J. Anat. (1990), **170**, pp. 193–198
With 1 figure
Printed in Great Britain

Nerve supply of the human vastus medialis muscle*

RAJANI THIRANAGAMA†
Department of Anatomy, Faculty of Medicine, University of Jaffna, Kokuvil, Jaffna, Sri Lanka

(*Accepted* 4 *January* 1990)

INTRODUCTION

The quadriceps femoris muscle group of the thigh forms the extensor apparatus of the knee. Structurally, the quadriceps is composed of four separate muscles: rectus femoris, vastus medialis, vastus lateralis and vastus intermedius. All four components function as extensors of the knee, with the rectus femoris having the additional function of flexion of the hip. The four heads of the quadriceps are reported to be innervated by the femoral nerve.

Apart from the flexor function of the rectus, a further specialisation has been ascribed to the lower fibres of the human vastus medialis. These fibres were believed to be responsible for the last 15° of extension of the knee, during which the femur rotates medially to attain the locked position. This hypothesis was the basis for designing therapeutic exercises to strengthen the vastus medialis after derangements of the knee (Smillie, 1949). However, electromyographic studies by Lieb & Perry (1971) and Basmajian, Harden & Regenos (1972) showed that all the components of the quadriceps act in concert and that none of the components is predominantly responsible for fully extending the knee. Speakman & Weisberg (1977), who made a thorough examination of the selective action hypothesis of the vastus medialis, concluded that there was little evidence to support the hypothesis.

A more plausible function for the distal fibres of the vastus medialis is that they participate in patellar alignment (Lieb & Perry, 1968; Basmajian *et al.* 1972; Bose, Kanagasuntheram & Osman, 1980). Lieb & Perry (1971) showed that the lower part of vastus medialis recorded an action potential count which was consistently twice that of the other quadriceps muscle components. Though electromyographic (EMG) readings portray the electrical manifestations of neuromuscular activity, no study has been made of the neuromuscular connections of vastus medialis. Scharf, Weinstabl & Orthner (1985), in their dissections of the human vastus medialis, used the presence of a neural hilum and a separation plane along a branch of the femoral nerve as a basis to divide the muscle into two anatomical heads, vastus medialis longus and vastus medialis oblique. Cursory observations have also been made reporting a double nerve supply to vastus medialis, both nerves emanating from the femoral nerve (Lieb & Perry 1968; Basmajian, 1980).

The intramuscular branches of a nerve pass to discrete, localised populations of motor units (Gans, 1982), and thus a study of the gross anatomical branching pattern

* Reprint requests to Professor B. A. Wood, Department of Human Anatomy and Cell Biology, The University of Liverpool, P.O. Box 147, Liverpool L69 3BX, UK.

† Since the completion of this work Dr Thiranagama was tragically killed outside her Department in September 1989.

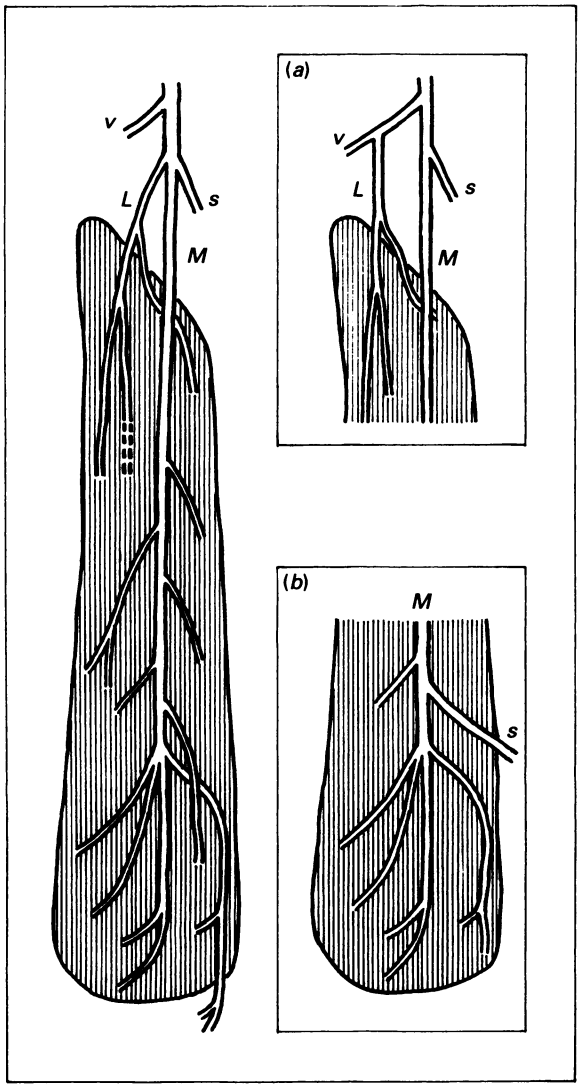

Fig. 1. Schematic view of the nerve supply to the human vastus medialis (right side, anterior aspect). *L*, lateral branch; *M*, medial branch; *s*, saphenous nerve; *v*, nerve to vastus intermedius. Interrupted line shows the terminal nerve that passes through the muscle to supply vastus intermedius. Inset (*a*) variant in which the lateral branch arises from the nerve to vastus intermedius. Inset (*b*) variant in which the main trunk continues as the saphenous nerve.

and muscular connections of the nerve supplying vastus medialis was undertaken with the aim of increasing our understanding of the function of this muscle.

MATERIALS AND METHODS

Thirty lower limbs were taken from fifteen human cadavers (2 female and 13 male, with ages ranging from 8 years to 60 years). All limbs were perfused with 10% formalin before dissection. The femoral nerve was exposed, the branches supplying the vastus medialis were dissected and terminal branches were traced into the muscle with the aid of a hand lens. Another three thighs from two different individuals were used for observations of the spinal segmental constitution of the branches supplying

Table 1. *Number of specimens exhibiting different numbers of terminal nerves from the lateral branch 'L' and the middle and lower parts of the medial branch 'M'*

No. of terminal nerves	Branch 'L' (no. of specimens)	Branch 'M' – middle (no. of specimens)	Branch 'M' – lower (no. of specimens)
None	0	0	0
One	1	2	0
Two	5	6	1
Three	14	9	7
Four	8	8	15
Five	2	4	5
Six	0	0	1
Seven	0	0	0
Eight	0	0	0
Nine	0	0	1

the vastus medialis by dissecting the nerve bundles up through the lumbar plexus. In two of these thighs the nerve supplying vastus intermedius was also traced using a dissecting microscope.

RESULTS

In all specimens the vastus medialis was innervated by two nerves arising from the posterior division of the femoral nerve. One nerve was slender and short, and is designated the lateral branch in this study (Fig. 1, *L*). The other, a long, thick branch, lay between the saphenous nerve and the lateral branch and is termed the medial branch (Fig. 1, *M*). The latter is similar to the classical nerve to vastus medialis, which is described in textbooks as running in the adductor canal, along with the saphenous nerve and the vascular bundle.

The slender lateral branch had a short course and passed posterior to the lateral circumflex femoral vessels. The nerve usually divided into three terminal branches which pierced the upper lateral part of the muscle (Fig. 1; variations in the number of terminal branches are given in Table 1). In most specimens one of these terminal branches passed through the deep aspect of the upper part of the vastus medialis, ran distally along the femoral shaft to supply the vastus intermedius and terminated in the superomedial part of the capsule of the knee joint. In three instances (10% of the limbs) one of the terminal branches gave twigs to the middle third of the vastus medialis as well. Finally, in six cases (17% of the limbs) the lateral branch arose from the nerve supplying the vastus intermedius (Fig. 1, inset *a*).

The thick, long, medial branch ran distally along the anteromedial border of the muscle. In the upper part of its course it usually had no branches but in two instances a twig was given to the upper one third of the muscle. In the middle part of its course the nerve usually gave off three or four slender branches from either side of the main trunk (Fig. 1; Table 1) supplying the middle third of the vastus medialis. In one instance (3% of limbs) there was a separate main branch that arose from the trunk and supplied the middle one third of the muscle.

The major part of the medial branch continued distally as a discrete bundle and divided into a spray of terminal branches which supplied the lower one third of the muscle. In three instances (10% of limbs), the nerve supply to the lower part of the muscle arose separately from the main trunk, which then continued distally as the saphenous nerve (Fig. 1, inset *b*). In all specimens the terminal branches of the nerve extended almost to the distal end of the muscle. Details of the variation in the terminal

branches are given in Table 1. The branches supplying the distal third of the muscle were more numerous than those supplying the middle third of the muscle. One of the distal set of terminal branches usually innervated the medial part of the capsule of the knee joint.

The gross morphology of the muscle mirrored the tripartite arrangement (upper, middle and lower) noted from the study of its innervation. The upper one third of the muscle, which obtained its supply from the lateral branch, was composed of parallel muscle fibres disposed almost vertically (i.e. within 10° of the longitudinal axis of the femoral shaft). These fibres arose from the intertrochanteric and spiral lines and converged onto the upper margin of an aponeurosis found on the deep aspect of the muscle. The middle one third of the muscle was also composed of parallel muscle fibres but these were disposed more obliquely, running approximately 15°–35° to the longitudinal axis of the femoral shaft. These fibres arose from the medial lip of the linea aspera and the medial intermuscular septum and were inserted into the medial margin and anterior surface of the aforementioned aponeurosis. The aponeurosis merged with the aponeurosis of the vastus intermedius and became part of the quadriceps tendon. The lower one third of the muscle was broader and was composed of parallel fibres, most of which were aligned even more obliquely at 40°–55° to the longitudinal axis of the femur with the lowermost fibres being almost horizontal. These fibres arose mainly from the tendon of the adductor magnus muscle and partly from the medial intermuscular septum. They were inserted as fleshy fibres into the medial patellar retinaculum and the upper half of the medial side of the patella, while some of the superficial fibres gained insertion into the tendon of the rectus femoris.

In all the three specimens dissected to observe the segmental innervation, the lateral branch mainly received nerve fibres from lumbar segments three and four. The medial branch mainly received fibres from lumbar segments two and three, with a few coming from the first lumbar segment. The connections of the nerve supplying the vastus intermedius were investigated in two specimens and, in both, it derived its segmental input mainly from lumbar segments three and four.

DISCUSSION

An unusual feature of the human vastus medialis is that nerves enter it from the proximal part of the muscle to its distal end. The upper one third of the muscle, with its almost vertically orientated muscle fibres, is usually supplied by a separate branch which is formed from the lower segments contributing to the femoral nerve. The innervation of the upper part is closely associated with that of the vastus intermedius, both in its peripheral distribution and its spinal segmental input. The middle and the lower thirds of the muscle usually receive branches from a common nerve fed from the upper lumbar spinal segments. In addition, in all cases, a larger number of terminal branches supply the lower third of the muscle (which corresponds morphologically to the vastus medialis oblique described by Lieb & Perry (1971), Bose *et al.* (1980) and Scharf *et al.* (1985)) compared to the middle and upper parts.

Though classically the nerve supply to the vastus medialis is thought to arise solely from the nerve to vastus medialis running in the adductor canal (cf. Williams & Warwick, 1980), Basmajian (1980) described a dual nerve supply, similar to the findings of this study; Lieb & Perry (1968) also described two nerves in one of their specimens. The observation in the present study, that the distal part was innervated by more numerous terminal nerve branches, may partly explain the electromyographic findings of Lieb & Perry (1971). The latter authors recorded double the number of

action potential counts in the vastus medialis oblique compared to the counts in the rest of the vastus medialis; the higher counts may reflect the richer innervation.

Functionally, though recent studies of the quadriceps have removed the importance attached to the vastus medialis as the prime mover causing the medial rotation of the femur in the terminal phase of extension, the lower fibres of the muscle are believed to have a special role in preventing the lateral displacement of the patella, especially at the end of extension (Basmajian *et al.* 1972; Bose *et al.* 1980). The structural subdivisions proposed in this study are further underlined by the distinct morphology of the lower part of the vastus medialis in man, when compared with the same structure in closely-related primates. In the chimpanzee (Sonntag, 1923; Swindler & Wood, 1973), the gorilla (Raven, 1950) and in monkeys (Swindler & Wood, 1973; Bose *et al.* 1980) the lower part of vastus medialis lacks the distal extension on the medial side of the patella. It is probable that the valgus angle of the human femur, that directs the pull of the quadriceps femoris in a lateral direction, results in a requirement for some structural specialisation in the human vastus medialis in order to stabilise the patella.

The muscles of the quadriceps group act synergistically but there are still morphological and physiological differences between the individual heads. In the brown lemur, EMG and histochemical studies have shown variations in the populations of muscle fibre types within the four heads of the quadriceps (Anapol & Jungers, 1987). Fibre type studies of the human vastus medialis have not been undertaken, but studies on the vastus intermedius and vastus lateralis have demonstrated differing populations of fibre types, with vastus lateralis containing a higher proportion of fast twitch fibres while vastus intermedius has a higher proportion of slow twitch fibres (Edgerton, Smith & Simpson, 1975). It is predicted that such differentiations may be demonstrable within the human vastus medialis, particularly between the three different portions of the muscle which have been defined in this study.

SUMMARY

Dissection of 30 human vastus medialis muscles and their nerves has revealed a consistent bipartite nerve supply from the posterior division of the femoral nerve. One part, a short and slender nerve termed the lateral branch, supplies the upper lateral portion of the muscle. The other part, a medial branch, supplies the middle and lower portion of the muscle. There is a distalward increase in the numbers of nerve fibres supplying the muscle, with the lowermost muscle fibres receiving the richest nerve supply.

The detailed connections of the two nerves of the vastus medialis were traced to the lumbar plexus in three cadavers. The lateral branch receives fibres from the lower roots which contribute to the femoral nerve (L3 and 4), while the medial branch, which supplies the middle and lower parts of the muscle, receives its fibres from higher segments of the lumbar spinal column (L1, 2 and 3). The lateral branch, which in some cases arises from the nerve that supplies the vastus intermedius, receives a similar spinal input to that of the vastus intermedius. Therefore, whereas the upper portion of the human vastus medialis muscle is closely aligned with the vastus intermedius, the lower third of the muscle has a richer innervation and also shows a distinct gross morphology that, among primates, may be unique to humans.

The gross structure of the muscle, taken together with this evidence from the pattern of innervation, suggests that the human vastus medialis is functionally tripartite.

The author is grateful to G. Vignarajan, who assisted with the dissections, and to R. Kanagasuntheram, Andrew Chamberlain and Bernard Wood for reading earlier drafts of the manuscript.

REFERENCES

ANAPOL, F. C. & JUNGERS, W. L. (1987). Telemetered electromyography of the fast and slow extensors of the leg of the brown lemur (*Lemur fulvus*). *Journal of Experimental Biology* **130**, 341–358.

BASMAJIAN J. V., HARDEN T. P. & REGENOS E. M. (1972). Integrated actions of the four heads of the quadriceps femoris: an electromyographic study. *Anatomical Record* **172**, 15–20.

BASMAJIAN, J. V. (1980). *Grant's Method of Anatomy*, 10th ed. Baltimore: Williams & Wilkins.

BOSE, K., KANAGASUNTHERAM, R. & OSMAN, M. B. H. (1980). Vastus medialis oblique: an anatomical and physiologic study. *Orthopedics* **3**, 880–883.

EDGERTON, R. V., SMITH, J. L. & SIMPSON, D. R. (1975). Muscle fibre type populations of human leg muscles. *Histochemical Journal* **7**, 259–266.

GANS, C. (1982). Fiber architecture and muscle function. *Exercise and Sports Science Reviews* **10**, 160–207.

LIEB, F. J. & PERRY, J. (1968). Quadriceps function; an anatomic and mechanical study using amputated limbs. *Journal of Bone and Joint Surgery* **50A**, 1535–1548.

LIEB, F. J. & PERRY, J. (1971). Quadriceps function: an electromyographic study under isometric conditions. *Journal of Bone and Joint Surgery* **53A**, 749–758.

RAVEN, H. C. (1950). *The Anatomy of the Gorilla*. New York: Columbia University Press.

SCHARF, W., WEINSTABL, R. & ORTHNER, E. (1985). Anatomische Unterscheidung und klinische Bedeutung zweier verschiedener Anteile des Musculus vastus medialis. *Acta anatomica* **123**, 108–111.

SMILLIE, I. S. (1949). The quadriceps in relation to recovery from injuries of the knee-joint. *Physiotherapy* **35**, 53–57.

SONNTAG, C. F. (1923). On the anatomy, physiology and pathology of the chimpanzee. *Proceedings of the Zoological Society of London* **23**, 323–429.

SPEAKMAN, H. G. B. & WEISBERG, J. (1977). The vastus medialis controversy. *Physiotherapy* **63**, 249–254.

SWINDLER, D. R. & WOOD, C. D. (1973). *An Atlas of Primate Gross Anatomy*. Seattle: University of Washington Press.

WILLIAMS, P. L. & WARWICK, R. (1980). *Gray's Anatomy*, 36th ed. Edinburgh: Churchill Livingstone.