Comparing Surgical and Conservative Treatment on Achilles Tendon Rupture: A Comprehensive Meta-Analysis of RCTs

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Abstract

Background Achilles tendon is the strongest tendon in human and frequently injured mainly in young to middle age active population. Increasing incidence of Achilles tendon rupture (ATR) is still reported in several studies. Surgical repair and conservative treatment are two major management strategy widely adopted in ATR patients but the consensus of optimal treatment strategy is still debated. We aimed at fully reviewing the ATR topic with additional assessments and performed a most comprehensive meta-analysis of randomized controlled trials (RCTs).

Method We comprehensively searched database of PubMed, Embase, Cochrane and ClinicalTrial.gov and retrieved all randomized controlled trials comparing surgical and conservative treatment on achilles tendon rupture for further analysis. Data extraction was performed by two independent reviewer and random effect model was adopted when $I^2 > 50\%$, with data presentation of risk ratio, risk difference or mean difference and 95% confidence interval.

Results A total of 13 randomized control trials were included in this meta-analysis. Significant difference was observed in events of re-rupture, complication rate, adhesion to underlying tendon, sural nerve injury and superficial infection. For surgical treatment, significant reduction in re-rupture rate could be observed while complication rate was higher compared with conservative treatment.

Conclusion Surgical treatment was revealed significance in reduction of re-rupture rate but associated with higher complication rate while conservative treatment showed similar outcomes with lower complication rate. Collectively, we recommend conservative treatment if patients' status and expectation are suitable, but surgeon as well as physician's discretion is also important in decision making.

Introduction

Achilles tendon (AT), combination of tendinous portion of gastrocnemius as well as solus muscles to form the most strongest tendon in human body, is frequently injured and mainly in young to middle age active population of society, with the average age ranging from 37 to 44 years[1, 2]. Increasing incidence of Achilles tendon rupture (ATR) is still reported in several studies due to increasing older active population in society and, male patients are more common than female patients even though a higher rupture force is required in male[2–4].

Etiology of ATR is rarely discussed while several risk factors are account for it such as steroid injection, rheumatoid arthritis, intake of fluoroquinolones and long term dialysis[5, 6]. For the sake of its specificity in ambulation and activity, appropriate management of ATR is essential.

Surgical repair and conservative treatment are two major management strategy widely adopted in ATR patients but the consensus of optimal treatment strategy is still debated. In several previous systemic reviews reported that similar results occurred in surgical or non-surgical treatment with the measurement of clinical scores as well as patient satisfaction[7, 8]. In former studies comparing surgical and non-surgical processes, re-rupture rate was the predominant outcome measure to assess the success of treatment, while it is relatively low with the current treatment protocols[9–11]. Collectively, it is necessary that fully restored function to former level and self-satisfaction from patients should be taken into considered as additional assessment.

Although two previous meta-analyses compared the surgical and non-surgical treatment in ATR, neither of them considered the abovementioned additional assessment and the situation of incomprehensive inclusion of study occurred in both studies. Consequently, we aimed at fully reviewing the ATR topic with additional assessments and performed a most comprehensive meta-analysis of randomized controlled trials (RCTs).

Method

Protocol

This meta-analysis was conducted and performed under the instruction of Meta-analysis Of Observational Studies in Epidemiology (MOOSE) and the Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) checklists[12-14].

Searching query and eligibility criteria

We completely searched the online public databases of PubMed, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), ClinicalTrials.gov until 1st July 2020 with the keywords of achilles tendon, surgery with their corresponding MeSH terms. We retrieved all studies comparing surgical versus conservative treatment in ATR patients for further review. Duplicate studies were excluded and two authors independently completed the initial title and abstract screening. Only RCTs reported on the comparison of surgical versus conservative treatment of ATR were included in this meta-analysis.

After initial title and abstract screening, two independent authors reviewed all retrieved articles with full text. We excluded reviews, letters, editorial comments, conference abstract, discussion, notes, viewpoint, no published full text and case reports. Delayed treatment more than 4 weeks was excluded and the same for treatment of re-rupture of ATR. There was no weight bearing or functional rehabilitation protocol restriction. The following eligibility criteria were patients with ATR, surgical treatment (open or minimally invasive surgery) versus conservative treatment (cast immobilization or functional bracing), age greater than 16 years old, treatment initiated within 4 weeks of injury, reporting of re-rupture, complications, functional outcomes, patients' satisfaction on corresponding treatment and outcomes. Any disagreement on study inclusion was resolved by consensus or routine meeting of all authors listed in this meta-analysis. Detailed information about the eligibility criteria were shown in Table 1.

Data extraction

Two authors independently extracted both baseline demographics with all outcomes data and disagreements were resolved by discussion in routine meeting to prevent occurrence of test-qualified pooling[15]. All baseline demographics data were extracted from included studies and intersection was obtained as for providing more detail information as far as possible. Author names, country, age, gender, time between injury and treatment, surgical technique and follow-up were essential elements to extract. Same strategy was administered in outcome data extraction in order to make the most comprehensive pooled analysis.

Primary and secondary outcome

Regarding to raised concerns from recent studies[9-11], different from previous meta-analysis, return to sports (same level as pre-treatment) and re-rupture rate were adopted as primary outcomes. Secondary outcomes consisted of complication rate (defined as complication occurred after treatment except re-rupture), deep vein thrombosis, adhesion of scar to underlying tendon, sural nerve injury, superficial infection, deep infection, period absence from work, functional scores of Achilles Tendon Rupture Score (ATRS)[16], mean of dorsiflexion and plantarflexion. In addition, number of patients was used in the analysis of return to sport and only return to the same level as pre-treatment was pooled, which might describe the efficacy of treatment distinctly. Combined results were pooled in studies that reported open as well as minimally invasive surgery.

Assessment of Heterogeneity

We analyzed statistical heterogeneity between studies by means of I^2 test and, the criteria were $I^2 > 50\%$ for existence of heterogeneity and $I^2 > 70\%$ for high heterogeneity[17].

Risk of bias assessment

Two authors independently assessed the risk of bias from each study under the instruction of Cochrane Risk of Bias Tool, and the same for protocols of included studies[18]. During the entire process of assessment, selection bias, performance bias, attrition bias, and reporting bias were analyzed, and publication bias was evaluated and visualization via egger's test[19]. Collectively, risk of bias summary graph and funnel plot would be used for better reviewing of bias existence.

Statistical analysis

All procedures involved in this meta-analysis were performed under Revman (Version 5.3). Both continuous and dichotomous variables were presented in this study. Continuous variables were presented as mean with standard deviation and, other forms of data presentation would be converted under the construction described in Cochrane Handbook for Systematic Reviews of Interventions and several methods reported in previous studies[20-24]. Dichotomous variables were presented as events and total number of events. Mantel-Haenszel model was used to analyze the pooled outcomes with the presentation of risk ratio (RR) and 95% confidence interval (CI). Fixed-model would be adopted when $I^2 < 50\%$ while random effect model was employed once $I^2 > 50\%$. We administered overall

effect Z test to determine the significance level for pooled effects and, for the stratified analysis, test for subgroup differences was used to determine the significant level. We set the significance level as a P value lower than 0.05.

Results

Literature searching

All literature screening processes were performed with Endnote X8. After literature searching, a total of 5974 citations from PubMed, 6587 citations from Embase, 23 citations from Cochrane and 18 citations from Clinicaltrial.gov were obtained. We excluded 6897 duplicate citations by using Endnote duplicate citations finding function. After initial title and abstract screening, 5593 citations were excluded and disagreement would be resolved by routine meeting of research group. During full text screening, a total of 97 citations not compliant to the criteria were excluded and 13 citations of studies were included in this meta-analysis eventually[11, 25-36]. The PRISMA flowchart of this meta-analysis was displayed in Figure 1.

Baseline characteristics

There were a total of 1164 patients included in this study, with 603 patients in surgical group and 561 patients in non-surgical group. The mean age of enrolled patients was around 40 years old ranging from 18 to 63 years old, which conformed to the regular ATR population. Overall, male and female patients consisted of 84% and 16% population included in the study, respectively. For the time period between injury and treatment, 2-day was the shortest period reported by Twaddle et al.[29] while 21-day was the longest period reported by Nistor et al.[25]. In addition, surgical techniques of each included studies were extracted for better interpretation of baseline characteristics and, end-to-end Bunnell-type was the most adopted technique for ATR repair. Last but not least, different follow-up period could be a significant factor affecting the results so that it was recorded as well. One and two year were the widely accepted follow-up period among the included RCTs. The detailed information of baseline characteristics of each RCTs was shown in Table 2.

Risk of bias assessment

Two independent authors strictly assessed the risk of bias across studies under the instruction of Cochrane Collaboration Tool[17] and the visualization of results was displayed in Figure S1. Risk of bias was relatively low owing to the characteristics of RCTs. However, assessment of unclear risk was occurred in several studies. Regarding to selection bias about random sequence generation, Moller et al.[27], and Keating et al.[33], did not state clearly about the situation and, unclear risk was assessed in Nistor et al.[25], Fischer et al. [36], and Cetti et al.[26], respectively. When it comes to blinding of participants and personnel in performance bias, unclear risk occurred in Nistor et al., and cetti et al. while high risk was assessed in Fischer et al.. Inadequate blinding of assessment was not clearly declared in Nistor et al. and Fischer et al. so that unclear risk was obtained.

Publication bias was assessed by administrating Revman software and egger's test was adopted. Each outcome measure was assessed individually and visualization of results were shown in Figure S2(A) to (L). Inspection of symmetry was obtained, indicating no publication bias among each outcome measure.

Primary outcomes

Re-rupture rate

All included 13 studies reported the result of re-rupture rate and we divided it into re-rupture in accelerated functional rehabilitation and re-rupture not in accelerated functional rehabilitation as subgroup analysis. In the subgroup of re-rupture occurred in accelerated functional rehabilitation, no significant difference between surgical and conservative treatment could be observed (3 studies, 289 participants, $Z=1.04$, $P=0.30$, $I^2=0\%$, RR: 0.59, 95% CI: 0.22 to 1.59). In contrast, compared with conservative group, significant reduction in re-rupture rate not in accelerated functional rehabilitation could be observed in surgical treatment group (10 studies, 850 participants, $Z=3.90$, $P < 0.0001$, $I^2=0\%$, RR: 0.34, 95% CI: 0.19 to 0.58). Collectively, the overall result showed that surgical treatment was associated with significant reduction in re-rupture rate (13 studies, 1139 participants, $Z=3.97$, $P < 0.0001$, $I^2=0\%$, RR: 0.38, 95% CI: 0.24 to 0.41). Detailed information about re-rupture rate was shown in Figure 2(A).

Return to sport

There were 8 studies reported the result of return to sport among patients receiving ATR repair. Cetti et al.[26] and Costa et al.[28] reported the favorable outcome of surgical treatment in recovering the sport capacity of ATR patients compared with conservative management, while Manent et al.[35] reported the opposite result favoring conservative treatment. Collectively, the overall result indicated that no significant difference between surgical and conservative treatment in sport capacity recovery (8 studies, 567 participants, $Z=0.35$, $P=0.73$, $I^2=75\%$, RR: 1.09, 95% CI: 0.67 to 1.77). Detailed information about return to sport was shown in Figure 2(B).

Secondary outcomes

Complication rate

We defined complication rate as complication occurred after ATR treatment other than re-rupture and it was reported in 12 of included studies. The overall result indicated that complication rate after treatment in conservative treatment group was significantly lower than that in surgical treatment group (12 studies, 1107 participants, $Z=2.56$, $P=0.01$, $I^2=69\%$, RR: 2.62, 95% CI: 1.25 to 5.46). Main complications occurred after ATR treatment were deep vein thrombosis, adhesion of scar to underlying tendon, sural nerve injury, superficial and deep infection. Detailed information about overall complication rate was shown in Figure 3(A).

Deep vein thrombosis

Deep vein thrombosis, a severe complication usually occurred after ATR treatment owing to plaster casting immobilization[28], was reported in 8 of included studies. The overall result showed that no significant evidence could be obtained to distinguish better management strategy to avoid deep vein thrombosis (8 studies, 777 participants, $Z=1.12$, $P=0.26$, $I^2=0\%$, RR: 0.58, 95% CI: 0.22 to 1.51). Detailed information about deep vein thrombosis was displayed in Figure 3(B).

Adhesion

Adhesion of scar to underlying tendon was reported in 3 of included studies and it might lead to secondary surgery. The overall result revealed that surgical process might lead to an increasing incidence of adhesion of scar to underlying tendon (3 studies, 294 participants, $Z=2.08$, $P=0.04$, $I^2=55\%$, RR: 8.77, 95% CI: 1.13 to 67.99). Detailed information about adhesion of scar to underlying tendon was displayed in Figure 3(C).

Sural nerve injury

Disturbance in sensation of ATR patients after treatment due to sural nerve injury was reported in 6 of included studies. The overall results showed that significantly increasing incidence of sural nerve injury occurred in patients with surgical treatment compared with conservative management in ATR (6 studies, 603 participants, $Z=3.71$, $P=0.0002$, $I^2=0\%$, RR: 6.77, 95% CI: 2.47 to 18.56). Detailed information was shown in Figure 3(D).

Infection

Wound infection was a common complication of surgical treatment in ATR repair and it could be divided into superficial and deep infection. For superficial infection, compared with surgical treatment group, conservative management showed significant evidence to prevent infection after treatment (7 studies, 659 participants, $Z=3.28$, $P=0.001$, $I^2=0\%$, RR: 7.34, 95% CI: 2.23 to 24.17). Detailed information was shown in Figure 3(E).

In contrast, regarding to deep infection, there was no significant difference between surgical treatment and conservative treatment group, even though no case of deep infection in conservative group was reported (8 studies, 653 participants, $Z=1.88$, $P=0.06$, $I^2=0\%$, RR: 3.85, 95% CI: 0.95 to 15.65). Detailed information about deep infection was shown in Figure 3(F).

Period absence from work

ATR results in loss of motor ability as well as absence from patients' occupation so that different time period is an essential assessment index. The pooled result showed that neither surgical treatment nor conservative management was in possession of shorter period absence from work (3 studies, 330 participants, $Z=0.10$, $P=0.92$, $I^2=77\%$, RR: -0.22, 95% CI: -4.32 to 3.89). Detailed information was displayed in Figure 4(A).

ATRS functional score

ATRS functional score, with high reliability, validity, and sensitivity for quantifying functional outcome of patient receiving ATR treatment, is an indispensable index to determine the better treatment[16]. According to pooled result, there was no significant difference between surgical and conservative treatment regarding ATRS assessment (3 studies, 207 participants, $Z=1.86$, $P=0.06$, $I^2=0\%$, RR: 4.27, 95%CI: -0.24 to 8.77). Detailed information about ATRS assessment was displayed in Figure 4(B).

Flexion

Range of motion is a reflection of joint motor ability and, dorsiflexion as well as plantarflexion are suitable index to the assessment. For mean dorsiflexion, surgical treatment group was similar with conservative treatment group (2 studies, 204 participants, $Z=0.32$, $P=0.75$, $I^2=51\%$, RR: 0.62, 95% CI: -3.23 to 4.46). Detailed information about dorsiflexion was shown in Figure 5(A).

Similarly, there was no significant difference could be observed regarding to pooled result of mean plantarflexion (4 studies, 349 participants, $Z=1.08$, $P=0.28$, $I^2=92\%$, RR: 2.43, 95% CI: -1.97 to 6.83). Detailed information about plantarflexion was shown in Figure 5(B).

Discussion

Innovation

This is the most comprehensive meta-analysis of RCTs comparing outcomes after receiving surgical treatment versus conservative treatment of ATR. The overall results revealed that surgical treatment was in possession of lower re-rupture rate, while no significant difference was found in subgroup of accelerated functional rehabilitation with early range of motion, which might indicate early involvement of rehabilitation was not beneficial to functional recovery. In addition, for pooled results of return to sport, which is firstly treated as primary outcome, no significant difference could be obtained. In contrast, conservative treatment was associated with lower complication rate (other than re-rupture), which should be taken into consideration when making a decision of treatment.

To the best of our knowledge, treatment on ATR should be focused on optimal functional recovery accompanied with the least complication. Combined with the novel primary outcome of return to sport included in this study, similar functional recovery was observed between surgical and conservative treatment group, even though surgical treatment was recommended owing to lower re-rupture rate according to previous studies[37, 38]. Moreover, conservative management accompanied with early weightbearing of the injured tendon was reported to be capable of stimulating collagen and healing process, leading similar re-rupture rate as surgical treatment[10, 39-41]. Collectively, a novel recommendation of more than just considering re-rupture and, conservative treatment with similar functional recovery as well as lesser complication on ATR might be considered if patients' status were suitable.

Exploration of complications

Till now, the optimal treatment for ATR patients is mainly based on expert consensus and on basis of judgement from chief clinician. Surgical repair, with lower re-rupture rate, is favorable in majority of the cases, while complications (20.4% vs 7.0%) other than re-rupture are troublesome such as deep vein thrombosis, wound infection, and sensation disturbance (sural nerve injury).

Incidence of deep vein thrombosis is reported from 0.3% to 50% and it is a significant factor causing poor quality of life as well as burden of society cost[42-45]. Immobilization such as plater casting has been a potential pathogenesis leading to deep vein thrombosis[46]. Although pooled results of deep vein thrombosis did not reveal significant difference, it seem to be occurred frequently in conservative group (2.1%), which might be attributable to long period of plater casting. Consequently, thromboprophylaxis is necessary after ATR treatment and, intermittent pneumatic compression has been reported to be highly effective in reducing deep vein thrombosis in ATR patients[42].

Wound infection, classified as superficial and deep infection, is one of the major complications in ATR patient receiving surgical repair. In our study, superficial (5.8%) and deep infection (2.2%) were reported in surgical treatment group, which was deleterious and intractable with poor outcome[47]. A recent meta-analysis has concluded that minimally invasive method could significantly reduce wound infection rate compared with open surgery[48]. Furthermore, negative pressure wound therapy has been reported to be effective in post-operative wound infection of ATR, which could be adopted[49].

Regarding to sural nerve injury, leading to sensational disturbance after treatment, the incidence in surgical treatment (7.8%) was significantly higher than conservative treatment. Direct injury in open repair or lack of visualization in minimally invasive operative procedures has been the potential reason causing injury and a modified medialization of percutaneous suture was reported with lower incidence of sural nerve injury[50].

Exploration of functional outcome

Functional outcomes were defined as period absence from work and ATRS score, and the pooled result revealed similar outcome between surgical and conservative treatment group. Not surprisingly, similar results were found in pooled outcomes of mean dorsiflexion and plantarflexion. Collectively, in functional recovery, conservative treatment might have similar prognosis as surgical repair.

Limitation and implication for future research

Although a total of 13 RCTs are included in this meta-analysis, the recorded categories of complications are still limited, which results in disturbance of comprehensive assessment of each treatment strategy. Specifically, for deep vein thrombosis, more cases occurred in conservative treatment group but thromboprophylaxis is only reported in four included studies[11, 27, 31, 33], which may confuse the result. Functional outcomes are similar in both groups according to the pooled result of our study, but the number of studies reporting functional outcomes such as period absence from work, ATRS score, dorsiflexion and plantarflexion are limited. Furthermore, different period of follow-up, surgical techniques and conservative management strategy may lead to difference outcome.

Future research with specific focus on comorbidities other than re-rupture is necessary and it will provide more clues for surgeons or physicians to make an optimal decision. Regarding to the summary of our results, a novel inspiration about adopting conservative management as a major treatment plan with lesser complication and similar outcome has generated. However, patients' expectation is also essential that athletic population may prefer surgical treatment to expedite recovery and prolong their professional career[51]. Consequently, future RCT is needed to be performed to investigate if surgical and conservative treatment are in possession of similar outcome and prognosis, especially in return to sport ability.

Conclusion

In this meta-analysis, surgical treatment was revealed significance in reduction of re-rupture rate but associated with higher complication rate. Conservative treatment was found to be capable of having similar functional outcome with surgical treatment. Collectively, we recommend conservative treatment if patients' status and expectation are suitable, but surgeon as well as physician's discretion is also important in decision making.

Declarations

Ethical approval and consent to participant

Not applicable.

Consent to publish

Not applicable.

Availability of data and materials

All original data used in this study can be found in referred articles.

Competing interests

All authors have no conflicts of interest to disclose.

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Authors' Contribution

All authors have read and approved the manuscript. The detailed contributions of each authors are listed as follows:

GRS and QT: conceptualization, literature researching, methodology, data analysis, manuscript writing.

JRL: investigation.

XFZ: investigation.

LC and HGH: supervision, conceptualization, professional suggestion and revision.

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References

1. Ames PR, Longo UG, Denaro V, Maffulli N: **Achilles tendon problems: not just an orthopaedic issue.** *Disability and rehabilitation* 2008, **30**(20-22):1646-1650.
2. 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 surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2016, **24**(12):3730-3737.
3. Egger AC, Berkowitz MJ: **Achilles tendon injuries.** *Current reviews in musculoskeletal medicine* 2017, **10**(1):72-80.
4. Longo UG, Rittweger J, Garau G, Radonic B, Gutwasser C, Gilliver SF, Kusy K, Zieliński J, Felsenberg D, Maffulli N: **No influence of age, gender, weight, height, and impact profile in achilles tendinopathy in masters track and field athletes.** *The American journal of sports medicine* 2009, **37**(7):1400-1405.
5. Sode J, Obel N, Hallas J, Lassen A: **Use of fluroquinolone and risk of Achilles tendon rupture: a population-based cohort study.** *Eur J Clin Pharmacol* 2007, **63**(5):499-503.
6. O'Brien T: **The needle test for complete rupture of the Achilles tendon.** *The Journal of bone and joint surgery American volume* 1984, **66**(7):1099-1101.
7. Holm C, Kjaer M, Eliasson P: **Achilles tendon rupture—treatment and complications: a systematic review.** *Scandinavian journal of medicine & science in sports* 2015, **25**(1):e1-10.
8. 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.** *The Journal of bone and joint surgery American volume* 2012, **94**(23):2136-2143.
9. 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.** *Clinical orthopaedics and related research* 2002(400):190-200.
10. 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.** *The Journal of bone and joint surgery American volume* 2005, **87**(10):2202-2210.
11. 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.** *The American journal of sports medicine* 2013, **41**(12):2867-2876.
12. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, Moher D, Becker BJ, Sipe TA, Thacker SB: **Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group.** *Jama* 2000, **283**(15):2008-2012.
13. Moher D, Liberati A, Tetzlaff J, Altman DG: **Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.** *Journal of clinical epidemiology* 2009, **62**(10):1006-1012.
14. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D: **The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration.** *Journal of clinical epidemiology* 2009, **62**(10):e1-34.

15. Colegrave N, Ruxton GD: **Statistical model specification and power: recommendations on the use of test-qualified pooling in analysis of experimental data.** *Proc Biol Sci* 2017, **284**(1851):20161850.
16. Nilsson-Helander K, Thomeé R, Silbernagel KG, Thomeé P, Faxén E, Eriksson BI, Karlsson J: **The Achilles tendon Total Rupture Score (ATRS): development and validation.** *The American journal of sports medicine* 2007, **35**(3):421-426.
17. Higgins JP, Altman DG, Gotzsche PC, Juni 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.
18. Higgins JPT, Altman DG: **Chapter 8: assessing risk of bias in included studies:** John Wiley & Sons, Ltd; 2008.
19. Lin L, Chu H: **Quantifying publication bias in meta-analysis.** *Biometrics* 2018, **74**(3):785-794.
20. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.0 (updated July 2019). Cochrane, 2019. Available from www.training.cochrane.org/handbook.
21. Wan X, Wang W, Liu J, Tong T: **Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range.** *BMC medical research methodology* 2014, **14**:135.
22. Higgins JP, White IR, Anzués-Cabrera J: **Meta-analysis of skewed data: combining results reported on log-transformed or raw scales.** *Statistics in medicine* 2008, **27**(29):6072-6092.
23. Hozo SP, Djulbegovic B, Hozo I: **Estimating the mean and variance from the median, range, and the size of a sample.** *BMC medical research methodology* 2005, **5**:13.
24. Luo D, Wan X, Liu J, Tong T: **Optimally estimating the sample mean from the sample size, median, mid-range, and/or mid-quartile range.** *Statistical methods in medical research* 2018, **27**(6):1785-1805.
25. Nistor L: **Surgical and non-surgical treatment of Achilles Tendon rupture. A prospective randomized study.** *The Journal of bone and joint surgery American volume* 1981, **63**(3):394-399.
26. 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.** *The American journal of sports medicine* 1993, **21**(6):791-799.
27. 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.** *The Journal of bone and joint surgery British volume* 2001, **83**(6):843-848.
28. 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.** *The Journal of bone and joint surgery British volume* 2006, **88**(1):69-77.
29. Twaddle BC, Poon P: **Early motion for Achilles tendon ruptures: is surgery important? A randomized, prospective study.** *The American journal of sports medicine* 2007, **35**(12):2033-2038.
30. 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.** *The American journal of sports medicine* 2008, **36**(9):1688-1694.
31. 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.** *The American journal of sports medicine* 2010, **38**(11):2186-2193.
32. 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.** *The Journal of bone and joint surgery American volume* 2010, **92**(17):2767-2775.
33. Keating JF, Will EM: **Operative versus non-operative treatment of acute rupture of tendo Achillis: a prospective randomised evaluation of functional outcome.** *The Journal of bone and joint surgery British volume* 2011, **93**(8):1071-1078.
34. 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.** *The American journal of sports medicine* 2016, **44**(9):2406-2414.
35. Manent A, López L, Corominas H, Santamaría A, Domínguez A, Llorens N, Sales M, Videla S: **Acute Achilles Tendon Ruptures: Efficacy of Conservative and Surgical (Percutaneous, Open) Treatment-A Randomized, Controlled, Clinical Trial.** *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2019, **58**(6):1229-1234.
36. Fischer S, Colcuc C, Gramlich Y, Stein T, Abdulazim A, von Welck S, Hoffmann R: **Prospective randomized clinical trial of open operative, minimally invasive and conservative treatments of acute Achilles tendon tear.** *Archives of orthopaedic and trauma*

surgery 2020.

37. Ochen Y, Beks RB, van Heijl M, Hietbrink F, Leenen LPH, van der Velde D, Heng M, van der Meijden O, Groenwold RHH, Houwert RM: **Operative treatment versus nonoperative treatment of Achilles tendon ruptures: systematic review and meta-analysis.** *Bmj* 2019, **364**:k5120.
38. Reda Y, Farouk A, Abdelmonem I, El Shazly OA: **Surgical versus non-surgical treatment for acute Achilles' tendon rupture. A systematic review of literature and meta-analysis.** *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2020, **26**(3):280-288.
39. 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.** *Medicine and science in sports and exercise* 1998, **30**(6):788-793.
40. Frankewycz B, Krutsch W, Weber J, Ernstberger A, Nerlich M, Pfeifer CG: **Rehabilitation of Achilles tendon ruptures: is early functional rehabilitation daily routine?** *Archives of orthopaedic and trauma surgery* 2017, **137**(3):333-340.
41. Suchak AA, Spooner C, Reid DC, Jomha NM: **Postoperative rehabilitation protocols for Achilles tendon ruptures: a meta-analysis.** *Clinical orthopaedics and related research* 2006, **445**:216-221.
42. Domeij-Arverud E, Labruto F, Latifi A, Nilsson G, Edman G, Ackermann PW: **Intermittent pneumatic compression reduces the risk of deep vein thrombosis during post-operative lower limb immobilisation: a prospective randomised trial of acute ruptures of the Achilles tendon.** *The bone & joint journal* 2015, **97-b**(5):675-680.
43. Makhdom AM, Cota A, Saran N, Chaytor R: **Incidence of symptomatic deep venous thrombosis after Achilles tendon rupture.** *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2013, **52**(5):584-587.
44. Patel A, Ogawa B, Charlton T, Thordarson D: **Incidence of deep vein thrombosis and pulmonary embolism after Achilles tendon rupture.** *Clinical orthopaedics and related research* 2012, **470**(1):270-274.
45. Barnes GD: **Predicting the Post-Thrombotic Syndrome: Not Quite Ready for Prime Time.** *Thromb Haemost* 2018, **118**(8):1345-1346.
46. Calder JD, Freeman R, Domeij-Arverud E, van Dijk CN, Ackermann PW: **Meta-analysis and suggested guidelines for prevention of venous thromboembolism (VTE) in foot and ankle surgery.** *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2016, **24**(4):1409-1420.
47. Mosser P, Kelm J, Anagnostakos K: **Negative pressure wound therapy in the management of late deep infections after open reconstruction of achilles tendon rupture.** *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2015, **54**(1):2-6.
48. Grassi A, Amendola A, Samuelsson K, Svantesson E, Romagnoli M, Bondi A, Mosca M, Zaffagnini S: **Minimally Invasive Versus Open Repair for Acute Achilles Tendon Rupture: Meta-Analysis Showing Reduced Complications, with Similar Outcomes, After Minimally Invasive Surgery.** *The Journal of bone and joint surgery American volume* 2018, **100**(22):1969-1981.
49. Saku I, Kanda S, Saito T, Fukushima T, Akiyama T: **Wound management with negative pressure wound therapy in postoperative infection after open reconstruction of chronic Achilles tendon rupture.** *Int J Surg Case Rep* 2017, **37**:106-108.
50. Makulavicius A, Martin Oliva X, Mazarevicius G, Klinga M, Uvarovas V, Porvaneckas N, Monzó Planella M, Mazurek T: **Comparative anatomical study of standard percutaneous and modified medialised percutaneous Bunnell type repair for artificial Achilles tendon rupture: positive effect of medialisation of the stitches with lower risk of sural nerve injury.** *Folia morphologica* 2016, **75**(1):53-59.
51. Khan RJ, Carey Smith RL: **Surgical interventions for treating acute Achilles tendon ruptures.** *The Cochrane database of systematic reviews* 2010(9):Cd003674.

Tables

Table 1
Eligibility criteria applied in this meta-analysis

Inclusion Criteria		Exclusion Criteria
Study type	Only randomized controlled trials.	1. Unfinished studies, unpublished data or no published full text. 2. Reviews, editorials, letters, notes, discussions, comments, conference abstracts etc.
Participants	Involved patients should conform to the following criteria: 1. Achilles tendon rupture within 4 weeks. 2. Age greater than 16-year-old. 3. Adopting comparison on surgical (open or minimally invasive surgery) versus conservative treatments (cast immobilization or functional bracing).	Non-human subjects
Intervention	Open or minimally invasive surgery.	N/A
Control	Non-surgical treatment (cast immobilization or functional bracing).	N/A
Outcome	1. Re-rupture. 2. Major or minor complication. 3. Functional outcomes. 4. Patients' satisfaction on corresponding treatment and outcomes.	Unpublished data

Table 2
Baseline characteristics of included studies.

Study	Country	Patients			Age		Gender (M/F)		Time between injury and treatment (days)	Surgical technique	Follow-up (months)	
		Overall No	OP	NON	OP	NON	OP	NON			OP	NON
Nistor 1981	Sweden	107	49	51	41 (21–77)		96/11		21 days or less	Bunnell-type with coaptation sutures to close the paratendon	30 (12–60)	
Cetti 1993	Denmark	111	56	55	41.2 (27–59)	37.8 (21–65)	47/9	45/10	7 days or less	End to end, Bunnell-type suture	12	12
Möller 2001	Sweden	112	59	53	39.6 (21–63)	38.5 (26–59)	51/8	48/5	7 days or less	End to end, modified Kessler	24	24
Costa 2006	United Kindom	96	48	48	42 (28–61)	42 (29–69)	18/4	22/3	7 days or less	End to end, augmented repair	12	12
Twaddle 2007	New Zealand	50	25	25	41.8	40.3	14/6	14/8	2 days or less	End to end, Krackow-type stitch	12	12
Metz 2008	Netherlands	83	42	41	40 (23–63)	41 (25–62)	31/11	35/6	3 days or less	Bunnell-type suture in proximal tendon, through lateral aspect of calcaneus distally	12	12
Nilsson-Helander 2010	Sweden	97	49	48	40.9 (8.8)	41.2 (9.5)	40/9	39/9	3 days or less	End to end, modified Kessler	12	12
Willits 2010	Canda	144	72	72	39.7 (11)	41.1 (8.0)	59/13	59/13	14 days or less	End to end, Krackow-type stitch	24	24
Keating 2011	United Kindom	80	39	41	41.2 (27–59)	39.5 (21–58)	28/11	32/9	10 days or less	End to end, Kessler stitch, interrupted circumferential stitch	12	12
Olsson 2013	Sweden	100	49	51	39.8 (8.9)	39.5 (9.7)	39/10	47/4	4 days or less	End to end, Mmodified Kessler, epitendnous cross-stitch	12	12
Lantto 2016	Finland	60	32	28	40 (27–57)	39 (28–60)	30/2	25/3	7 days or less	End-to-end open repair	18	18

Values are presented with mean (sd or range).

Abbreviations: OP: Operative group; NON: non-operative group.

Study	Country	Patients			Age		Gender (M/F)		Time between injury and treatment (days)	Surgical technique	Follow-up (months)	
Manent 2019	Spain	34	23	11	41 (18–51)	42 (26–51)	10/1	21/2	10 days or less	Percutaneous repair/ Double Bunnell suture	12	12
Fischer 2020	Germany	90	60	30	39.5 (21–58)	45.2 (25–60)	27/3	54/6	N/A	Already established protocol	24	24

Values are presented with mean (sd or range).

Abbreviations: OP: Operative group; NON: non-operative group.

Figures

Figure 1

PRISMA Flow chart of this meta-analysis.

A)

B)

Figure 2

Forrest-plot of primary outcome measure. A) Forrest-plot of re-rupture rate; B) Forrest-plot of return to sport (Same level).

Figure 3

Forrest-plot of secondary outcome measure indicating complication. A) Forrest-plot of complication rate. B) Forrest-plot of deep vein thrombosis; C) Forrest-plot of adhesion to underlying tendon; D) Forrest-plot of sural nerve injury; E) Forrest-plot of superficial infection; F) Forrest-plot of deep infection.

Figure 4

Forrest-plot of secondary outcome measure indicating period absence from work and ATRS. A) Forrest-plot of period absence from work; B) Forrest-plot of functional score (ATRS).

Figure 5

Forrest-plot of secondary outcome measure indicating flexion. A) Forrest-plot indicating mean of dorsiflexion; B) Forrest-plot indicating mean of plantarflexion.

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