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EFFICIENCY AND ACCURACY OF KNEE ULTRASOUND FOR DIAGNOSING ANTERIOR CRUCIATE LIGAMENT AND POSTERIOR CRUCIATE LIGAMENT INJURIES

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Abstract:

Introduction: *Knee injuries are common injuries that occur daily during sports activities and are common presentation in the emergency department. Among various knee injuries, anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are important structures as they have important biomechanical function, so their injuries are very important. That's why accurate and early diagnosis of ACL and PCL injuries are extremely important.*

Methodology: *The PubMed database was searched for studies published in the last 20 years from 1999 to 2019 which used ultrasound in diagnosis of ACL and PCL injuries.*

Results: *Knee ultrasound provides a high diagnostic value in the diagnosis of ACL and PCL injuries, especially when done by well experienced musculoskeletal radiologists.*

Conclusion and Recommendation

Ultrasound is cost-effective if compared to MRI scan and can be used as a first step of investigation in cases with suspected ACL and PCL injuries.

Key words: *Knee injuries, ACL, PCL, Ultrasound, MRI.*

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INTRODUCTION:

Knee injuries are common injuries that occur daily during sports activities and are common presentation in the emergency department [1]. Among various knee injuries, anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are important structures as they have important biomechanical function, so their injuries are very important [1]. Failure to diagnose acute injury in the ACL will result in damage to the menisci, especially the medial meniscus and the articular cartilage [2].Also, in combined ACL–PCL injuries, failure to diagnose acute injury of the PCL may lead to failure of treatment and a poor prognosis, although conservative treatment is preferred in isolated PCL tear [3]. That's why accurate and early diagnosis of ACL and PCL injuries are extremely important [2].

Regarding ACL injuries clinical examination in acute injured of the knee is not accurate because of severe pain and poor muscle relaxation. That's why early examination of ligament stability usually gives negative results [4]. ACL injuries was the cause of more than 70% of all acute hemarthrosis in young athletes [5]. Nowadays alternative non-invasive methods, like ultrasonography US and MRI, have been introduced in diagnosis of acute injuries of the AC [6].

Injury of the posterior cruciate ligament (PCL) is a relatively uncommon injury during knee trauma because it requires severe violence to the knee in order to disrupt the ligament [7]. In the acute clinical setting, diagnosis of PCL injury may be difficult at the initial physical examination. There are many clinical tests for diagnosis of PCL injuries like the posterior drawer, reverse pivot-shift, and quadriceps active drawer tests, these testes give positive results in case of a chronic injuries but usually give false-negative results in case of acute injuries [8]. physical examination during acute stag of knee injury also difficult due to swelling, hemarthrosis, pain, muscle spasm, and guarding [7]. IN addition, it will be clinically difficult to differentiate between a tear in the anterior cruciate ligament and a tear in the posterior cruciate ligament when anteroposterior instability of the knee is detected, and PCL insufficiency may be overlooked if both ligaments are torn [8].

Diagnosis of ACL and PCL injuries are initially diagnosed thorough clinical assessment of patients' medical history and physical examination tests. However, these tests have low sensitivity and highly variable [9]. Although magnetic resonance imaging (MRI) is the standard technique for the evaluation of ACL and PCL injuries, performing MRI as a routine initial technique is not cost-effective method and it is not usually available in the emergency situations [10]. Musculoskeletal ultrasonography has high diagnostic value in the emergency setting as it is accurate and take less time than other imaging techniques [11]. knee ultrasound imaging can be a better option in diagnosis of knee injuries as it has no risk of radiation exposure, cost-effective and time-effective as well. However, it has some disadvantages as it is operator-dependent technique, so some limitation appears as failure of detection, long learning curve, and limited reproducibility [12]. Ultrasound evaluation studies concerning ACL and PCL injuries have shown variable results. That's why the diagnosis of ACL and PCL through ultrasound needs further exploration, and evidences needs to be presented through recording data from previous studies [8].

METHODOLOGY:

Database used:

The PubMed database was searched for studies published in the last 20 years from 1999 to 2019 which used ultrasound in diagnosis of ACL and PCL injuries. Search terms related to ACL, PCL, and ultrasound combined with sensitivity, specificity as well.

The bibliographies of the articles identified were also screened to identify additional relevant studies. the titles and abstracts were screened for potential eligibility.

Study selection:

The inclusion criteria were the following:

1. Original research article published in the English language
2. Patients with acute knee injury alone or chronic instability or both.
3. Knee ultrasound as a diagnostic study.
4. MRI or surgical finding as the reference confirmation of the ACL and PCL injuries.

The exclusion criteria were as follows:

1. Non-human studies.
2. Case report or case series
3. Review articles, letters, and conference abstracts

RESULTS:

The electronic search initially resulted in 40 eligible articles. All the studies were screened by title and abstract for relevance, and subsequently, 23 irrelevant manuscripts were excluded. Then, 17 articles were reviewed which met the inclusion criteria. The sample sizes in the studies ranged

between 8 and 193 patients. A total of 1115 subjects were included in the 17 studies examined into the current study,11 studies including 878 patients for ACL injury, and 6 studies including 237 patients were selected for PCL injury.

Mautner et al., [13] conducted prospective cohort study, in which patients were collected from an academic sports medical center in Georgia. The study was approved from the University Institutional Review Board. Patients included in the study were between 16 and 50 years and had experienced an acute knee injury within 6 weeks. The primary care sports medicine physician had a suspicion of internal derangement of the knee like ACL, PCL or meniscus tear, all the patients had MRI of the knee. All patients underwent US examinations.

The study concluded that with MRI as the reference technique. The PCL injuries signs had the highest sensitivity (84.9%), and the notch sign had the highest specificity (93.8%). All 3 signs had high positive predictive values, ranging from 91.8% to 96.8%. The US examination was performed before the MRI, and the patient was included in the control group, as the objective was to assess the validity of indirect US signs of acute ACL tears. The 3 control patients with PCL tears had a false-positive PCL wave sign, and 2 of these patients had a false-positive capsular protrusion sign. The other control patient with a false-positive PCL sign had a bucket handle meniscus tear. There were 2 other bucket handle meniscus tears that had a negative PCL sign. One patient with a lateral meniscus tear also had a false-positive femoral notch sign.

Kumar et al., [14] conducted prospective clinical study, in which patients presenting to the outpatient clinics complaining of knee instability and/or locked knee were evaluated and enrolled in the study. All participants had informed consent for their participation and to undergo US examination and MRI. The study included 182 patients in the period between 2014 and 2016. Of all 182, 130 patients underwent all three examinations, which are the clinical examination, functional US, and MRI scan.

The results of the study showed that, the sensitivity of ACL tear which was correctly diagnosed by US was 81.65% with a specificity of 89%. Also, the positive predictive value of the test was 97.8%, and the negative predictive value of the test was 44%.

Two-tailed paired *t*-test was performed comparing various clinical tests, namely anterior drawer test, Lachman test, and pivot-shift test with anterior displacement on US examination taking 1-mm displacement as cutoff and MRI findings. Following Bonferroni correction, the statistically significant value was kept as - $P \leq 0.017$. Comparing the clinical tests with US anterior drawer test, *P* value came as 0.018015, Lachman test *P* value came 0.022758, and pivot-shift test *P* value was 0.158099. None of these clinical tests were found to be statistically significant (with a significant value of $P < 0.017$).

Comparing the clinical tests with MRI, the *P* value of pivot-shift test was 0.00001. All these tests, anterior drawer test was found to be 0.011996, that of Lachman test was 0.011996, and the *P* value was statistically significant (with a significant value of $P < 0.017$).

Wang et al., 2017 [15]conducted a study on Thirty-three patients who were clinically suspected to have PCL injuries and 30 normal participants as control group were enrolled in the study. Both groups were examined using US examination with reliability clinical testing. to prove the diagnostic criteria for posterior cruciate ligament (PCL) tear using US and the results showed that Good to excellent reliabilities were found by using 2 Dimensional US and red pixel intensity on US. In patients with knees injuries, PCL thicknesses were significantly greater, and red pixel intensities were significantly lower, compared to healthy control participants.

Palm et al., [16] underwent a study in which they measured anterior tibial translation by US in the injured and healthy knees in 41 patients with acute knee trauma. The results of study showed that if the examiner had no specialist knowledge in US, he could accurately diagnose acute ACL injuries through using functional US and that will not require additional clinical tests or MRI scan.

Sorrentino et al., [17] Conducted a study to compare high-resolution ultrasonography (HRUS) on 13 patients with a magnetic resonance imaging (MRI) for the diagnosis of PCL lesions (ten patients had acute injuries and three had chronic injuries) and 20 healthy participants as a control group, All participants had conventional and compound HRUS done by the same radiologist who was blinded to the subjects' case-control status. Either without or with compound imaging in order to evaluate the posterior

cruciate ligament (PCL) injuries. The study proved that HRUS is an accurate technique for diagnosis of the PCL injuries.

Wang et al., [18] underwent a retrospective study aimed to detect the accuracy of US examination compared with (MRI) in diagnosis of PCL tears. The study included Thirty-five patients who had traumatic knee injuries they were selected between the year 2003 to the year 2005 in the university hospital. PCL injury was detected by MRI scan. The study results showed that, from all the 35 patients, 13 were diagnosed to have PCL tears on US examination. Ten of these patients were diagnosed also by MRI. Two of 22 patients with normal PCL on US examination were diagnosed to have PCL injury following MRI. The study concluded that, there was significant matching between MRI and US results.

Khan et al., [19] conducted a study on 81 patients. The study was a double blind prospective study Between the year 1997 to the year 1999 and the result study s of the showed that ultrasound detected seven torn lateral menisci of the 8 lateral menisci which were diagnosed to be torn on arthroscopy, with a sensitivity 87.5% and specificity was 100%. While The sensitivity of MRI was 75% and specificity and 100% for lateral meniscus injuries.

Hsu et al., [20] preformed a study on Eight patients with anterior cruciate ligament injury who underwent US examination during arthroscopic examination and proved that the normal PCL appears on longitudinal US as a hypoechoic fan-shape structure. Ultrasound examination can diagnose different types of PCL lesions.

Fuchs & Chylarecki [21] conducted a prospective study on 193 patients to detect the three indirect criteria of ACL rupture which are S-shaped thickening of the PCL, echo-poor space at the femoral insertion of the ACL and protrusion of the posterior fibrous capsule. The study concluded that echo-poor space at the femoral insertion has a great significance in diagnosis, for ACL rupture the study showed that sensitivity was 0.91 and specificity was 0.80, sensitivity was 0.68 for protrusion of the posterior fibrous capsule and specificity was 0.77. However, the combination of both criteria increased the sensitivity of US to 0.98, although the specificity will decrease to less than 0.50. finally, the study concluded that the US examination with the three indirect signs of ACL tear has a very high diagnostic value in the acute knee injury.

Cho et al., [7] performed US images in 30 knees for 15 asymptomatic volunteers as a control group and also performed US in 35 patients who was clinically complaining of an acute PCL injury. In this study, the distal half only of the PCL was evaluated. From all the 35 patients, 28 participants had their PCL status confirmed and13 patients had a normal PCL at magnetic resonance (MR) imaging together with clinical examination, and 15 patients had a torn PCL at both MR scan and surgery or MR scan and clinical examination.

The study results claimed that US findings in cases of torn PCL in the 15 injured patients were as follows: (a) The mean thickness was 15.6mm; P, .01, (b) (80%) of the 15 patients the echogenicity was heterogeneously hypoechoic and (c) (73%) of the 15 patients had indistinct posterior margin of the ligament. The injured PCL was significantly thicker compared with that in the 13 patients who were confirmed as having normal anatomy with MR imaging and clinical data and with that in the volunteers. Surgery and/or MR scan in the 15 participants who had torn PCL, found that seven patients had tears in the middle third, five patients had tear in the distal third, and 3 patients had tears in the proximal third. US showed that thickness of the torn PCL was increased regardless the site of the tear. Of All 15 participants, Hematoma formation near the PCL was seen at US in three patients with PCL tears. Also, a transverse hypoechoic defect representing the tear was demonstrated at US in four patients.

Larsen & Rasmussen., [22] conducted a study in the period between 1996 and 1997 in which 62 patients with a knee trauma were included in the study, all patients had a US examination on the knee. The study included 21 women and 41 men between 11 and 62 years (mean 29.2 years). The patients were recruited from accident and emergency department of the hospital. The inclusion criteria were injury of the knee within the preceding 3 weeks with symptoms and clinical signs of hemarthrosis, no history of previous injury to the same knee, and no bone abnormality on plain radiographs.

The results of the study proved that, Arthroscopy or clinical examination showed a rupture of the Anterior Cruciate Ligament in 16 cases. US examination detected 14 of these ruptures. There were two missed cases with US. Also, 46 patients did not have an ACL rupture through arthroscopy and clinical examination. US showed negative results in 45 of these patients,

and in one case sonography clearly showed a hematoma consistent with a teared ACL. The sensitivity of US was 88%, the specificity 98% and the positive predictive values was 93 and negative predictive values and 96%.

Gebhard et al., [23] underwent a prospective clinical examination on 60 patients who had an US for the anterior stability of both knees. The inclusion criteria were acute ACL tears (group A) or arthroscopy after ACL repair (group B).

the study results showed that, in acute ACL injury there was no pain during the ultrasound examination. In group A (patients with an acute ACL lesion) the prone Lachman test with US control showed that, the mean anterior displacement was 14.1 mm (± 3.5 mm). In the group having intact internal ACL (control group), the mean anterior displacement measured 7.7 mm (± 2.9 mm) ($P < 0.001$). The supine anterior Lachman test with arthrometric control showed anterior displacement of 14.4 mm (± 3.9 mm) for the patients with knee injury and 8.3 mm (± 3.4 mm) in the internal control group ($P < 0.001$). Using US, there were no significant difference between the repaired (9.9 mm, ± 2.7) knee and its control (8.1 mm, ± 2.5) in patients of group B.

DISCUSSION:

The present study revealed that knee ultrasound was a perfect tool for the diagnosis in cases with ACL injuries with sensitivity of 88% and specificity of 96% and also PCL injuries with sensitivity of 99% and specificity of 99%.that is why knee Us is a helpful imaging technique for detection of ACL and PCL injuries.

In the past, patient with acute injuries in the knee joint who had suspected ACL or PCL injuries are initially evaluated thorough clinical physical examination [9] and stress radiographs [24]. If physician applied physical examinations there are the Lachman test, anterior drawer test, and pivot shift test used for detecting ACL tear. Although, the sensitivity of these tests are as follows, anterior drawer test (38–62%); Lachman test is (69–87%) and pivot shift test is (10–61%) and their specificity are anterior drawer test (25–92%), Lachman test (81–100%) and pivot shift test (81–99%) so, these physical examinations results varies widely [10]. however, previous studies concluded that less than 20% of patients having ACL injuries are diagnosed accurately by the use of the medical history and clinical physical examination tests during the initial presentation [25].

As regards ACL injuries, the current study claimed that US has high sensitivity and a very high specificity for diagnosing acute injuries of the ACL.

In contrast to the current study ***Jerosch et al.*** [26]and ***Tran et al***. [27] have concluded, that reliable direct visualization by US of the ACL injuries cannot be accurately done.

With regards to PCL injuries, physical examinations include many tests as, the posterior sag sign test, posterior drawer test and quadriceps active test. Similar to the tests used for ACL, these physical examinations tests for PCL injuries show variable sensitivity as follows, posterior drawer test sensitivity is about 51–90%; quadriceps active test sensitivity is about 54–98% and low sensitivity is shown in posterior sag sign (about 79%) [9]. Also, stress radiography can be done for the diagnosis of ACL and PCL injuries [24].

In accordance to the discussed studies ***lee et al.,*** [28] also found that as a point of care, US imaging of the knee in acute trauma patients can be of great help for diagnosis of ACL and PCL injuries by confirming findings of physical examinations in patients with severe pain and swelling in the knee. Also, it may lead to more accurate diagnosis and accordingly an accurate treatment plans in patients with knee trauma.

CONCLUSIONS:

- Knee ultrasound provides a high diagnostic value in the diagnosis of ACL and PCL injuries, especially when done by well experienced musculoskeletal radiologists.
- Ultrasound does not replace MRI scan but can be a guide for clinicians to decide further diagnostic tests and treatment plan in patients with acute knee trauma.
- Ultrasound signs for diagnosis of ACL and PCL injuries are easy to determine noninvasively, especially in acute cases in which the clinical examination is very painful and difficult.
- Ultrasound may help to decrease the number of missed ACL and PCL cases and can help patients in sparing unnecessary operations.
- Ultrasound is cost-effective if compared to MRI scan and can accurately and can give patients the same diagnosis of MRI in the same day and avoid the anxiety and worry with MRI scan.

Recommendations:

Ultrasound can be used as a first step of investigation in cases with suspected ACL and PCL injuries.

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