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CONSERVATIVELY MANAGED ACHILLES TENDON RUPTURE HEALING – A CASE COHORT ANALYSIS

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LEVEL OF EVIDENCE: 2b

ABSTRACT

Objectives: The objective of this study was to describe the morphological changes on ultrasound scan of healing Achilles tendons that have sustained a full thickness rupture.

Design: This is a case cohort study of patients referred for the conservative management of Achilles tendon ruptures.

Methods: This is an observational study of 100 patients presenting with Achilles tendon ruptures who attended a consultant podiatry clinic. All patients diagnosed with an Achilles tendon rupture were conservatively managed and placed in an air shell walker boot with the patient fully weightbearing with wedges in-situ to maintain the foot in an equinus position in order to reduce the ruptured tendon gap. The wedges were removed incrementally from week 6, and the boot removed at week 10. At the initial appointment and each follow up a series of ultrasound measures were captured at the musculotendinous junction of the soleus (MTJ), gap (rupture) location (GL), corresponding gap location (CGL) of contralateral tendon and the osseo-tendinous junction at the calcaneus (OTJ). A patient reported outcome measure (ATRS) was also collected at each contact.

Results: All ruptured Achilles tendons became fully united. ANOVA results of the ruptured Achilles tendon data conclude that there were statistically significant ($p \leq 0.05$) differences among the means of the three anatomical locations (MTJ, GL, OTJ) for the three time points (weeks 6, 10, and 20). This suggests that the AP measure changes significantly over time across the three time points. There was no statistically significant ($p < 0.05$) difference between measurements for each asymptomatic anatomical location over the same time period. The ruptured location of the Achilles tendon had a mean of 58.6 mm with a minimum of 14.1 mm and a maximum of 73.3 mm from the osseo-tendinous junction. 85 /100 patients ruptured between 30 mm and 60 mm proximally to the osseo-tendinous junction. The ruptured tendon gap reduced with the foot placed in 10 degrees of plantarflexed position during ultrasound. For 80 patients the gap was between 0 and 1.6 mm. Two patients presented with a gap between 8 and 9.6 mm with the foot plantarflexed. From baseline (0 weeks) to 20 weeks these data suggest a significant improvement in the ATRS scores from an average score of 3.25 at 0/52 weeks to 83.25 at 20 weeks. A Pearson's correlation coefficient of final 20 week ATRS score suggested that age does not appear to be correlated with outcomes for ATRS ($p \leq 0.05$).

Conclusions: All ruptured Achilles tendons became fully united and significantly thickened by the six week time point on the pathway. By the end of the pathway significant AP thickness was observed in most cases, with significant

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improvements in ATRS scores. AP measure thickness at each time point was a determinant of higher ATRS scores. No significant differences in AP thicknesses were observed in the OTJ and MTJ measures of the symptomatic or tendons.

KEYWORDS

Achilles rupture, conservative management, diagnostic ultrasound

INTRODUCTION

There is an increasing incidence of Achilles tendon ruptures across many Western countries in sporting and non-sporting related groups[1]. With some figures reported as 4.7 to 6.0/100 000 person-years in Scotland[2]; 18.2 to 37.3/100 000 person-years in Denmark[3]; and from 5.5 to 9.9/100 000 person-years in Canada[4].

Achilles tendon ruptures have been successfully managed conservatively for over two decades[5]. Conservative management of Achilles tendon ruptures is becoming the default approach in many countries, particularly in the UK. The UKSTAR trial of 540 patients concluded that there was no significant difference between functional bracing and plaster cast approaches[6]. It is worth considering that most patients who present with a ruptured Achilles tendon may not be elite athletes and functional outcomes should be considered for each patient[6] In addition to this, there does remain controversy surrounding conservative or surgical intervention choice. A meta analysis carried out by Guevara-Chavez et al. 2024[7] suggested that surgical management was more effective at reducing Achilles tendon re-ruptures. In addition to this another systematic review of chronic Achilles tendon ruptures managed surgically, demonstrated that 79% of patients were able to return to everyday activities and sport[8]. Evidence on long term outcomes for surgical and conservative approaches is required so that patients can make more informed decisions on their care. This may then represent a personalised approach based on required functional outcomes, rather than a one size fits all approach[9].

The management pathways have continuously evolved, with the most recent published in 2017 by Patel et al[10]. However there remains uncertainty regarding the healing of the Achilles tendon at each stage of the pathway, with particular emphasis on tendon thickness and union of the tendon margins as physiological measures within the pathway. As with all connective tissue, the Achilles tendon is not a passive loadbearing structure, but continuously reacts to gravity, compression and muscle forces[11]. This also applies during tendon healing, where studies of both animal and human tendons have demonstrated positive benefits as a result of early mobilisation[12-16].

Early mobilisation can be achieved with the use of functional bracing e.g. with use of walker boots, instead of plaster casting[17-22]. In addition to this, the use of functional bracing results in a return to sporting activities or work and increased patient satisfaction[23]. It has been previously documented that controlled loading may enhance healing, however loads which are too low may induce a catabolic tendon state and loads which are too high may induce micro-damage[24]. These states are controlled by mechanical load and cyclical strain signalling within the tendon known as mechanotransduction, which produces signals within the extracellular matrix[25].

Studies have demonstrated the composition of the extracellular matrix (ECM) adapts to changes in load, particularly mechanical stress which regulates ECM proteins indirectly, stimulating the release of paracrine growth hormones[26]. In addition, the fibroblasts sense strains within their ECM which is vital for mechanotransduction.

With all tendon healing the collagen matrix is not organised and its mechanical properties are not the same as normal tissue[27]. The structurally aligned collagen fibres may have no specific orientation. However, in vitro studies have demonstrated the ability of collagen fibres to re-align with contractility[27].

Clinical diagnosis of Achilles tendon ruptures has traditionally involved carrying out a calf squeeze test or a Matles test, which has been demonstrated as a reliable method of diagnosis[28]. The advancement and availability of diagnostic ultrasound technology at point of care has resulted in its use not only for diagnostics but also for monitoring and changing clinical decision making[29].

Ultrasound technology employs higher spatial resolution compared to MRI technology due to high frequency transducers[30]. Findings of a systematic review suggest diagnostic US measures of tendon size are reliable, both in terms of relative and absolute reliability[31]. In addition to this, the systematic review suggested good inter and intra-operator reliability.

Diagnostic ultrasound has been used to detect full thickness Achilles tendon ruptures with a reported accuracy of 92% compared to partial ruptures[32] Another study suggested a sensitivity of 94.8% and a specificity of 98.7% for detecting ruptures using ultrasound[33].

Diagnostic technology is often utilised to evaluate tissue healing. Initial and subsequent X-rays are often utilised to evaluate progression to union of fractured bone[34]. Ultrasound has also been used to evaluate bone healing successfully[35]. Ultrasound evaluation of surgically repaired Achilles tendons during healing at multiple intervals suggested tendon morphology was a robust method to evaluate healing progress[36]. However in clinical practice

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diagnostic ultrasound is rarely utilised as a routine tool to evaluate soft tissue healing. This may be due to increased strain on access to radiology services to provide even the most basic of care[37].

This study aims to provide insight into the anatomical changes observed during a cohort of Achilles tendons within a 20 week pathway, with the contralateral tendon utilised as a control measure.

AIMS OF THE STUDY

The aim of this study was to investigate the anatomical changes and patient reported outcome measures observed in full thickness Achilles tendon ruptures from baseline (week 0) to 20 weeks in a consecutive cohort of patients referred from Fracture clinic or the Emergency Department in a geographic locality (NHS UK).

METHODOLOGY

Trial design

This is an observational study with a sample size determined a priori without calculation of 100 patients presenting with Achilles tendon ruptures in Cwm Taf Morgannwg University Health Board, Wales, UK. Patients presented to the Emergency Department and were then referred and appointed within 48 hours with the Consultant Podiatrist with a suspect Achilles tendon (AT) rupture, based on examination and history during the Emergency Department assessment. The non-ruptured side AT was utilised as a control for this study. All non-ruptured tendons were recorded as asymptomatic. Patients attended the podiatry clinic where as part of the assessment and pathway process, received a diagnostic ultrasound scan. A standardised in-house Emergency Department venous thromboembolism risk assessment was carried out on each patient. All patients diagnosed with a rupture were conservatively managed and placed in an air shell walker boot (Promedics Airstep Walker Boot) with the patient fully weightbearing with four wedges (Promedics Walker Wedge) in situ to maintain the foot in an equinus position in order to reduce the ruptured tendon gap. The number of wedges utilised were determined by in-house orthopaedic pathway. The wedges were removed incrementally, starting at week 6, with the last wedge removed at week 9 and the boot removed at week 10. Each patient was advised to walk fully weight bearing in the boot for a minimum of four periods of 15 minutes per day. The patient was provided with non-weightbearing exercises (foot rotations, toe curling, seated heel raises) at week 6 and full weightbearing exercises (double limb progressing to single limb: eccentric / concentric loading & isometric loading) at week 10. At each follow up appointment at week 6, 10 and 20, the ultrasound measures were re-captured at each of these timeframes.

Procedure

An appropriately trained and fully qualified clinician (Consultant Podiatrist), conducted all ultrasound examinations and recorded all measures utilising a precise protocol. Only patients with a full thickness AT rupture were included in this study. Ultrasound (US) examinations were carried out on all patients in the prone position with feet extending beyond the examination table at a neutral (90 degrees) position and both AT exposed. A high frequency linear array transducer (4-16 MHz) with an ACUSON Juniper ultrasound system from Siemens Healthcare GmbH was utilised to carry out the US examinations and diagnosis. Image field depth was set to 2 cm. The central marker situated on the ultrasound probe was utilised to accurately locate the three anatomical locations of musculotendinous junction of the soleus (MTJ), gap (rupture) location (GL), corresponding Gap location (CGL) of contralateral tendon and the Osseo-tendinous Junction at the calcaneus (OTJ). To determine the presence of a full thickness AT rupture both Achilles Tendons were scanned in the long and short-axis from the tendon insertion at the calcaneus to the myotendinous junction. A two point digital calliper function on the ultrasound machine was utilised to measure the anterior-posterior (AP) tendon thickness. This software function is tested for accuracy within the annual qualitative assurance testing process.

Dynamic scanning was carried out with the foot at 90 degrees, utilising small movements of dorsiflexion and plantarflexion of the foot to evaluate full thickness tearing where necessary. While scanning in the short-axis plane the probe was tilted on each side of the tendon to assess the peritendinous envelope. The anterior-posterior (AP) thickness of the Achilles tendon was measured only in the long-axis. This plane was utilised to standardise all three measures. This was carried out at by moving the transducer from the medial to the lateral tendon fibres and measuring the thickest point in the AP direction. The foot was then plantarflexed and the tendon gap was re-measured to assess the total gap closure in mm.

Musculotendinous junction of soleus (MTJ)

This can be described as the anatomical location where the point of which the last fibres of the soleus muscle attach to the Achilles tendon[38]. The AP measure in mm was collected for the ruptured tendon and the asymptomatic side *(Fig. 1)*.

Gap location (GL) and corresponding gap location of contralateral tendon (CGL)

The GL was defined as the location at the Achilles tendon where it is no longer united *(Fig. 2)*.

GL AP thickness was re-measured at 6 weeks *(Fig. 3)* and 10 weeks *(Fig. 4)* for each ruptured tendon. The tendon was also assessed for unification at 6 weeks. A united tendon at 6 weeks was considered for this study to present with continuous tissue which, when dynamically tested with small movements of dorsiflexion and plantar flexion of the foot, moved as a continuum. A previous

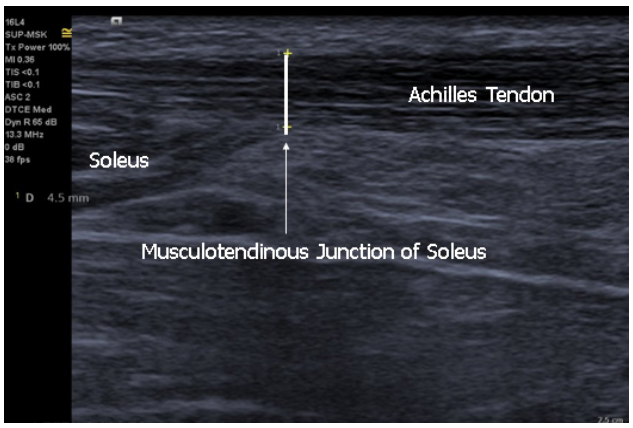


Figure 1. *Musculotendinous junction of soleus. Most distal tip of soleus fibres can be seen inserting at the tendon ventrally.*

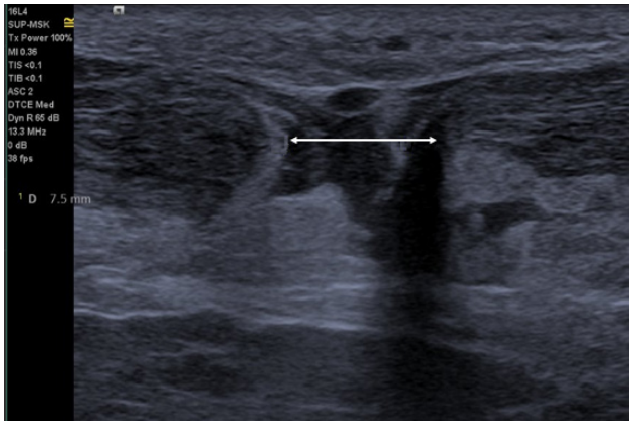


Figure 2. *Gap location of ruptured tendon with tendon margins at arrow.*

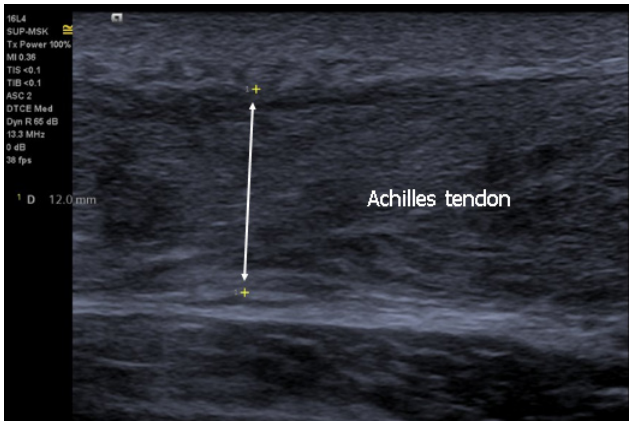


Figure 3. *GL at 6 weeks post rupture with calliper markers.*

review has suggested that unified Achilles tendons post rupture will present with a loss of fibrillar structure and inhomogeneity[36].

The corresponding gap location (CGL) *(Fig. 5)* was captured at each time point. The distal section of the torn tendon margin from the symptomatic side was used to locate a corresponding point on the asymptomatic side known as the CGL.

Distal Section of the torn tendon margin to the OTJ

This measure was a point at the torn distal tendon margin to the OTJ in mm, and was used to determine the GL and CGL at each subsequent visit.

Osseo-tendinous junction (OTJ)

This can be described as the anatomical location where the Achilles tendon crosses the most proximal point of the posterior surface of the calcaneus.

All ultrasound findings were saved and reported on local Radiology Information System (RadIS).

Data collected

At baseline six measures were collected at the ruptured side and three measures at the asymptomatic side:

- Ruptured Achilles tendon:
  1) Distal section of the torn tendon margin to the OTJ (mm) *(Fig. 6)*;
  2) Tendon gap size with the foot at 90 degrees (mm) *(Fig. 2)*;
  3) Tendon gap size with foot fully plantarflexed (mm);
  4) Anterior-posterior thickness of the MTJ;
  5) Anterior-posterior thickness of the tendon gap (mm) *(Fig. 1)*;
  6) Anterior-posterior thickness of the OTJ (mm) *(Fig. 7)*.
- Asymptomatic Achilles tendon:
  1) Anterior-posterior thickness of the corresponding gap location (CGL) (mm) *(Fig. 5)*;
  Note: measure 1 of the ruptured side was used to locate a corresponding point on the asymptomatic side;
  2) Anterior-posterior thickness of the MTJ (mm) *(Fig. 1)*;
  3) Anterior-Posterior thickness of the OTJ (mm) *(Fig. 7)*.

At 6, 10 and 20 weeks 3 measures were collected for the symptomatic ruptured and asymptomatic sides of each Achilles tendon:

- Ruptured Achilles:
  1) Anterior-posterior thickness of the MTJ (mm);
  2) Anterior-posterior thickness of the gap location (mm). Measure 1 from baseline was utilised to locate the same point at each visit. *(Fig. 3 and 4)*;
  3) Anterior-posterior thickness of the OTJ (mm).
- Asymptomatic Achilles:
  1) Anterior-posterior thickness of the MTJ (mm);
  2) Anterior-posterior thickness of the CGL (mm). Measure 1 from baseline was utilised to locate the same point at each visit;
  3) Anterior-posterior thickness of the OTJ (mm).

A patient reported outcome measure, Achilles tendon rupture index (ATRS) was also carried out at each contact (0, 6, 10, 20 weeks).

RESULTS

Statistical analysis

86 males and 14 females (ratio 43:7) were included in this study with an average age of 47.5, median age of 45.5 and an age range of 22-88. All data were collected in excel database clinically designed for this study. No complications were noted in the total sample.

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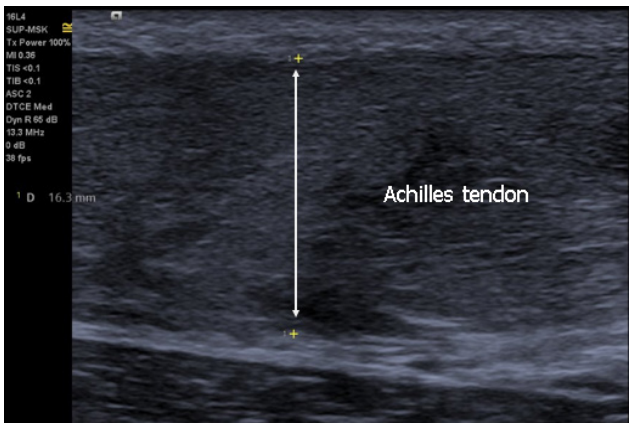


Figure 4. *GL at 10 weeks post rupture with calliper markers.*

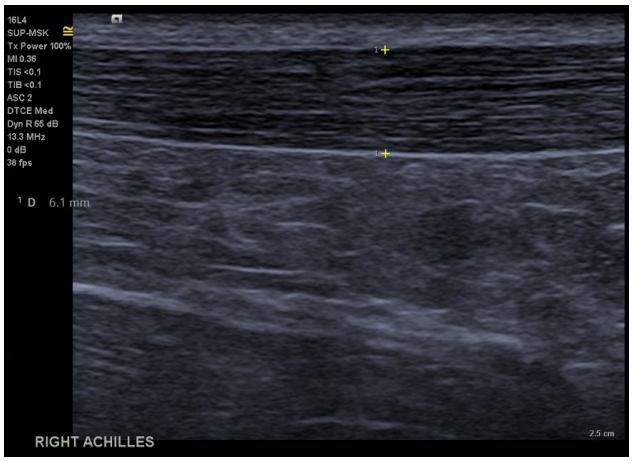


Figure 5. *CGL with calliper markers.*

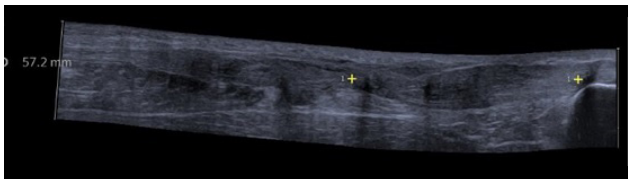


Figure 6. *Distal Section of the torn tendon margin to the OTJ.*

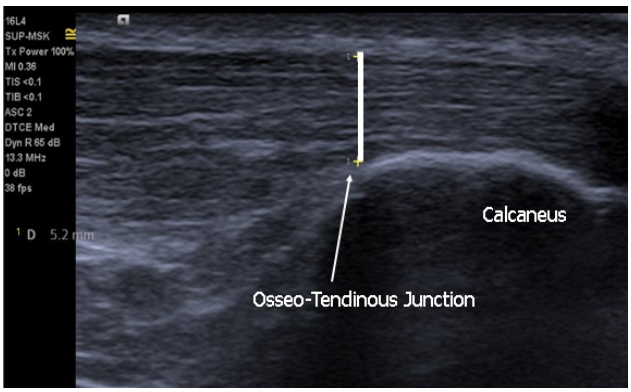


Figure 7. *Osseo-tendinous junction of Achilles tendon.*



Figure 8. *Clinical ultrasound technique.*

Ruptured side AP measures

The Shapiro-Wilk test for the ruptured side data for each week at each anatomical location i.e. MTJ, GL and OTJ demonstrated a normal distribution apart from week 0 of the MTJ and Gap locations *(Table 1)*.

As the Shapiro-Wilk test demonstrated normal distribution for weeks 6, 10 and 20, an ANOVA was carried out on these time points only to determine if there were significant differences in the measures over this time period *(Fig. 9 and Table 2)*.

The ANOVA results conclude that there were statistically significant differences among the means of the three anatomical locations (MTJ, GL, OTJ) for the three time points (weeks 6, 10, and 20). This suggests that the AP measure changes significantly over time across the three time points.

The ruptured tendon AP thickness was recorded as 0 mm for the initial contact i.e 0 weeks *(Table 3)*.

The mean range of the ruptured location was 58.6 mm with a minimum of 14.1 mm and a maximum of 73.3 mm from the osseo-tendinous junction. 85/100 patients ruptured between 30 mm and 60 mm from the osseo-tendinous

	Rupture side MTJ		Rupture side gap		Rupture side OTJ	
	Shapiro-Wilk statistic	p value	Shapiro-Wilk statistic	p value	Shapiro-Wilk statistic	p value
Week 0	0.9661	0.0162	0.9011	0	0.9892	0.1871
Week 6	0.9813	0.169	0.9864	0.3959	0.9642	0.014
Week 10	0.9897	0.647	0.9891	0.6008	0.9611	0.0086
Week 20	0.9858	0.3563	0.9866	0.4062	0.9323	0.0002

Table 1. *Shapiro-Wilk test of ruptured side data of each anatomical site (MTJ, Gap, OTJ) for weeks 0,6,10,20.*

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Rupture side MTJ		Rupture side gap		Rupture side OTJ	
ANOVA	p value	ANOVA	p value	ANOVA	pvalue
3.6305	0.0278	35.777	0	7.7424	0.00005

Table 2. *ANOVA of the Ruptured tendon sites MTJ, GL, OTJ over 6,10 and 20 weeks.*

	MTJ	GL	OTJ
0 weeks	7.06	0	5.8
6 weeks	8.76	8.65	7
10 weeks	9.9	11	6.3
20 weeks	11.9	14.3	6.6

Table 3. *Ruptured tendon Average AP measures of MTJ, GL, OTJ from 0-20 weeks.*

junction *(Fig. 10)*. The average gap size with the foot at neutral (90 degrees) was 4.4 mm, range 0-24.5 mm. 69 patients presented with a tendon gap between 0 and 4.9 mm, with the largest gap measuring between 19.6 mm and 24.5 mm for n = 6 patients *(Fig. 11)*.

The ruptured tendon gap reduced with the foot placed in 10 degrees of plantarflexed position during ultrasound. For 80 patients the gap was between 0 and 1.6 mm. 2 patients presented with a gap between 8 and 9.6 mm with the foot plantarflexed *(Fig. 11)*.

Non-ruptured side AP measures

The AP measures for the Asymptomatic contralateral tendon were utilised as a control for this study. None of the asymptomatic tendons demonstrated any abnormalities on grey scale ultrasound. In order to assess whether the data produced by this study presented with a normal distribution a Shapiro-Wilk test was performed for weeks 0, 6, 10, and 20 of the Asymptomatic data set for each anatomical site i.e. MTJ, CGL and OTJ. The Shapiro-Wilk test confirmed the Asymptomatic normative control data for each site did not presents with a normal distribution *(Table 4)*.

As the Asymptomatic data did not present with a normal distribution a Friedman Test was carried out. The Friedman Test concluded there was no statistically significant ($p < 0.05$) difference between measurements for each anatomical location over the time period (0, 6, 10, 20 weeks) *(Table 5)*.

The average measures for each time period of 0, 6, 10 and 20 weeks can be seen in *Table 5* and *Figure 12*.

ATRS data

A Shapiro-Wilk was performed on the ATRS scores at 0, 6, 10 and 20 weeks which demonstrated varying degrees from the distribution of normality *(Table 6)*.

Therefore a Friedman test was applied to detect differences across the multiple measures. The null hypothesis was assumed that there were no significant differences in the four time points. The Friedman test null hypothesis was rejected (test statistic: 22.9464, p value = 0.000) , suggests that there are statistically significant differences in the distributions of the measurements across the four time points.

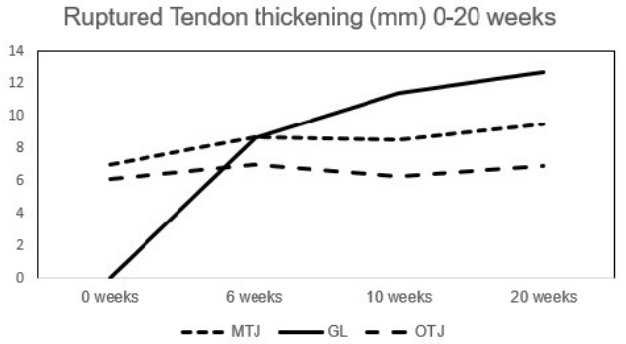


Figure 9. *Ruptured tendon average AP measures (mm) of MTJ, GL, OTJ from 0, 6, 10 and 20 weeks.*

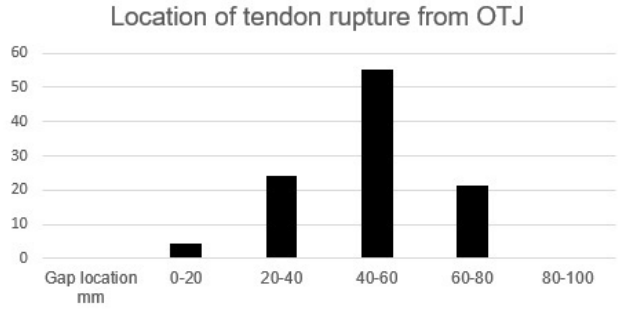


Figure 10*. Rupture Gap location of affected tendons from osseo-tendinous junction of calcaneus to distal tendon margin.*

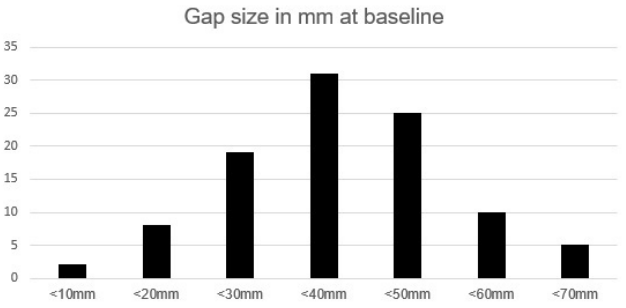


Figure 11*. Gap size of affected tendon at baseline with foot at 90 degrees.*

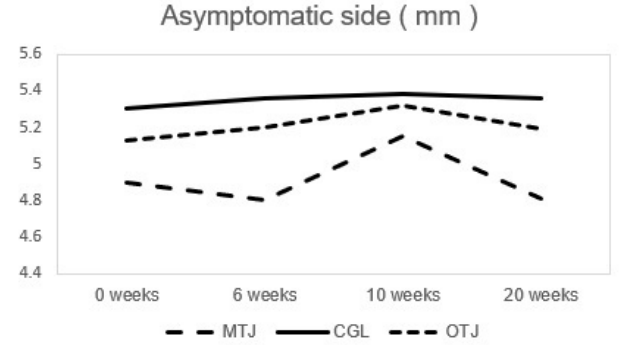


Figure 12*. Asymptomatic AP measures of MTJ, CGL, OTJ for Achilles tendon over 0, 6, 10 and 20 weeks.*

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	MTJ		CGL		OTJ	
	Shapiro-Wilk Statistic	p value	Shapiro-Wilk Statistic	p value	Shapiro-Wilk Statistic	p value
Week 0	0.9223	0	0.9405	0.0003	0.9663	0.008
Week 6	0.9152	0	0.9026	0	0.9638	0.0053
Week 10	0.9104	0	0.8179	0	0.9293	0
Week 20	0.7671	0	0.7427	0	0.933	0.0001

Table 4. *Shapiro-Wilk Test of Asymptomatic Data of each anatomical site (MTJ, GL, OTJ) for weeks 0, 6, 10, 20.*

From baseline (0 weeks) to 20 weeks these data suggest a significant improvement in the ATRS scores from an average score of 3.25 at 0/52 weeks to 83.25 at 20 weeks. This can be observed in *Figure 13*.

At 6 weeks participants with a tendon GL AP thickness of 0-5 mm had an average ATRS of 14/100. Participants with a tendon GL of 5-10 mm had an average ATRS of 39.3/100 and with a tendon GL AP measure of 10-20 mm had an average ATRS of 42.

At 10 weeks participants with a tendon GL AP thickness of 0-5 mm had an average ATRS of 37/100. Participants with a tendon GL o 5-10 mm had an average ATRS of 56.2/100 and with a tendon GL AP measure of 10-20 mm had an average ATRS of 56.7.

At 20 weeks there were no participants with a tendon GL AP thickness of 0-5mm. Participants with a tendon GL o 5-10 mm had an average ATRS of 58.3/100 and with a tendon GL AP measure of 10-20 mm had an average ATRS of 82.9. These data suggest that AP measures of GL is a determinant of ATRS scores.

	MTJ	CGL	OTJ
0 weeks	4.9	5.3	5.13
6 weeks	4.8	5.36	5.2
10 weeks	5.15	5.38	5.32
20 weeks	4.81	5.36	5.19

Table 5. *Asymptomatic tendon measures (mm) of MTJ, CGL and OTJ.*

	ATRS		
	Shapiro-Wilk Statistic	p value	ATRS Score
Week 0	0.8056	0.008	3.25
Week 6	0.8602	0.039	45.9
Week 10	0.9653	0.833	57.63
Week 20	0.7273	0.3563	83.25

Table 6. *Shapiro-Wilk test of ATRS scores for weeks 0, 6, 10 and 20.*

Effects of age and gender

Out of the 100 patients included in this study 86 were male and 14 female. This presents an unequal distribution of gender included in the sample. It may have been beneficial to have been able to include an equal proportion of females within the study, however, these data suggest that over the sample period, males represent a majority of patient presenting with Achilles tendon ruptures.

The age range was 22-88, with the average age 47.1 and the median age 45.5. This study supports previous Achilles tendon rupture rates prevalence in mid-age bracket cited in a review by Egger et al., 2017[40]. The age range provides a representation across ages, however the patient distribution in this study 0-39 was 22.5%, 40-59 was 65% and 60-90 was 12.5% of cases. Pearson's correlation coefficient of final 20 week ATRS score suggested that age does not appear to be correlated with outcomes for ATRS or AP thickness ($p \leq 0.05$).

Unexpected findings

During this study 1 participant sustained a partial re-rupture due to a fall at the 2 week mark during the pathway. In addition to this 1 participant was diagnosed with a VTE which was managed in A&E with appropriate anticoagulation. Both these participants proceeded to full healing uneventfully by the 20 week stage.

DISCUSSION

This is the first study available to provided longitudinal ultrasound measures of Achilles rupture healing from 0-20 weeks for conservatively managed Achilles tendon ruptures. Previous research has examined the use of ultrasound at initial contact to provide diagnostics and to determine management approaches[39,40].

This study supports previous research which has concluded that diagnostic ultrasound is useful not only in the diagnosis but also to determine pathway management based on anatomical findings[40]. The male to female ratio in this study was 43:7 which is higher than a previous study of 3:1[3].

All participants in this study achieved a fully united tendon at 6 weeks post rupture. We were unable to locate previous studies supporting this finding at 6 weeks along the pathway for conservatively managed patients. In a previous study, post operative ultrasound and MRI images of surgically repaired Achilles tendons revealed the tendon was larger and wider than the intact tendon, with a loss of fibrillar structure. The reported thickness of operated tendons had a mean thickness of 10 mm (range 7-16 mm)[41]. In this study 1 participant sustained a partial re-rupture at 2 weeks along the pathway. This study did not carry out a long term review of re-ruptures rates following the 10 week period.

A previous systematic review and meta-analysis of surgical versus conservatively managed Achilles tendon ruptures concluded that surgical management was more effective in reducing the re-rupture rates (65% lower rates) of Achilles tendons post management[7]. An increase in chronic pain in surgical cases compared to conservative management was also reported. Within this review 10 articles were examined from an original pool of 2,452. While the results of this review appear in favour of surgical management, there are systematic sample size imbalances within the studies included in the review which may limit the reliability of the conclusion. For example the sample size utilised in the Miller 2005 study cited in Guevara-Chávez et al.[7] had a ratio of 140 surgical to 32 conservatively managed patients within the study. Further to this five out of ten studies utilised in the review had a sample size imbalance of 1.5:1 and higher for surgical to conservative cases[7]. Another systematic review of 22 articles of surgically managed Achilles ruptures suggested a predictable return to sport and acceptable recovery function[42]. It is worth mentioning that on occasions conservatively managed patients may proceed to surgical management due to post healing lengthening of the tendon. In these cases surgical restoration of tendon and calf length provides successful outcomes[43].

This study demonstrated the anterior-posterior (AP) thickness of the ruptured site of the Achilles tendon increased in thickness significantly through ought the 20 week time period. The largest observed increase in average AP thickening of the AT was observed between 0 and 6 weeks i.e. 1.44 mm thickening per week. This decreased to 0.58mm thickening per week between 6 and 10 weeks, suggesting decreased hypertrophy of the AT. The AP thickening between weeks 10 and 20 was 0.56 mm per week. A previous review of the sonographic appearances of Achilles tendon ruptures has suggested an average AP thickness of 11.7 mm[44]. In this present study the average AP thickening observed at 20 weeks was 12.75 mm. No previous suggestions for variations in age and gender were evaluated[44].

There may be a sustained thickening between weeks 10 and 20 as a result of increased tendon loading between this time period due to the commencement of full weightbearing and tendon loading exercises by the participants, following removal of the boot at 10 weeks. Previous research by Langberg et al 2001[45] has suggested anabolic process and collagen type 1 is increased with training. In addition, Milgrom et al., 2014[46] demonstrated an increased cross sectional thickness of Achilles tendons with rigorous endurance type training, suggesting the ability of the Achilles tendon to remodel itself and in addition strengthen in response to load.

The OTJ AP measures remained relatively stable through ought the 20 weeks (from 5.8 to 6.6 mm). Whereas the MTJ AP measure of the tendon increased by 4.84 mm in total. The symptomatic Gap measures at 6 weeks were thicker (8.6 mm) than comparative normative tendon measures (5.3 mm) at the same time point.

In this study 85/100 patients ruptured between 30 and 60mm above the OTJ, supporting previous research suggesting 80% of patients rupture 30-60 cm above the insertion of the tendon at the calcaneus[47]. The reason suggested for this is that this is the anatomically thinnest part of the tendon and is subject to higher loads as a result, making it susceptible to potential rupture.

For this study there was a requirement to select three anatomical locations in the longitudinal plane at each tendon. It was therefore decided to measure AP only in the longitudinal plane utilising medio-lateral motion of the transducer to establish the thickest portion of the tendon at each site. A previous study of sonographic measures of Achilles tendons in patients with seronegative spondyloarthropathy were also successfully measured in the AP plane[48]. Previous research has suggested the optimal plane to measure Achilles' tendon anterior-posterior thickness is in the short axis[49]. In the paper by Nadeau et al., 2016[49] the minimal detectable change of quantitative ultrasound measures were evaluated of Achilles tendon measures. However, there were limited numbers of participants in the study, in addition the acquisition and interpretation of the ultrasound images may also have been a limitation, particularly due to the minimal experience of the physiotherapist carrying out the measures who received only 10 hours of training for the study Nadeau et al., 2016[49]. In contrast to this the consultant podiatrist carrying out the measures within this study has extensive experience within this field and this factor should be taken into consideration when comparing the appropriateness of AP measures in the long and short axis.

Previous OTJ measures have been demonstrated to have excellent Test-Re-test and intraclass correlation coefficients[49]. However Brouwer et al., 2018[50] utilised this measurement for Achilles length measures which required increased accuracy, particularly in the axial plane. One of the benefits to utilising one person as an evaluator to capture the ultrasound measures in this study is that this may reduce variation in measures, such as varying pressures on the ultrasound probe, which may influence

anatomical measures[50].

The ATRS data demonstrated significant improvement in patient outcomes and mobility across the 20 weeks, with the greatest improvements observed at 6 and 20 weeks (45.9 and 83.25 respectively). Participants with thicker AP measures of the healing tendon gap site appeared to produce higher ATRS scores, suggesting that functional outcomes are dependent on thickness of tendon healing. This supports a previous study comparing two protocols for Achilles tendon rehabilitation following surgical repair suggested a slowed-down protocol (SDP) offered more favourable Achilles Tendon Resting Angle and ATRS results compared to more traditional protocol. The SDP utilised a pathway whereby the removal of the wedges began at 4 weeks and the boot was removed at 8 weeks[51]. Comparatively, this study utilised a pathway where wedges were removed at 6 weeks and the boot removed at 10 weeks.

A limitation of this study was that no post healing tendon length measure was utilised eg. Achilles Tendon Resting Angle[51] to determine if the tendons in this cohort had healed long. Emphasis was instead placed on functional outcome measures i.e. ATRS. It is recommended that future research should include Achilles tendon length measures in particular measures of OTJ to MTJ.

The results of this paper may inform future research on shorter conservative pathways e.g. Leicester Achilles Management Protocol[52], particularly informing tendon thickness at each stage of the pathway and capturing ultrasound data for individualised patient management. The authors of this study have amended the Achilles management pathway utilised in this study to inform the development of a new hybrid pathway known as IMPACT ("Individualised Management Pathway of Achilles ruptures Cwm Taf") for local use. This new pathway utilises length measures of Achilles tendon healing and diagnostic ultrasound in order to monitor tendon thickness at each patient contact on the pathway, with view to informing a more individualised management based on tendon healing.

CONCLUSION

All ruptured Achilles tendons became fully united and significantly thickened by the six week time point on the pathway. By the end of the pathway significant AP thickness was observed in most cases, with significant improvements in ATRS scores. AP measure thickness at each time point was a determinant of higher ATRS scores. The asymptomatic tendons remained the same thickness across all measured sites. No significant differences in AP thicknesses were observed in the OTJ and MTJ measures of the symptomatic or tendons. Future studies of Achilles tendon rupture healing inter rater reliability may be beneficial, particularly an individualised patient pathway based on anatomical changes in tendon thickness.

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