The Achilles tendon is the strongest tendon in the human body. It is stiff but resilient, possesses a high tensile strength, and has the ability to stretch up to 4% before damage occurs. If the stretch exceeds 8%, macroscopic rupture occurs. Various methods have been used to treat acute ruptured Achilles tendons. Nonoperative treatment immobilizes the ankle in plantarflexion for between 6 and 8 weeks using plaster casts or splints. It avoids the risks of surgery, but may result in a lengthened tendon with reduced power of the calf muscle and a mean re-rupture rate up to 20%. Most reports have favored operative treatment because it significantly reduces the risk of re-rupture and allows earlier return to pre-injury activity. However, traditional open repair is associated with a higher rate of complications (11% to 29%), especially regarding wound healing (necrosis, infections, adhesions, and scarring).

Percutaneous methods described by Ma and Griffith and Bradley and Tibone avoid most of the disadvantages of open surgical treatment, but the degree of tendon regeneration cannot be ensured. The current authors report the mid-term results of a minimally invasive technique with echographic assistance to repair acute Achilles tendon ruptures. This technique avoids injury to the sural nerve, minimizes wound complications, and provides a strong repair.

**Materials and Methods**

The authors prospectively followed 40 patients with acute Achilles tendon rupture who underwent surgical treatment involving percutaneous repair. The diagnosis was made in all cases by both clinical and radiological examinations. The study participants included 35 men and 5 women with a mean age of 38 years (range, 24-62 years). The right tendon was involved in 25 cases and the left tendon in 15 cases.

Patients were excluded from this study if they had (1) a rupture more than 2 weeks old, (2) an open injury, or (3) a distal tendon stump of less than 3 cm from its insertion.

All patients underwent a preoperative physical examination in which the range of
motion (ROM) of the ankles (side-to-side) and the results of the Thompson test were evaluated and recorded.

Moreover, patients received an American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score and a visual analog scale score (VAS; 0=unbearable pain to 10=no pain).

Complete Achilles tendon rupture was confirmed in all patients by preoperative magnetic resonance imaging. Magnetic resonance imaging with the foot in neutral position was also used to measure the length of the tendon gap.

**Technique of Percutaneous Repair**

All patients underwent surgery at the authors’ institution performed by the same surgeon (A. Santucci). The repair was performed under regional anesthesia. Patients were placed prone on the operating table, and skin incisions were marked on the posterior aspect of the Achilles tendon. The leg was prepared and draped in the usual manner. No tourniquet was required. The ruptured ends of the tendon were identified by palpation and visualized using echography.

Symmetrical mini-incisions, medially and laterally, were performed along the course of the tendon at a distance of approximately 2 cm from each other in the distal and proximal directions to the tendon injury (**Figure 1**). To repair the tendon, a no. 5 non-absorbable suture wire ending with 2 needles was used. Guided by ultrasound control, a needle was inserted through the next mini-incision, which exited from the opposite one (**Figure 2**). Echographic guidance is useful for ensuring that the needle stays within the paratenon and tendon sheath during passage through the skin.

Echography shows the 2 needles entering the corresponding cutaneous accesses and crossing the context of the tendon (**Figure 3**). The passage of the needles in the tendon through the mini-incisions was repeated 2 to 3 times in a zigzag manner in both the distal and proximal stumps until the Achilles tendon ruptured (**Figure 2**). In most instances of echographic control performed after the insertion of the needle, it has been noticed that the position of the needle was not the best, being too superficial or too deep in relation to the tendon. This is why echographic control is now regularly performed during the passage of the needle.

In some cases, passage of the needle was repeated several times because ultrasound control was not optimally inserted in the context of the tendon. In this case, as shown in this figure, the needles are too superficial. Another no. 5 non-absorbable wire with 2 needles was passed in the same manner, under echographic guidance, distal to proximal on the point of rupture.

A longitudinal mini-incision centered on the side of the ruptured Achilles tendon was performed. The needles were brought out from the distal...
access (Figures 5-6). The 2 ruptured ends of the Achilles tendon were then tied together by pulling the sutures together, in a balanced way, assisted by plantarflexion of the foot (Figure 7). Reduction and conjunction of the tendon ends was performed under direct visualization. The suture was reinforced with a no. 2 absorbable wire. The skin incisions may be closed using absorbable sutures. The lower limb was placed in a functional bandage to maintain the ankle in plantarflexion for 4 weeks.

Statistical Analysis
The Student’s *t* test and analysis of variance were used to analyze the data for these patients. For power analysis, the alpha error was fixed at 5% (95% confidence interval) and the level of significance was *P*<.05.

Follow-up Evaluation
The authors evaluated all 40 patients at a mean of 12.7 months (range, 9-18 months). Patients underwent a physical examination and the Thompson test, and ankle ROM side-to-side was evaluated. Moreover, clinical evaluations at the mean follow-up included assessment of the ability to perform 10 repetitive single affected-side heel rises and of surgery-related complications.

New ratings were established using the AOFAS Ankle-Hindfoot Score and the VAS score.

RESULTS
Clinical examination showed satisfactory results in 38 patients. Postoperative ROM side-to-side was complete in 37 cases, in both dorsiflexion and plantarflexion. In 2 patients at 5, 7, and 8 months postoperatively, a limitation of dorsiflexion less than 10° was observed.

All patients were able to perform 10 repetitive single affected-side heel rises, demonstrating good recovery of strength in the calf muscles.

The AOFAS Ankle-Hindfoot Score increased significantly from 66.3 (range, 50 to 85) to 97.2 (range, 87 to 100) (*P*<.003). All patients reported a significant improvement in the painful symptoms, with the mean VAS score increasing from 6.7 (range, 5 to 8) to 8.9 (range, 8 to 10) (*P*<.002).

No surgery-related complications, such as wounds or deep infections, sural nerve injuries, or re-ruptures, were detected at follow-up (Figure 8).

DISCUSSION
The treatment of acute Achilles tendon rupture remains controversial, despite extensive research. Surgical methods have resulted in a lower re-rupture rate and earlier return to activity than conservative methods. 1,2,8,10 How-
ever, standard open repair is associated with higher complication rates, especially for wound healing and sural nerve injuries.\textsuperscript{4,11-14}

Adhesions of the scar to the underlying tendon are common after open repair. In a study by Nistor,\textsuperscript{12} this occurred in 45\% of cases, but it is rarely seen after percutaneous repair. Although the incidence of catastrophic breakdown of the wound after open repair is declining, it may still occur.

In 1977, Ma and Griffith\textsuperscript{7} were the first to describe a percutaneous technique for the repair of acute Achilles tendon rupture. This technique became popular with modifications as described by Blankstein et al.\textsuperscript{15} using real-time sonography. In the technique described by Ma and Griffith,\textsuperscript{7} no re-rupture or sural nerve injury was reported. According to Blankstein et al.,\textsuperscript{15} ultrasound is used to confirm the diagnosis, permits accurate marking of the tendon ends, and ensures that the ends of the tendon are brought together on passive plantarflexion. At the same time, ultrasound shows the precise location of the sural nerve as it crosses the Achilles tendon, thereby minimizing further risk of sural nerve damage.

However, others have reported an unacceptably high incidence of sural nerve injury and re-rupture when applying the same technique.\textsuperscript{5,16,17} Sural nerve injury was demonstrated by Hockenbury and Johns\textsuperscript{18} in a cadaveric study in 1990.

In recent years, several authors have described various techniques for endoscopy-assisted percutaneous repair of acute Achilles tendon tears. These techniques allowed good tendon healing and a more rapid return to sport, but sural nerve injury during surgery was a potential complication.\textsuperscript{19} Many surgeons have advocated several modifications to the percutaneous or minimally invasive techniques, each with advantages and disadvantages.\textsuperscript{10,20-22}

The percutaneous repair of the acute Achilles tendon rupture with echographic assistance described here is simple and easily mastered with a short learning curve. It is technically less demanding than a standard open repair. With this technique, ultrasound is useful when passing the needle in the tendon so as to create a strong repair and lower the risk of peritendinous adhesions. Furthermore, this technique permits determination of the initial gap and provides adequate apposition of the tendon ends.

In the study by Soubeyrand et al.,\textsuperscript{21} without imaging, 55\% of needles were correctly positioned. In the current study, although there was no control group, in approximately 50\% of cases the needle was passed several times because it was not perfectly inserted inside the tendon during echographic control. This aspect further confirms this technique’s utility. Also, no soft-tissue dissection is required because the sutures are percutaneously threaded proximally and distally through the tendon. The blood supplies of the paratenon and soft tissues are therefore preserved, enabling better healing of the wound and tendon. It is important that the needle be within the paratenon during percutaneous criss-crossing (zigzagging) of the suture. This helps to prevent entrapment of the sural nerve and other surrounding structures onto the Achilles tendon.

**CONCLUSION**

This surgical technique for the percutaneous repair of acute Achilles tendon rupture is simple, is reproducible, and has minimal cost. Combined with appropriate rehabilitation, the technique achieves excellent results and is associated with low morbidity and complication rates.

**REFERENCES**

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