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Review Article

Critical evaluation of the surgical techniques to correct the equinus deformity.

Avaliação crítica das técnicas cirúrgicas de correção do equino.

José Batista Volpon[1]; Leonardo Lima Natale[1].

1. University of São Paulo, Ribeirão Preto Medical School, Department of Biomechanics, Medicine and Locomotive Apparatus Rehabilitation, Ribeirão Preto, SP, Brazil.

ABSTRACT

The equinus deformity leads to several gait disorders, causing changes in the foot support and affecting more distant anatomical regions, such as the knee, hip and trunk. It is usually secondary to retraction, shortening or spasticity of the triceps surae, so it may require some surgical interventions. This is one of the oldest procedures of Orthopedics, previously performed only in the calcaneus tendon and that, over time, developed with different techniques according to the degree of deformity, underlying disease, and patient profile. The aim is to correct the deformity, with the least possible interference in muscle strength, and with this, reduce the incidence of complications such as crouch gait, dragged drag and calcaneus foot. From the anatomical point of view, the triceps surae presents five regions that can be approached surgically for equinus correction. Due to the complexity of the equinus patient, orthopedists should have experience with at least one technique in each zone. In this text, we critically approach and analyze the most important techniques for correction of the equinus, mainly in order to avoid complications. We conducted a search for the most common equinus correction surgical techniques in classic books, identifying original articles. Then we performed a database search in the last ten years.

Keywords: Foot. Ankle Joint. Achilles Tendon. Review. Equinus Deformity.

INTRODUCTION

The equinus gait alters the foot rolling mechanism by causing the support to initially occur in the forefoot. More than that, there are secondary accommodations in the knee and hip that assume compensatory flexion attitudes. Changes in anatomically distant, functionally associated regions such as abnormal pelvic oscillation, lumbar lordosis increase, and compensatory scoliosis may occur. This may lead to changes in posture, gait, increased energy consumption and segmental overloads. There will be greater repercussion if muscle groups are altered, as occurs in the sequelae of cerebral palsy.

Surgical interventions on the Achilles tendon are one of the oldest operations of Orthopedics. It is attributed to Hessen (*apud* David[1]), in 1784, the first section of the calcaneus tendon to treat a paralytic foot. However, even with favorable reports to the technique performed by renowned surgeons such as Petit in 1799, Sartorius in 1806 and Michaelis in 1809 (*apud* David[1]), the procedure was widely criticized because it was believed to be very dangerous, with low possibility of scarring and great risk of infection. Probably for this reason, the percutaneous section of the Achilles tendon has been developed, first performed by Delpech, in 1816 (*apud* Strayer[2]), for treatment of congenital clubfoot. It is well known that William John Little, a pioneer of English orthopedics and notorious for his contribution to the knowledge of cerebral palsy sequelae, had equinus secondary to poliomyelitis. This author was a trainee in Berlin, where he was recommended an evaluation with Stromeyer, Hanover. In 1836 Little (*apud* David[1]) was successfully submitted to the percutaneous section of the calcaneus tendon. Little then became enthusiastic about the technique, spread it in England and on a visit to the United States[1].

The "Z" section and lengthening were adequate for many cases of congenital foot or flaccid paralysis due to poliomyelitis. However, when these techniques were applied to the spastic equinus, in some patients there was clinical worsening and triggering of crouch gait, although the deformity had been corrected. One of the greatest challenges today is the treatment of equinus resulting from spasticity, often observed in the sequelae of cerebral palsy and stroke, since lengthening always weakens the muscle, and the triceps surae acts not only on the ankle but also on the knee and, indirectly, on the hip. One of the first attempts to approach this type of patient was Stoffel's surgery[3], which consisted of the selective denervation of the muscle, with the purpose of decreasing spasticity. However, others failed to reproduce the good results reported by this author, and the procedure fell into disuse.

In 1923, Silfverskiöld (*apud* Singh[4]) described the semiological test in which it differentiated the equinus caused only by the gastrocnemius retraction from that resulting from the retraction of the entire gastrocnemius-soleus complex. This same author developed the technique of transferring the origin of the twin muscle heads from the femur to the tibia[5]. This surgery was not spread, but the concept was used in 1950 by Strayer[2] with his technique for selective release of the gastrocnemius fascia for equinus correction. The goal was not only to obtain correction, but also to avoid significant weakening of the triceps surae. This idea represented an improvement in the spastic equinus correction and was followed by several technical modifications described by other authors.

Relevant anatomy

Anatomical details of the triceps surae have gained interest with the different techniques to treat equinus deformity from spasticity. The gastrocnemius-soleus complex is a potent unit whose primary function is to act in the ankle and hold the extension (or plantar flexion) of the foot, with significant contributions in the knee, in the static position and in dynamic gait. These muscles end up with a strong joint insertion in the calcaneus, the Achilles tendon. The triceps surae occupies the posterior surface compartment of the leg. The gastrocnemius comprises two heads that originate in the postero-superior region of the corresponding femoral condyle. About 70% of the force of the gastrocnemius is given by the musculature of the medial head[6]. A sesamoid accessory ossicle, the fabela, occurs in 10% to 30% of the population and is included in the lateral head tendon[7]. The medial head glides on a serous pouch that is in contact with the knee joint and the bursa of the semimembranous muscle, being the origin of the Baker's cyst[8]. From independent sources, the muscle fibers form two separate bundles that remain separated until they converge to form a large aponeurosis that binds to the soleus. The identification of this attachment point is important in some selective lengthening techniques. Branches of the tibial nerve that penetrate separately into the medial and lateral heads in the popliteal region perform the innervation of the gastrocnemius.

The other component of the sural triceps, the soleus, is formed by a large and voluminous muscle mass that lies deep in relation to the gastrocnemius. It has both tibial and fibular origin, in the proximal portion of the leg. In this region, the tendinous fibers converge to form a fibrous arch that gives passage to the tibial pedicle. The aponeurosis of the soleus occupies the anterior face of this muscle and thickens distally, forming a thickening that fuses with the aponeurosis of the gastrocnemius to give rise to the calcaneus tendon[9]. The soleus is the most powerful muscle of the ankle and represents

more than twice the entire flexion force[6]. The aponeurotic faces of the gastrocnemius and soleus are in contact and provide a slipping of one muscle over the other.

The calcaneus tendon is formed by the union of the aponeuroses of the gastrocnemius and soleus. It is a strong structure that is inserted into the posterior tuberosity of the bone. Although it is the largest tendon of the human body, it is also one of the most prone to degeneration and rupture[10]. The blood supply is given by vessels originating from the posterior tibial artery that irrigate the proximal and distal portions, the less vascularized middle portion being supplied by branches of the fibular artery. Spatially, the Achilles tendon is twisted clockwise on the left side and counterclockwise on the right side[11]. Figure 1 illustrates the applied anatomy.

Figure 1. Relevant muscle-tendon anatomy of the calf. A) Back view of the superficial muscular layer: 1- lateral portion of the gastrocnemius, 2- medial portion of the gastrocnemius, 3- aponeurosis of the gastrocnemius, 4- soleus muscle, 5- calcaneus tendon, 6- posterior deep fascia, 7- sartorius muscle, 8 - gracilis tendon, 9 - common fibular nerve, 10 - sural nerve, 11 - tibial nerve; B) Separation of the gastrocnemius and soleus, illustrating the aponeurotic faces of the two muscles that are in contact. (A) fusion region of the gastrocnemius and soleus aponeurosis, (B) gastrocnemius lateral head, (C) gastrocnemius medial head, (D) soleus aponeurosis, (E) plantar tendon, (F) calcaneus tendon, (I) tendon arch of the soleus, (J) deep posterior fascia of the leg, (K) medial intermuscular septum. Reprinted with permission of Dalmau-Pastor *et al*.[9].

Semiology of equinus deformity

Although the concept that the position of the knee influences the degree of dorsal flexion of the foot has been presented independently by Vulpius and Nutt, in 1913 (*apud* Singh[4]) and others[2], the clinical test that allows to differentiate the origin of the equinus secondary only to retraction of the gastrocnemius, or of the whole triceps, is associated

with the name of Silfverskiöld[4]. For this, with the patient in supine position, the foot is maintained in inversion to block the mediotarsic joint and, with the knee in extension, dorsiflexion is forced, and the equinus, quantified. Then the knee is flexed and if there is significant increase of dorsiflexion, the retraction is mainly caused by the gastrocnemius. If there is no equinus change, the entire triceps is shortened (Figure 2).

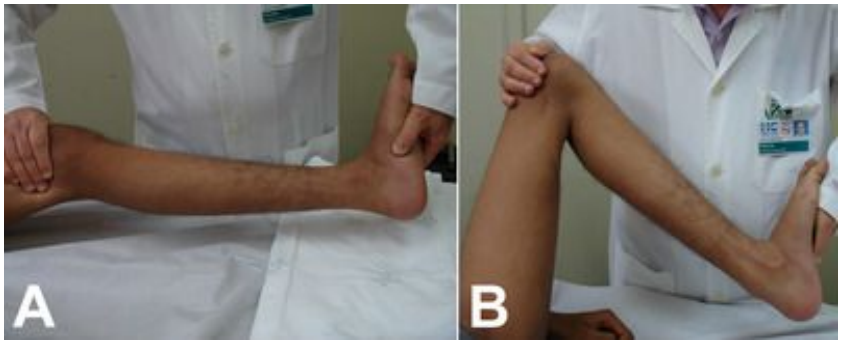

Figure 2. Silfverskiöld test to differentiate flexion contracture only from the gastrocnemius or for the whole triceps. (A) With the knee in full extension, forced ankle dorsiflexion reaches neutral (90°); (B) However, when the knee is flexed, the equinus disappears and the ankle can be brought in considerable dorsiflexion, which indicates an important gastrocnemius retraction. If there is no change, the whole triceps is shortened.

In the hemiplegic spastic, Winters *et al*.[12] described four walking patterns. In group I, there was equinus only in the swing phase. In group II, there was triceps contracture, with equinus in the support phase. Group III was similar to the previous one, but with knee involvement. And in group IV, besides the involvement of the knee, there were also primary changes in the hip.

However, it is in diplegic spastic that the evaluation of the equinus is more critical because these patients are more vulnerable to iatrogeny. The equinus may not be fully apparent and may be associated with a flat valgus foot. For this reason, the evaluation should be done with the foot in inversion to block the mediotarsic joint. In addition, knee conditions, such as flexion deformities, hamstring retraction, and quadriceps strength should be carefully considered. Finally, the strength of the triceps surae should be evaluated, since there may be an equinus deformity with weak triceps (retraction), and in this case, lengthening worsens gait.

METHODS

We conducted a search for the most common equinus correction surgical techniques in classic books, identified and consulted their original articles. Then we

searched in databases in the last ten years. Below we describe and critically analyze the main techniques for equinus correction.

RESULTS

Surgical interventions for equinus correction

The gastrocnemius contracture is well documented in patients with neurological sequelae[4], but more recent studies suggest that isolated retraction of this muscle may be present in neurologically intact individuals[13], being seen as a causal factor of affections such as plantar fasciitis[14], mechanical metatarsalgia[15], and plantar ulcers in insensible feet[16]. Due to this diversity of conditions, physicians seeks to use the most appropriate technique to correct the equinus, taking into account the cause, degree of deformity, baseline condition and patient's profile.

Postoperative immobilization should be performed for the shortest possible time, usually three to four weeks, and be supplemented by the use of orthosis. The gait with immobilization should be early.

The techniques over the gastrocnemius-soleus-Achilles complex can be performed in five levels[17], as shown in figure 3. The correction capability is greater the more distal the release is, being maximum when performed on the Achilles tendon. However, the greater the elongation, the greater the muscle weakness and the possibility of disabling secondary changes arising. Immobilization time is also longer for more distal surgeries. Procedures in zones 3 and 4 require three weeks of immobilization and early walking.

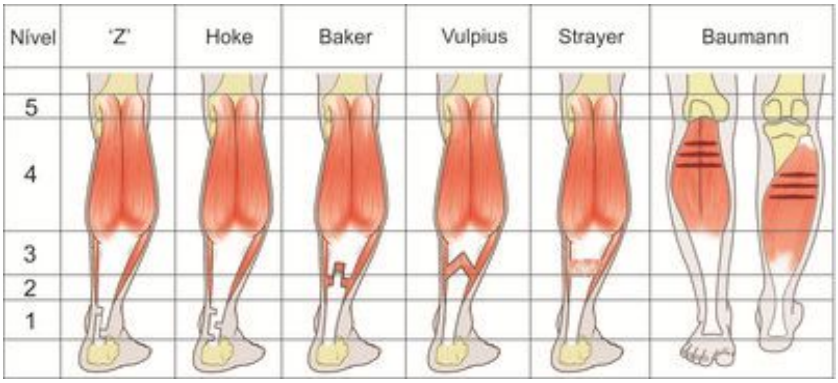

Figure 3. Illustration of the anatomical levels of the triceps surae and the most common surgical procedures at each level for equinus correction. Reprinted from Firth GB *et al*.[17], with permission, and adapted.

1) Interventions in zone 1: Achilles tendon

These techniques act indiscriminately on the gastrocnemius and soleus and, as a result, they weaken the whole muscle group. In the 1930s, in the United States, Achilles percutaneous tenotomy was abandoned because of its deleterious effects, such as calcaneal foot development and weakening of the knee and hip[18]. However, at that time, tenotomies were complete and the etiology of the deformity was not taken into account. For this reason, open lengthening in a "Z" fashion was preferred. Hatt and Lamphier, in 1947[19], showed good results with the triple percutaneous hemisection of the Achilles tendon and credited Hoke with the originality of the idea. Then, Bleck[20] disclosed the triple hemisection, performed openly as a way to treat the spastic equinus and avoid hypercorrections.

Complete Percutaneous Achilles Tendon Section

This technique is currently used in the correction of the congenital clubfoot equinus treated by the Ponseti method, and performed with a delicate blade or large caliber needle[21]. In the sequels of cerebral palsy, it is exceptionally indicated, being performed only in cases with severe impairment (Grade V by the Gross Motor Function Classification System – GMFCS V), with the purpose of adapting orthoses, shoes or wheelchairs. It is formally contraindicated in ambulating, spastic patients, due to the risk of triceps weakening, with serious consequences for the ankle, knee and hip, causing heel foot, and crouched and dragged gait[22]. The section is performed in the central and narrower portion of the tendon, which corresponds to the hypoascularized region (Figure 4).

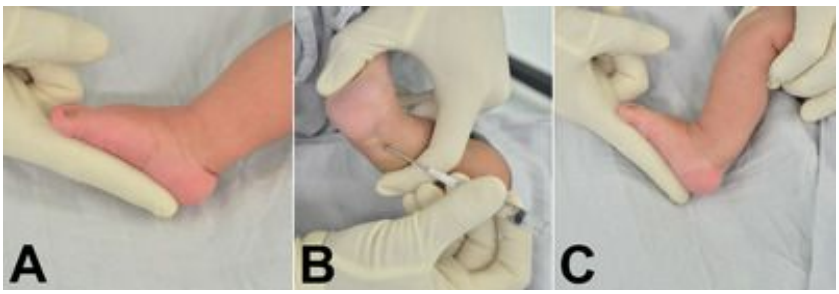

Figure 4. Percutaneous section technique of the calcaneus tendon in congenital clubfoot. (A) The equinus is evaluated and the narrower portion of the tendon is identified, as well as the lateral and medial borders; (B) The scalpel blade or a thick needle penetrates tangent to the medial border of the tendon and its bevel is used for tenotomy; (C) Correction obtained. Signs of complete section are the ankle dorsiflexion, the appearance of a depression in the cut region, and lack of plantar flexion when pressing the calf (Simmonds or Thompson's Sign).

Lengthening in "Z"

It is a classic technique, but currently it has limited indications. It can be performed as a procedure associated with neglected congenital clubfoot defects[23], or in the hemiplegic spastic child (GMFCS I or II), with great deformity, taking care not to cause excessive correction and weakening of the sural triceps.

The rectilinear cutaneous incision lies on the skin of the medial border of the tendon, and should expose only its posterior face, avoiding detachment of adjacent tissues that carry vascularization. From a medial, longitudinal cut in the tendon, the surgeon performs a proximal lateral hemisection and another in the distal and medial region. One should avoid dissecting the two branches of the "Z ", but only slide them with the dorsiflexion of the ankle till the neutral position (Figure 5). One of the great problems of this open lengthening is that the skin in the region is thin and poorly vascularized, which predisposes to dehiscence of suture and adhesion, especially in adults.

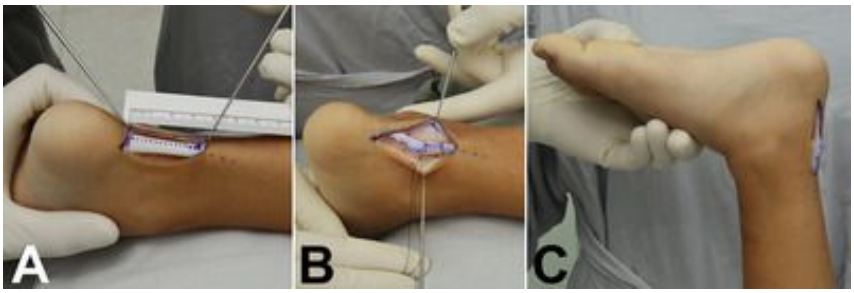

Figure 5. Technical steps for "Z" lengthening of the calcaneus tendon. (A) only the posterior aspect of the tendon is exposed and the "Z" is drawn; (B) the stumps that are sutured in the neutral correction position (C).

Triple hemisection technique (Hoke[24])

Although the triple hemisection technique of the calcaneus tendon has not been the subject of a specific publication by Hoke[24], it appears in an article by this author on flat foot treatment. It may be performed by open route, as disclosed by Bleck [20], or percutaneously, as a relatively safe technique[25]. With the patient in the supine position and the extremity of the foot forced against the body of the surgeon the limits of the calcaneal tendon are identified by palpation. Three markings on the tendon are made: the most distal is near the insertion in the more defined region of the tendon, in the medial direction. One inch above the middle marking is made the intermediate marking, which goes from the center of the tendon to the lateral edge. Finally, the third marking is one inch away from the middle marking and goes from the center to the medial border (Figure 6). In children, instead of using the adult inch (2.5cm), the length is the same as the patient's own thumb’s

distal phalanx. The cuts are made percutaneously on the markings and then dorsiflexion is forced, which will cause tendon shear and, consequently, its lengthening (Figure 6). Bleck[20] reported great use of this technique, with no cases of overcorrection. Potential complications by the closed technique include injury of neighboring structures (sural nerve, tibial nerve and long flexor hallucis tendon), as well as rupture of one of the cut branches or not opening of a cut[26].

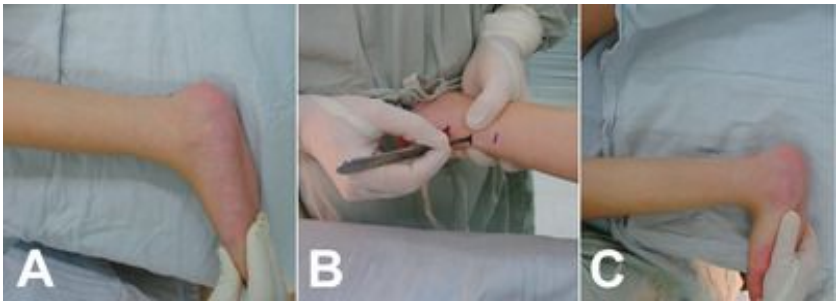

Figure 6. Illustration of the triple percutaneous hemisection technique (Hoke). (A) The equinus is evaluated; (B) The end of the foot is forced against the body of the surgeon to exert tension on the calcaneus tendon and its borders are delimited by palpation. Tenotomy sites are marked. In the center of the tendon width is introduced a delicate blade that performs the tendinous hemisection medially in the distal cut, laterally in the intermediate cut and medially in the proximal cut; (C) With the knee extended, the foot is carefully forced in dorsiflexion.

2) Interventions in zones 2 and 3: selective lengthening

Interventions in zones 2 and 3 are preferred for spastic corner correction, when the Silfverskiöld signal shows gastrocnemius retraction and little or no soleus involvement.

Vulpius technique[17]

With the patient in supine position, the muscle-tendon transition palpated and a longitudinal midline incision is performed. In the most distal portion of the tendon, but still close to the region of the soleus muscle, an inverted "V" section is made through the two layers formed by the aponeuroses of gastrocnemius and soleus, with the apex of the cut located at the midpoint of zone 2. The median raphe is also sectioned. The ankle is forced in dorsiflexion and there is separation of the cutting edges that expose the soleus muscle, which is maintained intact (Figure 3).

One variant is the Baker's lengthening[27], which is performed in the same region as the Vulpius one, but the cut is in an inverted "U" shaped. The dorsiflexion is applied by promoting the removal of the horizontal arms of the "U"[28]. The Baker and Vulpius procedures are similar and differ only in relation to the cut shape. Although Vulpius

lengthening is often associated with an inverted "V" cut, according to its original description the cuts may also be horizontal or diagonal[17] (Figure 3).

Strayer technique[2]

Strayer lengthening[2] is often used in the treatment of spastic equinus. It is especially indicated when the Silfversköld test is positive. The region is approached with the patient in prone position, through a median, straight incision on the muscle-tendon transition, identified by palpation (Figure 7). The sural nerve crossing the region must be identified and separated. The plane between the aponeuroses of gastrocnemius and soleus is dissected and the former is cross-sectioned in zone 3. The ankle is then dorsiflexed, promoting equinus correction. If the correction is incomplete, the aponeurosis of the soleus may be sectioned. If residual equinus is still present, the median raphe is dissected and sectioned under direct vision. Some refer to this procedure as modified Strayer[29].

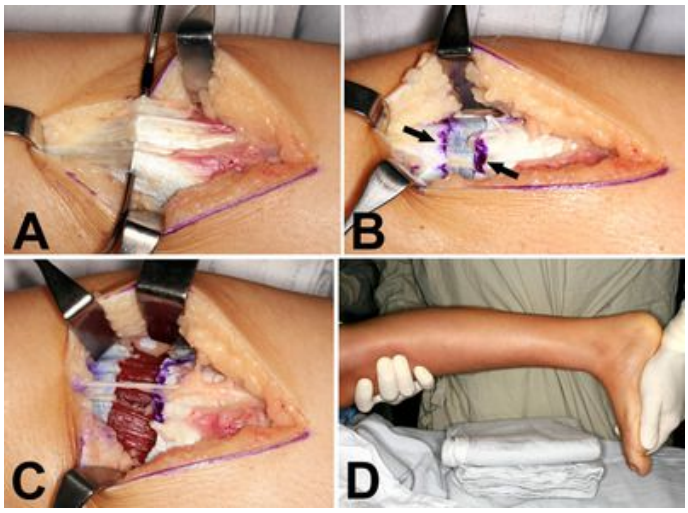

Figure 7. Main surgical times for Strayer's selective lengthening. (A) Through a medial incision in the posterior aspect of the calf, the gastrocnemius is approached and its aponeurosis is detached from the soleus; (B) After the gastrocnemius aponeurosis section, the foot is dorsiflexed and the extremities of the section move away from each other (arrows). Deep into the the incision, one can see the aponeurosis of the soleus, which can be also sectioned to increase the correction; (C) After the section of both aponeuroses, there is additional correction with the separation of the borders of the soleus. Its muscle body is not sectioned. Note the sural nerve crossing the surgical field. If too tight, paresthesia may occur; (D) Correction obtained.

One of the drawbacks of performing the classic Strayer technique is that the scar becomes very apparent and sometimes retracted and adherent. The same surgery can be conducted by medial access, with the advantage of being performed in the supine position,

which may facilitate other procedures when performing corrections at multiple levels. Special care should be taken to identify and separate the sural nerve.

Some authors and even textbooks confuse the Strayer's technique with that described by Vulpius and Baker. However, they are different procedures, because in the Strayer technique the release is sequential and even with the aponeurosis section of the soleus, the lengthening levels between the two muscles are different, as shown in figure 6. In the Vulpius and Baker procedures, on the other hand, there is section of both aponeuroses on the same level and they retract equally and may cause further decrease in the plantar flexion power[30].

3) Interventions in zone 4

Baumann and Koch technique[31]

According to Firth *et al*.[17], this lengthening technique is the one that provides the least correction. It takes advantage of the aponeuroses of the gastrocnemius and soleus being face to face and sliding one over the other (Figure 1). The triceps surae is approached by an incision 8cm to 12cm long on the inner side of the middle third of the leg. Carefully not to injure the saphenous vein, the gap between the muscles is dissected and three incisions are made in the aponeurotic portions of each. These sections should lie at different levels between the two muscles to avoid adhesions between the sheets (Figure 3). The equinus is corrected by forcing dorsiflexion.

4) Interventions in zone 5

Fasciotomy of the medial head of the gastrocnemius

It is indicated in painful affections of the foot, like metatarsalgias and fascites, accompanied by recession of the gastrocnemius. Through a small transverse posterior incision, the medial head of the gastrocnemius is isolated and complete fasciotomy is performed. Care should be taken not to impair muscle innervation, especially by forced removal of soft tissues.

FINAL CONSIDERATIONS

In anatomical terms, the triceps surae can be divided into several zones, and the interventions in each of them lead to varying degrees of equinus correction, as well as to different side effects. Over time, several techniques have been described and, as a general rule, the more distal the correction, the greater the corrective effect, but also the greater the muscle weakness. The orthopedist should be familiar with a technique at each

level. The choice of technique should take into account not only the corrective effect, but the etiology, degree of deformity, profile and age of the patient. Currently, for spastic patients walkers are preferred selective stretches acting on the distal aponeurosis of the gastrocnemius, with preservation of the soleus, which is largely responsible for the strength of plantar flexion of the foot.

RESUMO

A deformidade em equino leva a diversos transtornos da marcha, ao causar alterações no apoio do pé e afetar regiões anatômicas mais distantes, como o joelho, quadril e tronco. Geralmente é secundária à retração, encurtamento ou espasticidade do tríceps sural, de modo que algumas intervenções cirúrgicas podem ser necessárias para corrigi-la. Trata-se de um dos procedimentos mais antigos da Ortopedia, antes realizado apenas no tendão calcâneo e que, ao longo do tempo, evoluiu com técnicas diferentes de acordo com o grau de deformidade, doença de base e perfil do paciente. Busca-se corrigir a deformidade, com a menor interferência possível na força muscular e, com isso, diminuir a incidência de complicações, como marcha agachada, arrastada e pé calcâneo. Do ponto de vista anatômico, o tríceps sural apresenta cinco regiões que podem ser abordadas cirurgicamente para correção do equino. Em virtude da complexidade do paciente com equino, os ortopedistas devem ter experiência com pelo menos uma técnica em cada zona. Neste texto são abordadas e analisadas criticamente as técnicas mais importantes para correção do equino, principalmente de modo a evitar complicações. Foi realizada uma busca sobre técnicas cirúrgicas mais comuns de correção do equino em livros clássicos e identificação e consulta aos artigos originais. Em seguida fez-se uma busca em bases de dados nos últimos dez anos.

Descritores: Pé**.** Articulação do Tornozelo. Tendão do Calcâneo. Revisão. Pé Equino.

REFERENCES

1. David LV. Club-foot. In: David LV, editor. The History of Orthopaedics. London: Butler & Tanner; 1990. p. 497-501.
2. Strayer LM Jr. Recession of the gastrocnemius; an operation to relieve spastic contracture of the calf muscles. J Bone Joint Surg Am. 1950;32(3):671-6.
3. Stoffel A. The treatment of spastic contractures. Am J Orthop Surg. 1913;10(4):611-44.
4. Singh D. Nils Silfverskiöld (1888-1957) and gastrocnemius contracture. Foot Ankle Surg. 2013;19(2):135-8.

5. Silver CM, Simon SD. Gastrocnemius-muscle recession (Silfverskiold operation) for spastic equinus deformity in cerebral palsy. J Bone Joint Surg Am. 1959;41-A(6):1021-8.
6. Silver RL, de la Garza J, Rang M. The myth of the muscle imbalance. A study of relative strengths and excursions of normal muscles about the foot and ankle. J Bone Joint Surg Br. 1985;67(3):432-7.
7. El Shewy MT, El Barbary HM, Abdel-Ghani H. Repair of chronic rupture of the Achilles tendon using 2 intratendinous flaps from the proximal gastrocnemius-soleus complex. Am J Sports Med. 2004;37(8):1570-7.
8. Fritschy D, Fasel J, Imbert JC, Bianchi S, Verdonk R, Wirth CJ. The popliteal cyst. Knee Surg Sports Traumatol Arthrosc. 2006;14(7):623-8.
9. Dalmau-Pastor M, Fargues-Polo B Jr, Casanova-Martínez D Jr, Vega J, Golanó P. Anatomy of the triceps surae: a pictorial essay. Foot Ankle Clin North Am. 2014;19(4):603-35.
10. Alfredson H, Lorentzon R. Chronic Achilles tendinosis: recommendations for treatment and prevention. Sport Med. 2000;29(2):135-46.
11. van Gils CC, Steed RH, Page JC. Torsion of the human Achilles tendon. J Foot Ankle Surg. 1996;35(1):41-8.
12. Winters TF Jr, Gage JR, Hicks R. Gait patterns in spastic hemiplegia in children and young adults. J Bone Joint Surg Am. 1987;69(3):437-41.
13. DiGiovanni CW, Kuo R, Tejwani N, Price R, Hansen ST Jr, Cziernecki J, et al. Isolated gastrocnemius tightness. J Bone Joint Surg Am. 2002;84(6):962-70.
14. Monteagudo M, Maceira E, Garcia-Virto V, Canosa R. Chronic plantar fasciitis: plantar fasciotomy versus gastrocnemius recession. Int Orthop. 2013;37(9):1845-50.
15. Cychosz CC, Phisitkul P, Belatti DA, Glazebrook MA, DiGiovanni CW. Gastrocnemius recession for foot and ankle conditions in adults: Evidence-based recommendations. Foot Ankle Surg. 2015;21(2):77-85.
16. Lin SS, Lee TH, Wapner KL. Plantar forefoot ulceration with equinus deformity of the ankle in diabetic patients: the effect of tendo-Achilles lengthening and total contact casting. Orthopaedics. 1996;19(5):465-75.
17. Firth GB, McMullan M, Chin T, Ma F, Selber P, Eizenberg N, et al. Lengthening of the gastrocnemius-soleus complex. an anatomical and biomechanical study in human cadavers. J Bone Joint Surg Am. 2013;95(16):1489-96.
18. Hogden JT, Frantz CH. Subcutaneous tenotomy of the Achilles tendon. J Bone Joint Surg Am. 1938;20(2):419-23.

19. Hatt RN, Lamphier TA. Triple hemisection: a simplified procedure for lengthening the Achilles tendon. N Engl J Med. 1947;236(5):166-9.
20. Bleck EE. Orthopaedic management of cerebral palsy. Philadelphia: WB Saunders; 1979.
21. Maranho DAC, Nogueira-Barbosa MH, Simão MN, Volpon JB. Uso de agulha de grosso calibre na secção percutânea do tendão calcâneo no pé torto congênito. Acta Ortop Bras. 2010;18(5):271-6.
22. de Morais Filho MC, Kawamura CM, Kanaji PR, Juliano Y. The relation of triceps surae surgical lengthening and crouch gait in patients with cerebral palsy. J Pediatr Orthop B. 2010;19(3):226-30.
23. Turco VJ. Surgical correction of the resistant club foot. One-stage posteromedial release with internal fixation: a preliminary report. J Bone Joint Surg Am. 1971;53(3):477-97.
24. Hoke M. An operation for the correction of extremely relaxed flat feet. J Bone Joint Surg. 1931;13(4):773-83.
25. Salamon ML, Pinney SJ, Van Bergeyk A, Hazelwood S. Surgical anatomy and accuracy of percutaneous achilles tendon lengthening. Foot Ankle Int. 2006;27(6):411-3.
26. Hoefnagels EM, Waites MD, Belkoff SM, Swierstra BA. Percutaneous Achilles tendon lengthening: a cadaver-based study of failure of the triple hemisection technique. Acta Orthop. 2007;78(6):808-12.
27. Baker LD. Triceps surae syndrome in cerebral palsy; an operation to aid in its relief. AMA Arch Surg. 1954;68(2):216-21.
28. White JW. Torsion of the Achilles tendon: its surgical significance. Arch Surg. 1943;46(5):748-87.
29. Lamm BM, Paley D, Herzenberg JE. Gastrocnemius soleus recession: a simpler, more limited approach. J Am Podiatr Assoc. 2005;95(1):18-25.
30. Delp SL, Statler K, Carroll NC. Preserving plantar flexion strength after surgical treatment for contracture of the triceps surae: a computer simulation study. J Orthop Res. 1995;13(1):96-104.
31. Baumann JU, Koch HG. Ventrale aponeurotische verlängerung des musculus gastrocnemius. Oper Orthop Traumatol. 1989;1(4):254-8.

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Mailing address:

José Batista Volpon

E-mail: hc.ortopedia@gmail.com