Anatomical variations in vastus medialis obliquus and its implications in minimally-invasive total knee replacement

AN MRI STUDY

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The emergence of minimally-invasive total knee replacement (TKR) has led to the refinement of several surgical approaches, including the quadriceps-sparing and subvastus. There is some disagreement as to the precise definition of the term 'minimally-invasive', especially in regard to the preservation of vastus medialis obliquus (VMO). It is known that the termination of VMO is variable and may make these approaches difficult. We have attempted to assess the factors influencing the insertion of VMO and the impact which they have on the approach for TKR.

The MR scans of 198 knees were examined to assess the variation in the insertion of VMO in relation to the patella and the effect of variables such as age, gender and the presence of concurrent osteoarthritis of the knee on the insertion.

Our findings showed that both age and the presence of osteoarthritis were contributing factors to changes in the level of insertion of VMO. Therefore, not all capsular incisions which extend proximal to the midpole of the patella will violate the quadriceps tendon.

There are many options when considering the surgical approach for total knee replacement (TKR). In 2005, of the 59 037 TKRs recorded on the National Joint Registry of England and Wales,¹ 54 489 had a medial parapatellar approach, 1072 a lateral parapatellar approach, 1100 a subvastus approach and the remainder other approaches such as the midvastus, intra-vastus and trivector.

In recent years, minimally-invasive TKR has been used increasingly. Several approaches have been refined to allow this development, including the subvastus and quadriceps-sparing approaches. Both aim to position the arthrotomy incision in such a way that the patella can be retracted without violation of the quadriceps tendon or of vastus medialis.

In the subvastus approach, the arthrotomy is an inverted 'L'-shaped incision, which extends along the inferior border of vastus medialis obliquus (VMO) and requires the muscle to be released from the periosteum to the level of the adductor tubercle.² However, in some cases, this technique requires the division of the muscle fascia to allow adequate exposure and sufficient lateral mobility of the patella.³

In the quadriceps-sparing approach, the arthrotomy is described as beginning at the superomedial border of the patella where VMO inserts and ending 2 cm below the tibial

joint line.^{4,5} Recently, it has been suggested that such an approach could not be considered quadriceps-sparing since it was found that any capsular incision which extended proximal to the midpole of the patella violated a portion of the quadriceps tendon.⁶

The insertion of VMO is variable. Tria⁷ stated that in most patients it is at, or proximal to, the superior pole of the patella, but others have found that the muscle belly may extend distal to the midpoint of the patella.^{6,8} This has led to a debate as to whether the quadriceps-sparing approach, and to some extent the subvastus approach, can truly be VMO-sparing and be considered to be minimally-invasive. It is important to understand the anatomy of the knee, especially when there are obvious benefits to preserving the VMO.⁹ Compared with a standard TKR, a minimally-invasive procedure has been reported to have reduced blood loss, an improved pain score, a reduced hospital stay and an increased post-operative range of movement.⁹ Others, however, have reported no differences.¹⁰

Our aim was to clarify the anatomy of the medial side of the knee, particularly the insertion of VMO on the patella. We also determined the effect of age, gender, and the presence of concurrent osteoarthritis (OA) of the knee on the insertion.

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©2007 British Editorial Society
of Bone and Joint Surgery
doi:10.1302/0301-620X.89B11.
18636 \$2.00

J Bone Joint Surg [Br]
2007;89-B:1462-5.

Received 13 September 2006;
Accepted after revision 10 July
2007

Fig. 1

MR scan showing the reference slice at the apex of the patella.

Fig. 3

Axial MR scan showing the presence of vastus medialis obliquus.

Fig. 2

MR scan showing the inferior border of patella.

Patients and Methods

The axial MR scans of 262 knees taken over a period of 12 months between January 2005 and December 2005 were

examined.⁹ Of these, 38 were excluded in patients under the age of 16 years, those whose scans showed neoplastic pathology or were incomplete. In 26 patients, bilateral scans were available and only one was randomly selected for inclusion. The reasons for imaging the knee were not investigated. A total of 198 scans were analysed by two observers (VIR, PKRM). The radiographs of these patients were also assessed for the diagnosis of OA in the knee according to the Pridie classification.¹¹

There were 106 females and 92 males with a mean age of 43 years (16 to 86). Of these, 134 were aged less than 50 years and 64 were older.

The MR scans were performed on a 1.5 Tesla machine (Philips Medical System, Noord, Netherlands) with all patients positioned supine. Axial three-dimensional (3D) water excitation sequences performed with a slice thickness of 4 mm were examined.

In order to calculate the patellar height, the apex of the patella was considered as the 'reference slice 1' (Fig. 1). The consecutive slices were followed distally to the last slice in which the patella was visible (Fig. 2). The muscle length of VMO was considered to be the length of the muscle from the apex of the patella and was measured by following it from reference slice 1 to the slice in which it was last visible (Figs 3 and 4). The patellar height and muscle length were calculated as the product of the number of MR slices and the thickness of the slice.

The ratio of the muscle length to patellar height (VMO:patella) was also calculated since this equates to the level of insertion of VMO on to the patella. The level of

Fig. 4

Axial MR scan showing the absence of vastus medialis obliquus (arrow highlighting where the muscle was visible in the previous slice).

insertion was divided into two groups. Group 1 included those scans in which VMO terminated proximal to the mid-point of the patella (VMO:patella < 50%) and group 2 those in which VMO terminated at, or distal to, the mid-point of the patella (VMO:patella ≥ 50%).

In order to assess the intraobserver variation, each observer randomly selected 20 scans and blinded reassessment was done after eight weeks. In order to assess the interobserver variation, the 20 scans measured by the first observer (VIR) were randomly selected for blinded assessment by the second observer (PKRM).

Statistical analysis. This was done using SPSS version 14 (SPSS Inc., Chicago, Illinois). Non-parametric tests were used to calculate the significance. Statistical significance was set at a p -value ≤ 0.05.

Results

With reference to the VMO:patella ratio, there were 119 patients (60.1%) in group 1, and 79 (39.9%) in group 2. The effect of the different variables on muscle length, patellar height and the level of insertion was determined.

Effect of gender. The mean height of the patella in women was 33.5 mm (24 to 44) and in men it was 37.8 mm (28 to 48). The mean VMO muscle length was 14.4 mm in women (4 to 28) and 16.8 mm in men (8 to 32).

There was a statistically significant difference in the relationships between both the height of the patella and VMO length and gender (Mann-Whitney U test, $p < 0.0001$ and

$p < 0.0005$ respectively). The results showed that men had larger patellae and greater muscle length than women.

The mean VMO:patella ratio in women was 42.8% (13% to 71%), and in men it was 44.8% (18% to 80%). There was no statistically significant difference in the VMO:patella ratio between the genders (Mann-Whitney U test, $p = 0.2$).

Effect of age. Age had no impact on the height of the patella, with the mean patellar height being 35.3 mm (24 to 48) in patients younger than 50 years and 35.2 mm (24 to 44) in those older than 50 years. It had a statistically significant effect on muscle length. The mean length was 16.4 mm (4 to 32) in patients under 50 years, and 13.7 mm (8 to 28) in those aged 50 years or more (Mann-Whitney U test, $p < 0.0005$).

Of the patients aged under 50 years, 68 (50.7%) had a VMO which terminated in the proximal half of the patella. In the patients aged 50 years or older, 51 (79.7%) showed this, which represented a statistically significant inverse relationship between the age of the patient and the VMO:patella ratio (Mann-Whitney U test, $p < 0.0001$).

However, there was no statistically significant relationship between the level of insertion of VMO and the gender of the patient in either age group (Mann-Whitney U test, $p = 0.339$).

Effect of osteoarthritis. Osteoarthritis was detected in the radiographs of 82 patients (41.4%). A statistically significant relationship was noted between the presence of OA and the VMO length (Kruskal-Wallis test, $p = 0.001$). Patients with OA had a mean length of 14.2 mm (8 to 24) and those without a mean length of 16.5 mm (4 to 32) (Kruskal-Wallis test, $p = 0.001$). There was also a statistically significant relationship between OA and the VMO:patella ratio since patients with OA were found to have a more proximal insertion (Mann-Whitney U test, $p < 0.0005$). In those with OA, the mean VMO:patella ratio was 39.9% (18% to 60%), and in those without it was 46.7% (13% to 80%).

As expected, there was a statistically significant relationship between the age of the patient and OA (Kruskal-Wallis test, $p = 0.001$). However, there was no statistically significant difference between the gender of the patient and OA (Kruskal-Wallis test, $p = 0.54$).

Intra- and interobserver variation. There was no statistically significant difference in intra- and interobserver measurements (two-sample t -test, $p = 0.614$, $p = 0.530$, $p = 0.163$ and $p = 0.379$, respectively).

Discussion

The quadriceps-sparing and subvastus approaches are relatively new techniques which have aided the development of minimally-invasive TKR. With their emergence has come a new nomenclature, which has led to confusion and disagreement.

Our study was undertaken to clarify the anatomy of VMO, and to assess factors influencing its termination and their impact on the approach for TKR. Our results showed

that the point of insertion of VMO was variable and changed significantly with advancing age and the presence of OA of the knee.

There was no statistical difference in the level of insertion of VMO according to gender. However, there was a significant difference between the height of the patella and gender and between the length of the VMO muscle and gender. This may be related to the generally larger skeleton and muscle conformation of men compared with women.

Our results showed over 50% of patients aged under 50 years had a VMO which terminated at, or more distal, to the midpoint of the patella, whereas only 20% of patients aged 50 years or more had a similar termination. Therefore, only one-fifth of patients aged 50 years or more would be unlikely to be suitable for the quadriceps-sparing approach. Similar observations were reported by Bose, Kanagasuntheram and Osman¹² in a cadaveric study.

These age-related changes in the insertion of VMO have not been described previously. In our study, there was a statistically inverse relationship between the level of termination of VMO and the age of the patient so that with increasing age, the termination of VMO became more proximal, probably because of muscle atrophy.

We observed a significant relationship between the length of VMO and the presence of OA and therefore between patients who had OA and the level of insertion of the muscle. This could be explained by the muscular wasting encountered in OA.

Recent studies have shown that MRI is useful in studying the anatomy of the knee.^{6,13} Limitations of our study were that the patients included had MRI performed for various indications. In addition, it was a retrospective analysis and no details of the height and weight of the patients studied were available to define the reasons for the fact that men had a larger patella and a longer VMO than women.

The insertion of VMO is variable and the contributing factors for the anatomical changes in VMO are the age of the patient and the presence of OA. Therefore not all cap-

sular incisions which extend proximal to the midpoint of the patella will violate the quadriceps tendon, especially if the patient is aged over 50 years or has OA. However, the insertion of VMO can be distal to the midpoint of the patella in some patients, and could obscure the surgical view,⁴ or may even preclude the use of true minimally-invasive techniques.

We wish to thank Dr P. Evans (Consultant Radiologist) and Mrs D. Collins (Superintendent Radiographer) of Arrowe Park Hospital, Upton, Wirral, UK for their contribution to this study. The authors would like to state that V. I. Roberts and P. K. R. Merreddy made an equal contribution to this paper.

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.

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