

CURRENT METHODS OF PATELLAR INSTABILITY IMAGING IN CHILDREN. SELECTION OF THE BEST TREATMENT APPROACH

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Background. Patellar instability is a common problem in pediatric patients. Up to 2%–3% of all knee injuries are associated with acute patellar dislocation. According to the data in the literature, patients aged 10–17 years are at the highest risk of patellar dislocation and subsequent instability. These patients must be evaluated according to the proposed algorithm to select the optimal treatment method.

Aim. To diagnose patellar instability in children and subsequently select the optimal treatment method based on acquired data.

Materials and methods. The study is based on data acquired through the examination and treatment of 147 patients at the 9th Department of Pediatric Traumatology and Orthopedics. Great emphasis was put on computed tomography (CT) data, its essential parameters, which require the most thorough analysis, and assessment methods. These parameters include patellar tilt, dysplasia of the distal metaepiphysis of the femur, the tibial tubercle–trochlear groove index, and the rotational relation of the femur and tibia.

Results. A novel algorithm for patient examination using CT is proposed. Data obtained by multislice CT (MSCT) had a significant influence on the selection of the surgical method for treating patients with patellar instability.

Conclusion. The examination of patients with patellar instability using MSCT in adherence to the proposed diagnostic algorithm allows the selection of the optimal treatment method, which will increase the likelihood of rapid recovery of patients and their return to the level of activity similar to that before injury.

Keywords: knee joint; computed tomography; patellar instability; pediatric surgery.

СОВРЕМЕННЫЕ МЕТОДЫ ЛУЧЕВОЙ ДИАГНОСТИКИ НЕСТАБИЛЬНОСТИ НАДКОЛЕННИКА У ДЕТЕЙ. ВЫБОР СПОСОБА ЛЕЧЕНИЯ

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Введение. Нестабильность надколенника представляет собой распространенную проблему у детей. До 2–3 % всех травм коленного сустава приходится на острый вывих надколенника. По данным разных авторов, вывиху и последующему развитию нестабильности надколенника наиболее подвержены дети в возрасте 10–17 лет, поэтому необходимо обследовать детей с данной патологией по алгоритму и использовать адекватный метод лечения.

Цель — диагностика нестабильности надколенника у детей и последующий выбор метода лечения на основе полученных данных.

Материалы и методы. Работа основана на материале обследования и лечения 147 пациентов в 9-м детском травматолого-ортопедическом отделении. Большое внимание уделено компьютерной томографии, значимым параметрам и способам их измерения. Это такие параметры, как наклон надколенника, дисплазия дистального метаэпифиза бедренной кости, индекс TT-TG, ротационные соотношения бедра и голени.

Результаты. Предложен алгоритм обследования пациентов с использованием компьютерной томографии. Данные, полученные с применением МСКТ, принципиально влияли на выбор хирургического метода лечения пациентов.

Выводы. При обследовании пациентов с использованием МСКТ, в соответствии с определенным алгоритмом диагностики, появляется возможность выбора и использования необходимого метода лечения, что приведет к выздоровлению пациента и возвращению к уровню активности до травмы.

Ключевые слова: коленный сустав; компьютерная томография; надколенник; нестабильность, дети.

Introduction

Patellar instability refers to the pain syndrome in the anterior part of the knee joint that is diagnosed as patellofemoral pain syndrome. Diagnosis of patellar instability is not uncommon in diseases of the knee joint in childhood. Among injuries of the knee joint, 43% to 80% of cases are caused by damage to the capsular-ligamentous apparatus [1]. Acute dislocation accounts for 2% to 3% of all injuries and diseases of the knee joint. In 10 to 18-year-olds, the prevalence of the primary patellar instability is as high as 29 per 100 thousand of the population. According to Steiner (2010), among sport injuries, patellar dislocation occurs in 61% to 72% of cases. A systematic review by Stefancin and Parker reported that recurrence after primary patellar dislocation occurred in 48% of cases. In addition, most often (20% to 80% of cases), patellar instability occurs as a result of trauma in cases of dysplasia of the knee joint and in the whole lower limb [2–6]. Therefore, patellar instability is a significant problem in children.

Radiation diagnostics are required to establish a diagnosis. Damage to soft tissue structures of the knee joint can be diagnosed using magnetic resonance imaging (MRI). Patellar instability is characterized by thickening and cicatricial changes in the medial support apparatus, as well as damage to the cartilage of the patella and femoral bone. MRI also enables visualization of edema of the bone marrow of the articulating surfaces, as well as the lateroposition and slope of the patella relative to the patellar surface of the femur.

Ultrasound (US) can be used to evaluate the medial support apparatus, which may be damaged, thickened, or scarred if the patella is unstable. Damaged cartilage of the patellofemoral articulation can also be visualized.

The development of multispiral computed tomography (MSCT) in the late 1980s was of great importance [7]. Over time, MSCT methods have been developed, significantly improving diagnoses of dysplasia and acquired deformities in children

with patellar instability. Computed tomography (CT) enhances the analysis and study of the patellofemoral joint [8] as it reveals the bone morphology of the knee joint and enables a large number of parameters to be estimated [9]. Computed scanning is one of the first methods to determine the presence of factors that lead to patellar instability, and provide information for surgical correction of these disorders [10]. Different methods of selection of surgical treatment of patellar instability (surgery on the soft tissue component of the knee joint, tibial tuberosity transposition, and various embodiments of femoral corrective osteotomies) depend on the ratio of the condyles of the femur, namely, the patellar and tibial condyles. To overcome problems of tibial tuberosity transposition, the tibial tuberosity — trochlear groove (TT–TG) index is used. This index was first described by Goutallier and Bernageau in 1978 using an axial X-ray of the knee joint [11]. This distance quantitatively shows the direction of the action of the quadriceps, and in clinical practice it is known as the Q angle (the angle of the quadriceps). In 1987, Henry Dejour adapted the measurement for use in CT. The distance is determined between the projection lines drawn through the deepest point of the patellar femur surface and the center of the tibial tuberosity. The measurement is first made when the knee joint is bent at an angle of 15°, with full extension. The authors showed that there is no significant difference between the two measurements, therefore, for simplicity, the TT–TG index is calculated with full extension of the knee joint. In the presence of patella instability, a distance of more than 20 mm was observed in 56% of cases [12], whereas, according to the literature, this index is 12 mm in normal patella [12]. In addition, in cases with a TT–TG index of 15–20 mm, arthroscopic stabilization of the patella with grafting of the medial patellofemoral ligament (MPFL) is indicated [13]. Furthermore, the slope of the patella is determined. According to the literature, in patients without patellar instability or dislocations, this angle was less than 20°, and this value was only exceeded in 3% [10]. In addition,

the patella slope is directly proportional to the type of femoral block dysplasia, such that the greater the dysplasia, the greater the angle of the patella. Arthroscopic stabilization without lateral release is indicated in patients with a patella slope angle of less than 20° [14].

Most parameters for CT of the knee joint are evaluated using axial sections. One of the conditions for performing MSCT is the patient's ability to fully extend the knee joint. It is only possible to evaluate the majority of parameters, in particular, the slope and/or subluxation of the patella, in this position, as when the knee is bent, the patella is fixed in the notch of the femoral block, and, as a result, these disorders are corrected.

The present study **aimed** to create an algorithm for examining and diagnosing patients with patellar instability. The results of the examination obtained via radiological methods (US, MRI, and MSCT) were used to determine the indications for the choice of surgical treatment, such as arthroscopic stabilization of the patella according to the Yamamoto method, stabilization of the patella with grafting of the medial patellofemoral ligament, and stabilization of the patella with one of the listed procedures with transposition of tibial tuberosity.

Materials and methods

A total of 147 patients were observed, who were treated at the Department of Pediatric Trauma and its Consequences of the Central Institute of Traumatology and Orthopaedics (Priorov National Medical Research Center of Traumatology and Orthopedics). The patients were aged from 5 to 18 years, 86 were girls (58.5%), and 61 were boys (41.5%). The duration of the anamnesis from the moment of trauma to surgical treatment was up to 7 years. The largest groups were 1–2 years (33%, 49 patients) and 2–4 years (34%, 50 patients) from the moment of dislocation. Parents of the children, who were examined according to the developed algorithm, gave written informed voluntary consent and consent to the processing of personal data.

The study group comprised 113 children aged 12 to 18 years. The period from the moment of trauma that caused instability of the patella, ranged from 3 months to 4 years. A total of 84 patients had a luxating patella, and 29 had a subluxation

of the patella. Examination of these patients was performed using CT. Thus, MSCT was performed for all patients with closed growth zones, as well as for patients with a Q angle greater than 25°. During clinical examination, patellar hypermobility was noted, as well as outward displacement when bending the knee joint, a positive J-symptom, a positive symptom of the patella slope, pain in the patellar passive slipping on the patellar surface of the thigh, and pain along the inner edge of the patella when palpation, as well as in the projection of the external condyle of the thigh.

A comparison was also made with the control group. This group consisted of children without pathology in the patellofemoral articulation, as well as children who had unilateral patellar instability in the intact patellofemoral articulation on the contralateral side. This group included 48 patients: 31 with unilateral instability, and 17 without the pathology in the patellofemoral joint.

X-ray imaging of the knee joint was performed in three projections: frontal, lateral, and axial (with the knee joint at a 45° angle) [15]. The position of the patella was determined with respect to the condyles of the femur, as well as the presence or absence of concomitant bone pathology (bone-cartilaginous intraarticular bodies, fractures, etc.). Furthermore, US of the knee joint was performed in all 147 patients with patellar instability, as well as the control group. The US data showed the state of the medial support apparatus, as well as concomitant lesions (meniscus damage, fat body hypertrophy, etc.). Cicatricial changes of the supporting apparatus were revealed, such as defects, discontinuity, heterogeneity, thickening; damage to patella cartilage; and condyles of the femur. In the control group, the normal structure of the medial support apparatus, an absence of defects of the patellar cartilage covering, and the patellar surface of the femur were noted.

MRI was performed in 59 patients with patellar instability, frequent dislocations (more than 10 per year), and concomitant instability of the knee joint (clinical signs of rupture of cruciate ligaments, collateral ligaments).

Examination was performed using MSCT in 113 patients with patellar instability who were treated in the Department of Pediatric Trauma and its Consequences of the Priorov National Medical

Research Center of Traumatology and Orthopedics from 2012 to 2017. The study was performed using the computer tomograph LightSpeedVcT that was able to obtain 64 slices per revolution of the X-ray tube according to the standard program, with a slice thickness of 0.6 mm. The computer scans for patellar instability examined both lower extremities and provided information on the presence of deformities on the side of the lesion as well as the healthy side. This information enabled preventive maintenance of dislocation and further patellar instability on the contralateral side. Bone deformities were visualized on the side of the lesion to be corrected by surgical treatment. These included excessive patella slope, femoral neck antetorsion (increased external rotation of the femoral condyles), as well as valgus deformity of the knee joint and excessive lateral position of the tibial tuberosity, determined by the TT–TG index. Among these deformities, valgus deformity of the knee joint is of greatest importance in the development of patellar instability, as the tibial tuberosity is located more laterally than normal. Accordingly, this type of deformity of the lower limb most often requires surgical correction.

During examination, we adhered to rules based on the principles of performing MSCT of the lower extremities. The patient was placed in a supine position, while the knee joints were completely unbent, the patella was turned to the ceiling, and the feet were fixed at an angle 90° and an external rotation of 15°.

The following specific sections were measured:

- section through both femoral necks at the level of the apex of the trochanteric fossa;
- section through the center of the patella at the maximum diameter of the patella;
- section in the proximal part of the femoral block where the intercondylar fossa has the shape of a “Roman arch” and there is a slight induration on the lateral facet of the femoral block;
- section through the proximal part of the tibial tuberosity.

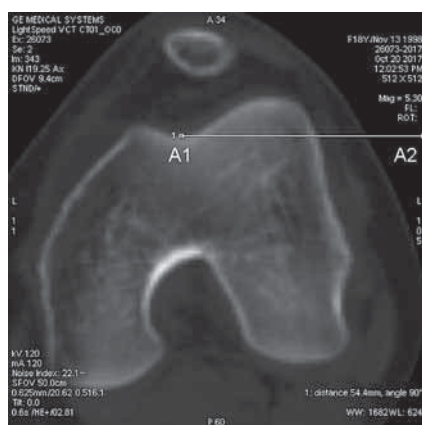
TT–TG Index

Two of the specific sections measured are required for calculation of the TT–TG index: the section in the proximal part of the femoral block,

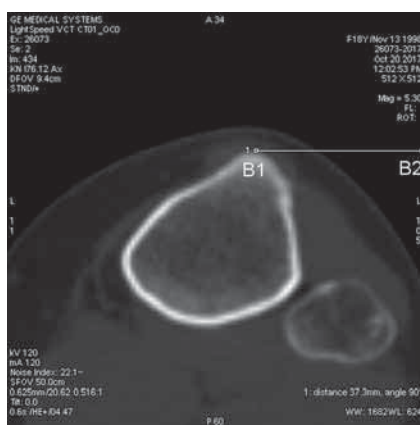
where the intercondylar fossa has the shape of a “Roman arch” and a slight induration is determined on the lateral facet of the femoral block (Fig. 1a), and the section through the proximal part of the tibial tuberosity (Fig. 1b). The distance between the deepest point of the patellar surface of the femur (line A1–A2) and the point at the center of the tibial tuberosity (line B1–B2) are calculated. In our study, the TT–TG index in the control group was less than 15 mm. In four patients with unilateral patellar instability on the contralateral side, the index value was 18 mm. This indicates a predisposition to subluxation and instability of the patella. Patients with a TT–TG index value of more than 20 mm underwent corrective osteotomy of tibial tuberosity in the treatment of patellar instability, and cases with a TT–TG index of 15–20 mm, the patients underwent arthroscopic stabilization of the patella with MPFL grafting. In addition, we noted that the greater the TT–TG index value, the more frequently the dislocations occurred and the signs of instability were more pronounced. However, the severity of the pain syndrome did not depend on this indicator.

Slope of the patella

To measure the slope of the patella, a section was used through the femoral block (the same as in the TT–TG measurement) as well as a section through the patella in the projection of the maximum diameter. In some cases, these sections coincided (Fig. 2). Two lines were then drawn: one through the patella in the frontal plane (A1–A2), and another through the posterior margins of the femoral condyles (B1–B3). The angle between the two lines represents the slope angle of the patella. In 90% of patients with patellar instability, this angle is more than 20°. In this group of pediatric patients, arthroscopic stabilization of the patella was performed with a lateral release, and in 10% of patients with a normal slope angle of the patella (less than 20°) the arthroscopic stabilization without a lateral release was conducted. Patients with a large angle of patella slope had a more pronounced pain syndrome at rest and during dislocation. We believe this is due to the fact that a large slope angle of the patella (more than 25°) at the time of dislocation and subluxation is associated with greater damage to the cartilage of the patella and the lateral condyle of the femur.



a



b

Fig. 1. Measurement of the TT-TG index

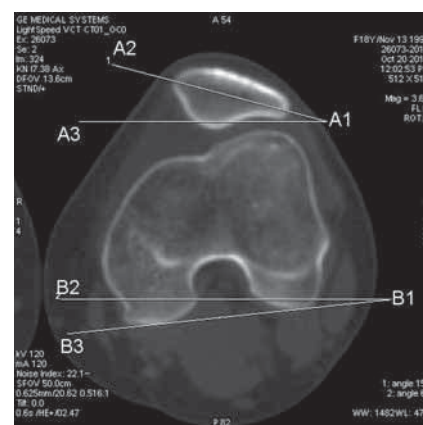
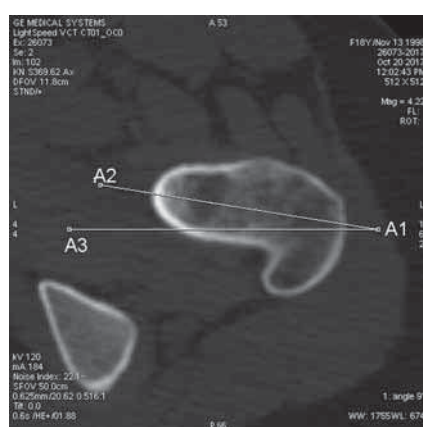
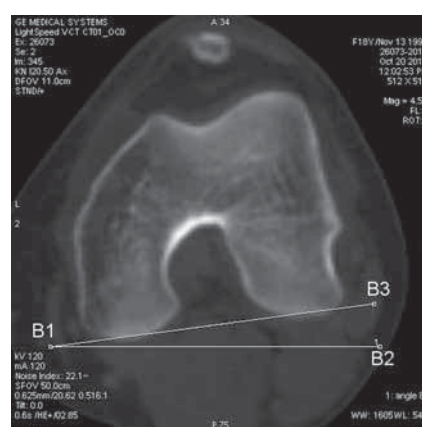


Fig. 2. Measurement of patella slope



a



b

Fig. 3. Measurement of the true anteversion (retroversion) of the femoral neck

True anteversion (retroversion) of the femoral neck

Two sections were used: one section through the distal segment of the femur (as in the measurement of the TT-TG index), and, accordingly, a line was drawn through the posterior edges of the femoral condyles (B1–B3) (Fig. 3b); the second section was made through the femoral neck, and a line was drawn through the center of the head and neck of the femur (A1–A2) (Fig. 3a). The angle between the two lines represents the cervical anteversion. According to Murphy, in patients with patellar instability this parameter is $15.6 \pm 9^\circ$, in patients without instability it is $10.8 \pm 8.7^\circ$ [16]. However, the values of both groups overlap, and the threshold value is not determined statistically significantly. Our data, as well as other data in the literature [17] indicate that a value of more than 30° is an important factor leading to posttraumatic

patellar instability. Consequently, these patients require surgical correction of the femoral deformity, such as corrective supracondylar osteotomy.

Results and discussion

Based on our sizeable clinical material (147 patients), we developed an algorithm for diagnosing and examining patients with suspected patellar instability to choose the surgical treatment method, namely, arthroscopic or open. The algorithm includes the use of clinical tests, radiography in three projections, US, MRI, and MSCT.

The clinical examination focused on the position of the patella, its hypermobility, and its displacement outwardly. Pain was noted during palpation along the medial edge of the patella, in the projection of the external condyle of the thigh, as well as a premonition of a dislocation, a positive symptom of patella slope. X-ray imaging of the knee joint was

performed in three projections: frontal, lateral, and axial (with the knee joint bent at an angle of 45°). This determined the position of the patella with respect to the femoral condyles, the height of the patella position, and the presence of concomitant pathology (intraarticular bodies, fractures, etc.). US was performed in all 147 patients to visualize the medial support apparatus of the patella. In acute dislocation, damage and impregnation with blood was determined, and in long-standing cases, thickening or thinning of the medial support apparatus of the patella, and heterogeneity were identified.

In the 14–18 years age group, 59 patients with recurrent dislocation and patellar instability underwent MRI of the knee joint to clarify other soft tissue injuries with pronounced patellar instability, as well as concomitant pathology (damage to the cruciate ligaments, edema of the bone tissue in the lateral condyle of the thigh, and patella, etc.).

CT was performed in 113 patients and provided information about the presence and appearance of deformities of the lower limb, which fundamentally affected the choice of surgical treatment method. Patients with a TT–TG index greater than 20 mm underwent arthroscopy, patellar stabilization using the Yamamoto method with a lateral release, and medialization of tibial tuberosity (26 patients). In patients with functioning growth zones but an index value of greater than 20 mm, soft tissue stabilization in various modifications was performed (Yamamoto surgery, lateral release). Patients with a TT–TG

index of 15–20 mm underwent arthroscopy and MPFL grafting with a lateral release. Lateral release was performed to rule out lateral hyperpressure of the patella with a patella slope greater than 20°. Almost all patients managed to achieve stabilization of the patella for a period of up to 6 years, without relapse. In addition, according to the results of the knee evaluation scales, an improvement was observed in all patients. Four patients had a relapse of the dislocation, but Yamamoto surgery was performed in this group and there were valgus and rotational deformities of the knee joint. The TT–TG index value was more than 20 mm; however, due to age it was not possible to transpose the tuberosity. These patients subsequently underwent a second surgery with medialization of the tibial tuberosity. These children had no recurrence of the patellar dislocation within 1–2 years after the surgery. In addition, corrective supracondylar antirotation osteotomy of the femur was initially performed to two patients. In one patient, the cervical anteversion was 37°. As a result of corrective osteotomy of the femur, at the control examination after 1 year, the cervical anteversion was equal to 15°, the plate was removed, and there was no recurrence of the patellar dislocation. According to the scales of the knee joint evaluation, there was also an improvement expressed in the decrease of the pain syndrome and improved knee joint stability (anterior knee pain, 2000 IKDc subjective knee evaluation form). These findings suggests that if all factors are identified using radiation examination methods, leading to

Table 1

Choice of treatment method based on data from radiation methods of examination

Method of surgical treatment	Patella slope	TT–TG index	High position of patella	Anteversion of the femoral neck
Lateral release	> 20°	Does not affect the choice	Does not affect the choice	Does not affect the choice
Yamamoto surgery	Does not affect the choice	< 15 and 20–25 mm	Does not affect the choice	Does not affect the choice
MPFL grafting	Does not affect the choice	Value of 15–20 and >25 mm	Does not affect the choice	Does not affect the choice
Tibial tuberosity transposition	Does not affect the choice	> 20 mm	Indices of Catton-Deschamps, Insall-Salvati > 1.2	Does not affect the choice
Corrective supracondylar osteotomy of the femur	Does not affect the choice	Does not affect the choice	Does not affect the choice	> 30°

Note: MPFL is a medial patellofemoral ligament.

a diagnosis of patellar instability, the necessary method of surgical treatment can be applied, and the patient may recover to the level of activity prior to injury.

Table 1 shows the choice of surgical treatment method for patellar instability, depending on the data obtained using radiation diagnostic methods.

It should be noted that any bone surgeries, including MPFL grafting, should be performed in patients with closed growth zones. In addition, the correcting supracondylar osteotomy of the femur was performed without any additional methods of stabilizing the patella, and the result was characterized by an absence of recurrence of the patellar dislocation.

Radiation load of CT

The total load for CT scan of the lower limb is 600 mGy/cm³: 100 for pelvic scanning and 500 for knee joint scanning. This is less than the previously used X-ray, in which the human body received a dose of 800 mGy. Furthermore, a dose of 600 mGy is approximately equal to the dose received by a person during a four-day stay in the mountains [12]. Thus, arguments against radiation load are not sufficient to exclude the use of CT.

Conclusion

The success of a patient's treatment depends on the correct diagnostics and the subsequent choice of surgical treatment method. Therefore, it is necessary to examine the patient consistently. First, a thorough clinical examination should be performed. Then, in cases of suspected patellar instability, radiography of the knee joint is performed in frontal, lateral, and axial projections, as well as US of the knee joint. MSCT of the knee joint is then performed according to the algorithm proposed above. When performing MSCT of the lower limb in patients with patellar instability, the choice of section level is of great importance. In case of incorrect selection of a section, the parameters may be distorted and lead to errors in diagnoses and, consequently, to an incorrect choice of treatment. The proposed algorithm for diagnosing and examining patients with patellar instability is highly effective and enables the appropriate selection of surgical treatment method, resulting in recovery.

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