The consistent presence of the human accessory deep peroneal nerve

HIROYUKI KUDOH¹, TATSUO SAKAI¹ AND MASAHARU HORIGUCHI²

¹ Department of Anatomy, Juntendo University School of Medicine, Tokyo, and ² Department of Anatomy, Iwate University School of Medicine, Morioka, Japan

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ABSTRACT

Twenty-four human legs were dissected macroscopically to study the morphological details of the accessory deep peroneal nerve. This nerve arose from the superficial peroneal nerve and descended in the lateral compartment of the leg, deep to peroneus longus along the posterior border of peroneus brevis. Approaching the ankle joint, this nerve passed through the peroneal tunnels to wind around the lateral malleolus; it then crossed beneath the peroneus brevis tendon anteriorly to reach the dorsum of the foot. The accessory deep peroneal nerve was found in every case examined and constantly gave off muscular branches to peroneus brevis and sensory branches to the ankle region. In addition, this nerve occasionally had muscular branches to peroneus longus and extensor digitorum brevis, and sensory branches to the fibula and the foot. The anomalous muscles around the lateral malleolus were also innervated by this nerve. Neither cutaneous branches nor communicating branches with other nerves were found. The present study reveals that the accessory deep peroneal nerve is consistently present and possesses a proper motor and sensory distribution in the lateral region of the leg and ankle. It is not an anomalous nerve as has previously been suggested.

Key words: Peripheral nerve; peroneal musculature.

INTRODUCTION

The accessory deep peroneal nerve (n. peroneus profundus accessorius, PPA) has been regarded as an anomalous nerve derived from the superficial peroneal nerve (n. peroneus superficialis, PS) or its branch and supplies motor innervation for extensor digitorum brevis and sensory innervation for the lateral part of the ankle and foot regions. The PPA was reported initially by Ruge (1878) on the basis of his observations on rodents and carnivores. The first anatomical description of the PPA in man was provided by Bryce (1897, 1901) who found this nerve in 9 legs out of 110 and reported that it gave off constant sensory branches to the ankle region and occasional motor branches to extensor digitorum brevis. Winckler (1934) performed a more detailed analysis of this nerve and reported a more frequent occurrence in man, namely in 7 of 19 legs. From the late 1960s, Lambert (1969) and several other authors have reported various frequencies of the PPA innervating extensor digitorum brevis by means of electrophysiological methods. In these studies, the sensory component of the PPA was practically neglected.

Accurate anatomical knowledge of the PPA is important when performing surgery on the ankle and foot. Surgery in this region is frequently undertaken by a lateral approach that requires an incision posterior to the lateral malleolus where the PPA runs. Cases with symptoms due to traumatic injury of this nerve have been reported (Dessi et al. 1992; Sander et al. 1998).

The PPA is generally identified by its localisation posterior to the lateral malleolus, but its origin, precise course and branches have been insufficiently described so that there have been various reports of the extent of the PPA by different authors. The purpose of the present study is to clarify the
anatomical details of the PPA. Special emphasis is paid to the frequency of the individual branches and their distribution fields.

MATERIALS AND METHODS

A total of 24 legs were obtained from Japanese adult cadavers of both sexes and of different ages in the gross anatomy course at Iwate Medical University School of Medicine. The fascia cruris on the lateral compartment and peroneus longus were reflected backwards extensively to reveal the PS and peroneus brevis. The PPA was found along the posterior border of peroneus brevis. If necessary, a stereomicroscope (Zeiss OPMI99, Germany) was used for dissection. Once identified the nerve was followed both proximally and distally to reveal its origin, entire course and all branches. Special care was taken not to damage the PS or the PPA nor to alter the branching pattern of these nerves by excessive elimination of the epineurium. In cases of variant muscles in the ankle region, the muscular branch to these variants from the PPA was investigated.

RESULTS

Course and frequency of the accessory deep peroneal nerve

The common peroneal nerve left the popliteal fossa by crossing superficial to the lateral head of gastrocnemius and penetrated into peroneus longus to bifurcate into the PS and deep peroneal nerves (n. peroneus profundus, PP). The latter immediately pierced the anterior crural intermuscular septum to enter the anterior compartment of the leg, whereas the former remained in the lateral compartment. Between the origin and the level of the superior end of peroneus brevis, the PS gave off several branches, including the PPA and muscular branches to peroneus longus. The PPA was characterised by its origin from the posterior border of the PS, its position posterior to the lateral malleolus, and its sensory and/or motor supply to the ankle region (Fig. 1). The PPA was found in every individual examined.

In the lateral compartment, the PS ran anteroinferiorly along the anterior border of the origin of peroneus brevis towards the anterior crural intermuscular septum, whereas the PPA ran posteriorinferiorly along the posterior border of this muscle to reach the posterior crural intermuscular septum. On the anterior surface of the posterior crural intermuscular septum, the PPA descended between the attachments of the 2 peroneal muscles, and did not penetrate the septum. Approaching the ankle joint, this nerve was still situated behind the tendons of insertion of the peroneal muscles to pass through the superior and inferior peroneal tunnels deep to the superior and inferior peroneal retinaculum, respectively. In the superior peroneal tunnel the nerve was found in the connective tissue surrounding the common synovial sheath for both peroneal muscles. The inferior peroneal tunnel was divided by a septum into a superficial-posterior compartment for the peroneus longus tendon and a deep-anterior compartment for both the peroneus brevis tendon and the PPA. At the exit of the inferior peroneal tunnel, the PPA turned anteriorly to cross beneath the peroneus brevis tendon towards the dorsum of the foot. Proximal to extensor digitorum brevis this nerve broke into several terminal twigs, including a muscular branch to this muscle and sensory branches to the ankle region.

There were some variations in the course of the PPA. The nerve terminated in the ankle region without any branches to the dorsum of the foot in 5 cases (Fig. 2c, e). The PPA was embedded partly in peroneus brevis during its course in 4 cases (Fig. 2a–c). In one of these cases, the nerve bifurcated in the proximal part of peroneus brevis, and one branch penetrated superficial fasciculus of the muscle to reunite with the other on the surface of the muscle (Fig. 2b). In 1 case, the PPA underlay the inferior half of peroneus brevis to make contact with the lateral surface of the fibula (Fig. 2c). The PPA occasionally entered the superficial-posterior compartment of the inferior peroneal tunnel with the peroneus longus tendon, and penetrated the dividing septum to reach the deep-anterior compartment (1 case).

Branches of the accessory deep peroneal nerve

The PPA gave off muscular branches to peroneus brevis and other muscles as well as deep sensory branches to the ankle region and surroundings (Fig. 3, Table). Neither cutaneous branches nor communicating branches arising from the PPA were found in the present study. In addition to constant muscular branches to peroneus brevis, occasional muscular branches to peroneus longus and extensor digitorum brevis as well as to small anomalous muscles such as peroneus quartus and peroneus digiti quinti were encountered. The deep sensory branches were distributed to the fibula, the ankle region surrounding muscular septum, the PPA descended between the attachments of the 2 peroneal muscles, and did not penetrate the septum. Approaching the ankle joint, this nerve was still situated behind the tendons of insertion of the peroneal muscles to pass through the superior and inferior peroneal tunnels deep to the superior and inferior peroneal retinaculum, respectively. In the superior peroneal tunnel the nerve was found in the connective tissue surrounding the common synovial sheath for both peroneal muscles. The inferior peroneal tunnel was divided by a septum into a superficial-posterior compartment for the peroneus longus tendon and a deep-anterior compartment for both the peroneus brevis tendon and the PPA. At the exit of the inferior peroneal tunnel, the PPA turned anteriorly to cross beneath the peroneus brevis tendon towards the dorsum of the foot. Proximal to extensor digitorum brevis this nerve broke into several terminal twigs, including a muscular branch to this muscle and sensory branches to the ankle region.

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the lateral malleolus and the lateral part of the metatarsal region. Peroneus brevis was innervated exclusively by muscular branches arising from the PPA (Fig. 2a–f). The number of these branches varied from 2 to 14 and was abundant in comparison with the number of muscular branches to other muscles (Table). The entry points of these branches to peroneus brevis were located along almost the entire length of the muscle. Branches entering the muscle at the upper half innervated both the anterior and posterior portions of this bipennate muscle, whereas those entering at the lower half innervated exclusively the posterior portion. These entry points shifted from the superficial to the deep surfaces as the points were located inferiorly (Fig. 2a, d). The muscular branches to peroneus longus were derived mainly from the PS and partly from the PPA. The PS gave off the muscular branches either from its anterior border or from its posterior border proximal
Fig. 2. Drawings showing various patterns for the course and branches of the accessory deep peroneal nerve. This nerve arises from the superficial peroneal nerve (▲). The nerve is partly covered by a slip from peroneus brevis in the cases shown in a, b and c (▲). In b, the nerve bifurcates and reunites at the proximal part of peroneus brevis. Muscular branches to peroneus brevis (►) and sensory branches to the ankle region (●) are present in all cases. Some of muscular branches to peroneus brevis enter from deep surface in the lower part of this muscle (● in the cases shown in a, d and e). A muscular branch arising from the accessory deep peroneal nerve to peroneus longus (▲) is found in cases a and c, and one to extensor digitorum brevis (▲) is observed in cases a, b, d and f. Peroneus quartus (Pq) is innervated by the accessory deep peroneal nerve via a branch arising from its proximal portion in case d or via 2 branches arising close to this muscle in case e (▲). In case f, the accessory deep peroneal nerve bifurcates into the branches to peroneus digiti quinti (▲) and extensor digitorum brevis. Sensory branches to the fibula (▲) are found in cases b, c, d and e, and to the metatarsal region (▲) are present in cases a and d. Edb, extensor digitorum brevis; MI, lateral malleolus; Pb, peroneus brevis; Pdq, peroneus digiti quinti; Pl, peroneus longus; Ps, superficial peroneal nerve.
Table. Branches arising from the accessory deep peroneal nerve

<table>
<thead>
<tr>
<th>Muscular branch</th>
<th>Legs accompanied by the muscle</th>
<th>Legs accompanied by the branch</th>
<th>Number of branches present</th>
</tr>
</thead>
<tbody>
<tr>
<td>To peroneus longus</td>
<td>24</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>To peroneus brevis</td>
<td>24</td>
<td>24</td>
<td>5.8</td>
</tr>
<tr>
<td>To extensor digitorum brevis</td>
<td>24</td>
<td>16</td>
<td>1.3</td>
</tr>
<tr>
<td>To peroneus quartus</td>
<td>3</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>To peroneus digiti quinti</td>
<td>4</td>
<td>4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Sensory branch

| To fibula | — | 9 | 2.6 |
| To ankle region | — | 24 | 3.9 |
| To metatarsal region | — | 5 | 1.4 |

Comparisons with previous studies

The present study reveals that the PPA is a constant nerve that possesses a proper distribution in the lateral region of the leg and ankle; it is not an anomalous nerve as has previous been suggested (Fig. 3). The proximal portion of this nerve sends off several muscular branches to peroneus brevis to become the distal portion containing sensory and motor components to the ankle region. In previous studies such as those by Bryce (1897, 1901), the PPA was usually regarded as an anomalous branch from the consistent muscular branches to peroneus brevis reaching the

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Fig. 3. Diagrammatic representation of the accessory deep peroneal nerve (Ppa) and its branches. Note that the motor components of this nerve mainly supply the peroneal muscles, and that the sensory components predominantly distribute around the lateral part of the ankle joint. A, ankle region; Edb, extensor digitorum brevis; F, fibula; Ml, lateral malleolus; Mt, metatarsal region; Pb, peroneus brevis; Pdq, peroneus digiti quinti; Pl, peroneus longus; Pq, peroneus quartus; Ps, superficial peroneal nerve.

The PPA has also been studied with electrophysiological techniques by detecting an evoked response in extensor digitorum brevis after stimulation of this nerve at a point posterior to the lateral malleolus using surface electrodes (Lambert, 1969; Infante & Kennedy, 1970; Crutchfield & Gutmann, 1973; Singh et al. 1973; Neundoerfer & Seiberth, 1975; Mapelli et al. 1978; Azouvi et al. 1986; Stamboulis, 1987). The frequency of occurrence of this nerve reported in these electrophysiological studies does not refer to that of the PPA per se, but to that of its muscular branches to extensor digitorum brevis. The reported figures of frequency in these studies, from 9% to 25%, are much lower than that found in the present study. This difference may be explained by difficulty in stimulation of this deeply located nerve with surface electrodes. Indeed, Infante & Kennedy (1970) reported that stronger stimulation of this nerve evoked a higher frequency of occurrence of response in the muscle.

Morphological features of the accessory deep peroneal nerve

Features in its course. At the level of the lateral malleolus, the PPA always passes posterior to the lateral malleolus and deep to the peroneus brevis tendon to reach the ankle region. There are 2 possibilities for the cause of this angulated course: (1) an angulated course was prepared for the anlage of nerve to the target, or (2) the angulation is secondary after the target was reached. The developmental process of the lower leg musculature suggests that the latter possibility is more plausible. The dorsal pre-muscular mesenchyme differentiates into an extensor mass and a peroneal mass, and the latter splits off from the former to shift laterally (Bardeen, 1907). At this time of lateral shift, the PPA is thought to have reached the target, since the PP is known to have established innervation to the dorsum of the foot (Bardeen, 1907). Thus it is reasonable to think that the angulated course as well as the deep localisation of the nerve relative to the peroneus brevis tendon are due to the lateral shift of the peroneal muscles during development.
Motor component of the accessory deep peroneal nerve. The PPA supplies motor innervation to peroneus brevis and some other peroneal and extensor muscles. The present study has revealed that peroneus brevis is innervated exclusively by the PPA, whereas previous authors such as Bryce (1897, 1901) took the view that this muscle receives motor branches arising from the PS. This apparent discrepancy is due to our new definition of the PPA including its proximal part with motor components to peroneus brevis.

Motor innervation to peroneus longus by the PPA in addition to a supply arising directly from the PS has been reported by Winckler (1934) who described more numerous branches to the muscle from the PPA than we found in the present study. It is interesting to note that except for motor branches to peroneus longus and the PPA, the PS sends off no motor components. There is a possibility that these motor components and the other sensory components are separated from each other in a more proximal portion of the PS. This possibility may be supported by the case observed by Winckler (1934) in which all the muscular branches to peroneus longus arose from the PPA. Further investigations are necessary to document this possibility.

The motor innervation of extensor digitorum brevis by the PPA in addition to that by the PP has been reported from anatomical studies (Bryce, 1897, 1901; Winckler, 1934) as well as by many electrophysiological studies (Lambert, 1969; Infante & Kennedy, 1970; Crutchfield & Gutmann 1973; Singh et al. 1973; Neundörfer & Seiberth, 1975; Mapelli et al. 1978; Azouvi et al. 1986; Stamboulis, 1987). It is of considerable interest that this muscle and peroneus digiti quinti, which is innervated by the PPA, are found in close apposition. Yoshida (1987) suggested 2 possibilities for the developmental origin of this condition: (1) peroneus digiti quinti splits off to fuse with extensor digitorum brevis, or (2) extensor digitorum brevis splits to form peroneus digiti quinti. Any conclusions as to the relation between these 2 muscles should be drawn on the basis of analysis on the intramuscular innervation of extensor digitorum brevis.

Sensory component of the accessory deep peroneal nerve. The present study revealed that the PPA participates in the sensory innervation of the human ankle joint (Fig. 4). In the previous studies, only the PP and the tibial nerve were known to innervate this joint (Casagrande et al. 1951; Champetier, 1970). In the cat, sensory innervation to the ankle region by the PPA is strongly suggested by illustrations in Ruge (1878), Frets (1908) and Winckler (1934), although Freeman & Wyke (1967) reported no sensory branch from the PPA to this region. A sensory network may be presumed around the ankle joint, because some branches arising from various nerves, including the PPA, were reported to communicate each other (Champetier, 1969, 1970). Unfortunately, this presumption was not confirmed by the findings of the present study.

Clinical importance of the accessory deep peroneal nerve

It is suspected that injury to the PPA can cause pain in the lateral portion of the ankle, since it provides a constant sensory nerve supply to the joint. Indeed there are previous clinical reports of neuropathic pain that seemed to be caused by injury to the PPA (Dessi et al. 1992; Sander et al. 1998). White et al. (1974) reported that chronic pain in the ankle region was cured by the excision of peroneus quartus (the ‘peroneus accessorius’ in White et al. 1974), a case which is well explained on the basis of the present findings on the course of the PPA. In this case the PPA was thought to be compressed between peroneus quartus and peroneus brevis. In the diagnosis of pain in the ankle region, the PPA should be considered as a possible site of origin.

The anatomical details of the PPA are crucial when performing surgery in the ankle region, such as reconstruction of the superior peroneal retinaculum using peroneus quartus (Mick & Lynch, 1987) or the peroneus brevis tendon (Stein, 1987; Colville & Grondel, 1995), to avoid damaging this nerve which is located near the surgical field. The lateral approach
for surgical procedures on the distal portion of the fibula or the ankle joint has every possibility of damaging this nerve owing to the position of the incision posterior to the lateral malleolus. Although Huene & Bunnell (1995) demonstrated the distribution of the cutaneous nerves to this region in detail for this surgical technique, they did not refer to deep sensory branches from the PPA. It is recommended that not only the cutaneous nerves but also the PPA to be taken into account in these procedures.

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REFERENCES


