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Blood Flow Restriction Therapy Following Achilles Tendon Repair in Male Patients

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Abstract

***Objective:** Our purpose is to assess the effectiveness of blood flow restriction therapy(BFRT) compared to a standard accelerated rehabilitation program following operative Achilles tendon repair.*

***Design:** This is a retrospective, unblinded cohort study.*

***Setting:** This study took place at a tertiary care institutional orthopaedic outpatient clinic.*

***Patients:** All patients who underwent primary Achilles tendon repair between 2013 and 2020 by the senior author were included. Patients of female sex and age greater than 65 were excluded due to low numbers. Patients with chronic pathology, prior surgery, reconstructions, tendon transfers, or history of injury or surgery on the contralateral ankle or foot were also excluded.*

***Interventions:** The primary outcome was calf circumference, measured at its approximate maximum diameter on the operative leg. Secondary outcomes include the presence of wound complications as well as any other postoperative complications. Those who underwent physical therapy with BFRT comprised the study group; those without BFRT were controls.*

***Main outcome measures:** Calf circumference at widest point before and after both BFRT and standard physical therapy without BFRT.*

***Results:** 19 patients receiving BFRT in addition to a standard accelerated rehabilitation program were compared to 89 patients undergoing astandard accelerated postoperative physical therapy program. Mean clinical follow-up was 9.3 months. There was a trend in patients undergoing BFRT to have a smaller difference in calf circumference at late term follow ups.However, this was not statistically significant.*

***Conclusions:** BFRT may allow fora more robust return of calf girth following Achilles repair, compared to a standard accelerated rehabilitation program, however larger studies are needed.*

Introduction

Blood flow restriction therapy (BFRT) has seen expanded use in the last decade.[8] Its efficacy in accelerating rehabilitation programs and return to sport has been described for many musculoskeletal injuries, including as an addition to postoperative rehabilitation. Within orthopaedics, improved outcomes compared to standards of care have been reported following anterior cruciate ligament reconstruction[9,14,16,20], isolated knee arthroscopy[26], knee arthroplasty[13], and for patellofemoral syndrome[6].

The complete mechanism of BFRT in inducing hypertrophy of muscle tissue is not entirely understood, though there are speculations that it is caused by combination of mechanical and hormonal changes[10, 21]. This potentially occurs because the cuff allows arterial inflowbut significantly restricts venous outflow causing the muscle to get engorged with blood. This may increase hormonal concentrations as well as increase the concentration of components of intracellular signaling pathways for muscle protein synthesis.

Notorious for slow recovery, Achilles tendon repair rehabilitation may be accelerated by BFRT.[2,3,28] As plantarflexion weakness and calf asymmetry frequently persist following Achilles tendon repair, there have been recent efforts to optimize rehabilitation protocols in the first year.[4,7,18]

To our knowledge there has been only one study reporting two patients receiving BFRT after surgical Achilles repair; one managed operatively and one managed nonoperatively. Both patients received BFRT as part of their rehabilitation program and the authors reported significant improvements in plantarflexion strength and power; however the sample size was limited and no control group was used.[29]

Achilles tears are notoriously difficult to manage postoperatively due to the simultaneous need to protect the repair while minimizing calf atrophy. Furthermore, due to the potential for re-tearing and the high rate of wound complications, Achilles repairs are typically more protected in their rehabilitation protocols compared to other tendon injuries. Hence, BFRT potentially presents an ideal solution for optimizing recovery due to its ability to provide muscle strengthening at markedly lower loads, thereby protecting the repair and potentially minimizing atrophy.

Our purpose is to assess the effectiveness of BFRT compared to a standard accelerated rehabilitation program following operative Achilles tendon repair. We believe that BFRT as part of the postoperative rehabilitation process will increase calf circumference to a similar level to the uninjured extremity at a faster rate than standard postoperative rehabilitation protocols.

Methods

This is a retrospective analysis of prospectively collected data. This study was approved and overseen by the Cedars-Sinai institutional review board. All patients who underwent primary Achilles tendon repair between 2013 and 2020 by the senior author (KJ) were included. Patients of female sex and age greater than 65 were excluded due to low numbers, which would have potentially skewed data and made meaningful comparisons challenging. Patients with chronic pathology, prior surgery, reconstructions, tendon transfers, or history of injury or surgery on the contralateral ankle or foot were also excluded. Postoperative metrics were obtained from the patients' electronic medical record. The primary outcome was calf circumference, measured at its approximate maximum diameter on the operative leg and at the same level distal to the tibial tubercle on the contralateral leg. Secondary outcomes include the presence of wound complications as well as any other postoperative complications. Parameters were recorded during postoperative follow-up visits with the surgeon. Patients selected their physical therapy center based on home location, insurance, or collegiate or professional team preference. Those who underwent physical therapy with BFRT comprised the study group; those without BFRT were controls.

Surgical Technique

A tourniquet was inflated throughout the procedure. A posteromedial approach to the Achilles tendon was performed, with thick skin flaps made above the paratenon. The paratenon was carefully opened to allow for repair at the endand the proximal and distal Achillestendon ends were debrided. SutureTape (Arthrex, Naples, FL, USA) was placed using a Krackow-type configuration along the proximal tendon stump and No. 0 braided suture was placed into the proximal end of the distal stump and eventually passed through the proximal tendon using a suture passer. A SpeedBridge technique was performed for fixation onto the calcaneus: two stab incisions were made over the distal calcaneus and 2 holes were drilled and tapped for 4.75mm SwiveLock anchors (Arthrex). A suture passer was used to bring the SutureTape from the proximal tendon limb down through the distal tendon and into the calcaneus, which was tensioned and secured into the anchors while holding the two ends reduced with the braided suture and ankle in plantarflexion.Tension was assessed through range of motion and Thompson's test was performed. A plantaris graft augmentation was incorporated into the repair when present. The No. 0 braided suture was sewn to the proximal tendon stump and the plantaris graft for added strength of the repair construct. Wounds were closed in a layered fashion (paratenon, subcuticular, skin) with monofilament suture. A sterile bulky dressing and splint were applied after skin closure.

Statistical analysis

A priori power analysis was performed with an alpha of 0.05 and power of 0.80. Assuming standard deviation of 10mm, it was found that 50 patients were required to detect a 5mm difference in calf circumference deficiency on the operative extremity, i.e. the difference between calf circumference of the operative and nonoperative leg being 5mm or less.

The difference between operative and nonoperative calf circumference was the primary outcome measure assessed. Means were compared using a repeated measure analysis of variance modelthat allows for non-independent multiple observations on the same subject (ANOVA). Both adjusted and unadjusted analyses were performed using propensity score matching. This was done to account for a significantdifference in BMI between groups. Continuous variables were compared using Student's t-test. Statistical significance was set at $p<0.05$ for all statistical tests. Computations were carried out using the R softwarepackage(R version 3.5.2, R Foundation for Statistical Computing, Vienna, Austria).

Rehabilitation Protocols

Weight bearing

Patients were directed to be non-weight bearing for the first 3 weeks. A splint was placed in the operating room and removed at 2 weeks, at which time sutures were removed and the patient was placed into a tall, controlled ankle motion (CAM) boot with a 2cm wedge. At 3 weeks, the patient began progressive weight bearing, starting at 25% body weight inthe boot and with the aid of crutches. Weightbearing was increased by 25% weekly which was patient directed. At 75% weightbearing(week 5), patientswere instructed to use one crutch.At 6 weeks patients progressed to full weightbearingin a tall CAM boot. The boot was weaned to ashoe with a lift until 12 weeks post operatively.

Physical Therapy

All patients began physical therapy between 2 and 3 weeks postoperatively. An accelerated functional rehabilitation program was followed as described in the literature for all patients[27]. Abductor strengthening, core strengthening, quadricep and hamstring strengthening were initiated 2 to 3 weeks post operativelywith gentle active motion of the ankle. Biking, range of motion exercises, and gait training began at 3 weeks postoperatively.Calf strengthening exercises began after 6 weeks as ambulation progressed.

In those receiving BFRT, the process began once the splint was removed at 2 weeks and performed in addition to the standard functional rehabilitation program. 80% occlusion was utilized for the BFRT exercises. These included lower extremity strengthening exercises for hip, abductor, quadriceps, calf, and foot intrinsic in one set of 30 repetitions followed by 3 sets of 15 for each muscle group. Cell swelling protocol was utilized in the early postoperative phase until strengthening was permitted; this comprised 5 minutes of tourniquet cuff inflation, then 1 minute of rest, performed for 5 sets at 80% occlusion. The cell swelling protocol is theorized to promote fluid migration into the myocyte in order to prevent muscle atrophy during the period of disuse.[5]

Results

205 Patients were identified who underwent Achilles repair for acute rupture between 2012 and 2020. 55 patients had a chronic injury to the Achilles tendon and were subsequently excluded.13female patients were excluded due to the fact that only one female had received BFRT. 12 patients had a partial tear and exostosis. 10 were excluded due revision surgery. 5 patients had incomplete medical records. 1 patient required a concomitant open reduction and internal fixation of an ankle fracture. 1 patient >65 years of age was excluded. A flow chart is illustrated below (FIGURE 1).

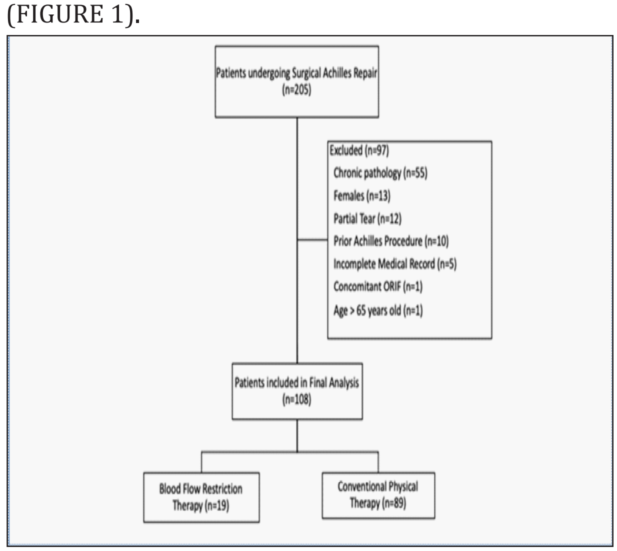

Figure 1. *Study inclusion information.*

108 patients were included in the final statistical analysis. Study group demographics are shown below (TABLE 1). Mean clinical follow up was 9.3 months (279 days).

Table 1. *Patient Demographics*

	BFRT	Control	p value
Number of patients	n = 19	n = 89	
Age (mean +/- SD)	39.2 +/- 9.8	37.9 +/- 11.6	0.67
BMI	25.6 +/- 1.8	27.2 +/- 3.2	0.03*
Left:Right	9:10	41:48	0.88

Table 1: Patient demographics. Data presented as mean ± standard deviation.BFRT: Blood-Flow Restriction Therapy. BMI: Body Mass Index.

* Denotes a significant difference at $p < 0.05$

Complications included 1 wound infection, 1 blister, 3 deep vein thromboses, and 2 re-ruptures. There was no significant difference between the two groups regarding complication rates.

BMI was significantly different between groups and this was addressed using propensity matching in the statistical analysis. Postoperative time bins were selected based on histogram analysis of the data points and were selected as outlined below (TABLE 2).

Table 2. *Time Bins for Analysis*

Bin #	Time Window (Days from Surgery)	Number of Observations (control)	Number of Observations (BFRT)
1	13-75	34	13
2	76-120	51	15
3	121-165	41	15
4	166-245	44	16
5	246-945	57	16

Table 2: Breakdown of postoperative time windows selected for analysis. BFRT: Blood-Flow Restriction Therapy

ANOVA was performed using both absolute calf circumference difference as well as percent circumference of non operative side, and results were similar. Absolute delta circumference is reported here in both unadjusted and propensity matching score adjusted results. There was a smaller mean delta circumference (6.46 mm compared to 10.71mm) in favor of BFRT in the unadjusted analysis at the last time bin (> 245 days), but this result was not statistically significant (p=0.181). The difference between operative and non operative calf circumference versus time from surgery is displayed (FIGURE 2, FIGURE 3). Difference in percentage of calf circumference failed to reach statistical significance ($p<0.05$).

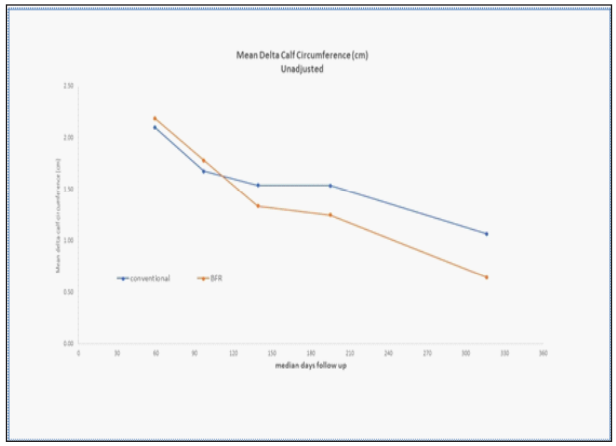

Figure 2. *Unadjusted results of mean calf circumference difference over time.*

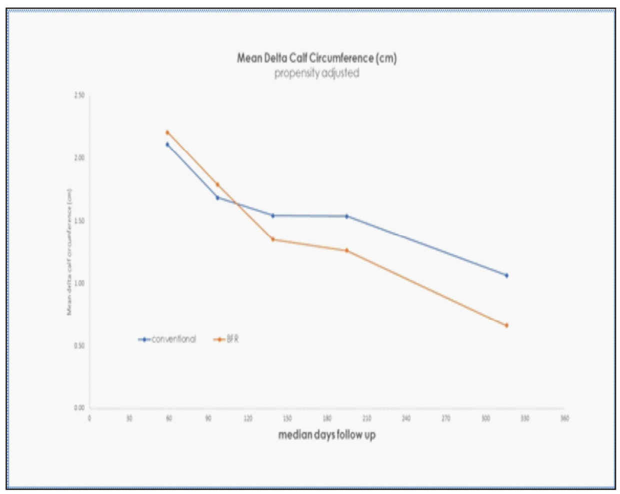

Figure 3. *Propensity adjusted results of mean calf circumference difference over time.*

Discussion

Our study fails to demonstrate statistically significant improvement in calf circumference following BFRT in patients who underwent surgical repair of Achilles tears. While our findings add to the existing knowledge, we are limited by the mean 9.3-month follow up. This is due to the fact thatpatients typically self-discharge from care once clinically recovered, resulting in follow-up terminating around this time point.

To our knowledge, the minimal clinically important difference (MCID) for differences in calf circumference has not been established. Though not statistically significant, our data at final follow up shows that BFRT may improve circumference by 4 mm compared to patients undergoing standard rehabilitation protocols. While the typical male calf is approximately 36 cm;[11] 4mm comprises a 1.1% improvement. With higher power, our study may have demonstrated statistical significance, however it is unclear whether a 4mm difference would be considered clinically significant.

There are many potential benefits of BFRT after this procedure. Firstly, BFRT strengthens the lower extremity without loading the tendon repair. Lower extremity BFRT has been found to increase squat strength[17], sprint speed, and increased rectus femoris muscle thickness[1, 15]. After knee arthroscopy, Tennent et al reported improved muscle strength and function with the addition of BFRT compared to standard rehabilitation.[25]As Achilles repair rehabilitation is centered around protecting the repair, BFRT presents an ideal treatment.

Secondly, BFRT has been associated with increased expression of pro-inflammatory cytokines which may promote wound healing.19Growth hormone24, reactive oxygen species12, and vascular mediators12 have been described with BFRT. While there has been no direct association with improved wound healing, there is a theoretical benefit in the milieu created during BFRT. With a wound complication rate of 5.2% or higher23, Achilles tendon repair may benefit from potential improvements in healing.

To our knowledge this is the first series to compare standard rehabilitation techniques to BFRT following Achilles tendon repair. Yow et al published a case report of two patients utilizing BFRT after Achilles tendon injury. One patient underwent operative repair and the other nonoperative management. Both patients had persistent weakness following standard rehabilitation and subsequently incorporated BFRT into their rehabilitation program. Both patients experienced peak plantarflexion torque improvements and return to sport.[29]

While our findings fail to reach statistical significance in calf circumference, we believe future randomized studies utilizing a homogenous therapy protocol will be needed tofully determine the effects of BFRT in the setting of Achillestendon repair. Additionally, though circumference was not statistically improved, there may be improvements in plantarflexion strength which was not measured in this study. Furthermore, observing patient reported outcomes scores (PROS) may be beneficial as patients who undergo BFRT after other orthopedic surgeries tend todemonstrate improvements.

Limitations

There are several limitations which may limit the generalizability of this study. First, there is heterogeneity in the physical therapy protocols due to differences amongst therapists and therapy locations. Second, there may be a selection bias as high-level athletes were possibly more likely to be referred to BFRT locations, and therefore benefit from unequal access to therapy compared to non-elite athletes. Thirdly, our population was younger than patients typically undergoing Achilles tendon repair.22 Hence our population may be more active and have a higher muscle mass that can atrophy to a greater extent due to prolonged disuse than an older population. Fourthly, there may also be selection bias in those patients who follow up after 1 year, suggesting that they may have a problem with their recovery. Finally, due to differences in patient specific anatomy, it is difficult to standardize the measurement of the calf musculature, as height and differences in muscular insertion may lead to non-optimal measurement of the calf.

Conclusion

This study found a trend of decreasing delta calf circumference in patients treated with BFRT compared to standard rehabilitation. The trend started atapproximately 4 months post operatively and continues through the final follow up.There were no increased complications with the addition BFRT to postoperative rehabilitation. More randomized studies are needed to assess differences in strength and patient reported outcomes.

Key Points

Findings: This study demonstrates a trend of decreasing delta calf circumference in patients treated with BFRT compared to standard rehabilitation. Though not significant, the trend starts at approximately 4 months post operatively and continues through the final follow up.

Implications: Our findings suggest that BFRT may help reduce the difference in calf circumference following Achilles tendon repair when compared to standard rehabilitation protocols, but more randomized studies are needed to assess differences in objective calf strength and patient reported outcomes.

Caution:There is heterogeneity in physical therapy protocols due to differences amongst therapists and therapy locationwhich may have affected outcomes. Second, due to differences in patient specific anatomy, it is difficult to standardize the measurement of the calf musculature, as height and differences in muscular insertion may lead to non-optimal measurement of the calf.

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