Factors affecting reliability of TT-TG measurements before and after medialization: a CT scan study

Facteurs d’erreur de la mesure per et postopératoire de la médialisation de la tubérosité tibiale antérieure

Étude tomodensitométrique

S. Lustig, E. Servien, T. Aït Si Selmi, P. Neyret

Service de Chirurgie Orthopédique, Centre Livet, Hôpital de la Croix-Rousse, 8, rue des Margnolles, 69300 Caluire-Lyon.

RÉSUMÉ

Le but de cette étude était d’évaluer la validité sur le plan pratique de la mesure par tomodensitométrie de la distance TAGT dans la prise en charge chirurgicale de l’instabilité rotulienne.

Nous avons étudié rétrospectivement une série de 42 patients opérés entre 1989 et 2002 d’une instabilité rotulienne objective (6 cas bilatéraux). Pour chacun, une tomodensitométrie des deux genoux avait été réalisée en pré et en postopératoire. Nous avons mesuré la TAGT pour chaque genou à partir de ces 84 scanners. Pour les genoux controlatéraux (n = 36) : nous avons étudié la différence entre les 2 mesures scanner consécutives de la TAGT. Pour les genoux opérés (n = 48) : nous avons comparé la mesure par le scanner de la médialisation effectuée (en comparant les TAGT préopératoires et postopératoires) avec la mesure durant l'opération de cette médialisation.

Les résultats ont été les suivants : pour les genoux controlatéraux (n = 36) : la différence, en valeur absolue, était en moyenne de 3,2 mm (min 0, max 13) avec un écart-type de 2,9 mm. La différence constatée entre les 2 mesures consécutives de la TAGT était significative (p = 0,03). Pour les genoux opérés (n = 48) : la médialisation mesurée au scanner était en moyenne de 8,6 mm. La discordance était (en valeur absolue) de 4,6 mm en moyenne lors de la mesure tomodensitométrique par rapport au geste de médialisation réalisé.

Il faut donc garder à l’esprit la marge d’erreur de l’ordre de 3,2 mm lors de l’interprétation de la mesure préopératoire de la TAGT. L'utilisation de la TAGT dans l'évaluation postopératoire est une technique radiologique exigeante, du fait de la modification des repères anatomiques par la chirurgie. La rédaction d'un protocole, strictement respecté, est impérative et l’analyse critique des valeurs trouvées doit rester du domaine du chirurgien.

Mots clés : Genou, TAGT, instabilité rotulienne, fixation rotulienne.

ABSTRACT

Purpose of the study

The purpose of this study was to evaluate the practical application of computed tomography (CT) measurements of the TT-TG (tibial tuberosity-trochlear groove) distance in patients undergoing surgery for patellar instability.

Material and methods

We retrospectively reviewed 42 patients (30 women, 12 men) who underwent surgery for patellar instability between 1989 and 2002. Objective evidence of unilateral instability was present in 36 patients and of bilateral instability in six. Pre- and postoperative CT scans of both knees were examined for each patient to measure the TT-TG distance for both knees (n = 48 knees). We also studied the difference in two consecutive TT-TG measurements made on 36 nonoperated knees. For the 48 operated knees, we compared the CT measurement of medialization (difference between the pre- and postoperative TT-TG) and the measurement made intraoperatively.
Results

For the 36 nonoperated knees, the mean difference between two consecutive TT-TG measurements was 3.2 mm (range, 0-13 mm). This difference was significant. For the 48 operated knees, medialization measured on the CT scan was 8.6 mm on average. Medialization measured intraoperatively was 6.9 mm on average for the same series of knees. Comparing these two types of measurement, the difference expressed in absolute value was 4.6 mm (range, 0-20 mm). This corresponded to a 67% difference (4.6/6.9) for the TT-TG measurement compared with surgically performed medialization.

Discussion

For some authors, preoperative measurement of the TT-TG distance remains a useful tool for establishing therapeutic choices for patellar instability. It must be recalled, however, that the measurement error is on the order of 3.25 mm. Use of the TT-TG for postoperative assessment is, however, a much more difficult technique since the anatomic landmarks have been modified by surgery. A rigorously applied standard radiographic protocol is required. The surgeon can then conduct a critical analysis of the landmarks retained, the slices used, and the values obtained.

Key words: Knee, TT-TG, patellar instability, patellar dislocation.

INTRODUCTION

Patellar instability or occasional dislocation of the patella is clinically manifested by at least one objective episode of luxation and the presence of one or several anatomical factors of instability: trochlear dysplasia, high-riding patella, substantial patella tilt, or excessive distance between the anterior tibial tuberosity (ATT) and the trochlear groove (TG) on the tangent to the posterior condyles of the femur [Dejour et al. (1)]. Objective measurement of the TT-TG distance integrates the external implantation of the ATT and the external rotation of the knee. This measurement was a decisive element in the management decisions for patellar instability [Dejour et al. (1), Goutallier (2)]. We studied the validity of the CT measurement of TT-TG distance, from a practical point of view, in the surgical management of patellar instability.

Excessive lateralization of the ATT corresponds to the bayonet sign described by Trillat et al. (3) and is evaluated by Q-angle in the English-language literature, as described by Insall et al. (4). In 1979, Goutallier et al. (5) described the TT-TG measurement, quantifying the distance between the anterior tibial tuberosity and the middle of the trochlear groove on the millimeter scale.

Initially, this was a radiological measurement: to measure the TT-TG based on a femoropatellar axial image, with 30° of flexion, with the lower limb rotated indifferently, Goutallier et al. (5) recommended measuring the distance between two points separating the projection of the top of the tibial tuberosity from the projection of the bottom of the trochlear groove (fig. 1).

Greater use of computerized tomography has made it possible to make these measurements more precise by superimposing two CT slices (one going through the bottom of the trochlear groove and the other through the middle of the ATT in the transversal plane) (fig. 2). For Bernageau and Goutallier (6), the CT was done with the knee flexed at 30°.

These data were studied again and modified (CT images with the knee extended) by Dejour et al. (1): threshold values were defined by comparing a group of patients with...
objective patella instability and a control group: 20 mm seemed to be the extreme value, because beyond this value 56% of patients presented objective patellar instability (luxation) and only 3% in the control group.

How is TT-TG distance used in our daily practice? First of all, the surgical act takes TT-TG distance into account in assessing the desired medialization. Postoperative TT-TG distance can then evaluate the TT-TG distance actually achieved. Finally, measuring the TT-TG distance can enter into the discussion of the lateralization of the ATT (the Déselmslie procedure). However, are these measurements reliable? Are they relevant?

A retrospective study was conducted on patients operated on in our unit for patellar instability. We studied both the precision of the TT-TG distance measurement to determine the surgical indication and after surgery in evaluating the surgical medialization achieved.

**MATERIAL AND METHODS**

**Material**

Of more than 200 patients operated on for patella instability between 1989 and 2002, we retrieved the 42 files containing preoperative and postoperative CT scans of both knees. For the knees that were not operated on, the inclusion criterion was two CTs obtained at different moments (and often different areas). For the operated knees, the inclusion criterion was a CT before and after surgery. We saw the 42 patients selected (n = 84 knees): 36 had a unilateral intervention (25 women, 11 men) and six a bilateral operation (five women, one man) (table I).

The mean age at surgery was 23 years. These patients had no history of knee surgery. A TT-TG value of 20 mm was retained as pathological and therefore the indication for tibial tuberosity medialization; surgery attempted to bring the TT-TG value to between 10 and 15 mm without excessive medialization (> 10 mm) [Dejour et al. (1), Goutallier et al. (5)].

ATT medialization was performed in 43 cases: a proximal realignment-lateral release was associated in all cases; the patella was lowered in cases of high-riding patella defined by a value greater than 1.2 on the Caton-Deschamps Index [Caton et al. (7)] (n = 40 cases); the vastus lateralis was repaired according to the technique described by Insall et al. (4) when the contracted and relaxed quadriceps patellar tilt was greater than 20° (n = 38 cases); trochlear repair was only indicated when the patient presented abnormal patellar movement associated with stage 3 dysplasia according to the classification established by Dejour et al. (8) (n = 4 cases).

**Methods**

For each of the 42 patients, a CT of both knees was done before surgery and during follow-up. The patient was in the supine position, feet together. The TT-TG measurement was taken according to the criteria defined by Bernageau and Goutallier (6), but with the knees in extension, for each of these 84 knees, using the technique reviewed during the 10th Knee Surgery Meetings in Lyon [Tavernier and Dejour (9)]: this value, measuring in millimeters the distance between the ATT (insertion zone for the patellar tendon) and the middle of the trochlear groove, was measured by superimposing one slice going through the bottom of the trochlear groove (the slice going through the top of the intercondylar notch where it is shaped like a Roman arch, the first slice with cartilage on the trochlea) and the other slice going through the middle of the ATT in the transversal plane.

During this measurement, two readings were done, one by the radiologist and the other when the radiological files were reviewed by an independent observer (when the two values differed, the value measured by the independent observer was retained). The center where the CT was taken was noted each time.

**Nonoperated knees**

Thirty-six contralateral nonoperated knees (23 right and 13 left knees) were studied.

For each knee, the difference in the TT-TG measurement on the two consecutive CT images was measured. The statistical analysis of variance (ANVA) calculating the variation coefficient was applied for each series of measurements and for the difference between each measurement. The p < 0.05 threshold was retained as significant. The scatter diagram was also produced.

**Operated knees**

For all 48 operated knees (19 right knees and 29 left knees) (42 patients [30 females, 12 males], 36 unilateral operations; and 12 knees of six patients [five females, one

---

**TABLE I. – Population studied.**

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Pre- and postoperative CT</th>
<th>Preoperative CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>200</td>
<td>42</td>
<td>168</td>
</tr>
<tr>
<td>Bilateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of patients</td>
<td>200</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>25 M</td>
<td>11 F</td>
<td>5 M 1 F</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operated knees</td>
<td>48</td>
<td>25</td>
<td>11 10 2</td>
</tr>
<tr>
<td>Nonoperated</td>
<td>36</td>
<td>25</td>
<td>11 0 0</td>
</tr>
<tr>
<td>knees</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

M: male; F: female.
male] with bilateral operations), we studied the preoperative and postoperative TT-TG measurements. To calculate preoperative TT-TG, we took the middle of the ATT as the reference point. To calculate the postoperative TT-TG, we took the middle of the ATT or the head of a screw when the material was still present, as the reference point (fig. 3).

From these preoperative and postoperative TT-TG measurements, we were able to calculate the medialization evaluated by CT by the preoperative TT-TG/postoperative TT-TG. We also noted the medialization measured by the surgeon during the operation.

For each knee, we compared the CT measurement of the medialization achieved surgically with the intraoperative measurement of this medialization. The difference between the two values was considered as a relative value but also as an absolute value so that the mean “error” committed for each operation could be compared to the total value of medialization achieved.

RESULTS

Nonoperated knees (table II)

The mean TT-TG distance on the first CT was 15.8 mm ± 3.5 (range, 8–22 mm). On the second CT, it was 14.2 mm ± 4.1 (range, 6.4–22).

The mean difference was 1.59 mm ± 4.15 (range, –13 to 5). Considering this difference as an absolute value, we found a mean of 3.2 mm ± 2.9 (range, 0–13 mm). The difference between the two consecutive TT-TG measurements was significant ($p = 0.03$).

The low level of reproducibility of the measurement in our series was clearly demonstrated on the scattergram, showing an asymmetric distribution of the measurements on both sides of the diagonal (fig. 4).

<table>
<thead>
<tr>
<th>TT-TG measurements</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st measurement</td>
<td>2nd measurement</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>Relative value</td>
</tr>
<tr>
<td>15.8 ± 3.5</td>
<td>-1.6 ± 4.1</td>
</tr>
<tr>
<td>Range</td>
<td>0–13</td>
</tr>
</tbody>
</table>

FIG. 3. – Pre- and postoperative CT measurement. a) Scanner préopératoire TAGT = 24 mm. b) Preoperative CT TT-GT = 9 mm. The surgical correction was 13 mm for a 15-mm medialization measured on CT.

FIG. 4. – Scattergram, nonoperated knees.
Operated knees (table III)

The mean preoperative TT-TG (T1) was 17.0 mm. The mean postoperative TT-TG (T2) was 8.4 mm. The mean CT medialization, T1-T2, was 8.6 mm.

The medialization achieved and measured by the surgeon during the operation was a mean 6.9 mm.

Considering for each operated knee the absolute value of the difference between the medialization measured during surgery and that measured with CT, we found a disagreement of 4.6 mm. We observed a CT error of 4.6/6.9 = 67% for this measurement compared to the manual measurement.

DISCUSSION

Variation in the TT-TG measurement

The English-language research teams use the Q-angle for occasional patella dislocation. According to Insall et al. (4), it is measured by placing the patient in the supine position with the knee in extension and the quadriceps relaxed; the Q-angle is formed by a line connecting the anterosuperior iliac spine to the center of the patella and a line connecting the center of the patella to the middle of the ATT. In 1993, Takeo et al. (10) suggested measuring this Q-angle using the center of the trochlear groove rather than the center of the patella, available on CT scans. This comes close to the CT TT-TG measurement as described by Bernageau and Goutallier (6) and underscores its value in evaluating and treating occasional patella dislocations. In 2000, Tsujimoto et al. (11) also pointed out the value of CT assessment of excessive ATT lateralization in relation to the trochlear groove in their analysis of patella instability.

In addition, in a series of 160 knees suffering from occasional patella dislocation, operated on based on a decisional tree using the preoperative CT TT-TG measurement, Servien et al. (12) found a 94.5% satisfaction rate; this measurement therefore seems well adapted before surgery in these patients.

However, the reliability of the CT measurements in the context of patella instability management has been questioned in several recent studies [Delgado-Martinez et al. (13), Saudan and Fritschy (14)]. The relative precision of the TT-TG measurement using CT is emphasized in Saudan and Fritschy’s article (14) but it was based on a sample of 13 patients. This article presented a classical reliability study with a panel of radiologists measuring the value studied two or three times on a population sample.

In our series of 36 nonoperated knees, we also found a low reproducibility for the CT TT-TG measurement, with a significant difference between the two series of consecutive TT-TG measurements: a mean of 3.25 mm.

This margin for error on the order of 4 mm was already underlined by Maldague and Malghem (15) and Galland et al. (16).

Several measurement biases may explain this difference. The first involves the CT measurement of TT-TG distance in patients presenting occasional patella dislocation. It was hampered by having chosen the point at the back of the trochlea, which is often dysplastic, even flat, making the middle of the groove difficult to determine (fig. 5). This can lead to using slices that are located lower so as to find a trochlear zone with the middle of the groove easier to identify.

![Fig. 5. – Example of a CT image with trochlear dysplasia: point GT1 was chose by the radiologist, but point GT2 seemed more appropriate. The slice was probably very high on the trochlea (entire length of patella).](image)

TABLE III. – Measurements of TT-TG distance for operated knees (mm).

<table>
<thead>
<tr>
<th></th>
<th>CT measurements of TT-TG</th>
<th>CT measurement of medialization (A)</th>
<th>Surgical measurement of medialization (B)</th>
<th>Difference between two measurements (A-B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative measurement T1</td>
<td>Postoperative measurement T2</td>
<td>Preoperative-postoperative (T1-T2)</td>
<td>Intraoperative measurement</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>17.0 ± 4.5</td>
<td>8.4 ± 4.9</td>
<td>8.6 ± 5.76</td>
<td>6.9 ± 3.6</td>
</tr>
<tr>
<td>Range</td>
<td>7-32</td>
<td>-6 to 19</td>
<td>-5 to 25</td>
<td>0-17</td>
</tr>
<tr>
<td>Relative value</td>
<td>1.75 ± 5.8</td>
<td>4.6 ± 3.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute value</td>
<td></td>
<td></td>
<td></td>
<td>0-20</td>
</tr>
</tbody>
</table>
The second bias stems from the fact that two identical CT views on the same knee are very difficult to take at exactly the same level at two different times: a measurement error on the order of 1 mm seems to be the rule. Selecting this view also seems to be part of the measurement error. On the femur, the search for the view where the intercondylar notch is like a rounded Roman arch can mean a choice between several views: generally, the first proximal slice with cartilage on the trochlea is selected. On the tibia, it seems even more difficult to select the same slice twice corresponding to the top of the ATT (fig. 6): usually, the first slice on which there is no fat between the ATT and the patella tendon is retained, corresponding to the insertion of the most proximal fibers of the tendon on the ATT.

The third bias results from the CTs in our series being done in different centers by different radiologists: consequently, there is a potential measurement bias due to the use of different machines (different acquisitions and view levels from one machine to another). The bias attributable to the choice of landmarks retained by the radiologists was removed in our series by a surgical verification of all the measurements taken by the radiologists. This critical analysis of the landmarks retained and the views selected seems indispensable before the values retained can be interpreted.

To reduce the variability of this measurement so as to take highly precise views, a frontal scout view of the knee should be taken during each CT, presenting the different slice levels. The radiologist could then identify the height corresponding to the bottom of the trochlear groove and the top of the ATT, before analyzing the CT images.

**Postoperative TT-TG measurement**

We observed a 67% difference in the medialization achieved using the TT-TG measured on CT compared to the intraoperative measurement of TT-TG distance. The error attributable to the manual measurement by the surgeon during the operation is added to the error inherent in CT measurement of TT-TG distance. Furthermore, in these operated patients, the postoperative presence of material or a bony wedge could make the middle of the tuberosity difficult to determine (fig. 7).

When evaluating the medialization achieved, it seems preferable to have the same radiologist do the radiological workups, or the radiologist should have the preceding plates or images available so as to take images at the same level for the postoperative CTs as for the images produced before the intervention.

For Goutallier and Bernageau (17), the value of TT-TG in extension declines with aging (contrary to TT-TG in flexion, which seems stable over time, the reason these authors used 30° flexion for this examination). Moreover, as for using TT-TG after surgery, they believe that this value does not appear to be predictive of the result of the therapy carried out on the

FIG. 7. – Postoperative TT-GT measurement with bony wedge on the tibia. It was difficult to choose the point corresponding to the top of the ATT because of a bony wedge from the preceding operation: point TA1 was chosen by the radiologist, but point TA2 seemed more appropriate.

FIG. 6. – Two CT measurements of the TT-GT distance of the same nonoperated knee with two different results because of two different slice levels for the tibia and the femur. a) TT-GT1 = 8.2 mm. b) TT-GT2 = 17 mm. The substantial difference between the two measurements can be explained by the very different slice level at the tibia (slice much higher for the first measurement) and the femur (patellae very different). The trochlear dysplasia makes it difficult to identify the bottom of the trochlear groove.
The femoral-patellar area, which follows the same line as our results: postoperative TT-TG measurement does not provide a precise evaluation of the medialization achieved.

The small number of patients in our sample compared to the starting population (42 patients for more than 200 operated cases) is directly related to the low number of CTs done after the operation (all patients had a preoperative CT). Therefore, this value contributed little useful information when the functional result was good and was only rarely measured in our practice (21% of the patients).

However, measuring TT-TG can be useful after the intervention, when the medialization achieved is too great. Indeed, if the functional result is poor, it may be necessary to lateralize the ATT (detransposition of the ATT or the “Déselmslie” procedure). The postoperative TT-TG value can then be used to specify by how many millimeters the ATT should be lateralized to reach the desired value between 10 and 15 mm.

However, as in the report by Dejour et al. (18), in these patients it is often observed that the lateralization achieved is insufficient. This error may be related to the fact that the screw, even if it is in the middle of the ATT, does not correspond to the middle of the patella tendon insertion on one projection (fig. 8): therefore, if the ATT fixation screw is used as a landmark, the TT-TG distance may be overestimated and consequently the lateralization to do underestimated.

CONCLUSION

The TT-TG distance in therapeutic management of occasional patella dislocation should be evaluated with knowledge of the relative imprecision of this measurement, more than 3 mm (3.25 mm in our experiment).

Using this measurement in the postoperative analysis remains an even more demanding radiological technique because surgery modifies the anatomical landmarks.

The examination procedure and the measurement methods remain too arbitrary and variable from one radiologist to another. Establishing a protocol that would be strictly respected is imperative. Despite these precautions, the critical analysis of the landmarks retained, the views selected, and the values found must be done by the surgeon. Only in these conditions can the measurement of the TT-TG distance be useful to the therapeutic decision.

Acknowledgements

To Drs. T. Tavernier and C. Lapra, radiologists, we extend our thanks for their precious collaboration.

References


Fig. 8.– Overestimation of TT-GT distance in the operated knee. Using the screw as the landmark, the TT-GT measurement can result in an overestimation of the TT-GT distance (TT-GT1 > TT-GT2). The screw does not match the middle of the patella tendon insertion on one projection.


