PERONEAL NERVE DYSFUNCTION AFTER HIGH TIBIAL OSTEOTOMY
An anatomical cadaver study

S. AYDOĞDU[1], H. YERCAN[1], C. SAYLAM[2], H. SUR[1]

An anatomical cadaver study was carried out on 13 human cadavers to disclose the close anatomical relationship between the peroneal nerve and the surgical area of the high tibial osteotomy techniques. The common peroneal nerve passes within 3 to 6 mm. of the posterior aspect of the fibular head and neck and divides into its superficial and deep branches, 22 to 28 mm. distal to the fibular apex. Generally the extensor hallucis longus (EHL) muscle is innervated by one of the motor branches of the deep peroneal nerve which is anatomically located 74 to 82 mm. distal to the fibular apex. To avoid neurological complications with a high tibial osteotomy, fibular osteotomy should be carried out at the junction of the middle and distal thirds of the fibula without excessive medial and anterior displacement of fragments ; a small fibular segment should be resected in knees which have a severe deformity and need a significant angle correction.

Keywords : high tibial osteotomy ; peroneal nerve.
Mots-clés : ostéotomie tibiale haute ; nerf sciatique poplité externe.

INTRODUCTION

High tibial osteotomy (HTO) is a valuable technique for the treatment of osteoarthritis of the knee ; it was described in 1958 by Jackson (8), and it is still frequently used. Potentially serious neurological complications related to the peroneal nerve have been experienced with this technique for a long time (2, 4, 7). Although the etiology of these complications is not precisely defined, some theories have been put forward such as anterior compartment syndrome, iatrogenic damage to the peroneal nerve or injury to the anterior tibial artery. The purpose of this cadaver study is to define the correct type and place of the osteotomy and of the external fixation, to avoid complications involving peripheral nerves when using one of the most commonly used HTO techniques, the "Maquet barrel - vault" type.

MATERIAL AND METHODS

Hemicylindrical high tibial osteotomy with external fixation as described by Maquet has been used as a method of choice for osteoarthritic knees in our department since 1984 (15). Some important characteristics of this technique are : 1. the use of two Steinman pins crossing the tibia ; one is parallel with and approximately 2 cm distal to the joint line, and the other is more distally placed in the proximal one-third of the tibia and introduced at the intended angle of correction, 2. a hemicylindrical tibial osteotomy proximal to the tibial tuberosity, 3. and a fibular osteotomy at the level of the junction of the middle and distal one-third of the fibula. After both osteotomies are completed, valgus displacement of the distal tibial fragment is carried out while fibular fragments are displaced in a medial-lateral direction.

We dissected the peroneal nerve in 13 fresh frozen cadavers to examine the course of the peroneal nerve in the surgical area. Dissection was carried out considering motor and sensory divisions of the nerve and their relationships with the fibula, the Steinman pin tract region ; and the osteotomy site. Theoretically, the peroneal nerve or its branches may be damaged in all the surgical areas. Therefore, in this cadaver study,

[1] Department of Orthopedics, School of Medicine, Ege University, 35100, Bornova, Izmir, Turkey.
[2] Department of Anatomy, School of Medicine, Ege University, 35100, Bornova, Izmir, Turkey.
Correspondence and reprints : H. Sur.

dissection beginning at the origin of the common peroneal nerve and on the sciatic nerve was carried out down to the dorsum of the foot, where only terminal sensory branches of the nerve are left. We tried to define risk and safe zones with respect to fibular osteotomy and pin tracts.

RESULTS

After the common peroneal nerve branches from the sciatic nerve, it gives off three small branches : the ramus articularis, the lateral cutaneous sural nerve and a communicating fibular branch ; it then deviates laterally in the popliteal fossa, arches around the posterior aspect of the fibular head and at this level enters the peroneal muscle mass. At the level of the fibular neck, it continues in the muscle mass in a posterior — anterior direction where it has a close relationship with the fibula (3-6 mm.). Approximately 25 mm. (range 22-28 mm.) distal to the tip of the fibula (fibular styloid process), it divides into its superficial and deep branches (fig. 1). The deep branch passes obliquely from the lateral to the anterior compartment through the intermuscular septum, and it runs away from the fibula. First it follows a path beneath the extensor digitorum longus (EDL) muscle, then between the EDL and the anterior tibial muscle and it supplies both muscles.

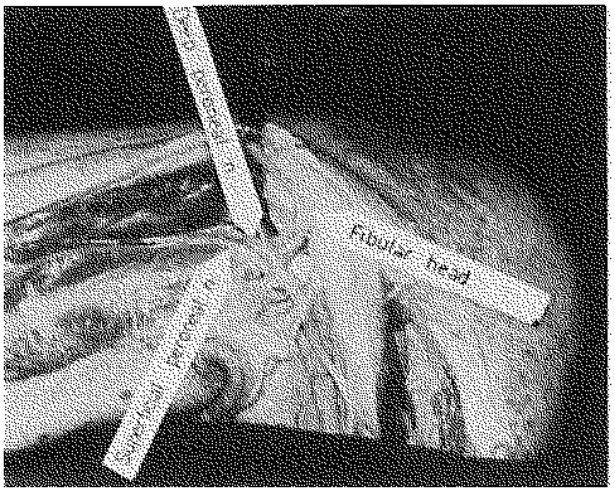

Fig. 1. — Division of the common peroneal nerve into deep and superficial branches.

We exposed in detail the innervation of the extensor hallucis longus muscle which is most commonly involved in peroneal nerve dysfunction after high tibial osteotomy. The nerve supply to this muscle comes mainly with a single motor branch which arises from the deep peroneal nerve at the level of the junction of the proximal and middle thirds of the leg on average 78 mm. (range 74-82 mm.) distal to the tip of the fibula. In only two of 13 cadavers, we noted a second and minor branch which was located 15 mm. more distally and contributed to the innervation (fig. 2). The distance between the deep peroneal nerve and the fibula at the level of the junction of the proximal and middle thirds of the leg was 4 mm. on average (range 3-6 mm.). Beginning at the middle-distal third junction, the nerve runs away from the fibula, and together with the anterior tibial artery it follows a more central pathway close to the tibial shaft. After it innervates the extensor digitorum brevis muscles on the dorsum of the foot, it ends with a terminal sensory branch.

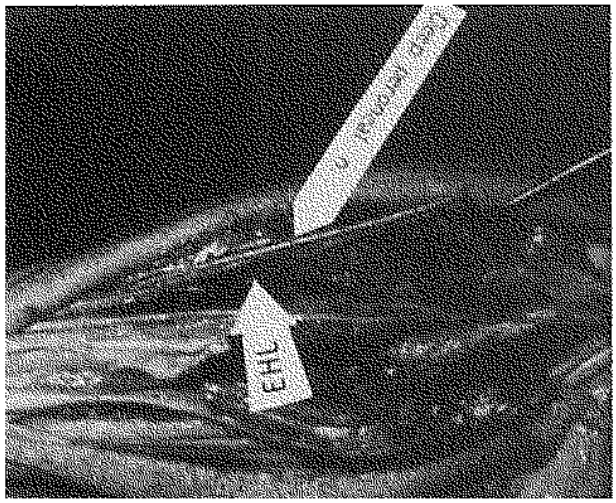

Fig. 2. — "Double" extensor hallucis longus (EHL) muscle innervation.

As for the superficial peroneal nerve, it traverses the lateral compartment after arising from the common peroneal nerve. First it runs in the long peroneal muscle and at the junction of the proximal and middle thirds, between the peroneal muscles and the EDL. At the level of the distal

one - fourth of the leg, it passes through the fascia and runs in the superficial subcutaneous tissue to divide into terminal sensory branches which innervate the skin on the whole dorsum of the foot except the small innervation area supplied by the deep peroneal nerve. While it courses distally in the lateral compartment, it is located on average 8 mm. (range 7-12 mm.) anterior at the level of the junction of the proximal and middle thirds (fig. 3).

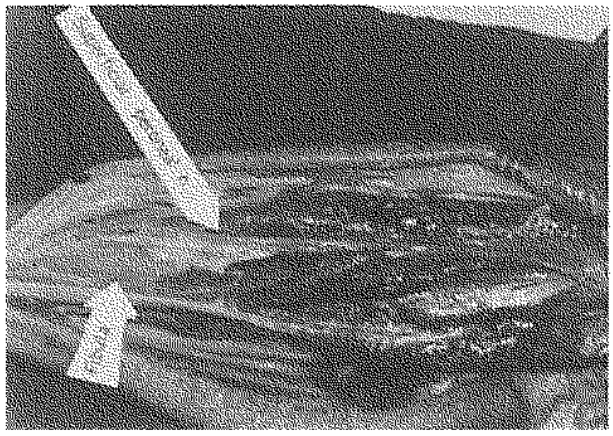

Fig. 3. — The relationship between fibula and superficial peroneal nerve at the proximal-middle third junction.

DISCUSSION

Motor and sensory problems of foot and toes are not uncommon after HTO. Jackson and Waugh (8) described weakness of dorsiflexion of the foot as "the most troublesome and potentially serious complication" after HTO. The etiology of this problem, which can be weakness of dorsiflexion of the foot and toes as well as sensory problems such as hypoesthesia, paresthesia and troublesome pain in the same area, is not clearly defined. In the past, tight plaster casts (2) and bandages (4), anterior tibial artery injury (8), anterior compartment syndrome (6, 11), tourniquet syndrome (16) and lastly peroneal nerve damage (9, 14) have been proposed as etiological factors. In our opinion, derived from more than 300 cases, the most frequent cause is "iatrogenic peroneal nerve damage". During surgery, the peroneal nerve may be damaged at different levels. We thought, like some others (9, 14), that the fibular osteotomy was the most dangerous step for causing peroneal nerve damage. The fibular osteotomy, which may be done at any level on the fibula, may cause muscular, osseous and neurologic complications. For these reasons this procedure requires as much care as the tibial osteotomy (5). The level and shape of the fibular osteotomy are important. As shown in our study, the close relationship of the fibula with the deep peroneal nerve (3-6 mm.) at the junction of the middle and distal thirds can result in nerve damage during the surgical approach and during manipulation into valgus with displacement of the fibular fragments in the soft tissues. The deep peroneal nerve gives off the important part of the motor branches supplying the ankle and toe extensors in the proximal and middle thirds of the leg. Especially after proximal fibular osteotomy, severe dysfunction of the common peroneal nerve has been reported (3). In fact, at the level of the fibular head and neck, iatrogenic damage to the common peroneal nerve, which courses only 3-6 mm. posterolaterally to the fibula, can result in serious problems such as weakness of dorsiflexion of the whole foot and toes as well as sensory disturbances of the dorsum of the foot. In order to avoid these potential complications, the peroneal nerve dissection prior to a proximal fibular osteotomy has been advocated ; but even mere dissection of the nerve may result in nerve dysfunction (5). On the contrary, Docquier *et al.* found no peroneal nerve lesion in 23 cases with HTO associated with subcapital fibular osteotomy by the anterior approach (5). Their technique preserves the mechanical properties of the fibula and promotes faster bone healing, but we doubt whether this type of fibular osteotomy is also a safe procedure in knees that need a significant correction. There may also be some approach problems in the combination of the semicylindrical high tibial osteotomy and the subcapital fibular osteotomy. Therefore, fibular osteotomy should be carried out distal to where the peroneal nerve gives off the important part of its motor branches, i.e at the junction of the proximal and middle thirds of the bone (85 mm. distally from the tip of the fibula), dissection especially medial to the fibula should be kept

strictly subperiosteal, fibular fragments should not be displaced too medially during valgization and a fibular fragment should be resected if a significant correction is needed.

The superficial peroneal nerve courses at a greater distance from the fibula than does the deep branch. However, because of its anterior course, it can be damaged if the fibula is exposed anteriorly rather than posteriorly to the lateral muscle group and especially if the fibular fragments are displaced during valgization. As mentioned before, resection of a short fibular fragment would be safer than displacement of fragments.

Another theory for peroneal nerve dysfunction after HTO is injury to the anterior tibial artery. Steel *et al.*, describing this complication for the first time in children, showed in a cadaver study the cessation of arterial blood flow after correction (13). Jackson and Waugh (8) also thought anterior tibial artery injury to be responsible because of the close anatomical relationship of the artery to the operation area. In patients with poliomyelitis treated by high tibial extension osteotomy, Çelebi *et al.* detected by Doppler ultrasonography pre- and postoperatively a decrease in blood flow in both the anterior and posterior tibial arteries proportional to the degree of hyperextension (1). In addition, the injury of the peroneal arteries which enter the fibula 7 to 12 cm distal to the fibular head may cause compartment syndrome resulting in motor and sensory problems (5, 8).

The Maquet type HTO is a safe and efficacious technique because of its inherent characteristics of "minor surgical approach, minor implantation". It provides faster bone healing and greater accuracy in angle correction (10), but it increases the danger of peroneal nerve injury because of the fibular osteotomy as well as the use of Steinman pins, especially the distal one. However, in a comparative study of this technique with the closed wedge osteotomy and blade - plate fixation, no difference was found regarding the peroneal nerve lesions (10).

Naumann *et al.* (12) have reported permanent paralysis of the EHL muscle in 9.3% of 428 cases in whom they had applied external fixation. In their experience, the risk of permanent EHL paralysis is three times greater with external fixation than with staple fixation. According to Kirgis *et al.* (9), who had used the HTO and external fixation, an isolated injury to the motor supply of the EHL muscle was the most probable explanation for this complication. They showed that the zone 68 to 153 mm. distal to the fibular head was the zone at risk since motor branches for the EHL muscle left the deep peroneal nerve in this zone. In our study, we showed that this zone was more limited (74 to 82 mm. distal to the tip), but in the presence of more than a single motor branch, the zone at risk would be larger. In addition, the zone from the fibular head to 65 mm. distal to it, which they acccepted as a safe zone, may be safe for the motor innervation but not for the sensory innervation. As shown in our study, the superficial peroneal nerve courses 7 to 12 mm. anteriorly to the fibula in the proximal and middle thirds. This brings about a zone at risk for sensory innervation in external fixation.

Our study confirmed that the EHL muscle was in general supplied by a single motor branch which had a close relationship with the operative area. The same findings have been reported by Stürz and Rosemeyer (14). Kirgis *et al.* (9), also showed a single motor branch innervation in 16 of 29 cases in their cadaver study. In our study , 11 out of 13 cadavers presented a single motor branch.

In conclusion, the main reason for peroneal nerve dysfunction after HTO is the fibular osteotomy because of its close relationship during the surgical approach and fragment displacement. To avoid this complication, the fibular osteotomy should be performed at the junction of its middle and distal thirds ; and in case of a considerable degree of correction, a short fibular fragment should be resected. Furthermore the problems caused specifically by external fixation can be avoided by the use of internal fixation.

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SAMENVATTING

S. AYDOĞDU, H. YERCAN, C. SAYLAM, H. SUR. Dysfunctie van de nervus peroneus na proximale tibia osteotomie.

De auteurs hebben op 13 humane lijken een anatomische studie gedaan over de precieze ligging van de nervus peroneus enerzijds en de osteotomiehaard, bij de chirurgische behandeling van gonarthrose, anderzijds. Er wordt aangetoond dat de nervus peroneus op 3 à 6 mm. van de posteriore cortex van caput en collum fibulae ligt en zich vervolgens splitst op een punt gelegen tussen 22 en 28 mm. distaal van processus styloïdeus fibulae, in een anteriore tibiale tak en een nervus cutaneus.
In het algemeen krijgt de musculus extensor hallucis proprius een motorische tak van de nervus tibialis anterior, gelegen tussen 74 en 82 mm. distaal van processus styloïdeus fibulae. Om neurologische complicaties na hoge tibiale osteotomie te voorkomen, moet de fibula osteotomie gebeuren aan de overgang tussen middenste en distale 1/3 van de fibula, minstens 10 cm. distaal van processus styloïdeus fibulae. Er mag ook geen overmatige verplaatsing gebeuren naar anterior of naar mediaal en een kleine segmentaire resectie van de fibula is aangewezen bij belangrijke desaxatie van de knieën waarbij een grote correctie nodig is.

RÉSUMÉ

S. AYDOĞDU, H. YERCAN, C. SAYLAM, H. SUR. Dysfonction du nerf sciatique poplité externe après ostéotomie tibiale haute.

Les auteurs présentent une étude sur 13 cadavres humains, des rapports anatomiques précis entre le site de l'ostéotomie et le nerf sciatique poplité externe, dans la chirurgie des gonarthroses. Le travail démontre que le tronc du nerf sciatique poplité externe passe à une distance de 3 à 6 mm. de la face postérieure de la tête et du col du péroné et se divise en branches, tibiale antérieure et musculocutanée, en un point situé entre 22 et 28 mm. en-dessous de l'apophyse styloïde du péroné. En général , le muscle long extenseur propre du gros orteil est innervé par une des branches motrices du nerf tibial antérieur se situant entre 74 et 82 mm. en-dessous de l'apophyse styloïde du péroné. Dans le but d'éviter les complications neurologiques rencontrées dans les ostéotomies tibiales hautes, l'ostéotomie du péroné doit etre effectuée à la jonction du tiers moyen et du tiers distal du péroné, et à au moins 10 cm. de l'apophyse styloïde du péroné. On doit prendre soin de ne pas provoquer un déplacement excessif dans le plan antérieur ou medial et une petite résection segmentaire du péroné doit être effectuée dans les genoux très désaxés qui nécessitent une correction importante.