Percutaneous repair versus open repair for acute Achilles tendon rupture

xiaomeng wang
Hebei Medical University Third Affiliated Hospital  https://orcid.org/0000-0002-3509-5383

Huixin Liu
Hebei Medical University Third Affiliated Hospital

dengke li
Hebei General Hospital

zixuan luo
Hebei Medical University Third Affiliated Hospital

Yansen Li
Hebei Medical University Third Affiliated Hospital

Fengqi Zhang (✉ drfqzhang@126.com )

Research article

Keywords: Achilles tendon repair, Modified Kessler suture, Bundle-Bundle suture, Rupture of Achilles tendon

Posted Date: October 24th, 2019

DOI: https://doi.org/10.21203/rs.2.16400/v1

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Version of Record: A version of this preprint was published on August 26th, 2020. See the published version at https://doi.org/10.1186/s12891-020-03588-5.
Abstract

Background: To compare the operative outcome between modified Kessler suture method and Bundle-Bundle suture for the treatment of acute rupture of Achilles tendon. Methods: A consecutive series of 72 patients who underwent operation of Achilles tendon rupture were evaluated. Thirty patients were treated by the bundle-bundle suture method (group A) and 31 patients by modified Kessler suture (group B). Functional examination included measurement of calf muscle circumference, and a single-leg heel-rise test. The diameter of the Achilles tendon of the trouble side was recorded compared with the contralateral limb through the MRI (magnetic resonance imaging). The number of single-leg heel-rise was recorded within 15s (height>5cm) compared with the uninjured side. The ankle joint range of motion is recorded. The evaluation form ATRS(Achilles Tendon Total Rupture Score), AOFAS(American Orthopedic Foot And ankle Society) Ankle-Hindfoot scale scores and VAS( visual analogue scale) pain score were used to evaluate the clinical outcome after a minimum follow-up period of 12 months postoperatively.

Results: 61 patients at 1 year following surgery. There was no difference in mean follow-up time between the two groups (group A: 23.73±2.81 months; group B: 22.61±3.96 months). There were significant differences between the groups in heel-rise test 1.74±0.96 in group A, 2.37±1.42 in group B. Compared with the group B, the calf circumference of the injured side was bigger in group A (p=0.043). The cross-sectional diameters of the Achilles tendon after open repair was significantly different from that after percutaneous repair. There were no significant differences in ATRS, AOFAS and VAS at the final follow-up between the two groups. One patients of group A experienced delayed wound healing, which resolved in about 40 days.

Conclusions : Two suture methods can provide good clinical results. Bundle-Bundle suture is more effective in solving the shortcomings of traditional methods. It is a safe and effective method, and is worthy of promotion.

Background

The Achilles tendon is the strongest tendon in the body and is still prone to rupture[1]. The incidence of Achilles tendon rupture is 6~37/ 100000 and it have increased in the last few decades [2]. The horsetail rupture of the Achilles tendon is often located 2~6 cm above the tendon attachment point of calcaneus[3]

Many Achilles tendon repair techniques have been described by scholars. Optimal treatment can be divided into open repair or percutaneous, or minimally invasive repair techniques [4–7]. Open repair carries surgical complications, such as skin-tendon adhesions, infection, delayed healing of the surgical wound and suture granulomas[8] [28–8]. Some scholars have reported that Achilles tendon repair using the percutaneous repair (modified kessler) reduce destruction of the blood supply and lower risk of wound complications and infections [9]. There may be gaps in the area of percutaneous repair, and appropriate tension and granulation hyperplasia in postoperative. The new open repair (Bundle-Bundle
suture) technique minimizes Achilles tendon length loss and restores good ankle function [7, 10, 11]. It is described for anatomically reconstructing the tendon and still protecting the soft tissue envelop, preserving its hypovascularity [12]. It can restore the anatomical structure of the Achilles tendon with fewer complications [12].

The objective of this research was to compare the outcome of Open repair (bundle-bundle suture) for fresh injury of Achilles tendon with percutaneous repair (modified kessler suture).

**Methods**

1. Study population

Ethical approval was obtained from the local ethical committee with the informed consent. All patients suffering from acute Achilles tendon rupture (≤ 7 days) were eligible for the study from May 2016 to January 2018 (n = 72). The diagnosis of Achilles rupture was assessed by clinical examination (Thompson's test) and magnetic resonance imaging in each patient.

Inclusion criteria: (1) 18~45 years; (2) BMI (Body Mass Index) < 34; (3) Closed injury; (4) Acute Achilles tendon rupture. Exclusion criteria: (1) partial-rupture of Achilles tendon (2) rupture of the insertion point of the Achilles tendon (3) some diseases that will affect the results of the functional study tests.

In total, 4 patients were excluded for the partial rupture of the Achilles tendon. Four patients were excluded for rupture of the insertion point. Three patients were eliminated by re-rupture. Finally, 61 patients were included in this clinical research. All patients knew that the definitive surgical procedure would be chosen by the surgeon, and they subsequently signed written consent forms to participate in the study and to return for standardized follow-up examination at 1, 3, 6 and 12 months after surgery.

Group A included 30 patients, while group B included 31 patients. Open repair technique (Bundle-Bundle suture) was performed in group A, while Percutaneous suturing (modified Kessler) was conducted in group B. Physical examination and operation of all enrolled patients were performed by the same surgeon (FQ.Z).

2. The procedure of surgery

- Bundle-Bundle suture

The posteromedial Achilles tendon approach was used with the Achilles tendon rupture as the center. The skin, subcutaneous tissue and deep fascia were dissected in turn without separation. After the Achilles tendon rupture has been exposed, rinsed thoroughly to remove the congestion, and uncovered the ruptured Achilles tendon to expose the deep soft tissue. The deep soft tissue was sutured first, and the soft tissue bed of Achilles tendon was repaired, which was beneficial to the recovery and healing of Achilles tendon blood supply. Then the horsetail rupture end of the tendon was aligned according to the
anatomical characteristics of the Achilles tendon. the tendon band of the superficial proximal gastrocnemius was turned laterally and sutured with the band of the distal lateral end of the tendon, while the tendon band of the deep proximal soleus was turned inward and sutured with the band of the distal medial end of the tendon. The Achilles tendon was typically divided into 4~5 bundles, and then the tendon bundles were repaired end-to-end, from deep to lamina, using absorbable 3–0 sutures to connect the ends of each bundle-bundle and (5–0 Prolene) to reinforce the repair. At the same time, the long tendon band was sutured (4–0Prolene thread) with the short tendon band, so as to avoid the short Achilles tendon and retraction and excessive plantar flexion of the ankle. Non-absorbable 4–0 suture was used to suture the outer membrane of Achilles tendon, deep fascia, subcutaneous tissue and skin. This procedure of Bundle-Bundle suture has been introduced by the zhao [12]. The ankle joint was fixed with plaster in a neutral position. (Fig.1)

- Modified Kessler suture

One mark was made in the middle of the depression of the broken Achilles tendon, and two or three marks were made on both sides of the distal and proximal Achilles tendon. Small incisions of 1. 0 cm were made with small sharp knives at each marker to reach deep fascia(11~13).The suture was performed with the PDSII suture through the small distal incision, the suture was threaded through the small central incision (Make sure the distal suture passes through the tendinous tissue). “Z” suture was performed with another suture through the small incision at the proximal end, and the suture was threaded through the small incision at the center. The distal and proximal sutures were tightened to tie the rupture end of the tendon and the knot was then examined by Thompson's test. Then the transverse incision was sutured, and the stab incisions were closed. Pay attention not to damage the sural nerve when suturing each small incision. The ankle joint was fixed with plaster in a Plantar flexion position. The procedure has been introduced by the Ma and Griffith[13].

- Postoperative rehabilitation

Our postoperative protocol was performed by an experienced physical therapist. After the operation, the affected limb was lifted up and the quadriceps femoris and triceps crus were exercised by isometric contraction and relaxation on the second day. The stitches were removed at 2 weeks postoperatively. Partial protected weightbearing with the walking boots was allowed to walking with load gradually, and the partial load was changed to full load within 2 ~ 6 weeks. Four layers of wedge insoles inside the walking boots was removed one layer every 1 ~ 2 weeks. Flexion and extension of the ankle joint was allowed in the neutral position 6 weeks after surgery. After 2 weeks of full weight-bearing exercise with walking boots, walking boots were removed. Walking with sneakers and functional exercise of ankle range of motion were allowed at two months at 2 months postoperatively and heel lifting functional exercise was allowed at 10 weeks postoperatively.

- Functional evaluation
Follow-up was performed 1, 3, 6, 12 months after surgery. Functional evaluation includes Functional examination and Clinical Score. Functional examination and Clinical Score were evaluated at 12 months.

Functional examination consisted of three main items, measurement of calf circumference, numerical values of Achilles tendon width and anteroposterosiosis, and single-leg heel-rise test. The calf circumference of the trouble side was recorded compared with the contralateral limb. The diameter of the Achilles tendon of the trouble side was recorded compared with the contralateral limb through the MRI. The number of single-leg heel-rise was recorded within 15s (height> 5cm) compared with the uninjured side. The ankle joint range of motion was recorded.

Clinical Score evaluation included the ATRS, the AOFAS Ankle-Hindfoot scale scores, and a VAS pain score[14].

5. Statistical analysis

Statistical analysis was performed using SPSS (version 21.0; SPSS Inc., Chicago, IL, USA). All outcome parameters were tested for deviation from the normal distribution. Differences between the injured versus the uninjured side and differences between the two groups were tested with a two-tailed, unpaired t-test. Differences in age, gender, BMI and time of follow-up time were examined by use of a paired-samples t test and Fisher or $\chi^2$ test for continuous variables and categorical data, respectively. Differences in ATRS, AOFAS, and VAS between both treatment groups were determined with an unpaired-samples t test or Mann-Whitney rank sum test. P values less than.05 were defined as significant difference.

Results

All data were collected during follow-up examination. No statistically significant differences were found in age, sex and BMI between the 2 groups. The demographics of the patients are displayed in Table 1.

There was no difference in mean follow-up time between the two groups (group A: 23.73±2.81 months; group B: 22.61±3.96 months). No patient exhibited a negative heel-rise test in the two groups at the final follow-up. There were significant differences between the groups in heel-rise test. Difference that observed in the single-leg heel-rise compared with the contralateral was smaller in group A (1.74±0.96) than in group B (2.37±1.42) (Table 2). No difference was observed in the range of motion of ankle joint (dorsiflexion and plantiflexion) between the two groups at the final evaluation. The calf circumferences of the trouble sides were smaller than the uninjured sides in the two groups. Compared with the group B, the calf circumference of the injured side was bigger in group A ($p = 0.043$). The cross-sectional diameters of the Achilles tendon after open repair was significantly different from that after percutaneus repair. (Table 2) However, no statistically significant differences were found between the groups. With respect to the clinical scores, the ATRS, the AOFAS and the VAS scores were not a statistically significant difference between the two groups. (Table 3) No patient exhibited postoperative complications (thrombophlebitis, infection, sural nerve lesion and re-rupture) in either group. However, one patients of group A experienced
delayed wound healing, which resolved in about 40 days. There was one patient in group A who exhibited delayed wound healing that was recovered at 40 days.

**Discussion**

The aim of this study was to determine the clinical effect of Bundle-Bundle suture for the patients with Achilles tendon ruptures. The functional examination and clinical Score were used to analyze the efficacy of open and percutaneous techniques.

An 8cm incision is required for open repair requires, while a 2cm incision is required for percutaneous repair in this study. Open repair can be accompanied by deep and superficial infection, poor wound healing [15, 16]. The aim of percutaneous repair is minimizing the risk of complications [16–18]. High complication rate of nerve injuries have been associated with percutaneous repair (2.9 %) [5]. In this study, the incidence of poor wound healing was 1 in the open repair group and 0 in the percutaneous repair group respectively. These incidences of nerve injury were 0 in both groups. Due to the small sample size in this study, the actual incidence of complications cannot be reflected. These findings are consistent with a systematic review by Li et al [9], showing that the rate of wound infection by percutaneous puncture is significantly lower than that by open surgery. No significant difference was found in another meta-analysis by McMahon et al[18] where the primary outcome was rerupture rate in open and percutaneous suturing.

Bundle-Bundle suture for Achilles tendon rupture is the most effective operation method to restore anatomical structure and physiological characteristics [4–6]. Open repair can directly repair the rupture site and obtain maximum mechanical stability [4–7, 19]. However, complex sutures can form an fiber block of Achilles tendon that can increase healing problems, shorten the length of the Achilles tendon [10, 20–24]. Open repair causes scar contracture of the Achilles tendon, which has been described previously [25]. In this research, the Achilles tendon was repaired with a bundle-bundle suture to prevent the thickening tendon and adhesion. Gigante consider that the antero-posterior and cross-sectional diameters of the Achilles tendon were not statistically different at 12 months after surgery between percutaneous repair group and open repair group[6]. Our results confirmed that the cross-sectional diameters of the Achilles tendon after open repair was significantly different from that after percutaneous repair by MRI measurement. The Cross-sectional diameter of the Achilles tendon was statistically bigger in the percutaneous repair group than that in the open repair group. So, the Bundle-Bundle suture is a more effective method to avoid Achilles tendon thickening.

Some scholars have proved that percutaneous repair can better retain the range of motion of the ankle joint than open repair, especially the dorsiflexion angle [5]. But, this study confirmed that no difference was observed in the range of motion of ankle joint after bundle-bundle suture and percutaneous repair at the final evaluation. There was no significant difference in the range of motion (plantarflexion and dorsiflexion) of the ankle between the two methods. This result confirms open repair (Bundle-Bundle
suture) techniques maximally preserve the length of the Achilles tendon and got good ankle function restoration.

Kaiuchi’s study confirmed that the affected side after surgery resulted in a 2% (0.67cm) reduction in calf circumference compared to that on the healthy side. The postoperative calf volume of the affected leg was 91% of the healthy side [26]. This study confirmed that the area of calf circumference in patients with percutaneous repair or open repair was smaller than that on the uninjured side. But further deviations from trends observed in patients with percutaneous repair in the area of calf circumference. Patients who can lift their heels more than 5cm are considered to have normal Achilles tendon strength. Haji confirmed that patients with percutaneous repair had more normal heel-rises than patients with open surgery( 92%:83%) [27]. Heel-rises test were comparable 12 months after Bundle-Bundle suture and modified Kessler suture, the numerical difference was 1.74 in patients undergoing Bundle-Bundle suture and that was 2.37 in patients undergoing modified Kessler suture. This result may be due to the fact that there is no gap in the tendon rupture after the Bundle-Bundle suture and the tendon heals better. The calf circumference after percutaneous repair was comparable with that after open repair at the final evaluation, whereas the calf circumference was greater in patients undergoing Bundle-Bundle suture.

Our results showed that no difference regard to clinical function scores (AOFAS and the VISA-A score) at the final evaluation between two groups. AOFAS ranged from 96.3 to 96.8 after percutaneous repair, and from 96.1 to 98.7 after open procedures [15, 28]. Postoperative AOFAS significantly improve in the two groups (group A 95.40±3.65, group B 95.38±3.44). The author consider that there was no difference in VAS score, which was assessed in this study, the average VAS score was 1.6 in the percutaneous surgery group and 1.7 in the open group respectively after 12 months (P>0.05). Clinical evaluation of ankle circumference at the final evaluation demonstrated that no significant differences were discovered between the two groups.

Several limitations have to be acknowledged when interpreting the results of the present study. There were fewer female patients in this series; whether this technique will cause problems in female patients. Randomized control trials may be the best way to find the best surgical method to treat recurrent peroneal tendon dislocations acute rupture of Achilles tendon. The number of included patients was small and outliers might have had a significant influence on the results. A short-term follow-up study was conducted, it is impossible to prove whether the results will change over time.

**Conclusions**

Both techniques provided high functional scores and low complication rates, in agreement with results in the literature. Bundle-bundle suturing is a reliable, inexpensive, and nearly physiologic operation for treatment of acute Achilles tendon ruptures with satisfactory results and lower complications.

**Abbreviations**
ATRS: Achilles Tendon Total Rupture Score, AOFAS: American Orthopedic Foot Andankle Society, VAS: visual analogue scale, MRI: Magnetic Resonance Imaging, BMI: Body Mass Index.

Declarations

Ethics approval and consent to participate

The investigation process was approved by the ethics committee of the Third Hospital of Hebei Medical University. Informed consent to participate in the study has been obtained from patients.

Consent for publication

Not Applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available because it contains patients’ personal information but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

None.

Authors’ contributions

XM.Wang carried out the research design and drafting of this manuscript. HX.Liu and HX.Liu completed the acquisition and interpretation of the data. JH.Niu, C.Liu and PK.Cao carried out measurements. F.Wang did the surgeries and critically revised the manuscript and provided final approval of the version to be published. All authors read and approved the final manuscript. Contributions section to the effect that all authors have read and approved the final manuscript, and ensure that this is the case.

Acknowledgements

None.

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**Tables**

### Table 1 Patient demographics

|                | Group A         | Group B         |
|----------------|-----------------|-----------------|
| Age            | 41.46±1.59      | 40.06±1.82      |
| Sex (Male/Female) | 28/2           | 28/3           |
| BMI            | 24.21±3.26      | 24.37±3.23      |

"*": statistically significant difference between two groups (P>0.05; Student’s t-test).

### Table 2 Functional outcome after percutaneous repair versus open repair rupture.

|                                | Group A        | Group B        |
|--------------------------------|----------------|----------------|
| Follow-up                      | 23.73±2.81     | 22.61±3.96     |
| Rerupture rate                 | 0              | 0              |
| Dorsiflexion                   | 19.06±2.42     | 19.25±3.24     |
| Plantflexion                   | 36.58±4.39     | 35.41±4.45     |
| Heel-rise (uninjured vs. injured) | 1.74±0.96*   | 2.37±1.42*     |
| Calf muscle circumference (uninjured vs. injured) | 2.34±1.45**   | 1.74±0.94**    |
| Anteroposterior diameter       | 10.16±2.04     | 9.94±2.01      |
| Cross-sectional diameter       | 16.54±1.55*    | 18.49±1.59*    |

"*": statistically significant difference between two groups (P>0.05; Student’s t-test).

### Table 3 Results of the postoperative score evaluation in both groups

|                | Group A        | Group B        |
|----------------|----------------|----------------|
| ATRS           | 90.67±2.67     | 91.10±2.50     |
| AOFAS          | 95.40±3.65     | 95.38±3.44     |
| VAS            | 0.36±0.49      | 0.32±0.48      |

"*": statistically significant difference between two groups (P>0.05; Student’s t-test).

ATRS: Achilles Tendon Total Rupture Score; VISA-A: Victorian Institute of Sports Assessment-Achilles score; VAS: visual analogue scale score.

**Figures**
Figure 1

Diagrammatic drawing of the Achilles tendon sutured using open repair (the bundle – bundle).
Figure 2

Diagrammatic drawing of the Achilles tendon sutured using percutaneous repair (modified kessler).