Comparison of Plain Radiograph and Computed Tomography Scan in the Evaluation of Tibial Plateau Fracture

Suwannee Surattanasophon MD[1*]

[1] Saraburi Regional Hospital, Saraburi Province, Thailand

* Corresponding author, e-mail address: patellarknee@yahoo.com

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Abstract

Objective: To compare the accuracy of radiographs (XR) imaging according to computed tomography (CT) scanning in the determination of fracture type (Schatzker classification), characteristics, and to identify indications for surgery in patients with tibial plateau fractures.

Methods: A retrospective study was conducted in 108 patients with tibial plateau fractures who underwent both radiograph and CT scan in Saraburi Regional Hospital from October 2017 to September 2021

Results: According to diagnostic concordance between XR imaging and CT scan, among the 6 types of tibial plateau fractures, type III had perfect concordance; type I, type IV and type VI had weak concordance; whereas type II and type V had minimal concordance between XR imaging and CT scan in determining the fracture characteristics with indication for surgery. For the XR findings of intra-articular displacement of ≥ 2 mm, metaphyseal-diaphyseal translation > 1 cm and angular deformity of > 10° (when compared with CT scanning), all of these three characteristic features for indication of surgery had both specificity and positive predictive value of 100%, but the sensitivity was only 43%, 52% and 56%, respectively, with negative predictive value of 62%, 88% and 88%, respectively. The concordances between XR imaging and CT scan in determining intra-articular displacement of ≥ 2 mm, metaphyseal-diaphyseal translation > 1 cm and angular deformity > 10° were weak, moderate and moderate, respectively.

Conclusion: Performing only XR imaging is insufficient to evaluate type of fracture and the indications for surgery in tibial plateau fractures, and additional CT scanning is needed for accurate assessment of severity, as well as surgical planning.

Keywords: Tibial plateau fracture, plain radiograph, CT scan

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การเปรียบเทียบผลการประเมินการหักของกระดูกทิเบียพลาโต ระหว่างการตรวจด้วยเอกซเรย์ธรรมดากับเอกซเรย์คอมพิวเตอร์

สุวรรณี สุรัตนโสภณ พ.บ.[1*]

[1] โรงพยาบาลศูนย์สระบุรี สระบุรี ประเทศไทย

* ผู้ติดต่อ, อีเมล: patellarknee@yhaoo.com

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาความแม่นยำของการใช้เอกซเรย์ธรรมดาเปรียบเทียบกับเอกซเรย์คอมพิวเตอร์ในการประเมินชนิดและรายละเอียดของการหักของกระดูกทิเบียพลาโต รวมถึงข้อบ่งชี้ในการผ่าตัด

วิธีดำเนินการวิจัย: เป็นการศึกษาย้อนหลังจากเวชระเบียนผู้ป่วย 108 รายที่ได้รับการวินิจฉัยว่ามีกระดูกทิเบียพลาโตหักที่ได้รับการตรวจด้วยเอกซเรย์ธรรมดาและเอกซเรย์คอมพิวเตอร์ในโรงพยาบาลสระบุรีตั้งแต่เดือนตุลาคม 2560 ถึงเดือนกันยายน 2564

ผลการวิจัย: เมื่อเปรียบเทียบการแปลผลด้วยเอกซเรย์ธรรมดากับผลที่ได้จากเอกซเรย์คอมพิวเตอร์ ในการวินิจฉัยการหักของกระดูกทิเบียพลาโตทั้ง 6 แบบ พบว่าความสอดคล้องในการวินิจฉัยการหักของกระดูกแบบที่ 3 มีความสอดคล้องอย่างสมบูรณ์ ส่วนแบบที่ 1,4,6 มีความสอดคล้องระดับต่ำ และแบบที่ 2, 5 มีความสอดคล้องระดับต่ำมาก ในการวินิจฉัยการหักของกระดูกทิเบียพลาโตที่มีข้อบ่งชี้ในการผ่าตัด 3 ลักษณะ ได้แก่ กระดูกในข้อเคลื่อน ≥ 2 มิลลิเมตร การเคลื่อนของกระดูกเมตาไฟซิสกับไดอะไฟซิส > 1 เซนติเมตรและการผิดรูปทำมุม > 10 องศา พบว่าทั้ง 3 ลักษณะนี้ในผลเอกซเรย์ธรรมดา มีความจำเพาะและค่าทำนายผลบวกร้อยละ 100 แต่มีค่าความไวในการประเมิน 3 ลักษณะดังกล่าว เพียงร้อยละ 43 ร้อยละ 52 และร้อยละ 56 ตามลำดับ โดยมีค่าทำนายผลลบที่ร้อยละ 62, ร้อยละ 88 และร้อยละ 88 ตามลำดับ ค่าความสอดคล้องของเอกซเรย์ธรรมดากับเอกซเรย์คอมพิวเตอร์ในการประเมินกระดูกในข้อเคลื่อน ≥ 2 มิลลิเมตร การเคลื่อนของกระดูกเมตาไฟซิสกับไดอะไฟซิส > 1 เซนติเมตรและการผิดรูปทำมุม > 10 องศา อยู่ที่ระดับต่ำ ปานกลางและปานกลาง ตามลำดับ

สรุป: การศึกษานี้แสดงให้เห็นว่า การส่งตรวจเอกซเรย์ธรรมดาเพียงอย่างเดียวไม่เพียงพอในการวินิจฉัยการหักของกระดูกทิเบียพลาโต การส่งตรวจเอกซเรย์คอมพิวเตอร์มีความจำเป็นเพื่อประเมินความรุนแรงของภาวะกระดูกหักชนิดนี้ รวมถึงการวางแผนการรักษาที่เหมาะสม

คำสำคัญ: กระดูกทิเบียพลาโตหัก เอกซเรย์ธรรมดา เอกซเรย์คอมพิวเตอร์

วันที่รับบทความ 9 พฤษภาคม 2565 **วันแก้ไขบทความ** 10 มิถุนายน 2565 **วันตอบรับบทความ** 17 มิถุนายน 2565

Introduction

Tibial plateau fractures are one of the most common injury among acute knee trauma[1], which occurs from traffic accidents, fall from height and extreme sports. These fractures demonstrate a bimodal distribution; usually affecting male in 40s, mostly due to high-energy trauma and female in 70s, due to falls. Tibial plateau fractures are divided into 6 types according to Schatzker classification, and treatment plan options are various depending on the type of fractures. Accuracy of diagnosis of tibial plateau fractures is important for the optimal choice of treatment[1-3]. Incorrect or delayed diagnosis may cause limitation of movement, knee instability, angular deformity, or persistent pain. Although, Ottawa knee and Pittsburgh knee injury rules have been applied as the clinical decision criteria to aid clinician in ordering radiography and reduce unnecessary radiation exposure[3,4-5]. However, plain radiograph (XR imaging) is still the first-line and most common used imaging modality to evaluate tibial plateau fracture[1,6-7]. In daily practice, anterior-posterior and lateral views are performed to evaluate the tibial plateau fracture[1,3,6]. Additional view, such as internal oblique, external oblique or tangential views can be performed if clinicians required[6].

Not all patients with tibial plateau fractures, are performed computed tomography (CT) scan because of the high cost and high radiation exposure. In general practice, CT scanning is requested following XR imaging to evaluate the injury[8-9] in selected patients. There are several studies comparing the value of different imaging methods in the diagnosis of knee injury such as XR imaging vs magnetic resonance imaging (MRI)[2,10], XR imaging vs ultrasonography (US)[11-13], US vs CT scan[14], CT scan vs MRI[15], US vs MRI[16], and XR imaging vs CT scan[1,5,8-9,17-19]. The aim of this study was to compare the accuracy of XR imaging according to CT scan in the diagnosis of tibial plateau fractures, and in the determination of fracture type (Schatzker classification) and fracture characteristics (intraarticular displacement, metaphyseal-diaphyseal translation and angulation deformity).

Methods

This is a single center retrospective study conducted in the patients who was diagnosed with tibial plateau fractures according to International Classification of Diseases and Related Health Problem 10th Revision (ICD10) between October 2017 and September 2021 in Saraburi regional hospital. Data were collected from the hospital automation system and PACs database, which included patient demographic data and radiographic imagings. The CT imaging studies were obtained using CT scanners (TOSHIBA, Aquillon, 160 slices, Japan) with sagittal, coronal, axial and three-dimensional reformatted images. The device used for routine XR imaging is the X-RAY device with conventional recent technology HF radiographic system. Of a total of 284 patients diagnosed with tibial plateau fractures, 108 patients underwent both XR imaging and CT scan were included in this study. Plain XR imagings and CT imagings were interpreted by a body-imaged radiologist who has eighteen years of experience. Both XR and CT imagings were reanalyzed and validated by the same radiologist. The details of data included type of tibial plateau fracture according to Schatzker classification[20], intraarticular displacement ≥ 2 mm, metaphyseal-diaphyseal translation > 1 cm and angulation > 10 degree; according to indication of surgical treatment[21] (table 1). The findings from XR imaging were compared with CT scan to determine the diagnostic accuracy. This study was approved by the Clinical Research Ethics Committee of Saraburi Regional Hospital.

Table 1:

Indication of Surgical Treatment
Intra-articular displacement of ≥ 2 mm
Metaphyseal-diaphyseal translation > 1 cm
Angular deformity of > 10° in the coronal or sagittal plane
Open fracture
Associated compartment syndrome
Associated ligament injury requiring repair
Associated fractures of the ipsilateral tibia or fibula

Statistical Analysis

Analysis of the data was performed using the Statistical Package for the Social Sciences 22 statistical software package (IBM Corporation, IL, USA). The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Kappa (k) coefficient of the XR imagings were calculated and compared to the CT scans. Concordance was graded according to the k coefficient. A k value of > 0.90, 0.80-0.90, 0.60-0.79, 0.40-0.59, 0.21-0.39, and 0-0.20 was considered as almost perfect, strong, moderate, weak, minimal, and none concordance, respectively[22]. To determine the statistical significance and assumptions of the predictions, $P < 0.05$ with 95% confidence interval was considered significant in all analyses.

Results

One hundred and eight patients examined by both XR imaging and CT scan were included in this study. The mean age of the patients was 47.65 ± 14.81 years, and 62 patients (57.4%) were female. All of tibial plateau fractures were classified according to the Schatzker classification into 6 types (fig 1) based on XR imaging or CT scan, and the results of types of fracture were compared as shown in Table 2. Tibial plateau fracture type VI, a transverse subcondylar fracture with dissociation of the metaphysis from the diaphysis, is the most common fracture type found in both XR imaging (33 patient, 30.5%), and CT scan (39 patients, 36.1%). Of the 39 patients diagnosed tibial plateau

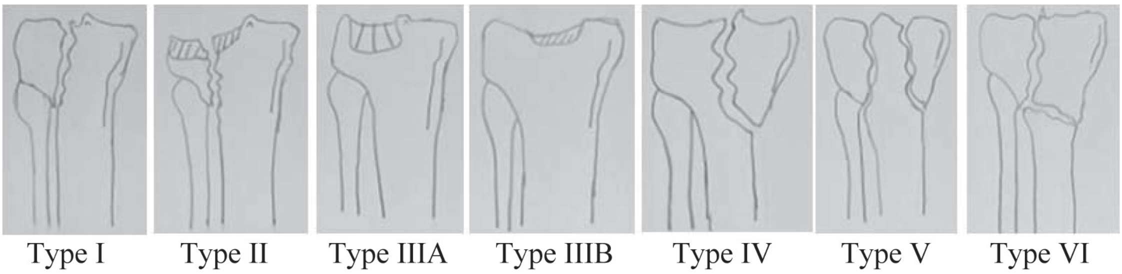

Figure 1: The classification according to Schatzker divides the tibial plateau fractures into six types: lateral split fracture (type I), lateral split fracture with depression (type II), central depression fracture (III), medial condyle fracture (type IV), bicondylar fracture (type V), and fracture with diaphyseal discontinuity (type VI) Adapted from Radiographics 2009;29:585-597

Table 2:
Comparison of the determination of the type of tibial plateau fracture between XR imagings and CT imagings according to Schatzker classification

Fracture type		CT scans							Kappa values
		I	II	III	IV	V	VI	Total	
XR imagings	I	3	6	0	0	4	0	13	0.429
	II	0	9	0	0	5	1	15	0.300
	III	1	6	9	1	1	0	18	1.00
	IV	0	0	0	10	3	2	15	0.478
	V	0	0	0	0	11	3	14	0.314
	VI	0	0	0	0	0	33	33	0.458
Total		4	21	9	11	24	39	108	0.619

fracture type VI on CT scan, 33 patients were diagnosed as the same type of fracture on XR imaging, whereas the others (6 patients, 15.4%) were diagnosed as fracture type II (1 patient), type IV (2 patients) and type V (3 patients) (fig 2, table 2). For the overall diagnostic accuracy of the type of tibial plateau fracture, there was a moderate concordance (k value = 0.619) between XR imaging and CT scan. For the diagnostic concordance between XR imaging and CT scan among the 6 types of Schatzker classification, type III had perfect concordance (fig 3), whereas type I, type IV and type VI had weak concordance, type II and type V had minimal concordance.

According to the kappa value, there was determined a weak concordance between the XR imaging and the CT scan in identifying intra-articular displacement ≥ 2 mm (k value = 0.419), moderate concordance in both angular deformity (k value = 0.662) and metaphyseal-diaphyseal translation > 1 cm (k value = 0.625). Of the total 108 patients, 56 patients had intra-articular displacement ≥ 2 mm found on CT scan, but it was only found on XR imaging in 24 patients. Compared to the CT scan in the diagnosis of intra-articular displacement ≥ 2 mm, XR imaging had sensitivity of 43%, specificity of 100%, PPV of 100% and NPV of 62% with confidence interval (CI)

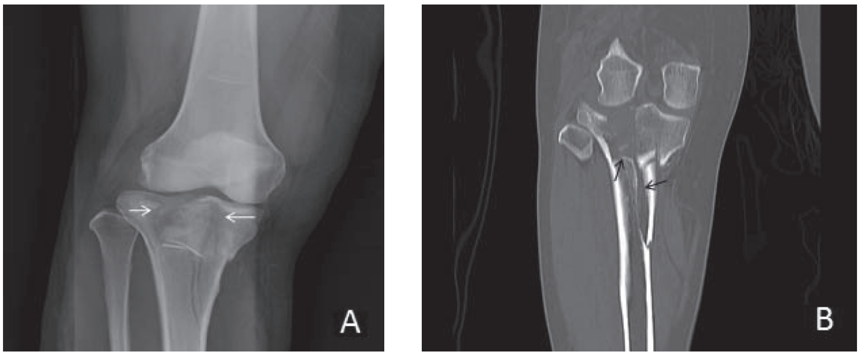

Figure 2: The right knee images of a 35-year-old female patient. (A) Antero-posterior XR image shows wedge fractures of the medial and lateral tibial plateau (white arrows), Schatzker V. (B) Coronal CT scan shows transverse subcondylar fracture with dissociation of the metaphysis from the diaphysis (black arrows), Schatzker VI.

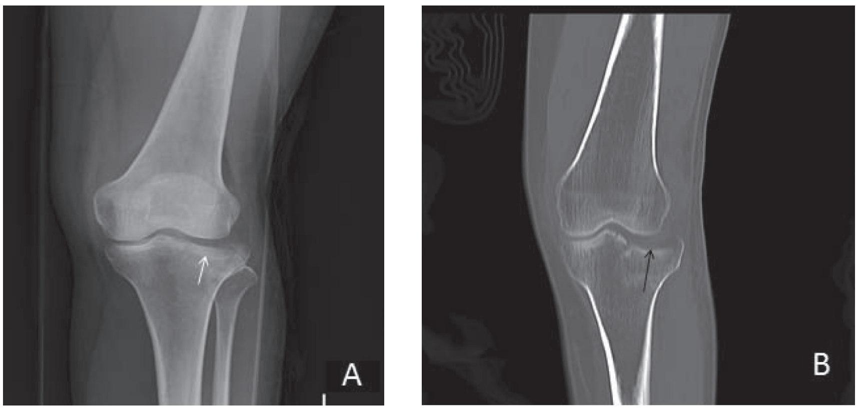

Figure 3: The left knee images of a 55-year-old female patient. (A) Antero-posterior XR image shows pure compression fracture of the lateral tibial plateau (white arrow), Schatzker III. (B) Coronal CT scan shows pure compression fracture of the lateral tibial plateau (black arrow), Schatzker III representing good concordance.

of 0.618-0.790. For metaphyseal-diaphyseal translation > 1 cm, it was found on CT scan in 25 patients and on XR imaging in 13 patients. The sensitivity, specificity, PPV and NPV of XR imaging in identifying metaphyseal-diaphyseal translation > 1 cm were 52%, 100%, 100% and 87%, respectively, with CI of 0.830-0.948. For angular deformity > 10°, it was found on CT scans in 25 patients and on XR imagings in 14 patients. The sensitivity, specificity, PPV and NPV of XR imaging in identifying angular deformity > 10° were 56%, 100%, 100% and 88%, respectively, with CI of 0.841-0.955 (table 3). The highest sensitivity of XR imaging in determining the characteristics of fractures was angulation deformity > 10° with the sensitivity of 56%, whereas the sensitivity to diagnose intra-articular displacement of ≥ 2 mm was only 43% with the lowest NPV of 62% (table 3).

Discussion

Although CT scan is an excellent tool to evaluate the tibial plateau fracture for the treatment plan. However, not all patients are examined by CT scans because of in some cases XR imaging is sufficient to evaluate the fractures, and the high cost and high radiation dose of CT scan preventing it for routine used as shown in this study that only 38% of the patients with tibial plateau fractures performing CT scans. Further investigation with CT scans is depended on the XR findings and clinical characteristics of the patients, as well as surgical planning of the orthopedists. Treatment decisions are made according to the characteristics of fractures. In partial articular fractures (Schatzker type I, II, III and some cases of type IV), articular surface restoration can be achieved via an open or a percutaneous technique, whereas in complete/complex articular fractures (Schatzker type IV, V, VI) open reduction and internal fixation (ORIF) treatment is the gold standard[21]. The indications of surgery for complicated fractures[21] are intra-articular displacement of ≥ 2 mm, metaphyseal-diaphyseal translation > 1 cm and angular deformity of > 10°.

In this study, the most common type of tibial plateau fracture was type VI (36%), which found to have a weak diagnostic concordance between XR imagings and CT scans. Of the 39 patients with diagnostic of fracture type VI on CT scans, 6 patients (15.4%) were misdiagnosed on XR imaging. For the diagnostic accuracy of the type of tibial plateau fracture, there was a poor (weak or minimal) concordance between XR imagings and CT scans in almost all fracture types, except type III (with perfect concordance). Consistent with our results, Chan PS et al[23] found single radiographs misinterpreted the fracture classification in 5% to 24% (mean 12%) and treatment plan was changed in an average of 26% of patients after performed additional CT scan. Wicky S et al[17] found CT 3D reconstructions give a better and more accurate demonstration of tibial plateau fractures, which surgical plans were modified and adjusted following additional CT administration in 59% of patients.

There was a weak to moderate concordance between XR imaging and CT scan in determining the fracture characteristics with indications for surgery. For the XR findings of intra-articular displacement of ≥ 2 mm, metaphyseal-diaphyseal translation > 1 cm and angular deformity of > 10° (when compared with

Table 3:
Diagnostic accuracy of XR imaging in determining the characteristics of tibial plateau fractures when compared with CT scans

Fracture Characteristics	Sensitivity	Specificity	PPV	NPV	Kappa values
Intra-articular displacement of ≥ 2 mm	43%	100%	100%	62%	0.419
Metaphyseal-diaphyseal translation > 1 cm	52%	100%	100%	88%	0.625
Angular deformity of > 10°	56%	100%	100%	88%	0.662

CT scan), all of these 3 characteristic features for indication of surgery had both specificity and PPV of 100%, but the sensitivity was only 43%, 52% and 56%, respectively, with NPV of 62%, 88% and 88%, respectively. The results indicated that performing only XR imaging in tibial plateau fractures is insufficient to evaluate the indications for surgery, especially in complex fractures, and may misinterprete the fracture type and treatment plan. In a study conducted in knee trauma[19], the concordance of XR imaging and CT scan in determining the fracture characteristic is moderate to strong concordance (kappa value is 0.746-0.811) and the sensitivity is between 71-78%. In one study, compared to a CT scan, the sensitivity of XR imaging in determining the angulation and the stepping off was found to be very low, as 56% and 49%, respectively[5]. In the similar study comparing XR imaging to CT scans in investigating the extension of the fracture into the joint space was found to be 48%[5]. The results of this study were consistent with these previous studies, which suggest that CT scans should be chosen because of the better visualization of the extension of the fracture into joint space. On the other hand, there is a study by Stroet MA et al[24] showing no increase in inter- and intra-agreement of additional CT scan compared to plain radiographs for the classification and treatment plan in tibial plateau fractures.

CT scan has the advantage of accurate fracture assessment and also offers additional evaluation of soft tissue injury, which was frequently found with tibial plateau fracture. Post traumatic hemarthrosis in tibial plateau fracture suggests an important intra-articular injury such as anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) disruption, which may be found in combination with other injuries[10]. Magnetic resonance imaging (MRI) may be required for the evaluation of soft tissue, and especially in patients with suspected ligament and meniscus injury.

There are some limitations in this study. First, the majority of patients (57.4%) in this study were classified into the complete/complex tibial plateau fractures group (Schatzker type IV, V, VI) resulting from a more extensive knee injury in this study population. Therefore, the results of this study may not apply to the patients with less severe knee injury. Second, this study was a retrospective study and only 38% of patients underwent both XR imaging and CT scan, resulting to loss of the data on the outcome of misdiagnosis on XR imaging in the patients performing only XR imaging.

Conclusion

Performing only plain radiographic imaging in patients with tibial plateau fracture is insufficient to determine the type of fracture and characteristics features for indications of surgery. CT scans should be performed for more accurate assessment and appropriate management in these complex injuries.

Conflict of interest

The author reports no conflict of interest.

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