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Anatomic relationship of the sural nerve when performing Achilles tendon repair using the percutaneous Achilles repair system, a cadaveric study

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ABSTRACT

Background: Minimally invasive techniques for Achilles tendon repair are increasing due to reports of similar rerupture rates using open and percutaneous techniques with fewer wound complications and quicker recovery with percutaneous methods. The goal of this study was to investigate quantitatively the relationship and risk of injury to the sural nerve during Achilles tendon repair when using the Percutaneous Achilles Repair System (PARS) (Arthrex®, Naples, FL), by recording the distance between the passed needles and the sural nerve as well identifying any direct violation of the nerve with needle passage or nerve entrapment within the suture after the jig was removed. The hypothesis of the study is that the PARS technique can be performed safely and without significant risk of injury to the sural nerve.
Methods: A total of five needles were placed through the PARS jig in each of 10 lower extremity cadaveric specimens using the proximal portion after simulation of a midsubstance Achilles tendon rupture. Careful dissection was performed to measure the distance of the sural nerve in relation to the passed needles. The sutures were then pulled out through the incision as the jig was removed from the proximal portion of the tendon and observation of the suture in relation to the tendon was documented.
Results: Of the 10 cadaveric specimens, none had violation of the sural nerve. Zero of the 50 (0%) needles directly punctured the sural nerve. In addition, upon retraction of the jig, all sutures were noted to reside within the tendon sheath with no entrapment of the sural nerve noted.
Conclusion: This study demonstrated the variable course of the sural nerve and identifies the potential risk for sural nerve injury when using the PARS for Achilles tendon repair. However, this study provides additional evidence of safety from an anatomic standpoint that explains the outcomes demonstrated in the clinical trials. With this information the authors believe surgeons should feel comfortable they can replicate those outcomes while minimizing risk of sural nerve injury when the technique is used correctly.

1. Introduction

Rupture of the Achilles tendon most frequently occurs in recreational athletes in their fourth and fifth decade. Although goals of treatment have not changed in over a decade, there has been a push to nonoperative management, specifically functional bracing with early range of motion, to decrease wound and soft tissue complications. Operative treatments consist of open repair, percutaneous repair, mini open repair, and augmentative repair. Historically, there is lower rerupture rates with traditional open repair however there are higher risks of complications [1,2].

Minimally invasive incision techniques for Achilles tendon ruptures have evolved to reduce postoperative wound complications by avoiding excessive dissection and disturbance of local vascularity [3]. A study comparing traditional Krakow end to end to the percutaneous Achillon® System™ (Integra Life Sciences Corporation, Plainsboro, NJ), found the minimally invasive technique had lesser local tenderness, skin adhesions, scar formation and tendon thickness [4]. Additionally, percutaneous repair of the Achilles tendon has demonstrated superior rerupture

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rates, ankle mobility, gait strength and stability with minimal morbidity when compared with open repair [1,5].

The Percutaneous Achilles Repair System (PARS) (Arthrex®, Naples, FL) utilizes a transverse incision proximal to the Achilles tendon rupture site. The anatomically contoured PARS jig is inserted within the paratenon of the Achilles tendon and the PARS needles are passed through multiple guide holes to capture intratendinous position. The advantage of this system from others is that it incorporates a locking FiberWire (Arthrex®, Naples, FL) suture which results in a stronger repair then simply passing transverse sutures across the tendon. Although caution is used to prevent entrapment of the sural nerve with a percutaneous technique, it is still performed blindly, making the risk of iatrogenic nerve injury possible.

The sural nerve crosses the lateral border of the Achilles tendon around 57 mm (±14 mm) proximally from the insertion [6]. The mean distance between the nerve and the tendon was found to be 21.48, 11.47, 5.8, and 0.81 mm lateral to the Achilles tendon as measured at the insertion and 4, 8, and 11 cm proximally, respectively [7]. Cadaveric studies have demonstrated that the proximal course of the sural nerve coursed midline crossing the lateral border of the Achilles tendon at an average distance of 9.8 cm from the calcaneal tuberosity [8].

The goal of this study was to investigate quantitatively the relationship and risk of injury to the sural nerve during Achilles tendon repair when using the Percutaneous Achilles Repair System, by recording the distance between the passed needles and the sural nerve as well identifying any direct violation of the nerve with needle passage or nerve entrapment within the suture after the jig was removed. The hypothesis of the study is that the PARS technique can be performed safely and without significant risk of injury to the sural nerve.

2. Materials and methods

2.1. Cadaver specimens

10 lower extremity cadavers (five left and five right) from the tibial plateau through the distal phalanxes were used (Table 1). There was no history or signs of previous trauma to the lower limb or evidence of operative scars. The specimens were embalmed using 99% IMS (denatured alcohol, 80% phenol, glycerol and water through the femoral artery). Anatomical dissections were performed under the guidance of the designated individual in compliance with legislation in the Human Tissue Act 2004.

2.2. Achilles simulated tear location

The Achilles tendon was transected through a 2 cm transverse incision made at 4 cm proximal to the superior border of the calcaneus which was identified with the use of fluoroscopy. This was performed at the midsubstance of the tendon to mimic the relative diminished vascular watershed region of the tendon (2–6 cm proximal to the insertion the most common site of rupture) [7]. The superior border of the calcaneus was used since it is a reproducible landmark for measurement.

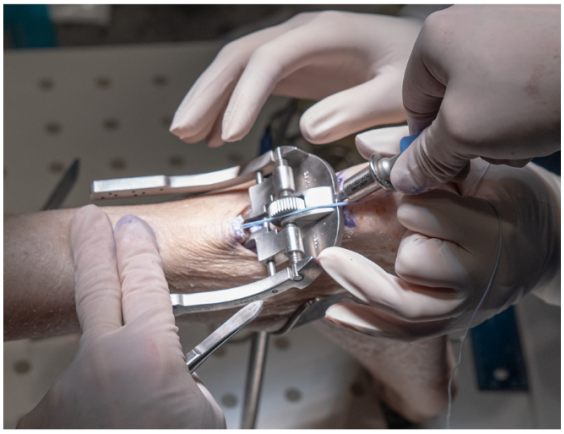

Fig. 1. Insertion of PARS jig beneath paratenon of a left lower extremity in the prone position.

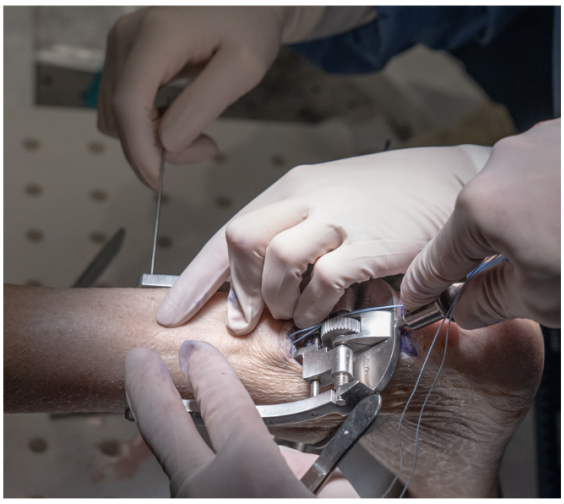

Fig. 2. Insertion of needle #1 percutaneously through the PARS jig of a left lower extremity in the prone position.

2.3. Placement of PARS

The PARS jig was inserted by a foot and ankle fellowship trained orthopaedic surgeon beneath the paratenon, directed proximally, (Fig. 1) and the needles were passed through the jig percutaneously (Fig. 2). The foot was placed in resting plantarflexion and neutral rotation for device insertion to simulate the operative position of the lower extremity. The authors preferred technique for Achilles midsubstance tendon repair utilizes 5 needle passes through the jig into the proximal stump for each specimen. The distal stump is fixed with a suture passer placed through two small stab incisions at the level of the calcaneus and passing the suture passer intrasubstance through the Achilles tendon in a retrograde fashion and passing the proximal sutures out the distal incisions

Table 1
Cadaver specimen details.

Specimen	1	2	3	4	5	6	7	8	9	10
Laterality	Left	Left	Right	Left	Right	Left	Left	Right	Right	Right
Sex	Male	Male	Female	Female	Female	Female	Male	Male	Female	Female
Age	62	62	74	91	88	77	88	94	70	59
Weight (lbs)	203	122	120	150	149	150	165	140	119	150

Details of lower extremity cadaveric specimens used in this study.

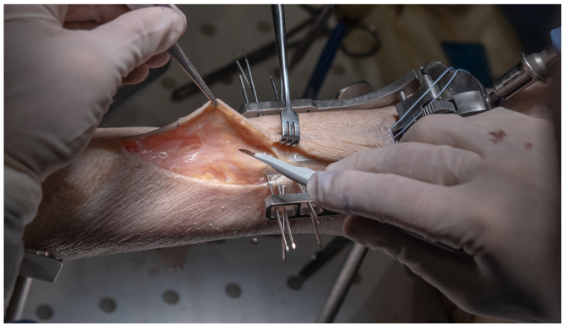

Fig. 3. Dissection of sural nerve after PARS jig and all needles placed in a left lower extremity in the prone position.

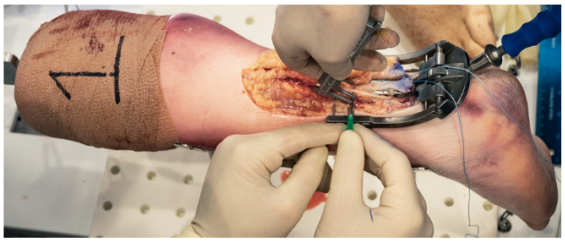

Fig. 4. A caliper was used to measure the distance from sural nerve to needle #5 through the PARS jig after dissection on a left lower extremity placed in the prone position.

which are then secured with two SwiveLock® anchors (Arthrex®, Naples, FL) into the calcaneus as described by McWilliam and Mackay [9]. The distal fixation was not performed in this study since we were only concerned with the PARS jig and potential injury to the sural nerve where it is used at the proximal stump of the Achilles tendon as there is no risk to the sural nerve with the distal fixation.

2.4. Sural nerve measurements

With the PARS jig still in position, careful dissection was done to evaluate the needles course and measure their relation to the sural nerve (Figs. 3 and 4).

Data collected include the rate of sural nerve violation per specimen and per needle pass. Nerve violation was defined as a needle passing within, and through, the nerve substance. The following parameters were measured (Table 2):

1 Specimen
2 Violation (needle #)
3 Location of nerve violation measured from the superior calcaneus
4 Vertical distance from the superior calcaneus to the most proximal needle
5 Vertical distance from the superior calcaneus to the most distal needle
6 Anterior/posterior distance between sural nerve and needle #1
7 Anterior/posterior distance between sural nerve and needle #5
8 Vertical distance from the superior calcaneus to the point where the sural nerve crossed the lateral border of the Achilles tendon

2.5. Statistical analysis

The Wilson confidence interval with no continuity correction was used to estimate the 95% confidence interval for the number of needle violations observed [10]. Spearman rank correlations were used to estimate relationships between selected variables. Analysis was conducted in R3.5.1 R Core Team using the 'PropCIs' package [11].

3. Results

Needle placement relative to the location of the sural nerve crossing the lateral border of the Achilles tendon are seen in Fig. 5. The average distance from the superior calcaneus to the most proximal needle of PARS jig (#1) was 110 (range, 97–120) mm. The average distance from the superior calcaneus to the most distal needle (#5) was 93.6 (range, 82–105) mm. The average anterior to posterior distance between the sural nerve and the most proximal needle (#1) was 4.25 (range, 0.5–7) mm. The average anterior to posterior distance between the sural nerve and the most distal needle (#5) was 2.8 (range, 0–5) mm. The average distance from the superior calcaneus to where the sural nerve crosses the lateral border of the Achilles tendon was 107.2 (range, 85–126) mm. Due to the high variability in sural nerve crossing location, the position of the needles was either above, below, or in the same immediate area as the sural nerve crossing (Fig. 5). The vertical sural nerve crossing location was negatively correlated with the weight of the subject ($r_s = -0.78$, $P = 0.008$), and considering gender along with weight may also help generally predict vertical sural nerve crossing (Fig. 6).

The anterior to posterior distance between the sural nerve and the needle was not related to the proximity of the sural nerve

Table 2
Relationship of sural nerve to needle placement.

Specimen	Laterality	Violation	Vertical needle 1	Vertical needle 5	A/P needle 1	A/P needle 5	Vertical sural N. crossing
1	Left	No	97	82	7	5	101
2	Left	No	120	105	0.5	0	125
3	Right	No	108	94	6	5	126
4	Left	No	108	92	4	2	87
5	Right	No	110	90	8	2	105
6	Left	No	116	98	2	4	85
7	Left	No	105	90	5	3	104
8	Right	No	104	88	3	2	116
9	Right	No	112	97	4	3	125
10	Right	No	120	100	3	2	98
Average			110	93.6	4.25	2.8	107.2
Minimum			97	82	0.5	0	85
Maximum			120	105	7	5	126

Demonstrates the specimen, lower extremity laterality, if a violation of the sural nerve occurred, the vertical distance from the superior calcaneus to the most proximal needle (#1), the vertical distance from the superior calcaneus to the most distal needle (#5), the anterior/posterior distance between sural nerve to the most proximal needle (#1), the anterior/posterior distance between sural nerve to the most distal needle (#5) and the vertical distance from the superior calcaneus to the point where the sural nerve crossed the lateral border of the tendon.

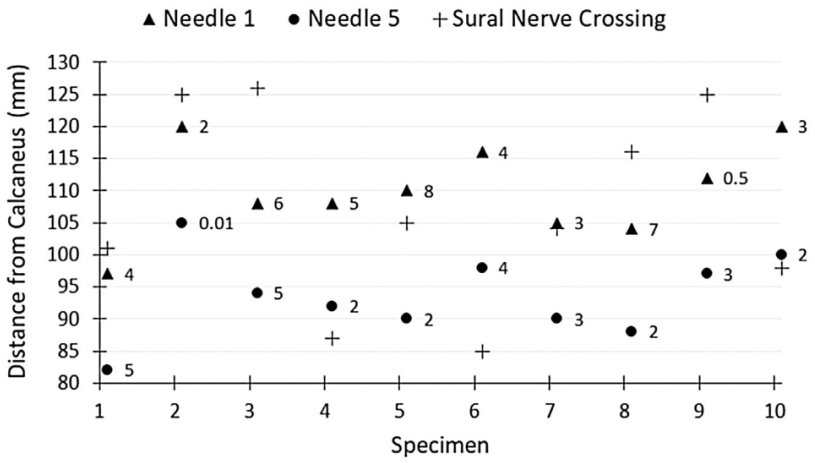

Fig. 5. Location of sural nerve crossing relative to the positions of vertical needles 1 and 5 for each specimen. Numbers next to vertical needles represent the anterior to posterior distance from the needle to the sural nerve in millimeters. Location of the sural nerve crossing the lateral border of the Achilles is shown (+).

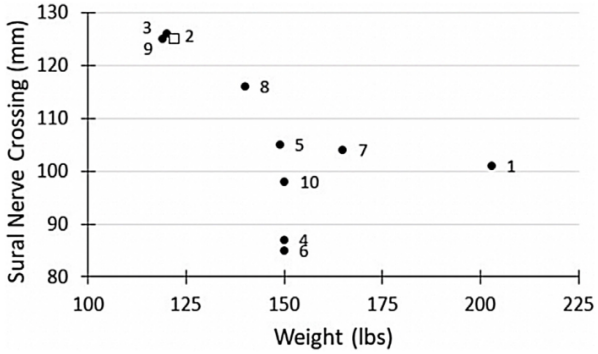

Fig. 6. Location of sural nerve crossing the lateral border of the Achilles relative to weight. The gender of each specimen (F, female and M, male) is indicated next to each point. The open box indicates the specimen in which the needle touched but did not puncture the sural nerve.

crossing to the needle (Needle 1: Spearman correlation = −0.45, P = 0.189; Needle 5: Spearman correlation = 0.25, P = 0.493; Fig. 5).

Of the 10 specimens, there were no violations of the sural nerve during percutaneous needle passage (95% CI: 0, 0.28). Zero of the 50 (95% CI: 0, 0.07) needles passed directly pierced the substance of the sural nerve, but one needle was touching but not violating the nerve (Fig. 7). Once the suture was passed and the PARS jig removed, the nerve was intact, with no evidence of entrapment in all needle passes (Fig. 8).

4. Discussion

4.1. Sural nerve violation

Our study demonstrated that sural nerve violations occurred in 0% (0/50) of needle passes when using the PARS jig (Table 2). Hsu et al. compared open versus PARS repair in 270 patients and found no cases of sural neuritis with the PARS group versus 3% incidence of sural neuritis in the open group, with no difference in rerupture, wound dehiscence, superficial infection, deep infection or reoperation rates [12]. Haji et al. demonstrated transient sural neuritis in 10.5% of patients and no wound infections with percutaneous repair [13].

The transient nature of the neuritis may be due to manipulation of the sural nerve when the needle comes into close proximity to the nerve. The symptoms are often transient because there is no entrapment of the nerve as long as the jig is placed within the tendon sheath. In this study, only one needle was in close proximity to the sural nerve as it touched the epineural sheath, separating the small saphenous vein from the sural nerve (Fig. 7). Once the sutures were passed and the PARS jig was removed, the

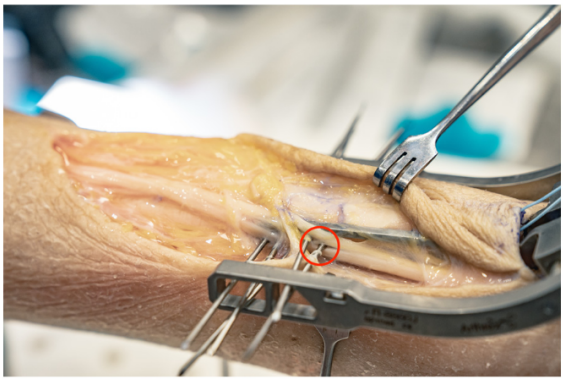

Fig. 7. Left lower extremity in the prone position (specimen #2) which had the closest passing needles to the sural nerve. The sural nerve was touched, but not punctured by needle #5, separating the small saphenous vein from the epineuron of the sural nerve (circled in red) (For interpretation of the references to colour in the figure legend, the reader is referred to the web version of this article).

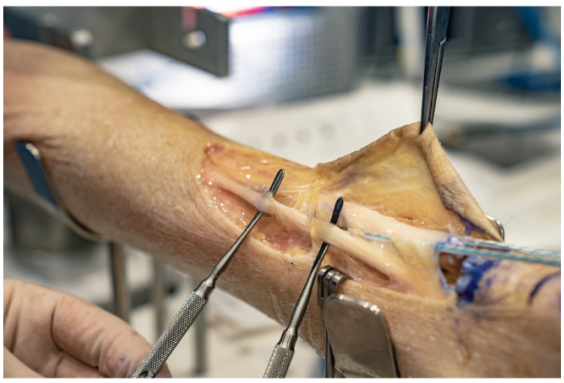

Fig. 8. Left lower extremity in the prone position (specimen #2) after the sutures were passed and the PARS jig was removed. The sutures were drawn closer to the Achilles and into the paratenon when the jig was removed. Even though needle #5 touched the sural nerve, there is no violation of the nerve by the sutures.

sutures did not remain in the nerve substance, but were safely and appropriately on top of the paratenon and within the sheath of the Achilles tendon (Fig. 8). The authors believe that this may account for the reports of transient sural nerve neuritis utilizing percutaneous Achilles approach.

We hypothesized that the location of the sural nerve relative to the location of the PARS jig would play an important role in the risk for sural nerve injury. This hypothesis was not supported by the data. The specimen where the needle was in closest proximity to the sural nerve had a sural nerve which crossed the lateral border of the Achilles above the position of the needles and in the top 30% overall. However, the other two specimens with sural nerves which crossed the lateral border at approximately the same point did not have needles passing close to the sural nerve. The analysis comes with the caveat that there was only one specimen which combined a high sural nerve crossing point with a relatively high placement of the PARS jig. Additional samples with high sural nerve crossing points need to be evaluated to explore the possibility that a high sural crossing point coupled with high placement of the PARS jig elevates the risk of nerve injury.

Porter et al. reported the sural nerve crossing the lateral border of the Achilles tendon around 57 mm (±14 mm) proximally from the insertion [6]. Kammer et al. found that the mean distance between the nerve and the tendon was found to be between 0.81 mm to 21.48 mm lateral to the Achilles tendon [7]. The data in our study demonstrated the sural nerve crossed the lateral border of the Achilles tendon at 10.7 cm on average, consistent with other cadaveric studies that demonstrate an average distance of 9.8 cm from the calcaneus [8].

4.2. Limitations and future directions

Previous studies completed using Achillon® System™ (Integra Life Sciences Corporation, Plainsboro, NJ), demonstrated that with internal rotation, 8 of 13 specimens had at least one violation of the needle directly piercing the sural nerve. However, they found that with external rotation, there were no violations of the nerve, decreasing the risk of sural nerve violation even compared to neutral rotation [14]. In this study we simulated operative positioning of the limb with resting plantarflexion and neutral rotation.

The greatest limitation of this study was the small sample size of 10 cadaveric specimens. Given the fact that the sural nerve crossed at three different locations relative to the PARS jig, the sample size made generalization difficult. Further studies are indicated with larger sample sizes to be able to have more statistically sound global assertions. Another limitation was that height of the cadaveric specimens was unknown, so it is possible that the observed relationship between sural nerve crossing location and weight is driven by differences in height. In addition, the distance between sural nerve and needle was recorded as an absolute value, so it was not possible to get a statistical estimate of the likelihood that a needle would directly violate the nerve. Future studies should address these limitations.

5. Conclusion

Our cadaveric study found that the Percutaneous Achilles Repair System punctured the sural nerve in 0% (0/50) of needles passed and had no nerve entrapment within the suture. This study demonstrates the variability of the sural nerve anatomy and identifies the potential risk of sural nerve injury when using the PARS for Achilles tendon repair. This study provides additional evidence of safety from an anatomic standpoint that explains the outcomes demonstrated in the clinical trials. With this information the authors believe that surgeons should feel comfortable they can replicate those outcomes while minimizing risk of sural nerve injury when the technique is used correctly. The authors believe when surgery is considered for Achilles tendon repair that limited incision surgery should be employed as a safe and effective technique with few complications and little risk for sural nerve complications.

Conflict of interest statement

One author declared a potential conflict of interest as a consultant for Arthrex® for product development, course instructor and royalties, none of which are directly related to this product. The remaining authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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