Peroneal nerve injury associated with sports-related knee injury

DOSANG CHO, M.D., PH.D.,1 KRIANGSAK SAETIA, M.D.,2 SANGOOK LEE, M.D.,4 DAVID G. KLINE, M.D.,3 AND DANIEL H. KIM, M.D.4

1Department of Neurosurgery, School of Medicine, Ewha Womans University, Seoul, Korea; 2Division of Neurosurgery, Department of Surgery, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand; 3Department of Neurosurgery, Louisiana State University Health Sciences Center, New Orleans, Louisiana; and 4Department of Neurosurgery, Baylor College of Medicine, Houston, Texas

Object. This study analyzes 84 cases of peroneal nerve injuries associated with sports-related knee injuries and their surgical outcome and management.

Methods. The authors retrospectively reviewed the cases of peroneal nerve injury associated with sports between the years 1970 and 2010. Each patient was evaluated for injury mechanism, preoperative neurological status, electrophysiological studies, lesion type, and operative technique (neurolysis and graft repair). Preoperative status of injury was evaluated by using a grading system published by the senior authors. All lesions in continuity had intraoperative nerve action potential recordings.

Results. Eighty-four (approximately 18%) of 448 cases of peroneal nerve injury were found to be sports related, which included skiing (42 cases), football (23 cases), soccer (8 cases), basketball (6 cases), ice hockey (2 cases), track (2 cases) and volleyball (1 case). Of these 84 cases, 48 were identified as not having fracture/dislocation and 36 cases were identified with fracture/dislocation for surgical interventions. Good functional outcomes from graft repair of graft length < 6 cm (70%) and neurolysis (85%) in low-intensity peroneal nerve injuries associated with sports were obtained. Recovery from graft repair of graft length between 6 and 12 cm (43%) was good and measured between Grades 3 and 4. However, recovery from graft repair of graft length between 13 and 24 cm was obtained in only 25% of patients.

Conclusions. Traumatic knee-level peroneal nerve injury due to sports is usually associated with stretch/contusion, which more often requires graft repair. Graft length is the factor to be considered for the prognosis of nerve repair. (DOI: 10.3171/2011.9.FOCUS11187)

Key Words: • peroneal nerve • stretch/contusion • sports-related injury • graft repair • neurolysis

Common peroneal nerve palsy is a debilitating complication, and its incidence due to sports-related knee injury has been reported to be as high as 50%.6 The mechanism for peroneal nerve injury as a group includes laceration, stretch/contusion, entrapments, iatrogenic, compression, or gunshot wounds. However, peroneal nerve injuries caused by sports are found to be frequently associated with severe ligamentous knee injuries. Most of the peroneal nerve injuries sustained by players come under the category of stretch/contusion injuries. The occurrence of peroneal nerve injury in association with knee dislocations has been reported to be between 14% and 40%, with most studies reporting an incidence in the range of 25%–35%.10 Reports show that the most common cause of knee injury is motor vehicle accidents, followed by those that are sports related;14 however, recent studies have shown an increase in knee injuries associated with sports.1,2 Peroneal nerve injuries may occur in as many as 23% of patients with knee dislocations. Nearly one-half of the patients with peroneal nerve injuries have a permanent deficit.15 The type of sport plays a major role in defining the mechanism and frequency of peroneal nerve injuries. In the 84 sports-related peroneal nerve injuries represented in this series, skiing, football, soccer, basketball, ice hockey, and volleyball were found to be responsible for the knee injuries leading to peroneal nerve palsy. The major sports that were found to be highly responsible for peroneal nerve injuries were skiing (50%) as the most frequent, followed by football (27%). The reasons for this are not only the frequency with which they are prolonged but also biomechanical forces involved and the chances of a direct blow to the knee. Some of the low-intensity sports

Abbreviations used in this paper: CPN = common peroneal nerve; NAP = nerve action potential; PCL = posterior cruciate ligament.
like basketball, track, and volleyball require repeated usage of muscles and ligaments, frequent twists and turns, and on occasion sudden jerk to the knee, which makes the peroneal nerve vulnerable to either injury or compression.

**Methods**

**Patient Population**

Retrospectively, 448 cases of peroneal nerve injuries were identified, which were surgically managed between 1970 and 2010. The mechanism of injury for these cases included stretch/contusion without fracture/dislocation (215 cases), stretch/contusion with fracture/dislocation (57), tumor (62), laceration (47), entrapment (53), and gunshot wound (14; Fig. 1). Most of the 272 patients who had stretch/contusion from high-velocity injuries were involved in motor vehicle accidents. Of 272 stretch/contusion cases, 84 (approximately 30%) were identified as sports-related (Table 1), which included skiing (42 cases), football (23), soccer (8), basketball (6), ice hockey (2), track (2), and volleyball (1). The 84 sports-related peroneal nerve injuries were categorized into those without fracture/dislocation (48 cases) and those with fracture/dislocation (36 cases). All 84 of these cases underwent surgical exploration. Postoperative evaluations were performed over an average follow-up duration of 16 months (range 1–6 years).

**Surgical Anatomy**

The CPN originates as the sciatic nerve divided into the CPN and the tibial nerve at the mid- to distal-third of the thigh. The CPN descends obliquely over the proximal gastrocnemius muscle from the apex of the popliteal fossa to the lateral popliteal fossa and usually lies beneath the medial aspect of the lateral hamstring muscle. It then curves around the proximal peroneus longus muscle to travel toward the anterior lower leg, where it divides into deep and superficial branches (Fig. 2).

The deep branch of the CPN quickly divides after passing beneath the fibrous lateral edge of the peroneus longus muscle. The initial branch supplies the anterior tibial muscle, and subsequent branches supply the extensor digitorum longus, extensor hallucis longus, and peroneus tertius muscles. The deep branch is divided further as it approaches the foot into a medial sensory branch and a lateral motor branch. The medial branch supplies a small area of skin over the first dorsal web space of the foot, whereas the lateral branch innervates the extensor digitorum brevis and extensor hallucis brevis muscles.

The superficial peroneal branch supplies the peroneus longus and then the brevis muscles as it descends in a straight course between them, becoming gradually more superficial in the distal third of the lower leg. It then branches in front of the ankle joint into the medial and lateral branches. The superficial peroneal branch supplies cutaneous sensation to the anterolateral lower leg and ankle and also supplies sensation to the dorsum of the foot.

**Surgical Exposure**

The patient is placed prone with the leg slightly flexed at the knee. An S-shaped incision begins in the lower thigh, medial to the long head of the biceps femoris muscle (lateral hamstring). A lateral curvilinear extension crosses the surgical neck of the fibula and continues toward the proximal lateral surface of the leg (Fig. 3). As the proximal portion of the incision is deepened, the lateral hamstring is moved away from the underlying peroneal nerve. The peroneal nerve is in the fatty tissue behind the long
biceps (lateral hamstring) head. Dissection is then carried toward the lateral popliteal space. Usually in the popliteal fossa, a large sensory branch, the lateral sural cutaneous nerve, originates from the peroneal nerve. The nerve then curves around the surgical neck of the fibula and divides into the deep and superficial peroneal branches. By splitting the peroneal nerve, branches are exposed distal to the surgical neck and fibular head. The deep branch is traced around the surgical neck of the fibula using a plastic loop. The more distal deep branches can be traced only a short distance into the anterior compartment. Small vessels are coagulated and fine neural branches running to the knee joint can be sacrificed. In this series, NAP stimuli were used to evaluate the lesion in continuity. If NAP stimulus traces were flat, the lesion in continuity was resected and the nerve ends were prepared for graft repair. If NAPs were transmitted across the lesion or lesions, then neurolysis was usually performed. The head of the fibula was usually levered off using Leksell rongeurs and bone wax was applied. A split hamstring muscle was reapproximated with 2-0 or 3-0 suture, as was the more distal portion of the peroneus longus and brevis muscles.

Surgical Methods

Each patient was initially followed up from 3 to 6 months and checked for spontaneous functional recovery. When there was no significant positive functional outcome as confirmed by electromyography and clinical examination, surgical exploration and repair was recommended. The grading system for knee-level CPN injuries (Table 2), previously published by the senior authors, was used to evaluate preoperative and postoperative function. Neurolysis was performed on lesions in continuity when intraoperative NAP could be recorded across the lesion. However, graft repair was performed on lesions that were not in continuity or on lesions in continuity with no intraoperative NAPs across the lesion. After resection of proximal and distal stumps or a segment of neuroma, healthy appearing fascicles could be observed under high magnification on both the nerve ends. Length of the graft needed (usually sural nerve) was determined by the nerve gap as measured during surgical exploration. For graft repair, 3 different ranges of the graft lengths were used: < 6 cm, 6–12 cm, and 13–24 cm.

Results

Eighty-four cases of sports-related traumatic CPN injury with stretch/contusion injury underwent surgical repair. Mechanisms of injury included 48 cases without fracture/dislocations and 36 with fracture/dislocations of stretch/contusions (Table 3). A total of 58 graft repairs were performed, using 3 ranges of graft length (< 6 cm, 6–12 cm, and 13–24 cm).

Stretch/Contusion Without Fracture/Dislocation

Of the 48 cases (57%) with stretch/contusion without fracture/dislocation, 17 patients (35%) underwent neu-
rolysis because of an intraoperative NAP recorded distal to the lesion, whereas 31 patients (65%) underwent sural nerve graft repair because of negative NAP across the lesion or due to complete disruption of the CPN where proximal and distal stumps were found. These injuries were presented with complete or severe loss of CPN function, that is, loss or severe weakness of dorsiflexion of the foot and toes and of eversion of the foot.

Despite complete functional loss, careful neurolysis was performed across the lesions in continuity where a NAP could be recorded. Functional recovery of Grade 3 or better was achieved in the neurolysis group in 85% of cases, which was attributed to a lower severity of injury compared with those in which graft repair was required.

**Stretch/Contusion With Fracture/Dislocation**

Thirty-six (43%) of 84 patients with CPN lesions underwent operative intervention for stretch/contusion injuries associated with fibular or tibial fractures or dislocations. Nine (25%) of these 36 patients with stretch/contusions had transmittable NAPs across their lesions in continuity and thus underwent neurolysis. Twenty-seven patients (75%) with severe nerve lesions required graft repairs. Graft length depended on the nerve gap between the 2 stumps of the nerve after neuromas had been removed. Ten (17%) of the 58 graft repairs performed were less than 6 cm in length, and 7 (70%) of 10 achieved functional grades between 3 and 4. Forty of the 58 patients undergoing graft repairs had graft lengths between 6 and 12 cm, and 17 (43%) of these 40 achieved functional recovery grade of 3 or better. If the length of the graft was between 13 and 24 cm, which was used in 8 (14%) of the 58 grafts, only 2 (25%) of the 8 patients showed functional outcome of Grade 3 or 4. Not surprisingly, the functional outcomes were higher for the short grafts than for the longer ones.

**TABLE 2: Grading scale of the Louisiana State University Health Sciences Center for peroneal nerve palsy**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no palpable muscle contraction</td>
</tr>
<tr>
<td>1</td>
<td>palpable contraction of peronei or anterior tibial muscles</td>
</tr>
<tr>
<td>2</td>
<td>peronei or anterior tibial muscles contract against gravity</td>
</tr>
<tr>
<td>3</td>
<td>peronei &amp; anterior tibial muscles contract against gravity &amp; some resistance</td>
</tr>
<tr>
<td>4</td>
<td>peronei &amp; anterior tibial muscles contract against moderate resistance</td>
</tr>
<tr>
<td>5</td>
<td>peronei &amp; anterior tibial muscles contract w/ full strength</td>
</tr>
</tbody>
</table>

* From Kim et al., 2004.

**TABLE 3: Peroneal nerve injuries as a result of sports and surgical results**

<table>
<thead>
<tr>
<th>Stretch/Contusion Injury</th>
<th>No. of Pts</th>
<th>Neurolysis</th>
<th>&lt;6</th>
<th>6–12</th>
<th>13–24</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/o fracture/dislocation</td>
<td>48</td>
<td>17</td>
<td>8</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>w/ fracture/dislocation</td>
<td>36</td>
<td>9</td>
<td>2</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>total</td>
<td>84</td>
<td>26</td>
<td>10</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>no. w/ postop Grade 3 or better results (%)</td>
<td>22 (85)</td>
<td>7 (70)</td>
<td>17 (43)</td>
<td>2 (25)</td>
<td></td>
</tr>
</tbody>
</table>

* Pts = patients.
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Discussion

The highest number of CPN injuries at the knee level fall into the category of stretch/contusion. For example, there is a large incidence of CPN injuries reported with dislocation of the knee. Knowledge of the mechanisms of injuries involved in sports enables analysis and classification as to location and type, guides surgery, and facilitates assessment. The reasons that peroneal nerve injuries are associated with sports is because of extreme biomechanical demand by the body while playing, such as stretching, twisting, jumping, running, falling, and direct blows in the contact sports. Different sports require different physical demands, thereby making peroneal nerve injuries specific to some and not as common to others. A series of cases of peroneal nerve injuries from football, skiing, soccer, and basketball and other sports has been presented in this paper. Peroneal nerve injuries are most commonly found to occur when the posterolateral corner structures of the knee are also injured. Considerable connective tissue damage may occur with severe stretch injuries, which can lead to both intraneural and extraneural scar formation. In this series, peroneal nerve stretch/contusion injury that occurred during sports was associated with knee joint soft-tissue injuries and ligamentous and/or cartilaginous stretches or tears caused by impact-induced knee adduction and torsion. Other than this, compression injury is also found in participants in contact sports. Babwah reported a case of CPN injury in a soccer player because of excessive cooling with ice.

Most studies have reported an incidence of 25%–36% of peroneal nerve palsy in knee dislocations. Recent studies show that the occurrence rate of CPN palsy associated with knee dislocation or bicruciate ligament injury ranges from 10% to 40%. Palsy of the CPN was associated with dislocation of the knee in 25% of patients as reported by Niall et al., exclusively with dislocations involving a disruption of the PCL and posterolateral corner. It is important to note that in dislocations with disruption of the PCL and posterolateral corner, the incidence is greater and may be as high as 45%. Fractures of either the distal femur or proximal tibia are present in 16% of peroneal nerve injury cases. Marginal avulsion fractures of the lateral tibial plateau may be observed in some cases, indicating significant capsular, collateral, and cruciate disruption. Fractures of the anteromedial tibial plateau in particular are associated with the presence of disruption of the PCL and posterolateral corner. A significant number (43%) of stretch/contusion cases was found to be associated with fracture/dislocation.

Timing of Surgery

The time from trauma to repair has been found to have a profound influence on positive functional outcome of the injured peroneal nerve. Recommendations regarding the timing of surgical intervention differ, but most peripheral neurosurgeons emphasize careful clinical follow-up after the initial injury by physical examination and electromyography for approximately 3 months postinjury before operating.

Vulnerability of the CPN to Injury

Several anatomical factors predispose the CPN to injury. The CPN passes lateral to the surgical neck of the fibula, at which point it is superficial and relatively fixed. At this point, it is vulnerable to direct external compression, but is also vulnerable to stretch due to relative fixation. The severity of CPN injuries depends on the direction and force of the displacement causing the various ligament ruptures, which in turn depends on intensity of the trauma: the neurological lesion, like the popliteal vascular lesion, is part of regional trauma sustained by the knee. There is consensus as to the parallel nature of the neurological and ligamentous lesions: the more extensive and severe the latter, the more frequent and severe the CPN palsy.

As the second branch of the sciatic nerve, the tibial nerve is less prone to injury associated with knee injuries. It lies deep in the posterior compartment of the leg, is not as tethered in the leg as the CPN, and is therefore less vulnerable to injury than the CPN. The tibial nerve is most often injured in association with knee dislocation or very severe injuries to the posterior knee capsule. Anatomically, as explained by Sunderland, the number of fascicles doubles and the percentage of connective tissue decreases distally in the lower extremities. Thus, the maximum load that the CPN may sustain before reaching its elastic limit is less than that of the tibial nerve in this same region. This suggests that when the CPN is subjected to the same force, it is more susceptible to injury than the posterior tibial nerve in the same location; that is, the internal arrangement of the nerve makes it less able to absorb axially directed forces.

Manifestations of Peroneal Nerve Injuries

Foot drop is a common and significant manifestation of peroneal nerve injury. This condition results from the loss of motor innervations of the tibialis anterior muscle and causes significant gait impairment and disability. The complaint of numbness or tingling over the anterolateral leg, foot, or first web space is very common in athletes. Athletes may complain of foot drop or weakness of ankle dorsiflexion.

Injury to the CPN or to both its superficial and deep branches causes weakness of the deep branch-innervated ankle dorsiflexors (the anterior tibialis and peroneus tertius) and toe extensors, including the extensor digitorum brevis and longus and the extensor hallucis brevis and longus, which extend the second through fifth toes and the great toe, respectively. There is also paresis of the superficial branch-innervated ankle evertors, the peroneus longus and brevis muscles. Deep branch involvement results in decreased sensation in the area between the great and second toes while superficial branch involvement results in numbness in the anterolateral calf and the dorsum of the foot. If there is involvement of only one of the branches, it is usually the deep branch that is involved.

Associated Vascular Injuries

The incidence of vascular injuries in association with knee dislocation varies between reports, ranging from 7% to 64%. Stretch/contusion to the CPN from high-im-
pact sports injury not only damages the nerve but also can rupture the vasa nervorum, which causes bleeding into the nerve sheath and a compressive hematoma resulting in ischemia. A high prevalence (4%–20%) of disruption of the popliteal vascular supply in patients with knee dislocations has been reported. The majority of the acute sports-related combined neuronal and vascular injuries are associated with contact sports such as rugby, football, and ice hockey.

**Surgical Approach**

Recently, Giuseffi et al. reviewed the future prospects of surgical treatment of peroneal nerve palsy after knee dislocation. Nerve regeneration following CPN repair is poor compared with other peripheral nerves, and this can explain the reluctant attitude of many physicians toward exploration and repair of this nerve. One factor explaining the poor outcome of CPN reinnervation might be the imbalance between the functioning flexors and the weakly innervated extensors that can result in fixed equinism of the foot with associated heel cord (Achilles tendon) shortening.

Other surgical options besides direct nerve repairs include nerve transfers and tendon transfers. Nerve transfer involves taking a branch from a less important lower leg muscle in the tibial distribution and connecting it to nerve to the muscle that lifts the foot in the peroneal distribution. A tendon transfer involves taking a tendon that moves the foot inward, and connecting it to the top of the foot so that it now lifts the foot up and out, thereby resolving the foot

![Peroneal nerve injury as a result of various fractures and dislocations of the knee joint.](image)
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drop. Successful functional outcomes of foot drop by nerve transfers to deep peroneal nerve have been reported in the literature.\textsuperscript{12,15,21} In this series, either neurolysis and/or graft repair was selected for the 84 patients with CPN injuries due to sports. Follow-up showed 85\% of positive functional outcomes of Grade 3 or more in cases of neurolysis based on a positive NAP across the lesion.

\textit{Tibialis Posterior Tendon Transfers}

Tendon transfer procedures for CPN palsies due to stretch are promising.\textsuperscript{7} Yeap et al.\textsuperscript{26,27} concluded that tibialis posterior tendon transfers as a group produced 83\% excellent or good results in terms of patient satisfaction. These procedures can be recommended to patients who would prefer to discard an ankle/foot orthosis. The results are likely to be more successful if the nerve lesion causing the drop foot is at the common peroneal level rather than at the sciatic level, where posterior tibialis may be paralyzed and in men less than 30 years of age, which is the usual case with sports injuries. Posterior tibial tendon transfer procedures have had reasonable success in allowing patients to return to ambulation without assistive devices; however, dorsiflexion strength on the affected side has been reported as only 30\% that of the normal contralateral side, and return to activities more strenuous than walking has not been reported.\textsuperscript{15} Vigasio et al.\textsuperscript{23} reported the outcomes of combined posterior tibial tendon/flexor digitorum longus transfers for CPN palsy in 16 patients and concluded that their procedure effectively restored balance to foot dorsiflexion and gait without the use of orthosis. It should be noted, however, that tendon transfer can lead to flatfoot and/or hind foot valgus, which can hinder full functional recovery.\textsuperscript{9}

Recent surgical reports for peroneal nerve palsies of various origins confirm success for nerve grafting without tendon transfer in 75\% of patients with a nerve gap of < 6 cm and 16\% with a nerve gap of > 6 cm.\textsuperscript{7} By contrast, success (Grade M3 to M4+) of 85\%–90\% has been reported recently when tendon transfer is added to the nerve grafting.\textsuperscript{7}

\textit{Length of Graft}

Functional outcome of nerve grafting result is dependent on nerve graft length necessary to close the gap, with documented recovery rates of only 44\% for nerve grafts longer than 6 cm.\textsuperscript{5,24} Sedel and Nizard\textsuperscript{19} also reported results of nerve grafting for traction injury of the CPN. Of the 17 patients who underwent grafting for nerve gaps ranging from 7 to 20 cm, only 6 had a functionally satisfactory result. The authors attributed these poor graft results to the significant length of their traction injuries (up to 15 cm).

As reported by Prasad et al.,\textsuperscript{17} the reason for failure of nerve grafting for CPN disruption due to stretch/traction is that the zone of injury has transformed the normal intercalation of the terminal motor axons and muscle into a region of collagen, thereby not allowing even an expertly performed interfascicular interposition nerve graft from having regenerating axon branches reach the target end-organ, the denervated muscle. Conceptually, this problem might be solved by direct neurotization of the muscle, instead of performing interfascicular interposition nerve grafting.

\textbf{Conclusions}

Common peroneal nerve palsy is an incapacitating complication, and its incidence, because of sports-related knee injury, is relatively common. Recent studies have shown an increase in knee injuries associated with sports. Traumatic knee-level peroneal nerve injury is usually due to stretch/contusion, which often requires graft repair. Surgical repair using neurolysis if NAPs across the lesion are positive, and nerve grafting to the nerve, can rescue dorsiflexion of the foot but only when grafts are relatively short (< 6 cm). Graft length is one of the major factors to be considered in the prognosis of peroneal nerve repair. Tendon transfer, either in addition to CPN repair or without it, is a reliable procedure for restoring dorsiflexion, even though not with full strength.

\textbf{Disclosure}

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Kim, Kline. Acquisition of data: Cho, Saetia, Lee. Analysis and interpretation of data: Kim, Cho, Saetia, Lee. Drafting the article: Cho, Saetia, Lee. Critically revising the article: Kline. Reviewed submitted version of manuscript: Kim, Kline. Approved the final version of the manuscript on behalf of all authors: Kim. Statistical analysis: Cho, Saetia. Administrative/technical/material support: Kim, Cho. Study supervision: Kim.

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Address correspondence to: Daniel H. Kim, M.D., Department of Neurosurgery, Baylor College of Medicine, 1709 Dryden Street, Suite 750, Houston, Texas 77030. email: dhkim@bcm.edu.