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ORIGINAL ARTICLE

Correction of Asymmetric Calf Hypertrophy with Differential Selective Neurectomy

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Abstract Contour asymmetry of the legs is a major aesthetic concern among Asian women. This study enrolled 60 patients with asymmetric calf hypertrophy, defined as a differential calf circumference exceeding 0.6 cm. Differential selective neurectomy techniques, which depend on the sizes of the small and large calves, were performed exactly via a 1-cm popliteal wound. The pre- and postoperative mean differences between the larger and smaller calf circumferences at the 1-year follow-up consultation were 1.38 ± 0.65 and 0.42 ± 0.38 cm, respectively ($p < 0.01$). The reduction was significantly greater in the leg that was initially larger. The procedure was effective in reducing circumference discrepancies so that leg contours were more balanced. All the patients were able to ambulate normally within 5 months after the procedure without disability. The authors posit that differential neurectomy is a safe and reliable technique for the correction of asymmetric calf hypertrophy, with minimal morbidities.

Keywords Asymmetry · Calf hypertrophy · Radish leg · Selective neurectomy

Theoretically, the symmetry of an object is defined in terms of the transformations that return the object to its initial state or that leave the object unchanged or invariant. If no transformation can return a body part to its initial state, that part is said to be asymmetric [1].

The lower limbs are a highly exposed part of the human anatomy. As a result, beautiful legs are a highly desired physical attribute, especially among women. The ideal aesthetic contour of the leg has been defined as relatively flat in the medial upper third of the calf, with a gradual taper to the ankle [2]. This contour gives the impression that the leg is long and slender, a perception of beauty that is prevalent and consistent in both Western and Eastern cultures.

Calf hypertrophy, particularly on the medial side, produces a bulge in the upper half of the leg that distorts the leg contour. This deformity is a serious concern to many women, and several techniques have been developed to correct it [3–10]. Tsai et al. [11, 12] reported a new technique that involves selective neurectomy of the nerve to both the medial gastronemius muscle and the medial soleus muscle. However, some patients present with asymmetric calf hypertrophy and request symmetry in addition to a significant reduction in the size of the muscle.

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We postulate that the degree of denervated muscle atrophy is correlated with the number of transected nerves. This report describes our novel technique of differential selective neurectomy, which we recommend for patients concerned about this specific issue.

Materials and Methods

From December 1999 to November 2007, calf reduction with the selective neurectomy technique was performed for 1,500 patients who presented with calf hypertrophy. Of these patients, 60 exhibited significant calf asymmetry and specifically requested correction of the condition. Their mean age was 25.9 years (range, 18–40 years), and their mean height was 163.5 cm (range, 159–169 cm). Patients met the inclusion criteria for this study if they exhibited significant calf asymmetry (defined as a differential circumference greater than 0.6 cm), had undergone no adjunctive procedures (e.g., liposucton, Botox) to rectify the problem, and agreed to a minimum follow-up period of 1 year.

The patients gave informed consent to undergo the differential selective neurectomy technique. They were counseled on the irreversible nature of the procedure and the expected reduction that could be achieved. It was impressed on the patients that although their gait would not be affected, high-demand activities such as sprinting and jumping probably would be compromised. If such activities (e.g., professional athletes) were important to patients, they were discouraged from undergoing the procedure. Maximal calf measurements were taken pre- and postoperatively.

Statistical analysis was performed using the SPSS statistical software, version 11.0, and the Wilcoxon signed rank test was applied to compare the mean measurements. A p value less than 0.01 was considered statistically significant.

Surgical Technique

The patients are measured in the standing position, and the midline of the popliteal fossa in the popliteal crease is marked. The procedure is performed with the patient under general anesthesia and in the prone position.

A 1-cm incision is made, starting at the midpoint of the popliteal fossa and extending medially. The entire leg is exposed to allow easy observation of muscle contractions when nerves are stimulated. No muscle relaxants are given because they make accurate intraoperative identification of motor nerves more difficult.

After dissection of the subcutaneous plane, the first structure encountered is the short saphenous vein, which is preserved and retracted medially. The deep fascia then is cut, and blunt dissection is performed subfascially to locate the motor nerves. From the medial to the lateral points, three small nerves usually can be identified, namely, the nerve to the medial gastrocnemius muscle, the nerve to the lateral gastrocnemius muscle, and the nerve to the soleus muscle (Fig. 1a). These nerves are isolated and their innervations confirmed with a nerve stimulator (the VARI_STIM III surgical nerve locator; Medtronic Xomed, Inc., Jacksonville, FL, USA). Stimulation of the nerve must clearly trigger contraction of both the medial gastrocnemius muscle and the soleus muscle for their positive identification. Sensory nerves that do not produce muscle contractions must be preserved.

Once a positive identification is made, a 1-cm-segment neurectomy of the nerve to the medial gastrocnemius is performed to prevent spontaneous reinnervation of the

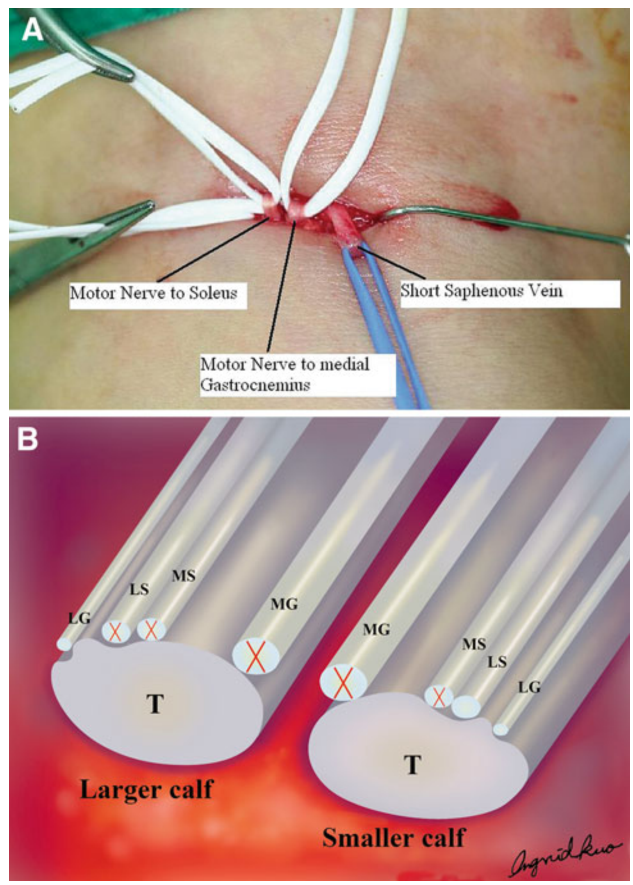

Fig. 1 **a** The first structure encountered in the subcutaneous plane usually is the short saphenous vein, which is preserved and retracted medially. After the deep fascia is cut, the nerve to the medial gastrocnemius muscle usually presents first near the inner surface of the medial gastrocnemius muscle. The nerve to the soleus muscle, which adheres slightly to the nerves to the toes is slightly lateral to this nerve. The identities of these nerves must be confirmed by direct stimulation before neurectomy. **b** Schematic diagram showing the number of resected nerves in different-sized calves, which are marked with X's. The order from medial to lateral location is as follows: *MG* medial gastrocnemius muscle, *MS* medial soleus muscle, *LS* lateral soleus muscle, and *LG* lateral gastrocnemius muscle

muscle due to the close proximity of the cut ends. Then on the smaller side of the calf, one-half of the nerve to the soleus muscle is cut; and on the larger side, the soleus motor nerve is transected completely, as shown in Fig. 1b. Next, the wound is closed in layers, and the stitches are removed after 2 weeks. Mobilization is encouraged immediately after the procedure, and the patients are required to wear lower limb compressive stockings for at least 3 months.

Results

The mean preoperative diameters were 34.01 ± 1.70 cm (range, 31.6–37.6 cm) for the larger leg and 32.63 ± 1.67 cm (range, 30.6–36.2 cm) for the smaller leg. Postoperatively, the respective mean diameters were 31.45 ± 1.07 cm (range, 30.5–33.3 cm) and 31.03 ± 1.12 cm (range, 29.5–32.9 cm). The larger calves were located mainly in the left leg (left-to-right ratio, 8:4). The discrepancy between the larger and smaller calves in terms of mean preoperative leg circumference was 1.38 ± 0.65 cm, and the postoperative discrepancy was reduced to 0.42 ± 0.38 cm ($p < 0.01$) (Table 1 and Fig. 2).

Morbidity was minimal for both legs. However, the patients experienced a longer period of disability (~5 months) than the patients who had undergone previous symmetric calf techniques. All the patients were satisfied with their results, and they were able to walk at a regular pace without any discomfort within 5 months after the operation. Notably, none of the patients reported greater weakness in the leg that had complete transection of the nerve to the soleus muscle. Lower limb edema developed in four patients but resolved within 6 months. Moreover, one of the patients reported numbness and hyperesthesia over the lateral ankle. A hypertrophic scar over the incision developed in four patients but was managed effectively by intralesional steroids and massage so that none required scar revision. The results for two cases of asymmetric calf hypertrophy are shown in Figs. 3 and 4.

Discussion

Because calf hypertrophy is a significant deformity, many patients seek surgical correction of the problem. In Asia,

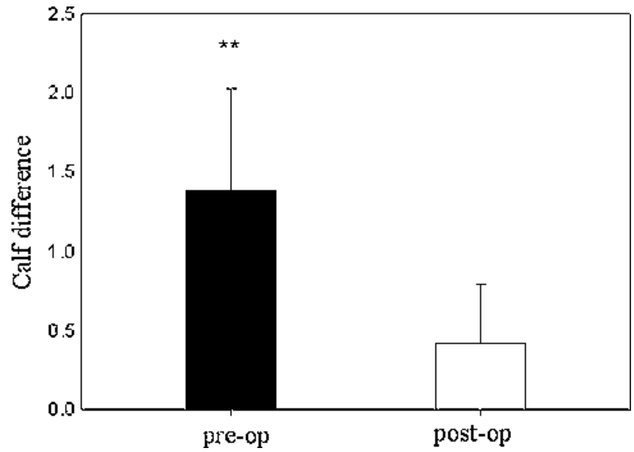

Fig. 2 The differences (in centimeters) between the pre- and postoperative calf measurements are statistically significant

Fig. 3 A 32-year-old woman reporting asymmetric calf enlargement requested surgical correction. Her right and left calf muscles measured 33.2 and 31.5 cm, respectively (*left*). Selective neurectomy using the described technique was performed. Postoperatively, she experienced bilateral swelling as well as weakness when climbing stairs. She wore compressive stockings, which resolved the swelling and weakness over the next 2 months. At the 1-year follow-up consultation, long-lasting calf reduction was noted. The woman's right and left calf muscles measured 30.5 and 29.9 cm, respectively (*right*). Both legs appeared significantly smaller and much more symmetric

Table 1 Statistical results of the preoperative (preop) and postoperative (postop) calf circumferences and the differences in the sizes of the legs

	Preop		Postop		*p* Value	
	Larger leg	Smaller leg	Larger leg	Smaller leg	Larger leg	Smaller leg
Calf circumference (cm)	34.01 ± 1.70	32.63 ± 1.67	31.45 ± 1.07	31.03 ± 1.12	<0.01	<0.01
Difference (cm)	1.38 ± 0.65		0.42 ± 0.38		<0.01	

Fig. 4 A 29-year-old woman presented reporting asymmetric hypertrophy of her calf muscles, which was causing her social embarrassment. She requested reduction in the calf size and improvement in the symmetry of her legs. Examination showed her left calf muscle (37.6 cm) to be significantly larger than her right calf muscle (36.2 cm) (*left*). After selective neurectomy, the woman experienced some discomfort and weakness during ambulation, but it resolved within 1 month of the surgery. Subsequently, she had no difficulties with her daily activities and no other morbidities. At the 1-year follow-up consultation, permanent calf reduction was observed. The medial calf muscle was soft, even on tip-toe; and both calf muscles measured 32.6 cm (*right*)

such a deformity is referred to as "radish leg" because its stocky form resembles that of the vegetable. Techniques that debulk the muscle are effective, but their use is severely limited by the long incisions needed in this highly visible part of the anatomy, the prolonged recovery period, and the contour irregularities that commonly result [6, 7] .

Liposuction is becoming increasingly popular, but its use as the sole method for patients whose main problem is muscle hypertrophy proves to be limited because it does not address the underlying problem [4, 5]. It exacerbates the deformity by making the underlying muscle more prominent.

In recent years, Botox has been advocated as a noninvasive treatment of muscle hypertrophy [3]. But although it is effective for selected patients, we have found it difficult to achieve significant reduction in calf circumference with Botox alone. The effect is transient, and the return of the functional deficit is earlier than in facial muscles.

Neurectomy also has been attempted with variable results [13–16]. Early neurectomy techniques transected the nerve only to the medial gastrocnemius muscle. The results were suboptimal and inadequate for many patients [17]. More importantly, the soleus muscle contributes significantly to calf hypertrophy, particularly in the middle third of the leg. To resolve this problem effectively, a more aggressive approach to denervation that targets both the gastrocnemius and soleus muscles is needed.

Based on anatomic and functional evidences, Tsai et al. [11, 12] applied selective neurectomy of the nerves to the medial gastrocnemius muscle and the soleus muscle. These authors demonstrated that this approach is safe, reliable, and effective in resolving calf hypertrophy. After the procedure, their patients exhibited flaccidity in the medial calf muscle even on tip-toe. Total medial calf denervation was demonstrated in electromyographic studies, and a mean calf circumference reduction of 2.7 cm was achieved. The morbidity of this procedure was minimal (2.6%) and resolved within 4 months of the procedure. Patient satisfaction was high.

Based on our experience, we conclude that to manage hypertrophic calf problems with neurectomy techniques effectively, the motor nerves to the medial gastrocnemius muscle and the soleus muscle need to be resected. Among the patients in this study, complete transection of the former muscle and partial transaction of the latter muscle seemed to be well tolerated and resulted in minimal functional deficit. Our previous study provided the following information about postoperative leg variables with good patient satisfaction levels: a buttock circumference of 87.85 cm, a thigh circumference of 44.20 cm, a maximal calf circumference of 32.24 cm, and a calf ratio of 0.78 [12]. Each preoperative body mass index (BMI) increment represents a 0.3% circumference improvement around the buttocks after surgery. In other words, patients with larger BMI values exhibit better aesthetic improvement than those with smaller values.

When significant asymmetry exists, achieving symmetry becomes as challenging as absolute reduction in muscle volume. Equal amounts of neurectomy cannot correct calf asymmetry. Patients always hope to achieve two goals with body sculpture: reduction in the size of body parts and improvement in their symmetry. With differential neurectomy, we postulate that to achieve more muscle atrophy, a greater degree of muscle denervation is needed on the more enlarged side than on the contralateral side. Complete transection of the motor nerve to the soleus muscle produces an even greater degree of muscle atrophy with little discernable morbidity. This is consistent with our clinical observations in this study. In fact, the results of selectively reducing the more enlarged side compared with the contralateral side are statistically significant. This differential reduction results in legs more in harmony and balanced. Interestingly, larger calf muscles often are noted in the left leg, which may mean that the axis of the body weight inclines to the left and causes the calf to be larger. Our new technique seems to cause a more imbalanced gait than that induced by our equal neurectomy technique Thus, the period required for a return to normal may extend to 5 months.

Based on our experiences with this group of patients, we further extended our procedure for complete transection of the motor nerves to the medial gastrocnemius and soleus muscles in the following two groups: cases with severe (symmetric) enlargement of the calf who demanded a greater reduction in muscle volume and redo cases in which half of the nerve to the soleus muscle had been transected during previous surgery with inadequate reduction in the size of the calf area and unsatisfactory aesthetic results from the patient's perspective. Complete transection was performed during the subsequent operation, and further reduction in the calf size was noted. In both groups, the morbidity with this procedure was minimal.

Conclusion

We achieved the described results by complete transection of the motor nerves to the medial gastrocnemius muscle and the soleus muscle on the more enlarged side. In the smaller leg, the motor nerves to the medial gastrocnemius muscle and one-half of the nerve to the soleus muscle were cut. Asymmetric calf hypertrophy can be corrected effectively by greater denervation of the calf muscle without increased morbidity on the more enlarged side.

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