Gastrocnemius Soleus Recession

A Simpler, More Limited Approach

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Multiple surgical procedures have been described for the correction of equinus deformity. We present a review of the anatomy, biomechanics, and clinical assessment of equinus. In addition, we provide a detailed surgical technique for gastrocnemius soleus recession and introduce an anatomical guide for surgical treatment. (J Am Podiatr Med Assoc 95(1): 18-25, 2005)

Equinus deformity is defined as a limitation of dorsiflexion motion of the ankle joint. Although many authors have attempted to specify the necessary degrees of ankle dorsiflexion, normative values have been limited.[1, 2] Biomechanically, the maximum amount of dorsiflexion in the stance phase of normal gait occurs just before heel lift with the knee extended.[1] The minimum amount of ankle range of motion necessary for normal gait is 10° of dorsiflexion and 20° of plantarflexion.[1-3] DiGiovanni et al[2] differentiated gastrocnemius equinus from gastrocnemius soleus equinus. Gastrocnemius equinus is defined as 5° or less of ankle dorsiflexion with the knee in full extension, and gastrocnemius soleus equinus is defined as 10° or less of ankle dorsiflexion with the knee in full extension or in 90° of flexion.

Equinus imparts a major deforming force on the foot and is a causative factor in many foot and ankle pathologic entities, including plantar fasciitis, pes planus, hallux abducto valgus, Achilles tendinosis, Charcot's midfoot collapse, and diabetic ulcerations.[3] DiGiovanni et al[2] found either gastrocnemius or gastrocnemius soleus equinus in patients with a symptomatic foot and ankle. In asymptomatic patients, gastrocnemius and gastrocnemius soleus equinus are not uncommon (33% and 17%, respectively).[4]

Many types of equinus have been described: osseous equinus, pseudoequinus (plantarflexed forefoot without ankle equinus), gastrocnemius equinus, gastrocnemius soleus equinus, and a combination of types.[3] In addition, an ankle joint capsule contracture can produce or contribute to any type of equinus.[5]

We present a review of the anatomy, biomechanics, and clinical assessment of equinus. A detailed surgical technique for gastrocnemius soleus recession is outlined, and an anatomical guide for surgical treatment is presented.

Anatomy

The gastrocnemius muscle has two heads (medial and lateral) that originate from the posterior aspect of the medial and lateral femoral condyles, the supracondylar ridge, and the posterior capsule of the knee joint. The gastrocnemius heads expand to reach their greatest size just proximal to the middle of the leg. The medial head is typically larger and extends more distally than the lateral head. The gastrocnemius muscle fibers insert into an aponeurotic tendon that forms along the anterior surface of the muscle. This aponeurotic junction marks the division between the proximal and middle thirds of the posterior leg.[6]

The soleus muscle arises from the posterior surface of the fibular shaft and head, from the posterior proximal tibia at the soleal line, and from the middle third of the medial border of the tibial shaft. In addition, a fibrous arch forms proximally between the tibia and the fibula and gives rise to the soleus muscle. This fibrous arch is the upper end of a central aponeurotic tendon of origin that descends on the

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anterior surface of the soleus muscle, protecting the deep neurovascular bundle and giving rise to the bulk of the muscle fibers. The soleus muscle is bipennate, with the fibers directed in an inferior and posterior direction, making the soleus muscle thicker distally. The most distal soleus muscle fibers mark the division between the middle and distal thirds of the posterior leg.[6]

In the distal third of the posterior leg, the gastrocnemius aponeurosis and the soleus tendon merge and form the Achilles tendon, which inserts into the posterior upper third of the posterior calcaneus. The Achilles tendon is the largest and strongest tendon in the body, measuring up to 2.5 cm in diameter.[6, 7] The Achilles tendon fibers, from origin to insertion, spiral from medial to lateral such that the gastrocnemius fibers insert on the lateral aspect of the calcaneus and the soleus fibers insert on the medial aspect of the calcaneus.[6-8]

The plantaris is a small muscle that arises from the distal lateral femur and posterior knee joint capsule. This small, flat muscle runs inferomedially between the gastrocnemius and soleus muscles to the medial edge of the Achilles tendon. The plantaris muscle inserts on the posteromedial calcaneus adjacent to the Achilles tendon insertion. As in the gastrocnemius muscle, the plantaris muscle flexes the knee and plantarflexes the ankle. Compared with the gastrocnemius and soleus muscles, the plantaris muscle is much weaker and smaller.[6]

We defined anatomical levels that are simple to identify topographically and proposed a surgical treatment guide for each level. The posterior leg and the triceps surae muscle (the gastrocnemius and soleus muscles) can be divided into five anatomical levels. A surgical guide is presented for each specific type of equinus correction in conjunction with these anatomical levels. The proximal fifth of the leg is level 5, which consists of the origin and the tendons or the medial and lateral heads of the gastrocnemius muscle. At level 5, a proximal gastrocnemius tenotomy can be performed. Level 4 begins with the gastrocnemius muscle and includes the medial and lateral heads of the gastrocnemius muscle. At level 4, a deep gastrocnemius or soleus recession (intermuscular lengthening) can be performed. Level 3 begins as the gastrocnemius muscle becomes tendon and comprises the soleus muscle and the distal gastrocnemius tendon. The distal extent of level 3 is defined by the aponeurotic tendon (combined gastrocnemius and soleus tendon). At level 3, a distal gastrocnemius tenotomy can be performed. Level 2 begins at the gastrocnemius soleus aponeurotic tendon and ends at the most distal extent of the soleus muscle. At level 2, a gastrocnemius soleus recession can be performed. The distal fifth of the leg is defined as level 1, at which a tendo Achillis lengthening can be performed. Level 1 consists of the rotating tendon fibers of the triceps surae muscle that constitute the Achilles tendon (Fig. 1).

Biomechanics

Ankle equinus is most noticeable during the midstance phase of gait. By inducing a more rapid entrance and exit into and out of the midstance phase of gait, equinus produces a reduced step length and thus a slower walking velocity. Compensatory mechanisms for equinus deformity include forward torso lean, pelvic rotation, hip flexion, knee hyperextension, and external rotation of the leg.[9] Equinus of the ankle results in compensatory subtalar pronation, thereby unlocking the midtarsal joint and producing midtarsal joint pronation. This motion results in dorsiflexion of the forefoot on the rearfoot. Pronation of the subtalar and midtarsal joints then produces a hy-

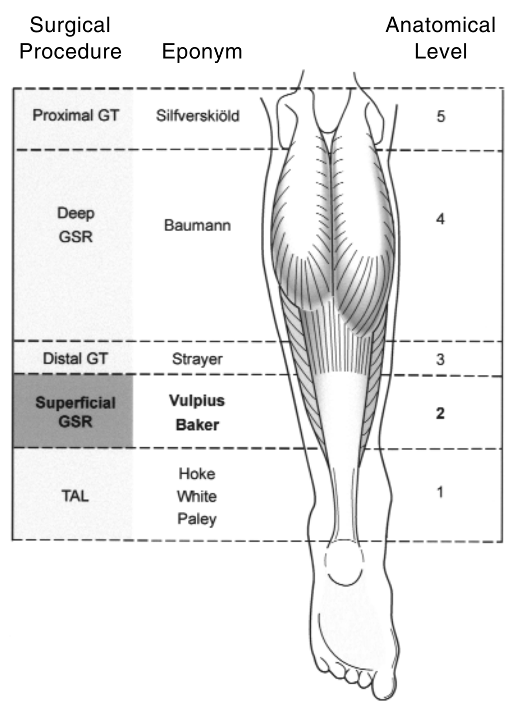

Figure 1. The posterior leg can be divided into five anatomical levels. Based on anatomical level and clinical assessment, specific surgical procedures are indicated. The location for superficial gastrocnemius soleus recession is highlighted. GT, gastrocnemius tenotomy; GSR, gastrocnemius soleus recession; TAL, tendo Achillis lengthening.

permobile first ray and a subsequent forefoot pathologic abnormality.[3]

In static stance, the soleus and gastrocnemius muscles are active postural stabilizers that help maintain balance. The gastrocnemius muscle is active intermittently when the knees flex but shows no activity when the knees are fully extended. The lateral portion of the soleus muscle is the only muscle in the leg that is active during bipedal postural stance.[5]

The gastrocnemius, soleus, and plantaris muscles are located in the superficial posterior compartment of the leg, and they all cross the subtalar and ankle joints. The soleus and plantaris muscles have been described as two-joint muscles. Because the gastrocnemius muscle spans the knee, ankle, and subtalar joints, it has been described as a three-joint muscle.[3]

During the midstance and propulsive phases of gait, the soleus and gastrocnemius muscles are active. The gastrocnemius and soleus muscles plantarflex the ankle joint and, because of the ankle joint's oblique axis, act to invert the rearfoot during plantarflexion.[3] The gastrocnemius muscle acts on the ankle joint only when the knee is flexed. During the propulsive phase of gait, the knee is slightly flexed; therefore, the gastrocnemius and soleus muscles act on the ankle joint during propulsion. Gait analysis has shown the importance of a minimum of 10° of ankle dorsiflexion in the propulsive phase of gait to allow for foot clearance.[1,5] The soleus muscle acts independently of the knee position but serves as a stabilizer of the tibia by preventing anterior translation of the tibia at the knee joint when the foot is planted. This is important in the anterior cruciate ligament–deficient knee.[10]

Clinical Assessment

Equinus should be measured with the knee extended and with the knee flexed. The amount of ankle dorsiflexion is measured using a goniometer. Measurements can be obtained by determining the angle between the plantar aspect of the heel (medially or laterally) and the tibia. When clinically assessing for equinus, care must be taken to maintain the subtalar joint in a neutral position and to measure ankle dorsiflexion and not midfoot dorsiflexion (rocker-bottom) or midfoot equinus (pseudoequinus). Osseous and muscular equinus can be differentiated radiographically in standing mortise lateral radiographs of the foot and ankle in maximum dorsiflexion.[11] Osseous equinus may result from bony procurvatum of the distal tibia or from osteophytes on the anterior lip of the distal tibia or neck of the talus.[9]

Once osseous equinus is ruled out, the Silfverskiöld test is performed to differentiate gastrocnemius equinus from other types of equinus.[12] The medial and lateral heads of the gastrocnemius and plantaris muscles originate from the femoral condyles proximal to the knee joint. Therefore, when the knee is flexed, the gastrocnemius and plantaris muscles relax. The generally accepted amount of normal ankle dorsiflexion is approximately 10° with the knee extended and 20° with the knee flexed (Fig. 2).[1-3, 13] Gastrocnemius equinus is indicated by the inability of the ankle to dorsiflex normally with the knee extended but the ability of the ankle to dorsiflex more than 10° with the knee flexed (Fig. 3). Gastrocnemius soleus equinus is defined by the inability of the ankle to dorsiflex beyond a neutral position with the knee extended (it remains $<0°$) or with the knee flexed (it remains $<0°$) (Fig. 4).[2, 3, 12] None of these tests would differentiate a situation in which the soleus was tight but the gastrocnemius was lax. However, it is difficult to imagine such a clinical situation.

Surgical Treatments

Surgical strategies to correct ankle equinus are based on clinical evaluation. The Silfverskiöld test has been the gold standard for determining whether a patient has gastrocnemius or gastrocnemius soleus equinus. Many techniques, therefore, have been developed to treat positive (gastrocnemius recession) and negative (tendo Achillis lengthening) Silfverskiöld test results. The surgical procedure that is most appropriate for the specific pathologic abnormality should be selected. For example, lengthening of the Achilles tendon should be avoided if the problem is limited to a tight gastrocnemius muscle. In such a case, recessing the gastrocnemius muscle will preserve soleus muscle strength.

The techniques presented by Vulpius and Stoffel in 1924[14] and by Strayer[15, 16] in the 1950s for triceps surae muscle lengthening were described as being performed in levels 2 and 3, respectively. These two procedures are often confused. The Vulpius procedure is a gastrocnemius soleus recession performed at level 2. Vulpius made one or more chevron-shaped cuts through the gastrocnemius tendon and incised the deep tendon raphe of the soleus muscle. Baker[17] modified the Vulpius procedure by making a tongue-shaped recession of the gastrocnemius soleus tendon. Strayer[15, 16] described a gastrocnemius tenotomy at level 3, just proximal to the gastrocnemius soleus aponeurotic tendon. He separated these two muscles to allow the gastrocnemius muscle to retract proximally and then sutured it in its new, more proximal loca-

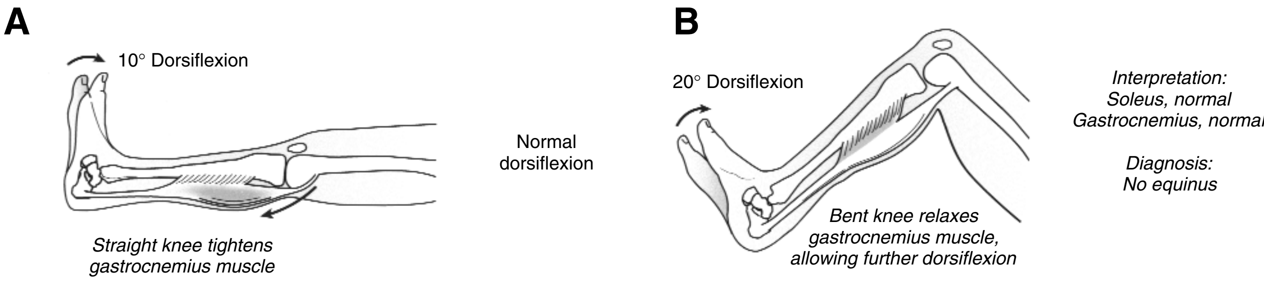

Figure 2. Silfverskiöld test results show normal ankle dorsiflexion with the knee extended (A) and with the knee flexed to 90° (B).

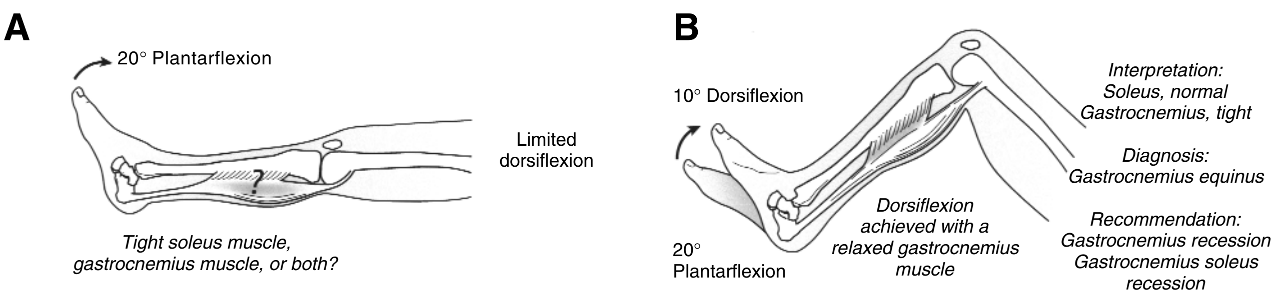

Figure 3. Silfverskiöld test results show limited ankle dorsiflexion with knee extension (A) and improved ankle dorsiflexion with knee flexion (90°) (B). This is an example of pure gastrocnemius equinus, which would benefit from isolated gastrocnemius recession or gastrocnemius soleus recession.

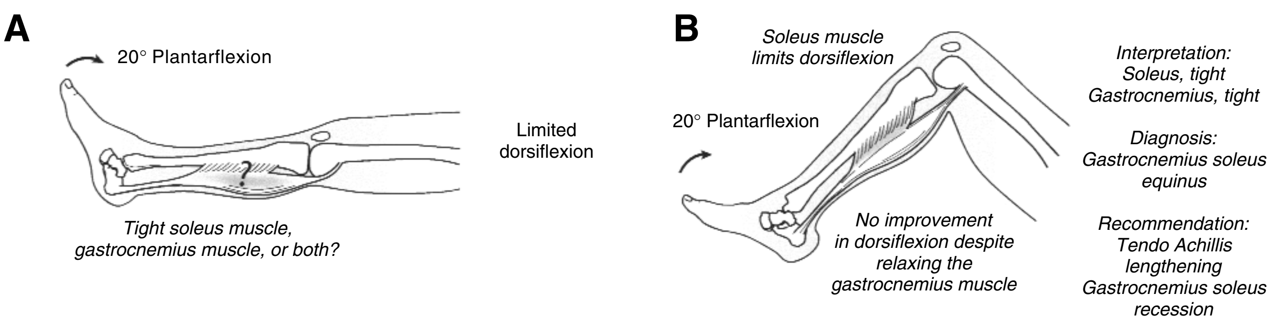

Figure 4. Silfverskiöld test results show that ankle dorsiflexion greater than neutral (0°) is not present with the knee extended (A) or with the knee flexed to 90° (B). This is an example of gastrocnemius soleus equinus, which would benefit from tendo Achillis lengthening or gastrocnemius soleus recession.

tion, calling this technique a gastrocnemius recession.

The advantage of the Vulpius technique over that presented by Strayer is that the gastrocnemius soleus recession includes intramuscular lengthening of the soleus muscle. The Baumann procedure, which has been described for cases of cerebral palsy, is a gastrocnemius and/or soleus recession performed at level 4.[18, 19] At level 5, Silfverskiöld described a proximal gastrocnemius tenotomy. A tendo Achillis lengthening at level 1 can be performed by percutaneous Z-lengthening,[9] percutaneous triple hemisectioning,[20] or open Z-lengthening.[21]

Gastrocnemius Soleus Recession Technique

We found that most children and adults present with combined gastrocnemius soleus equinus. As an alternative to tendo Achillis lengthening, which weakens the entire triceps surae muscle, we prefer gastrocnemius soleus recession, except in cases of very severe contracture, for which maximal lengthening is needed. Since 1996, the senior author (D.P.) has used this modified Vulpius technique when performing gastrocnemius soleus recession.

The patient, under general anesthesia, is positioned supine, with a thigh tourniquet in place. After exsanguination with elevation of the lower extremity and inflation of the tourniquet, an assistant holds the leg up at an angle of 45° from the table, with the ankle placed in a neutral position. A 3-cm longitudinal midline incision is made at the distal end of level 2 (Fig. 1). Careful dissection is then performed at that interval to identify the sural nerve and lesser saphenous vein (Fig. 5). These structures are retracted to either side. The tendon sheath is identified, and a longitudinal incision is made through it. The plantaris muscle is identified and completely released. With the ankle maintained in a neutral position, the gastrocnemius tendon is transversely incised. The underlying soleus tendon is then cut, stopping when the soleus muscle fibers are seen. The soleus tendon extends farther medially than laterally, covering the soleus muscle fibers. It is important to retract one side at a time so that the tendon can be cut under direct visualization (Figs. 6 and 7). The ankle should then be maximally dorsiflexed with the knee in full extension to separate the cut tendons (recession). The Silfverskiöld test is again performed to assess the remaining equinus deformity. If the equinus deformity is not completely corrected, the soleus tendon median raphe is identified and cut. To cut this safely, the median raphe, or central tendon portion of the soleus muscle, is dissected from the muscle medially and laterally (Fig. 8). Direct visualization of the median raphe is recommended to avoid injury to the posterior tibial nerve bundle. Using a Beaver blade (BD Ophthalmic Systems, Waltham, Massachusetts), the thick longitudinal soleus raphe is released. The wound is then irrigated with normal saline. The sheath covering the outer border of the tendon is closed if possible. The skin incision is closed in two layers. A small gauze pad and a transparent dressing (Tegaderm; 3M Health Care, St Paul, Minnesota) are then applied.

Rehabilitation typically depends on the concomitant procedures. In general, after undergoing this type of recession, patients are protected in a weight-bearing, removable, short-leg cast or boot for 3 weeks and undergo early range-of-motion exercises. The patient should be encouraged to keep the knee extended with a knee immobilizer to maintain the maximum recession effect of the gastrocnemius muscle obtained at surgery. Active physical therapy is started 3 weeks after surgery.

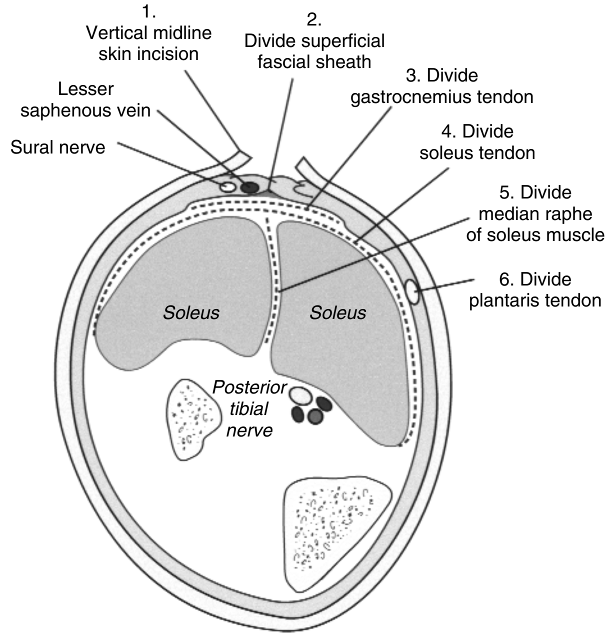

Figure 5. Cross-sectional view of level 2. The broken line represents the tendon portion of the gastrocnemius and soleus muscles and the median raphe of the soleus muscle. Steps in performing gastrocnemius soleus recession are numbered sequentially.

Discussion

We present a new technique of gastrocnemius soleus recession. A surgical guide for each specific type of equinus correction has been introduced in conjunction with the respective anatomical levels (Fig. 1). When a positive Silfverskiöld test result is elicited, a proximal gastrocnemius tenotomy (level 5, Silfverskiöld), a deep gastrocnemius recession (level 4, Baumann), or a distal gastrocnemius tenotomy (level 3, Strayer) is recommended. When the Silfverskiöld test result is negative, the recommended treatment is either tendo Achillis lengthening (level 1)[9, 20, 21] or superficial gastrocnemius soleus recession (level 2).

Our approach, like the Vulpius approach, is gastrocnemius soleus recession. Our technique differs, however, in that the incision through the tendons is a single transverse cut, not a single or multiple chevron-

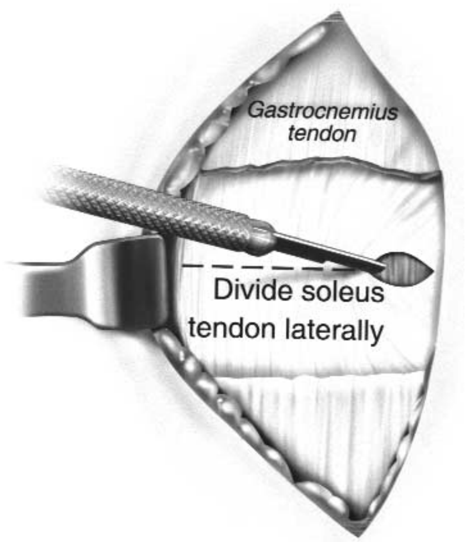

Figure 6. After the midline vertical incision, vertical division of the superficial fascia, and horizontal release of the gastrocnemius tendon, the soleus tendon is released. Deep retraction allows for full release at the more anterior edge of the tendon laterally.

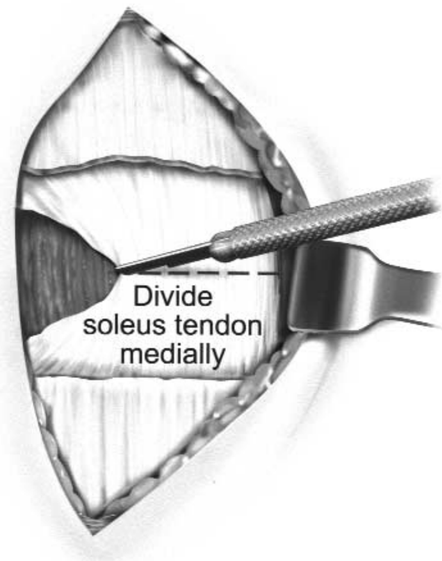

Figure 7. The soleus tendon is also released horizontally to the opposite edge (medially) of the tendon using deep retraction.

type cuts. In addition, we use a minimally invasive approach that is performed exclusively in level 2.

Differentiation between the need for tendo Achillis lengthening and the need for gastrocnemius soleus recession is based on the degree of the deformity and the cause of the equinus. Large equinus contractures typically require open tendo Achillis lengthening to gain the needed amount of length and to determine the appropriate length-tension ratio for the tendon. Smaller amounts of equinus can be corrected through percutaneous slide-type procedures, such as the triple hemisection technique; however, slide-type techniques render an unpredictable final length. Gastrocnemius soleus recession leaves some of the soleus muscle strength undisturbed compared with tendo Achillis lengthening, which weakens the entire soleus muscle. Gastrocnemius soleus recession allows for sequential lengthening and obviates the need for resuturing the cut tendons. After transverse release of the gastrocnemius soleus tendon, the Silfverskiöld test is conducted to reassess the deformity before release of the median raphe of the soleus muscle. This clinical reassessment of equinus during the procedure allows for more accurate correction. It is important to remember that restriction of ankle motion can be attributed to contracture of one muscle or a group of muscles. A recession of the soleus muscle maintains muscle strength and is preferred to a tendo

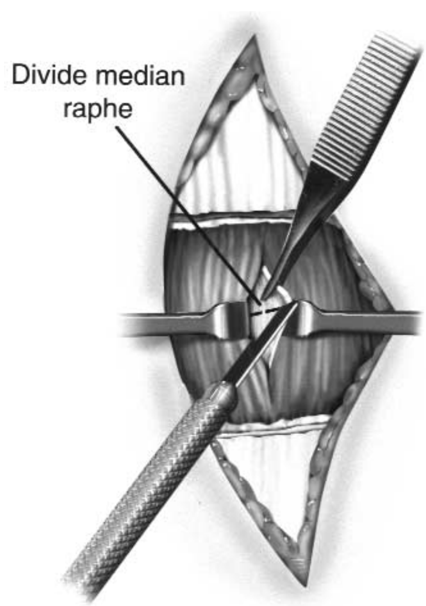

Figure 8. Locate the median raphe (central tendon) of the soleus muscle. Release of this tendon using a blade or dissecting scissors achieves additional lengthening.

Achillis lengthening, which causes maximum loss of strength, especially if the tendon is overlengthened.

The advantage of performing gastrocnemius or gastrocnemius soleus recession is that these procedures preserve the magnitude of muscle strength because they are intramuscular lengthenings.[3, 22] Tendo Achillis tendon lengthening has been shown to markedly decrease the strength of the triceps surae muscle because of partial or complete division of the tendon.[22] Delp and Zajac[22] found that lengthening the soleus tendon by 1.2 cm or lengthening the gastrocnemius tendon by 1.5 cm reduces the respective muscle force by 50%. Their results confirm the importance of conservative lengthening of the tendo Achillis to avoid plantarflexion weakness.

In static bipedal stance, the soleus is active and thus important for balance. Patients who undergo tendo Achillis lengthening may have decreased strength in the soleus muscle during static stance, thereby impairing imbalance. Therefore, the gastrocnemius soleus recession may be advantageous for patients with diabetes mellitus with peripheral neuropathy, who typically have diminished proprioception and lack of balance after lengthening of the tendo Achillis. Patients with diabetes often undergo tendo Achillis lengthening to reduce excessive pressure on the forefoot. Complete disruption of a tendon will inhibit the stretch reflex, whereby sufficient impulses cannot be released from the Golgi tendon organs and the spindle fibers of the muscle to excite the motor neuron.[23] Theoretically, this muscular deficiency could create a static and dynamic postural imbalance, especially in the already insensate patient with diabetes. Simmons et al[24] studied patients with diabetic neuropathy and loss of protective sensation as confirmed by a 10-g monofilament. They found significantly reduced active and passive ankle joint mobility compared with control participants. These authors also theorized that limited ankle joint mobility might contribute to a decrease in postural stability.

Surgical decisions should be made systemically to obtain optimal results. Osseous equinus should be treated initially with a bone procedure and then retested intraoperatively to assess the soft tissues. After completion of each step of a procedure, the surgeon should repeat the Silfverskiöld test to reassess the deformity. Long-standing deformities can also result in ankle joint capsule contracture, which may require capsulotomy or gradual distraction with external fixation.

Conclusion

This article presents a new technique for gastrocnemius soleus recession and introduces an anatomical guide for surgical treatment of equinus deformity. An accurate clinical assessment and Silfverskiöld test, coupled with an understanding of the anatomical levels of the posterior leg, provide a specific guide for the surgeon. Our gastrocnemius soleus recession, a modified Vulpius procedure, is performed in level 2 as a simpler and more limited approach. Moreover, our technique is an intermuscular lengthening of the soleus, which limits the amount of triceps surae muscle weakening.

References

1. Root ML, Orien WP, Weed JH: *Normal and Abnormal Function of the Foot*, Clinical Biomechanics Corp, Los Angeles, 1977.
2. DiGiovanni CW, Kuo R, Tejwani N, et al: Isolated gastrocnemius tightness. J Bone Joint Surg Am **84:** 962, 2002.
3. Downey MS, Banks AS: Gastrocnemius recession in the treatment of nonspastic ankle equinus: a retrospective study. JAPMA **79:** 159, 1989.
4. Brodersen A, Pedersen B, Reimers J: Foot deformities and relation to the length of leg muscles in Danish children aged 3-17 years. Ugeskr Laeger **155:** 3914, 1993.
5. Paley D: "Gait Considerations," in *Principles of Deformity Correction*, 2nd Ed, p 717, Springer-Verlag, Berlin, 2003.
6. Gray H: *Gray's Anatomy*, 37th Ed, p 647, Churchill Livingstone, London, 1989.
7. Cummins EJ, Anson BJ, Carr BW, et al: The structure of the calcaneal tendon (of Achilles) in relation to orthopedic surgery: with additional observations on the plantaris muscle. Surg Gynecol Obstet **83:** 107, 1946.
8. van Gils CC, Steed RH, Page JC: Torsion of the human Achilles tendon. J Foot Ankle Surg **35:** 41, 1996.
9. Paley D: *Principles of Deformity Correction*, 2nd Ed, Springer-Verlag, Berlin, 2003.
10. Sherbondy PS, Queale WS, McFarland EG, et al: Soleus and gastrocnemius muscle loading decreases anterior tibial translation in anterior cruciate ligament intact and deficient knees. J Knee Surg **16:** 152, 2003.
11. Lamm BM, Paley D: Deformity correction planning for foot, ankle, and lower limb. Clin Podiatr Med Surg **21:** 305, 2004.
12. Silfverskiöld N: Reduction of the uncrossed two-joint muscles of the leg to one-joint muscles in spastic conditions. Acta Chir Scand **56:** 315, 1924.
13. Downey MS: "Ankle Equinus," in *Comprehensive Textbook of Foot Surgery*, 2nd Ed, Vol 1, ed by ED McGlamry, AS Banks, MS Downey, p 687, Williams & Wilkins, Baltimore, 1992.
14. Vulpius O, Stoffel A: *Orthopädische Operationslehre*, Verlag von Ferdinand Enke, Stuttgart, Germany, 1924.
15. Strayer LM Jr: Recession of the gastrocnemius: an operation to relieve spastic contracture of the calf muscles. J Bone Joint Surg Am **32:** 671, 1950.
16. Strayer LM Jr: Gastrocnemius recession: five-year report of cases. J Bone Joint Surg Am **40:** 1019, 1958.
17. Baker LD: A rational approach to the surgical needs of the cerebral palsy patient. J Bone Joint Surg Am **38:** 313, 1956.
18. Baumann JU, Koch HG: Lengthening of the anterior aponeurosis of the gastrocnemius muscle [in German]. Operat Orthop Traumatol **1:** 254, 1989.

19. Saraph V, Zwick EB, Uitz C, et al: The Baumann procedure for fixed contracture of the gastrosoleus in cerebral palsy: evaluation of function of the ankle after multilevel surgery. J Bone Joint Surg Br **82:** 535, 2000.
20. Hoke M: An operation for the correction of extremely relaxed flat feet. J Bone Joint Surg **13:** 773, 1931.
21. White JW: Torsion of the Achilles tendon: its surgical significance. Arch Surg **46:** 784, 1943.
22. Delp SL, Zajac FE: Force- and moment-generating capacity of lower-extremity muscles before and after tendon lengthening. Clin Orthop **284:** 247, 1995.
23. Ganong WF: "Excitable Tissue: Muscle," in *Review of Medical Physiology*, 16th Ed, p 56, Appleton & Lange, East Norwalk, CT, 1993.
24. Simmons RW, Richardson C, Deutsch K: Limited joint mobility of the ankle in diabetic patients with cutaneous sensory deficit. Diabetes Res Clin Pract **37:** 137, 1997.