The alignment alteration of transverse plane in growing rabbits after patella dislocation

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Abstract

Background: Torsional malalignment in transverse plan has been regarded as a risk factor for patella dislocation. But the influence of patella dislocation for torsional alignment development remains unknown. The present study aims to investigate whether the torsion alteration of the hindlimb occur after patella dislocation in growing rabbits.

Methods: Thirty rabbits that were 1 months old were included in the study. The left knees of each rabbit (N = 30 knees/group), were underwent patella lateral dislocation operation and defined as the experimental group. The right knees of each rabbit, defined as the control group (N =30 knees/group), did not undergo any surgical procedures. Computed tomography was performed on each knee immediately post-surgery and 5 months post-surgery to measure femoral version and tibial torsion. The angles was analyzed between the experimental group and control group.

Results: The femoral version and tibia torsion in the experimental and control group were not significantly different immediately after surgery. However, 5 months after surgery, the femoral version of the experimental group (-5.50±6.13°) was significantly different with that of the experimental group (-10.90±4.74°) (P < 0.05). But the tibia angle in the experimental group (7.17±7.25°) and control group (4.47±6.34°) were not significantly different (P = 0.144).

Conclusion: Patella dislocation can lead to significant change in femoral version in growing rabbits. Thus if adolescents suffer from patella dislocation or instability for a long time in growing period, the torsional malalignment in lower limbs may occur.

Background

Anatomic factors, such as patella alta, increased tibial tubercle–trochlear groove (TT-TG) distance, rotational deformities, and trochlear dysplasia, are associated with dislocation of the patella[1, 2, 3, 4, 5] Of these factors, the lower extremity alignment is very important in pathophysiology and aetiology of patella dislocation. Rotational malalignment may be a risk factor in patellar dislocation and achieved more and more attention. For example, Dejour et al. [2] found that femoral anteversion in controls was 10.8 and 15.6°in patients with patellar instability (P = 0.013). In another study, it was found a 1.56-fold higher mean femoral anteversion in patients with a history of patellofemoral instability compared with controls. But no significant differences in tibial torsion were found in patients with patellofemoral instability compared to the control group in the above two studies[3, 4].

Clinically, the torsion of the lower limbs may influence choice of surgical treatment for patients with recurrent patellar dislocation. With high degrees of internal femoral torsion, isolated medial patellofemoral ligament reconstruction for patella instability is insufficient. Femoral internal torsion of more than 15°– 25°is considered as the indication for derotational femoral osteotomy[6].
The influence of patella instability on the morphology of the patellofemoral joint has been investigated. Wang and Li found femoral trochlear dysplasia or flattening after patella instability in growing rabbits[7, 8]. Trochlea flattening after surgery with respect to the patella alta was demonstrated in growing rabbits by Kaymaz[9]. Niu found the sectional shape and articular surface of the patella became more flattened after patella instability in growing rabbits[10]. These studies indicate that patellofemoral joint dysplasia could be caused by patella instability. In the experimental study by Niu[11], tibial tubercle lateralization and an increased tibial tuberosity–trochlear groove (TT-TG) distance were proved after patella dislocation. TT-TG distance reflects the relative location between distal femur and proximal tibia, and affects the lower extremity alignment.

Because two-dimensional (2D) measurements can be affected by the location of the radiation source and/or the limb position, it is possible that the alignment factors have not been assessed correctly. Recently, three-dimensional (3D) evaluation for the lower extremity of alignment has been applied, which was proved to have high intra-observer and inter-observer reliability regardless of femoral neck-shaft angle or postural deformity[5, 12, 13, 14, 15]. Considering the high accuracy of the measurement and the extreme flexion of knee and hip joints in rabbits, the 3D method has been taken account in this study.

Although low extremity malalignment is considered as a predisposing factor for patella dislocation, the effect of patella dislocation on low extremity alignment has remained unclear. Based on the previous studies, we hypothesized that early patella dislocation lead to lower extremity malalignment in the growing rabbits. The objectives of the present study were to elucidate the alignment alteration in transverse plane after patella dislocation in growing rabbits and to discuss the influence of patella dislocation on lower extremity alignment.

**Methods**

**Study design and surgical procedure**

This study was approved by the local Animal Ethics Committee (Number:Z2019-006-1). Sixty knees from 30 healthy, 1-month-old New Zealand white rabbits, weighing between 350 and 450 g (provided by the Animal Test Center of the local medical university), were divided into two groups. The experimental group comprised the left knees, which were subjected to patella dislocation surgery. The control group comprised the right knees, and no surgical interventions were performed.

The rabbits were administered anaesthesia of ketamine hydrochloride and xylazine at a dosage of 20 and 5 mg/kg body weight, respectively, into an ear vein. Then, the left knees were shaved and disinfected by standard procedures. A 3-cm incision was performed on the knees, and the soft tissue was dissected to expose the medial retinaculum and medial side of the joint capsule. The medial retinaculum and medial joint capsule were incised while avoiding damage to blood vessels and cartilage. The patella was then pushed laterally, and the lateral joint capsule was sutured with overlapping tissue. Following these procedures, patella dislocation was seen intraoperatively (Fig. 1). The patella dislocated (the femoral
trochlear could be seen) when the knee was flexed and extended. After the operation, the incision was sutured, and bandages were applied over the incision. CT scans were performed immediately after surgery to confirm lateral patellar dislocation. Ciprofloxacin (10 mg/kg, po) was administered 3 days after surgery for antibiotic prophylaxis. Because the rabbits achieve skeletal maturation at 28 weeks, both groups were followed for 5 months after dislocation surgery.

**Measurements**

CT scans of the rabbits were performed immediately post-operatively and 5 months post-operatively using a 16-slice CT scanner (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany). The rabbits were anaesthetized and were placed in a supine position. The knee joints were fully extended. The hindlimbs were fixed on a board to prevent any movements during scanning. Contiguous slices (1.0 mm) were obtained from the upper rim of the acetabulum to the most distal part of the lower limbs. Considering the different structure of the hindlimbs in rabbits and the accuracy of the measurements, the measurements were performed in a 3-dimensional strategy. The CT slices were sent to RadiAnt DICOM software (Medixant Ltd., Poznan, Poland) and reconstructed for 3D models. Our measurement methods had an accuracy of 0.01°.

After 3D image construction, horizontal view (femur looking down from top) was acquired by 90° rotation through the program from anteroposterior view for femoral version measurement. The lowest point of the greater trochanter and the lowest point of the medial and lateral condyle were moved and rotated. After adjustment, the lowest point of the greater trochanter were located in the middle between medial and lateral condyle. The three points were connected by the horizontal line C (Fig. 2). The femoral neck version was the angle formed by the line B (parallel to line C) and the line A connecting the point of centre of the femoral head with the midpoint of the narrowest femoral neck (positive values: femoral neck is anterior to posterior condylar line) [12].

For tibia torsion measurement, the most posterior points of the medial and lateral tibia condyles were connected by Line C. Tibia torsion was measured by the angle between the line B (parallel to line C) and the line A which was drawn through the center of medial and lateral malleoli (positive values: external rotation of the ankle) [5, 16].

**Statistical Analysis**

Statistical analysis was performed using the SPSS version 21.0 (SPSS, IL, USA). The mean difference of femoral version and tibia torsion between the control group and the experimental group were evaluated by Student’s t test. A P value < 0.05 was determined as statistically significant.

The results are expressed as mean ± standard deviation. No a priori power analysis could be performed because of the paucity of research on the topic. To determine the intra-observer variation, the observer A repeated the measurement 2 weeks after first observation. To determine the inter-observer variation, the
measurements were performed by observer A, observer B and observer C. Intra-observer consistency and interobserver consistency were analysed using intra-class correlation coefficient (ICC). ICC > 0.75 was regarded as excellent, ICC 0.40–0.75 was fair to good, and ICC < 0.40 was poor.

**Result**

In this study, the femoral version and tibia torsion in the experimental and control groups before surgery were not significantly different (Table 1). Two rabbits died before the last CT scanning. So 28 rabbits were taken CT scanning 5 months after surgery. The femoral version of the experimental group (-5.50 ± 6.13°) was significantly different with that of the experimental group (-10.90 ± 4.74°). But the tibia torsion in the experimental group (7.17 ± 7.25°) and control group (4.47 ± 6.34°) were not significantly different (Table 2). The intra-observer consistency and interobserver consistency were showed in Table 3.

| Measurement(*) | Experimental group | Control group | P value |
|----------------|--------------------|---------------|---------|
| Femoral version | 11.88 ± 4.89       | 13.50 ± 5.51  | 0.205   |
| Tibia torsion   | 11.56 ± 4.03       | 12.94 ± 3.48  | 0.164   |

| Measurement(*) | Experimental group | Control group | P value |
|----------------|--------------------|---------------|---------|
| Femoral version | -5.50 ± 6.13       | -10.90 ± 4.74 | 0.001   |
| Tibia torsion   | 7.17 ± 7.25        | 4.47 ± 6.34   | 0.144   |
Table 3
Inter- and Intraobserver Reliability of the Different Measurements

| Measurements     | Immediately after surgery | 5 months postoperatively |
|------------------|---------------------------|--------------------------|
| Femoral version  |                           |                          |
| Intraobserver Reliability | 0.931 (0.877–0.961) | 0.939 (0.860–0.970) |
| Interobserver Reliability | 0.912 (0.868–0.944) | 0.870 (0.807–0.917) |
| Tibia torsion    |                           |                          |
| Intraobserver Reliability | 0.838 (0.733–0.902) | 0.971 (0.953–0.984) |
| Interobserver Reliability | 0.838 (0.765–0.893) | 0.966 (0.947–0.979) |

Discussion

The most important finding of this study is that abnormal femoral version was found in growing rabbits after patella dislocation.

Femoral version reflects the relationship of the femoral neck axis to the transcondylar axis or coronal axis of the distal femur. Femoral anteversion is defined as anterior rotation of the femoral head from the coronal plane. While Femoral retroversion refers to the condition where the femoral neck axis is oriented posterior to the transcondylar axis, positioning the femoral neck and head posterior to the coronal plane of the femur [17].

For human beings, there is 30°to 40°of femoral anteversion at birth on average, and it decreases with time to approximately 10°to 15°in skeletally mature individuals. Most of the improvement occurs before the age of 8 years[18, 19]. For rabbits, there were 10°of anteversion in the femur at birth. This had disappeared by the eighth week and by the time the animal was skeletally mature, 10°to 15°degrees of retroversion had developed[20]. The decreasing trends of the femoral version development between human-beings and rabbits are same. For adults, femoral retroversion is not as common as femoral anteversion. In the study by Hartel. A total of 1070 thin-slice CT datasets of left femurs were analyzed and 77 subjects (7.8%) were found with retroverted femur (range − 23.6°–0.2°)[21].

Femoral version relates to the stability and function of the hip and knee joints and is an important clinical factor in many disease, including torsional syndromes, femoral fractures, hip dysplasia, Legg-Calve-Perthes disease, slipped capital femoral epiphysis and anterior cruciate ligament (ACL) rupture[22, 23, 24, 25, 26, 27, 28, 29, 30, 31]. Femoral version also affects patellar stability. The increased femoral anteversion has been regarded as a risk factor for patellar instability, as it produces a lateralizing force on
the patella. The lateralizing force exists after MPFL reconstruction, contributes to the inferior clinical outcomes, even reconstruction failure[6, 32, 33, 34].

In this study, the femoral retroversion decreased after patella dislocation in growing rabbits. Patella dislocation may cause the alteration of the strength direction of rectus fomoris muscle. Also, we found knee or ankle lateral rotation in activities of rabbits after patella dislocation. The change of strength direction and position may be the cause for the femoral version difference. The version of the femur changed significantly after patella dislocation, but the tibia torsion did not change significantly. Similar with humans, in the lower extremity, the femur may be markedly abnormal yet the tibia and fibula well formed or only slightly hypoplastic. And the foot may be normal despite severe proximal anomalies[35].

Just like the previous animal experiments[7, 8, 9, 10, 11], the outcomes of the studies indicates that the aberrant version of the femur may not only be the risk factor for patellar instability, but also be the consequence of patellar instability. This founding may develop pathology and etiology of patella instability. This emphasize the importance of the early effective treatments for patellar instability in children, considering the pathological conditions caused by femur version deformity.

The first limitation of the study is the animal model choice. Although rabbits have been widely used for the orthopedic studies, the structure of the lower limbs are different from human beings’. Therefore, the results of this study may not be directly applicable to humans. Second the knee rotation measurements were not involved in this study because of the extreme flexion in the knee joints in the rabbits. The third limitation is the sample size of the rabbits. And it could give more reliable results if a higher number of experimental animals were used.

Conclusion

Based on the outcomes of this study, we conclude that early patellar dislocation can lead to abnormal femur version in growing rabbits. Thus if adolescents suffer from patella dislocation or instability for a long time in growing period, the torsional malalignment in lower limbs may occur. Clinically, early intervention for adolescent patients with patellar dislocation will be particularly important.

Abbreviations

CT: Computerized tomography; 2D: Two dimensional; 3D: Three-dimensional

Declarations

Ethics approval and consent for participate

All animals were treated humanely according to the guidelines of the Guidebook for the Care and Use of Laboratory Animals. The investigation process was approved by the ethics committee of the Third
Hospital of Hebei Medical University. The number is Z2019-006-1. The study is an animal experiment, so no consent was needed.

**Consent for publication**

Not Applicable.

**Availability of data and materials**

The supporting data for the conclusions of the study are included within the article and are available upon request from the corresponding author.

**Competing interests**

None

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**Authors’ contributions**

JHN carried out the research design and drafting of this manuscript. QQ completed the acquisition and interpretation of the data. JHN and KH raised the rabbits and performed the surgeries. KH, KP, and WL carried out measurements. FW critically revised the manuscript and provided final approval of the version to be published. All authors read and approved the final manuscript.

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Figures
Figure 1

The picture during surgery. Medial retinaculum and joint capsule were incised. Patella was moved laterally and femoral trochlear could be seen.
Figure 2

The schematic diagram of femoral version angle measurement. Line C connects the lowest point of the greater trochanter and femoral medial and lateral condyle. Line B parallels to line C. Line A connects the point of centre of the femoral head with the midpoint of the narrowest femoral neck.
Figure 3

The schematic diagram of tibia torsion angle measurement. Line C connects the medial and lateral tibia condyles. Line B parallels to line C. Line A is drawn through the center of medial and lateral malleoli.