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"Floating Meniscus" a Specific Indicator of Anterior Cruciate Ligament Rupture

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Although Magnetic Resonance (MR) imaging is accurate in diagnosis Anterior Cruciate Ligament (ACL) rupture, in many cases using indirect signs are inevitable for appropriate decision-making. This study aimed to investigate the diagnostic accuracy of complete medial meniscal tear (floating meniscus) in predicting ACL rupture. In a cross-sectional, prospective study, 620 knee MR images were reviewed in Tabriz Sheikholraeis Center from September 2011 to January 2013. Cases with knee degenerative disease, articular infection, intervening fracture(s) and previous constructive surgeries on the knee were excluded. Totally, 110 cases had floating meniscus in their MR images. ACL rupture was reported in 355 cases, including 206 cases with partial and 149 cases with total subtypes. ACL rupture and floating meniscus coexisted in 97.3% of the studied cases. A floating meniscus predicted the presence of a concomitant ACL rupture with sensitivity, specificity, positive predictive value and negative predictive value of 30.1, 98.9, 97.3 and 51.4%, respectively. In conclusion, a complete medial meniscal rupture or floating meniscus is a highly specific indicator of ACL injury in patients with equivocal findings in their MR images. Unlike other suggested indirect signs of ACL rupture, floating meniscus is independent of patient's position during MR imaging.

Key words: Magnetic resonance imaging, anterior cruciate ligament, medial meniscus

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INTRODUCTION

The knees are among the most important weight bearing joints in the body and their stability is essential for a normal, independent life. The Anterior Cruciate Ligament (ACL) is 3-3.5 cm in length; arises from the posteromedial aspect of lateral femoral condyle and ends in the tibial interspinous area. This ligament injuries lead to knee instability and increased possibility of osteoarthritis. Only in the United States, there are 200000 new cases of ACL tear each year, over half of which undergo surgical repair ultimately (De Roeck and Lang-Stevenson, 2003; Sivananthan *et al*., 2012). Magnetic Resonance Imaging (MRI) is a safe and accurate method for detecting ACL injuries, with a sensitivity and specificity of 96 and 98, respectively (Vinson *et al*., 2008). Considering the anatomical position of the ACL, an oblique, sagittal image provides the best view of this ligament with MRI (Barberie *et al*., 2001). In spite of its accuracy, however, MRI may not give a detailed image of the ACL due to shortness, thinness and angulation of this ligament in superoinferior and posteroanterior directions. This shortcoming has persuaded radiologists to employ other accompanying signs such as varying posterior cruciate ligament (PCL) angle, forward sagittal dislocation of the tibia relative to the femur and peripheral longitudinal/vertical tears of the meniscus particularly when the posterior horn tear is also available to predict ACL injury when MRI findings are not completely reliable (Jabbour, 1994; Chen *et al*., 2002). The knee meniscuses are two semilunar, fibrocartilaginous, C-shape discs which are firmly attached to superior view of tibial condyles. Their superior aspects are concave and articulate with convex femoral condyles. Meniscal tears may be seen in various shapes such as longitudinal, vertical, peripheral, radial and buckling. When meniscal tear is complete, floating cartilages may be seen in the synovial fluid. This "floating" meniscus indicates a severe traumatic insult to the knee which is usually accompanied with other lesions such as ligamentous tears (Bikkina *et al*., 2005). The objective of the present study is to test the hypothesis that when a complete medial meniscal tear (floating meniscus) happens, an ACL rupture is always present.

MATERIALS AND METHODS

In this cross-sectional, prospective study, 620 MR images of the knee were reviewed in Tabriz Sheikholraeis MRI Center from September 2011 to January 2013. The exclusion criteria were: Degenerative knee disease, articular infection, interfering fractures, previous surgical repair of the knee and chronic rupture of the ACL. This study was approved by the ethics committee of Tabriz University of Medical Sciences. All MR images were reviewed by two skilled radiologists, with an "almost perfect" inter-observer agreement (Cohen's kappa = 0.89) (Landis and Koch, 1977). In case of disagreement, a third radiologist was inquired. MR imaging was performed using a Hitachi, IRIS II machine (0.3 tesla, Japan). Among the studied images, there were 110 cases with medial meniscal tear (Fig. 1). All the cases with acute (<6weeks) ACL rupture in MRI (Fig. 2) underwent arthroscopy and the presence of complete medial meniscal tear was investigated in the meantime. Documented variables obtained from MR images of the knees were: Complete medial meniscal tear, ACL rupture, joint effusion, forward sagittal dislocation of the tibia and buckling PCL.

Statistical analysis: The SPSS software version 19.0 (IBM Corporation, NY, USA) was used for data analysis. The inter-observer agreement was analyzed using Cohen's kappa statistics. Accuracy of the studied signs were examined according to the following equations:

$$\text{Sensitivity} = \frac{\text{True positive}}{\text{True positive+False negative}}$$

Fig. 1: Medial Meniscus is not visible in its anatomic location and is moved under PCL in this coronal image. Please pay attention to coexistent ACL tearing, as normal signals of ACL are absent

Table 1: Accuracy of magnetic resonance imaging findings in predicting rupture of the anterior cruciate ligament

Sign	FM	JE	FTD	BPCL
True positive	107 (17.3)	303 (48.9)	192 (31)	203 (32.7)
True negative	262 (42.3)	106 (17.1)	243 (39.2)	226 (36.5)
False positive	3 (0.5)	159 (25.6)	22(3.5)	39 (6.3)
False negative	248(40)	52 (8.4)	163 (26.3)	152 (24.5)
Sensitivity	30.1 [25.4-35.2]	85.4 [81.2-88.9]	54.1 [49-59.4]	57.2[51.9-62.4]
Specificity	98.9 [96.7-99.8]	40 [34.1-46.2]	91.7 [87.7-94.7]	85.3[80.4-89.3]
PPV	97.3 [92.2-99.4]	65.6 [61-69.9]	89.7 [84.9-93.4]	83.9[78.6-88.3]
NPV	51.4 [46.9-55.8]	67.1 [59.2-74.4]	59.9 [55-64.7]	59.8[54.7-64.8]

FM: Floating meniscus, JE: Joint effusion, FTD: Forward tibial dislocation, BPCL: Buckling of the posterior cruciate ligament, NPV: Negative predictive value, PPV: Positive predictive value, Data are presented as frequency (percentage) or percentage [95% confidence interval]

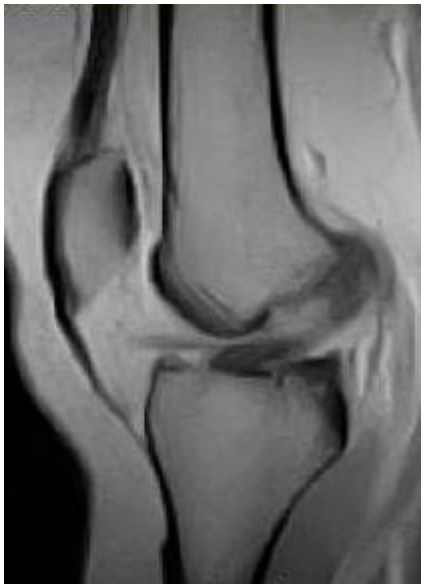

Fig. 2: ACL is torn and the course of ACL is changed and is seen more horizontal than expected. Please pay attention to its high signal on proximal half

$$\text{Specificity} = \frac{\text{True negative}}{\text{True negative} + \text{False positive}}$$

$$\text{Positive predictive value} = \frac{\text{True positive}}{\text{Positive results}}$$

$$\text{Negative predictive value} = \frac{\text{True negative}}{\text{Negative results}}$$

RESULTS

Among the studied 620 MR images of the knee, an ACL rupture was detected in 355 cases (57.3%; 206 partial, 149 complete), complete medial meniscal tear (floating meniscus) in 110 cases (17.7%), joint effusion in 462 cases (74.5%), forward sagittal dislocation of the tibia in 214 cases (34.5%) and buckling tear of the PCL in 242 cases (39%).

Accuracy of each finding in predicting ACL rupture is summarized in Table 1.

DISCUSSION

Whether a complete medial meniscal tear (floating meniscus) in MRI is an indirect sign suggestive of ACL avulsion was the main question of the present study. Since MRI has been shown to be very sensitive (86%) and specific (100%) in detecting ACL ruptures (Von Engelhardt *et al*., 2008; Van Dyck *et al*., 2010), this imaging method was considered gold standard here. In the studied sample, ACL avulsion was accompanied with floating meniscus in 97.3% of the cases. According, the sensitivity, specificity, PPV and NPV of observing a floating meniscus in predicting the presence of a simultaneous ACL rupture were 30.1, 98.9, 97.3 and 51.4%, respectively. According o available data by previous reports, a concomitant ACL rupture and medial meniscal tear may be found in 17 to 53% of MR images of problematic knees (Feagin, 1988; Remer *et al*., 1992; Binfield *et al*., 1993; De Smet and Graf, 1994; Duncan *et al*., 1995; Kruger-Franke *et al*., 1995; Seitz *et al*., 1996; Naranje *et al*., 2008). The rate of 30% in the present work lies in the reported range in the literature. Many factors may justify this wide range, such as recruiting different sample sizes, using diverse methodologies and variability in time between primary traumatic insults and MR imaging of the knees. In addition, it has been suggested that in chronic ACL injuries, possibility of a concomitant medial meniscal injury is higher than that in cases with acute ACL rupture (Keene *et al*., 1993; Winters and Tregonning, 2005). It should be reminded that only acute cases were enrolled into the present study. Although, as mentioned before, there are similar reports regarding the frequency of concomitant meniscal tear and ACL rupture, the present study is the first one which has used floating meniscus as an indirect sign of ACL rupture. Low sensitivity of indirect signs of ACL injury in MR images is not new

in the literature (Kaye, 1993; Chan *et al*., 1994; Robertson *et al*., 1994; Brandser *et al*., 1996; Lee *et al*., 1999). Although sensitivity of floating meniscus was lower than the sensitivity of other markers such as joint effusion (85.4%), forward tibial dislocation (54.1%) and buckling of the posterior cruciate ligament (57.2%), its specificity was significantly higher. This is clinically important; because in cases with both medial meniscal tear and ACL rupture rapid surgical reconstruction can avoid progression of the injury (Navarro-Holgado *et al*., 2007). On the other hand, it has been shown that presence of a secondary sign may increase self-esteem of radiologist in accurate diagnosis of actual injury in such cases (McCauley *et al*., 1994; Brandser *et al*., 1996). Like in other studies, anatomical variations (Pouriesa *et al*., 2013), age (Babaeinejad *et al*., 2011; Khodaeiani *et al*., 2012; Khodaeiani *et al*., 2013) and other unknown factors may play role in this association, which could be investigated in future studies.

CONCLUSION

Complete medial meniscal tear or "floating meniscus" in MRI patients with equivocal findings can serve as a specific indicator of ACL rupture.

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