OPEN Research Article

The Medial Mini-Open Supine Achilles Repair: Outcomes of a Medially Based Mini-Open Technique Compared With Prone Techniques

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ABSTRACT

Background: Achilles tendon rupture treatment has changed substantially in the past decade, with an evolution toward less-invasive techniques and more convenient patient positioning. This review aims to report on the 1-year clinical outcomes of a medially based, mini-open, supine, Achilles tendon repair technique.

Methods: In this retrospective review, all patients who underwent surgical management of an Achilles tendon rupture were included and analyzed based on approach, including (1) standard open prone technique, (2) mini-open repair, prone, and (3) medial mini-open repair, supine. Primary outcomes were the Patient-Reported Outcome Measures Information Systems (PROMIS) Physical Function, PROMIS Pain Interference, and PROMIS Depression scores. Secondary outcomes of interest were surgical time and complications.

Results: Seventy-eight patients were included in this study who underwent Achilles tendon repair and were seen in follow-up at least 1-year postoperatively. Demographics are displayed in Table 1. No statistical difference was observed regarding sex, laterality, age, and mechanism between those with 1-year follow-up data and those who were lost to follow-up before the 1-year mark. Primary outcomes were notable for statistically significant difference in the PROMIS Depression score between the mini-open repair, prone group, and the mini-open repair, supine group. The remainder of the primary outcomes of interest were not statistically significant. Secondary outcomes were notable for markedly shorter surgical time for the mini-open repair, supine group compared with both the standard open prone and mini-open repair, prone groups, with times being 89, 72, and 58 minutes, respectively. Surgical time was defined as starting from the time the patient was anesthetized in the room and included positioning and time up until extubation.

Conclusion: The medial mini-open repair, supine technique shows promise as a noninferior surgical option for acute Achilles tendon

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rupture repair with markedly decreased operating room time and 1-year outcomes with comparable results to both open and mini-open prone techniques.

Acute Achilles tendon rupture is a common injury with substantially debated treatment options.[1-3] Multiple studies have demonstrated the effectiveness of both surgical and nonsurgical methods.[4-7] Surgical intervention was usually performed through an open exposure[8]; however, minimally invasive techniques have demonstrated equal if not superior clinical results.[9]

Prior studies have demonstrated that surgical treatment of acute Achilles rupture allows return to activity with greater postoperative strength, decreased tendon elongation, and less muscle atrophy.[4,5] Usually, surgical intervention has been offered to patients with more robust preinjury functional activity status. When deciding between surgical versus nonsurgical management, these benefits must be weighed against the higher costs associated with surgery and the increased risk of complications, namely, wound infection and sural nerve injury.[1,2,10,11]

Although the intent of surgical intervention is restoration of function with minimal risk of complication, open surgical approaches are associated with wound complication rates as high as 21%[12]; thus, minimally invasive surgical techniques are becoming increasingly popular.[13-15] This trend is strengthened by the recent literature demonstrating that mini-open techniques may yield equivalent or superior outcomes compared with standard open approaches [16] and similar or slightly superior outcomes to nonsurgical treatment.[4,5]

However, the downside to both the standard open and mini-open repair prone techniques is patient positioning, which can increase operating room times and presents additional concerns for surgical, nursing, and anesthetic teams. Additional time and personnel are required, fall risk may be heightened, and patient considerations such as body mass index and ability to ventilate adequately prone may preclude an efficient surgical experience and may require endotracheal tube with general anesthesia rather than options with regional and/or monitored anesthesia care (MAC) anesthesia. Careful attention must be paid to padding and weight distribution as to avoid pressure-related vascular, skin, or nerve injury.[17]

Recently, O'Donnell et al[18] reported a medial mini-open Achilles tendon repair technique allowing for the procedure to be completed in a supine position. However, outcomes data were not reported in this study, which served primarily as a technique description. Thus, the primary goal of this study is to examine 1-year patient-reported outcome measures (PROMs) following the use of this medial mini-open achilles repair technique. Secondary outcomes include operating room time, surgical time, and postoperative complication rates across all three groups.

Methods

Patient Population

This study was approved by our institutional review board before initiation (IRB# 2019P000230). A retrospective medical record review and prospective patient surveys were conducted on all patients older than 18 years who had surgical treatment by two fellowship-trained foot and ankle orthopaedic surgeons for isolated Achilles tendon ruptures from February 2015 to September 2021 at our institution. Diagnosis of the Achilles rupture was made based on the patient's history and physical examination including a palpable gap in the tendon and an abnormal Thompson test. Patients were identified using Current Procedural Terminology code 27650. The patients' medical records were reviewed to collect data on demographics, injury laterality, injury mechanism, medical comorbidities, surgical technique, operating room times, surgical times, and any complications occurring within 90 days postoperatively. Patients who had concurrent trauma requiring surgical treatment or chronic (>6 weeks from injury) Achilles tendon injuries were excluded from this study. Group 1 consisted of patients treated with a standard open, prone technique, group 2 underwent a mini-open prone repair, and group 3 had the medial mini-open supine repair.

Operating room times were recorded at the time the patient entered the room, start of incision, end of surgery when dressing was in place, and when patient exited the operating room. Surgical time was defined as start of incision to end of surgery when dressing was in place. The choice of technique was determined by surgeon preference. Complications were recorded for all patients during the follow-up period.

Patient-Reported Outcomes

Only patients with 1-year follow-up were included in the final analysis. Visual analog scale pain scores were

collected for patients in all three groups. The Foot and Ankle Ability Measures (FAAM ADL and Sport sub scores) and the Patient-Reported Outcome Measures Information Systems (PROMIS) Physical Function, Pain interference and Depression questionnaires were obtained at a minimum of 12 months postoperatively for all patients. Patients in groups 1 and 2 were contacted at the time of the study, and a phone interview was conducted by the study staff (C.W., K.S.) to obtain PROMs, whereas patients in group 3 had PROMs collected in office at the 12-month postoperative visit. Questionnaire distribution and response data were managed using OBERD (OBERD), an online data collection and reporting platform.

Surgical Technique

Full description of the technique can be reviewed in the O'Donnell et al[18] article. Summary of specific steps for the medial mini-open repair, supine (MMOS) technique are as follows:

(1) Ring forceps are custom bent in two planes (up and to the side) as opposed to a uniplanar fashion upward, for ease of forceps passage around the Achilles tendon without soft-tissue interference (Figure 1). Two pairs of ring forceps will be needed, one bent to the left and one to the right, to address both the proximal and distal stumps.

(2) A preoperative regional nerve block is performed. When positioning the patient supine in the OR, a hip bump placed on the contralateral side further externally rotates the injured lower extremity, allowing direct medial access to the Achilles injury (Figure 2, A).

Figure 1

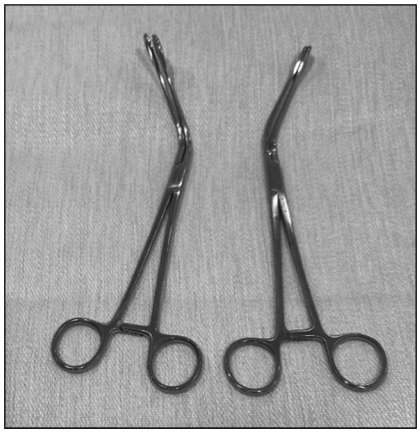


Image of bent ring forceps used to pass the suture. Both are bent up approximately 30° and either to the left or right by approximately 30°. Both are used during the case.

(3) The gap in the Achilles tendon is palpated. A longitudinal incision of <2 cm is made just medial to the tendon, at the level of the injury gap. The paratenon is visualized and opened in a single layer (Figure 2, B)

(4) An Allis clamp is used to grasp and deliver the ruptured tendon ends out of the incision. A small malleable retractor is used to gently free up adhesions between the tendon and the paratenon on the medial and lateral sides, to allow passage of the ring forceps. This gentle dissection is performed for both the proximal and distal ends of the tendon (Figure 3, A and B).

(5) The modified ring forceps are passed between the tendon and the paratenon for the proximal stump (Figure 4, A). A nonabsorbable suture (#2 FiberWire or SutureTape, Arthrex) is then loaded onto a Keith needle (Size 3.5 Keith Abdominal Needle, Anchor Products) and passed medial to lateral through the eyelets of the forceps (Figure 4, B). The forceps are pulled back out of the incision, thus pulling the suture through the skin and into the desired layer under the paratenon to minimize sural nerve entrapment (Figure 5, A). This step is performed 3 times across a span of 4 to 6 cm along the proximal length of the tendon. Suture ends are kept separate with diligent suture management to avoid crossing of sutures within the incision (Figure 5, B). This is the most challenging portion of the procedure and even in experienced hands, it is easy to miss the eyelets. If so, the forceps are removed, and the needle is reintroduced until all three sutures are securely passed.

(6) Attention is now turned to the distal stump. Using the other pair of ring forceps, a disposable shuttle suture is passed medial to lateral at the most distal position along the distal stump (Figure 6, A). The forceps are retracted, leaving the shuttle suture in the desired layer. Then, the most proximal medial strand from the proximal stump is tied to the shuttle suture and shuttled across the distal stump. This step is then repeated for the middle and distal medial strands from the proximal stump, creating 3 separate loops spanning the Achilles tendon gap (Figure 6, B).

(7) The ankle is then plantarflexed to the appropriate tension, recreating the resting tension of the uninjured side and approximating the tendon edges, each suture strand is tensioned, and the three suture ends from each stump are tied

Figure 2

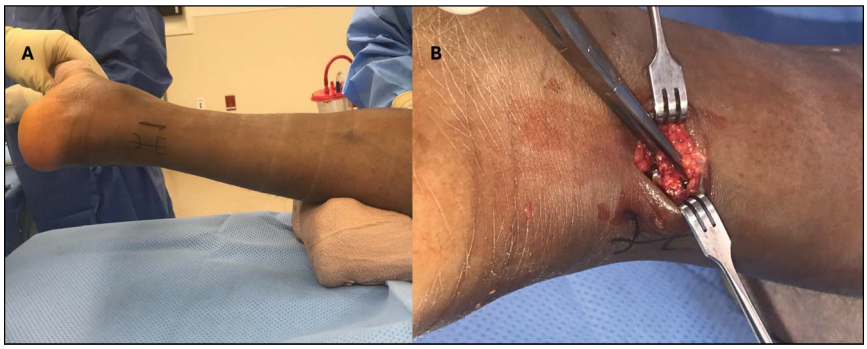


Image showing (**A**) patient positioning and (**B**) proximal tendon stump.

together in a knot. Alternatively, each strand could be tied individually to its partner per surgeon preference. The knots are then buried deep to the tendon, resting on the lateral aspect of the tendon, to decrease irritation and tension on the medial skin closure (Figure 7, A).

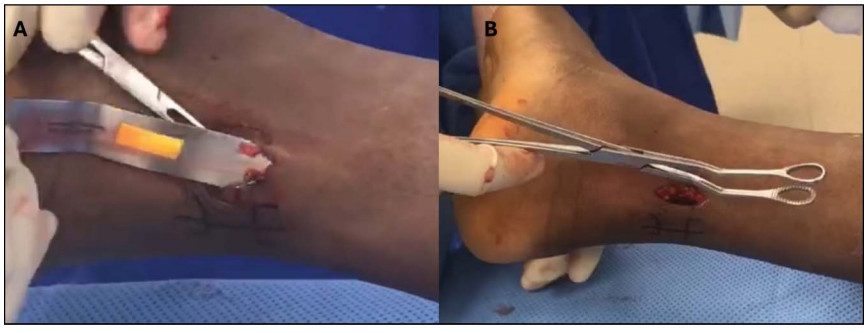
(8) Layered closure of the paratenon, subcutaneous tissues, and skin is then performed. A splint is applied to maintain a plantarflexed ankle position (Figure 7, B).

The main modifications of the MMOS technique compared with prior ring forceps techniques include the direction of forceps bending and relocation of the incision site from midline position to just medial to the tendon at the level of the tendon rupture. Both of these modifications together allow for the patient to remain supine for the Achilles repair procedure while maintaining surgical efficiency and surgeon comfort. In addition, there is only one knot at the end of the case, and it is buried at the lateral aspect of the rupture, which is well away from the incision. This technique can be performed on a stretcher as opposed to an operating room table, thus reducing transition time duration, and patients seldom will require general anesthesia with endotracheal intubation.

Postoperative Course

The patient is typically provided with aspirin 81 mg twice daily for venous thromboembolic (VTE) prophylaxis. The exception to this is if the patient has a medical condition that raises the VTE risk, or personal or family history of VTE. In these cases, Xarelto 10 mg daily or Eliquis 5 mg twice daily for 6 weeks is provided. The patient remains in a splint for 2 weeks and non–weight-bearing and then follows a postoperative recovery similar to what is described by Willits et al.[19] The patient will be transitioned to a boot with wedges at 2 weeks, provided that the incision has healed. They are advanced to partial weight-bearing. The wedges are removed gradually, and the weight-bearing status is progressed every 2 weeks. They are weight-bearing as tolerated in an immobilizer boot by 6 weeks and weaned from the boot at 8 weeks. Passive dorsiflexion and resisted plantarflexion are limited for the first 6 weeks.

Figure 3



A, Image showing releasing the paratenon from the Achilles proximally using a malleable retractor. This is also repeated distally to permit passage of the ring forceps on either side of the tendon. **B**, Image showing the position of the ring forceps will go into the incision and on either side of the tendon.

Figure 4

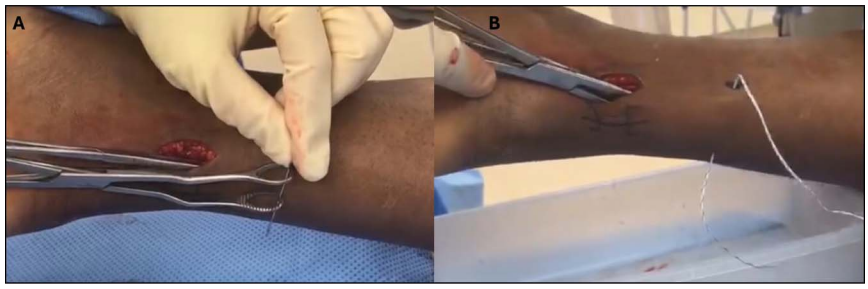


Image showing that the Keith needle is passed percutaneously, through the tendon and the eyes of the ring forceps. **A**, Image showing this extracorporally. **B**, Image showing that the suture passed through the tendon and the ring forceps and exiting laterally.

Strengthening and sport-specific training are initiated at the 10- to 12-week mark.

Statistical Analysis

Descriptive and comparative statistics of demographics, surgical times, and patient-reported outcomes were analyzed for all patients. Normality of data was tested through the Shapiro-Wilk test. Analysis to assess for notable differences in demographic data between respondents and nonresponders was completed within each of the groups. Surgical times for all patients originally enrolled in the study, including those lost to follow-up before 1 year postoperatively, were compared between the three groups through analysis of variance with post hoc Tukey test and the Kruskal-Wallis test with post-hoc Nemenyi test. PROM scores were compared through analysis of variance. Complication rates were compared among the groups through the chi-squared test for patients with a minimum of 3-month follow-up. Significance was defined as $P < 0.05$ for all analyses. We compared the descriptive statistical data of patients with 1-year follow-up survey data with those who were lost to follow-up before the 1-year mark. All statistical analysis was performed using SPSS Statistics version 26 (IBM SPSS Statistics).

Results

Patient Population

One hundred and 12 patients were included in this study after exclusion criteria were met (group 1 open prone: n = 18, group 2 mini prone: n = 14, group 3 mini supine: n = 80). Only patients with minimum of 1-year follow-up were included in the primary outcomes analysis; only patients with a minimum of 3-month follow-up were included in the secondary outcomes analysis (group 1: 18, group 2: 14, group 3: 46 for secondary outcomes analysis) Sex, laterality, and age distribution were not statistically significant among the three groups (Table 1). Among all patients, regardless of surgical technique, the most common mechanism of injury was basketball (44.6%) followed by soccer (17.9%) and other (37.5%).

Surgical Times

Surgery time, patient in room to incision time, and total operating room time data were found to have normal distributions, whereas closed to out of room times were nonparametric. The mean (±SD) times and pairwise comparisons for surgical times are demonstrated in Figure 8 and Tables 2 and 3. Group 3 had markedly shorter times for each measured period compared with

Figure 5

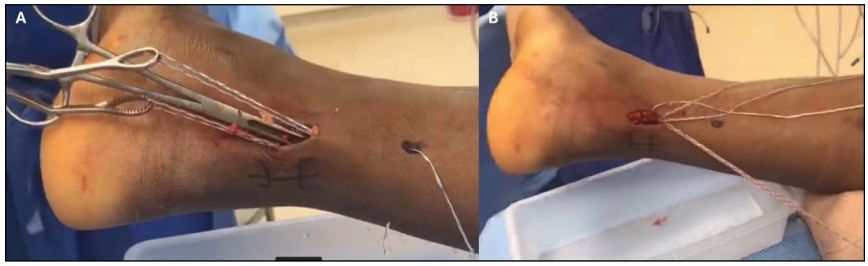
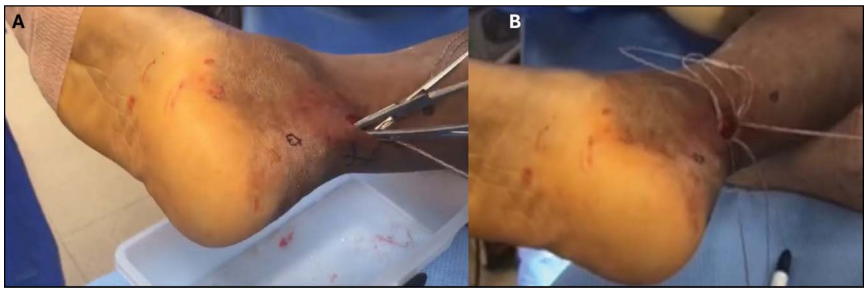


Image showing the suture management. **A**, The suture is retrieved to the main incision. **B**, Three sutures have been passed through the proximal stump and retrieved to the incision.

Figure 6



A, Image showing a temporary suture is passed through the distal tendon in the same fashion as the proximal sutures. **B**, Image showing that the medial limbs of the proximal sutures are then passed through the distal tendon so that three loops are created and all of the suture ends are on the lateral side of the rupture.

the open approach, group 1. Group 3 also had shorter times compared with group 2 except for the actual "surgery time" (P = 0.439). Groups 1 and 2 did not show any differences on pairwise comparisons.

Anesthesia Technique

All patients received a peripheral nerve block. The rate of general anesthesia utilization was 100% (n = 42), 83.3% (n = 20), and 13.8%% (n = 11) in groups 1, 2, and 3, respectively. In group 3, all patients receiving general anesthesia were managed with laryngeal mask airway; none of the patients required endotracheal intubation. Three of these 11 cases initially started with MAC but subsequently required conversion to laryngeal mask airway due to patient movement despite sedation. One case was done under general anesthesia at the anesthesia team's request as they were not confident in their peripheral nerve block placement. All other patients in group 3 received MAC.

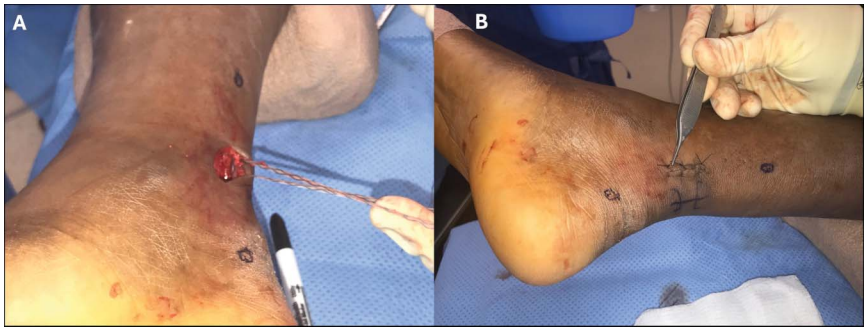
Pain and Functional Outcomes

Mean and standard deviations for PROM scores collected are detailed in Table 4. PROMIS Depression scores were found to be statistically significant at the 1-year postoperative time mark (36.1 ± 7.4, 43.05 ± 9.6, respectively, P = 0.037). PROMIS scores x and y were not found to be statistically significant between the three groups.

Complications

No reported reruptures were found in any of the surgically managed groups. Rerupture was defined on the basis of a positive Thompspon squeeze test, the presence of a palpable gap, and an acute loss of plantar flexion strength. Among all surgically managed patients, the overall 3-month complication rate was 7.1% (n = 8/112). In group 1, one case of pulmonary embolism was found and managed with therapeutic anticoagulation (5.5%, n = 1/18). In group 2, two patients experienced superficial cellulitis around the incision and were treated with oral antibiotics and local wound care management (14.3%, n = 2/14). In group 3, one case of cellulitis was treated with oral antibiotics, one wound dehiscence required irrigation and débridement with primary closure, and three cases of VTE requiring anticoagulation (6.3%, n = 5/80).

Figure 7



A, Image showing that the lateral sutures are tightened and tied together. This approximates the tendon edges. **B**, Image of the final closure.

Table 1. Demographics and Clinical Characteristics of Treatment Groups 1, 2, and 3[a]

Factor or Variable	Group 1 Open Prone	Group 2 Mini Prone	Group 3 Mini Supine	*P*
Age (mean ± SD)	36.9 ± 7.47	38.6 ± 10.43	39.55 ± 11.66	0.597
Sex n (%)				
Male	16 (88.9%)	12 (85.7%)	62 (77.5%)	0.473
Female	2 (11.1%)	2 (14.3%)	18 (22.5%)	
Laterality n (%)				
Left	12 (66.7%)	8 (57.1%)	41 (51.3%%)	0.483
Right	6 (33.3%)	6 (42.9%)	39 (48.7%)	
Months of follow-up ± SD	28.8 ± 17.2	30.8 ± 12.2	14.3 ± 12.4	<0.001

[a]Data reflect analysis on patients with ≥ 12-month postoperative follow-up.

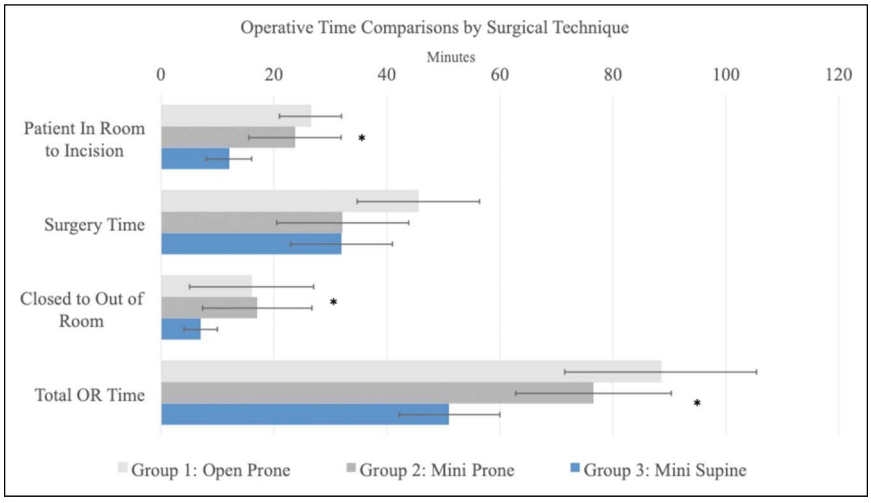
Discussion

Optimal management for acute Achilles tendon ruptures is still a topic of active debate. Each treatment technique has its risks and benefits that must be balanced with individual patient comorbidities and risk factors. Similar techniques have been described using either ringed forceps[20,21] or Dresden suture retrievers[22] to pass suture across Achilles tendon while preserving the paratenon in a minimally invasive fashion, all which require prone positioning of the patient. The MMOS repair technique, first described by O'Donnell et al,[18] further modifies an existing mini-open Achilles tendon repair.[23] This switch from prone to supine positioning allows for decreased time in the operating room by reducing transition time periods in addition to facilitating improved airway and cardiovascular access.

This study expands upon preliminary data presented by O'Donnell et al[18] by adding longitudinal follow-up data. We followed 46 patients treated with the MMOS technique for a minimum of 12 months postoperatively to examine clinical and patient-reported outcomes. This study demonstrates that patient-reported outcomes for the MMOS at 12 months postoperatively are not markedly different from those who underwent the standard open prone or mini-open prone techniques (Table 2).

In addition, MMOS technique is not associated with increased complications in comparison to commonly used prone techniques. The overall postoperative complication rate for treatment with the MMOS technique was 6.3%,

Figure 8



Bar chart showing comparison of surgical times between groups 1, 2, and 3. Error bars indicate SD intervals. *Indicates a statistical significance between group 3 and groups 1 and 2.

Table 2. Average Surgical Times (Minutes, Mean ± SD) for Groups 1, 2, and 3

Factor or Variable	Group 1 Open Prone	Group 2 Mini Prone	Group 3 Mini Supine	*P*
Patient in room to incision	30 ± 14	26 ± 6	17 ± 7	<0.001
Surgery time	43 ± 13	36 ± 11	32 ± 10	0.001
Closed to out of room	14 ± 11	19 ± 11	8 ± 4	<0.001
Total OR time	89 ± 18	82 ± 9	58 ± 17	<0.001

OR = operating room

with no known reruptures. In comparison, the complication rate in the study of Willits et al[19] evaluating the surgical vs nonsurgical treatment of Achilles rupture showed an 18% rate of complications for the surgical group. In addition, no patients treated with MMOS technique required endotracheal intubation, and the majority were performed under MAC with peripheral nerve block. This allowed the patient to receive less anesthesia during the case and benefit from faster emergence from surgery. As many of these procedures are performed in a high-volume outpatient setting, efficiency is critical. By eliminating the need for intubation and deep anesthesia, not only did we save time in the surgery itself, but, likely, also in the postanesthesia recovery unit as patients were, anecdotally, felt to be able to mobilize faster out of bed. We did not have the ability to map the flow of patients through the postanesthesia recovery unit in this study, and therefore, we cannot definitively comment on time savings at this stage of the OR process.

The results of this study confirms what has been previously demonstrated in the literature comparing surgical times for procedures done in the prone versus supine positions[24-26]; total surgical times observed with the MMOS technique were markedly shorter than those seen with open and mini prone techniques. Using the MMOS technique, the mean total OR time, as measured from patient entering the room to exiting the room, decreased by approximately 30 minutes compared with prone surgeries. In comparison to open surgery, the mini-open approach is demonstrated to have shorter surgical time from incision to closure (Figure 8 and Table 2). By performing the procedure supine and reducing the need for general endotracheal intubation, nonsurgical portions of time spent positioning and inducing the patient is reduced, resulting in the total OR time decreasing by 35.0%.

This study has several limitations. First, it is a relatively small sample size with a large proportion of the group 1 and group 2 patients lost to follow-up. In addition, we were only able to collect 1-year PROMs for a subgroup (46 of 80) of the patients treated with the new technique (group 3, MMOS). In addition, the PROMIS data for groups 1 and 2 were collected over the phone, whereas the PROMIS scores for group 3 were collected in office, which may incur some degree of response bias or sampling error. However, no statistical difference was found in demographic data (sex, laterality, age, and mechanism of injury) between those with 1-year follow-up data and those who were lost to follow-up before the 1-year mark. In addition, although we did compare three surgical techniques, we did not include a nonsurgical treatment arm to determine if the mini-open repair supine technique is noninferior to nonsurgical management. Another limitation of the study is that this was a single-center, largely outpatient surgical, single-midcareer surgeon, retrospective study and may not translate to all practice settings or surgeon skills. As such, different hospital practices and surgeon skill may limit the generalizability of these results. Other limitations include that all of the ruptures were repaired acutely, within 3 weeks of injury, this technique may not be appropriate for injuries that are subacute or chronic. Finally, we did not measure the tendon gaps at the time of surgery, so we

Table 3. Pairwise Comparison of Surgical Times for Groups 1, 2, and 3

Group Pair	Tukey HSD *P*			
	In Room to Incision	Surgery Time	Closed to Out of Room	Total or Time
1 vs. 2	0.395	0.198	0.175	0.513
1 vs. 3	**<0.001**	**<0.001**	**0.004**	**<0.001**
2 vs. 3	**<0.001**	0.439	**<0.001**	**<0.001**

Bolded text indicates a notable *P* value, with significance defined as $P \leq 0.001$. HSD = honestly significant difference

Table 4. **Averages and SDs of 1-Year Postoperative Patient-Reported Outcome Scores for Open Prone, Mini Prone, and Mini Supine Groups**

Outcome Measure	Open Prone	Mini Prone	Mini Supine	*P*
PROMIS pain interference (mean ± SD)	45.22 ± 8.8	40.88 ± 8.23	44.4 ± 8.08	0.30
PROMIS depression (mean ± SD)	40.6 ± 8	36.18 ± 7.5	43.05 ± 9.6	0.045
PROMIS physical function (mean ± SD)	60.13 ± 11.32	65.66 ± 13.65	59 ± 11.8	0.25
FAAM ADL (mean ± SD)	93.04 ± 8.83	94.35 ± 13.3	93.3 ± 9.99	0.934
FAAM sport (mean ± SD)	82.36 ± 17.21	80.26 ± 25.69	80.31 ± 23.81	0.95
Preoperative VAS pain (mean ± SD)	5.22 ± 2.65	5.36 ± 2.44	4.39 ± 2.47	0.23
1-Year VAS pain (mean ± SD)	0.83 ± 1.15	0.57 ± 1.65	0.52 ± 0.99	0.62

ADL = Activities of daily living, FAAM = Foot and Ankle Ability Measures, PROMIS = Patient-Reported Outcome Measures Information Systems, VAS = visual analog scale

cannot describe what the preoperative retraction was for these cases. It is possible that some cases with more severe retraction would not be suitable for this technique.

The MMOS technique described by O'Donnell et al was developed in pursuit of combining the benefits of supine positioning and mini-open approaches for acute distal Achilles rupture repair. In addition to decreased operating room times, this technique reduced the need for endotracheal intubation, decreased anesthesia requirements, and was performed safely with similar outcomes and surgical risk profile to standard surgeries performed in the prone position.

Conclusion

The medial mini-open supine Achilles repair technique shows promise as a viable option for Achilles tendon rupture repair; with improved ease of patient positioning, minimizing anesthesia requirements, improving operating room efficiency without compromising surgical outcome, or increasing surgical complication rate. In particular, the supine position permits the repair to be more easily performed under spinal anesthesia or with peripheral nerve block and monitored anesthetic care. The MMOS had a 6.3% complication rate, including wound and thromboembolic events. This must be considered when discussing surgical options. Continued future studies are needed to evaluate the generalizability and long-term outcomes of this supine, medially based mini-open surgical approach.

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