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Which patellae are likely to redislocate?

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Abstract

Purpose The purpose of this study was to identify the risk factors for recurrent lateral patellar dislocations and to incorporate those factors into a patellar instability severity score.

Methods Sixty-one patients [male/female 35/26; median age 19 years (range 9–51 years)] formed the study group for this investigation. Within the study group, 40 patients experienced a patellar redislocation within 24 months after the primary dislocation, whereas 21 patients, who were assessed after a median follow-up of 37 months (range 24–60 months), had not experienced a subsequent episode of lateral patellar instability. In all patients, age at the time of the primary dislocation, gender, the affected body side, body mass index, bilateral instability, physical activity according to Baecke's questionnaire, the grade of trochlear dysplasia, patellar height, tibial tuberosity–trochlear groove (TT–TG) distance, and patellar tilt were assessed. The odds ratio (OR) of each factor with regard to the patellar redislocation was calculated using contingency tables. Based on these data, a "patellar instability severity score" was calculated.

Results The patellar instability severity score has six factors: age, bilateral instability, the severity of trochlear dysplasia, patella alta, TT–TG distance, and patellar tilt; the total possible score is seven. Reapplying this score to the study population revealed a median score of 4 points (range 2–7) for those patients with an early episode of patellar redislocation and a median score of 3 points (range 1–6) for those without a redislocation ($p = 0.0004$). The OR for recurrent dislocations was 4.88 (95 % CI 1.57–15.17) for the patients who scored 4 or more points when compared with the patients who scored 3 or fewer points ($p = 0.0064$).

Conclusion Based on the individual patient data, the patellar instability severity score allows an initial risk assessment for experiencing a recurrent patellar dislocation and might help differentiate between responders and non-responders to conservative treatment after primary lateral patellar instability.

Level of evidence Case–control study, Level III.

Keywords Patellar instability · Patellar dislocation · Redislocation · Score

Introduction

Lateral dislocation of the patella is a common injury in active adolescents and young adults [1, 11]. In recent years, the understanding of the biomechanics of the patellofemoral joint and patellar stabilising mechanisms has increased tremendously [22, 23]. However, despite a large amount of literature on lateral patellar instability, the decision on how to treat a first-time dislocation is still controversial. Although high redislocation rates after non-operative treatment, particularly in adolescents and young adults [20], have been reported, most authors advocate non-operative management as the first-line treatment [14]. This recommendation is mainly based on results from recent randomised studies that have failed to demonstrate the superiority of operative over non-operative treatment

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programmes when using proximal soft tissue realignment procedures [7, 17, 18, 24, 25].

The indications for operative treatment after primary patellar dislocation include the presence of an osteochondral fragment, substantial disruption of the medial soft tissue stabilisers, and a laterally subluxed patella with normal alignment of the contralateral knee [27]. However, injury to the medial soft tissue stabilisers, i.e. the medial patellofemoral ligament (MPFL), has been described in almost all patients after primary dislocation [4, 10, 19], but redislocations occur in approximately 30 % of patients only [27]. In addition, the indications do not consider individual anatomy, including the identification and evaluation of predisposing factors that contribute to primary and (obviously) recurrent dislocations. Thus, there is an increasing need to define more objective criteria for identifying those patients who are at risk of subsequent instability episodes after primary patellar dislocation; this identification will help guide physicians in the decision-making process towards an operative or non-operative treatment plan. Therefore, the purpose of this study was to identify the risk factors for recurrent lateral patellar instability in a cohort study of consecutive patients treated non-operatively after primary patellar dislocation and to incorporate those factors into a patellar instability severity score to identify the patients at high risk of recurrent patellar instability episodes after primary dislocation. It was hypothesised that an instability score that represents the relevant factors of lateral patellar instability, based on their forms and degrees, might reflect the individual risk profile of subsequent lateral patellar instability episodes after a primary dislocation.

Materials and methods

A retrospective case–control study was conducted comparing the patients who had an early recurrence of lateral patellar instability (redislocation within 2 years) after initial non-operative treatment (first inclusion criterion), with those in whom non-operative treatment was successful for a minimum follow-up of 2 years (second inclusion criterion). The exclusion criteria were primary patellar dislocation without a minimum 24-month follow-up or primary surgery caused by an osteochondral flake fracture with concomitant refixation or suture of the injured MPFL. In addition, traumatic patellar dislocation due to a direct hit against the medial patella, recurrent dislocations after any prior proximal or distal realignment procedure, trochleoplasty, fractures of the distal femur or tibial head, or a multiligamentous knee joint injury were also excluded.

The medical records of 97 consecutive unselected patients who had been treated for lateral patellar instability between January 2007 and October 2010 were screened. Twenty-nine patients underwent primary surgery due to an osteochondral flake fracture (12 patients) or decided to undergo primary MPFL augmentation surgery to reduce the risk of a patellar redislocation after a thorough informed consent discussion (17 patients). Therefore, 68 patients were identified, 7 of whom were lost to follow-up. The remaining 61 patients [male/female 35/26; median age 19 years (range 9–51 years)] comprised the study group for this investigation. Within the study group, 40 patients experienced a patellar redislocation within 24 months after the primary dislocation, whereas 21 patients, who were assessed after a median follow-up of 37 months (range 24–60 months), had not experienced a subsequent episode of patellar instability after the non-operative treatment of primary dislocation. In all patients, primary patellar dislocations occurred during various activities that included non-risk, low-risk or high-risk pivoting activities as published recently by Balcarek et al. [3]. In all of the patients, the conservative treatment included partial weight bearing on crutches for 4 weeks with a range of motion limitation from full extension to 60° of knee flexion and knee stabilisation in a knee brace. The patients concurrently underwent a physiotherapy programme for strengthening of the quadriceps and hamstring muscles over a 6-week period.

At the final follow-up, patient age at the time of the primary patellar dislocation, gender, the affected body side, body mass index (BMI), bilateral instability, and physical activity according to Baecke's questionnaire were assessed [2]. In addition, coronal, sagittal, and transverse magnetic resonance images (MRI) were available in all patients and were used to assess the grade of trochlear dysplasia, patellar height, tibial tuberosity–trochlear groove (TT–TG) distance, and patellar tilt. MRIs were taken from 4 days to 6 weeks after primary dislocation. The measurements were performed using the annotation tools from the digital picture archiving and communications system (PACS) workstation (Centricity, GE Healthcare, St. Gilles, UK). The software presented angular values and length measurements to within one decimal place; these figures were rounded to a single-digit integer format; therefore, if the true value of an angle was, for example, 5.4°, it was rounded to 5°. However, if the actual angle was 5.5°, it was rounded to 6°.

Image evaluation

Trochlear dysplasia was assessed on the transverse MRI, as described by Fucentese et al. [12]. The classification system was performed according to Dejour et al. [8]: in type A, trochlear morphology was preserved with a fairly shallow trochlea; type B consisted of flat or convex trochlea; type C consisted of asymmetrical trochlear facets with a convex lateral facet and a hypoplastic medial facet;

and type D consisted of asymmetrical trochlear facets, a hypoplastic medial facet and a cliff pattern. To improve the reliability of the trochlear dysplasia classification, we integrated Dejour's 4-grade classification (type A–D) into a 2-grade classification system that has been recently recommended [16]: low-grade (type A) and high-grade trochlear dysplasia (types B–D).

The patellar height was evaluated on the sagittal T1-weighted images according to the Insall and Salvati index (the patellar tendon length to the longest sagittal dimension of the patella). Patella alta was considered with a ratio of 1.3 or greater [15].

The TT–TG distance was assessed according to the method of Schoettle et al. [21]. The first transverse craniocaudal image that depicted a complete cartilaginous trochlea was used to determine the deepest point within the trochlear groove. A line was drawn through the deepest point of the trochlear groove perpendicular to the posterior condyle tangent. A second line was drawn parallel to the trochlear line through the most anterior portion of the tibial tubercle. The distance between the 2 lines represented the TT–TG distance. According to recently published parameters, the TT–TG distance was considered increased when a value of $\geq$16 mm was measured [3].

The patellar tilt was measured according to Dejour et al. [8]. The tilt angle was measured by the line through the transverse axis of the patella (first arm) and a second line tangential to the posterior aspect of both of the femoral condyles (second arm). The threshold was set at 20° for the pathologic tilt [8].

IRB approval (IRB No.13/5/09) of the University Medical Centre Göttingen was obtained prior to this investigation.

Statistical analysis

The data are presented as absolute (relative) frequencies and as the median and range. Fisher's exact test was used to test for categorical values, and an unpaired t test or the Mann–Whitney U test was used to compare the medians, respectively. The odds ratio (OR) of each factor with regard to the patellar redislocation was calculated using contingency tables. Based on these data, a "patellar instability severity score" was calculated using factors with a p value <0.05 and with an OR of >1.3. This score was then reapplied to the study group, and a receiver operating characteristic (ROC) analysis was used to determine the best discriminatory threshold.

To study intra- and inter-rater reliability, two measurement series on 15 randomly taken MRI were drawn either repeatedly by a single rater with a 2-week interval or independently by 2 different raters. Reliability was assessed by the correlation (Pearson r) between the two measurement series or by the mean difference (t test) between them. All of the analyses were performed with the GraphPad Prism program (version 4; GraphPad Software, San Diego, CA, USA). In addition, the score results (absolute values and score threshold) underwent a post hoc power analysis using the free G*Power Software, Version 3.1.3. A p value <0.05 was considered to be significant.

Results

The patients' demographics and risk factors for lateral patellar instability are presented in Table 1. Young age, a severe dysplastic trochlear groove, and a high patellar tilt were significantly associated with an early episode of patellar redislocation. Though not significant, bilateral instability, patella alta, and the TT–TG distance were also more pronounced in the patients with early redislocation. Gender, the affected knee, and physical activity were not different between the groups.

OR analyses were used to evaluate the influence of significant and apparent factors of recurrent patellar dislocations. With a given threshold of 16 years of age, the existence of a bilateral instability, the severity of trochlear dysplasia, a patella height >1.2, a TT–TG distance of $\geq$16 mm, and a patellar tilt $>20°$ all showed an OR of >1.3 for early patellar redislocation and therefore were interpreted as having a relevant effect on recurrent patellar instability (Table 2). These six factors were integrated into the "patellar instability severity score" (Table 3). The categories of age, bilateral instability, patellar alta, TT–TG distance, patellar tilt, and mild trochlear dysplasia each scored one point, and severe trochlear dysplasia scored two points for a maximum score of 7 points. Reapplying this score to the study population revealed a median score of 4 points (range 2–7) for those patients with an early episode of patellar redislocation and a mean score of 3 points (range 1–6) for those without a redislocation ($p < 0.0004$; 95 % CI 0.64–2.09). The score thresholds were tested, and the OR for recurrent dislocations was 4.88 (95 % CI 1.57–15.17) for the patients who scored 4 or more points when compared with the patients who scored 3 or fewer points ($p = 0.0064$, area under the ROC curve 0.77), i.e. the odds of receiving an early episode of patellar redislocation was 4.88 times higher in those patients who had 4 or more points. The post hoc power analysis revealed a power ($1-\beta$ error probability) of 0.95 (effect size $d = 1.036$) for the absolute score values and 0.99 for the score threshold (0–3 and 4–7 points) (effect size $w = 0.811$). Inter-rater and intra-rater reliability was clearly positively significant for all investigated parameters with a Pearson's r ranging from 0.79 to 0.88 ($p = 0.0057$ to $p = 0.0008$). Concomitantly, differences between means were non-significant for all measurement series.

Table 1 Distribution of patients' demographics and risk factors for lateral patellar instability within the study group

Risk factors	Redislocation (%) [range]	No redislocation (%) [range]	*p* value (95 % CI)
Male/female	21/19 (53)/(47)	14/7 (67)/(33)	ns
Age at primary LPD (years)	15 [9–29]	22 [14–55]	<0.001 (−13.22 to −4.94)
Affected knee			
Right	19 (47)	9 (43)	ns
Left	21 (53)	12 (57)	
Bilateral instability	10 (25)	2 (10)	ns
Physical activity score[a]	2.75 [1.5–4.75]	2.75 [1.5–4.0]	ns (−0.49 to 0.49)
Body mass index	22.7 [17.7–40]	24.25 [20–29.3]	ns (−3.18 to 1.74)
Trochlear dysplasia			
Mild	6 (15)	9 (43)	0.027
Severe	34 (85)	12 (57)	
Patellar height	1.35 [0.8–1.7]	1.3 [1.0–1.5]	ns (−0.03 to 0.18)
TT–TG distance (mm)	16 [7.0–27.0]	14 [8.0–24.0]	ns (−0.64 to 3.59)
Patellar tilt (°)	20 [12–48]	17 [0–28]	0.024 (0.63–8.74)

LPD lateral patellar dislocation, *TT–TG* tibial tuberosity–trochlear groove, *CI* confidence interval, *ns* non-significant

[a] Physical activity score according to Baecke's questionnaire (minimum–maximum: 1–5 points) [2]

Table 2 Distribution and contribution of risk factors in recurrent lateral patellar instability within the study group in terms of our thresholds of 16 years of age, bilateral instability, trochlear dysplasia severity, patella alta, a TT–TG distance of 16 mm or more, and a patellar tilt >20°

Risk factors	Redislocation (%)	No redislocation (%)	Odds ratio (95 % CI)
Age (years)			
≤16	27 (71)	3 (15)	11.2 (3.079–40.78)
>16	11 (29)	17 (85)	
Bilateral instability	10 (26)	2 (10)	3.167 (0.62–16.06)
Trochlear dysplasia			
Mild	6 (15)	9 (43)	4.25 (1.25–14.47)
Severe	34 (85)	12 (57)	
Patellar height			
≤1.2	16 (42)	10 (50)	1.364 (0.47–3.96)
>1.2	22 (58)	10 (50)	
TT–TG (mm)			
<16	20 (53)	12 (60)	1.47 (0.50–4.32)
≥16	18 (47)	8 (40)	
Patellar tilt (°)			
≤20	20 (53)	14 (70)	1.93 (0.62–6.04)
>20	18 (47)	6 (30)	

TT–TG tibial tuberosity–trochlear groove, *CI* confidence interval

Discussion

The most important finding of the present study was that, based on individual patient data, the patellar instability severity score allows an initial risk assessment for experiencing a recurrent episode of lateral patellar instability after primary patellar dislocation.

Several predisposing factors have been associated with lateral patellar instability. The main anatomical factors include trochlear dysplasia, patella alta, increased TT–TG distance, and patellar tilt [8]. The secondary factors are genu valgum and recurvatum, increased femoral antetorsion, external tibial rotation, and vastus medialis hypoplasia. In addition, age and gender have also been shown to influence both the onset of primary lateral patellar instability and the risk of recurrent patellar dislocations [11, 18]. Fithian et al. [11] have found that between the ages of 10 and 17 years, the risk of primary dislocation was approximately 33 % greater in girls than in boys, and the risk for subsequent dislocations was 3 times greater in the female patients who had prior patellar subluxation or dislocation. Similarly, Nikku et al. [18] have reported that the female patients who have open growth plates and bilateral instability are at the highest risk for subsequent instability episodes. Overall, redislocation rates of 52–60 % in patients younger than 15 years have been reported compared with redislocation rates of 26–33 % in patients aged 15–18 years [5, 6]. However, the influence of age still must be determined, as no difference in the severity of trochlear dysplasia or the incidence of MPFL injury between children, adolescents, and adults after primary patellar dislocation has been found [4]. However, in female patients, trochlear dysplasia and the TT–TG distance are more pronounced compared with male patients [3]. In addition, a small but significant difference has also been reported for the quadriceps angle and foot–thigh angle, indicating a slightly greater degree of torsional malalignment among female patients [11]. Thus, it could be argued that these factors might contribute to the slightly increased risk of recurrent instability episodes in women compared with

Table 3 Patellar instability severity score

Risk factors	Points
Age (years)	
>16	0
≤16	1
Bilateral instability	
No	0
Yes	1
Trochlear dysplasia	
None	0
Mild	1
Severe	2
Patellar height	
≤1.2	0
>1.2	1
TT–TG (mm)	
<16	0
≥16	1
Patellar tilt (°)	
≤20	0
>20	1
Total points	7

TT–TG tibial tuberosity–trochlear groove

men [11]. However, the overall incidence of lateral patellar dislocation is nearly identical between the sexes (male/female 47/53 %) [27].

A profile of the patients who sustain recurrent patellar dislocations is difficult to present. Many studies did not supply comprehensive data about their patients' ages, genders, cause of redislocation, or detailed analyses of the individual anatomical risk factors [27]. This analysis is further complicated by the great individual variability in terms of combinations of and differences in risk factors that make it difficult to accurately isolate their roles and contributions to recurrent dislocations. For example, in our study group, all of the patients had at least a mild dysplastic trochlear groove. In addition, 57 % (35 patients) also had patella alta, and 43 % (26 patients) had increased TT–TG distances; in more than half of our patients, at least two risk factors formed the basis for patellar instability, and one-fifth of the patients (12/61) had at least three anatomical risk factors. However, we do not have any information to weight the relative importance of these factors.

Recent randomised control trials of operatively treated primary patellar dislocations failed to improve the redislocation rates or the subjective clinical outcome compared with conservative management [7, 17, 18, 24, 25]. Thus, non-operative therapy has been recommended as the treatment of choice in primary dislocations [14]. However, in view of the high rates of patellar redislocations, particularly in young patients, this recommendation is unsatisfying and necessitates a better understanding of the factors that lead to recurrent instability episodes. Before we begin analysing the success of different operative treatment modalities, we should pause and first differentiate between those patients who have a high likelihood of recurrent dislocations and those for whom conservative treatment might be successful.

Age, trochlear dysplasia, and patellar tilt were significantly associated with an early episode of recurrent patellar dislocations. Although not significant, bilateral instability, patella height, and the TT–TG distance were also incorporated into the patellar instability severity score because of their strong support in the literature and because of their OR for recurrent patellar dislocations (all OR >1.3) in our study population. We noticed that, for several parameters, the differences were small (ns) between those who experienced a redislocation and those who did not. This fact may be due to the relatively small sample size of this study; however, it might also reflect that the mean value of a single parameter is particularly small between the subgroups. For example, the median TT–TG distance was 16 mm (range 7–27) in the patients who had a patellar redislocation and 14 mm (range 8–24) in the patients who did not have a redislocation (ns). The post hoc power analysis revealed a power of only 0.39. However, given the data, a sample size of $n = 202$ would have been required to achieve a power of at least 0.80. This shows that differences are indeed small when they are presented as mean values in the study population. Regardless, extreme values (e.g. 20 mm or more) might have a great impact on individual lateral patellar instability. Thus, the integrative approach of the patellar instability severity score might better reflect the individual risk profile and ensures that each factor is represented based on its forms and degrees. Accordingly, the score data achieved excellent power.

Although it is biomechanically important for the stability of the patellofemoral joint, we did not include the MPFL injury patterns in this investigation for several reasons. First, an MPFL injury occurs in almost all patients after the primary patellar dislocation [4, 10, 19]; therefore, this condition is likely to be similar in patients with or without further instability episodes. Second, an MPFL suture or refixation after primary dislocation could not prevent further instability episodes [7, 17, 18, 20, 24]. Therefore, it seems likely that the predisposing anatomical factors are more relevant in determining which patellae are likely to redislocate. Finally, the time between the primary dislocations and the MRI was heterogeneous within the study group and ranged between 4 days and 6 weeks. The authors therefore did not feel confident that an MPFL injury could be diagnosed as precisely as necessary for this study.

Several limitations were noticed and deserve mention. First, the retrospective study design and the relatively small

sample size have already been mentioned. This included that control about the rehabilitation protocol could not be made. Our patients were treated with partial weight bearing on crutches for 4 weeks with a range of motion limitation from full extension to 60° of knee flexion and knee stabilisation in a knee brace according to Sillanpää et al. [25]. Other authors favoured our more conservative approach with complete immobilisation of the knee joint for about 1 week [17]. However, we do not have comprehensive information on the impact of the duration of knee immobilisation on the redislocation rate after primary patellar dislocation. Second, in addition to the demographic data, such as age, gender, BMI, the affected knee side, and physical activity, we measured the four most relevant anatomical parameters of lateral patellar instability for which a normal range has been defined. In addition, torsional malalignment is often more pronounced in patients with patellar instability [9], but radiological evaluations of lower limb alignment were only performed in those cases where the clinical examination indicated a malalignment ($n = 6$). The radiological criteria could exclude a relevant malalignment in all of our six cases, but it might be relevant in other cases. Third, MRI examinations were performed within 4 days–6 weeks after primary dislocation. Thus, all patients had a certain amount of joint effusion that might have influenced patellar tilt. However, time from dislocation to MRI investigation was not different between the subgroups, but tilt results were found to be different. Fourth, the control patients were followed up for a median of 37 months (range 24–60 months) after non-operatively treated primary dislocation. Although more than half of patellar redislocations typically occur within the first 2 years after primary patellar dislocation [19], it is also reasonable to assume that some patients will experience a second episode within the following months or years. Thus, the results of this study should be re-evaluated after mid- and long-term follow-ups.

This study was designed to identify the risk factors for recurrent lateral patellar instability and to incorporate those factors into a patellar instability severity score. In addition to the most recently published Norwich Patellar Instability (NPI) Score [26] and the WARPS/STAID classification that recognises two distinct subsets of patients within the patellofemoral instability [13], this score provides an opportunity to assess the risk of patellar redislocation based on individual anatomical patient data.

Conclusion

Based on individual patient data, the patellar instability severity score allows an initial risk assessment for experiencing recurrent patellar instability episodes after primary dislocation. The OR for an early episode of patellar redislocation was nearly 5 times higher for the patients who scored 4–7 points than for the patients who scored 0–3 points. Therefore, this score might help differentiate between responders and non-responders to conservative treatment within the first 2 years after primary lateral patellar instability.

Conflict of interest The authors report no potential conflict of interest.

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