Correlation Between CT Images of Lateral Plateau and Lateral Meniscus Injuries in Patients With Schatzker II Tibial Plateau Fractures：A Retrospective Study

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Research Article

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Abstract

Background: There is a great deal of controversy on whether routine MRI examination is needed for fresh fractures while the vast majority of patients with tibial plateau fractures receive preoperative X-ray and CT examinations. The purpose of the study was to analyze the exact correlation between CT images of lateral plateau and lateral meniscus injuries in Schatzker II tibial plateau fractures.

Methods: Two hundred and ninety-six Schatzker II tibial plateau fracture patients from August 2012 to January 2021 in two trauma centers were enrolled for the analysis. According to the actual situation during open reduction internal fixation (ORIF) and knee arthroscopic surgery, patients were divided into meniscus injury (including rupture, incarceration, etc.) and non-meniscus injury groups. By measuring the value of both lateral plateau depression (LPD) and lateral plateau widening (LPW) of lateral tibial plateau on the coronary CT images, the correlation of which and lateral meniscus injury was analyzed. Meanwhile, the relevant receiver operating characteristic (ROC) curve was drawn to evaluate the optimal operating point of these two indicators which could predict meniscus injury.

Results: Meniscus injury group mainly showed injuries involving the mid-body and posterior horn of the meniscus (98.1%, 157/160). The average LPD was 13.2 ± 3.2 mm, while the average value of the group without meniscus injury was 9.4 ± 3.2 mm. The difference was statistically significant ($P < 0.05$). The average LPW was 8.0 ± 1.4 mm and 6.8 ± 1.6 mm in two groups with a significant difference ($P < 0.05$). The optimal operating point of LPD and LPW was 7.9 mm (sensitivity-95.0%, specificity-58.8%, area under the curve (AUC-0.818) and 7.5 mm (sensitivity-70.0%, specificity-70.6%, AUC-0.724), respectively.

Conclusions: The mid-body and posterior horn of lateral meniscus injury is more likely to occur in patients who had Schatzker II tibial plateau fractures when LPD > 7.9 mm and/or LPW > 7.5 mm on CT manifestations and these findings will definitely provide guidance for orthopedic surgeons in treating such injuries. During the operation, more attention should be paid to the treatment of the meniscus and full consideration is needed be taken to situations such as meniscus rupture, incarceration and other possible fracture reduction difficulties, poor vertical line, etc., in order to achieve better surgical results.

Background

As we all know, tibial plateau fractures are usually accompanied with injuries of soft tissues which mainly including medial and lateral meniscus, medial and lateral collateral ligaments, and anterior and posterior cruciate ligaments. Under these conditions, early diagnosis and treatment of meniscus and ligament injuries can often provide a better prognosis of knee function [1-3]. In clinic, it is noticeable that there exists a limit of physical examinations on patients due to joint pain, swelling, and confined activity. Identifications of soft tissue damage often depend on imaging examinations and intraoperatively direct or arthroscopic explorations. In this regard, magnetic resonance imaging (MRI) has been confirmed to have unique advantages in the diagnosis of meniscus and ligament injuries of knee joint [4]. However, with respect to the high cost, examination and maintenance, long examination time, and relatively poor

timeliness of MRI, it is still not widely promoted and used in quite a number of hospitals below grade □ in China. According to the Chinese experts' consensus on the diagnosis and treatment of tibial plateau fractures published in 2015, there is a great deal of controversy on whether routine MRI examination is needed for fresh fractures while the vast majority of patients with tibial plateau fractures receive preoperative X-ray and CT examinations. In recent years, some clinical studies have pointed out that preoperative knee X-ray and CT examination can also indicate tibial plateau fracture combined with soft tissue injury, especially meniscus injury [5-11].

This study aims to combine CT examination results of patients with Schatzker II tibial plateau fractures and the injury of lateral meniscus seen during open reduction internal fixation (ORIF) and knee arthroscopic surgery. Through a morphological evaluation of lateral plateau fractures, especially the measurement of both LPD and LPW which will be used to analyze the exact correlation with lateral meniscus injury. Importantly, we tried to predict the possibility of lateral meniscus injury according to CT appearance of lateral plateau before surgery, so as to provide increasing evidence for a more comprehensive and integral treatment of bone and soft tissue injuries in Schatzker II tibial plateau fractures patients.

Methods

General data

From August 2014 to January 2021, patients with Schatzker II tibial plateau fractures were consecutively collected from two departments of orthopedics respectively. Inclusion criteria was: (1) a history of knee joint trauma, a clear diagnosis of Schatzker II tibial plateau fracture based on Schatzker classifications by X-ray and CT, and an articular surface collapse or separation distance of more than 3 cm; (2) the time from injury to operation is not exceeding 3 weeks; (3) informed consents were obtained of this study which was approved by the ethics committees of two hospitals. Exclusion criteria was also listed as follows: (1) severe bone metabolic diseases, pathological fractures, etc.; (2) periarticular fractures in ipsilateral lower limb and simple intercondylar protrusion fractures; (3) a history of tibial plateau trauma and/or lateral meniscus injury; (4) refusal of surgery for conservative treatment. Therefore, a total of 296 patients from two departments of orthopedics who had Schatzker II tibial plateau fractures met the criteria were enrolled in this study.

Surgery

All patients received preoperative X-ray and CT examinations to assess the fracture injury. At the first step, all 296 patients underwent ORIF surgery using buttress plates and crews with the objective of good reduction of the articular surface, stable fracture support and fixation, and avoidance of soft tissue complications. Exploration of lateral meniscus injury was conducted during the operation, and repairs or sutures were performed under direct vision when the anterior horn and body of lateral meniscus were found (including rupture and incarceration). Subsequently, routine inspection under knee arthroscopy is to check whether the articular surface collapse and soft tissues are well treated. If the posterior horn of

lateral meniscus or medial meniscus were injured and difficult to be repaired or shaped directly in the open incision, arthroscopic treatment was performed.

Observation index

Preoperative CT examination results of the patients were reviewed by 2 senior surgeons in each hospital, who did not know the findings of patients' physical examination or intraoperative exploration. The collapse and widening of lateral plateau of the patients were measured by Picture Archiving and Communication Systems. The main imaging measurement indexes were as follows : (1) LPD, which refers to taking the deepest layer of compression on coronal CT to measure the vertical distance from the lowest point of the collapse of the lateral plateau to the articular surface of the tibial plateau; (2) LPW, which refers to taking the widened maximum plane on coronal CT and the articular surface of medial plateau as the horizontal reference line, and then measuring the parallel distance from the vertical line to lateral femoral condyle on the outermost edge of lateral plateau fracture. The measurement schematic diagram is shown in Figure 1 and all the measurements were completed by these 4 doctors. All the imaging data were measured for three times and the average values were taken.

Statistical Methods

All data were analyzed by SPSS 25.0 statistical software. Data of normal distribution were expressed in the form of mean ± standard deviation, and the Student’s *t* test and Chi-square test were adopted. A *P*-value < 0.05 was considered statistically significant.

Results

296 patients of Schatzker II tibial plateau fractures were included in this study, of which 160 patients (54.0%) had lateral meniscus injury (including 7 patients of both medial and lateral meniscus injuries). They were incorporated into meniscus injury group with an average age of 46.0 ± 16.0 years old and the ratio of male-to-female was 88 : 72. Thereinto, there were 5, 114, and 64 patients with simple or combined injury of the anterior horn, midbody and posterior horn of lateral meniscus, respectively. The proportion of involving the midbody or posterior horn of lateral meniscus was about 97.5% (156/160) (Table 1) with 40 patients of hypertension and 16 patients of diabetes (Table 2). In addition, the average age of non-meniscus injury patients was 43.8 ± 15.2 years and the male-to-female ratio was 86 : 50. 24 hypertension patients and 8 diabetes patients were included in non-meniscus injury group (Table 2). There was no statistically significant difference between the above comparisons (P > 0.05) (Table 2). No cruciate ligament injury was found in all patients during arthroscopy and 13 patients were complicated with medial collateral ligament injury. Among them, 9 patients received conservative treatment with adjustable knee brace after surgery, and 4 patients received ligament repair.

In meniscus injury group, LPD can be obtained by measuring the coronal CT data. The minimum, maximum, and average LPD were 8.0 mm, 25.4 mm, 13.2 ± 3.2 mm, respectively. In the group without meniscus injury, the minimum and maximum LPD were 5.1 mm and 16.0 mm with an average value of

9.4 ± 3.2 mm. There existed remarkable differences of the average LPD between two groups (P < 0.001). Also, the average LPW were 8.0 ± 1.4 mm and 6.8 ± 1.6 mm in two groups, and the differences was statistically significant (P = 0.017) (Table 2).

By drawing the ROC curve, it could be found that the optimal cut-off point for LPD was 7.9 mm (sensitivity-95.0%, specificity-58.8%, AUC-0.818) (Figure 2). The optimal LPW cut-off point was 7.5mm (sensitivity-70.0%, specificity-70.6%, AUC-0.724) (Figure 3).

Discussion

The fact is that tibial plateau fractures are often combined with knee ligament and meniscus injuries. According to relevant studies, the probability of tibial plateau fracture with meniscus injury is approximately from 28.6% to 81.0% and lateral meniscus injury is dominant [5-9,11,12]. For Schatzker II tibial plateau fractures characterized by lateral spilt depression, Stahl et al. [13] have previously pointed out that there is a 45.0% possibility of lateral meniscus injury. Over the last decade or so, it is worth nothing that some clinical studies have gradually focused on the correlation between the X-ray, MRI, and CT findings of lateral plateau and the injury of lateral meniscus. By analyzing the X-ray and MRI manifestations of lateral plateau in 62 Schatzker type II fracture patients, Gardner et al. [6] found that when lateral plateau collapsed > 6 mm and the width increased > 5 mm, the positive rate of lateral meniscus injury could reach as high as 83.0%. Ringus et al. [7] also studied the CT findings of 85 Schatzker type I-VI plateau fractures, of which 21 were type II fractures. They indicated an 8-fold increase in the risk of lateral meniscus tear when the articular surface depression was ≥ 10 mm. Durakbasa et al. [5] reported 20 cases of Schatzker type II plateau fracture with lateral plateau X-ray images and intraoperative direct vision of lateral meniscus, and demonstrated that a plateau depression ≥14 mm and/or widening ≥10 mm is related with a significantly high risk of meniscus injury. Furthermore, Tang et al. [11] compared the CT presentations with arthroscopic examination results of 132 patients of Schatzker I-VI plateau fractures, among which 25 cases were type II fractures. The results showed that the positive incidence of lateral meniscus injury was about 70.3% when plateau collapsed >11mm. Kolb et al. [9] researched CT and MRI appearances of 55 patients of Schatzker type I-III plateau fractures (50 patients of type II fractures) and proposed that the probability of lateral meniscus injury increased by 40% for each 1 mm increase in LPW. Lately, a study based on the CT and arthroscopic results of 102 patients of Schatzker I-VI plateau fractures (33 patients of type II fractures) revealed a higher risk of lateral meniscus injury in patients with > 6.3 mm of lateral joint depression [8].

The results of this study are somewhat consistent with those of the above studies. In Schatzker II tibial plateau fractures, the morphology of lateral plateau is positively correlated with the injury of lateral meniscus. The mechanism is mainly due to the different position of knee joint and the axial violence of femoral condyle, which can lead to lateral plateau splitting and collapse under the action of external force. After the fracture, knee joint often undergoes varus or rotation due to the continued transmission of violence and lateral meniscus is prone to injury under stress [12]. The ROC curves for LPD and LPW show that the AUC values were 0.818 and 0.724, which implied the diagnostic value of these two indicators is

relatively high. When LPD > 7.9 mm, the positive rate for the diagnosis of lateral meniscus injury is 95.0% with the specificity of 58.8%. When LPW > 7.5 mm, the positive rate for a lateral meniscus injury diagnosis is 70.0% with a specificity of 70.6%. This retrospective study only focused on lower-energy Schatzker II tibial plateau fractures and detailedly confirmed that LPD and LW can be used as risk factors for predicting lateral meniscus injury. Accordingly, both LPD and LPW have certain specificity and sensitivity, which is of great guiding significance for the comprehensive surgical management of Schatzker II tibial plateau fracture. Because of its simple and feasible measuring method, measurement of LPD and LPW will be a kind of technical evaluation means to make up for the lack of preoperative MRI diagnosis in hospitals below Grade III.

296 Patients in our study were from two large-scale tertiary hospitals in southern Jiangsu over a long study time. The diagnosis of lateral meniscus injury in patients was made on the basis of intraoperative direct exploration and patients with a history of old meniscus injury were excluded. Still, the average age of patients was 45 years old, which can underlyingly ensure that lateral meniscus injury is caused by trauma. This is in line with the purpose of this study and the conclusions are accurate and reliable. During the operation, we found that lateral meniscus injury could occur in different locations in Schatzker II tibial plateau fracture and there were combined injuries of the anterior horn, midbody, and posterior horn in the meniscus, as well as simultaneous injuries of medial and lateral meniscus. A relatively high proportion of patients with meniscocapsular separation (ie, meniscus peripheral rim tears or avulsions) (88/160, 55.0%) is also in accordance with the results of Stahl et al [13]. Intrinsically, lateral meniscus injury majorly occurred in the midbody and posterior horn, which may be deemed as a noteworthy finding and related to the injury mechanism of such patients. The injury involving the anterior horn of lateral meniscus may be potentially caused by hyperextension and valgus knee joint during the injury process. Taking into account the concept and incidence of tibial plateau hyperextensible and valgus injury put forward by Gonzalez et al [14], we have reasons to believe that the possibility of damaging the anterior horn of lateral meniscus in type II plateau fracture is quite low. Conventional follow-up exploration under arthroscopy after internal fixation of fracture can better deal with the posterior horn of lateral meniscus, medial meniscus, ligament and other injuries, so as to achieve better soft tissue repair and avoid missed diagnosis. The surgical treatment under direct vision may be mostly meniscoplasty and meniscectomy, which is more likely to cause long-term complications after surgery. Meanwhile, the incidence of simultaneous medial and lateral meniscus injury was 4.4% (7/160). The omission of medial meniscus injury during open surgery may also be an important cause of postoperative pain in patients with Schatzker II tibial plateau fracture, which has been attaching much attention from the orthopedic surgeons.

Certainly, some limitations existed in our study. The author's subjective factors may lead to partial deviation in the measurement of LPD and LPW. Moreover, we failed to further analyze the underlying association between LPD/LPW and the pattern/type of lateral meniscus injury due to the limited sample size. The existing data on the incidence of meniscus injury associated with tibial plateau fractures was reported to be in the range of 49.0% – 91.0% by using preoperative MRI [15-17]. In spite of this, the emerging evidence suggested a lower incidence of meniscus injury requiring surgical intervention than

previously demonstrated according to MRI images before surgery [13]. Recently, Salari et al. [10] described that CT measurement of fracture location and articular impaction/displacement in tibial plateau fractures can be used to predict lateral meniscus injury with a high accuracy. With the further expansion of the sample size, the rational use of CT image analysis will provide a more accurate clinical reference for the in-depth study on the relationship between the location and pattern of meniscus injury and the morphology of tibial plateau fractures in different types.

Conclusion

In summary, the present study showed that the coronal CT morphology of Schatzker II tibial plateau fracture was tightly correlated with the lateral meniscus injury. When LPD > 7.9 mm and/or LPW > 7.5 mm, it is extremely necessary to consider the influential impact of the injury to the midbody or posterior horn of lateral meniscus on fracture reduction and soft tissue repair during the operation. At the same time, conditionally using arthroscopy after fracture fixation will be beneficial to obtain better postoperative outcomes.

Abbreviations

LPD: Lateral plateau depression; LPW: Lateral plateau widening; MRI: Magnetic resonance imaging; ORIF: open reduction internal fixation; ROC: Receiver operating characteristic; AUC: Area under the curve

Declarations

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

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Authors' contributions

YP and DXY designed, executed this study and wrote the manuscript. ZL, DWG, XY and JXW performed the material preparation, data collection and analysis. WKJ, ZYW and HZH reviewed and edited the manuscript.

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Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol was approved by the local institutional review board (Ethics committee of Changshu Hospital Affiliated to Nanjing University of Chinese Medicine and The Third Affiliated Hospital of Soochow University). In this retrospective study, written informed consent was obtained from all patients included in this study.

Consent for publication

Not applicable.

Competing interests

All authors declare that they have no competing interests.

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Tables

Table 1 Different locations and patterns of lateral meniscus injury

Locations and patterns of lateral meniscus injury	No.
Simple injury of lateral meniscus	**130**
The anterior horn	**3**
Longitudinal/oblique tears	1
Radial tears	2
The midbody	**86**
Longitudinal/oblique tears	11
Radial tears	13
Horizontal tears	8
Meniscocapsular separation	54
The posterior horn	**41**
Longitudinal/oblique tears	7
Radial tears	6
Horizontal tears	4
Meniscocapsular separation	24
Multiple injuries of lateral meniscus	**23**
Radial tears in the anterior horn and midbody	1
Longitudinal/oblique tears in the midbody and posterior horn	4
Radial tears in the midbody and posterior horn	5
Horizontal tears in the midbody and posterior horn	3
Radial tears in the midbody and meniscocapsular separation in the posterior horn	4
Longitudinal/oblique tears in the midbody and meniscocapsular separation in the posterior horn	6
Simultaneous injuries of medial and lateral meniscus	**7**
Radial tears in the anterior horn of lateral meniscus and horizontal tears in the posterior horn of medial meniscus	1
Longitudinal/oblique tears in the midbody of lateral meniscus and radial tears in the posterior horn of medial meniscus	2
Longitudinal/oblique tears in the midbody of lateral meniscus and horizontal tears in the posterior horn of medial meniscus	1

Longitudinal/oblique tears in the midbody of lateral meniscus and the posterior horn of medial meniscus	1
Radial tears in the midbody of lateral meniscus and the posterior horn of medial meniscus	1
Radial tears in the posterior horn of lateral meniscus and the midbody of medial meniscus	1

Table 2 Comparisons of general data and coronal CT results

	Lateral meniscus injury group	**Non-lateral meniscus injury group**	***P*-value**
Patients, No. (%)	160 (54.1%)	136 (46%)	
Mean age, y (SD)	46.0 ± 16.0	43.8 ± 15.2	0.681[a]
Gender, No. (Males : Females)	88:72	86:50	0.151[b]
Hypertension, No.	40	24	0.126[b]
Diabetes, No.	16	8	0.196[b]
LPD, mm (SD)	13.2 ± 3.2	9.4 ± 3.2	<0.001[a]
LPW, mm (SD)	8.0 ± 1.4	6.8 ± 1.6	0.017[a]

No. number; SD, standard deviation; LPD, lateral plateau depression; LPW, lateral plateau widening

[a]The Student's *t*-test

[b]Pearson Chi-square test

Figures

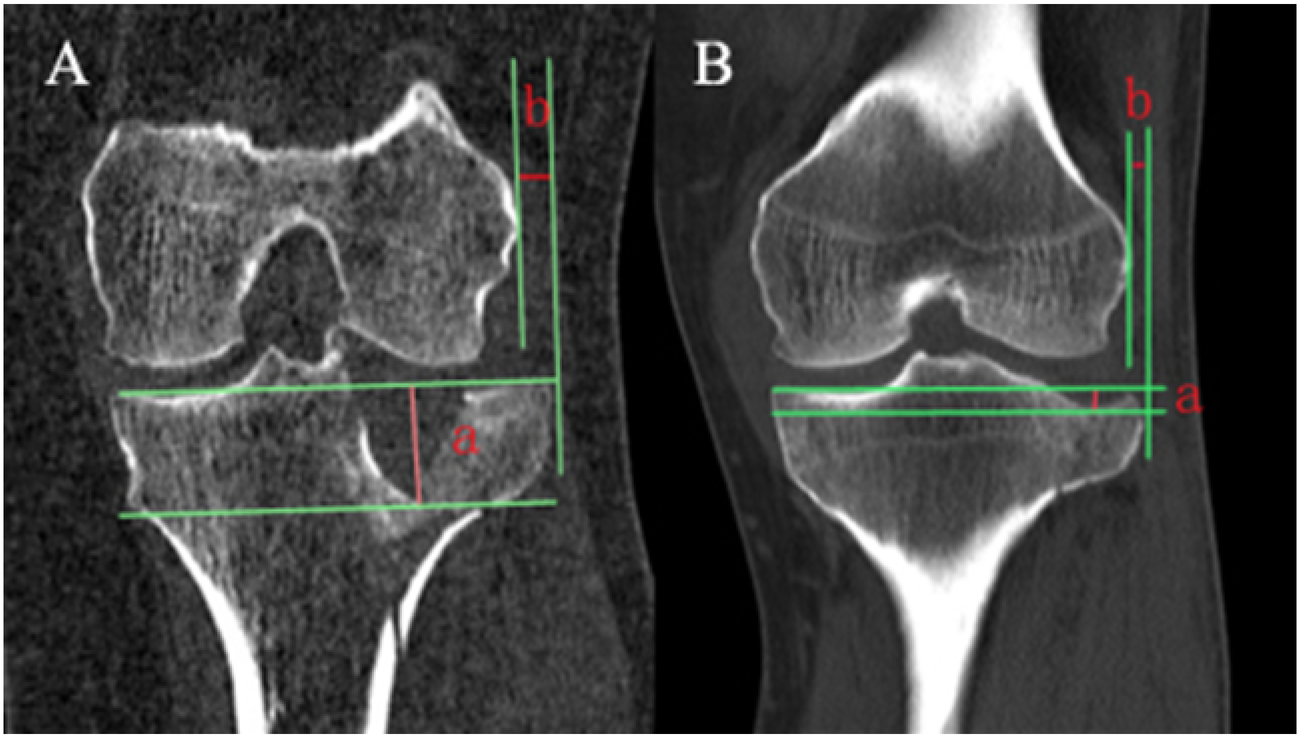

Figure 1

Measurement of LPD and LPW (A) A 41-year-old woman who had Schatzker type II tibial plateau fracture and lateral meniscus injury, a = LPD (19.2mm), b = LPW (5.2 mm); (B) A 45-year-old man who had Schatzker type II tibial plateau fracture without lateral meniscus injury, a = LPD (4.1mm), b = LPW (3.9 mm).

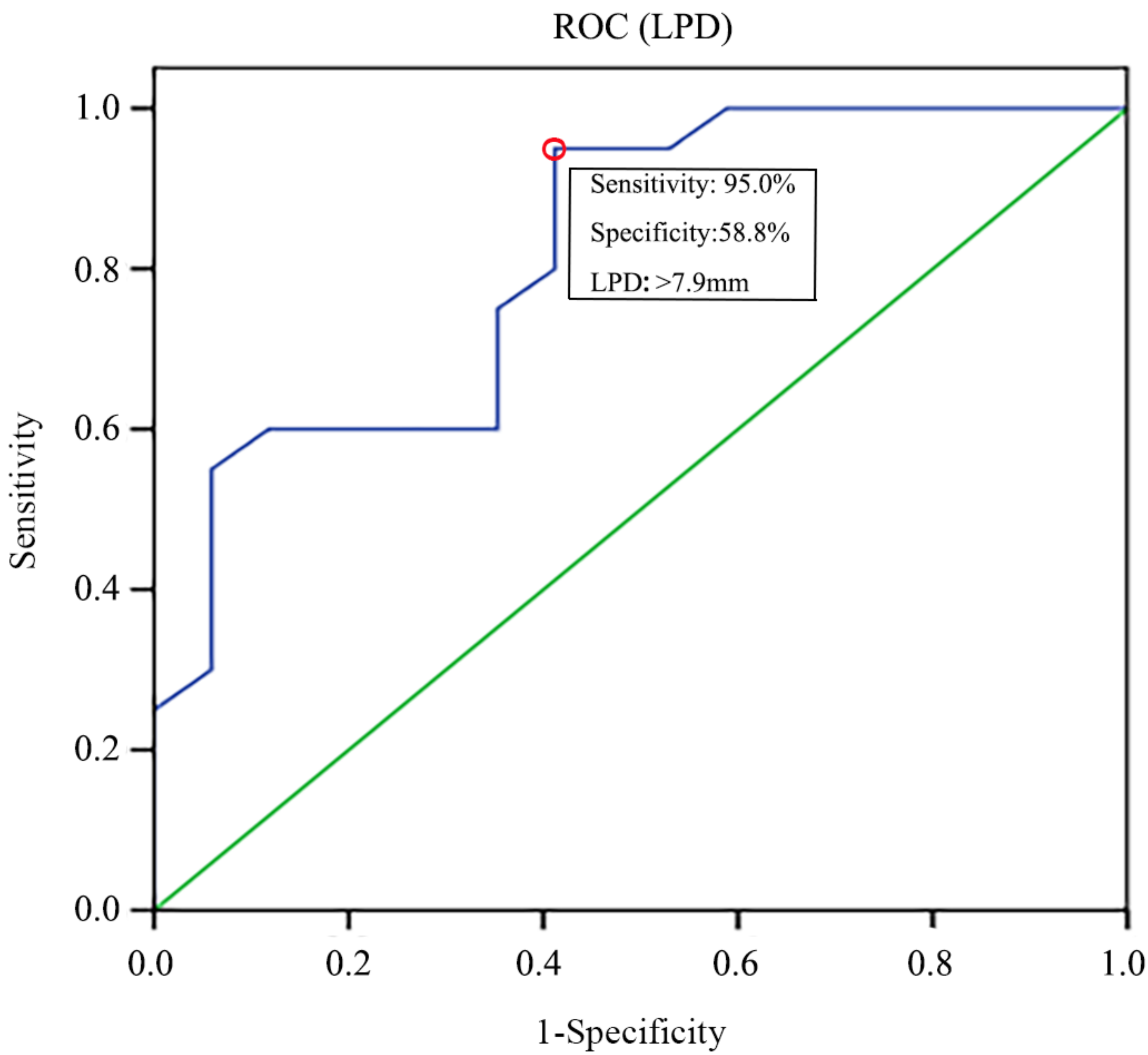

Figure 2

ROC analysis of LPD to predict lateral meniscus injury in Schatzker type II tibial plateau fracture patients.

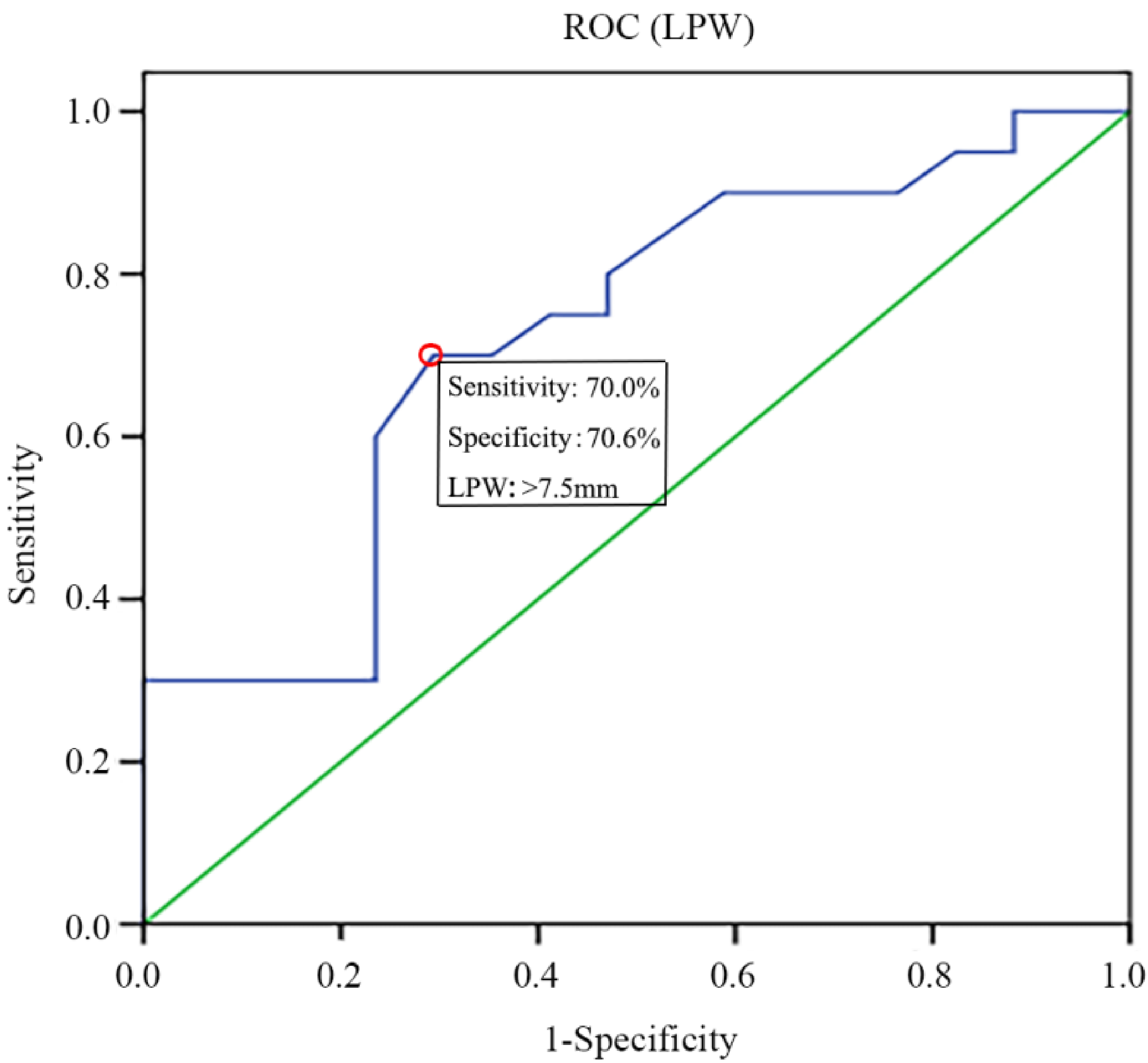

Figure 3

ROC analysis of LPW to predict lateral meniscus injury in Schatzker type II tibial plateau fracture patients.