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Intercondylar Notch Stenosis of Knee Osteoarthritis and Relationship between Stenosis and Osteoarthritis Complicated with Anterior Cruciate Ligament Injury

A Study in MRI

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Abstract: The aim of this study was to research whether the patients with knee osteoarthritis (OA) exist intercondylar notch stenosis and the relationship between stenosis and OA complicated with anterior cruciate ligament (ACL) injury from magnetic resonance imaging (MRI).

A total of 79 cases of moderate–severe OA patients and 71 cases of healthy people were collected; among these OA patients, 38 were OA complicated with ACL injury and 41 were simple OA. The intercondylar notch was divided into A, U, and W types according to the notch shape in the axial sequence of MRI. Measurement of the notch width index (NWI) in the sequences of axial (NWI-1), coronal (NWI-2), and ACL attachment point at femoral (NWI-A) was done. The differences of NWI in different groups and different sequences were compared and the NWI cut-off values in different sequences were resolved by a receiver operating characteristic (ROC) curve which could be used as indicators for intercondylar notch narrowing were calculated.

The proportion of type A in moderate–severe OA group was larger than healthy group, and similar to OA complicated with ACL injury and simple OA groups ($P < 0.05$). The NWI values of the moderate–severe OA group in three sequences were smaller than the healthy group, and similar to OA complicated with ACL injury and simple OA groups ($P < 0.001$). The cut-off values of ROC curve were NWI-1 <0.266, NWI-2 <0.247, and NWI-A <0.253 in the moderate–severe OA group, and NWI-1 <0.263, NWI-2 <0.246, and NWI-A <0.253 in the OA complicated with ACL injury group. The intercondylar notch of moderate–severe OA patients exist significant stenosis. Type A is one of the variables that predispose a notch to stenosis. Intercondylar notch stenosis and type A are risk factors for moderate–severe OA patients complicated with ACL injury.

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Abbreviations: ACL = anterior cruciate ligament, CI = confidence interval, MRI = magnetic resonance imaging, NWI = notch width index, OA = osteoarthritis, OR = odds ratio, ROC = receiver operating characteristic, SD = standard deviation.

INTRODUCTION

Knee osteoarthritis (OA) is characterized by the destruction of articular cartilage and osteophyte formation, resulting in joint space narrowing. The incidence is higher in the elderly, especially in women. Knee OA can cause severe joint pains and lead to disability at last. The existence of osteophyte will increase the risk of the complication of anterior cruciate ligament (ACL) injury. There are not any sound clinical treatments against OA, the common method to cure severe OA patients is knee replacement surgery. In view of the serious consequences and expensive treatment cost of OA, the prevention of high-risk population is essential and crucial.

Studies show that, the osteophyte of OA patients will lead to intercondylar notch stenosis.[1,2] Anderson et al[3] and Souryal et al[4] put forward the concept of notch width index (NWI) successively, so as to evaluate the intercondylar notch stenosis. NWI equals intercondylar notch width divided by femoral condyles width. It is a relative index, which can reduce measurement error, balance individual difference, and reflect the size of intercondylar notch more accurately. Both x-ray and CT (computed tomography) images can calculate NWI; however, the images can't see the soft tissue such as ligament and they may exist overlapping,[5] so the error is high. Fortunately, there are no such problems in MR (magnetic resonance) images, so we choose MR images in this study. Many scholars have studied the magnetic resonance imaging (MRI) images of intercondylar notch, they choose the sequence of axial,[6] coronal,[7] and the ACL attachment point at femoral,[8] and the intercondylar notch shape type into A, U, and W typing.[9] In this study, moderate–severe OA patients were selected as the main research object and these OA patients were divided into two groups based on complication with ACL injury. Different sequences of NWI in MRI were compared in different groups to determine the relationship between intercondylar notch stenosis and OA complicated with ACL injury.

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MATERIALS AND METHODS

Research Object

A retrospective case-control study was conducted in Lanzhou University Second Hospital (Lanzhou, China) during January 2011 to June 2015. Inclusion criteria: (1) middle-aged and old people (≥45 years old). (2) The diagnosis was OA according to the American Rheumatism Association knee OA diagnostic criteria,[10] furthermore we choose moderate–severe OA patients whose K-L score[11,12] was grade II, III, IV in MRI and the severity index of KOA (ISOA) score[13] was >4. (3) No clear knee joint injury or operation history. (4) MRI images are clear and sequences are complete. (5) OA is the first occurrence of the disease. Exclusion criteria: (1) <45 years old. (2) The diagnosis was not clear or mild OA whose K-L score was I or ISOA score was no >4. (3) The ACL injury occurred before the OA. Out of an initial cohort of 1107 MRI, we selected 150 cases, 79 patients and 71 controls. All of the patients gave informed consent; the study was conducted under the supervision of the Ethics Committee of Lanzhou University Second Hospital.

Measurement Methods

Using the Phillips 3.0-T MRI scanner, patients were placed in a supine position, knee flexion 10°–15°, with the center of the coil located at the lower pole of the patella. Scan sequence: proton fast spin echo with fat saturation (PD-TSE-FS-TRA) in axial, TR 2886 ms, TE 25 ms, 160 mm FOV, layer thickness 3 mm. SE-T1WI sequence in coronal, TR 520 ms, TE 20 ms, FOV 160 mm, layer thickness 3 mm. The sequence was selected which showed intercondylar notch clearly and was consistent with the measurement position. RadiAnt DICOM Viewer 1.9 software was used to measure. The classification of the intercondylar notch shape in axial is divided into three types: A, U, and W refers to Al-Saeed et al[9] (Figure 1A–C). Measurement of NWI-1 in axial refers to Stein et al[6] (Figure 1 D), NWI-2 in coronal refers to Domzalski et al[7] (Figure 1E), and NWI-A in ACL attachment point at femoral refers to Hoteya et al[8] (Figure 1F). The measurement was completed by three people independently; the final data was the average value, negotiation when the shape type is different.

Statistical Analysis

Data were analyzed by SPSS 22.0 software; results were displayed in the form of $\bar{X} \pm SD$. Comparison of different levels of NWI among different groups was done by one-way ANOVA; comparison of rates were done by the chi-square test. Two parameters correlation test were done by the Spearman test. $P < 0.05$ was seen as statistically significant.

RESULTS

General Information

As shown in Tables 1 and 2, there were 71 cases in the healthy group and 79 cases in the moderate–severe OA group. Divided these OA patients into two groups based on whether complicated with ACL injury. There were 41 cases in the simple

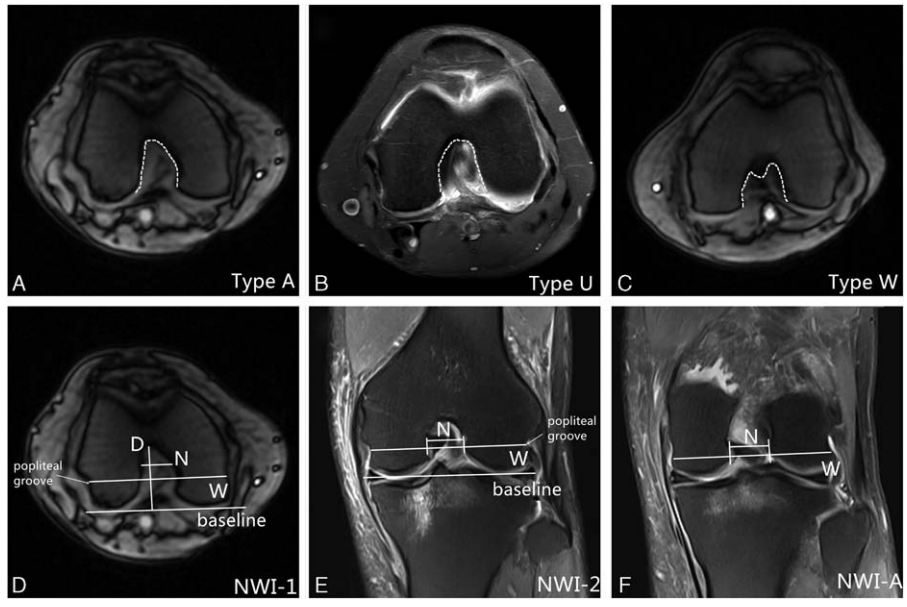

FIGURE 1. Intercondylar notch shape typing on an axial image and the measurement of different levels of NWI. (A) Type A: the tip of the notch is small and pointed, like the letter ''A.'' (B), Type U: the tip of the notch is large and dull, like the reverse letter ''U.'' (C) Type W: two tops; there are two tip edges which are large in shape, like the reverse letter ''W.'' (D) Measurement of NWI-1 on an axial image. The image is most clear in axial sequence, the baseline is the tangent of cartilage at internal and external condyle of femur, notch depth (D) is the distance between the tip of the notch and the baseline, condylar width (W) is the length of a line which passes the popliteal groove in the lateral femoral condyle and parallel to the baseline, notch width (N) is the length of a line which is at the upper 2/3 of D parallel to the baseline. (E) Measurement of NWI-2 on a coronal image. The image which we choose can show two cruciate ligaments and condyle ridge. Baseline and W are similar to (D), N is the notch width on W. (F) Measurement of NWI-2 on ACL attachment point at femoral. The image we choose can show two cruciate ligaments and the ACL attachment point at femoral. W is the length of a line which passes the exit of lateral femoral condyle and is parallel to the baseline, N is the notch width on W. ACL = anterior cruciate ligament, NWI = notch width index, NWI-1 = notch width index in the sequences of axial, NWI-2 = notch width index in the sequences of coronal.

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TABLE 1. Gender and Age (Year) in Healthy Group and OA Group

	Healthy Group		OA Group		
	Cases	Age	Cases	Age	Total
Male	33	53.42 ± 6.50	27	56.44 ± 8.41	60
Female	38	52.32 ± 6.18	52	57.44 ± 8.92	90
Total	71	52.83 ± 6.31	79	57.10 ± 8.71	150

OA = osteoarthritis.

TABLE 2. Gender and Age (Year) in Simple OA Group and OA + ACL Injury Group

	Simple OA Group		OA + ACL Injury Group		
	Cases	Age	Cases	Age	Total
Male	17	55.12 ± 8.71	10	58.70 ± 7.78	27
Female	24	57.79 ± 9.26	28	57.14 ± 8.78	52
Total	41	56.68 ± 9.03	38	57.55 ± 8.45	79

ACL = anterior cruciate ligament, OA = osteoarthritis.

OA group, 38 cases in the OA complicated with ACL injury group.

Comparison of Intercondylar Notch Shape Type Between Different Groups

As shown in Table 3, there were only 2 cases in the healthy group and 1 case in the moderate–severe OA group about type W. Because the cases in type W were very less, and the notch width was close to type U, so type W was merged into type U. Type A in the OA group accounted for 75.9%, significantly >57.7% in the healthy group. The result of chi-square test was $\chi^2 = 5.633$, $P = 0.018$, $P < 0.05$, means that the shape type between OA group and the healthy group was significantly different. Type A was more and type U was less in the OA group than the healthy group. Odds ratio (OR) = 2.311 means that the probability of occurrence of OA in type A was 2.311 times than that of type U.

As shown in Table 4, only 1 case was in the simple OA group and none in the OA complicated with ACL injury group about type W. Merge type W into type U. The proportion of type A in simple OA group was significantly higher than that of the

TABLE 3. Comparison of Notch Types Between OA Group and Healthy Group

	Healthy Group	OA Group	Total	Statistic
A	41 (57.7%)	60* (75.9%)	101	$\chi^2 = 5.633$
U	30 (42.3%)	19* (24.1%)	49	$P = 0.018$
Total	71 (100%)	79 (100%)	150	OR = 2.311

OA = osteoarthritis, OR = odd ratio.
*OA group compared with healthy group $P < 0.05$.

TABLE 4. Comparison of Notch Types Between OA + ACL Injury Group and Simple OA Group

	Simple OA Group	OA + ACL Injury Group	Total	Statistic
A	27 (65.9%)	33* (86.8%)	60	$\chi^2 = 4.756$
U	14 (34.1%)	5* (12.2%)	19	$P = 0.029$
Total	41 (100%)	38 (100%)	79	OR = 3.422

ACL = anterior cruciate ligament, OA = osteoarthritis, OR = odd ratio.
*OA complicated with ACL injury group compared with simple OA group $P < 0.05$.

OA complicated with ACL injury group. The result of the chi-square test was $\chi^2 = 4.756$, $P = 0.029$, $P < 0.05$, means that the shape type between the simple OA group and OA complicated with ACL injury group was significantly different. Type A was more and type U was less in the OA complicated with ACL injury group than the simple OA group. Odds ratio (OR) = 3.422, means that the probability of OA patients complicated with ACL injury in type A was 3.422 times than that of type U.

Comparison of NWI in Different Sequences Between Different Groups

As shown in Table 5, the cut-off values of NWI-1 in axial, NWI-2 in coronal, and NWI-A in ACL attachment point at femoral were smaller in the OA group than the healthy group. The one-way ANOVA result were $P \leq 0.001$, which means the difference about NWI between the two groups were statistically significant ($F = 10.549/14.456/12.027$, $P \leq 0.001$).

As shown in Table 6, the cut-off values of NWI-1 in axial, NWI-2 in coronal, and NWI-A in ACL attachment point at femoral were smaller in the OA complicated with ACL injury group than the simple OA group. The one-way ANOVA result is $P < 0.001$, which means the differences about NWI between the two groups were statistically significant ($F = 25.216/14.963/23.855$, $P < 0.001$).

Correlation Test

The correlation between NWI and whether suffering from OA in healthy and OA groups was tested. As whether suffering from disease was a binary data, NWI was a measurement data, so we used the Spearman test. The correlation coefficient and P values of NWI-1, NWI-2, and NWI-A were $r = -0.212/-0.209/-0.232$, $P = 0.009/0.010/0.004$, respectively. $P \leq 0.01$, therefore there was a significant correlation between whether suffering from moderate–severe OA, and NWI-1, NWI-2, and NWI-A in different sequences.

The correlation between NWI and whether complicated with ACL injury in OA patients was tested. The correlation coefficient and the P values of NWI-1, NWI-2, and NWI-A were, $r = -0.503/-0.338/-0.484$, $P < 0.001$. Therefore, there was an extremely significant correlation between whether complicated with ACL injury in OA patients, and NWI-1, NWI-2, and NWI-A in different sequences.

Receiver Operating Characteristic Curve

Figure 2 shows the receiver operating characteristic (ROC) curve of the NWI-1, NWI-2, and NWI-A of different sequences

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TABLE 5. Comparison of Different Sequences of NWI Between OA Group and Healthy Group

	Healthy Group		OA Group		
	$\bar{X} \pm SD$	95%CI	$\bar{X} \pm SD$	95%CI	Statistic
NWI-1	0.272 ± 0.017	(0.268,0.276)	$0.265 \pm 0.012^*$	(0.262,0.267)	$F = 10.549$, $P = 0.001$
NWI-2	0.254 ± 0.017	(0.250,0.258)	$0.244 \pm 0.016^*$	(0.240,0.247)	$F = 14.456$, $P < 0.001$
NWI-A	0.262 ± 0.023	(0.256,0.267)	$0.250 \pm 0.019^*$	(0.245,0.254)	$F = 12.072$, $P = 0.001$

CI = confidence interval, NWI-1 = notch width index in the sequences of axial, NWI-2 = notch width index in the sequences of coronal, NWI-A = notch width index in the ACL attachment point at femoral, OA = osteoarthritis, SD = standard deviation.
*OA group compared with healthy group $P \leq 0.001$.

TABLE 6. Comparison of Different Sequences of NWI Between OA + ACL Injury Group and Simple OA Group

	Simple OA Group		OA + ACL Injury Group		
	$\bar{X} \pm SD$	95%CI	$\bar{X} \pm SD$	95%CI	Statistic
NWI-1	0.270 ± 0.010	(0.267,0.274)	$0.258 \pm 0.011^*$	(0.255,0.262)	$F = 25.216$, $P < 0.001$
NWI-2	0.250 ± 0.012	(0.246,0.254)	$0.237 \pm 0.018^*$	(0.231,0.243)	$F = 14.963$, $P < 0.001$
NWI-A	0.259 ± 0.015	(0.254,0.263)	$0.240 \pm 0.019^*$	(0.234,0.246)	$F = 23.855$, $P < 0.001$

ACL = anterior cruciate ligament, CI = confidence interval, NWI-1 = notch width index in the sequences of axial, NWI-2 = notch width index in the sequences of coronal, NWI-A = notch width index in ACL attachment point at femoral, OA = osteoarthritis, SD = standard deviation.
*OA complicated with ACL injury group compared with simple OA group $P < 0.001$.

in OA and healthy patients. The area under curve (AUC) values were, respectively, $A = 0.622/0.621/0.634$, $P = 0.010/0.011/0.005$; among them the AUC of NWI-A was the largest. The best cut-off value of ROC curve is corresponding to the maximum value of Youden index (sensitivity + specificity − 1). So the cut-off values of NWI-1, NWI-2, and NWI-A were 0.266/0.247/0.253, respectively. The cut-off values of NWI were <95% confidence interval (CI) of healthy group in the corresponding sequence, and the AUC were >0.5; P value was <0.05, so the cut-off values were reasonable. Therefore, NWI-1 <0.266, NWI-2 <0.247, and NWI-A <0.253 can be considered as intercondylar notch stenosis and risk factors of suffering from OA.

Figure 3 shows the ROC curve of the NWI-1, NWI-2, NWI-A of different sequences in OA patients. The AUC were, respectively, $A = 0.791/0.724/0.780$, $P \leq 0.001$; among them the AUC of NWI-1 was the largest. The best cut-off values of NWI-1, NWI-2, and NWI-A were 0.263/0.246/0.253, respectively. The cut-off values of NWI were <95% CI of simple OA group in the corresponding sequence, and the AUC were >0.5; P value was <0.01, so the cut-off values were reasonable. Therefore, NWI-1 <0.263, NWI-2 <0.246, and NWI-A <0.253 can be considered as risk factors for OA patients complicated with ACL injury.

DISCUSSION

Many scholars have studied the intercondylar notch of OA patients. Shepstone et al[14] found that the differences between healthy and OA patients are related mostly to the shape of the medial condyle edge: in the nonosteoarthritic group it tends to exhibit a concavity and in the osteoarthritic group it tends to be

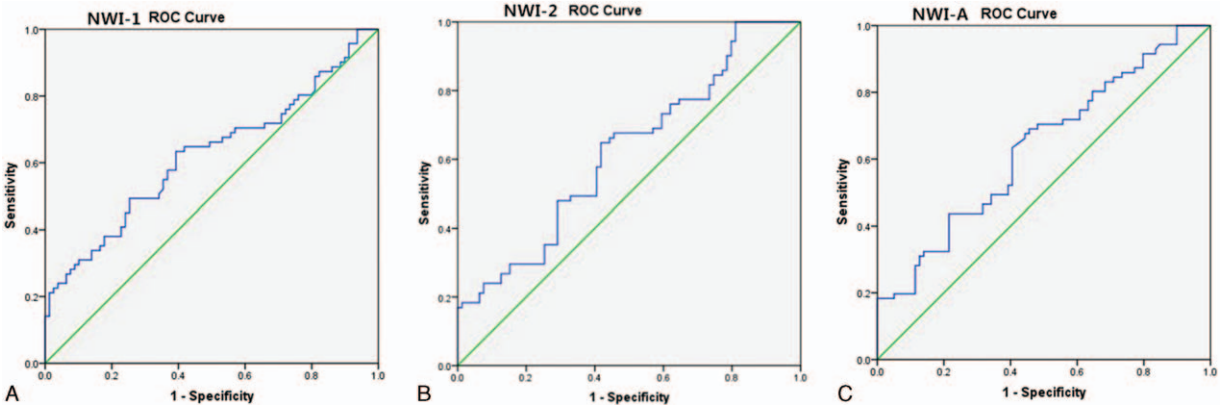

FIGURE 2. ROC curves of different sequences in OA and healthy groups. OA = osteoarthritis, ROC = receiver operating characteristic.

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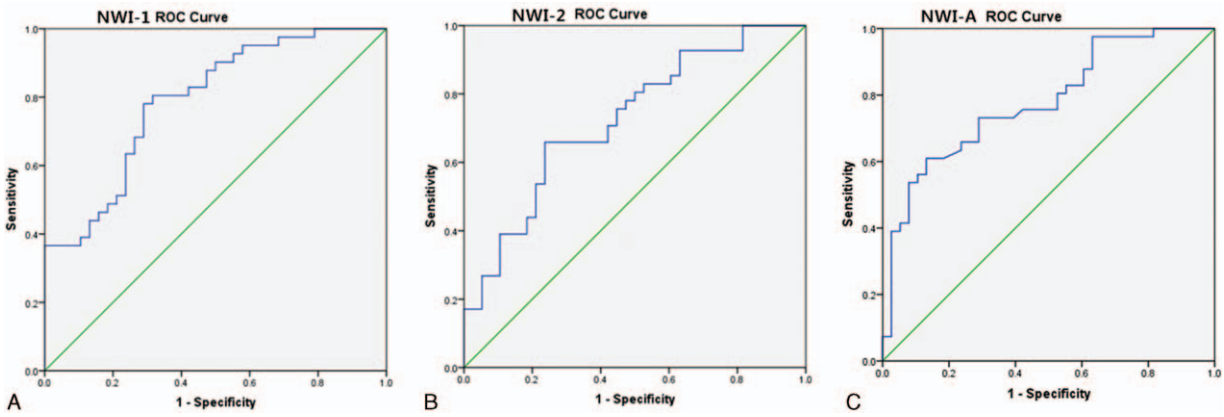

FIGURE 3. ROC curves of different sequences in OA complicated with ACL injury and simple OA groups. ACL = anterior cruciate ligament, OA = osteoarthritis, ROC = receiver operating characteristic.

straight. This difference in shape may reduce the width of the notch; the morphology of OA patients may be the response to altered biomechanics. Wada et al[1] through anatomic measurement of intercondylar notch in OA patients found that osteophyte growth seems to correlate with the progression of OA, which will narrow the intercondylar notch and reduce the NWI. León et al[2] used arthroscope and examined 69 knees with degenerative knee arthritis but without ACL laxity; he found that there may appear four types of hyperplasia in intercondylar notch, among these the hyperplasia in top and opening was the most common type; the hyperplasia is responsible for the reduction in intercondylar notch width and decreases the NWI and leads to intercondylar notch narrowing. In this study, we found that the cut-off values of NWI-1, NWI-2, and NWI-A in moderate–severe OA patients were significantly less than those of healthy persons ($P < 0.01$), which showed that there was a significant intercondylar notch stenosis in moderate–severe OA patients, these were consistent with the conclusions of the above-mentioned scholars.

In the studies of intercondylar notch shape, most scholars divided it into three types of A, U, and W. Anderson et al[3] in the study of CT images found that the shape of the notch in type U was not easy to be narrow. Van Eck et al[15] in the study of arthroscopic found that the width of the intercondylar notch in type A was smaller than that of type U. In a study Sutton et al[16] showed that the shape of notch was related to gender; the proportion of type A in female was larger than male, and the notch width was smaller than that of male, which means that type A shape of intercondylar notch is easy to narrow. In the study of MRI, Al-Saeed et al[9] found that the notch width of type A was smaller than other types and the shape of the notch was a risk factor for ACL injury, and the type A patients were easier to suffer from ACL injury. In this study, we found that the proportion of type A in moderate–severe OA patients was higher than that of healthy people. As well as the proportion of type A, OA complicated with ACL injury patients was significantly higher than that of simple OA patients. These two points indicate that type A shape was easy to cause intercondylar notch stenosis.

Many scholars have measured NWI by imageology. However, both x-ray and CT images have overlapped picture[5] and are influenced by the photograph position heavily,[17] so the error is large. MRI don't have ghosting, and can display the soft tissue such as joint ligaments clearly, so the error is negligible. Therefore, there were many studies of intercondylar notch on MRI, but no clear NWI cut-off value of intercondylar notch stenosis was made. Al-Saeed et al[9] measured NWI on MRI of 560 cases at the depth of 1/2 in the axial sequence; they considered NWI >0.270 was normal and NWI <0.269 was intercondylar notch stenosis; but in this article, the authors didn't propose the method for formulating the cut-off value. Stein et al[6] measured axial NWI at the depth of 2/3 on MRI of 160 patients with knee OA, the result was that the NWI of simple OA patients was 0.263 ± 0.03, OA complicated with ACL injury was 0.246 ± 0.03, and they took NWI <0.2 as the index intercondylar notch stenosis. But the proportion whose NWI <0.2 was just 0.7% in simple OA patients, and in OA complicated with ACL injury patients the proportion was just 4.4%, so we believe that the cut-off value was not reasonable. Sonnery-Cottet et al[18] measured the NWI of coronal sequence; the NWI in healthy group was 0.27 ± 0.02, in ACL injury group was 0.22 ± 0.02, and they considered that NWI <0.21 was a risk factor for ACL injury. Park et al[19] obtained that the NWI of healthy women in MRI coronal sequence was 0.25 ± 0.02. Domzalski et al[7] measured 76 cases of juveniles on MRI coronal sequence, found that the NWI $= 0.254 \pm 0.032$ at the age of 15 to 17, and NWI decrease with the increase of age. In order to measure the NWI at ACL attachment point more accurately, Hoteya et al[8] selected two images as ACL attachment point at femoral (A) and an image after ACL attachment point (P), in healthy people NWI-A $= 0.266 \pm 0.030$and NWI-P $= 0.273 \pm 0.033$. Their conclusion is that NWI <0.25 can be considered as intercondylar notch stenosis. There is no ACL existing in the level of P, so the guidance of ACL injury maybe little, but the other three levels exist in ACL, so we choose axial, coronal, ACL attachment point at femoral in this study. We found that cut-off value of NWI in different sequences of moderate–severe OA group was smaller than the healthy group, and it was a statistical difference. So we considered that moderate–severe OA patients had obviously intercondylar notch stenosis. Meanwhile, NWI in different sequences of OA complicated with ACL injury group was smaller than simple OA group also with statistical difference. This means that the intercondylar notch of OA complicated with ACL injury patients was more stenosis than simple OA patients; intercondylar notch stenosis was a risk factor for OA patients complicated with ACL injury. We obtained cut-off values of NWI in different sequences of the moderate–severe OA group and OA complicated with ACL

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injury group according to ROC curve, which can be used as indicators to determine the stenosis of the intercondylar notch.

A number of studies have confirmed that intercondylar notch stenosis is an independent risk factor for ACL injury, and the cut-off value of NWI of stenosis patients is smaller than the healthy people.[5,18–22] Patients with left and right bilateral ACL injuries have cut-off value of NWI smaller than unilateral injury patients.[4,8] The reason of ACL injury caused by the intercondylar notch stenosis is variable. Stijak et al[23] and Dienst et al[24], as per their research work, think that the ACL's cross-sectional area was small, strength was weak, biological performance was poor and easy to injury in intercondylar notch stenosis patients. Everhart et al[25] found that in the knee joint movement, ACL can collide with the stenotic intercondylar notch, resulting to wear and tear and finally lead to ACL injury. León et al[2] found that OA patients can appear with various types of osteophytosis and different intercondylar fossa impingement. When the osteophyte is in notch outlet which can lead to impingement of middle ACL and when the osteophyte is on top of notch outlet, it can lead to impingement of middle and front ACL, Grade IV OA with severe intercondylar notch stenosis, most parts of the notch have osteophyte, can lead to extrusion and deformation of large part of ACL. This intercondylar notch impingement syndrome described previously can lead to ACL injury. Comerford et al[26] found the phenomenon that the dog with narrow intercondylar notch had a high risk of ACL injury. Molecular biology research found that narrow intercondylar fossa could wear ACL, increase the activity of matrix metalloproteinase (MMP) activity, the deposition of sulfated glycosaminoglycan (GAG), and the remodeling of collagen in wear areas, and then cause irreversible damage to ACL. Hernigou et al[27] studied x-ray and CT images of 30 cases of OA patients, they discovered that in OA complicated with ACL injury patients, the intercondylar notch width, angle, and area were smaller than those of the simple OA patients, and in OA complicated with ACL rupture patients the above index were rather smaller. The anatomic study of Wada et al[1] found that in a large number of OA patients complicated with ACL injury, the more serious ACL injury is, the more smaller cut-off value NWI is. Stein et al[6] studied 160 cases of MRI images with different severities of OA, and found that cut-off values of the axial and coronal NWI of patients with ACL injury were significantly smaller than that of simple OA. A large number of studies have found that the ACL injury of young people will ultimately lead to the formation of OA; the main reason is that the injury of ACL will cause instability and change local biomechanics of knee joint, and then will damage the articular cartilage, produce joint inflammation, lead to the proliferation of osteophyte, the osteophyma will further aggravate the wear of the joint, and eventually lead to OA.[28,29] Even after an ACL injury, reconstruction still not effectively prevents the occurrence of OA.[30,31] The intercondylar notch stenosis caused by the proliferation of osteophytes in OA patients can induce ACL injury, the change of the lower limbs force line caused by ACL injury can also increase the severity of OA. Given this mutual relationship between ACL injury and OA, making early prevention and treatment for OA patients whose intercondylar notch is stenosed is essential to prevent ACL injury complication and alleviate the progress of OA. Take these methods, such as making physical examination regularly, providing timely prevention advice, losing weight, reducing joint load, limiting movement, as beneficial for the prevention of ACL injury. Furthermore, Schencking et al[32,33] found that Kneipp hydrotherapy showed improvement of restricted joint mobility along with significant pain reduction and an increase of quality of life.

The study has several limitations. First, the cases of this research were selected from just one hospital, the sample range was narrow and the sample size was not much enough, there may be some bias. Second, the position was not united when shooting knee MRI, this may bring some errors to the measurement of data. Third, the selection of different sequences and the measurement of data were completed artificially; the results were greatly influenced by subjective factors. Nevertheless, the conclusion that intercondylar notch stenosis is a risk factor for OA patients complicated with ACL injury is of great value. However, the cut-off values should be confirmed by further research with a multicenter and large sample.

CONCLUSIONS

In summary, moderate–severe OA patients exist intercondylar notch stenosis, and the A type of intercondylar notch shape was more likely to be narrow. Meanwhile, the occurrence of OA patients complicated with ACL injury was positively related to the intercondylar notch stenosis. In OA complicated with ACL injury patients the width of the intercondylar notch was smaller and the proportion of type A was larger than simple OA patients. Intercondylar notch stenosis is a risk factor for OA patients complicated with ACL injury. Measurement of different levels of NWI was helpful for the judgment of intercondylar notch stenosis, providing timely prevention measures for OA patients that could reduce the incidence of ACL injury complication.

REFERENCES

1. Wada M, Tatsuo H, Baba H, et al. Femoral intercondylar notch measurements in osteoarthritic knees. *Rheumatology (Oxford).* 1999;38:554–558.
2. León HO, Blanco CER, Guthrie TB, et al. Intercondylar notch stenosis in degenerative arthritis of the knee. *Arthroscopy.* 2005;21:294–302.
3. Anderson AF, Lipscomb AB, Liudahl KJ, et al. Analysis of the intercondylar notch by computed tomography. *Am J Sports Med.* 1987;15:547–552.
4. Souryal TO, Moore HA, Evans JP. Bilaterality in anterior cruciate ligament injuries: associated intercondylar notch stenosis. *Am J Sports Med.* 1988;16:449–454.
5. Keays SL, Keays R, Newcombe PA. Femoral intercondylar notch width size: a comparison between siblings with and without anterior cruciate ligament injuries. *Knee Surg Sports Traumatol Arthrosc.* 2016;24:672–679.
6. Stein V, Li L, Guermazi A, et al. The relation of femoral notch stenosis to ACL tears in persons with knee osteoarthritis. *Osteoarthritis Cartilage.* 2010;18:192–199.
7. Domzalski ME, Keller MS, Grzelak P, et al. MRI evaluation of the development of intercondylar notch width in children. *Surg Radiol Anat.* 2015;37:609–615.
8. Hoteya K, Kato Y, Motojima S, et al. Association between intercondylar notch narrowing and bilateral anterior cruciate ligament injuries in athletes. *Arch Orthop Trauma Surg.* 2011;131:371–376.
9. Al-Saeed O, Brown M, Athyal R, et al. Association of femoral intercondylar notch morphology, width index and the risk of anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc.* 2013;21:678–682.
10. Chen WH, Liu XX, Tong PJ, et al. Diagnosis and management of knee osteoarthritis: Chinese medicine expert consensus (2015). *Chin J Integr Med.* 2016;22:150–153.

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11. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. *Ann Rheum Dis.* 1957;16:494–502.
12. Kim H, Lee J, Kim T, et al. Association between serum vitamin D status and health-related quality of life (HRQOL) in an older Korean population with radiographic knee osteoarthritis: data from the Korean national health and nutrition examination survey (2010–2011). *Health Qual Life Out.* 2015;13:48.
13. Lequesne M. Indices of severity and disease activity for osteoarthritis. *Semin Arthritis Rheum.* 1991;20(6 Suppl 2):48–54.
14. Shepstone L, Rogers J, Kirwan JR, et al. Shape of the intercondylar notch of the human femur: a comparison of osteoarthritic and non-osteoarthritic bones from a skeletal sample. *Ann Rheum Dis.* 2001;60:968–973.
15. van Eck CF, Martins CAQ, Vyas SM, et al. Femoral intercondylar notch shape and dimensions in ACL-injured patients. *Knee Surg Sports Traumatol Arthrosc.* 2010;18:1257–1262.
16. Sutton KM, Bullock JM. Anterior cruciate ligament rupture: differences between males and females. *J Am Acad Orthop Surg.* 2013;21:41–50.
17. van Eck CF, Martins CA, Lorenz SG, et al. Assessment of correlation between knee notch width index and the three-dimensional notch volume. *Knee Surg Sports Traumatol Arthrosc.* 2010;18:1239–1244.
18. Sonnery-Cottet B, Archbold P, Cucurulo T, et al. The influence of the tibial slope and the size of the intercondylar notch on rupture of the anterior cruciate ligament. *J Bone Joint Surg Br.* 2011;93:1475–1478.
19. Park JS, Nam DC, Kim DH, et al. Measurement of knee morphometrics using MRI: a comparative study between ACL-injured and non-injured knees. *Knee Surg Relat Res.* 2012;24:180.
20. Domzalski M, Grzelak P, Gabos P. Risk factors for anterior cruciate ligament injury in skeletally immature patients: analysis of intercondylar notch width using magnetic resonance imaging. *Int Orthop.* 2010;34:703–707.
21. Ireland ML, Ballantyne BT, Little K, et al. A radiographic analysis of the relationship between the size and shape of the intercondylar notch and anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc.* 2001;9:200–205.
22. Souryal TO, Freeman TR. Intercondylar notch size and anterior cruciate ligament injuries in athletes. A prospective study. *Am J Sports Med.* 1993;21:535–539.
23. Stijak L, Bumbasirevic M, Kadija M, et al. Morphometric parameters as risk factors for anterior cruciate ligament injuries—a MRI case-control study. *Vojnosanit Pregl.* 2014;71:271–276.
24. Dienst M, Schneider G, Altmeyer K, et al. Correlation of intercondylar notch cross sections to the ACL size: a high resolution MR tomographic in vivo analysis. *Arch Orthop Trauma Surg.* 2007;127:253–260.
25. Everhart JS, Flanigan DC, Simon RA, et al. Association of noncontact anterior cruciate ligament injury with presence and thickness of a bony ridge on the anteromedial aspect of the femoral intercondylar notch. *Am J Sports Med.* 2010;38:1667–1673.
26. Comerford EJ, Tarlton JF, Avery NC, et al. Distal femoral intercondylar notch dimensions and their relationship to composition and metabolism of the canine anterior cruciate ligament. *Osteoarthritis Cartilage.* 2006;14:273–278.
27. Hernigou P, Garabedian JM. Intercondylar notch width and the risk for anterior cruciate ligament rupture in the osteoarthritic knee: evaluation by plain radiography and CT scan. *Knee.* 2002;9:313–316.
28. Simon D, Mascarenhas R, Saltzman BM, et al. The relationship between anterior cruciate ligament injury and osteoarthritis of the knee. *Adv Orthop.* 2015;2015:928301.
29. Dare D, Rodeo S. Mechanisms of post-traumatic osteoarthritis after ACL injury. *Curr Rheumatol Rep.* 2014;16:448.
30. Barenius B, Ponzer S, Shalabi A, et al. Increased risk of osteoarthritis after anterior cruciate ligament reconstruction: a 14-year follow-up study of a randomized controlled trial. *Am J Sports Med.* 2014;42:1049–1057.
31. Janssen RP, du Mee AW, van Valkenburg J, et al. Anterior cruciate ligament reconstruction with 4-strand hamstring autograft and accelerated rehabilitation: a 10-year prospective study on clinical results, knee osteoarthritis and its predictors. *Knee Surg Sports Traumatol Arthrosc.* 2013;21:1977–1988.
32. Schencking M, Otto A, Deutsch T, et al. A comparison of Kneipp hydrotherapy with conventional physiotherapy in the treatment of osteoarthritis of the hip or knee: protocol of a prospective randomised controlled clinical trial. *BMC Musculoskelet Disord.* 2009;10:104.
33. Schencking M, Wilm S, Redaelli M. A comparison of Kneipp hydrotherapy with conventional physiotherapy in the treatment of osteoarthritis: a pilot trial. *J Integr Med.* 2013;11:17–25.

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