

Morphological variations of the human vastus lateralis muscle

P. L. T. WILLAN, M. MAHON AND JENNIFER A. GOLLAND

*Human Anatomy, Department of Cell and Structural Biology, Medical School,
University of Manchester, M13 9PT, UK*

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INTRODUCTION

The quadriceps femoris complex has recently been the subject of renewed interest with regard to histological composition and the anterolateral part of the muscle is frequently chosen for electromyography and skeletal muscle biopsy (Saltin *et al.* 1977; Swash & Schwartz, 1981; Dubowitz, 1985). Most biopsy samples are assumed to be from vastus lateralis although the samples may show considerable variation in muscle fibre size and fibre type proportions between individuals and even between samples from the same individual (Mahon, Toman, Willan & Bagnall, 1984). It is interesting to note that Edgerton, Smith & Simpson (1975) showed quantitative histological differences between samples from vastus lateralis and the underlying vastus intermedius. Such findings stimulated our interest in the gross morphology of the quadriceps, particularly the vastus lateralis, and preliminary studies showed frequent variation in form (Golland, Mahon & Willan, 1986).

Current anatomical textbooks make little of possible variations in quadriceps topography, although older texts contain more detailed accounts of the muscle with occasional references to *abnormalities*. This study set out to investigate the variability of vastus lateralis, particularly in relation to fusion with the underlying vastus intermedius and with regard to variability of the fleshy and fibrous parts of the muscle.

MATERIALS AND METHODS

Material was obtained from 40 cadavers, 19 female and 21 male, of Caucasian origin, aged 57 to 86 years. The thighs were examined after removal of skin, superficial fascia and fascia lata. In addition, transverse sections of frozen thighs were cut at several levels and examined when thawed. Three specific assessments were undertaken: the thighs were examined to confirm the presence of the four parts of the quadriceps and additional fleshy lamellae or muscle bellies were sought; the nature of the anteromedial edge of vastus lateralis was recorded; and the amount of fusion between the deep surface of vastus lateralis and the underlying vastus intermedius was estimated. Data from 75 limbs, including 35 right and left pairs, was assessed. Comparisons were made using Chi squared tests and differences were considered to be significant at $P < 0.05$.

RESULTS

All the quadriceps muscles possessed three vasti and a rectus femoris component which was unfused and easily removed. Data on the frequency of occurrence of anatomical variations is given in Table 1.

Table 1. *Frequencies of occurrence of gross anatomical variations in quadriceps femoris. (VL, vastus lateralis; VI, vastus intermedius.)*

Number of limbs	Right 38	Left 37	Male 41	Female 34	Total 75
Fusion of VL to VI					
More than $\frac{3}{4}$	15	10	16	9	25
About $\frac{1}{2}$	14	18	17	15	32
Less than $\frac{1}{4}$	9	9	8	10	18
Anterior edge of VL					
Fleshy	13	9	15	7	22
Tendinous more than 5 mm	13	15	16	12	28
Tendinous less than 5 mm	12	12	10	14	24
Separate deep tendinous lamina	10	12	13	9	22
Separate deep fleshy lamella					
Fused to tendinous lamina	7	6	8	5	13
Fused to VL	2	4	2	4	6
Fused to VI	5	3	3	5	8



Fig. 1(a, b). Anterior aspects of two thighs dissected to reveal quadriceps. Rectus femoris has been excised. (a) Vastus lateralis includes a fleshy lamella (F) which attaches inferiorly to a tendinous lamina (T). (b) The anteromedial edge (E) of vastus lateralis comprises a tendinous lamina wider than 5 mm.

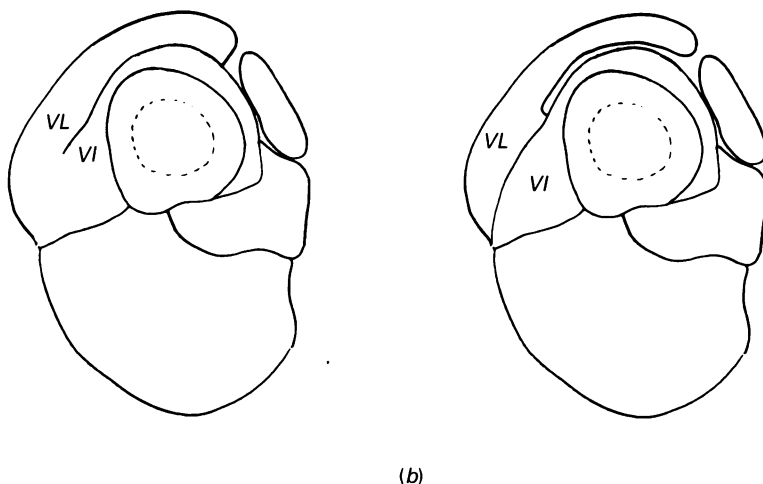


Fig. 2(a, b). Drawings of transverse sections of thighs to illustrate interface between vastus lateralis (VL) and vastus intermedius (VI). (a) VL and VI are distinct, except posterolaterally where there is no fascial boundary, but are not separate. (b) VL and VI are completely distinct, but are only partly separate. Posterolaterally, fibres from both muscles attach to the fascial boundary.

An additional fleshy lamella between vastus lateralis and vastus intermedius (Fig. 1a) was identified in 27 (36%) thighs, bilateral in 10 subjects, unilateral in 7. Proximally the fleshy lamella was attached to the anterior aspect of the femoral shaft. Distally the muscle belly was usually replaced by a tendinous lamina (Fig. 1a) which contributed to the quadriceps tendon, but occasionally it fused directly with vastus intermedius or vastus lateralis. Discrete tendinous laminae from vastus lateralis or intermedius were identified in 22 (29%) limbs, bilateral in 7 subjects, unilateral in 8. Usually the lamina received the extra muscle belly, but sometimes it was unrelated to an additional fleshy lamella.

Variations in fusion between vastus lateralis and intermedius were apparent in dissected specimens, but were more easily assessed on transverse sections. The patterns of fusion were seen to vary widely and in places fascial boundaries between components were indistinct or absent (Fig. 2).

Assessments of the distal halves of transversely sectioned thighs revealed that there was fusion of more than three quarters of the deep surface of vastus lateralis with vastus intermedius in 25 (33%) limbs, whereas less than one quarter was fused in 18 (24%) limbs. Different degrees of fusion between paired vasti from right and left sides were identified in 18 (51%) cadavers.

The anteromedial edge of the distal half of vastus lateralis was predominantly fleshy in 22 (29%) limbs, whereas in 28 (37%) there was an anterior tendinous lamina wider than 5 mm (Fig. 1b).

There was no apparent association between the occurrence of an additional muscle belly, tendinous lamina or fleshy lamella, and the degree of fusion of vastus lateralis with vastus intermedius. Nor were there significant differences in the occurrences of the findings between right and left limbs or between limbs from male and female subjects.

DISCUSSION

Although variations within the quadriceps femoris have been described (Bryce, 1923; Bergman, Thompson & Afifi, 1984), they appear to be minimal and infrequent.

Williams (1878), Le Double (1897) and Bryce (1923) reported variable fusion between the vastus lateralis and the adjacent musculature. In addition, Dwight (1887) noted bilaminar vastus lateralis muscles and recently Holyoke (1987) reported an additional muscle belly. The frequent occurrence of two neurovascular hila for vastus lateralis (see Brash, 1955) may also suggest an underlying bilaminar nature.

The present study shows more variation in the gross anatomy of vastus lateralis than is usually acknowledged and indeed shows some variations to be common. For example, about one third of subjects possessed an additional head associated with vastus lateralis; thus, the extensor group in these individuals might be more accurately described as *quinticeps femoris*. In about one third of thighs there was a separate deep tendinous lamina associated with vastus lateralis. Even more variable was the amount of fusion distally between vastus lateralis and vastus intermedius, ranging from almost complete separation to complete fusion. Le Double (1897) described the vastus externus (lateralis), in man, as separated from the crureus (intermedius) proximally but joined to it distally. He noted that separation of the quadriceps into different heads appears in the reptilia but that in some mammals, including primates, the vasti may be continuous with the crureus forming a common fleshy mass, whereas in other mammals and certain birds the crureus is independent. Bryce (1923) noted that the parts of the human quadriceps differentiated from a rudiment which was at first single.

Our findings of morphological variation could explain in part some of the intersubject variability found in electromyographic recordings from this muscle (Basmajian, 1979) and the difficulty in providing a clear understanding of the relative biomechanical roles of the three vasti (Lieb & Perry, 1968). Accurate knowledge of the possible anatomical arrangements of muscle components is also necessary in the interpretation of data from neuroradiological studies using modern imaging techniques (Sambrook, Rickards & Cumming, 1988). Furthermore, biopsies from quadriceps are usually assumed to be of vastus lateralis, but clearly in some subjects might be derived from an adjacent fleshy lamina or from a fused muscle mass not specifically vastus lateralis. Most authors ignore the possibility that morphological variation of the gross muscle architecture could contribute to the wide variations in histomorphometric data derived from biopsy samples. The present study therefore indicates the need for further elucidation of the histological and histochemical features of fused vastus muscles and of fleshy lamellae at the commonly used biopsy site in the anterolateral thigh.

SUMMARY

Variations in the gross morphology of quadriceps femoris were assessed in 40 cadavers. An additional (fifth) head was present in about one third of the limbs. Distally, fusion between vastus lateralis and vastus intermedius varied from almost complete fusion to less than one third of the interface between the muscles. Discrete tendinous laminae arising from vastus lateralis were present in 29% of the limbs. In half the cadavers there were differences in quadriceps topography on right and left sides but there were no significant differences between muscles from male and female subjects. These findings may have important implications in clinical and microscopic studies of the quadriceps muscle.

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