); NS, 0 (0)
Costa et al (23), 2006	SG, mobilized with FWB in carbon-fiber orthosis for 8 wk postoperatively	SG, mobilized with FWB in carbon-fiber orthosis for 12 wk	S, 2 (4.2); NS, 2 (4.2)	S, 0 (0); NS, 1 (2.1)	S, 1 (2.1); NS, 0 (0)	S, 1 (2.1); NS, 0 (0)
Twaddle et al (28), 2007	Immobilized with hanging equinus plaster for 10 days; followed by removable below-the-knee orthosis for 8 wk; AROM at 10 days, PWB at 6 wk		S, 2 (8.0); NS, 1 (4.0)	NR	NR	NR
Metz et al (19), 2008	Immobilized for 1 wk with cast; followed by tape bandage for next 6 wk; FWB postoperatively	Immobilized for 1 wk with cast; followed by multifunctional below-the-knee splint for next 6 wk	S, 3 (7.1); NS, 5 (12.2)	S, 0 (0); NS, 1 (2.4)	S, 0 (0); NS, 0 (0)	S, 3 (7.1); NS, 1 (2.4)
Nilsson-Helander et al (10), 2010	Immobilization with below-the-knee cast in equinus position for 2 wk; followed by adjustable brace for next 6 wk; PWB at 6 to 8 wk		S, 2 (4.1); NS, 6 (12.5)	NR	S, 2 (4.1); NS, 0 (0)	S, 2 (4.1); NS, 0 (0)
Willits et al (11), 2010	Immobilization in posterior back slab for 2 wk; changed to removable below-the-knee orthosis for 6 wk; AROM and PWB at 2 wk		S, 2 (2.8); NS, 3 (4.2)	S, 1 (1.4); NS, 1 (1.4)	S, 5 (6.9); NS, 0 (0)	NR
Keating et al (12), 2011	Immobilization in equinus cast for 6 wk; PWB at 6 wk	Immobilization with cast for 10 wk; PWB at 8 wk	S, 2 (5.1); NS, 4 (9.8)	S, 0 (0); NS, 2 (4.9)	S, 3 (7.7); NS, 0 (0)	NR
Olsson et al (13), 2013	FWB postoperatively; AROM at 2 wk; immobilization with brace for 6 wk	FWB at beginning; protected AROM at beginning; immobilization with brace for 8 wk	S, 0 (0); NS, 5 (9.8)	S, 1 (2.0); NS, 2 (3.9)	S, 6 (12.2); NS, 0 (0)	S, 1 (2.0); NS, 0

Abbreviations: AROM, active range of motion; DVT, deep vein thrombosis; FWB, full weightbearing; NI, nerve injury; NR, not reported; NS, nonsurgical group; PWB, partial weightbearing; S, surgical group; SG, study group.
Twaddle and Poon (28), Nilsson-Helander et al (10), and Willits et al (11) used the same rehabilitation protocols for the surgical and nonsurgical groups.

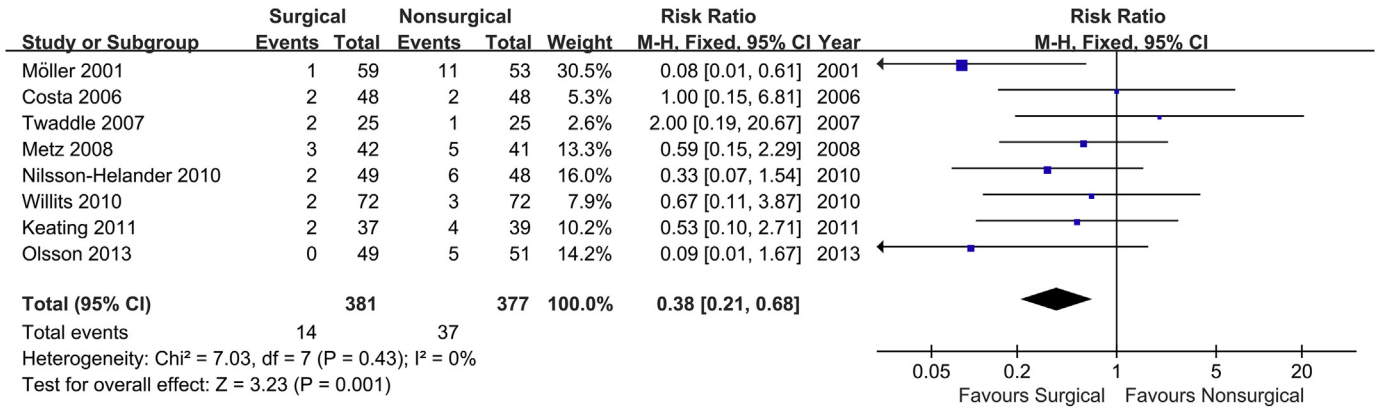

Fig. 2. Forest plot of meta-analysis for re-rupture rate. CI, confidence interval; M-H, Mantel-Haenszel.

these included studies were level 1, and one was level 2. The examiners and patients of all the included studies had not been blinded to the treatment. Randomization was computer-generated in 5 studies and by tossing a coin in 1 study; the remaining 2 studies did not mention the randomization method. Concealment of allocation was applied in all the studies by sealed envelopes. The details of the modified Jadad quality scale for the included studies are listed in Table 1.

Baseline Patient Characteristics

The data from a total of 762 patients were extracted from the included studies. The patients were predominantly male (613 of 762, 80.4%). Of the 762 patients, 383 (50.3%) had undergone surgical intervention (mean age 40.85 ± 7.67 years) and 379 (49.7%) had received nonoperative treatment (mean age 41.08 ± 8.17 years). The minimum follow-up duration was 12 months, and the effective follow-up rate ranged from 84% to 100% (Table 2) (10–14,19,23,28).

The injured side, interval from injury to treatment, surgical technique, and treatment outcomes of the included randomized controlled trials are listed in Table 3 (10–14,19,23,28). The left Achilles tendon was relatively more prone to rupture. The interval from injury to treatment was within 2 to 14 days. Five 5 different surgical techniques were used.

The rehabilitation protocols and complications for each included study are listed in Table 4 (10–14,19,23,28). Three studies used the same rehabilitation protocols for the surgical and nonsurgical groups. The other 5 studies used rehabilitation protocols that differed between the surgical and nonsurgical groups. In general, the nonsurgical group required a longer rehabilitation time than did the surgical group. The complications between the 2, including re-rupture, DVT, wound infection, and nerve injury, are listed in Table 4. The overall incidence of wound infection in the surgical group was 5.0% (range 1.7% to 12.2%).

Meta-Analysis of Clinical Outcomes

Re-Rupture Rate

All the included studies reported the re-rupture rate (10–14,19,23,28). Re-rupture occurred in 14 of 381 surgically treated patients (3.7%) and 37 of 377 nonsurgically treated patients (9.8%). The pooled results showed that the total re-rupture rate was significantly lower in the surgical group than in the nonsurgical group (RR 0.38, 95% CI 0.21 to 0.68; $p = .001$) with no heterogeneity detected ($I^2 = 0\%$; Fig. 2).

Incidence of DVT

Of the 8 included studies, 6 reported the incidence of DVT (11–14,19,23). The meta-analysis found no significant difference in the incidence of DVT between the 2 groups (RR 0.40, 95% CI 0.13 to 1.26, $p = .12$) and no heterogeneity ($I^2 = 0\%$; Fig. 3).

Patients Returning to Sport

Of the 8 included trials, 4 reported the number of patients returning to sports activities (12,14,19,23). The meta-analysis did not find a significant difference between the 2 treatment groups (RR 1.06, 95% CI 0.90 to 1.24; $p = .50$). A random effects model was used because the heterogeneity was slightly significant ($I^2 = 51\%$; Fig. 4). In addition, 3 trials reported the time required to return to sport and/or work. Möller et al (14) reported that the time before patients could return to work in the surgical group was 54.9 ± 47.9 days versus 73.4

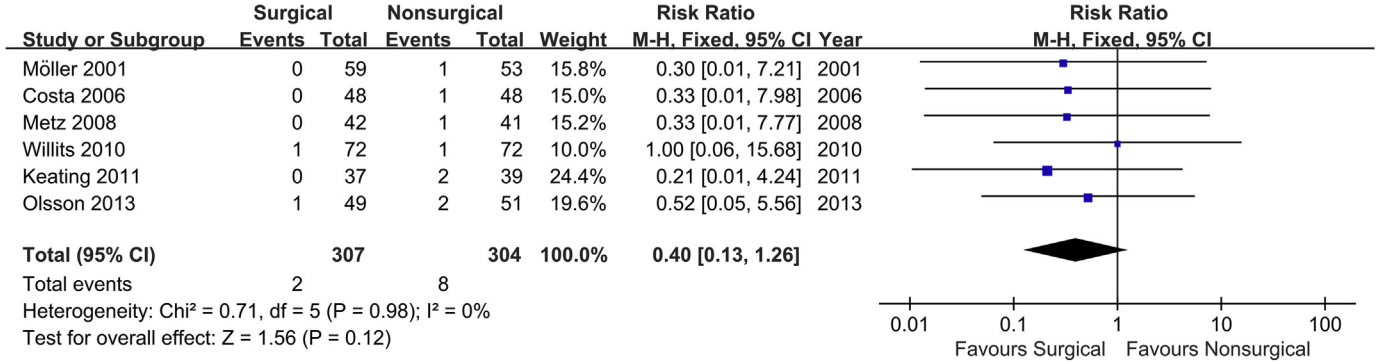

Fig. 3. Forest plot of meta-analysis for deep venous thrombosis. CI, confidence interval; M-H, Mantel-Haenszel.

Fig. 4. Forest plot of meta-analysis showing number of patients who successfully resumed preinjury sports level. CI, confidence interval; M-H, Mantel-Haenszel.

± 56.5 days in the conservative treatment group ($p = .06$). Metz et al (19) reported the mean time off work was 59 ± 82 days for the surgically treated patients and 108 ± 115 days for the nonoperatively treated patients (difference of 49 days; 95% CI 4 to 94; $p < .05$). Keating and Will (12) reported a mean time to return to full sporting activity of 34 (range 14 to 52) weeks for the operative group and 35 (range 17 to 52) weeks in the nonoperative group (no significant difference), with a mean time to return to work of 12 weeks in both groups (no significant difference).

Ankle ROM (Dorsiflexion, Plantarflexion)

Two studies documented the ankle ROM postoperatively, expressed as the degree of dorsiflexion and plantarflexion (11,12). The overall effect suggested that no significant difference was present between the surgical and nonsurgical intervention for dorsiflexion (mean difference 0.80, 95% CI −1.87 to 3.47; $p = .56$; $I^2 = 51\%$; Fig. 5*A*) or plantarflexion (mean difference −0.11, 95% CI −4.52 to 4.31; $p = .96$; $I^2 = 75\%$; Fig. 5*B*). A random effects model was used because of the clinical heterogeneity.

Functional Scores (ATRS and PAS)

Functional scores, including the ATRS and PAS, were reported in 2 studies (10,13). When the data were pooled, the fixed effects analysis showed no statistically significant differences between the operative and nonoperative groups in the ATRS (mean difference 2.00, 95% CI −3.49 to 7.49; $p = .47$; $I^2 = 0\%$; Fig. 6*A*) or PAS (mean difference −0.05, 95% CI −0.37 to 0.27; $p = .77$; $I^2 = 0\%$; Fig. 6*B*).

Discussion

The results of the present study suggest that surgical treatment can effectively reduce the incidence of re-rupture; however, inherent to surgical repair is an increased risk of wound infection compared with conservative treatment. However, no statistically significant differences were found in the functional outcomes between the surgical and nonsurgical groups for DVT, number of patients returning to sport, dorsiflexion, plantarflexion, ATRS, and PAS.

Re-rupture was our primary outcome. The pooled results showed that the total re-rupture rate was significantly lower in the surgical group than in the nonsurgical group. Re-rupture occurred in 14 of 381 surgically treated patients (3.7%) and 37 of 377 nonsurgically treated patients (9.8%), for a decrease of 6.1% favoring the surgical group. We consider that a 6.1% decrease in the re-rupture rate is clinically significant and should not be overlooked by clinicians. The results were consistent with those from previously reported meta-analyses (16–18), which concluded that the rate of re-rupture ranged from 3.5% to 4.3% in the surgical group versus 8.8% to 9.7% in the nonsurgical group. Although a meta-analysis of randomized trials in 2012 (17) showed that conservative management involving early weightbearing and controlled ankle motion could decrease the rate of re-rupture to the same level after surgical treatment and avoid the complications related to surgical treatment, our meta-analysis data did not show this.

Another important factor in clinical decision-making is the prevalence of other complications that are mainly secondary to operative treatment, such as DVT, wound infection, nerve injury, and skin-related complications. Our meta-analysis results indicated that no significant difference was present in the incidence of DVT between the surgical and nonsurgical groups. The overall incidence of wound infection was 5.0% (range 1.7% to 12.2%) in the surgical group, which should not be overlooked. However, the complications related to open surgery can be effectively reduced using a percutaneous surgical technique, which has advantages such as being minimally invasive and resulting in a lower rate of re-rupture and wound infection and

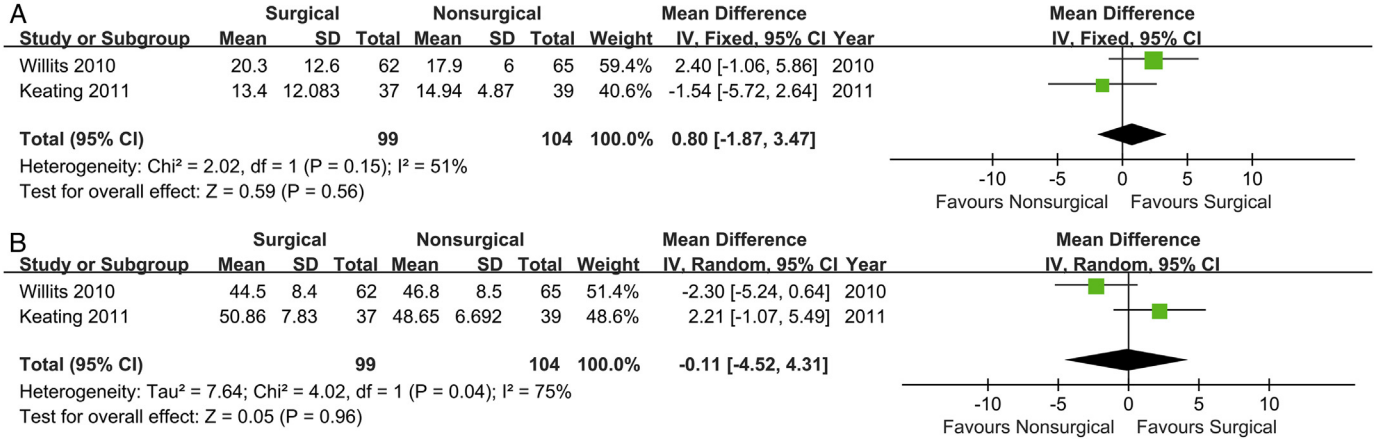

Fig. 5. Forest plot of meta-analysis for (*A*) dorsiflexion and (*B*) plantarflexion. CI, confidence interval; IV, inverse variance.

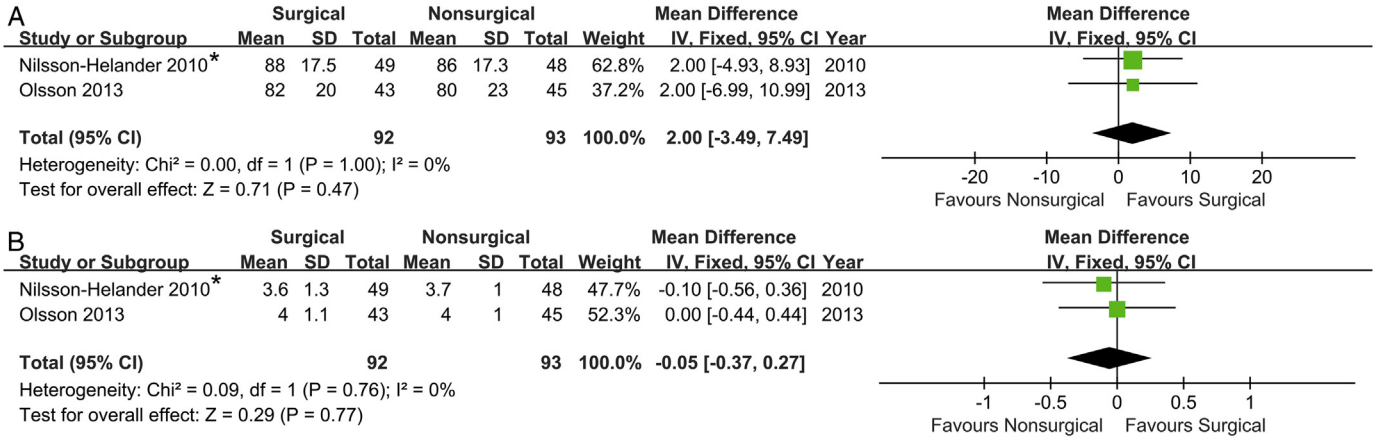

Fig. 6. Forest plot of meta-analysis for (*A*) Achilles tendon total rupture score (ATRS) and (*B*) physical activity scale (PAS). CI, confidence interval; IV, inverse variance. *The standard deviations were estimated using the method introduced by Hozo et al (29).

a better cosmetic appearance (30–32). Therefore, we consider that a modified surgical technique for acute Achilles tendon rupture is a promising method to increase the successful outcomes and decrease the complications related to surgery.

Although no significant difference was found for the overall number of patients returning to sport between the surgical and nonsurgical groups, the time to return to work was significantly different between the 2 groups in 1 of 3 trials, with an increase of 49 days in the nonsurgical groups, another factor that should be considered by clinicians. Further research is needed to investigate the differences in the time to return to work and/or sport between the surgical and nonsurgical groups.

In our meta-analysis, we could not find any clinically significant differences between the surgically and nonsurgically treated patients in the ankle ROM and functional scores. The findings were consistent with a study by Wallace et al (33) in 2011. They showed no clinically significant differences between surgical and nonsurgical treatment in ROM, calf circumference, or functional scores (33).

Epidemiologic studies (4,34,35) have shown that the proportion of surgically treated patients decreased remarkably, although the incidence of acute Achilles tendon rupture has increased in the past years. In a registry study in Finland in 2015, Mattila et al (35) concluded that the decline in operative treatment started in 2007, with a decrease in surgical population of 42% in adult males and 55% in adult females since then. A possible explanation for this decline could be that a large amount of high-quality evidence has been reported since then showing similar outcomes between surgical and nonsurgical approaches published, which has affected treatment policies.

In our practice, we have treated almost every acute Achilles tendon rupture surgically within 3 days after injury, except for those occurring in morbidly obese patients, elderly and inactive patients, and those not healthy enough to undergo surgery. The surgical technique we use is an “end to end, modified Kessler” procedure with or without augmentation. Almost all the patients have achieved excellent outcomes without severe complications. A recent cohort study used acute ultrasonography to predict the risk of re-rupture and successful outcomes after surgical or nonsurgical treatment of acute Achilles tendon ruptures (36). They found that nonsurgical management of Achilles ruptures with a gap >10 mm resulted in a significantly greater rate of re-rupture than did nonoperative treatment with a gap <10 mm (36). Also, they reported that nonsurgical management of ruptures with a gap >5 mm led to inferior outcomes for heel-rise height and heel-rise work compared with surgical treatment (36). To some degree, their study provided a reference for us to determine when surgical or nonsurgical treatment should be undertaken, although further research is needed.

Our meta-analysis had several limitations. First, the present meta-analysis contained relatively small studies with relatively few target patients; thus, the data might have been insufficient to draw powerful comparisons. Second, the mean follow-up period was 15.4 (range 12 to 24) months, which was relatively short to effectively corroborate the clinical outcomes. Third, different variables were included in each study, including demographics, surgical techniques, outcome measurements, and postoperative rehabilitation protocols, which could potentially make the results ambiguous, and we might have been unable to detect a subtle difference in these outcomes. Fourth, we did not perform a subgroup analysis because no adequate studies had reported the outcomes of subgroups. Finally, unpublished studies were not searched for or included in the present review, which could have resulted in a publication bias. Long-term, multicenter follow-up data with stratification are needed.

In conclusion, the results of the present study suggest that surgical treatment can effectively reduce the re-rupture rate and might be a better choice for the treatment of acute Achilles tendon rupture. Multicenter, double-blind randomized controlled trials with stratification and long-term follow-up data are needed to obtain a higher level of evidence and to guide clinical practice, especially for the comparison and selection of different treatment options.

References

1. Gwynne-Jones DP, Sims M, Handcock D. Epidemiology and outcomes of acute Achilles tendon rupture with operative or nonoperative treatment using an identical functional bracing protocol. Foot Ankle Int 32:337–343, 2011.
2. Jarvinen TA, Kannus P, Maffulli N, Khan KM. Achilles tendon disorders: etiology and epidemiology. Foot Ankle Clin 10:255–266, 2005.
3. Nyyssonen T, Luthje P, Kroger H. The increasing incidence and difference in sex distribution of Achilles tendon rupture in Finland in 1987-1999. Scand J Surg 97:272–275, 2008.
4. Ganestam A, Kallemose T, Troelsen A, Barfod KW. Increasing incidence of acute Achilles tendon rupture and a noticeable decline in surgical treatment from 1994 to 2013: a nationwide registry study of 33,160 patients. Knee Surg Sports Traumatol Arthrosc 24:3730–3737, 2016.
5. McQuillan R, Gregan P. Tendon rupture as a complication of corticosteroid therapy. Palliative Med 19:352–353, 2005.
6. Seeger JD, West WA, Fife D, Noel GJ, Johnson LN, Walker AM. Achilles tendon rupture and its association with fluoroquinolone antibiotics and other potential risk factors in a managed care population. Pharmacoepidemiol Drug Saf 15:784–792, 2006.
7. Kraemer R, Wuerfel W, Lorenzen J, Busche M, Vogt PM, Knobloch K. Analysis of hereditary and medical risk factors in Achilles tendinopathy and Achilles tendon ruptures: a matched pair analysis. Arch Orthop Trauma Surg 132:847–853, 2012.

8. Kocher MS, Bishop J, Marshall R, Briggs KK, Hawkins RJ. Operative versus nonoperative management of acute Achilles tendon rupture: expected-value decision analysis. Am J Sports Med 30:783–790, 2002.
9. Wang D, Sandlin MI, Cohen JR, Lord EL, Petrigliano FA, SooHoo NF. Operative versus nonoperative treatment of acute Achilles tendon rupture: an analysis of 12,570 patients in a large healthcare database. Foot Ankle Surg 21:250–253, 2015.
10. Nilsson-Helander K, Silbernagel KG, Thomee R, Faxen E, Olsson N, Eriksson BI, Karlsson J. Acute Achilles tendon rupture: a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. Am J Sports Med 38:2186–2193, 2010.
11. Willits K, Amendola A, Bryant D, Mohtadi NG, Giffin JR, Fowler P, Kean CO, Kirkley A. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am 92:2767–2775, 2010.
12. Keating JF, Will EM. Operative versus non-operative treatment of acute rupture of tendo Achillis: a prospective randomised evaluation of functional outcome. J Bone Joint Surg Br 93:1071–1078, 2011.
13. Olsson N, Silbernagel KG, Eriksson BI, Sansone M, Brorsson A, Nilsson-Helander K, Karlsson J. Stable surgical repair with accelerated rehabilitation versus nonsurgical treatment for acute Achilles tendon ruptures: a randomized controlled study. Am J Sports Med 41:2867–2876, 2013.
14. Möller M, Movin T, Granhed H, Lind K, Faxen E, Karlsson J. Acute rupture of tendon Achillis: a prospective randomised study of comparison between surgical and nonsurgical treatment. J Bone Joint Surg Br 83:843–848, 2001.
15. Khan RJ, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute Achilles tendon ruptures: a meta-analysis of randomized, controlled trials. J Bone Joint Surg Am 87:2202–2210, 2005.
16. Jiang N, Wang B, Chen A, Dong F, Yu B. Operative versus nonoperative treatment for acute Achilles tendon rupture: a meta-analysis based on current evidence. Int Orthop 36:765–773, 2012.
17. Soroceanu A, Sidhwa F, Aarabi S, Kaufman A, Glazebrook M. Surgical versus nonsurgical treatment of acute Achilles tendon rupture: a meta-analysis of randomized trials. J Bone Joint Surg Am 94:2136–2143, 2012.
18. Wilkins R, Bisson LJ. Operative versus nonoperative management of acute Achilles tendon ruptures: a quantitative systematic review of randomized controlled trials. Am J Sports Med 40:2154–2160, 2012.
19. Metz R, Verleisdonk EJ, van der Heijden GJ, Clevers GJ, Hammacher ER, Verhofstad MH, van der Werken C. Acute Achilles tendon rupture: minimally invasive surgery versus nonoperative treatment with immediate full weight-bearing—a randomized controlled trial. Am J Sports Med 36:1688–1694, 2008.
20. Maffulli N, Tallon C, Wong J, Lim K, Bleakney R. Early weightbearing and ankle mobilization after open repair of acute midsubstance tears of the Achilles tendon. Am J Sports Med 31:692–700, 2003.
21. Suchak AA, Bostick GP, Beaupre LA, Durand DC, Jomha NM. The influence of early weight-bearing compared with non-weight-bearing after surgical repair of the Achilles tendon. J Bone Joint Surg Am 90:1876–1883, 2008.
22. Barfod KW, Bencke J, Lauridsen HB, Ban I, Ebskov L, Troelsen A. Nonoperative dynamic treatment of acute Achilles tendon rupture: the influence of early weight-bearing on clinical outcome: a blinded, randomized controlled trial. J Bone Joint Surg Am 96:1497–1503, 2014.
23. Costa ML, MacMillan K, Halliday D, Chester R, Shepstone L, Robinson AH, Donell ST. Randomised controlled trials of immediate weight-bearing mobilisation for rupture of the tendo Achillis. J Bone Joint Surg Br 88:66–77, 2006.
24. Moher D, Liberati A, Tetzlaff J, Altman D, Group P. Preferred reporting items for systematic reviews and meta-analysis: the PRISMA statement. PLoS Med 6:e1000097, 2009.
25. Kearney RS, Achten J, Lamb SE, Parsons N, Costa ML. The Achilles tendon total rupture score: a study of responsiveness, internal consistency and convergent validity on patients with acute Achilles tendon ruptures. Health Qual Life Outcomes 10:24, 2012.
26. Grimby G. Physical activity and muscle training in the elderly. Acta Med Scand Suppl 711:233–237, 1986.
27. Oremus M, Wolfson C, Perrault A, Demers L, Momoli F, Moride Y. Interrater reliability of the modified Jadad quality scale for systematic reviews of Alzheimer's disease drug trials. Dement Geriatr Cogn Disord 12:232–236, 2001.
28. Twaddle BC, Poon P. Early motion for Achilles tendon ruptures: is surgery important? A randomized, prospective study. Am J Sports Med 35:2033–2038, 2007.
29. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 5:13, 2005.
30. Cukelj F, Bandalovic A, Knezevic J, Pavic A, Pivalica B, Bakota B. Treatment of ruptured Achilles tendon: operative or non-operative procedure? Injury 46:137–142, 2015.
31. Henríquez H, Muñoz R, Carcuro G, Bastías C. Is percutaneous repair better than open repair in acute Achilles tendon rupture? Clin Orthop Relat Res 470:998–1003, 2011.
32. Daghino W, Enrietti E, Sprio AE, di Prun NB, Berta GN, Masse A. Subcutaneous Achilles tendon rupture: a comparison between open technique and mini-invasive tenorrhaphy with Achillon(R) suture system. Injury 47:2591–2595, 2016.
33. Wallace RG, Heyes GJ, Michael AL. The non-operative functional management of patients with a rupture of the tendo Achillis leads to low rates of re-rupture. J Bone Joint Surg Br 93:1362–1366, 2011.
34. Huttunen TT, Kannus P, Rolf C, Fellander-Tsai L, Mattila VM. Acute Achilles tendon ruptures: incidence of injury and surgery in Sweden between 2001 and 2012. Am J Sports Med 42:2419–2423, 2014.
35. Mattila VM, Huttunen TT, Haapasalo H, Sillanpaa P, Malmivaara A, Pihlajamaki H. Declining incidence of surgery for Achilles tendon rupture follows publication of major RCTs: evidence-influenced change evident using the Finnish registry study. Br J Sports Med 49:1084–1086, 2015.
36. Westin O, Nilsson Helander K, Gravare Silbernagel K, Moller M, Kalebo P, Karlsson J. Acute ultrasonography investigation to predict reruptures and outcomes in patients with an Achilles tendon rupture. Orthop J Sports Med 4, 2016. 2325967116667920.

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Surgical Versus Non-Surgical Methods for Acute Achilles Tendon Rupture: A Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

We performed a meta-analysis to (1) compare surgical and non-surgical treatment methods for repair of acute rupture of the Achilles tendon, in terms of the re-rupture rate, incidence of complications other than re-rupture, functional outcomes, and proportion of patients returning to previous levels of sporting activities, and (2) explore the difference in the re-rupture rate if proven early functional rehabilitation protocols were followed.

PubMed, EMBASE, Medline, and Cochrane Central Register of Controlled Trials databases were searched to identify randomized clinical trials. The quality of included studies was assessed by the Cochrane risk-of-bias tool. The random-effects model or subgroup analysis would be chosen to perform the meta-analysis if the data were heterogeneous; otherwise, the fixed-effect model would be selected.

Ten randomized clinical trials with a total of 934 randomized patients were included. Patients in the non-surgical group underwent higher re-ruptures than patients in the surgical group ($p = .0002$), but the re-rupture rates were equivalent in the non-surgical group and the surgical group ($p = .08$) if an early range of motion exercises protocol was performed. Lower incidence of complications excluding re-rupture was found in non-surgical patients ($p = .006$). However, the surgical group had better results in functional outcomes when evaluated by 2 different jump tests (drop counter-movement jump [$p = .002$], Hopping [$p = .004$]) and 1 muscular endurance test (Heel-rise work [$p = .01$]). The 2 groups had no significant difference in the proportion of patients returning to previous levels of sporting activities ($p = 0.87$).

The risk of re-rupture after surgical or non-surgical treatment was equivalent if a functional rehabilitation protocol with early range of motion was performed, but the risk of other complications happening after surgical treatment was higher than in non-surgical treatment.

The Achilles tendon is the largest and strongest tendon in the human body; however, it is also one of the most frequently injured tendons (1). Most patients suffering Achilles tendon ruptures are males who participate in sports, particularly in recreational sports that involve sudden accelerations and jumping (2,3). In Finland, the incidence of Achilles tendon ruptures per 100,000 person-years increased from 2.1 in 1979 to 21.5 in 2011 (3), and in the United States, the incidence of Achilles tendon increased from 0.67 per 10,000 in 2005 to 1.08 per 10,000 in 2011 (4), which may be due to the growing number of aging adults who participate in high-demand sports and the increase in the prevalence of chronic metabolic diseases, such as type 1 diabetes (5,6). Usually, the diagnosis of an acute rupture requires that clinicians conduct detailed musculoskeletal examinations that focus on 'look, feel, move' and take a comprehensive medical history (7,8). Ultrasound or magnetic resonance imaging may be used to help with confirmation diagnoses if necessary (8).

Treatment for acute Achilles tendon rupture can be broadly divided into surgical treatment and non-surgical treatment. Surgical treatments include open and percutaneous repair of the tendon, whereas cast immobilization and functional bracing are the most common non-surgical techniques. It is generally accepted that surgical treatment may be suitable for athletes, and young and fit patients, and that non-surgical treatment should be performed for the elderly. However, whether to perform surgical or non-surgical treatments for acute Achilles tendon rupture remains controversial (9,10). Some randomized clinical trials (RCTs) have found that surgical treatment of acute Achilles tendon

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ruptures could reduce the risk of re-rupture when compared with non-surgical treatment, but that it might also lead to a higher complication rate (11–13). Furthermore, 1 overlapping meta-analysis and 2 randomized trial meta-analyses comparing surgical with non-surgical treatment came to the same conclusion about the above hypotheses (14–16). However, these meta-analyses were based on only a few RCTs, and recently published studies of RCTs showed that early functional rehabilitation could stimulate tendon repair. Specifically, early weightbearing and range of motion exercises might be of importance. Those studies found that early weightbearing exercises with protected range of motion contributed to decreased re-rupture rates and are helpful for patients to return to normal activities (10,13,17–22). For the above reasons, performing early rehabilitation protocols after surgical and non-surgical treatment of Achilles tendon ruptures has been advocated.

We performed a meta-analysis of RCTs to (1) compare surgical and non-surgical treatment methods for repair of acute rupture of the Achilles tendon, in terms of the re-rupture rate, incidence of complications other than re-rupture, functional outcomes, and proportion of patients returning to previous levels of sporting activities, and (2) explore the difference in the re-rupture rate if proven early functional rehabilitation protocols were followed.

Materials and Methods

Inclusion and Exclusion Criteria

Our meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (23). Studies were eligible for inclusion if they met the following criteria: participants were adults with closed acute Achilles tendon rupture; RCTs comparing surgical intervention with non-surgical intervention; at least 1- year follow-up; unpublished studies were included. Studies were excluded if they met the following criteria: retrospective studies, cohort studies, or clinical controlled studies; insufficient reporting of primary outcomes (the data of the main evaluation index, e.g., the re-rupture rate, was not complete); patients with delayed presentation (>3 weeks after the injury). In the present study, early weightbearing and range of motion exercises meant that patients initiated their rehabilitation protocol within the first 2 weeks after treatment.

Search Strategy

A comprehensive literature search was performed in PubMed, EMBASE, Medline, and Cochrane Central Register of Controlled Trials databases from inception to July 2016. There were no language restrictions, and foreign language papers were translated. The following search strategy was used: “Achilles Tendon” [MeSH] OR “Tendo Achilles” [Title/Abstract] OR “Calcaneal” [Title/Abstract] OR “Calcanean” [Title/Abstract] OR “Calcaneus” [Title/Abstract] AND “Rupture” [MeSH] OR “Rupture” [Title/Abstract] OR “Ruptures” [Title/Abstract] OR “Ruptured” [Title/Abstract] OR “Lesion” [Title/Abstract] OR “Lesions” [Title/Abstract] OR “Tear” [Title/Abstract] OR “Tears” [Title/Abstract]. We also conducted hand retrieval about conference literature to identify additional information that might have been missed in the database. (URLs for all of the databases are presented in the Appendix.)

Study Selection

The literature selection was performed by 2 reviewers (KZ and LS) independently with the use of standardized study selection forms. Titles and abstracts were first reviewed, and the full texts were acquired if the information was not enough. A third reviewer (PZ) would be consulted and a decision would be made through discussion if there was any disagreement between the first 2 reviewers. Our literature search identified a total of 2360 studies, and after excluding obviously irrelevant and duplicate reports, the remaining 19 articles were assessed using eligibility criteria after reading the full text. Finally, 10 eligible RCTs were included in our meta-analysis (9–13,19,20,24–26). A flow chart of the article selection steps is shown in Fig. 1.

Data Extraction

Two authors (KZ, LS) independently extracted data from eligible studies by completing a pre-designed data form, with discrepancies being arbitrated by a third reviewer (PZ). The primary outcomes extracted from each study included the re-rupture rate, incidence of complications other than re-rupture, functional outcomes, and proportion of patients returning to previous levels of sporting activities.

Methodological Assessment

The Cochrane risk-of-bias tool was used to evaluate the methodological quality of the included studies (27) and was performed by 2 reviewers (KZ and LS) independently. Disagreements were resolved by consulting a third reviewer (PZ). In our meta-analysis, we found that the most common shortcoming of the included studies was lack of blinding of patients and surgical personnel (Fig. 2). In fact, it was very hard to have a blind trial for surgeons.

Statistical Analysis

All statistical analyses were performed using RevMan 5.1 (Cochrane Collaboration, Oxford, UK). Publication bias was assessed by visual inspection of funnel plots of the primary outcomes (Fig. 3). For each study, risk ratios (RRs) and 95% confidence intervals (CIs) were calculated for dichotomous outcomes, and mean differences and 95% CIs were calculated for continuous outcomes. Heterogeneity was evaluated by the chi-square test, which described the percentage of total variation across studies that was due to heterogeneity rather than chance. The random-effects model or subgroup analysis would be chosen to perform the meta-analysis if the data were heterogeneous; otherwise, the fixed-effect model would be selected. Furthermore, I^2 values were calculated as an objective basis of heterogeneity judgment (28).The p value from the chi-square test was required to be $<.05$ and $I^2 > 50\%$.

Results

Study Characteristics

Ten published RCTs with a total of 934 patients met all inclusion criteria. Four trials were performed in multiple centers, and all trials were

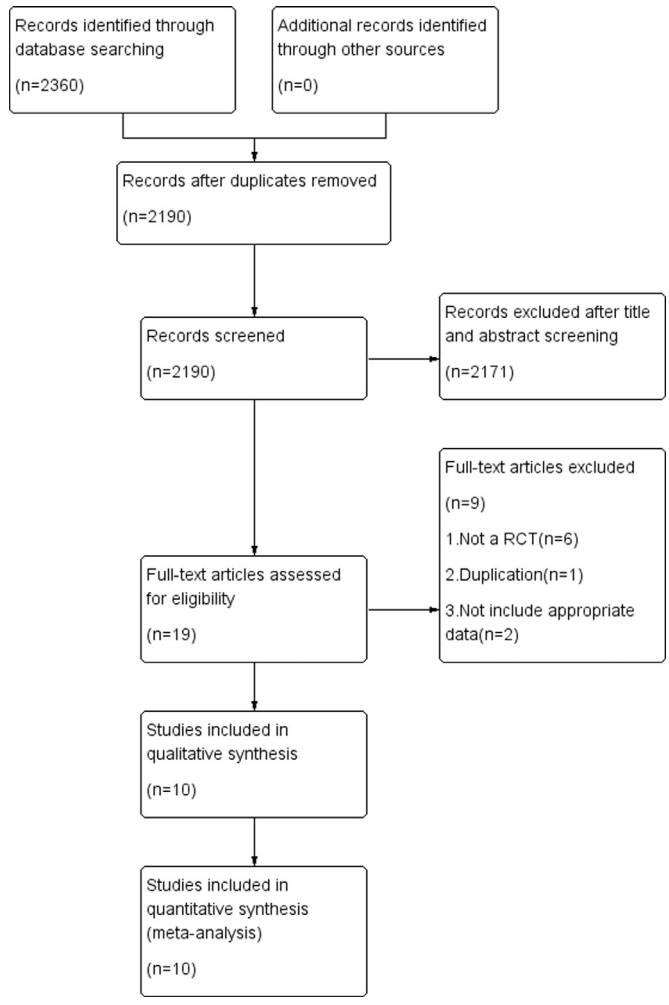


Fig. 1. Process of publication selection.

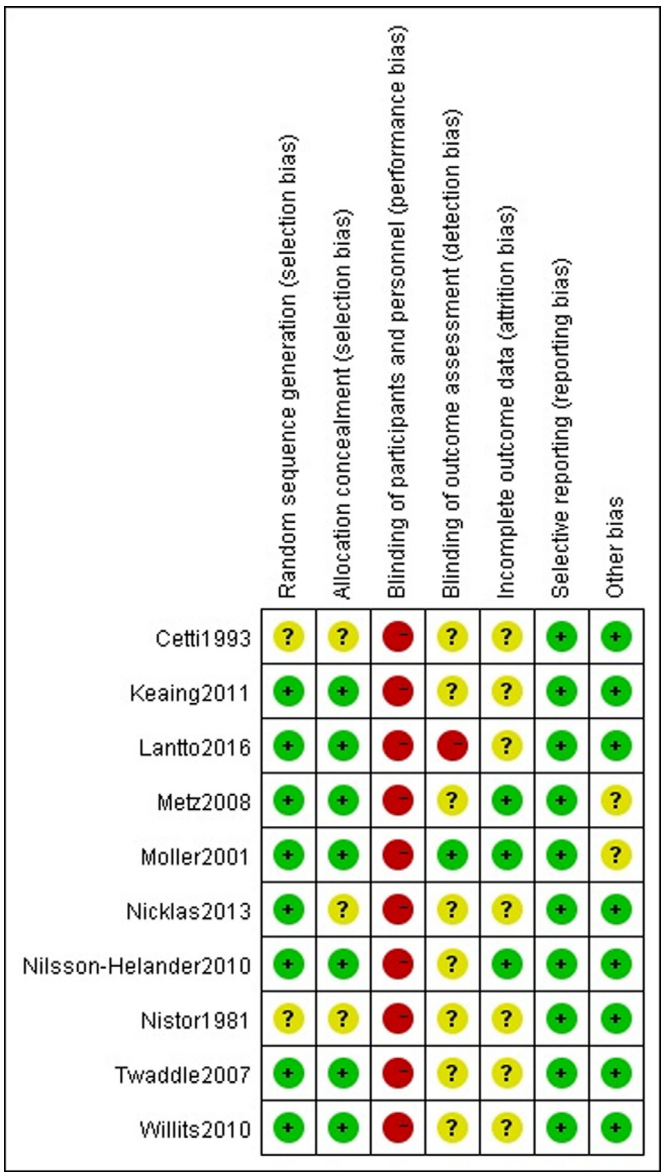


Fig. 2. Risk of bias summary: review authors' judgments about each risk of bias item for each included study.

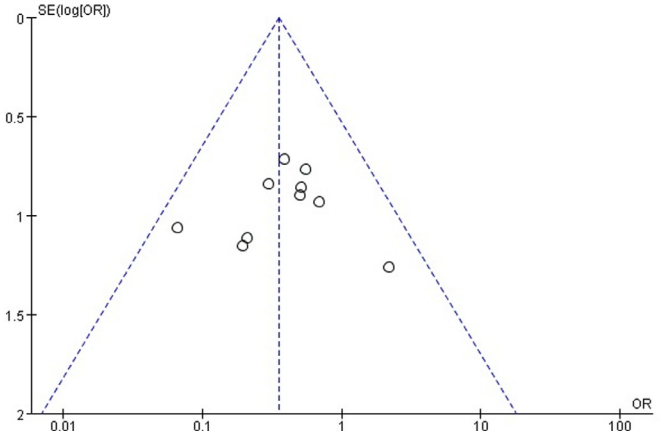


Fig. 3. Funnel plots illustrating the publication bias of the re-rupture rate.

written in English. Information on general characteristics of studies and participants are summarized in the Table.

Rate of Re-Rupture

Patients in the non-surgical group experienced higher re-ruptures than patients in the surgical group (RR, 0.38; 95% CI, 0.23 to 0.63; $p = .0002$) (Fig. 4). The ratio of re-rupture was 11.04% (51 of 462) in the non-surgical group and 4.24% (19 of 448) in surgical group. There was no heterogeneity between studies ($p = .74$; $I^2 = 0\%$), and finally a fixed-effects model was used.

Four studies used early weightbearing within the first 2 weeks after initial treatment. Pooled analysis showed that fewer re-ruptures occurred in the surgical group (RR, 0.41; 95% CI, 0.18 to 0.97; $p = .04$) (Fig. 5*A*). Four studies used early range of motion within the first 2 weeks after initial treatment. When pooled, we found that the re-rupture rate in the non-surgical group and surgical group were equivalent (RR, 0.52; 95% CI, 0.25 to 1.08; $p = .08$) (Fig. 5*B*).

Incidence of Complications Other Than Re-Rupture

Nine studies reported complications other than re-rupture. The pooled results showed that patients in the non-surgical group had lower prevalence of complications than patients in the surgical group (RR, 4.10; 95% CI, 1.49 to 11.27; $p = .006$) (Fig. 6). The ratio of complications was 6.91% (30 of 434) in the non-surgical group and 28.47% (121 of 425) in the surgical group. There was significant heterogeneity across studies ($p < .0001$; $I^2 = 78\%$), and the subgroup analysis was used.

The most commonly reported complications were deep and superficial infection, adhesions, sural nerve injury, and deep venous thrombosis. Subgroup analysis showed that the surgical group showed a significantly higher rate than the non-surgical group in terms of deep infection (RR, 4.18; 95% CI, 1.20 to 14.53; $p = .02$), adhesions (RR, 10.24; 95% CI, 4.03 to 26.03; $p < .00001$), and sural nerve injury (RR, 7.94; 95% CI, 1.93 to 32.71; $p = .004$) (Fig. 7). However, there were no significant differences between groups regarding the prevalence of deep vein thrombosis (RR, 0.42; 95% CI, 0.12 to 1.42; $p = .16$) and superficial infection (RR, 1.13; 95% CI, 0.58 to 2.19; $p = .72$) (Fig. 7).

Functional Outcomes

Seven studies reported functional evaluations, but only 2 studies used the same method of testing functional outcomes (the MuscleLab measurement system). The test consisted of 2 different strength tests, 2 different jump tests, and 2 muscular endurance tests. The jump tests were a drop counter-movement jump (Drop CMJ) and Hopping. The strength tests were a Concentric power and an Eccentric power. The muscular endurance tests were Heel-rise work and Heel-rise height. Pooled analysis at the 12-month evaluations showed that patients in the surgical group had better results in 2 different jump tests [Drop CMJ (MD, 7.30; 95% CI, 2.71 to 11.90; $p = .002$) (Fig. 8), Hopping (MD, 12.86; 95% CI, 4.05 to 21.67; $p = .004$) (Fig. 8)] and 1 muscular endurance test [Heel-rise work (MD, 7.36; 95% CI, 1.51 to 13.20; $p = .01$) (Fig. 8)] than patients in the non-surgical group. However, there were no significant differences between groups regarding the result of 2 different strength tests [Concentric power (MD, 7.23; 95% CI, −2.59 to 17.06; $p = .15$) (Fig. 8), Eccentric power (MD, 5.67; 95% CI, −1.46 to 12.79; $p = .12$) (Fig. 8)] and 1 muscular endurance test [Heel-rise height (MD, 2.76; 95% CI, −1.45 to 6.97; $p = .20$) (Fig. 8)].

Proportion of Patients Returning to Previous Levels of Sporting Activity

Pooled analysis showed that the 2 groups had no significant difference in the proportion of patients returning to previous levels of

Table
Summary of study characteristics

Study	Year, Country	Sample Size		Sex (M/F)		Mean Age (y)		Start Weightbearing		Start Range of Motion		Follow-Up (y)	Center
		S	N	S	N	S	N	S	N	S	N		
Nistor	1981, Sweden	45	60	NM	NM	41	41	4w	4w	2w	4w	2.5	Single
Cetti et al.	1993, Denmark	56	55	47/9	45/10	37.2	37.8	6w	4w	6w	4w	1	Multi
Moller et al.	2001, Sweden	59	53	51/8	48/5	39.6	38.5	3w	4w	12d	4w	2	Multi
Twaddle et al.	2007, New Zealand	20	22	14/6	14/8	41.8	40.3	6w	6w	10d	10d	1	Single
Metz et al.	2008, Netherlands	42	41	31/11	35/6	40	41	1w	1w	1w	1w	1	Multi
Nilsson-Helander et al.	2010, Sweden	49	48	40/9	39/9	40.9	41.2	6–8w	6–8w	2w	2w	1	Single
Willits et al.	2010, Canada	72	72	59/13	59/13	39.7	41.1	2w	2w	2w	2w	2	Multi
Keating et al.	2011, England	39	41	28/11	32/9	41.2	39.5	6w	8w	4w	4w	1	Single
Olsson et al.	2013, Sweden	49	51	39/10	47/4	39.8	39.5	1d	1d	2w	8w	1	Single
Lantto et al.	2016, Finland	32	28	30/2	25/3	40	39	1w	1w	1w	1w	1.5	Single

Abbreviations: NM, not mentioned; N, non-surgical treatment group; S, surgical treatment group.

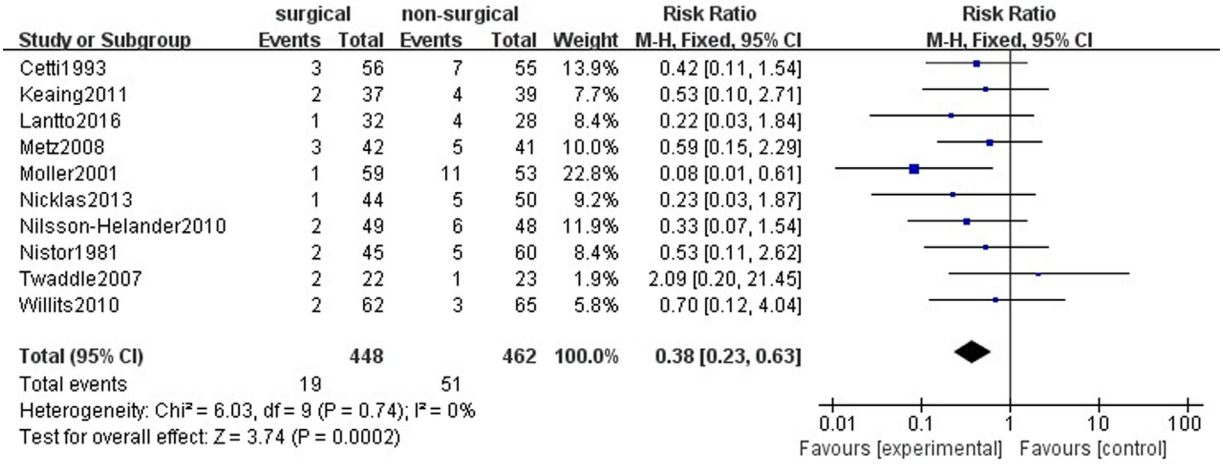
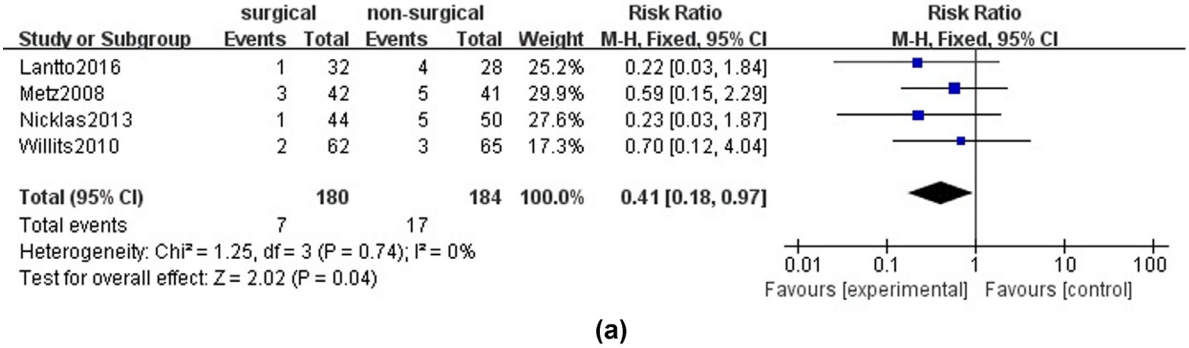
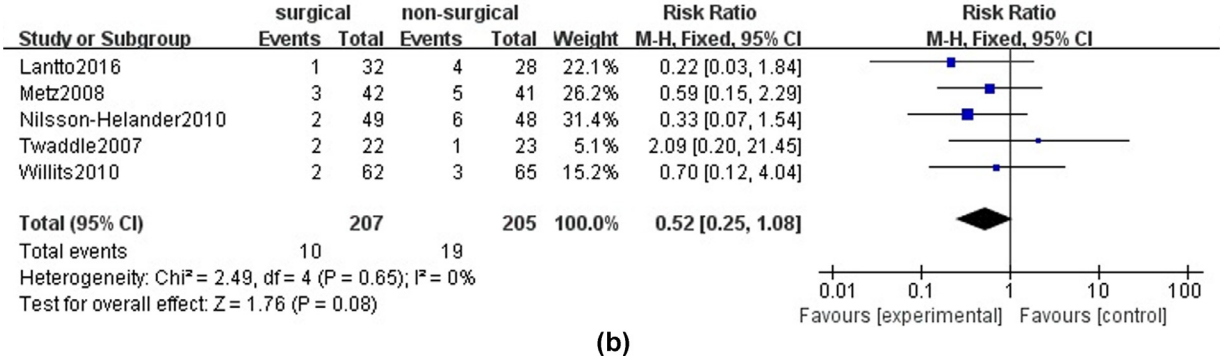


Fig. 4. Forest plot showing the rate of re-rupture after surgical treatment versus non-surgical treatment.



(a)



(b)

Fig. 5. Forest plot showing the rate of re-rupture used early weightbearing (*A*) and early range of motion (*B*) after surgical treatment versus non-surgical treatment.

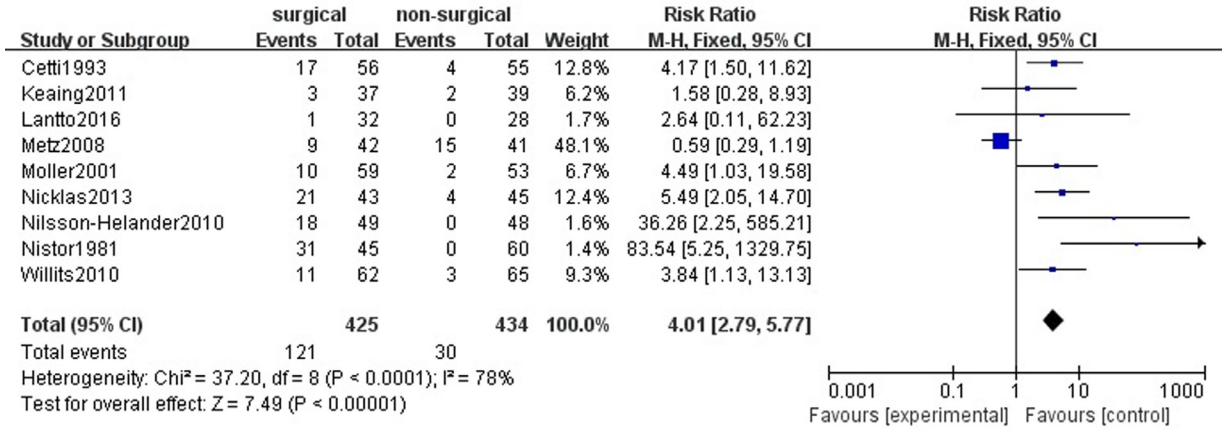


Fig. 6. Forest plot showing the rate of complications other than re-rupture after surgical treatment versus non-surgical treatment.

sporting activities (RR, 1.04; 95% CI, 0.65 to 1.67; $p = .87$) (Fig. 9). There was significant heterogeneity across studies ($p = .004$; $I^2 = 78\%$), and a random-effects model was used.

Sensitivity Analysis

Sensitivity analysis was performed in the superficial infection group by excluding 1 study (24). The heterogeneity was decreased to a lower level ($p = .91$; $I^2 = 0\%$), and the surgical group showed a significantly higher rate of superficial infection than the non-surgical group (RR, 6.29; 95% CI, 1.69 to 23.46; $p = .006$) (Fig. 10).

Discussion

Non-surgical treatment may reduce the rate of complication other than re-rupture in patients with acute Achilles tendon rupture (29). Despite the advantage of this method, it is obvious that non-surgical treatment has an important shortcoming, which is "high risk of re-rupture" (30). Concerns regarding this issue led to the development of surgical treatment. Compared with non-surgical treatment, surgical treatment may reduce the risk of re-rupture. However, Twaddle et al. (19) reported that the re-rupture rate was lower in the non-surgical group if early functional rehabilitation were performed than in the non-surgical group without rehabilitation. It is controversial whether surgical treatment has a lower risk of re-rupture when compared with non-surgical treatment if early functional rehabilitation were performed in both. Therefore, the aim of our meta-analysis is to compare the rate of re-rupture between these 2 procedures. Both functional outcomes and the possibility of returning to previous levels of sporting activities have been evaluated for the first time in the meta-analysis. We found that surgically treated patients and non-surgically treated patients were equivalent with regard to re-rupture if a functional rehabilitation protocol with early range of motion was performed, and that there were no significant differences in the proportion of patients returning to previous levels of sporting activities. In term of the results of functional evaluations, patients undergoing surgical treatment were better in 2 different jump tests and 1 muscular endurance test.

In our meta-analysis, we identified a number of limitations in the literature we included. First, we attempted to assess functional outcomes with only 2 RCTs (10,20), because different functional assessment systems were used in the other included studies. We suggest that the measurement method of functional outcome should be unified in future studies.

Second, surgical treatment methods include open and percutaneous repair of the tendon. Important to note is that included in our study were both open and percutaneous repair of the tendon. Because of the limited number of RCTs, we combined them into 1 group in our study. A systematic review performed by Rozis et al. (31) and Yang et al. (32) indicated that the method of percutaneous repair had a lower complication rate and better functional outcomes compared with that found with open repair. Moreover, Tejwani et al. (33) found that percutaneous repair had a higher rate of sural nerve injury, whereas conventional open repair had a higher rate of wound complications. Furthermore, Karabinas et al. (34) showed that cosmetic appearance was superior in the group of patients who had a percutaneous treatment. Therefore, the clinical heterogeneity may be caused by the combining analysis method when analyzing complications. We encourage investigators to perform more high-quality RCTs to compare the results of non-surgical treatment with open repair or percutaneous repair in the future.

Last, our study explored the effects of early functional rehabilitation protocols on reducing the re-rupture rate. The results that early functional rehabilitation could reduce the re-rupture rate were very helpful aimed to clinical decision. However, the early functional rehabilitation protocols in the included studies were not exactly the same. We performed a meta-analysis among similar studies with early functional rehabilitation protocols to explore whether the re-rupture rate can be reduced. Therefore, we advocate that future RCTs should contain the same functional rehabilitation protocols.

In this meta-analysis, we found a lower re-rupture risk in non-surgical treatment compared with that in surgical treatment if a functional rehabilitation protocol with early range of motion was performed in both, which is consistent with findings in the literature (35). In contrast to other studies, we found that the re-rupture risk was lower in the surgical group compared with that in the non-surgical group if an early weightbearing protocol was performed. Van der Eng et al. (36) found that the re-rupture rate in the surgical group was similar to that in non-surgical groups when both were followed by early weightbearing. The different result may be caused by the different inclusion criteria used for early weightbearing. Our study showed that the risk of other complications happening for surgically treated patients was higher than in non-surgically treated patients, but high heterogeneity was detected across studies. Subsequently, in subgroups analysis, we found that the group of superficial infection was the major reason for heterogeneity ($p = .02$; $I^2 = 64\%$). Furthermore, sensitivity analysis was performed in the superficial infection group, and 1 study was excluded (24). The heterogeneity was decreased to a lower level ($p = .91$; $I^2 = 0\%$), and the surgical group showed a significantly higher rate of superficial infection than that in the non-surgical group (RR, 6.29; 95% CI, 1.69 to 23.46;

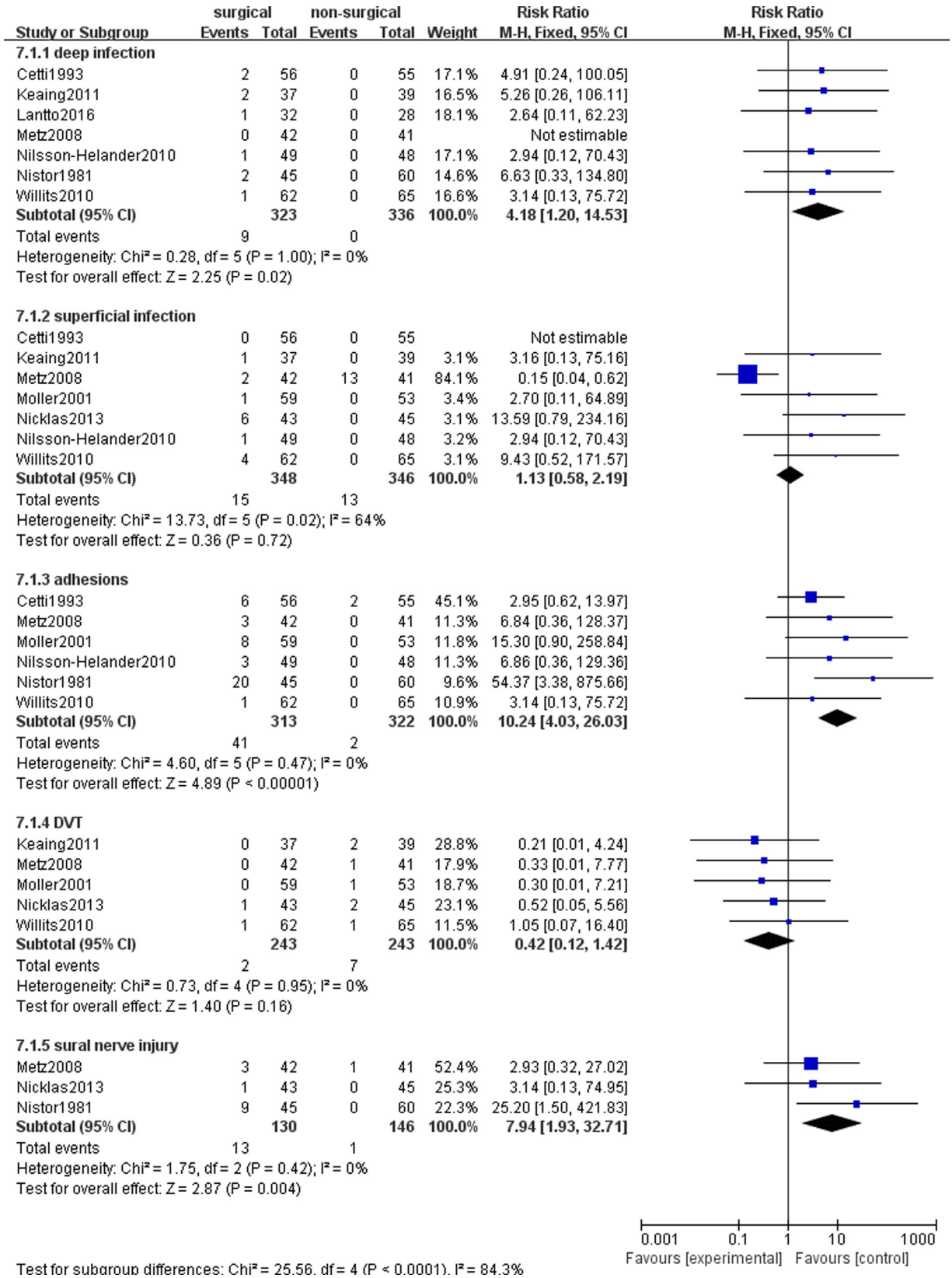


Fig. 7. Forest plot for the subgroup analysis showing the rate of complications including deep and superficial infection, adhesions, sural nerve injury, and deep vein thrombosis after surgical treatment versus non-surgical treatment.

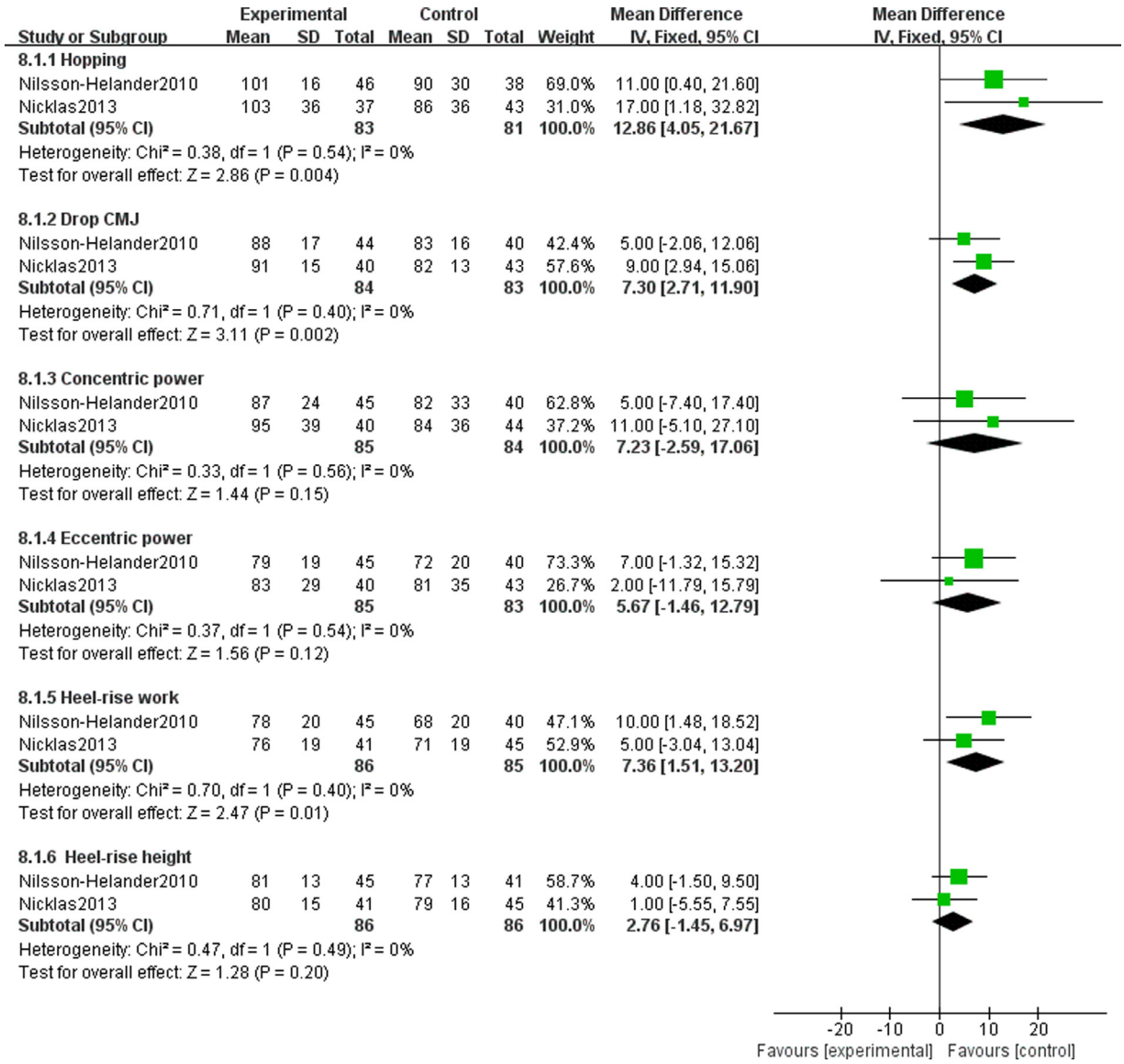


Fig. 8. Forest plot showing the LSI (Limb symmetry index) of 2 strength tests including Concentric and Eccentric power, 2 muscular endurance tests includes Heel-rise height and Heel-rise work and 2 jump tests includes Drop CMJ and Hopping after surgical treatment versus non-surgical treatment.

$p = .006$). In that excluded study, patients in the non-surgically treated group had a higher rate of superficial infection caused by the bracing system than that found in the surgically treated group. Generally, bracing systems do not need to be worn at all times, but patients in that study were not allowed to remove the brace in the follow-up period. This may have caused the high risk of superficial infection.

Ultimately, the number of patients returning to previous levels of sporting activity in the surgical group was different from that in the non-surgical

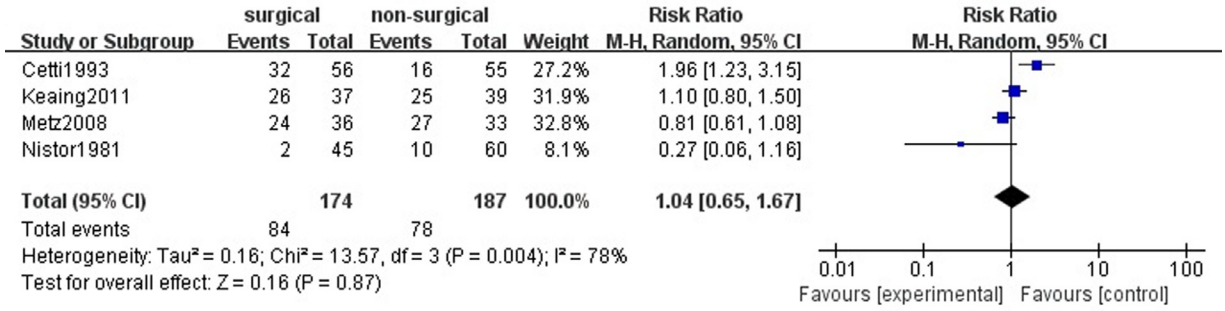


Fig. 9. Forest plot showing the proportion of patients returning to previous levels of sporting activities after surgical treatment versus no-surgical treatment.

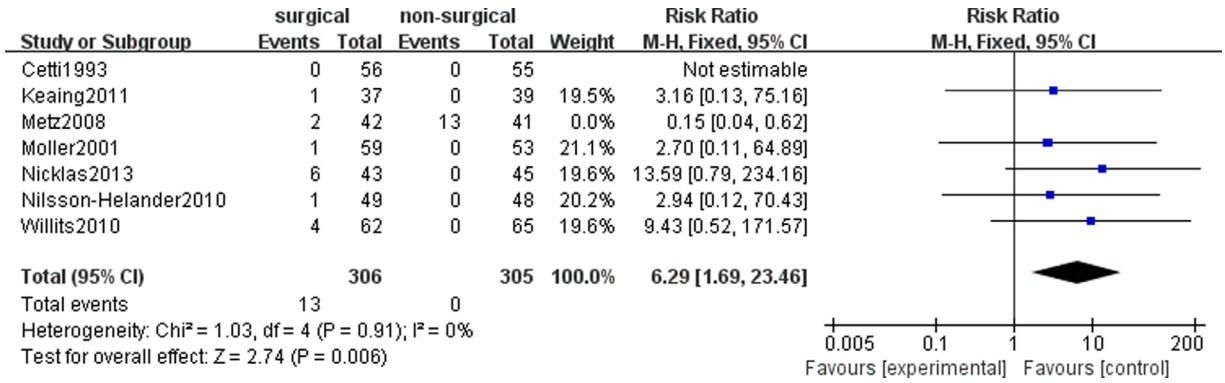


Fig. 10. Forest plot showing the rate of superficial infection after sensitivity analysis.

group. However, Metz et al. (24) and Nistor (11) reported that some patients claimed that their Achilles tendon ruptures were not the actual reason for changing or quitting sports but rather psychological factors.

In conclusion, our study demonstrates that the risk of re-rupture after surgical or non-surgical treatment was equivalent if a functional rehabilitation protocol with early range of motion was performed, but the risk of other complications occurring after surgical treatment was higher than that with non-surgical treatment. Therefore, non-surgical treatment for acute Achilles tendon rupture may be preferred if the hospital can offer a functional rehabilitation protocol with early range of motion. If not, surgical treatment should be considered because of the lower rate of re-rupture.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1053/j.jfas.2018.05.007.

References

1. Calleja M, Connell DA. The Achilles tendon. Semin Musculoskelet Radiol 2010;14:307–322.
2. Józsa L, Kvist M, Bálint BJ, Reffy A, Järvinen M, Lehto M, Barzo M. The role of recreational sport activity in Achilles tendon rupture. A clinical, pathoanatomical, and sociological study of 292 cases. Am J Sports Med 1989;17:338–343.
3. Lantto I, Heikkinen J, Flinkkilä T, Ohtonen P, Leppilahti J. Epidemiology of Achilles tendon ruptures: increasing incidence over a 33-year period. Scand J Med Sci Sports 2015;25:e133–e138.
4. Erickson BJ, Cvetanovich GL, Nwachukwu BU, Villarroel LD, Lin JL, Bach BR, McCormick FM. Trends in the management of Achilles tendon ruptures in the United States Medicare population, 2005-2011. Orthop J Sports Med 2014;2. 2325967114549948.
5. Tuomilehto J. The emerging global epidemic of type 1 diabetes. Curr Diab Rep 2013;13:795–804.
6. Huttunen TT, Kannus P, Rolf C, Felländer-Tsai L, Mattila VM. Acute Achilles tendon ruptures: incidence of injury and surgery in Sweden between 2001 and 2012. Am J Sports Med 2014;42:2419–2423.
7. Sloan J. Soft tissue injuries: introduction and basic principles. Emerg Med J 2008;25:33–37.
8. Gibbons L. Diagnosing Achilles tendon injuries in the emergency department. Emerg Nurse 2013;21:26–30. quiz 31.
9. Keating JF, Will EM. Operative versus non-operative treatment of acute rupture of tendo Achillis: a prospective randomised evaluation of functional outcome. J Bone Joint Surg Br 2011;93:1071–1078.
10. Nilsson-Helander K, Silbernagel KG, Thomeé R, Faxén E, Olsson N, Eriksson BI, Karlsson J. Acute Achilles tendon rupture: a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. Am J Sports Med 2010;38:2186–2193.
11. Nistor L. Surgical and non-surgical treatment of Achilles tendon rupture. A prospective randomized study. J Bone Joint Surg Am 1981;63:394–399.
12. Cetti R, Christensen SE, Ejsted R, Jensen NM, Jorgensen U. Operative versus nonoperative treatment of Achilles tendon rupture. A prospective randomized study and review of the literature. Am J Sports Med 1993;21:791–799.
13. Möller M, Movin T, Granhed H, Lind K, Faxén E, Karlsson J. Acute rupture of tendon Achillis. A prospective randomised study of comparison between surgical and non-surgical treatment. J Bone Joint Surg Br 2001;83:843–848.
14. Khan RJ, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute Achilles tendon ruptures. A meta-analysis of randomized, controlled trials. J Bone Joint Surg Am 2005;87:2202–2210.
15. Erickson BJ, Mascarenhas R, Saltzman BM, Walton D, Lee S, Cole BJ, Bach BR. Is operative treatment of Achilles tendon ruptures superior to nonoperative treatment? A systematic review of overlapping meta-analyses. Orthop J Sports Med 2015;3. 2325967115579188.
16. Bhandari M, Guyatt GH, Siddiqui F, Morrow F, Busse J, Leighton RK, Sprague S, Schemitsch EH. Treatment of acute Achilles tendon ruptures: a systematic overview and metaanalysis. Clin Orthop Relat Res 2002;400:190–200.
17. Maffulli N, Tallon C, Wong J, Lim KP, Bleakney R. Early weightbearing and ankle mobilization after open repair of acute midsubstance tears of the Achilles tendon. Am J Sports Med 2003;31:692–700.
18. Saleh M, Marshall PD, Senior R, MacFarlane A. The Sheffield splint for controlled early mobilisation after rupture of the calcaneal tendon. A prospective, randomised comparison with plaster treatment. J Bone Joint Surg Br 1992;74:206–209.
19. Twaddle BC, Poon P. Early motion for Achilles tendon ruptures: is surgery important? A randomized, prospective study. Am J Sports Med 2007;35:2033–2038.
20. Olsson N, Silbernagel KG, Eriksson BI, Sansone M, Brorsson A, Nilsson-Helander K, Karlsson J. Stable surgical repair with accelerated rehabilitation versus nonsurgical treatment for acute Achilles tendon ruptures: a randomized controlled study. Am J Sports Med 2013;41:2867–2876.
21. De la Fuente C, Peña YLR, Carreño G, Marambio H. Prospective randomized clinical trial of aggressive rehabilitation after acute Achilles tendon ruptures repaired with Dresden technique. Foot (Edinb) 2016;26:15–22.
22. Groetelaers RP, Janssen L, van der Velden J, Wieland AW, Amendt AG, Geelen PH, Janzing HM. Functional treatment or cast immobilization after minimally invasive repair of an acute Achilles tendon rupture: prospective, randomized trial. Foot Ankle Int 2014;35:771–778.
23. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg 2010;8:336–341.
24. Metz R, Verleisdonk EJ, van der Heijden GJ, Clevers GJ, Hammacher ER, Verhofstad MH, van der Werken C. Acute Achilles tendon rupture: minimally invasive surgery versus nonoperative treatment with immediate full weightbearing—a randomized controlled trial. Am J Sports Med 2008;36:1688–1694.
25. Willits K, Amendola A, Bryant D, Mohtadi NG, Giffin JR, Fowler P, Kean CO, Kirkley A. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am 2010;92:2767–2775.
26. Lantto I, Heikkinen J, Flinkkila T, Ohtonen P, Siira P, Laine V, Leppilahti J. A prospective randomized trial comparing surgical and nonsurgical treatments of acute Achilles tendon ruptures. Am J Sports Med 2016;44:2406–2414.
27. Higgins JP, Altman DG, Gùtzsche PC, Jüni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928.
28. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002;21:1539–1558.
29. Weber M, Niemann M, Lanz R, Müller T. Nonoperative treatment of acute rupture of the Achilles tendon: results of a new protocol and comparison with operative treatment. Am J Sports Med 2003;31:685–691.
30. Deng S, Sun Z, Zhang C, Chen G, Li J. Surgical treatment versus conservative management for acute Achilles tendon rupture: a systematic review and meta-analysis of randomized controlled trials. J Foot Ankle Surg 2017;56:1236–1243.
31. Rozis M, Benetos I, Karampinas P, Polyzois V, Vlamis J, Pneumaticos S. Outcome of percutaneous fixation of acute Achilles tendon ruptures. Foot Ankle Int 2018. Mar 1doi: 10.71100718757971[Epub ahead of print].
32. Yang B, Liu Y, Kan S, Zhang D, Xu H, Liu F, Ning G, Feng S. Outcomes and complications of percutaneous versus open repair of acute Achilles tendon rupture: a meta-analysis. Int J Surg 2017;40:178–186.

33. Tejwani NC, Lee J, Weatherall J, Sherman O. Acute Achilles tendon ruptures: a comparison of minimally invasive and open approach repairs followed by early rehabilitation. Am J Orthop (Belle Mead NJ) 2014;43:E221–E225.
34. Karabinas PK, Benetos IS, Lampropoulou-Adamidou K, Romoudis P, Mavrogenis AF, Vlamis J. Percutaneous versus open repair of acute Achilles tendon ruptures. Eur J Orthop Surg Traumatol 2014;24:607–613.
35. Soroceanu A, Sidhwa F, Aarabi S, Kaufman A, Glazebrook M. Surgical versus nonsurgical treatment of acute Achilles tendon rupture: a meta-analysis of randomized trials. J Bone Joint Surg Am 2012;94:2136–2143.
36. van der Eng DM, Schepers T, Goslings JC, Schep NW. Rerupture rate after early weightbearing in operative versus conservative treatment of Achilles tendon ruptures: a meta-analysis. J Foot Ankle Surg 2013;52:622–628.

Function after Achilles tendon rupture in the elderly

25 patients older than 65 years followed for 3 years

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ABSTRACT – We retrospectively analyzed the function after Achilles tendon rupture in 25 patients older than 65 years, 3 (1–5) years after the initial treatment. The patients' median age at the time of injury was 71 (65–86) years. The initial management was surgical in 14 patients and non-surgical (8-week immobilization) in 10, 1 patient was not treated.

The ratio of the number of heel-raises on the injured to the uninjured side was median 0.64 (0–1.14), showing a reduction in performance. However, in both surgically- and non-surgically-treated patients, the subjective impairment was mild, and the patients were able to perform most walking activities. Only 9 patients reached their previous activity level. Co-morbidity was frequent: 17 patients had other diseases that affected their performance.

14 complications occurred in 11 patients. 5 patients sustained a rerupture (4 following initial closed treatment with plaster), 1 a deep venous thrombosis and 4 had superficial infections requiring antibiotic treatment. 1 patient sustained a fibular nerve injury following compression by the plaster cast and another a sural nerve injury during the operation. 2 patients had symptoms due to adhesions between the tendon and the skin.

We conclude that Achilles tendon rupture in patients older than 65 years reduces lower limb function and that complications are common following surgical and non-surgical treatment.

■

The treatment of Achilles tendon rupture is still controversial. The outcome and complications are well documented in studies mainly involving patients active in sports (Nistor 1981, Cetti et al. 1993, Lo et al. 1997). Epidemiological data from Malmö, Sweden, have shown an incidence curve with two peaks (Möller et al. 1996), one in young, middle-aged subjects and one in the 70s. We have found no studies on the outcome in elderly patients with Achilles tendon rupture. We report the functional outcome and complications after Achilles tendon rupture in 25 patients older than 65 years.

Patients and methods

243 Achilles tendon ruptures were registered between 1992 and July 1997 in two hospitals, Huddinge University Hospital and Sahlgrenska University Hospital/Östra, with a catchment area of more than 500,000 people. 31 (13%) of the ruptures occurred in 29 patients older than 65 years. 2 patients had died, 1 with bilateral injury was too ill to participate, and 1 could not be traced. Of the remaining 25 patients (median age 71 (65–87) years, 21 men), all answered the questionnaire and 23 were examined by an independent observer, who had not been involved in the treatment of the patient. 2 patients refused to undergo the physical examination.

The physician on call decided on the initial treatment together with the patient. Local tradition and the general health of the patient mainly influenced the decision of the management. 1 patient received no treatment, 14 were treated surgically with end-to-end sutures followed by 8 weeks in a below-the-knee plaster cast and 10 were treated

Table 1. Stratification of the patients according to initial treatment

Treatment	n	Male	Co-morbidity	Age median	Age range
Surgical	14	11	9	72	65–79
Non-surgical	10	9	7	71	65–86

non-surgically with either a cast or brace for 8 weeks (Table 1). 1 of these patients had bilateral injuries and was treated with a cast on one side and a brace on the other. The untreated patient had rheumatoid arthritis and had been taking methotrexate and cortisone for a long time. The retrospective follow-up period was 39 (13–65) months.

All patients received a questionnaire, divided into two parts. One part consisted of general questions concerning overall health, medical problems and activity. The second part concerned the Achilles tendon injury with emphasis on treatment, complications and current problems. The patient's subjective opinion of the treatment and its outcome was assessed by visual analogue scales (VAS, 0–100 mm) with 100 representing the best possible. Impairment in performance of the lower extremity was assessed by 5 criteria: walk on even surface, walk on uneven surface, climb up stairs, walk down stairs and walk for 30 minutes without pain in the Achilles tendon region. An estimation was made on one VAS scale for each question. The sum of the 5 VAS measurements (0–500 mm) is presented and indicates the subjective impairment in function.

The clinical examination consisted of evaluation of the ankle motion, skin sensitivity, the homogeneity of the tendon and adherence between skin and tendon. No imaging assessments were done.

The endurance of the calf muscles was evaluated by comparing the number of heel-raises (above 2.5 cm) the patient managed on the injured side with that on the uninjured side. The ratio injured/uninjured side is presented. The height was controlled by photocells. When the heel was lifted over the photocell, a click-sound was generated to a speaker and the heel-raise was counted. A metronome was used to obtain a frequency of 40 heel-raises per minute. This method of endurance measurement of the calf muscles has been validated and reported in Achilles tendon rupture patients by Häggmark et al. (1986).

Co-morbidity was classified as any disease affecting the circulatory system, lungs, malignant tumor or rheumatoid arthritis.

Statistics

The results are presented as median and range values.

Statistical analysis was performed for the entire group of patients regarding the hypothesis concerning no differences in the calf muscle endurance of the injured, compared with the uninjured side by using the paired two-sided Student's t-test. The results in surgically- and non-surgically-treated patients were analyzed by non-parametric statistics by using the Mann-Whitney U-test. A probability level of < 0.05 was considered significant.

Results (Tables 2 and 3)

Calf muscle endurance with the heel-raise test showed a ratio of the injured/uninjured side of 0.64 (0–1.14; n 18) ($p = 0.002$). 5 patients could not perform the test on either side.

The median value of subjective impairment in function from the five VAS questions was 471 (190–500) mm. 9 of the 25 patients reached the same level of activity as before the injury.

14 complications occurred in 11 patients: 5 reruptures, 1 deep venous thrombosis, 4 infections, 2 nerve injuries and 2 had a symptomatic adherence between the tendon and skin.

Of the 14 surgically treated patients, 5 had no symptoms from their Achilles tendon and 6 had returned to their previous activity level. Complications among these 14 patients included 1 rerupture, 3 superficial infections responding to antibiotic treatment, 1 injury to the sural nerve and 2 patients who had adherent tendon and skin.

10 patients were treated non-surgically, 3 were asymptomatic. 3 had returned to their previous activity level. 4 sustained a rerupture and all 4 were treated surgically. 2 patients developed complications from the plaster cast, 1 had a fibular nerve injury following compression and another a skin injury with superficial infection. 1 patient had deep venous thrombosis.

Table 2. Individual data of the 25 patients included in the study

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	m	70	c	n	1	n		n			ni	y	0.15	244
2	m	71	c	n	7	n		n	y [a]	s		y		256
3	m	86	c	n	1	n		n				y		190
4	m	74	c	y	12	n		n				y	0.87	490
5	m	69	c	n	4	n		y	y	s		y	1	461
6	m	65	c	y	14	n		n	y	s		n	1	485
7	m	66	c	n	1	n		y				n	0.79	349
8	m	76	b	n	14	n		n				y	0	
9	m	78	c	y	30	y	a	y	y	s		n	0	485
10	f	71	c,b	n	>180	n		n			d,in	y		238
11	m	72	s	y	6	y	c	y				y	0.07	485
12	m	65	s	n	1	y	c	y			in	y	0.88	475
13	m	75	s	y	7	y	c	n				y	1	485
14	m	71	s	y	1	n		y				n	0.9	490
15	m	65	s	n	3	y	c	n				n	0.27	315
16	m	79	s	n	1	y	ca	n	y	s	ni	y		250
17	m	75	s	y	1	y	c	y				n	0.91	500
18	m	69	s	n	21	y		n				y	0	430
19	m	70	s	y	7	y	pt	y			a	y	1.14	486
20	m	65	s	n	1	n		y				y	0.49	460
21	f	76	s	n	[b]	y	c	n			in	y		
22	f	69	s	n	30	n		n			in,a	y		500
23	m	75	s	n	30	n		n				n	0.39	474
24	f	75	s	n	>180	n						n		438
25	m	70	0	n	>180	y	c	y				y	0	379

A Patient no.
B Sex
C Age
D Treatment
  c cast
  b brace
  s surgery
E Asymptomatic
  y yes
  n no
F Days to treatment
G Symptoms before rupture
  y yes
  n no
H Treatment of previous symptoms
  c inj. corticosteroids
  ca cast
  pt physical therapy
  a antiinflammatory medication
I Returned to previous level of activity
  y yes
  n no
J Rerupture
  y yes
K Treatment of rerupture
  s surgical
L Complications
  a adherence tendon to skin
  d deep venous thrombosis
  in infection
  ni nerve injury
M Co-morbidity
  y yes
  n no
N Heel-raise injured/uninjured
O Functional impairment
  0–500, see text

[a] rerupture twice, both surgically treated
[b] medical records missing

The patient who did not receive any treatment could not perform a heel-raise on the injured side.

Discussion

The number of elderly Achilles tendon rupture patients is probably increasing, since the mean age of the population is increasing. Furthermore, the incidence of all Achilles tendon ruptures has been increasing in Scandinavia (Leppilahti et al. 1996, Möller et al. 1996).

Mechanical load during sports is a major factor in the middle-aged recreational athlete (Nillius et al. 1976, Nistor 1981). Other factors such as aging and co-morbidity may explain the bi-modal distri-

Table 3. Summary of results in surgically- and non-surgically-treated elderly persons with Achilles tendon rupture presented as median and range values. From the top: a) the ratio of heel-raises of the injured to the uninjured side, b) the sum of five questions with VAS measurements regarding functional impairment where 500 represents no difficulty in performing walking activities, and VAS assessment of the subjective opinion of c) the treatment and d) its outcome, with 100 representing an optimal result

	Surgically-treated (n 14)	Non-surgically-treated (n 10)	P-value
Calf endurance performance	0.49 (0–1.14)	0.79 (0–1)	0.63
Subjective impairment in function	475 (250–500)	349 (190–490)	0.21
Subjective opinion of treatment	92 (24–100)	72 (4–96)	0.20
Subjective opinion of outcome	89 (25–100)	23 (4–97)	0.10

bution curve related to age. The blood supply decreases in the aging human Achilles tendon (Håstad et al. 1958/59, Åström and Westlin 1994), which may diminish its nutritional supply. With age, the tendon collagen volume increases and the glycosaminoglycans and water content decrease (Ippolito et al. 1980), which affect the tensile properties. Age significantly affects the ultimate tensile strength and the tangent of the modulus of elasticity (Lewis and Shaw 1997). A preexisting Achilles tendon disorder may precede the rupture. In a study of 397 patients with Achilles tendon rupture, all tendons were classified as pathological by their microstructure (Kannus and Józsa 1991). Histological studies of patients with achillodynia and tendinosis have shown a correlation between increased tendon pathology and increasing age (Åström and Rausing 1995, Movin et al. 1997).

In our series, 11 of 25 patients had had local symptoms in the Achilles tendon region and 7 had been treated with local cortisone injections. The use of corticosteroid injections is controversial, since there is no convincing evidence for or against their use in Achilles tendon disorders (Read and Motto 1992, Shrier et al. 1996, Kannus and Natri 1997).

The elderly patients in our study had a high frequency of co-morbidity (17/25), which affected the performance. Tendons subjected to low activity have abnormally grouped collagen fibrils (Józsa 1984), which may add to the reduced mechanical properties of the tendon. Furthermore, the co-morbidity probably influenced the initial treatment and the prospects of for rehabilitation. Retrospective comparison of the results of surgical versus non-surgical management therefore has obvious limitations.

The main reason why the non-surgically-treated patients were displeased with the outcome of the treatment was that 4 of 10 patients had a rerupture and were operated on.

The objective measurement of calf muscle endurance showed a reduction to two-thirds of the uninjured leg. However, the subjective impairment was low and the patients could perform most walking activities with only minor difficulty. This was consistent with Nistor's (1981) findings that the reduction in plantar flexion strength appears to have little clinical importance.

We found 14 complications (including 5 reruptures) in 11 of the 25 elderly patients, which is higher than in a literature review of patients of all ages with Achilles tendon rupture (Lo et al. 1997).

Achilles tendon rupture may be missed in as many as 25% of patients (Ballas et al. 1998). This was evident in our series of 9/25 patients having a delay of more than 1 week to treatment. Carden et al. (1987) recommended that Achilles tendon rupture should be treated with plaster in full equinus when it is diagnosed within 48 hours, and by operation when the diagnosis has been delayed for more than 1 week. None of the patients treated with plaster who subsequently sustained a rerupture in our series had been treated within 48 hours.

We found that the treatment of Achilles tendon rupture in patients older than 65 years was associated with many complications. The calf muscle endurance was reduced to two-thirds of the uninjured side, but the reduction seemed to have limited clinical importance, since the patients could perform most walking activities. However, most

of them did not return to their previous level of activity.

Ballas M T, Tytko J, Mannarino F. Commonly missed orthopedic problems. Am Fam Physician 1998; 57: 267-74.

Carden D G, Noble J, Chalmers J, Lunn P, Ellis J. Rupture of the calcaneal tendon. The early and late management. J Bone Joint Surg (Br) 1987; 69: 416-20.

Cetti R, Christensen S E, Ejsted R, Jensen N M, Jorgensen U. Operative versus nonoperative treatment of Achilles tendon rupture. A prospective randomized study and review of the literature. Am J Sports Med 1993; 21: 791-9.

Håstad K, Larsson L G, Lindholm Å. Clearance of radiosodium after local deposit in the Achilles tendon. Acta Chir Scand 1958/59; 116: 251-5.

Häggmark T, Liedberg H, Eriksson E, Wredmark T. Calf muscle atrophy and muscle function after non-operative vs operative treatment of Achilles tendon ruptures. Orthopaedics 1986; 9:160-4.

Ippolito E, Natali P G, Postacchini F, Accinni L, De Martino C. Morphological, immunochemical, and biochemical study of rabbit Achilles tendon at various ages. J Bone Joint Surg (Am) 1980; 62: 583-98.

Józsa L. Morphological and biochemical alterations in hypokinetic human tendons. Finn Sports and Exerc Med 1984 3: 111-5.

Kannus P, Józsa L. Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. J Bone Joint Surg (Am) 1991; 73: 1507-25.

Kannus P, Natri A. Etiology and pathophysiology of tendon ruptures in sports. Scand J Med Sci Sports 1997; 7: 107-12.

Leppilahti J, Puranen J, Orava S. Incidence of Achilles tendon rupture. Acta Orthop Scand 1996; 67: 277-9.

Lewis G, Shaw K M. Tensile properties of human tendo Achillis: effect of donor age and strain rate. J Foot Ankle Surg 1997; 36: 435-45.

Lo I K, Kirkley A, Nonweiler B, Kumbhare D A. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a quantitative review. Clin J Sport Med 1997; 7: 207-11.

Möller A, Åstrom M, Westlin N. Increasing incidence of Achilles tendon rupture. Acta Orthop Scand 1996; 67: 479-81.

Movin T, Gad A, Reinholt F P, Rolf C. Tendon pathology in long-standing achillodynia. Biopsy findings in 40 patients. Acta Orthop Scand 1997; 68: 170-5.

Nillius S A, Nilsson B E, Westlin N E. The incidence of Achilles tendon rupture. Acta Orthop Scand 1976; 47: 118-21.

Nistor L. Surgical and non-surgical treatment of Achilles tendon rupture. A prospective randomized study. J Bone Joint Surg (Am) 1981; 63: 394-9.

Read M T F, Motto S G. Tendo Achillis pain: steroids and outcome. Br J Sports Med 1992; 26: 15-21.

Shrier I, Matheson G O, Kohl H W 3rd. Achilles tendonitis: are corticosteroid injections useful or harmful? Clin J Sport Med 1996; 6: 245-50.

Åström M, Westlin N. Blood flow in the human Achilles tendon assessed by laser Doppler flowmetry. J Orthop Res 1994; 12: 246-52.

Åström M, Rausing A. Chronic Achilles tendinopathy. A survey of surgical and histopathologic findings. Clin Orthop 1995; 316: 151-64.

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Treatment of Acute Achilles Tendon Rupture

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There is no clear consensus on the optimal treatment of acute Achilles tendon rupture. Recently, studies have demonstrated the critical role of functional rehabilitation in the treatment of ruptured Achilles tendons. Hence, conservative treatment is preferred by a growing number of surgeons seeking to treat the condition without the risk of complications from surgery. However, operative treatment is still considered as a more reliable treatment option for acute Achilles tendon rupture. In this review article, we provide an overview of recent treatment strategies for acute rupture of the Achilles tendon.

Keywords: *Achilles tendon, Injuries, Surgery, Rehabilitation*

The Achilles tendon is the strongest and largest tendon in the body, but it is also the most commonly ruptured tendon. The overall incidence of Achilles tendon rupture is on the rise recently[1,2] because of the aging of the population, growing prevalence of obesity, and increased participation in sports.[3]

Controversy has surrounded the optimal treatment of acute Achilles tendon rupture.[4] In the past, aggressive surgical intervention was recommended over conservative management on the basis of early studies that associated conservative treatment with high rerupture rates.[5-8] These studies provided a rationale for operative treatment of acute rupture of the Achilles tendon, despite the risk of complications from surgery such as wound infection. However, recent studies have demonstrated favorable outcomes of conservative treatment using accelerated functional rehabilitation. In such studies, functional rehabilitation was more effective in reducing rerupture rates than long-term cast immobilization, and functional improvement after nonoperative treatment was comparable to that after operative repair.[9-11] Currently, regardless of the treatment modality—either conservative or operative—used, aggressive early rehabilitation is advocated for acute Achilles tendon ruptures to allow for an early return to activities of daily living, high patient satisfaction, and functional improvement. In this review article, we provide a comprehensive review of the literature on acute rupture of the Achilles tendon and discuss appropriate treatment options.

EPIDEMIOLOGY

Achilles tendon rupture accounts for 20% of all large tendon ruptures.[12] The estimated incidence ranges from 11 to 37 per 100,000 population.[13-15] Men are 2 to 12 times more prone to Achilles tendon rupture than women.[16] In a 2012 meta-analysis by Soroceanu et al.,[10] the mean age at the time of injury among 826 patients with an acute Achilles tendon rupture was 39.8 years. The injury has a bimodal age distribution with the first peak in patients between 25 years and 40 years of age and the second peak in those over 60 years.[17,18] High-energy injuries in sports are responsible for the first peak, whereas the second peak occurring in the elderly is mostly associated with low-energy injuries, such as spontaneous rupture of the degenerated Achilles tendon or rupture in chronic Achilles tendinopathy. In young patients with acute sports injures, conservative management is usually sufficient for tendon healing. However, rupture of the degenerated tendon in the elderly requires a different treatment approach because the tendon remains vulnerable to rerupture even after operative

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repair. Therefore, it is important to differentiate acute rupture of the Achilles tendon from rupture of the degenerated tendon.

ANATOMY

The Achilles tendon is the largest and strongest tendon in the body.[19] Tendinous fibers of the gastrocnemius originating from the distal femur and those of the soleus muscle originating from the proximal tibia coalesce above the insertion on the posterior calcaneal tuberosity.[20] The approximately 15-cm-long Achilles tendon travels distally and twists approximately 90º internally so that the initially anterior fibers of the gastrocnemius insert laterally and the initially posterior fibers of the soleus insert on the medial aspect of the Achilles tendon. The Kager's fat pad located anterior to the Achilles tendon protects blood vessels entering the tendon.[21]

The Achilles tendon has no tendon sheath but a highly vascularized paratenon[22] that acts as a conduit for the vasculature of the tendon and facilitates tendon gliding between the subcutaneous tissue and posterior fascia.[22] The proximal and distal sections of the tendon are supplied by the posterior tibial artery and the midsection (2 to 6 cm from the insertion point) is supplied by the peroneal artery.[23] Since the midsection receives a relatively poor blood supply, it is most vulnerable to degeneration and rupture.[24]

DIAGNOSIS

Clinical Findings

The diagnosis of acute Achilles tendon rupture is mostly based on a thorough history taking and physical examination. Typical patients are in their third or fourth decade of life and present with sudden inability to walk and acute pain during running or jumping. Patients with an acute rupture of the tendon often describe that they heard a popping sound in the back of the leg in dorsiflexion of the ankle or had the feeling of being kicked in the back of the ankle. Signs of a ruptured tendon include plantar flexion weakness, difficulty with weight-bearing ambulation, and limping. A false-negative Thompson test result can occur if plantar flexion is produced by intact extrinsic foot flexors; approximately 25% of acute ruptures are initially neglected for this reason.[25]

According to the American Academy of Orthopaedic Surgeons clinical practice guidelines, the diagnosis of an acute Achilles tendon rupture can be established by two or more of the following physical examination tests: (1) a positive Thompson test, (2) decreased plantar flexion strength, (3) presence of a palpable defect, and (4) increased passive ankle dorsiflexion with gentle manipulation.[26] During diagnosis, it is important to differentiate traumatic sports injuries from low-energy injuries (Fig. 1). The latter is often associated with the degenerative process of the tendon, chronic tendinosis, a history of steroid injection, and older age.

Radiological Findings

The diagnosis of acute Achilles tendon rupture is primarily clinical, supported by imaging tests. Magnetic resonance imaging (MRI) or ultrasonography can be useful as a confirmatory test. Since MRI is not a dynamic imaging modality, it is not reliable in adequately determining partial or complete rupture. By contrast, ultrasonography is more effective in identifying the location of a tear, gap between the torn ends of the tendon, and partial/complete rupture.[27] Plain radiography (lateral views of the ankle) is used in treatment planning. It also aids in identification of tendon swelling and increased soft tissue density in the Kager's fat pad. Above all, it is superior to other imaging modalities in detecting presence of a calcific lesion, Haglund prominence, or calcaneus avulsion fracture, suggestive of pre-existing degeneration or chronic tendinosis (Fig. 2). In the case of a rupture in chronic Achilles tendinopathy, the risk of rerupture is high after either conservative treatment or direct repair. Direct healing of the pathologic tissue at the ruptured ends is oftentimes not feasible in this case. Then, the surgeon should consider other treatment options using healthy tissue, such as tendon reconstruction. Therefore, it is of utmost importance to confirm the presence or absence of pre-existing tendinopathy for differential diagno-

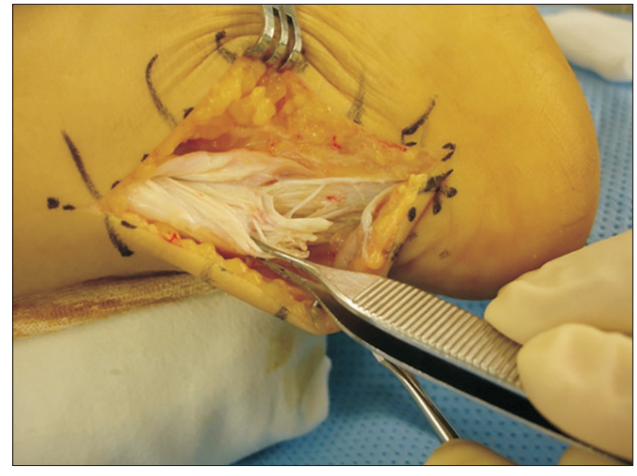

Fig. 1. Degenerated fibers of an Achilles tendon with chronic tendinitis.

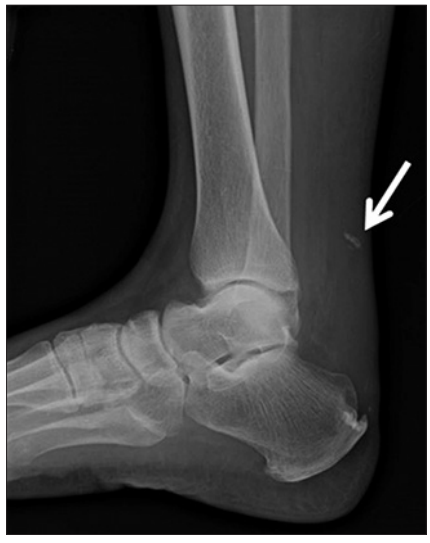

Fig. 2. Calcaneal spur and calcification (arrow) were observed in the degenerated Achilles tendon.

sis of acute Achilles tendon rupture. Plain radiography is a more appropriate than MRI or ultrasonography for this purpose.

CONSERVATIVE TREATMENT

There is still controversy over which treatment—conservative or operative—is more effective for acute Achilles tendon rupture. The concern related to conservative management is whether healing of a ruptured tendon is feasible without direct contact with surrounding structures. Delayed healing can result in calf weakness, and incomplete healing may increase the risk of rerupture. Bae et al.[28] reported that the tendon healed without direct contact of the ruptured ends despite the presence of a large defect. Although the study was based on the premise that the tissue at the margin of the ruptured ends should remain healthy, not pathologic, it supported the feasibility of tendon healing without direct repair.

The conventional conservative treatment entails 6 to 8 weeks of cast immobilization. The ankle is placed in a cast in plantar flexion position for initial 4 weeks and in neutral position for the following 2 to 4 weeks. Conservative management has been associated with a higher rerupture rate compared with operative repair (12.6% vs. 3.5%).[6] However, recent studies have suggested that the rerupture rates can be lowered by reducing the period of cast immobilization and using early functional rehabilitation.[11,29] Rehabilitation is an integral part of treatment, either conservative or operative. Hence, much effort is focused on the development of optimal rehabilitations strategies.

FUNCTIONAL REHABILITATION IN CONSERVATIVE TREATMENT

In nonoperative treatment, rehabilitation is essential to treatment success. In the past, range of motion exercises and weight bearing after conservative treatment were not allowed as early as those after operative repair. However, recent studies underscore the benefits of early rehabilitation after conservative treatment of acute Achilles tendon rupture.[30]

As important as early rehabilitation after cast immobilization is the timely application of a functional walking brace. In a prospective randomized study, Saleh et al.[31] compared 8-week cast immobilization with 3-week cast immobilization followed by early mobilization in a functional brace. They found the use of a functional brace led to more rapid improvement of ankle dorsiflexion and earlier return to normal activities. Various rehabilitation protocols for conservative management of Achilles tendon ruptures are well documented in the literature.[11,32-35] Conservative management should not be misconstrued as "no treatment." Validated functional rehabilitation protocols are an integral part of conservative management of acute Achilles tendon rupture. These protocols should be effective when implemented in informed and cooperative patients; for uncooperative patients, operative repair should be considered as a treatment option. For the initial 8 weeks after an acute Achilles tendon injury, patients are required to wear a brace to prevent hyperdorsiflexion. Unfortunately, in Korea where people do not wear shoes indoors, patient's adherence to the use of a brace is relatively low; therefore, judicious patient selection is advised. Until 6 months after injury, low-impact activities are performed in a progressive manner; after 6 months, high-impact activities, such as soccer and basketball, are allowed.[11] To promote recovery to preinjury level of calf muscle strength, rehabilitation should be reasonably aggressive during the first year after injury, especially, for the first 6 months. It is because the recovery of calf muscle strength cannot be ensured with either conservative or operative treatment once 1 year has passed after injury. In a study by Lantto et al.,[36] calf muscle strength in patients with acute Achilles tendon rupture did not recover to the normal level even at 11-years' follow-up and the isokinetic strength changed minimally between 1 year and 11 years of follow-up.

OPERATIVE TREATMENT

Various operative procedures for acute Achilles tendon rupture are described in the literature. They can be broadly categorized into open, mini-open, and percutaneous

repair.[37] Among those, the posteromedial approach has been most frequently used since the hypervascularity on the medial side of the Achilles tendon was confirmed by angiography in a cadaver study.[38] The surgeon can determine repair techniques other than the Krackow suture method on the basis of his or her preference. Irrespective of the operative approach, however, one should restore the proper length of the tendon, guarding against excessive elongation. In general, the proper length is determined during surgery by comparing with the intact plantaris tendon; however, if the plantaris tendon is absent, the range of dorsiflexion on the contralateral side should be measured before draping or during surgery to use as a guide. After that, to prevent an infection, the paratenon surrounding the Achilles tendon should be repaired. While the open technique has shown good clinical results, it has also been associated with superficial and deep wound complications requiring reoperation.[37]

Percutaneous repair can be done by using multiple puncture wounds. A suture is woven through the proximal and distal portions of the tendon via puncture wounds. The suture is tied, bringing tendon ends into apposition in plantar flexion of the ankle. Blindly passing the suture in percutaneous repair can cause a sural nerve injury. The mini-open repair technique has been developed to minimize the complications such as postoperative wound infection of open repair and sural nerve injury in percutaneous repair. A small skin incision over the rupture site is made and subcutaneous soft-tissue is bluntly spread. Various devices are necessary for the mini-open repair technique. A device is introduced through the incision under the paratenon and the suture is passed from the external guide through the skin into the tendon and out to the opposite side. Usually, three sutures are passed through the proximal and distal tendon ends. The device and the suture are pulled out for apposition of ruptured tendon ends, and the sutures are tied with the ankle in plantar flexed position. Percutaneous repair with the mini-open technique, compared with open repair, results in lower wound complication rates and improves cosmetic appearance. However, overall complication rates are not significantly different between the mini-open, percutaneous repair and the open repair.[37]

FUNCTIONAL REHABILITATION IN OPERATIVE TREATMENT

For tendon healing, early functional rehabilitation is more important than the surgery itself. Huang et al.[39] reported that early weight bearing combined with early ankle motion exercises was more effective for postoperative recovery than the conventional immobilization or early ankle motion exercises alone. Brumann et al.[40] also emphasized the importance of accelerated rehabilitation. According to their rehabilitation protocol, full weight bearing in 30° fixed plantar flexion is started immediately after surgery; controlled ankle mobilization in free plantar flexion and limited dorsiflexion at 0°, after the second postoperative week.

Prolonged postoperative immobilization is not desirable. In particular, more than 3 weeks of immobilization in a splint or cast should be avoided. Long-leg cast immobilization is no longer recommended. Full weight bearing in an orthosis is initiated immediately after surgery or at least within 3 weeks after surgery, and it should be worn for 6 to 8 postoperative weeks. Although the use of a removable brace is allowed for early range of motion exercises, the patient should be cautioned to avoid hyperdorsiflexion of the ankle.

Although there is a broad consensus on the importance of early weight bearing, postoperative ankle position still remains the subject of debate. In general, the ankle is initially maintained in plantar flexion position with gradual dorsiflexion. However, some authors recommend neutral ankle position immediately after surgery to allow for full weight bearing,[41] because rerupture occurs frequently in gradual dorsiflexion of the plantar-flexed ankle during rehabilitation. Ryu et al.[41] reported there was no case of rerupture in the total 112 patients who started weight-bearing ambulation in neutral ankle position immediately after surgery. Regardless of the postoperative ankle position, however, it is important to avoid tendon elongation. An elongated Achilles tendon characterized by hyperdorsiflexion of the ankle in physical examination (Fig. 3) has been associated with plantar flexor weakness and functional deficit.

COMPLICATIONS

Complications of operative treatment of acute Achilles tendon rupture include sural nerve injury, infection, rerupture, deep vein thrombosis, and hypertrophic scars. Therefore, operative treatment may not be appropriate for low-demand patients or those with diabetes mellitus or peripheral vascular disease.

Infection

The most serious complication of open repair is infection. Infection and wound problems mostly occur after surgery with an incidence of 12.5%.[10,42] To prevent an infection,

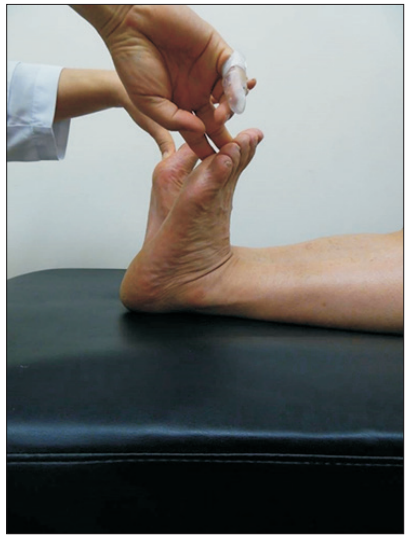

Fig. 3. Hyperdorsiflexed left ankle of a patient with the elongated Achilles tendon after an acute rupture.

the surgeon should avoid superficial dissection during incision and restore the synovial tissue envelope as much as possible before repair of the paratenon. In addition, one should use the minimal number of sutures to obviate delayed infection around the subcutaneous suture knot. Since the sutures need to hold the tendon for approximately 3 months of healing period after repair, absorbable sutures are preferable to nonabsorbable sutures, which increase the risk of delayed infection or irritation.

Calf Muscle Weakness

Patients are able to walk even without proper healing of a ruptured Achilles tendon; however, a permanent functional deficit will remain. Therefore, the ultimate goal of treatment is to prevent residual calf muscle weakness. The ability to perform a single heel raise is a valid indicator of calf muscle weakness; indeed, most patients with a neglected tear are unable to perform a single heel raise.[43,44]

Rerupture

One of the most important considerations in selecting operative versus nonoperative treatment is the risk of rerupture. Rettig et al.[45] reported that the overall postoperative rerupture rate was 4.5% in their patients, and 16.6% of which occurred in those aged 30 years or younger. They suggested that caution should be observed during aggressive rehabilitation in younger patients. Reito et al.[46] also reported a rerupture rate of 7.1% in 210 patients with Acute Achilles tendon rupture after conservative treatment. The complication occurred within 12 weeks after treatment in most cases, and they suggested extra care should be taken in the first month after nonoperative treatment. Young et al.[47] noted that nine of the total 12 reruptures (75%) occurred within 3 months after surgery and there was no association between the rerupture rate and the repair method.

PROGNOSIS

In general, patients will resume normal ambulation within 12.5 to 18 weeks after an acute rupture of the Achilles tendon,[48] but there is no doubt that early weight bearing and rehabilitation contribute to improved prognosis.[11,29,48] Patients are conventionally advised against running and non-contact sports for 16 to 20 weeks after injury.[49] The criteria for return to running suggested by Van Sterkenburg et al.[50] include the ability to perform repetitive single heel raises and toe walking and ≤ 25% calf strength deficit compared to the normal contralateral side, which should be met approximately 12 weeks after injury. Olsson et al.[51] also reported the heel raise ability as an important indicator of general level of healing. In their study, 40 out of 81 patients (49%) with acute Achilles tendon ruptures were unable to perform a single heel raise at 12 weeks after the injury. In a study by Ryu et al.,[41] 87 of 112 patients with acute Achilles tendon ruptures had difficulty with a single heel raise at 3 months after open tenorrhaphy followed by early rehabilitation; however, all patients were able to raise the heel 6 months postoperatively.

McCormack and Bovard[52] noted a 10% to 30% calf strength deficit on the injured side compared to the uninjured side in their patients with acute Achilles tendon tears. Ryu et al.[41] also reported that even in patients who were able to perform single heel raises and sports after operative repair of acute tears and early rehabilitation, the calf circumference decreased by an average of 1.6 cm on the injured side and the isokinetic flexion peak torque deficit at 30°/sec was 16% (range, 0% to 21%) on the injured side compared with the uninjured side.

CONCLUSIONS

Acute Achilles tendon ruptures should be differentiated from ruptures that occur as the result of chronic degeneration of the tendon. An acute rupture of a healthy tendon can be successfully treated either conservatively or operatively. Irrespective of the treatment method, however, rehabilitation is a crucial component of treatment. Thus, patient's adherence to rehabilitation should be taken into consideration in determining a treatment strategy. Re-

habilitation during the first 6 months after injury is of great importance for patients with an acute rupture of the Achilles tendon. While specifics of the rehabilitation protocol may vary, the focus of rehabilitation is on preventing rerupture for the first 2 months after injury and improving calf muscle strength for the next 1 month (between 2 months and 3 months after injury). Then, for the following 3 months (between 3 months and 6 months after injury), rehabilitation efforts are directed toward a return to sports through vigorous strengthening and proprioceptive exercises. Furthermore, during rehabilitation after either treatment, care should be taken not to cause hyperdorsiflexion of the ankle to prevent calf muscle weakness.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Huttunen TT, Kannus P, Rolf C, Fellander-Tsai L, Mattila VM. Acute achilles tendon ruptures: incidence of injury and surgery in Sweden between 2001 and 2012. Am J Sports Med. 2014;42(10):2419-23.
2. Lantto I, Heikkinen J, Flinkkila T, Ohtonen P, Leppilahti J. Epidemiology of Achilles tendon ruptures: increasing incidence over a 33-year period. Scand J Med Sci Sports. 2015;25(1):e133-8.
3. Raikin SM, Garras DN, Krapchev PV. Achilles tendon injuries in a United States population. Foot Ankle Int. 2013;34(4):475-80.
4. Thevendran G, Sarraf KM, Patel NK, Sadri A, Rosenfeld P. The ruptured Achilles tendon: a current overview from biology of rupture to treatment. Musculoskelet Surg. 2013; 97(1):9-20.
5. Cetti R, Christensen SE, Ejsted R, Jensen NM, Jorgensen U. Operative versus nonoperative treatment of Achilles tendon rupture: a prospective randomized study and review of the literature. Am J Sports Med. 1993;21(6):791-9.
6. Khan RJ, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute achilles tendon ruptures: a meta-analysis of randomized, controlled trials. J Bone Joint Surg Am. 2005;87(10):2202-10.
7. Moller M, Movin T, Granhed H, Lind K, Faxen E, Karlsson J. Acute rupture of tendon Achillis: a prospective randomised study of comparison between surgical and non-surgical treatment. J Bone Joint Surg Br. 2001;83(6):843-8.
8. Roberts CP, Palmer S, Vince A, Deliss LJ. Dynamised cast management of Achilles tendon ruptures. Injury. 2001;32(5):423-6.
9. Keating JF, Will EM. Operative versus non-operative treatment of acute rupture of tendo Achillis: a prospective randomised evaluation of functional outcome. J Bone Joint Surg Br. 2011;93(8):1071-8.
10. Soroceanu A, Sidhwa F, Aarabi S, Kaufman A, Glazebrook M. Surgical versus nonsurgical treatment of acute Achilles tendon rupture: a meta-analysis of randomized trials. J Bone Joint Surg Am. 2012;94(23):2136-43.
11. Willits K, Amendola A, Bryant D, et al. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am. 2010;92(17):2767-75.
12. Gillies H, Chalmers J. The management of fresh ruptures of the tendo achillis. J Bone Joint Surg Am. 1970;52(2):337-43.
13. Houshian S, Tscherning T, Riegels-Nielsen P. The epidemiology of Achilles tendon rupture in a Danish county. Injury. 1998;29(9):651-4.
14. Jarvinen TA, Kannus P, Maffulli N, Khan KM. Achilles tendon disorders: etiology and epidemiology. Foot Ankle Clin. 2005;10(2):255-66.
15. Levi N. The incidence of Achilles tendon rupture in Copenhagen. Injury. 1997;28(4):311-3.
16. Movin T, Ryberg A, McBride DJ, Maffulli N. Acute rupture of the Achilles tendon. Foot Ankle Clin. 2005;10(2):331-56.
17. Moller A, Astron M, Westlin N. Increasing incidence of Achilles tendon rupture. Acta Orthop Scand. 1996;67(5): 479-81.
18. Nillius SA, Nilsson BE, Westlin NE. The incidence of Achilles tendon rupture. Acta Orthop Scand. 1976;47(1):118-21.
19. O'Brien M. The anatomy of the Achilles tendon. Foot Ankle Clin. 2005;10(2):225-38.
20. Rufai A, Ralphs JR, Benjamin M. Structure and histopathology of the insertional region of the human Achilles tendon. J Orthop Res. 1995;13(4):585-93.
21. Benjamin M, Moriggl B, Brenner E, Emery P, McGonagle D, Redman S. The "enthesis organ" concept: why enthesopathies may not present as focal insertional disorders. Arthritis Rheum. 2004;50(10):3306-13.
22. Lohrer H, Arentz S, Nauck T, Dorn-Lange NV, Konerding MA. The Achilles tendon insertion is crescent-shaped:

an in vitro anatomic investigation. Clin Orthop Relat Res. 2008;466(9):2230-7.

23. Chen TM, Rozen WM, Pan WR, Ashton MW, Richardson MD, Taylor GI. The arterial anatomy of the Achilles tendon: anatomical study and clinical implications. Clin Anat. 2009;22(3):377-85.
24. Gwynne-Jones DP, Sims M, Handcock D. Epidemiology and outcomes of acute Achilles tendon rupture with operative or nonoperative treatment using an identical functional bracing protocol. Foot Ankle Int. 2011;32(4):337-43.
25. Inglis AE, Sculco TP. Surgical repair of ruptures of the tendo Achillis. Clin Orthop Relat Res. 1981;(156):160-9.
26. Chiodo CP, Glazebrook M, Bluman EM, et al. Diagnosis and treatment of acute Achilles tendon rupture. J Am Acad Orthop Surg. 2010;18(8):503-10.
27. Maffulli N, Dymond NP, Regine R. Surgical repair of ruptured Achilles tendon in sportsmen and sedentary patients: a longitudinal ultrasound assessment. Int J Sports Med. 1990;11(1):78-84.
28. Bae SH, Lee HS, Seo SG, Kim SW, Gwak HC, Bae SY. Debridement and functional rehabilitation for Achilles tendon infection following tendon repair. J Bone Joint Surg Am. 2016;98(14):1161-7.
29. Nilsson-Helander K, Silbernagel KG, Thomee R, et al. Acute achilles tendon rupture: a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. Am J Sports Med. 2010;38(11):2186-93.
30. Young SW, Patel A, Zhu M, et al. Weight-bearing in the nonoperative treatment of acute Achilles tendon ruptures: a randomized controlled trial. J Bone Joint Surg Am. 2014;96(13):1073-9.
31. Saleh M, Marshall PD, Senior R, MacFarlane A. The Sheffield splint for controlled early mobilisation after rupture of the calcaneal tendon: a prospective, randomised comparison with plaster treatment. J Bone Joint Surg Br. 1992;74(2):206-9.
32. Hutchison AM, Topliss C, Beard D, Evans RM, Williams P. The treatment of a rupture of the Achilles tendon using a dedicated management programme. Bone Joint J. 2015;97(4):510-5.
33. Ecker TM, Bremer AK, Krause FG, Muller T, Weber M. Prospective use of a standardized nonoperative early weightbearing protocol for achilles tendon rupture: 17 years of experience. Am J Sports Med. 2016;44(4):1004-10.
34. Barfod KW, Bencke J, Lauridsen HB, Ban I, Ebskov L, Troelsen A. Nonoperative dynamic treatment of acute achilles tendon rupture: the influence of early weight-bearing on clinical outcome: a blinded, randomized controlled trial. J Bone Joint Surg Am. 2014;96(18):1497-503.
35. Kauwe M. Acute Achilles tendon rupture: clinical evaluation, conservative management, and early active rehabilitation. Clin Podiatr Med Surg. 2017;34(2):229-43.
36. Lantto I, Heikkinen J, Flinkkila T, et al. Early functional treatment versus cast immobilization in tension after achilles rupture repair: results of a prospective randomized trial with 10 or more years of follow-up. Am J Sports Med. 2015;43(9):2302-9.
37. Hsu AR, Jones CP, Cohen BE, Davis WH, Ellington JK, Anderson RB. Clinical outcomes and complications of percutaneous Achilles repair system versus open technique for acute Achilles tendon ruptures. Foot Ankle Int. 2015;36(11):1279-86.
38. Yepes H, Tang M, Geddes C, Glazebrook M, Morris SF, Stanish WD. Digital vascular mapping of the integument about the Achilles tendon. J Bone Joint Surg Am. 2010;92(5):1215-20.
39. Huang J, Wang C, Ma X, Wang X, Zhang C, Chen L. Rehabilitation regimen after surgical treatment of acute Achilles tendon ruptures: a systematic review with meta-analysis. Am J Sports Med. 2015;43(4):1008-16.
40. Brumann M, Baumbach SF, Mutschler W, Polzer H. Accelerated rehabilitation following Achilles tendon repair after acute rupture: development of an evidence-based treatment protocol. Injury. 2014;45(11):1782-90.
41. Ryu CH, Lee HS, Seo SG, Kim HY. Results of tenorrhaphy with early rehabilitation for acute tear of Achilles tendon. J Orthop Surg (Hong Kong). 2018;26(3):2309499018802483.
42. Kadakia AR, Dekker RG 2nd, Ho BS. Acute Achilles tendon ruptures: an update on treatment. J Am Acad Orthop Surg. 2017;25(1):23-31.
43. Elias I, Besser M, Nazarian LN, Raikin SM. Reconstruction for missed or neglected Achilles tendon rupture with V-Y lengthening and flexor hallucis longus tendon transfer through one incision. Foot Ankle Int. 2007;28(12):1238-48.
44. Yasuda T, Shima H, Mori K, Kizawa M, Neo M. Direct repair of chronic Achilles tendon ruptures using scar tissue located between the tendon stumps. J Bone Joint Surg Am. 2016;98(14):1168-75.
45. Rettig AC, Liotta FJ, Klootwyk TE, Porter DA, Mieling P. Potential risk of rerupture in primary achilles tendon repair in athletes younger than 30 years of age. Am J Sports Med. 2005;33(1):119-23.
46. Reito A, Logren HL, Ahonen K, Nurmi H, Paloneva J. Risk factors for failed nonoperative treatment and rerupture in acute Achilles tendon rupture. Foot Ankle Int.

2018;39(6):694-703.

47. Young KW, Lee HS, Park SC. Rerupture risk after tenorrhaphy for Achilles tendon rupture. In: Proceedings of the 32nd Annual Meeting of Korean Orthopedic Society for Sports Medicine; 2018 Sep 15; Seoul, Korea. Daejeon: Korean Orthopaedic Society for Sports Medicine; 2018.
48. Costa ML, Donell ST, Tucker K. The long-term outcome of tendon lengthening for chronic Achilles tendon pain. Foot Ankle Int. 2006;27(9):672-6.
49. Maffulli N, Longo UG, Maffulli GD, Khanna A, Denaro V. Achilles tendon ruptures in elite athletes. Foot Ankle Int. 2011;32(1):9-15.
50. van Sterkenburg MN, Kerkhoffs GM, van Dijk CN. Good outcome after stripping the plantaris tendon in patients with chronic mid-portion Achilles tendinopathy. Knee Surg Sports Traumatol Arthrosc. 2011;19(8):1362-6.
51. Olsson N, Karlsson J, Eriksson BI, Brorsson A, Lundberg M, Silbernagel KG. Ability to perform a single heel-rise is significantly related to patient-reported outcome after Achilles tendon rupture. Scand J Med Sci Sports. 2014;24(1):152-8.
52. McCormack R, Bovard J. Early functional rehabilitation or cast immobilisation for the postoperative management of acute Achilles tendon rupture? A systematic review and meta-analysis of randomised controlled trials. Br J Sports Med. 2015;49(20):1329-35.