Palsy of the Deep Peroneal Nerve After Proximal Tibial Osteotomy

An Anatomical Study*

BY A. KIRGIS, M.D.†, AND S. ALBRECHT, M.D.†, BERLIN, FEDERAL REPUBLIC OF GERMANY

Investigation performed at the Department of Anatomy, Ev. Waldkrankenhaus Spandau, Teaching Hospital, Free University of Berlin—Medical School, Berlin

ABSTRACT: Iatrogenic, isolated weakness or paralysis of the extensor hallucis longus muscle is a common complication in patients who have had a proximal tibial and fibular osteotomy. To investigate why this complication occurs, we dissected the deep peroneal nerve and neighboring structures, such as the tibia and fibula and the muscles of the leg, in twenty-nine specimens from cadavera, paying special attention to the motor branches supplying the extensor hallucis longus. Of forty-six motor nerves that were identified, eight entered the muscle from the lateral side in an area seventy to 150 millimeters distal to the fibular head; all of them ran close to the fibular periosteum.

We suggest that, in some patients, the nerve supply to the extensor hallucis longus is at high risk for injury during a tibial osteotomy because of the proximity of the bone to the motor branches.

Proximal tibial osteotomy is an accepted treatment for varus deformity secondary to osteoarthrosis of the knee[1]. Two types of operative technique are currently popular: a cuneiform osteotomy, commonly followed by internal fixation[4], and a dome osteotomy[3,6,8], followed by application of an external fixation device. Both techniques include a fibular osteotomy. Regardless of which technique is used, palsy of the deep peroneal nerve has been reported as a frequent complication, and the motor supply to the extensor hallucis longus seems to be at greatest risk.

Stürz and Rosemeyer studied iatrogenic, isolated paralysis of the extensor hallucis longus. They dissected four legs from cadavera and examined five affected patients electromyographically. In the patients, they found persistent electromyographic signs of a denervation of the extensor hallucis longus and reactive hypertrophy of the extensor hallucis brevis. In the specimens, they noted a constant single branch of the peroneal nerve, which supplied the extensor hallucis longus and ran close to the fibular periosteum. They concluded that the fibular osteotomy was responsible for the neuropathy[7].

The purpose of the current study was to confirm and amplify the observations of Stürz and Rosemeyer.

Material and Methods

We dissected twenty-nine unselected specimens of legs from cadavera and obtained measurements with a longitudinal scale, placed parallel to the specimen on its fibular aspect. At each point of interest, a perpendicular line was dropped from the point to the scale, and distances between points were measured with a pair of calipers, applied to the scale (Fig. 1). The proximal reference point was the fibular head (the tuberculum innominatum). All points of interest distal to it, such as the point of division of the nerve from the truncus of the deep peroneal nerve and the point of entry of the motor nerve into the muscle, were used for the measurements, which were recorded in millimeters (standard error, ±3 millimeters).

To reveal more graphically the relationship between the nerves and the osseous and fibrous structures, transverse serial sections were obtained from eight specimens with use of a frozen-section technique. For this part of the study, the thickness of each section was four millimeters (range, 3.8 to 4.2 millimeters). The average number of sections obtained for each leg was fifty-four (range, forty-nine to fifty-six sections).

Finally, the anatomical findings from the dissected specimens were compared with the postoperative radiographs of four patients in whom various types of neural deficits had developed after a proximal tibial osteotomy.

Results

In all of the specimens, the common peroneal nerve coursed around the fibular head, close to the bone. Proximal to the fibular head, it split into deep and superficial trunci. Fibers of connective tissue linked the nerve to both the tibial and the fibular periosteum, at various locations. The deep peroneal nerve then took an arched course across the lateral compartment to perforate the anterior intermuscular septum and reach the anterior compartment. The nerve first ran deep to the extensor digitorum longus muscle and then passed between the

*No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. No funds were received in support of this study.

†Abteilung für Orthopädie, Ev. Waldkrankenhaus Spandau, Stadtrandstrasse 555, D-1000 Berlin 20, Federal Republic of Germany.

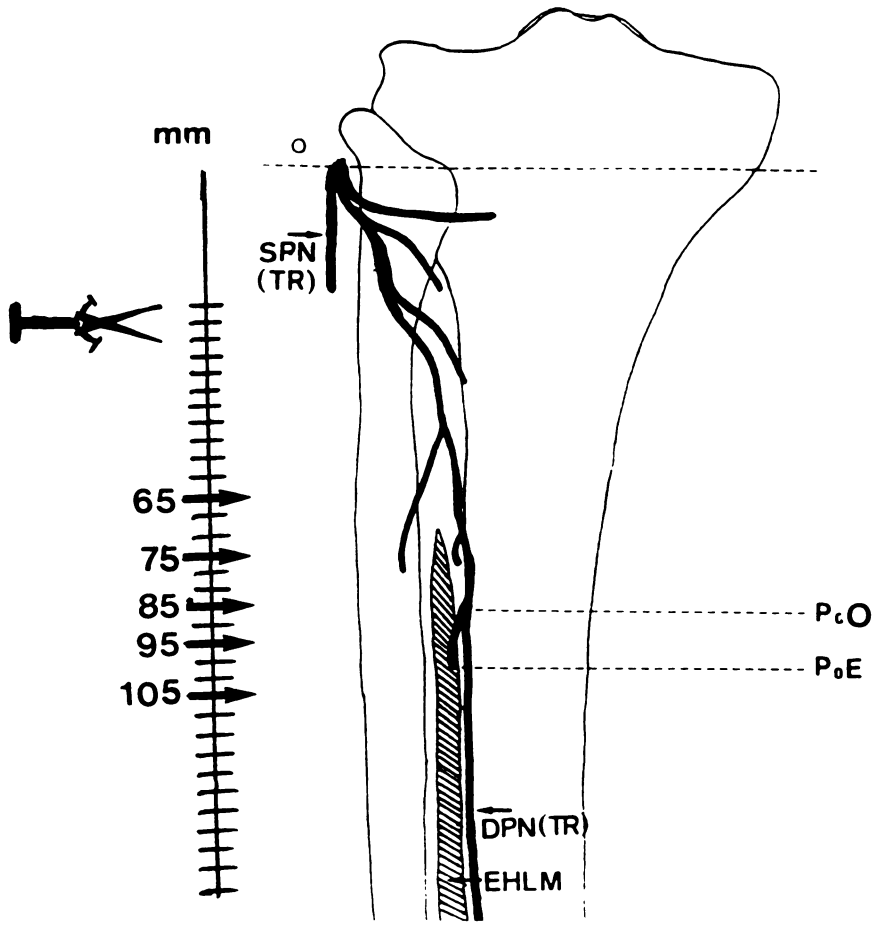

FIG. 1

Procedure for measurement of the points of origin (PoO) and entry (PoE) in specimens of the leg from cadavera. SPN (TR) = truncus of the superficial peroneal nerve, DPN (TR) = truncus of the deep peroneal nerve, and EHLM = extensor hallucis longus muscle.

extensor digitorum longus and tibialis anterior muscles. In the proximal third of its course, a number of motor branches supplying the extensor muscles were found, some of them close to the fibular periosteum. We did a detailed study of the motor supply of the extensor hallucis longus and found variations in number, sites of subdivision, course, and places of entry of the nerve branches into the extensor hallucis longus.

Forty-six motor branches to the extensor hallucis longus were dissected in the twenty-nine specimens. Sixteen muscles were found to be innervated by a single nerve and thirteen, by two or three. When there was double or triple innervation, the proximal nerves were larger in eight specimens and the distal nerves, in five. Their diameters ranged from 0.3 to one millimeter.

The distances between the points of origin of the branches from the truncus of the deep peroneal nerve to the fibular head ranged from sixty-eight to 192 millimeters. Most of the points of origin (91 per cent) were observed sixty-eight to 136 millimeters distal to the fibular head. Farther distally, there were only a few small accessory branches (Fig. 2-A).

The course of the nerves between their points of origin and entry in the extensor hallucis longus ranged from four to sixty-nine millimeters. Most nerves (83 per cent) had a course ranging from five to twenty-eight millimeters (Fig. 2-B).

The extensor hallucis longus is formed like a triangle, with two of its angles pointing to the tibia and fibula. The apical angle points to the ventral aspect of the leg. According to this model, we found three variations of entry of the nerve into the muscle. Most of the twenty-nine motor nerves entered the muscle from the ventral aspect, nine entered from the tibial side, and eight entered from the fibular side. Only the fibular-related variation was found anatomically to be close to the fibular periosteum. In the tibial and ventral-related variations, the motor nerves were covered by soft tissue (Figs. 3-A, 3-B, and 3-C).

Discussion

Proximal tibial osteotomy is an accepted treatment for varus deformity secondary to osteoarthrosis of the knee. A number of causes have been suggested to explain the high rates of neurological complications after the operation. In our opinion, explanations involving major damage to nerves, such as a postoperative compartment syndrome[4] or a tourniquet syndrome[9], ignore

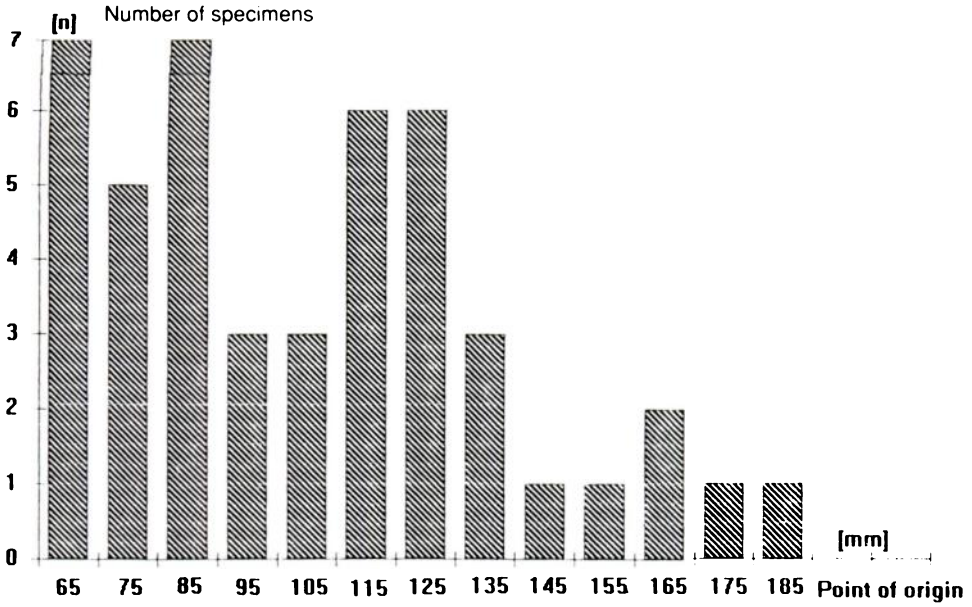

FIG. 2-A

Graph showing points of origin of the motor branches from the truncus of the deep peroneal nerve in relation to the fibular head. All distances were recorded in ten-millimeter increments.

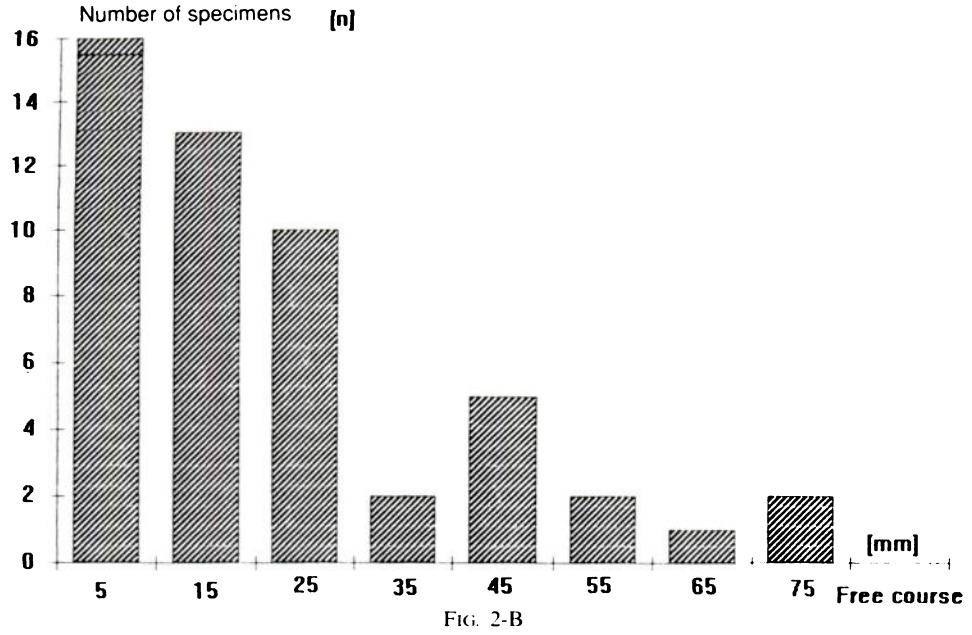

FIG. 2-B

Graph showing distances of free courses of the motor branches between points of origin from the truncus of the deep peroneal nerve and points of entry into the extensor hallucis longus. All distances were recorded in ten-millimeter increments.

certain facts. None of these explanations account for the high rates of paresis or paralysis of the extensor hallucis longus when the other muscles of the anterior compartment are not affected. An injury of the deep peroneal nerve should harm all of the muscles in the compartment similarly. The association between the complication and the technique of osteosynthesis[5] also is ignored.

Naumann et al.[6] reported a 9.3 per cent prevalence of temporary paralysis and a 3.5 per cent prevalence of persistent paralysis of the extensor hallucis longus in 428 patients in whom an external fixation device had been used. Isolated paralysis of the extensor hallucis longus after clamp osteosynthesis has been described[5], as well as combined motor and sensory defects[6] and complete palsy of the deep peroneal nerve[3]. Naumann et al. also noted a relationship between the technique of osteosynthesis and the incidence of palsy of the deep peroneal nerve. The rate of persistent paralysis of the extensor hallucis longus was three times higher (9.8 per cent) when an external fixation device was used com-

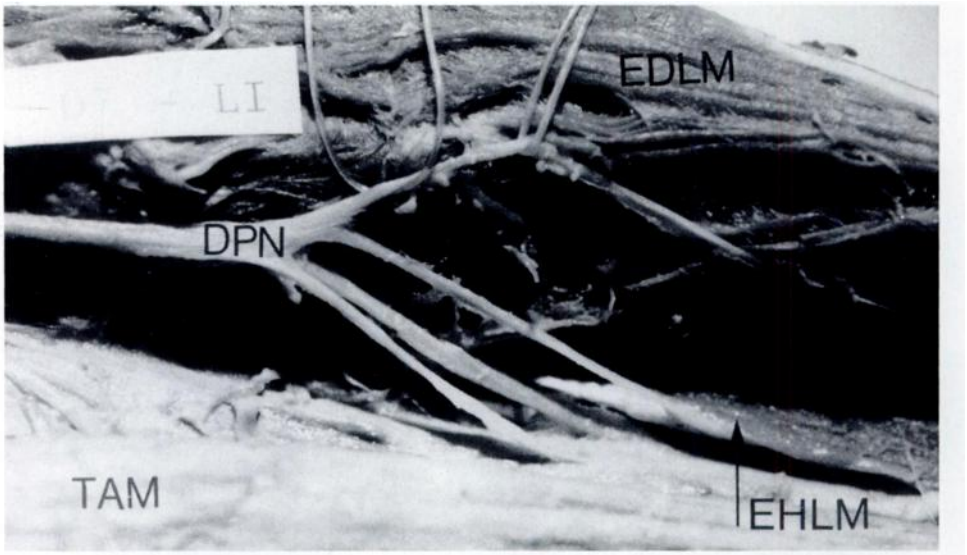

FIG. 3-A

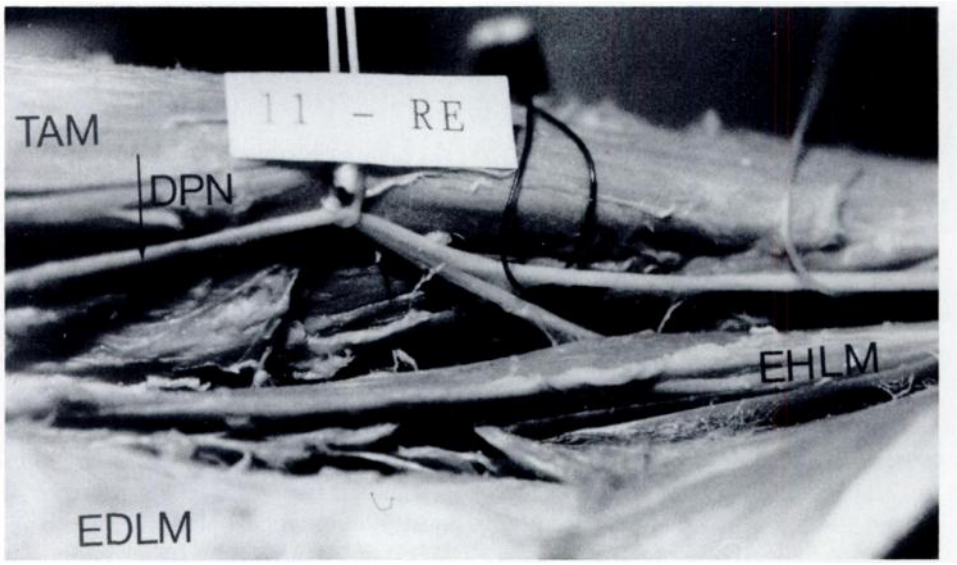

FIG. 3-B

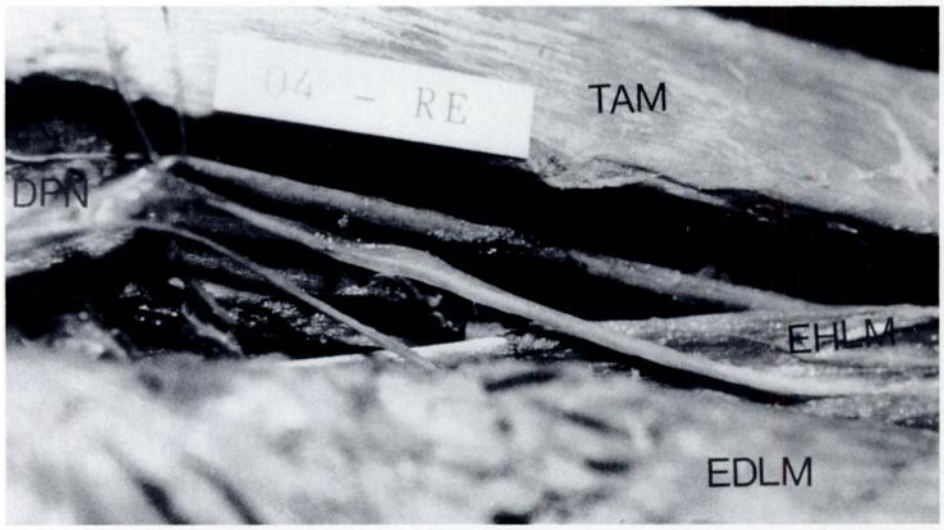

FIG. 3-C

Photographs of a dissected specimen of the leg, showing the ventral (Fig. 3-A), tibial (Fig. 3-B), and fibular (Fig. 3-C) variations of entry into the extensor hallucis longus muscle (EHLM). TAM = tibialis anterior muscle, DPN = deep peroneal nerve, and EDLM = extensor digitorum longus muscle.

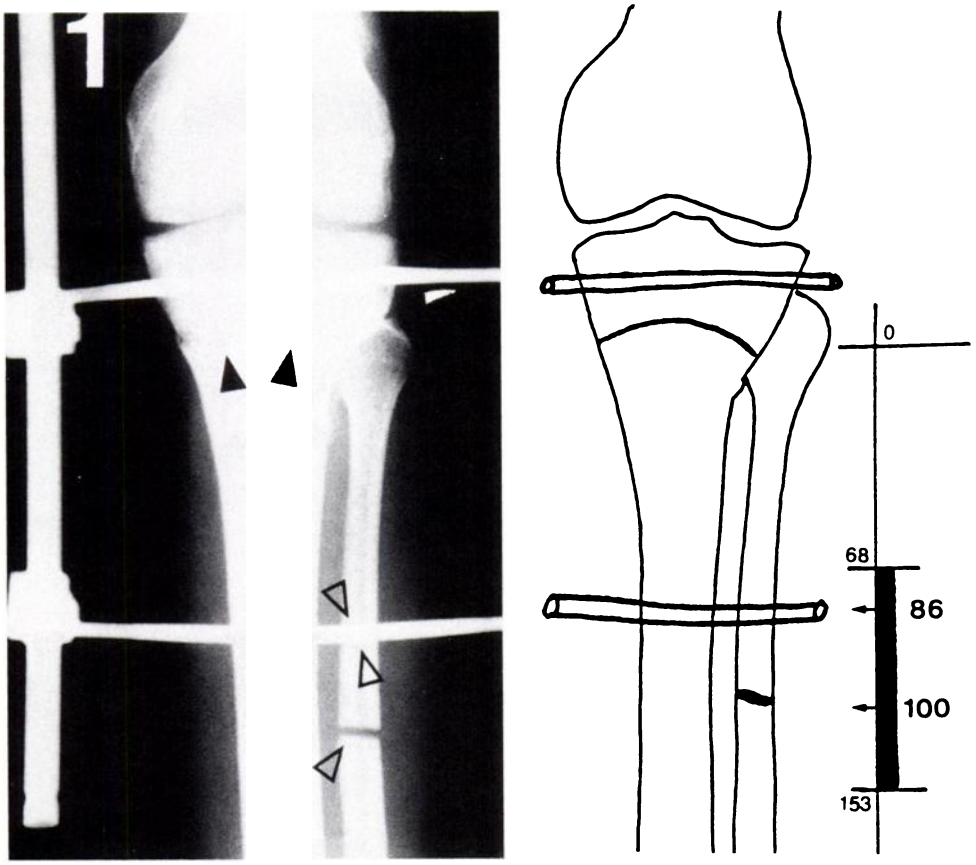

FIG. 4

Postoperative radiograph and sketch showing the leg of a patient who had persistent weakness of the extensor hallucis longus and transient weakness of the extensor digitorum and tibialis anterior after a proximal tibial and fibular osteotomy. The fibular osteotomy (single open arrowhead) and the insertion of the distal Steinmann pin (double open arrowheads) were performed in regions that were at high risk for intraoperative injury. The closed arrowheads point to the tibial osteotomy.

pared with when Blount clamps (1.0 per cent) or a plaster cast (2.3 per cent) was applied.

On the basis of these observations and our anatomical findings, we suggest that an isolated injury of motor branches to the extensor hallucis longus is the most probable explanation for this complication. Isolated paralysis of the extensor hallucis longus may be associated with use of an external fixation device that causes traction injury to the nerve to the extensor hallucis longus. In contrast to Stürz and Rosemeyer, who described a constant single motor branch to the extensor hallucis longus in close relation to the fibular periosteum, we saw this variation in only eight (17 per cent) of the forty-six motor nerves.

The distance between the point of origin of the nerves to the extensor hallucis longus and the point of entry of each nerve into the muscle must be regarded as an important indicator of the risk for iatrogenic damage to the nerve (Figs. 4 and 5). In all twenty-nine specimens, the region of high risk was located between two points, sixty-eight and 153 millimeters distal to the fibular head. Another high-risk region was located about thirty millimeters distal to the fibular head, where fibrous bands between the motor branches supply the tibialis anterior muscle and the fibula. Variations in the number and course of the motor nerves to the extensor hallucis longus, as well as a secondary hypertrophy of the extensor hallucis brevis when the extensor hallucis longus is paralyzed, were described by Stürz and Rosemeyer.

In addition to the risk of damage to nerves — for example, injury from pressure, retractors, or an error in positioning — there is a danger when an external fixation device is applied after a proximal tibial osteotomy. A Steinmann pin, placed sixty-eight to 153 millimeters distal to the fibular head, may cause damage to the nerve. Other risky maneuvers include dissection of the motor branches and use of a stab incision. The distal Steinmann pin should always be placed in the safe region, forty to sixty millimeters distal to the fibular tubercle, and it should always be inserted from the medial side.

Fibular osteotomy, performed sixty-eight to 153 millimeters distal to the fibular head, is liable to harm a motor branch to the extensor hallucis longus whenever that branch enters the muscle from the fibular side. Fibular osteotomy can be carried out safely in the region between the middle and distal thirds of the fibula, about 160 millimeters distal to the fibular head. We have seen a total of seven neural complications in forty-two patients who had had a tibial osteotomy of the dome

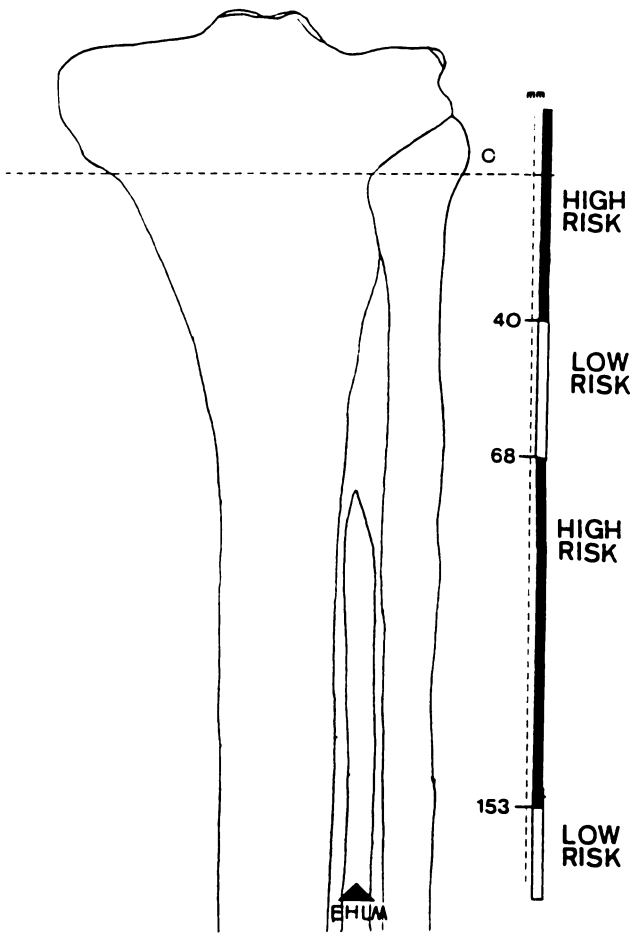

FIG. 5

Frontal view showing a leg, with a longitudinal scale. The scale illustrates regions that are at high and low risk for intraoperative injury relative to the presence of motor branches from the truncus of the deep peroneal nerve. EHLM = extensor hallucis longus muscle.

type. Three complications were transient sensory neuropathies involving the areas supplied by the superficial and deep peroneal nerves on the medial aspect of the dorsum of the foot. Three other complications were transient motor neuropathies of the extensor hallucis longus. Only one patient, who had a transient paralysis of all of the extensors of the foot and toes, had permanent, persistent weakness of the extensor hallucis longus. In all seven cases, the distal Steinmann pin was inserted in an area of high risk for fixation of the osteotomy.

In summary, paresthesia or combined motor and sensory deficits are iatrogenic neuropathies, commonly encountered as complications of tibial osteotomy because the sensory branches of the deep peroneal nerve ordinarily originate from the nerve distal to the origins of the motor branches. A high-risk region for such complications is close to the fibular head, where the common peroneal nerve is fixed to the bone by connective tissue. Preparation of the tibia for the osteotomy procedure can stretch the nerve, and paralysis may also be caused by pressure due to the use of Hohmann retractors. In order to protect the structures in the popliteal fossa from pressure by the retractor against the fibula, thereby stretching the nerve, the subperiosteal region must be carefully prepared and the retractor must be handled with caution.

Variations in the innervation of the extensor hallucis longus are frequent. However, there is a region where the fibular osteotomy and the insertion of Steinmann pins can be performed safely.

NOTE: The authors thank Professor Dr. G. Bogusch, Department of Anatomy, Free University of Berlin, for his help and encouragement.

References

1. **Blauth, W.,** and **Hepp, W.:** Zur Wahl der operativen Methode bei Genu varum. *Orthop. Praxis,* 12: 176, 1976.
2. **Lang, J.,** and **Wachsmuth, W.:** Bein und Statik. In *Praktische Anatomie.* Ed. 2, vol. 1, part 4, pp. 83-88, 229-230. Berlin, Springer, 1972.
3. **Legal, H.:** Die kniegelenksnahen Osteotomien in der Behandlung der Gonarthrose, Indikation und Ergebnisse. *Orthop. Praxis,* 23: 53-62, 1987.
4. **Maquet, Paul:** The treatment of choice in osteoarthritis of the knee. *Clin. Orthop.,* 192: 108-112, 1985.
5. **Naumann, T.,** and **Stephan, E.:** Ergebnisse von 221 Tibiakopf-Pendelosteotomien. *Orthop. Praxis,* 20: 914-916, 1984.
6. **Naumann, T.; Köhler, G.;** and **Stephan, E.:** Komplikationen bei Tibiakopfosteotomien in Abhängigkeit von der Fixierung. *Orthop. Praxis,* 23: 466-471, 1987.
7. **Stürz, H.,** and **Rosemeyer, B.:** Die isolierte Großzehenheberschwäche nach Fibulaosteotomie. Eine anatomische und elektromyographische Untersuchung. *Zeitschr. Orthop. Grenzgeb.,* 117: 31-38, 1979.
8. **Wasmer, G.; Milachowski, B.;** and **Rosemeyer, B.:** Langzeitergebnisse der Pendelosteotomien. *Orthop. Praxis,* 23: 453-458, 1987.
9. **Weingarden, S. I.; Louis, D. L.;** and **Waylonis, G. W.:** Electromyographic changes in postmeniscectomy patients — role of the pneumatic tourniquet. *J. Am. Med. Assn.,* 241: 1248-1250, 1979.