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Proximal Ultrasound-Guided Gastrocnemius Recession: A New Ultra-Minimally Invasive Surgical Technique

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ABSTRACT

Selective proximal recession of the medial gastrocnemius head has clear advantages over other approaches and can be performed as a single or combined open procedure for many indications. The purpose of this study was to evaluate the safety and efficacy of a new technique based on ultrasound-guided ultraminimally invasive proximal gastrocnemius recession. We performed a pilot study with 16 cadavers to ensure that the technique was effective and safe; we then prospectively performed gastrocnemius recession in 12 patients (23 cases) with gastrocnemius contracture associated with other indications. We evaluated pre- and postprocedure dorsiflexion, clinical outcomes (based on the visual analog scale and American Orthopedic Foot and Ankle Society scores), and potential complications. We achieved effective release of the proximal medial gastrocnemius tendon in all cases, with no damage to other tissue. Ankle dorsiflexion increased 12° (range 6° to 18°) ($p = .05$) and was maintained throughout follow-up. The mean preoperative visual analog scale score was 7 (range 5 to 9), which improved to 1 (range 0 to 2) ($p = .01$). The American Orthopedic Foot and Ankle Society Ankle-Hindfoot Score improved from a mean of 25 (range 20 to 40) to 85 (range 80 to 100) at 6 months and 90 at 12 months ($p = .01$). No major complications were observed. We considered the technique to be safe and effective for ultrasound-guided ultraminimally invasive proximal-medial gastrocnemius recession using a 1-mm incision in vivo. This novel technique is an alternative to open techniques, with encouraging results and with the potential advantages of reducing pain and obviating lower limb ischemia and deep anesthesia, thus decreasing complications and contraindications and accelerating recovery, although further studies are required.

Gastrocnemius contracture is defined as ankle dorsiflexion <10° with the knee extended. Isolated gastrocnemius contracture is thought to predispose to or aggravate numerous foot and ankle conditions such as plantar fasciitis, Achilles tendinosis, flatfoot, diabetic foot ulcer, knee hyperextension (genu recurvatum), metatarsalgia, midfoot pain or arthritis, lateral foot pain, and nerve entrapment. In children, the deformity has been associated with equinus foot, spasticity, and cerebral palsy (1–10).

Gastrocnemius recession is indicated in adults with dorsiflexion <10° with the knee extended and can be performed alone or in combination with other approaches (11,12). Distal gastrocnemius recession can be performed as an open or an endoscopic procedure (13–17). We recently reported an ultrasound-guided ultraminimally invasive method for distal gastrocnemius recession (10).

The potential benefits of ultrasound-guided gastrocnemius recession include administration of local anesthesia, reduced pain, no need for exsanguination, smaller incisions (1 to 2 mm), shorter operative time, fewer complications, reduced morbidity, and the possibility of performing bilateral procedures alone or in combination with other ultrasound-guided surgical techniques under an outpatient regimen. Proximal gastrocnemius lengthening was first described in cases of cerebral palsy in 1923 by Silfverskiöld (18), who recessed both the medial and lateral muscle bellies at the femoral condyles. Proximal medial gastrocnemius recession was recently described by Barouk et al (19,20), who released only the white fibers (aponeurosis) of the gemelli (21,22). Amis (23) termed this selective approach “the modern method to surgically lengthen.”

To our knowledge, ultrasound-guided proximal medial gastrocnemius recession has not been previously described. The aim of this study,

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therefore, was to evaluate the safety and efficacy of a new ultraminimally invasive technique for gastrocnemius recession. We study the feasibility and effectiveness of the technique in cadavers and report our preliminary results in patients with various conditions and associated gastrocnemius contracture. This approach was based on evaluation of pre- and postprocedure dorsiflexion, clinical outcomes, and potential complications, including neurovascular injuries.

Patients and Methods

We performed a pilot study with 16 cadavers to ensure that the technique was effective and safe. The mean age of the cadaver donors at the time of death was 57 ± 8 years. There were 11 (68.75%) male and 5 (31.25%) female specimens, and 10 (62.5%) were right side and 6 (37.5%) were left side specimens.

No damage to neurovascular structures or hamstring tendons was observed. In a second phase between January 2016 and January 2017, we performed proximal medial gastrocnemius recession in 12 patients (23 cases) with various conditions. Gastrocnemius tightness was assessed clinically using the Silfverskiöld test. In most patients, the procedures were combined with other ultrasound-guided ultraminimally invasive techniques, all of which were performed under local anesthesia plus sedation without lower limb ischemia or stitches.

All recessions but 1 were bilateral and were performed simultaneously. The indication for the procedure was gastrocnemius contracture; although patients also had other conditions such as noninsertional Achilles tendinopathy in 1 patient (2 cases; 8.6%), tarsal tunnel syndrome in 5 (10 cases; 43.4%), metatarsalgia in 2 (4 cases; 17.4%), piriformis syndrome and common peroneal nerve entrapment in 1 (4.3%), and plantar fasciitis in 3 (6 cases; 26%). Patients complained of ankle and foot numbness, plantar pain, difficulty walking in flat shoes, and calf tension or pain.

In most patients, gastrocnemius lengthening was performed in combination with other ultrasound-guided techniques, such as tarsal tunnel release, selective plantar fasciotomy, and Achilles tenotomy, and some open procedures (piriformis release or Morton's neuromata). In 2 cases with metatarsalgia, we did not perform any associated procedure. Gastrocnemius contracture was considered a predisposing condition for these pathologies.

Associated ultrasound-guided procedures were Achilles tenotomy and release of the paratenon, selective plantar fasciotomy as previously described by our group (24), tarsal tunnel release (release of the laciniate ligament and deep aponeurosis of the hallucis abductor muscle and occasionally subcutaneous release of the medial branches of the calcaneus), release of the common peroneal nerve in the knee, superficial peroneal nerve entrapment in the distal one-third of the leg, and removal of bilateral Morton's neuroma. In 1 (4.3%) patient, open release of the piriformis tendon was performed under general anesthesia after the release of the gastrocnemius tendon with local anesthesia. Dorsiflexion ranged from −10° to 5° before surgery. For contractures greater than −10° of dorsiflexion, we prefer distal ultrasound-guided recession, which can also be performed bilaterally and simultaneously with minimal limitation and local anesthesia and visualization of the sural nerve to prevent damage (10).

The study population comprised 6 males and 6 females, and their mean age was 42 (range 31 to 55) years. Five of our patients (9 cases; 39.1%) were young and athletic (those with Achilles tendinopathy, plantar fasciitis, and piriformis syndrome) or active (17.4%; those with metatarsalgia, 2 patients, 4 cases). Five patients (43.5%; 10 cases) with tarsal tunnel syndrome were sedentary as a result of their disease.

All of the patients had previously received multiple treatments and had had at least 6 months of conservative management before surgery, including modification of daily activity, night orthosis, medication, injections, stretching programs, and physical therapy; however, their symptoms failed to resolve. The duration of symptoms ranged from 1 to 21 years, because the patients we diagnosed with tarsal tunnel syndrome had been unsuccessfully treated for years for other erroneously diagnosed conditions. We reached the diagnosis of tarsal tunnel syndrome guided by clinical picture, response to a specific antineuritic medication, or response to ultrasound-guided perineural injection of procaine or another local anesthetic at minimal doses.

Our prospective study was performed in accordance with the principles of the 1964 Declaration of Helsinki (2013 revision) and approved by the Research Ethics Committee of Hospital Beata María. All participants gave their informed consent to participate in the study and for their clinical and radiological data to be reproduced. The Anatomy Department of Francisco de Vitoria University provided the specimens used in this study. Surgical studies using specimens from body donors do not require ethics committee approval.

Evaluation of Results

Pain was evaluated using a visual analogue scale (VAS) (from 0 [no pain] to 10 [severe pain]) at baseline, 1 month, 3 months, 6 months, and 1 year after surgery. Pain was also evaluated using the Ankle-Hind foot Score of the American Orthopedic Foot and Ankle Society (AOFAS) (24,25) (pain, 40 points; function, 50 points; alignment, 10 points) at baseline, 1 month, 3 months, 6 months, and 1 year after surgery. The other variables analyzed included the ability to support autonomous comfortable plantigrade weightbearing after surgery, calf strength, or days on painkillers.

M.V. and A.I. performed or participated in all surgeries. M.d.M.R. and P.S.-R. assisted in some interventions of the series. All authors reviewed the study, and read and approved the final version of the manuscript. P.S.-R. participated in anatomic dissection of the cadaver series and assessed in the design of the study.

Surgical Technique

The instrument set used in the present study was used in our previous report (10). Imaging was performed using the Alpinion ECube15 ultrasound device (Alpinion Medical Systems, Gyeonggi-do, Korea) with a 10- to 17-MHz linear transducer and the Needle Vision Plus^{TM} software package (Alpinion Medical System; Seoul, Korea) (Fig. 1). In our clinic, the procedure is always performed by 2 surgeons.

Medial proximal gastrocnemius recession was performed with the patient in the prone position and the ankle hanging off the edge of the operating table to flex it dorsally for recession. No tourniquet was used, and operations were performed under local anesthesia plus sedation. Using our technique, we place the probe in the transverse plane (short axis) and follow the tract of the hamstring tendons from proximal to distal until they become anterior and medial, where they are very flat and more difficult to identify because they are not perpendicular to the probe and their image is not clear. The tendons define the medial border of the release.

Proximal release of the medial head of the gastrocnemius is performed 2 to 3 cm distal to the popliteal crease and fossa at a point where the hamstring tendons can still be identified and the proximal belly of the gastrocnemius is usually V-shaped. We select an entry point medial to the lateral border of the medial gastrocnemius head, generally staying superficial and close to the minor saphenous vein and sural nerveto control the position of the tip of the needle and instruments and their relationship to these structures (Fig. 2). Recession is performed via a single 1- to 2-mm incision with the probe in the transverse position. At the selected point, we inject anesthesia under the fascia and create a working space between the superficial fascia and the tendinous part of the proximal gastrocnemius muscle. Following our protocol (10), we insert 2 V-shaped straight curettes (small and medium) guided by the needle to enlarge the entry point at the skin and fascia (10) (Fig. 3). Sealing the entry point with Betadine gel^{TM} prevents air bubbles from entering and distorting the ultrasound image.

We insert the hook knife following the curve of the blade so as not to enlarge the incision and advance toward the medial border of the head of the gastrocnemius in a horizontal plane and with the transducer placed in the transverse position (Figs. 4 and 5). Because the shape of the head is rounded, we need to elevate the tail of the hook knife and press its tip down while advancing slightly further to stay beneath the hamstring tendons and make an effective recession. At the medial border of the tendon, we turn the blade 90° toward the tendon and start severing the tendon in a medial to lateral direction. During this stage, the first surgeon pulls back the hook knife with both hands, with at least 1 resting on the calf, to avoid uncontrolled advance of the knife or losing the direction of the cut. The second surgeon holds the probe and stretches the gastrocnemius tendon by flexing the ankle and foot dorsally, keeping the knee in full extension, thus making it easier for the first surgeon to accurately position the instruments (Fig. 6).

We then check dorsal flexion. If there is any doubt over whether some fascial fibers remain uncut, we check with the blunt dissector. If necessary, we repeat the previous part of the procedure and check that dorsal flexion has improved significantly.

Placing the knife facing toward the skin or positioning the instruments too superficially over the fascia may damage sensory superficial nerves, as occurred in 1 patient at the beginning of the series. We use the blunt dissector to ensure that there is no tension in the tendon.

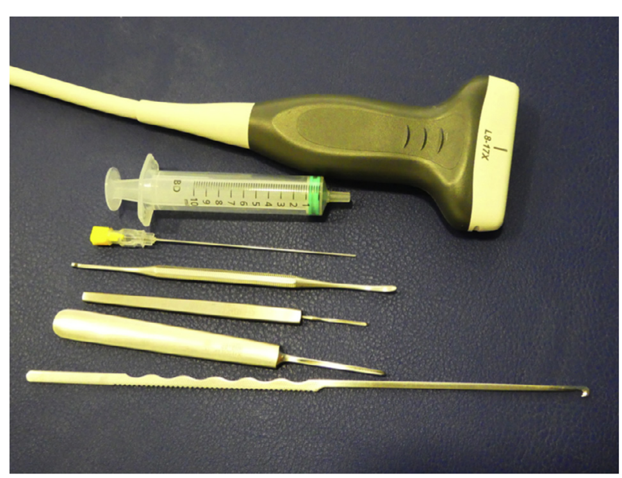


Fig. 1. Instrument set.

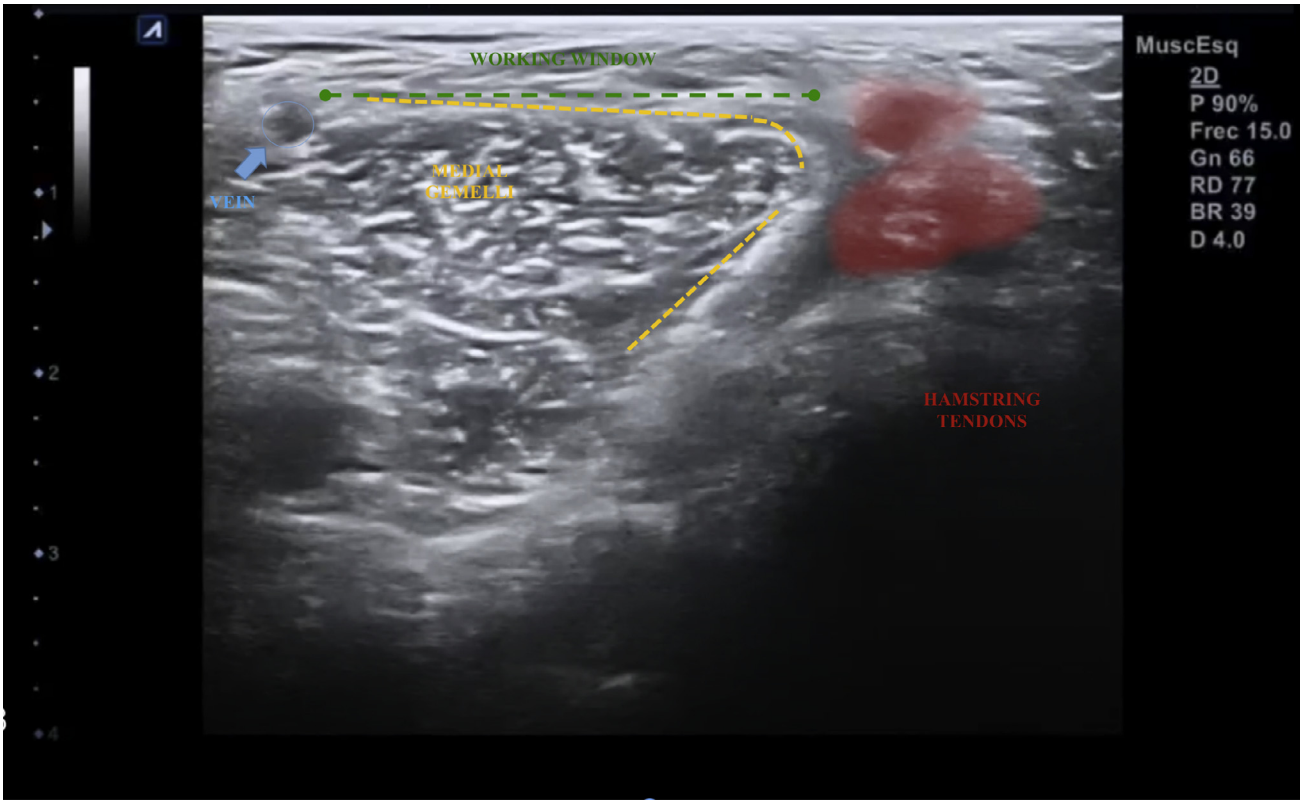


Fig. 2. Transverse ultrasound views of the sural vein, gemelli, and hamstrings.

Fig. 3. Long needle guides the V-shape curette.

Fig. 4. Advancing the hook knife under ultrasound control.

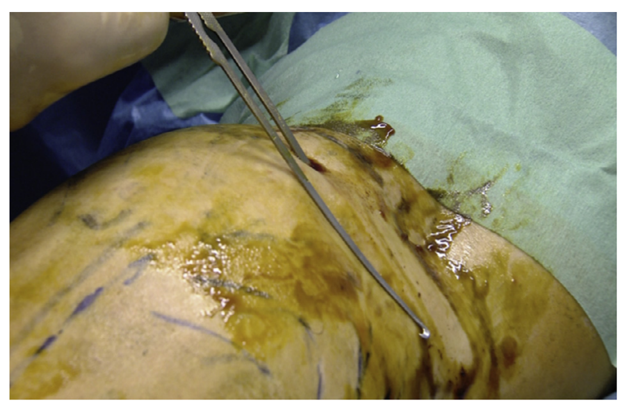


Fig. 5. The hook knife position before turning it down and starting the gastrocnemius release.

We test the range of motion of the ankle immediately after surgery, first passively, as described by Barouk et al (19,20), with the knee extended and the subtalar joint reduced to slight varus. Because the anesthesia is local, the patient can flex the foot (both dorsal and plantar flexion) immediately after the procedure. No stitches are required. We use plastic adhesive strips and an elastic bandage.

Rehabilitation Protocol

Active dorsiflexion and plantar flexion of the ankle are encouraged immediately after surgery. Patients are allowed to walk with elbow crutches and partial weightbearing on the day of surgery. An orthotic boot is not necessary. Passive dorsiflexion of the ankle with the knee in extension is encouraged with the assistance of a therapist or performed by the patient him/herself using a band. Full weightbearing is allowed after 3 to 7 days, depending on pain and discomfort. Patients with tarsal tunnel syndrome received medication for 3 to 6 months (low-dose gabapentin plus alpha lipoid acid). Patients were able to progress to a regular shoe and start physiotherapy with eccentric calf stretching exercises as soon as these could be tolerated.

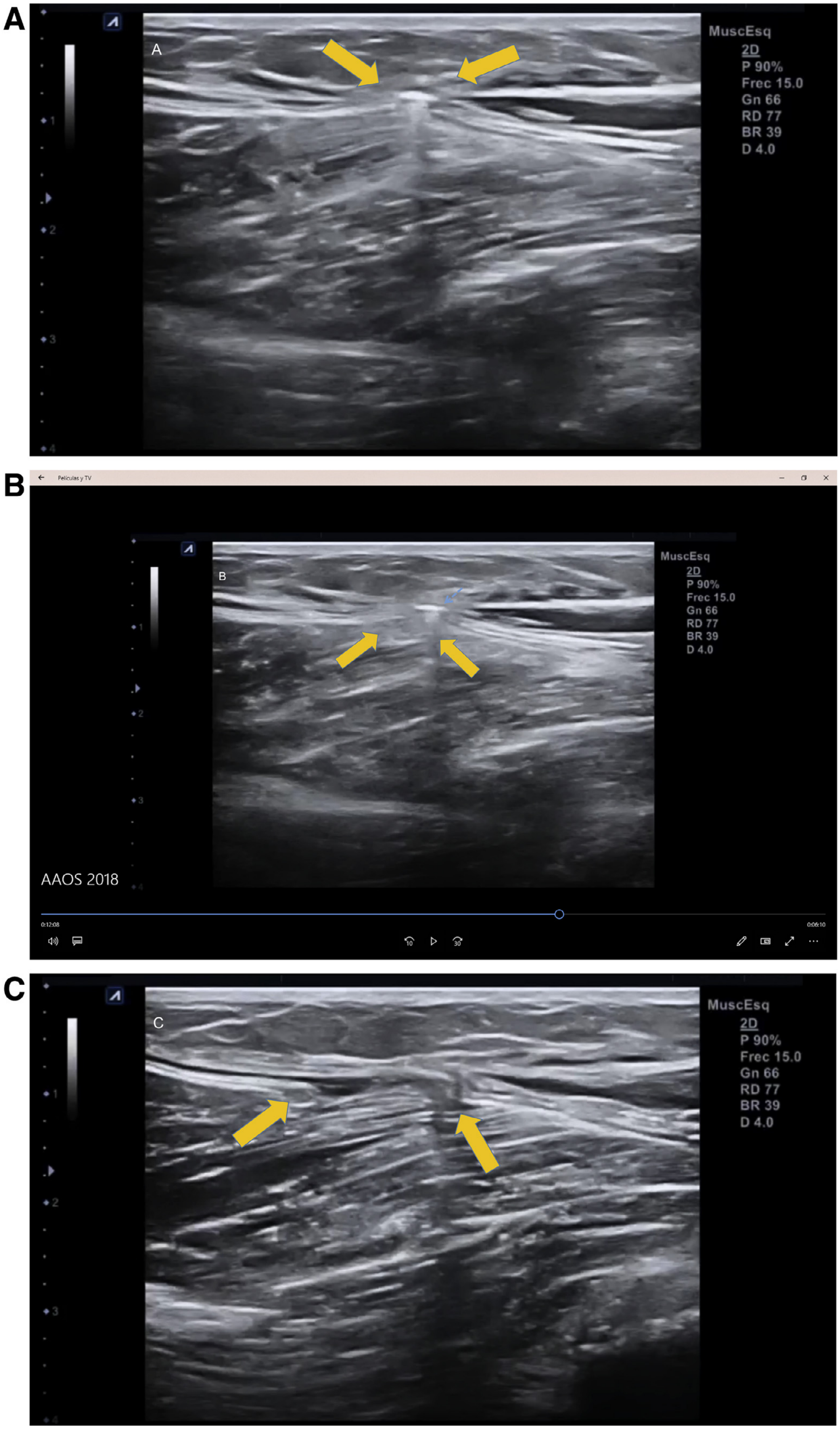


Fig. 6. Longitudinal view of medial gastrocnemius fascia release. *(A)* Image before starting fascia release. *(B)* Fascia releasing; the hook knife (dot arrow) is in the opening. *(C)* Fascia releasing; the hook knife (dot arrow) in the opening.

Statistical Plan

Statistical analysis was performed using SPSS 11.0 for Windows (SPSS Inc, Chicago, IL); statistical significance was defined at $\alpha \leq .05$ (2-tailed). Statistical differences between pre- and postoperative functional outcome (VAS and AOFAS Ankle-Hindfoot Score) were evaluated using a repeated-measures nonparametric Friedman test for more than 2 measures and a Wilcoxon signed-rank test with a Bonferroni correction to identify the specific differences.

Results

Cadaver Study

We achieved effective release of the gastrocnemius tendon in all the cadavers, with no damage to the saphenous vein or nerve or the hamstring tendons. Damage to the underlying muscle fibers was minimal. We considered the technique to be sufficiently safe and effective for ultrasound-guided gastrocnemius recession using a 1-mm incision in vivo.

Clinical Study

A total of 23 extremities in 12 patients were included in the statistical analyses. In the clinical series, ankle dorsiflexion increased for every patient in the study (mean 12°; standard deviation ± 3°) and remained unchanged throughout follow-up. There were no statistically significant differences ($p < .01$) in ankle dorsiflexion measurements between the different indications at any time point, even in cases treated with combined procedures; however, our series was too short to draw definitive conclusions from this result.

Pain and function improved in all patients at 3 months. Because the main diagnoses varied considerably and gastrocnemius recession was an associated or indirect procedure, we inquired about pain not only in the ankle and foot but also in the gastrocnemius and soleus area. Our patients did not complain of calf weakness, but complete strength recovery may take as long as 6 months. The mean preoperative VAS pain score for the gastrocnemius was 7 (range 5 to 9), which improved to 3 at 3 months ($p = .01$), 2 at 6 months ($p = .01$), and 1 (range 0 to 2) at the most recent follow-up visit (12 months) ($p = .01$) (Table 1).

The mean preoperative VAS score for pain in the ankle and foot area was 5 (range 4 to 6). At 3 months, it was 0 (range 0 to 1) ($p = .03$) (Table 2); therefore, every change compared with preoperative situations were significant at $p < .01$. One (4%) patient experienced invalidating pain in the calf muscles for 10 days. The remainder had mild pain requiring painkillers for 1 to 2 weeks, although this did not prevent them from walking slowly without crutches.

The mean AOFAS Ankle-Hindfoot Score was 25 (range 20 to 40) at baseline, and then improved to a mean of 26 (range 20 to 40) at 1 month ($p = .03$), 64 (range 44 to 82) at 3 months ($p = .01$), 85 (range 85 to 100) at 6 months ($p = .01$), and 90 at 1 year (= 0.01) (Table 3). Improvement in pain was therefore statistically significant ($p = .01$) at 3 months. Improvement in function was statistically significant at 3 months ($p = .01$) and stabilized at 6 months for the 5 patients (10 cases) without neurologic syndromes and at 6 to 12 months for those with tarsal tunnel syndrome. All 10 cases (5 patients) with tarsal tunnel syndrome remained on antineuritic medication for 3 to 6 months because of neurological hypersensitivity. These patients had the worst VAS and AOFAS scores and the slowest recovery.

Complications

We observed no infections or wound complications. All patients developed mild superficial hematomas that resolved in 2 to 3 weeks. One (4%) patient had a severely painful hematoma and was only able to walk very short distances during the first week. There were no keloid scars and no weakness of the calf muscles. The scars were not visible in most patients at the most recent follow-up visit. One (4%) patient had an area of anesthesia and surrounding hypoesthesia measuring 7 cm, which decreased to 2 cm after 6 months. This was probably because the fascia was cut with the hook knife facing superficially instead of toward the white fibers of the aponeurosis. This patient underwent surgery simultaneously for bilateral Morton's neuroma. One of the neuromata

Table 1
Progress of VAS over time. Gastrocnemius area (12 patients, 23 extremities)

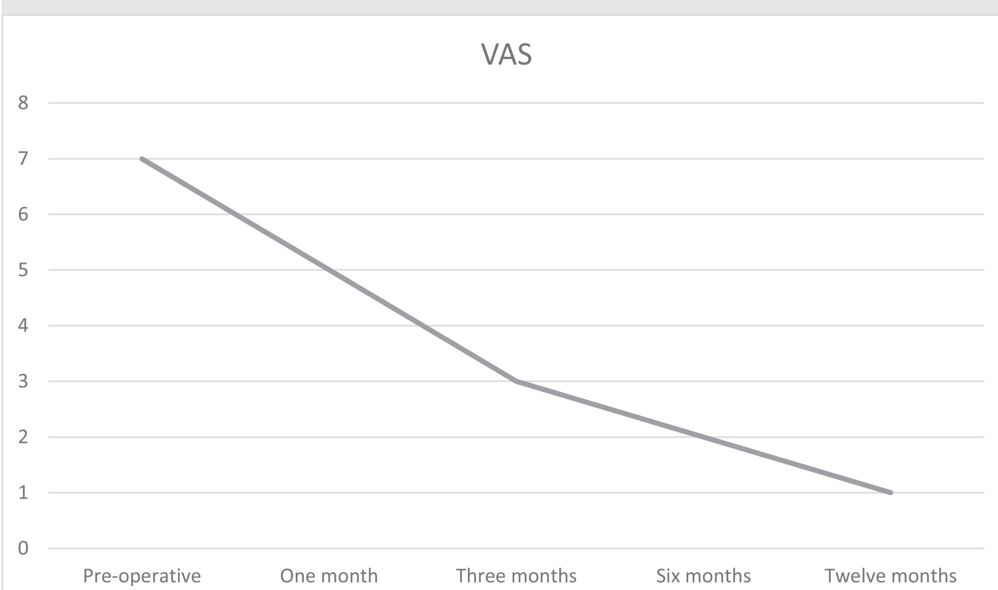


Table 2
Progress of VAS over time. Foot and ankle (12 patients, 23 extremities)

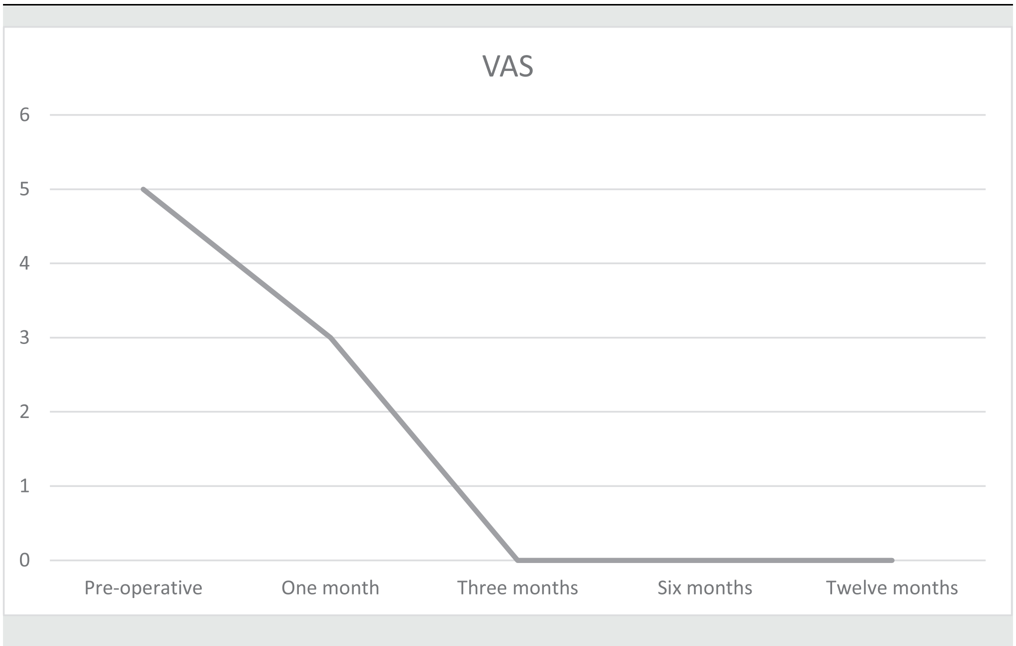
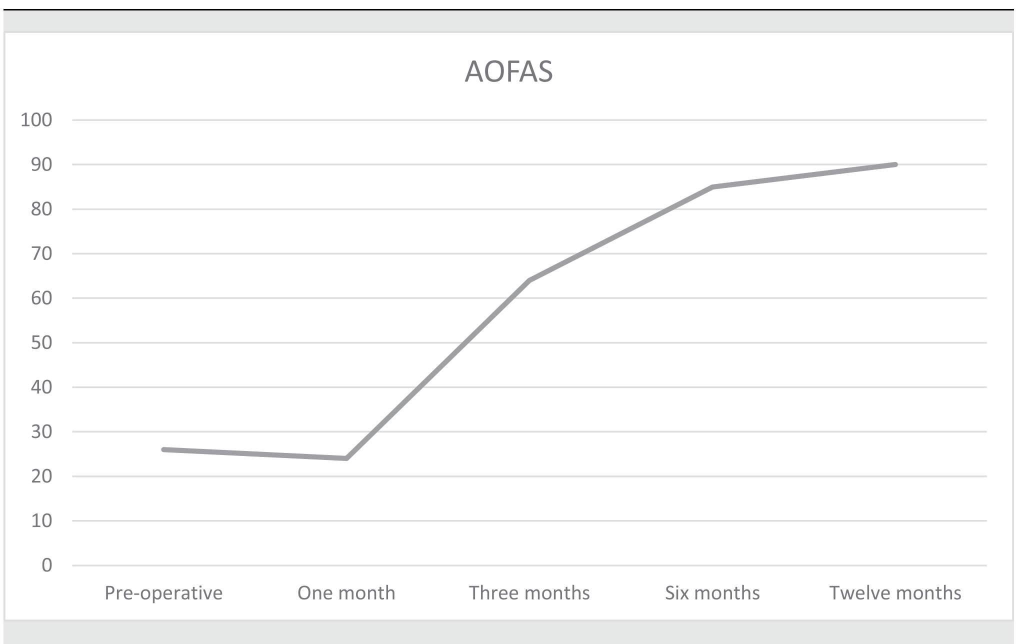


Table 3
Progress of AOFAS over time (12 patients, 23 extremities)



was extremely large, and the ultrasound-guided release of the intermetatarsal ligament failed, necessitating open surgery and nerve excision.

Discussion

As mentioned, proximal gastrocnemius lengthening was first described by in 1923 by Silfverskiöld (18), who severed both the medial and the lateral muscle bellies at the femoral condyles. Selective proximal medial gastrocnemius recession based on release of the white fibers only (aponeurosis) of the gemelli has been reported (19–23).

Ultraminimally invasive surgery has been defined as surgery that requires a 1-mm incision such as that left by a 16-gauge (1.7-mm-diameter) Abbocath needle (Abbott Laboratories, North Chicago, IL) (26,27). To our knowledge, ultrasound-guided ultraminimally invasive proximal medial gastrocnemius recession has not been previously described. We found the procedure to be safe and effective in both the pilot cadaver study and the clinical series.

Clinical outcomes were significantly better than before surgery. Ankle dorsiflexion increased for every patient in the study, and there were no statistically significant differences in ankle dorsiflexion measurements between different indications, despite the use of combined procedures. In addition, both the VAS and the AOFAS Ankle-Hindfoot score improved.

The range of dorsiflexion improved without weakness in the calf muscles, and complications were minor. Only 1 patient experienced paresthesia in the surgical area, probably because of inappropriate surgical technique. Tightness, pain, and soreness in the calf improved in all cases at 3 months.

In the present series, pain in the gastrocnemius area was minimal in all but 1 patient, who had severe pain for more than 1 week after surgery. Patients took medication for 1 to 15 days depending on the damage to muscle fibers.

We selected proximal lengthening in patients with less marked gastrocnemius contracture than in our previous series, which was based on distal ultrasound-guided lengthening. In addition, consistent with findings from cadaver studies, improvement in the range of motion was less than with distal lengthening (11,28–32). Both techniques are considered stable, with no undesired overlengthening despite immediate weightbearing, thus avoiding weakness and crouch gait (15).

Our novel procedure may become the gold standard for proximal gastrocnemius recession, not only because it reduces the size of the incision and ensures better cosmetic but also for its potential benefits, namely local anesthesia, less pain, no need for exsanguination, smaller incisions (1 to 2 mm), shorter operative time, minor complications, and negligible morbidity. The possibility of performing bilateral procedures alone or in combination with other ultrasound-guided surgical techniques in an outpatient regimen—as described in the present and previous series of patients (10)—with proximal or distal ultrasound-guided procedures is one of the most attractive features of this novel surgical procedure. We can thus reduce complications and contraindications and accelerate recovery.

A major drawback of our study is that gastrocnemius lengthening was an associated procedure in the setting of an additional condition, thus limiting evaluation of the clinical results to the evolution of the main condition. However, we believe this does not diminish the benefit of the technique or its efficacy, as demonstrated in the findings of the cadaver study, the improvement in final dorsiflexion, and the favorable medium-term clinical results, even though some patients had not been successfully treated for months or years. Another drawback of our technique is the steep learning curve, which obliges the surgeon to perfect the technique with cadavers and become competent in the use of ultrasound. Availability of high-resolution equipment will ease the learning curve.

In conclusion, preclinical studies in cadavers and favorable preliminary clinical results show the technique to be safe and at least as effective as open procedures for lengthening the gastrocnemius. Data from more prospective randomized studies will help to consolidate the advantages of combining surgical techniques in many lower limb disorders.

Acknowledgments

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jfas.2018.12.027.

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