Can the Apex of Tibial Tubercle Represent the Insertion of Patellar Tendon in Measurement of Quadriceps Angles? Imaging Verification

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Research article

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Abstract

Background Clinical measurement of a quadriceps angle (Q-angle) has yet achieved consensus. The patellar stability is generally low despite that the tibial tubercle (TT) is fixed. The aim of this retrospective study was to verify whether the lower arm of a Q-angle (i.e. the patellar tendon [PT]) can be represented by the localization of TT.

Methods The locations of the apex of TT and the center of PT in magnetic resonance imaging (MRI) were investigated in 100 consecutive young adult patients (50 men and 50 women; average, 27 years). The tibial width (TW), the distance from the apex of TT and the center of PT to the lateral edge of TW, and the PT width were measured. The ratios of the TT and PT to TW were compared statistically.

Results The TW was 64 mm (62-66 mm). The apex of TT was 38% (37-39%) from the lateral edge of TW. The center of PT was 37% (36-38%) from the lateral edge of TW. Except the TW and PT width (both, $p < 0.001$), there was no statistical significance in all other comparisons between sexes ($p > 0.05$). The correlation between the TT and PT in 100 patients was 0.84. There was statistical difference between the two parameters ($p = 0.02$).

Conclusion Although the center of PT is lateral to the apex of TT, the discrepancy is minimal (1% of TW, about 0.6 mm; or 3% of PT width). Clinically, using the TT to represent the insertion of PT may be reasonable.

Background

Although it is still controversial, a quadriceps angle (Q-angle) is believed one of important contributing factors in causing patellar malalignment (PM) by some supporters [1]. A Q-angle is traditionally measured with a clinical technique and is assigned first by Brattstroem in 1964: the intersecting angle of two lines (one is from the anterior superior iliac spine to the patellar center and the other is from the patellar center to the tibial tubercle [TT]) [2]. Because the TT is generally located lateral to the center of the tibial width (TW), a Q-angle is normally larger than the angle of an anatomic axis of the lower extremity (normal angle of an anatomic axis, 5^{o}-7^{o} valgus) [3.4].

Clinical measurement of a Q-angle is still controversial [5, 6]. Various measurements with persons in the supine or standing position and the knee in extension with the quadriceps muscles contracted or relaxed may greatly affect the results. Moreover, measurement of a Q-angle in PM may lower the value [7]. All studies involving a Q-angle may therefore become unbelievable. To avoid soft tissue interference, imaging studies may provide a potentially resolving route. However, until now a convincing imaging technique has few been reported.

In clinical measurement of a Q-angle, the apex of TT is generally considered to represent the insertion of patellar tendon (PT) [2, 5–7]. Therefore, a more laterally located TT may maximize a Q-angle. In the literature, the vertical distance from the TT to the trochlear groove (TT-TG distance) is considered an important factor for causing PM [8–10]. Normally, TT-TG distance is 1.0-1.4 cm and more than 2.0 cm distance is considered an absolute indication for osteotomy correction of the TT [11, 12]. Initially, the TT-TG distance is measured in computed tomogram (CT) [13]. Later, magnetic resonance imaging (MRI) becomes popular and is used for TT-TG distance measurement [14]. Unexpectedly, both examinations have some discrepancies and which is more accurate has not achieved a consensus. The aim of this retrospective study was to verify whether the lower arm of a Q-angle (i.e. the patellar tendon [PT]) can be represented by the localization of TT. Besides, using the TT for clinical application might be more convincing.

Methods

This study had been approved by Institutional Review Board of the authors' institution (IRB No. 201700752B0).

Establishing MRI data:

From February 2017 to April 2018, 100 consecutive adult patients (50 men and 50 women) who had undergone knee MRI examination were included in this study. These patients aged from 18 to 40 years (average, 27 years). They underwent the MRI for ligament or meniscus injury and no fractures or bony anomalies were noted.

All patients were placed on the MRI examining table in the supine position without anesthesia. MRIs were obtained by the knee routine protocol using a 1.5T GE Signa HDe MRI machine (Milwaukee, WI, USA) with a dedicated knee surface coil. The knee was fully extended with the quadriceps femoris relaxed. The interval of MRI slices was 4 mm.

MRIs of all 100 patients were stored in picture achieving and communication systems (PACS) software (GE Healthcare, Waukesha, WI, USA) at the authors' institution [15]. Data around the knee were selected for analysis.

Positioning of the TT and PT on MRI:

In the frontal view of the MRI, a line-A connecting medial and lateral tibial plateau surfaces was drawn (Fig. 1a). Consequently, the line-A was externally rotated of 3^{o} and kept horizontal in the frontal plane (Fig. 1b). A line-B was created along the medial femoral epicondyle with parallel to the line-A (Fig. 1c). The axial view at the line-B was demonstrated (Fig. 1d). A line-C was drawn with connecting the posterior cortices of both medial and lateral femoral condyles (Fig. 1d). The line-C was rotated until it became horizontal (Fig. 1d). Now, the reference MRI plane was completed (Fig. 1).

The MRI cursor was moved distally until the most distal inserting site of the PT on the TT was exposed. A line-D (points l-m) was made with traversing the TW, which was parallel to the line-C (Fig. 2). The point l was at the most lateral edge and the point m was vertical to the most medial edge of the tibia. Three lines were created (lines e, f, and g) and all were vertical to the line-D (Fig. 2). The line-e was along the medial edge of the PT. The line-f was at the apex of the TT. The line-g was along the lateral edge of the PT. The lengths of l-m, e-l, f-l, and g-l were measured. They were expressed by mm. The ratios of e-l / l-m, f-l / l-m, and g-l / l-m were measured. They were expressed by % of the l-m.

Various related parameters in 100 patients were investigated and compared. The difference between sexes was also compared.

Statistical analysis:

Data were analyzed using SPSS 20.0 version (IBM Corporation, Armonk, NY, USA) software. Statistical comparison used a two-sample unpaired Student’s t-test and $p < 0.05$ was considered statistically significant. A Person’s product-moment correlation coefficient was used to study the correlation between two samples. A simple linear regression was used to predict the relationship.

Results

The data in 100 consecutive patients (50 men and 50 women) could be collected for statistical comparison. All data were showed with an average (95% confidence interval) (Table 1).

The age of 100 patients was 27 (26–28) years. In 50 men, the age was 28 (26–30) years. In 50 women, the age was 26 (24–28) years ($p = 0.19$).

The TW in 100 patients was 64 (62–66) mm. In 50 men, the TW was 69 (67–71) mm. In 50 women, the TW was 59 (57–61) mm ($p < 0.001$).

The medial edge of the PT in 100 patients was 55% (54–56%) from the lateral end of the TW. In 50 men, the value was 55% (54–56%) and in 50 women, the value was 55% (54–56%, $p = 0.63$).

The apex of the TT in 100 patients was 38% (37–39%) from the lateral end of the TW. In 50 men, the value was 39% (38–40%) and in 50 women, the value was 38% (37–39%, $p = 0.09$).

The lateral edge of the PT in 100 patients was 19% (18–20%) from the lateral end of the TW. In 50 men, the value was 19% (18–20%) and in 50 women, the value was 19% (18–20%, $p = 0.96$).

The center of the PT in 100 patients was 37% (36–38%) from the lateral end of the TW. In 50 men, the value was 37% (36–38%) and in 50 women, the value was 37% (36–38%, $p = 0.92$).

The PT width in 100 patients was 23 (22–24) mm. In 50 men, the PT width was 25 (24–26) mm and in 50 women, the PT width was 21 (20–22) mm ($p < 0.001$).

The apex of TT was 1% of TW (or 2.8% of PT width, about 0.64 mm) medial to the center of the PT.

The correlation between the apex of the TT and the center of the PT in 100 patients was 0.84. However, there was statistical difference between the two (38% versus 37%, $p = 0.02$).

The apex of TT against the center of PT was plotted and a simple linear regression was measured (Fig. 3). The apex of TT_{total} = (0.843 X the center of PT_{total}) + 7.092. The apex of TT_{men} = (0.822 X the center of PT_{men}) + 8.48. The apex of TT_{women} = (0.871 X the center of PT_{women}) + 5.451.

The correlation for the TW and the PT width in 100 patients was 0.71.

Discussion

In the literature, the location of the TT related to the TW will migrate laterally following chronology [16, 17]. Anatomically, the PT inserts on the TT to aid extension of the knee. The anatomic alignment of the knee is 5^{o}-7^{o} valgus and the TT is more laterally located [3, 4]. If the patella is not laterally subluxed, a normal Q-angle is reported of 8^{o}-20^{o} in clinical measurement [18].

Bone is not an inert tissue and has turnover at all times [19, 20]. In principle, the components of bone increase following compressive stresses due to osteoblast accumulation [21]. On the other hands, the components of bone decrease under tensile stresses due to osteoclast accumulation [21]. The PT has 2.3 cm width and the non-linear traction by the quadriceps femoris will introduce inconsistent traction stresses on the TT. The final results may cause the TT deviating from the center of PT.

Clinical measurement of the lower arm of a Q-angle normally uses palpation on the apex of TT [2]. Ideally, the resultant force of PT action should be at the center of PT. Whether the apex of TT can be used to represent the traction fulcrum of the PT should be clarified. In the current study, with MRI evaluation the apex of TT and the center of PT are almost without discrepancy (0.64 mm of separation). Therefore, clinical use of the TT for quadriceps angle measurement may be believable,

Although the apex of TT and the center of PT are very close, in the literature which is medial or lateral is still debated. Using computed tomography (CT) in studying TT-TG distance, the values are generally larger as compare to MRI studies (12–19 mm versus 8–16 mm, Table 2) [13, 16, 22–27]. Using both CT and MRI studies of TT-TG distance in the same group of patients, the CT values are also larger [28–30]. However, in the current study with MRI measurement, the apex of TT is medial to the center of PT by 0.64 mm. Because the two parameters are very close, they may be regarded as identical and specifically distinguishing the two may be practically unnecessary.

Statistically, there is high significance ($p < 0.001$) between the sexes for the TW and PT width. The cause may be men to be taller [31]. Bone and the PT are consequently larger. However, this difference does not influence the relative location of the apex of TT and the center of PT between sexes ($p > 0.05$).

The TT-TG distance had been numerously reported to affect PM. The value of excessing 2 cm is suggested an absolute indication for medial transfer osteotomy for the TT [11, 12, 32]. Recently, a relative value is reported with consideration of the size effect of the knee [33]. Practically, measuring the TT-TG distance may avoid the interference of an unstable patella. However, it can only provide one of contributing factors in causing PM. In the literature, imbalance of peripatellar soft tissue tension is considered the most important factor in causing PM [34, 35].

The high correlation (r = 0.84) between the apex of TT and the center of PT may reveal that the latter may be evaluated reliably with clinical measurement of the former alone. Concomitant measurement of the two parameters may be unnecessary. Therefore, clinical measurement of a Q-angle may become convenient.

The limitations of the current study may include (1) all study samples are patients with knee injuries. Practically, persuading normal individuals to accept MRI examinations for pure studies are difficult. Theoretically, patients in the current study will not interfere the investigations due to without bone involvement. The results should be reliable. (2) The MRI slices are 4 mm separated. The end of the PT may be not just at the TT. Predictably, the exact TT may be more distal. The apex of TT in the current study may be at the upper part of the exact TT. However, this discrepancy may not greatly hinder the measurement.

Conclusion

Although the center of PT is lateral to the apex of TT, the discrepancy is minimal (1% of TW, about 0.6 mm; or 3% of PT width). Clinically, using the TT to represent the insertion of PT may be reasonable.

Declarations

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Availability of data and materials

All the data are contained within the manuscript.

Authors’ contributions

CCW organized the whole concepts and study procedures, the writing of the manuscript, and submission of the manuscript.

YCW provided and analyzed MRI data.

Competing interests

All authors declare that they have no competing interests.

Consent for publication

No applicable.

Ethics approval and consent to participates

This study had been approved by Institutional Review Board of the authors' institution

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Tables

Please see the supplementary files section to access the tables.

Figures

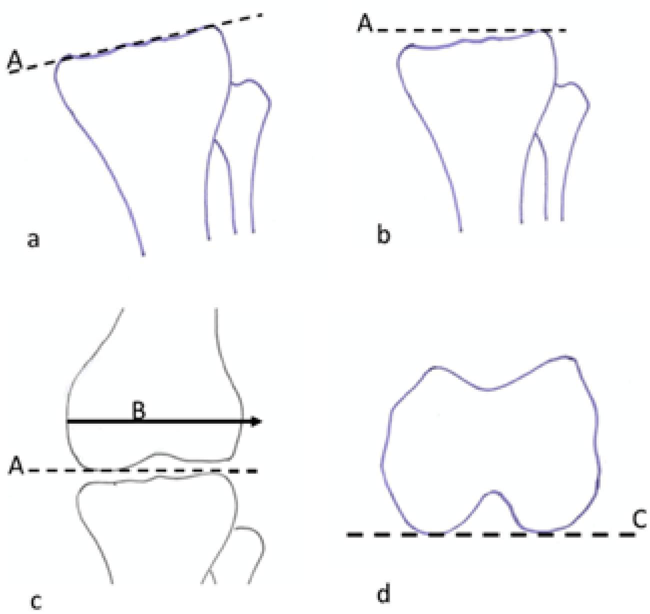

Figure 1

A standardized magnetic resonance imaging (MRI) is created: (a) A line-A is drawn to connect medial and lateral tibial plateau surfaces. (b) The line-A is externally rotated 3o and kept horizontal. (c) A line-B is created at the medial femoral epicondyle with parallel to the line-A. (d) The axial plane is exposed and a line-C is drawn to connect posterior cortices of medial and lateral femoral condyles. The line-C is kept horizontal.

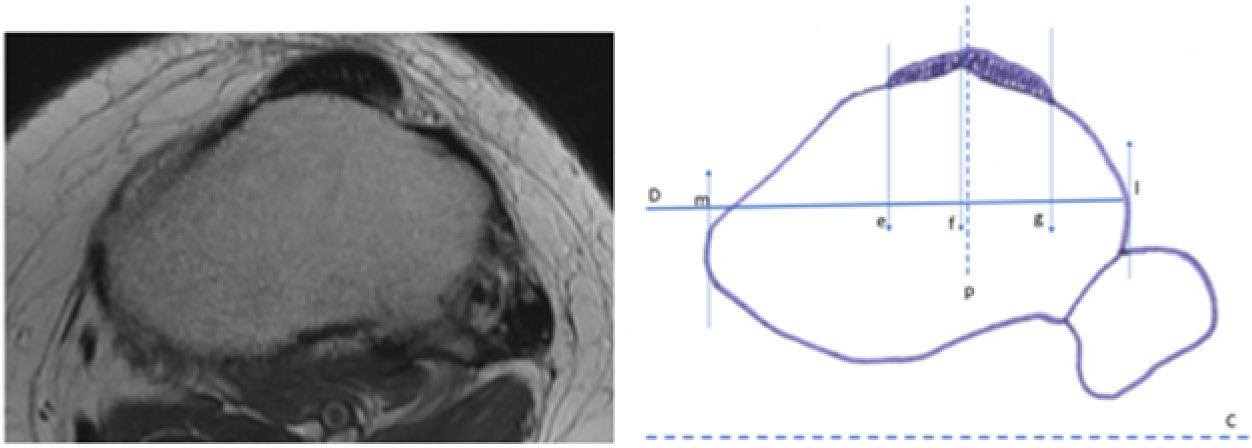

Figure 2

The axial plane of the tibial tubercle (TT) is showed. A line-D (parallel to the line-C) is drawn from the most lateral edge (point l) to the most medial edge (point m) of the tibial width. Three lines (lines e, f, and g) which are vertical to the line-D are created. The line-p is the midline between the line-e and line-g. The line-e is along the medial edge of the patellar tendon (PT). The line-f is at the apex of the TT. The line-g is along the lateral edge of the PT.

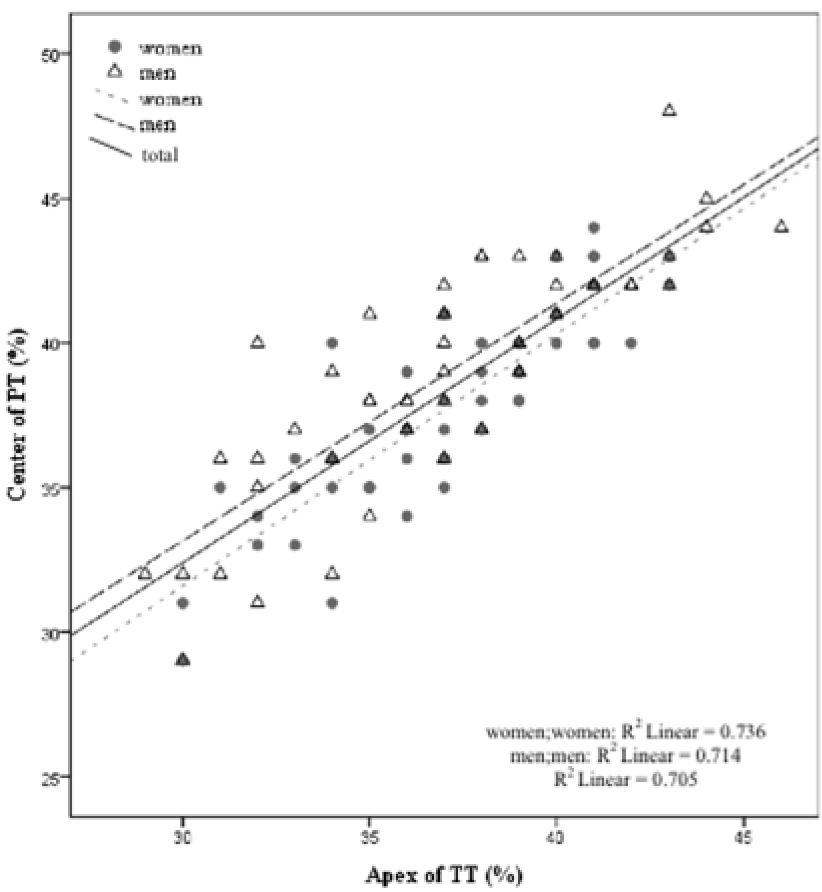

Figure 3

The apex of TT against the center of PT is plotted. There is no significant difference between the sexes (p= 0.09, 0.92, respectively).

Supplementary Files

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- bmcapextable.doc
- TTnew.xls