Journal of Orthopaedic Surgery and Research

RESEARCH

Open Access

Functional outcomes following minimally invasive Achilles rupture repair: a retrospective comparative study of PARS and midsubstance speedbridge techniques

John J. Peabody[1,2], Steven M. Hadley, Jr.[1], Rachel Bergman[2], Sarah J. Westvold[3], Fikayo O. Olamigoke[1], Shaun Chang[2], Milap Patel[2] and Anish R. Kadakia[2,4*]

Abstract

Background Prior studies have compared patient-reported outcomes between open repair and one of either the two minimally invasive techniques for Achilles tendon rupture: Percutaneous Achilles Repair System (PARS) and Midsubstance Speedbridge Implant System (MSB). However, no study has compared patient-reported outcomes measured by Patient Reported Outcomes Measurement Information System (PROMIS) physical function (PF) and PROMIS pain interference (PI) and the Achilles Tendon Total Rupture Score (ATRS) between PARS and MSB. Our study compared patient-reported outcomes measured by PROMIS and ATRS scores between PARS and MSB. We hypothesized that patient-reported outcomes would be similar between groups.

Methods This was a retrospective review of 434 patients who underwent Achilles rupture repair from 2018 to 2023 at a single institution. Tendinopathies, open injuries, concomitant fractures, tendon transfers, gastrocnemius recessions, and open repairs were excluded. A total of 316 patients met inclusion criteria and were contacted to complete a postoperative questionnaire containing PROMIS and ATRS. 119 (78 PARS and 41 MSB) completed all surveys and were included for final analysis. Wilcoxon rank-sum and Kruskal-Wallis tests were used to assess differences in mean scores. Chi-squared and Fisher's exact tests were used to compare incidence of complications. All tests were conducted at a significance level of $\alpha = 0.05$.

Results Average follow-up was 30 months at time of survey completion. There were no significant differences in PROMIS PF, PROMIS PI, and ATRS measures between groups ($p > 0.05$). Mean PARS PROMIS PF, PROMIS PI, and ATRS were 58.8, 44.2, and 86.0, respectively. Mean MSB PROMIS PF, PROMIS PI, and ATRS were 55.3, 44.0, and 82.5, respectively. No significant differences existed in incidence of each postoperative complication between groups ($p > 0.05$).

Conclusion In the largest study to compare patient-reported outcomes between PARS and MSB, outcomes were similar between both groups. Both techniques resulted in PROMIS PF greater than the population mean and PROMIS

*Correspondence:
Anish R. Kadakia
Akadaki1@nm.org

Full list of author information is available at the end of the article

PI lower than the population mean. Each had similar ATRS scores. Overall, both MSB and PARS were safe and effective strategies for surgically managing Achilles ruptures.

Keywords Achilles, Achilles tendon rupture, Achilles tendon rupture repair, PROMIS, Patient-reported outcomes, Speedbridge, PARS, Minimally invasive surgery

Background

Achilles tendon ruptures occur at an incidence of 5–10 per 100,000 people in the general population and impacts up to 8.3% of competitive athletes [1–5]. If the tendon is lengthened beyond 8% of its physiological length, the tendon ruptures [6]. While Achilles ruptures commonly occur during traumatic injury during sports due to overextension, other risk factors include poor conditioning before exercise, fluroquinolone or corticosteroid use, older age, male sex, previous tendinopathy, renal disease, sciatica, and prior rupture [7–10].

Prior literature supports operative management for Achilles tendon ruptures, as nonoperative management has a 10 times greater risk of re-rupture compared to operative management [11, 12]. Although surgical management has associated risks, reported complication rates are low [13–17]. Operative management also results in improved function and rates of return to pre-injury activity level (PIAL) compared to nonoperative management [11–19].

The optimal surgical technique remains controversial. Traditionally, an open approach was utilized where Krackow locking sutures are used to grasp each end of the torn tendon and bring them together for end-to-end repair with the foot in plantarflexion [20]. While this open approach allows for direct visualization of the rupture and sural nerve, this technique requires a larger incision compared to minimally invasive surgery (MIS) and prior studies have demonstrated increased risk and incidence of wound complications compared to MIS [15, 18, 21–27]. McMahon et al. found in a meta-analysis that MIS reduces the risk of superficial wound infection, with three-times greater patient satisfaction compared to open [27].

Of the two MIS techniques, the Percutaneous Achilles Repair System (PARS) (Arthrex Inc; Naples, FL) approximates the distal and proximal ends of the ruptured Achilles through smaller incisions than are required for open repair. PARS utilizes nonlocking and locking sutures to grasp the tendon ends and potentially improves the strength of the repair, allowing for earlier mobilization [28]. Hsu et al. found that 98% of patients treated with PARS returned to PIAL in five months compared to 82% of patients managed with open repair [29]. Moreover, though not reaching statistical significance, Hsu et al. revealed that PARS has decreased rates of sural neuritis and wound infections compared to open repair (0% vs. 3.0% and 0% vs. 1.8%, respectively) [29].

The Midsubstance Speedbridge Implant System (MSB) (Arthrex Inc; Naples, FL) uses the PARS jig to fasten the proximal tendon and two suture anchors distally to secure the tendon at its attachment on the calcaneus. Stake et al. found no significant differences in patient satisfaction and patient-reported outcomes (PROs) between MSB and open repair [26]. Prior biomechanical studies on Achilles repairs using MSB compared to PARS in cadaveric models reported similar strength prior to failure, although the MSB technique may prevent early elongation of the repaired tendon, which may result in faster rehabilitation and improved functional recovery [30, 31].

No prior studies have compared PROs between these novel minimally invasive techniques. It is therefore unknown whether PROs differ between PARS and MSB. Further understanding on any differences in PROs between techniques may help guide decisions on which technique to use. This single center retrospective cohort study contains the largest known number of patients who underwent minimally invasive Achilles repair by either PARS or MSB. The present study aimed to compare PROs between PARS and MSB, as determined by the validated Patient-Reported Outcomes Measurement Information System (PROMIS) measures of physical function (PF) and PROMIS pain interference (PI) and Achilles Tendon Total Rupture Score (ATRS), which are all validated specifically for Achilles rupture [32–42]. We hypothesized that PROs would be similar between PARS and MSB.

Methods

Population

This was an institutional review board approved single-center retrospective cohort study (STU00219496) of all 434 patients who underwent Achilles tendon repair between January 2018-January 2023. Two reviewers independently examined all patients. Tendinopathies, open injuries, concomitant fractures, tendon transfers, gastrocnemius recessions, and open repairs were excluded. 316 remaining patients were emailed postoperative questionnaires via REDCap (Research Electronic Data Capture, Nashville, TN) [43]. Patients were contacted a minimum of one year post-operatively. After two initial emails, patients were then called one week after initial emails were sent if they did not respond and if they had not declined consent. Subsequently, two more follow-up emails were sent prior to ceasing contact attempts. 136 patients completed the questionnaire (89 PARS, 47 MSB). 17 patients were subsequently excluded due to lack of

sufficient follow-up and/or incomplete survey responses. 119 patients (78 PARS, 41 MSB) were included for final analysis (Fig. 1). Surgeon preference ($n=4$) determined whether patients received PARS or MSB.

Outcomes

The primary outcomes were PROMIS PF and PROMIS PI and ATRS. PROMIS exhibits extensive reliability and an effective ability to detect clinically meaningful differences in functional outcomes compared to other legacy scales including the Foot and Function Index and the Foot and Ankle Ability Measure [36, 37]. The ATRS is a validated metric that assesses function specific to an Achilles injury and has demonstrated substantial reliability and consistency as an outcome measure following Achilles rupture [38–42]. PROMIS PF and PROMIS PI calculate a t-score from adaptive questionnaires that have been developed for a mean US general population score of 50 [33]. Higher PROMIS PF indicates better physical function, while higher PROMIS PI indicates more pain interfering

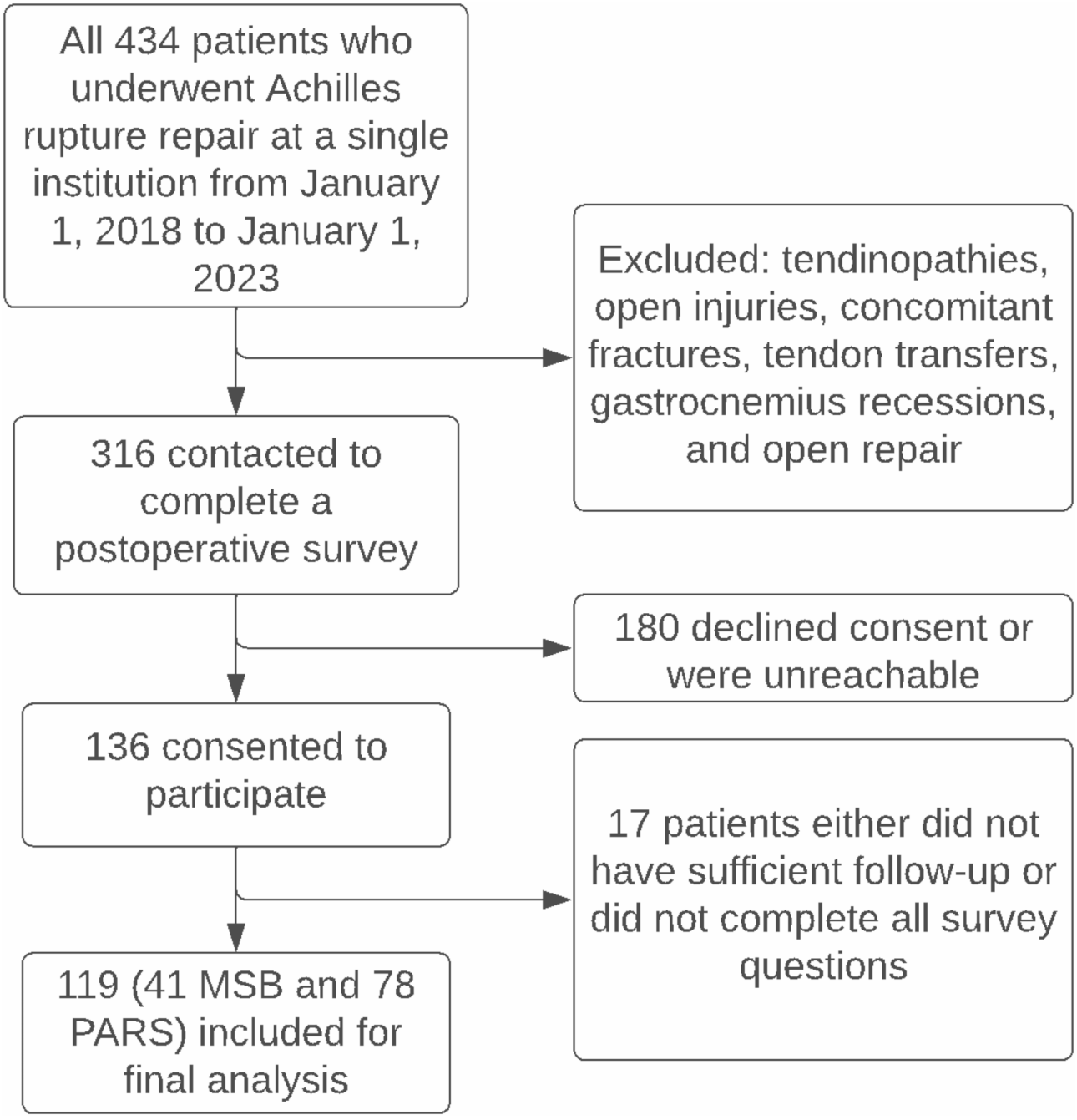

Fig. 1 Study flowchart

with activity [33]. The reported minimal clinically important difference (MCID) within foot and ankle orthopedic population is 3–30 for PROMIS PF and 3–25 for PROMIS PI [33]. The ATRS is a 10-item questionnaire with a maximum score of 100 indicating no functional limitations specific to Achilles injuries. The reported MCID is 8–10 [38, 41, 42].

Secondary outcomes included self-reported return to PIAL and months to achieve PIAL. The survey queried patients' activity level both before and after surgery. "Sedentary" was defined as little to no activity, "light" as little daily activity including walking, "moderate" as moderate daily activity, on feet most of the day, moderate intensity recreational athletics, shelf stacking, street salespeople etc., and "high" as hard daily activity, working long days with intense labor, high intensity athletics, etc.

Postoperative complications between groups were compared, including deep vein thrombosis (DVT), pulmonary embolism (PE), sural nerve injury, re-rupture, superficial wounds (wound dehiscence) and deep wounds (wound infections) and reoperations. The incidence of heel pain at final follow-up was also examined.

Surgical technique

Both MIS techniques were previously described in the literature [44]. All patients were given preoperative antibiotics and placed in the prone position after either regional block or general anesthesia. The operative extremity was supported by a small bolster, with the feet extending beyond the end of the surgical table. Sequential Compression Devices (SCD) were used on the contralateral leg to for venous thromboembolism (VTE) prophylaxis.

For the PARS repair, a 3 cm longitudinal incision was made paramedially, 1 cm proximal to the distal stump of the ruptured tendon extending toward the proximal stump. The crural fascia and paratenon were incised, and the rupture was identified via blunt dissection. Two Allis clamps were used to grasp the distal ends of the proximal stump within the paratenon which was then pulled longitudinally through the incision. The PARS jig was inserted into the proximal paratenon sheath with the inner arms around the proximal stump. In total, five sutures (FiberTape, Arthrex Inc; Naples, FL) were passed through the PARS jig and proximal stump creating one locking stitch and two nonlocking sutures. The inner arms of the PARS jig carrying the sutures were then removed from the incision and tension is placed on the sutures. The PARS jig was then reinserted in the same fashion distally. The sutures from the proximal stump were passed through the PARS jig into the distal stump. Sutures were preconditioned by placing axial tension on each suture individually for 20 cycles to prevent suture creep postoperatively. The inner arms of the PARS jig were removed with the sutures. The sutures were tied to secure the repair [45].

Tensioning was performed with the ankle positioned in at least 15 degrees of plantarflexion with maximum tension applied to the repair to ensure apposition. Prior to cutting the suture, the foot was dorsiflexed to assess the quality of the repair and to ensure significant tension at -5 degrees of plantarflexion. The repair was then tested via the Thompson test prior to closure [46].

Wound closure was performed in standard fashion regardless of repair system utilized. The paratenon and subcutaneous tissue were approximated with Monocryl sutures and the skin with nylon sutures. A sterile xeroform dressing was placed onto the wound, followed by a well-padded splint in resting plantarflexion. All patients were instructed to take aspirin 325 mg orally twice per day for 30 days for DVT prophylaxis unless risk factors were present for VTE (such as smoking, prior VTE, or anticoagulation use.)

For MSB, the same approach was utilized using the PARS jig. Two stab incisions were then made over the calcaneus, and the calcaneus was drilled for medial and lateral anchor placement using a 3.4 mm drill bit. The sutures of the proximal stump were retrieved using a Banana SutureLasso (Arthrex Inc; Naples, FL), and maximum tension was applied to the tendon. The sutures were then loaded on the BioComposite SwiveLock eyelet. The BioComposite SwiveLock anchor (Arthrex Inc; Naples, FL) was inserted into each anchor hole, which secured the sutures into the calcaneus. In 2021, the surgeons in this investigation modified the MSB technique to adjust to superior to inferior placement of anchors from prior posterior to anterior position on the calcaneus in efforts to minimize postoperative heel pain.

All patients began an accelerated functional rehabilitation protocol detailed in prior literature [44, 47]. Patients were non-weight bearing in a splint for the first two weeks postoperatively, after which they were seen in clinic for a wound check. If healed appropriately, the sutures were removed, and the patient was transitioned into a weightbearing tall controlled ankle motion (CAM) boot with two 1 cm heel lifts. Physical therapy (PT) was begun at two weeks with a detailed protocol with removal of one lift at four weeks and the second lift at six weeks. Transition to athletic shoewear was initiated at six weeks with one 1 cm lift in the shoe, which was subsequently removed at nine weeks postoperatively. By 12 weeks postoperatively patients began increasing dynamic weight bearing exercises and sport-specific retraining. PT was progressed strengthening and low impact activity (biking, elliptical, swimming, walking).

Table 1 Patient Characteristics

	Total	PARS-PARS	PARS-Speedbridge	*p*-value
Total	**119**	**78 (65.5)**	**41 (34.5)**	
Sex				0.84
Female	20 (16.8)	14 (17.9)	6 (14.6)	
Male	99 (83.2)	64 (82.1)	35 (85.4)	
Age				0.57
19(min)-30	31 (26.1)	20 (25.6)	11 (26.8)	
31–40	45 (37.8)	32 (41.0)	13 (31.7)	
41–69 (max)	43 (36.1)	26 (33.3)	17 (41.5)	
BMI				0.11
18.0 (min)-25	24 (20.2)	20 (25.6)	4 (9.8)	
> 25–29	54 (45.4)	33 (42.3)	21 (51.2)	
> 29-41.2 (max)	37 (31.1)	22 (28.2)	15 (36.6)	
Smoking				0.12
No	115 (96.6)	77 (98.7)	38 (92.7)	
Yes	4 (3.4)	1 (1.3)	3 (7.3)	
Diabetes				-
No	116 (97.5)	75 (96.2)	41 (100.0)	
Yes	2 (1.7)	2 (2.6)	0 (0.0)	
Return to pre-injury level of activity				0.67
No	45 (37.8)	29 (37.2)	16 (39.0)	
Yes	74 (62.1)	49 (62.8)	25 (61.0)	

Table 2 Patient reported outcomes of minimally invasive Achilles rupture repair

	PROMIS Physical Function		PROMIS Pain Interference		ATRS		Time to return to pre-injury level of activity	
	Mean (SD)	*p*-value	Mean (SD)	*p*-value	Mean (SD)	*p*-value	Mean (SD)	*p*-value
Overall	44.1 (6.3)		57.6 (8.1)		84.8 (15.4)		9.3 (5.0)	
Technique								
PARS-PARS	58.8 (8.7)	0.07	44.2 (6.3)	0.9	86.0 (14.5)	0.21	9.3 (5.0)	0.96
PARS-Speedbridge	55.3 (6.3)		44.0 (6.5)		82.5 (17.0)		9.4 (5.0)	
Presence of Complications		0.61		0.88		0.41		0.09
No complication	57.3 (7.5)		44.09 (6.2)		85.0 (14.5)		9.5 (4.9)	
Any complication	60.2 (12.8)		44.71 (8.2)		83 (24.3)		6.2 (5.3)	
Level of activity		0.54		0.22		0.63		0.55
Light	54.4 (6.9)		44.8 (6.7)		85.2 (14.3)		8.7 (4.7)	
Moderate	57.2 (9.0)		43.9 (6.5)		82.8 (18.1)		8.9 (4.5)	
High	59.4 (7.7)		43.7 (5.8)		87.4 (11.7)		11.0 (5.9)	

Statistical analysis

Hypothesis-driven testing with R Version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria) was used. Wilcoxon rank-sum test was used to assess differences in distribution of PROMIS and ATRS scores for comparisons of two groups. Kruskal-Wallis test was used for comparisons of more than two groups. Fisher's exact test was employed to compare incidence of heel pain at final follow-up and incidence of complications between PARS and MSB. With a sample size of 119, the study had 80% power to detect a moderate effect size (Cohen's d = 0.36) using a two-sided test at a 0.05 significance level.

Results

Table 1 displays no significant differences in baseline characteristics between groups. Average follow-up was 30 months at time of survey completion. No statistically significant differences were observed in PROMIS PF, PROMIS PI, and ATRS between groups ($p > 0.05$, Table 2). Mean PARS PROMIS PF, PROMIS PI, and ATRS were 58.8, 44.2, and 86.0, respectively. Mean MSB PROMIS PF, PROMIS PI, and ATRS were 55.3, 44.0, and 82.5, respectively. Mean months to achieve PIAL was 9.3 for PARS and 9.4 for MSB ($p = 0.96$). No significant differences were observed in ability to achieve PIAL between groups ($p = 0.67$, Table 3). PIAL, regardless of technique, was not associated with ability to achieve PIAL ($p = 0.79$, Table 3).

Table 3 Number of patients who returned to Pre-Injury level of activity by Pre-Injury activity level

	Total	No	Yes	*p*-value
Total		45 (37.8)	74 (62.1)	
Pre-injury level of activity				0.79
Light	37 (31.1)	12 (32.4)	25 (67.7)	
Moderate	50 (42.0)	20 (40)	30 (60)	
High	32 (26.9)	13 (40.6)	19 (59.4)	

Table 4 Incidence of complications

	PARS-PARS	PARS-Speedbridge	*p*-value
Total	78 (65.5)	41 (34.5)	
DVT			1
No	77 (98.7)	41	
Yes	1 (1.3)	0	
PE			1
No	78	41	
Yes	0	0	
Sural Nerve Injury			0.29
No	74 (94.9)	41	
Yes	4 (5.1)	0	
Nerve block			
No	78	41	
Yes	0	0	
Re-rupture			0.54
No	76 (97.4)	41	
Yes	2 (2.6)	0	
Wound Complications			0.42
No	77 (98.7)	39 (95.2)	
Superficial	1 (1.3)	1 (2.4)	
Deep	0	1 (2.4)	
Return to OR			0.61
No	76 (97.4)	39 (95.1)	
Yes	2 (2.6)	2 (4.9)	
Heel Pain			0.04
No	78	38 (92.7)	
Yes	0	3 (7.3)	
Any Complication			1
No	71 (91.0)	38 (92.7)	
Yes	7 (9.0)	3 (7.3)	

No significant differences were observed in incidence of postoperative complications between groups (Table 4). The complications rates for PARS and MSB, respectively, were 1.3% (1/78) and 0% DVT, 5.1% (4/78) and 0% sural nerve injury, 2.6% (2/78) and 0% re-rupture, 1.3% (1/78) and 2.4% (1/41) superficial wounds, 0% and 2.4% (1/41) deep wounds, and 2.6% (2/78) and 4.9% (2/41) reoperation. There was a higher incidence of heel pain at final follow-up in MSB (0% vs. 7.3%, $p = 0.04$).

All four sural nerve injuries resolved by final follow-up with no neurological sequelae. The reason for reoperation was incision and drainage in two cases (one PARS, one MSB), one re-rupture (PARS), and one hardware removal (MSB).

Discussion

Both MIS Achilles repair techniques resulted in similarly excellent PROs. PARS had mean PROMIS PF of 58.8, PROMIS PI of 44.2, and ATRS of 86. MSB had mean PROMIS PF 55.3, PROMIS PI of 44.0 and ATRS of 82.5.

Both techniques demonstrated PROMIS PF superior to the US population mean [33]. Despite prior injuries, these patients likely have higher PROMIS PF than the population mean given a greater incidence of Achilles ruptures in active and physically fit people who likely had higher preoperative PROMIS scores [48]. We postulated that these MIS techniques can return patients to their pre-injury level of function and does not imply that surgery improves their level of functioning. These group means were similar to reported PROMIS PF

after Achilles repairs with MIS (54.8) and open (56.4), described by Caolo et al. [49]. Mean PROMIS PF trended towards a greater value in PARS compared to MSB, but this did not reach statistical significance. Hung et al. concluded that scores within the interquartile range (IQR) should be used for decision-making rather than values on the edge of the ranges [33]. Given that the difference in the t-value was 3.5, this difference was likely neither clinically relevant nor significantly dissimilar, as the value failed to meet the lower end of the IQR (5.0) reported by Hung et al. and failed to reach statistical significance [33].

Both groups reported lower PROMIS PI than the US population mean (50) [33]. Lower PROMIS PI may reflect higher PIAL among patients who sustain Achilles ruptures [48]. Both groups had similar PROMIS PI, which corroborated prior literature where Caolo et al. reported mean PROMIS PI of 45.3 for MIS and mean PROMIS PI of 45.3 for open repair [49]. Despite heel pain occurring more frequently in MSB, the presence of heel pain did not impact PROMIS PI.

The mean ATRS did not significantly differ between groups. These results corroborate prior literature; Attia et al. reported in a meta-analysis a mean of 84.8, Metz et al. in a retrospective study a mean of 84, and Maffulli et al. a mean of 90.5–90.7 [50–52]. Nilsson-Helander et al. surveyed 52 healthy individuals without prior Achilles rupture and identified a mean ATRS of 99.8 [41]. Perhaps fear of reinjury impacted patient ability to perform some activities investigated in the ATRS, which may account for lower ATRS scores than those of the healthy patient mean described by Nilsson-Helander et al. [41]. Fear of reinjury impacting functionality is a well-documented limitation for patients recovering from Achilles rupture [53–55]. Kaalund et al. found that 15% (6/39) of badminton players who suffered Achilles ruptures did not return to PIALs out of fear of reinjury despite demonstrating functional capability [53]. Future studies should evaluate strategies to address fear in these patients. Further studies on each individual item of the ATRS should be evaluated in relation to patients' perceptions of fear limiting activity to identify patients who have deficits postoperatively.

Time to return to PIAL did not significantly vary between groups. Zellers et al. reported 80% of patients return to sport at six months [56]. With an average of 9.3 and 9.4 months for MIS, our findings suggested that return to PIAL may take longer than six months, and, depending on activity intensity, may take up to 11 months ("high" PIAL). The discrepancy compared to prior literature may be due to differences in reporting return to activity. Carmont et al. found the greatest increase in ATRS within the first six months after percutaneous Achilles repair with continued increases over 12 months, representing continued functional improvement through the first year postoperatively [57]. Because our survey asked about return to PIAL rather than evaluating trajectory of recovery, patient responses may have been subject to recall bias. Discrepancies in patient interpretation of questions could also explain lower rates of return to PIAL in our study (61.0% MSB, 62.8% PARS) compared to prior literature; Hsu et al. found that 98% of patients returned to pre-injury activities at five months after PARS repair [29]. However, this collection was through internal review of PT evaluations rather than patient-reported surveys [29]. Nevertheless, MSB and PARS were effective in allowing most patients to achieve PIALs, regardless of PIALs. Additionally, prior literature demonstrated that earlier return to activity is a risk factor for re-rupture (31% risk vs. 13% in longer recovery periods), so the longer duration of return to activity with MIS in our study compared to prior literature could enable improved tendon healing, protect against early overextension of the tendon, and lower re-rupture risk [9].

Both techniques demonstrated low complication rates that did not affect PROs, underscoring the safety of MIS repair. The complication rate for MIS repair was 8.4% (10/119), which is consistent with rates reported in the literature [29, 49, 50] and lower than reported rates of 10.6-21% for open repair [22, 29, 49, 50, 58]. Thus, our findings supported MIS in favor of open repair [12, 23].

Deep wound incidence was 0.84% (1/119), which corroborates reported low deep wound incidence following MIS repair (0-2.5%) and proves lower than reported range of 0–5% for open [22, 29, 49, 50]. Two patients experienced re-rupture [1.7% (2/119) total, 2.6% (2/78) PARS, 0% MSB]. Regardless of technique, the cohort's re-rupture rate was lower than rates reported for nonoperative management and similar to reports for open and MIS [11–16, 19, 22, 23, 29, 49, 50, 58]. PARS may have a higher re-rupture rate compared to MSB because the PARS technique relies on the surgical knots to give the repair its strength. In contrast, MSB may be more reproducible, as the strength of the repair is independent of knot-tying, instead depending on suture anchors in the calcaneus.

MSB resulted in greater heel pain incidence at final follow-up than PARS, likely from surrounding soft tissue irritation from anchors placed in the calcaneus. One patient underwent re-operation for MSB anchor removal because of irritation. During reoperation, we found that the interference screw in this patient was prominent. When interference screws are not found prominent, there were no cases of reoperation for symptomatic hardware in this cohort. In 2021, the surgeons in this study modified MSB technique to adjust to superior to inferior from anterior to posterior placement of anchors to minimize heel pain. A prior study conducted by the investigators at this institution demonstrated that this

modification resulted in a lower incidence of heel pain at final follow-up (6.5% vs. 14.8%) [59]. This same study also found that patients who underwent repair with MSB were 70% less likely to have a postoperative complication compared to patients who underwent repair with PARS [59]. Regardless, heel pain did not affect PROs.

The main strength of this study is that it represented the largest cohort in the literature to evaluate PROs of MIS Achilles repair and is the only investigation to examine both validated PROMIS and ATRS within and between groups. Both MIS techniques had low complication rates—lower than values reported for open repair. Because MIS had equivalent PROs compared to the values reported in the literature for open but lower complication rates than those reported in the literature for open, MIS for Achilles repair may be the preferred option for surgical management of Achilles rupture.

This study had some limitations. This retrospective investigation did not collect preoperative PROs to compare changes and baseline PROs. 180 of eligible participants (57%) did not respond to surveys, which may introduce selection bias. This participation rate is similar to the American Orthopaedic Foot & Ankle Society's (AOFAS) established Orthopaedic Foot and Ankle Outcomes Research (OFAR) Network for PROMIS which reported an average 56% survey response rate [60]. Patients may also have interpreted survey questions differently, which introduces measurement bias. Despite patients having adequate follow-up and no significant differences in follow-up between groups, patients were necessarily at different time points post-operatively when responding to the survey (patients did not all fill out the survey at one year post-operatively for example), which may introduce some measurement bias.

Future research should include prospective trials to compare preoperative and postoperative PROs.

Conclusion

PARS and MSB were safe and effective methods for Achilles rupture repair and resulted in excellent PROs. Patients report higher PROMIS PF and lower PROMIS PI than the population mean after both techniques. ATRS and time to achieve PIAL were similar between techniques. Most patients returned to PIAL regardless of MIS technique and PIAL. Both techniques had similarly low complication rates.

Abbreviations

AOFAS	American orthopaedic foot and ankle society
ATRS	Achilles tendon total rupture score
CAM	Controlled ankle motion
DVT	Deep vein thrombosis
IQR	Interquartile range
MCID	Minimal clinically important difference
MIS	Minimally invasive surgery
MSB	Midsubstance speedbridge implant system
OFAR	Orthopaedic foot and ankle outcomes research
PARS	Percutaneous achilles repair system
PE	Pulmonary embolism
PF	Physical function
PI	Pain interference
PIAL	Pre–injury activity level
PROs	Patient reported outcomes
PROMIS	Patient reported outcomes measurement information system
SCD	Sequential compression device
VTE	Venous thromboembolism

Acknowledgements

None.

Author contributions

All authors participated in the conception, design, data acquisition, analysis, interpretation of the data, and drafting of this manuscript.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Data availability

Please contact the corresponding or senior author.

Declarations

Ethics approval and consent to participate

This study received ethical approval from the Northwestern University IRB (STU00219496) on 5/31/23. All patients included consented to participation.

Consent for publication

All patients included consented to have the data presented published.

Competing interests

Anish Kadakia MD: Arthrex: consultant, royalties, Speakers Bureau, DePuy Synthes: royalties, Elsevier: royalties; Steven Hadley: HydroCision, Inc.: consultant.

Author details

[1]Northwestern University Feinberg School of Medicine, Chicago, IL, USA
[2]Department of Orthopaedic Surgery, Northwestern University Feinberg School of Medicine, Chicago, IL, USA
[3]Yale School of Medicine, New Haven, CT, USA
[4]Department of Orthopaedic Surgery, Northwestern University Feinberg School of Medicine, Lavin Family Pavilion, 259 E Erie St 13th Fl, Chicago, IL 60611, USA

Received: 2 February 2025 / Accepted: 22 March 2025
Published online: 18 April 2025

References

1. Leppilahti J, Puranen J, Orava S. Incidence of Achilles tendon rupture. Acta Orthop Scand. 1996;67(3):277–9. https://doi.org/10.3109/17453679608994688
2. Suchak AA, Bostick G, Reid D, Blitz S, Jomha N. The incidence of Achilles tendon ruptures in Edmonton, Canada. Foot Ankle Int. 2005;26(11):932–6. https://doi.org/10.1177/107110070502601106
3. Huttunen TT, Kannus P, Rolf C, Felländer-Tsai L, Mattila VM. Acute Achilles tendon ruptures: incidence of injury and surgery in Sweden between 2001 and 2012. Am J Sports Med. 2014;42(10):2419–23. https://doi.org/10.1177/0363546514540599
4. Sheth U, Wasserstein D, Jenkinson R, Moineddin R, Kreder H, Jaglal SB. The epidemiology and trends in management of acute Achilles tendon ruptures in Ontario, Canada: a population-based study of 27 607 patients. Bone Joint J. 2017;99–B(1):78–86. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0434.R1

5. Kujala UM, Sarna S, Kaprio J. Cumulative incidence of Achilles tendon rupture and tendinopathy in male former elite athletes. Clin J Sport Med. 2005;15(3):133–5. https://doi.org/10.1097/01.jsm.0000165347.55638.23
6. Maffulli N. Current concepts in the management of subcutaneous tears of the Achilles tendon. Bull Hosp Jt Dis. 1998;57(3):152–8.
7. Shamrock AG, Dreyer MA, Varacallo MA. Achilles Tendon Rupture. [Updated 2023 Aug 17]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430844/
8. Godoy-Santos AL, Bruschini H, Cury J, et al. Fluoroquinolones and the risk of Achilles tendon disorders: update on a neglected complication. Urology. 2018;113:20–5. https://doi.org/10.1016/j.urology.2017.10.017
9. Gajhede-Knudsen M, Ekstrand J, Magnusson H, Maffulli N. Recurrence of Achilles tendon injuries in elite male football players is more common after early return to play: an 11-year follow-up of the UEFA champions league injury study [published correction appears in Br J sports med. 2013;47(13):856]. Br J Sports Med. 2013;47(12):763–8. https://doi.org/10.1136/bjsports-2013-092271
10. Maffulli N, Irwin AS, Kenward MG, Smith F, Porter RW. Achilles tendon rupture and sciatica: a possible correlation. Br J Sports Med. 1998;32(2):174–7. https://doi.org/10.1136/bjsm.32.2.174
11. Myhrvold SB, Brouwer EF, Andresen TKM, et al. Nonoperative or surgical treatment of acute Achilles' tendon rupture. N Engl J Med. 2022;386(15):1409–20. https://doi.org/10.1056/NEJMoa2108447
12. Seow D, Yasui Y, Calder JDF, Kennedy JG, Pearce CJ. Treatment of acute Achilles tendon ruptures: A systematic review and Meta-analysis of complication rates with Best- and Worst-Case analyses for rerupture rates. Am J Sports Med. 2021;49(13):3728–48. https://doi.org/10.1177/0363546521998284
13. Cetti R, Christensen SE, Ejsted R, Jensen NM, Jorgensen U. Operative versus nonoperative treatment of Achilles tendon rupture. A prospective randomized study and review of the literature. Am J Sports Med. 1993;21(6):791–9. https://doi.org/10.1177/036354659302100606
14. Jiang N, Wang B, Chen A, Dong F, Yu B. Operative versus nonoperative treatment for acute Achilles tendon rupture: a meta-analysis based on current evidence. Int Orthop. 2012;36(4):765–73. https://doi.org/10.1007/s00264-011-1431-3
15. Khan RJ, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute Achilles tendon ruptures. A meta-analysis of randomized, controlled trials. J Bone Joint Surg Am. 2005;87(10):2202–10. https://doi.org/10.2106/JBJS.D.03049
16. Ochen Y, Beks RB, van Heijl M, et al. Operative treatment versus nonoperative treatment of Achilles tendon ruptures: systematic review and meta-analysis. BMJ. 2019;364. https://doi.org/10.1136/bmj.k5120
17. Wilkins R, Bisson LJ. Operative versus nonoperative management of acute Achilles tendon ruptures: a quantitative systematic review of randomized controlled trials. Am J Sports Med. 2012;40(9):2154–60. https://doi.org/10.1177/0363546512453293
18. Lantto I, Heikkinen J, Flinkkila T, et al. A prospective randomized trial comparing surgical and nonsurgical treatments of acute Achilles tendon ruptures. Am J Sports Med. 2016;44(9):2406–14. https://doi.org/10.1177/0363546516651060
19. Möller M, Movin T, Granhed H, Lind K, Faxén E, Karlsson J. Acute rupture of tendon achillis. A prospective randomised study of comparison between surgical and non-surgical treatment. J Bone Joint Surg Br. 2001;83(6):843–8. https://doi.org/10.1302/0301-620x.83b6.11676
20. Krackow KA, Thomas SC, Jones LC. Ligament-tendon fixation: analysis of a new stitch and comparison with standard techniques. Orthopedics. 1988;11(6):909–17.
21. Carmont MR, Rossi R, Scheffler S, Mei-Dan O, Beaufils P. Percutaneous & mini invasive Achilles tendon repair. Sports Med Arthrosc Rehabil Ther Technol. 2011;3:28. https://doi.org/10.1186/1758-2555-3-28
22. Cretnik A, Kosanovic M, Smrkolj V. Percutaneous versus open repair of the ruptured Achilles tendon: a comparative study. Am J Sports Med. 2005;33(9):1369–79. https://doi.org/10.1177/0363546504271501
23. Grassi A, Amendola A, Samuelsson K, et al. Minimally invasive versus open repair for acute Achilles tendon rupture: meta-analysis showing reduced complications, with similar outcomes, after minimally invasive surgery. J Bone Joint Surg Am. 2018;100(22):1969–81. https://doi.org/10.2106/JBJS.17.01364
24. Lim J, Dalal R, Waseem M. Percutaneous vs. open repair of the ruptured Achilles tendon–a prospective randomized controlled study. Foot Ankle Int. 2001;22(7):559–68. https://doi.org/10.1177/107110070102200705
25. McMellen CJ, Desai B, Sinkler MA, Miskovsky S. Hybrid percutaneous management of acute midsubstance Achilles tendon ruptures. Video J Sports Med. 2023;3(2). https://doi.org/10.1177/26350254231152660
26. Stake IK, Matheny LM, Comfort SM, Dornan GJ, Haytmanek CT, Clanton TO. Outcomes following repair of Achilles midsubstance tears: percutaneous knotless repair vs open repair. Foot Ankle Int. 2023;44(6):499–507. https://doi.org/10.1177/10711007231160998
27. McMahon SE, Smith TO, Hing CB. A meta-analysis of randomised controlled trials comparing conventional to minimally invasive approaches for repair of an Achilles tendon rupture. Foot Ankle Surg. 2011;17(4):211–7.
28. Demetracopoulos CA, Gilbert SL, Young E, Baxter JR, Deland JT. Limited-Open Achilles tendon repair using locking sutures versus nonlocking sutures: an in vitro model. Foot Ankle Int. 2014;35(6):612–8. https://doi.org/10.1177/1071100714524550
29. Hsu AR, Jones CP, Cohen BE, Davis WH, Ellington JK, Anderson RB. Clinical outcomes and complications of percutaneous Achilles repair system versus open technique for acute Achilles tendon ruptures. Foot Ankle Int. 2015;36(11):1279–86. https://doi.org/10.1177/1071100715589632
30. Melcher C, Renner C, Piepenbrink M, et al. Biomechanical comparisons of three minimally invasive Achilles tendon percutaneous repair suture techniques. Clin Biomech (Bristol Avon). 2022;92:105578. https://doi.org/10.1016/j.clinbiomech.2022.105578
31. Clanton TO, Haytmanek CT, Williams BT, et al. A Biomechanical comparison of an open repair and 3 minimally invasive percutaneous Achilles tendon repair techniques during a simulated, progressive rehabilitation protocol. Am J Sports Med. 2015;43(8):1957–64. https://doi.org/10.1177/0363546515587082
32. Hung M, Baumhauer JF, Latt LD, et al. Validation of PROMIS ® physical function computerized adaptive tests for orthopaedic foot and ankle outcome research. Clin Orthop Relat Res. 2013;471(11):3466–74. https://doi.org/10.1007/s11999-013-3097-1
33. Hung M, Baumhauer JF, Licari FW, Voss MW, Bounsanga J, Saltzman CL. PROMIS and FAAM minimal clinically important differences in foot and ankle orthopedics. Foot Ankle Int. 2019;40(1):65–73. https://doi.org/10.1177/1071100718800304
34. Spennacchio P, Vascellari A, Cucchi D, Canata GL, Randelli P. Outcome evaluation after Achilles tendon ruptures. A review of the literature. Joints. 2016;4(1):52–61. https://doi.org/10.11138/jts/2016.4.1.052. Published 2016 Jun 13.
35. Ochen Y, Guss D, Houwert RM, et al. Validation of PROMIS physical function for evaluating outcome after acute Achilles tendon rupture. Orthop J Sports Med. 2021;9(10). https://doi.org/10.1177/23259671211022686
36. Gausden EB, Levack A, Nwachukwu BU, Sin D, Wellman DS, Lorich DG. Computerized adaptive testing for patient reported outcomes in ankle fracture surgery. Foot Ankle Int. 2018;39(10):1192–8. https://doi.org/10.1177/1071100718782487
37. Hung M, Clegg DO, Greene T, Weir C, Saltzman CL. A lower extremity physical function computerized adaptive testing instrument for orthopaedic patients. Foot Ankle Int. 2012;33(4):326–35. https://doi.org/10.3113/FAI.2012.0326
38. Costa ML, Achten J, Marian IR, et al. Plaster cast versus functional Brace for non-surgical treatment of Achilles tendon rupture (UKSTAR): a multicentre randomised controlled trial and economic evaluation. Lancet. 2020;395(10222):441–8. https://doi.org/10.1016/S0140-6736(19)32942-3
39. Dams OC, Reininga IHF, Zwerver J, Diercks RL, van den Akker-Scheek I. The Achilles tendon total rupture score is a responsive primary outcome measure: an evaluation of the Dutch version including minimally important change. Knee Surg Sports Traumatol Arthrosc. 2020;28(10):3330–8. https://doi.org/10.1007/s00167-020-05924-7
40. Kearney RS, Achten J, Lamb SE, Parsons N, Costa ML. The Achilles tendon total rupture score: a study of responsiveness, internal consistency and convergent validity on patients with acute Achilles tendon ruptures. Health Qual Life Outcomes. 2012;10:24. https://doi.org/10.1186/1477-7525-10-24. Published 2012 Feb 29.
41. Nilsson-Helander K, Thomeé R, Silbernagel KG, et al. The Achilles tendon total rupture score (ATRS): development and validation. Am J Sports Med. 2007;35(3):421–6. https://doi.org/10.1177/0363546506294856
42. Westin O, Sjögren T, Svedman S, et al. Treatment of acute Achilles tendon rupture - a multicentre, non-inferiority analysis. BMC Musculoskelet Disord. 2020;21(1):358. https://doi.org/10.1186/s12891-020-03320-3. Published 2020 Jun 8.
43. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and

workflow process for providing translational research informatics support. J Biomed Inf. 2009;42(2):377–81. https://doi.org/10.1016/j.jbi.2008.08.010
44. Patel MS, Kadakia AR. Minimally invasive treatments of acute Achilles tendon ruptures. Foot Ankle Clin. 2019;24(3):399–424. https://doi.org/10.1016/j.fcl.2019.05.002
45. Clanton T, Stake IK, Bartush K, Jamieson MD. Minimally invasive Achilles repair techniques. Orthop Clin North Am. 2020;51(3):391–402. https://doi.org/10.1016/j.ocl.2020.02.005
46. THOMPSON TC, DOHERTY JH. Spontaneous rupture of tendon of Achilles: a new clinical diagnostic test. J Trauma. 1962;2:126–9. https://doi.org/10.1097/00005373-196203000-00003
47. Willits K, Amendola A, Bryant D, et al. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am. 2010;92(17):2767–75. https://doi.org/10.2106/JBJS.I.01401
48. Lemme NJ, Li NY, DeFroda SF, Kleiner J, Owens BD. Epidemiology of Achilles tendon ruptures in the united States: athletic and nonathletic injuries from 2012 to 2016. Orthop J Sports Med. 2018;6(11):2325967118808238. https://doi.org/10.1177/2325967118808238. Published 2018 Nov 26.
49. Caolo KC, Eble SK, Rider C, et al. Clinical outcomes and complications with open vs minimally invasive Achilles tendon repair. Foot Ankle Orthop. 2021;6(4). https://doi.org/10.1177/24730114211060063
50. Attia AK, Mahmoud K, d'Hooghe P, Bariteau J, Labib SA, Myerson MS. Outcomes and complications of open versus minimally invasive repair of acute Achilles tendon ruptures: a systematic review and meta-analysis of randomized controlled trials. Am J Sports Med. 2023;51(3):825–36. https://doi.org/10.1177/03635465211053619
51. Metz R, van der Heijden GJ, Verleisdonk EJ, Kolfschoten N, Verhofstad MH, van der Werken C. Effect of complications after minimally invasive surgical repair of acute Achilles tendon ruptures: report on 211 cases. Am J Sports Med. 2011;39(4):820–4. https://doi.org/10.1177/0363546510392012
52. Maffulli N, Christidis G, Gougoulias N, et al. Percutaneous repair of the Achilles tendon with one knot offers equivalent results as the same procedure with two knots. A comparative prospective study. Br Med Bull. 2025;153(1):ldae019. https://doi.org/10.1093/bmb/ldae019
53. Kaalund S, Lass P, Høgsaa B, Nøhr M. Achilles tendon rupture in badminton. Br J Sports Med. 1989;23(2):102–4. https://doi.org/10.1136/bjsm.23.2.102
54. Olsson N, Karlsson J, Eriksson BI, Brorsson A, Lundberg M, Silbernagel KG. Ability to perform a single heel-rise is significantly related to patient-reported outcome after Achilles tendon rupture. Scand J Med Sci Sports. 2014;24(1):152–8. https://doi.org/10.1111/j.1600-0838.2012.01497.x
55. Kvist J, Silbernagel KG. Fear of movement and reinjury in sports medicine: relevance for rehabilitation and return to sport. Phys Ther. 2022;102(2):pzab272. https://doi.org/10.1093/ptj/pzab272
56. Zellers JA, Carmont MR, Grävare Silbernagel K. Return to play post-Achilles tendon rupture: a systematic review and meta-analysis of rate and measures of return to play. Br J Sports Med. 2016;50(21):1325–32. https://doi.org/10.1136/bjsports-2016-096106
57. Carmont MR, Silbernagel KG, Edge A, Mei-Dan O, Karlsson J, Maffulli N. Functional outcome of percutaneous Achilles repair: improvements in Achilles tendon total rupture score during the first year. Orthop J Sports Med. 2013;1(1). https://doi.org/10.1177/2325967113494584
58. Tejwani NC, Lee J, Weatherall J, Sherman O. Acute Achilles tendon ruptures: a comparison of minimally invasive and open approach repairs followed by early rehabilitation. Am J Orthop (Belle Mead NJ). 2014;43(10):E221–5.
59. Peabody JJ, Hadley SM, Westvold S et al. Complications of Minimally Invasive Achilles Repair Using the Midsubstance Speedbridge and Percutaneous Achilles Repair System. Foot Ankle Orthop. 2024;9(4):24730114245S00216. Published 2024 Dec 23. https://doi.org/10.1177/24730114245S00216
60. Hunt KJ, Alexander I, Baumhauer J, et al. The orthopaedic foot and ankle outcomes research (OFAR) network: feasibility of a multicenter network for patient outcomes assessment in foot and ankle. Foot Ankle Int. 2014;35(9):847–54. https://doi.org/10.1177/1071100714544157

Publisher's note