석 사 학 위 논 문

Valid diagnostic parameters in static bilateral CT scan for predicting unstable syndesmotic injury in ankle fracture

계 명 대 학 교 대 학 원

의 학 과

권 혁 준

지도교수 이 시 욱

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이 논문을 석사학위 논문으로 제출함

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의학과 정형과학 전공

권 혁 준

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주 심　　송 광 순

부 심　　이 시 욱

부 심　　박 철 현

계명대학교 대학원

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1. Introduction

Syndesmotic injuries in ankle fractures are common, with around one-third of ankle fracture patients experiencing this type of injury.[1-3] Although x-ray is the standard for measuring tibiofibular clear space (TFCS) and tibiofibular overlap (TFO),[4-6] X-ray images show only one side of the ankle structure. Fractures around the tibia and fibular, however, may result in various clinical features that complicate plain radiography diagnoses. Another diagnostic tool is intraoperative external rotation stress test or hook test,7,8) but this too has its own limitations, as it requires anesthesia.

On the other hand, computed tomography (CT) scan has recently been showing potential in diagnosing fracture patterns and associated syndesmotic ankle injuries. CT scans provide much information on the fracture patterns, and a clear visualization of the bones and surrounding anatomic structures; it also provides a contralateral ankle image as a template of a patient's uninjured anatomy.[9,10] In particular, the role of axial CT image is sensitive at detecting rotational malreduction.[11]

Recent studies tudies have introduced several parameters in CT scans to determine diastasis in a syndesmotic injury, but their results concerning the diagnostic sensitivity and specificity of CT in an ankle fracture have been inconsistent.

TFCS and TFO are relatively well-known measurements that can be acquired from plain radiography.[4,12] Some studies aimed to provide parameters in CT scans. Parameters such as anterior fibular distance (AFD), posterior fibular distance (PFD), anterior translation distance (AT), fibular diastasis (FD), anterior-posterior translation (APT), and fibular length (FL) were thus introduced.[13,14] However, these parameters still have limits and remain inconsistent regarding their reliability for predicting syndesmotic ankle injury.[15−17] The differences in reported values may be the result of methodological differences in research designs, in techniques used to produce the measurements, measurement errors, or the differences between the characteristics of the patients' population.

Although the CT scan is thought to be a valid method for detecting syndesmotic injury, there was no substantial attempt to evaluate the diastasis using the surface area. We thus introduced here a new parameter that applies 2-D information. Based on our investigation, measured values from X-rays and CT scans would provide similar consistency and accuracy about syndesmotic injury in an ankle fracture as that of an intraoperative stress test. This study aimed to evaluate valid and reasonable parameters to predict unstable syndesmotic injury using static CT scan.

2. Methods

From 2008 to 2017, 70 consecutive cases among data from 450 surgical patients with ankle fracture were included for retrospective study. Patients who had to undergo conservative management such as using casts or splints were excluded; additionally, the study had two exclusion criteria: (1) patients with unilateral CT scan; and (2) patients whose fracture images cannot be measured in CT scans such as fractures with dislocations or highly comminuted fracture patterns. Thus, seventy patients with bilateral CT scans were included to compare the intact side with the injured side. All patients with ankle fractures were diagnosed through detailed documentation of medical history, physical examination, and radiographic study.

2.1. Radiologic Measurements

We reviewed preoperative X-rays and bilateral ankle CT scans. CT scans were acquired using a Siemens SOMATOM Sensation 64-slice CT scanner (Siemens, Erlangen, Germany) and a standard ankle coil with 1- or 2-mm sliced cuts. Imaging was first performed in the standard axial, coronal, and sagittal planes. TFCS and TFO were measured from the X-ray; the AFD, PFD, AT, FD, APT, and FL[13,14,17] were measured in preoperative bilateral CT scans.

The study also employed a new parameter to evaluate syndesmotic injury—the surface area of syndesmosis (SAS) (1 cm and 1.5 cm above the ankle joint line) between the tibia and the fibula. The SAS was measured manually between four anatomic landmark lines on the axial CT image (see Fig. 1):

The SAS was measured manually between four anatomic landmark lines on axial CT image;

(i) A line that links the most anterior aspect of fibular (B) and anterior colliculus of tibia (A).

(ii) A line that links the most posterior aspect of fibular (D) and posterior colliculus of tibia (C).

(iii) A line of medial cortex of fibular (iv) A line of incisura fibularis tibiae The penetrating angles were measured using the extended line which was used to measure the FD

2.2. Operative Technique and Intraoperative Evaluation of Syndesmotic Injury

An unstable syndesmotic injury was confirmed under anesthesia with an external rotational stress test after plate fixation of the fibular fracture by a single surgeon. The surgeon was blinded to previous information collected from CT scans.

All patients laid supine as routine drap was applied. During the external rotation stress test, the tibia is stabilized while the foot is neutrally flexed and externally rotated under fluoroscopy. A positive external-rotation stress test, indicated by a widened tibiofibular clear space of more than 5 mm, suggests syndesmotic injury.[7)] For the hook test, the surgeon pulled the lateral malleolus with a bone hook while stabilizing the tibia. Lateral fibula movement of more than 2 mm indicated a positive hook test.[8)]

Twenty patients found to have unstable syndesmotic injury were treated with open reduction and internal fixation followed by transfixing a 3.5- or 4.5-mm cortical screw or TightRope® (Arthrex, Naples, FL).[18)] Under fluoroscopic guidance or open surgery, syndesmosis was reduced and maintained by an assistant, with clamps used occasionally to maintain reduction. Four cortices were drilled, and then a 4.5-mm long cortical screw or tight rope was inserted, parallel to the distal tibia joint line and anterior from the fibular to the tibia. The other 50 patients with stable syndesmosis did not require tibiofibular transfixation.

All 70 patients were classified into two groups: Group A, whose intraoperative stress tests were positive and required transfixation during treatment; and Group B, whose intraoperative stress tests were negative and did not require transfixation.

2.3. Statistical Measurement

Statistical analyses were performed using SPSS software 21.0 (SPSS Inc., Chicago, IL). Mann-Whitney test was used to compare the absolute difference between groups A and B. The receiver-operating characteristic curve (ROC) was also analyzed to find the ideal parameter. Statistical significance was set at a p value of <0.05.

3. Results

The patients' mean age was 51.0 years (range: 18–78 years), with 41 males and 29 females. The affected limbs were 26 left-side ankles and 44 right-side ankles, all of which were from four found causes for ankle fracture: so called, slip-and-fall injury (43 cases) and compression injury from heavy objects (5 cases), as well as from a traffic accident (18 cases) and falling from a height (4 cases) (Table 1).

Statistically significant differences were found between the ratio (injured/uninjured) of TFO ($p=0.001$), PFD ($p=0.047$), APT ($p=0.044$), FD ($p=0.003$), and SAS ($p=0.002$) of the two groups. Group A showed statistically significant difference, compared to those of Group B (Table 2).

Through ROC curve analysis, the SAS measurement ratio was found most reasonable for predicting transfixation (95% confidence interval = 0.598–0.869; cut-off value = 1.555).

4. Discussion

Syndesmotic injury in ankle fractures are initially observed through plain X-rays as they are believed to provide sufficient information for diagnoses.[5] Results of our study confirm that TFO and TFCS are prominent parameters for diagnosing syndesmotic injury, as those can be measured through X-rays. However, some syndesmotic injuries in ankle fractures are occasionally concealed or overlooked in a plain X-ray.[19] Specifically, tibia and fibula displacement involving anterior-posterior (AP) direction is not sufficiently observable in an AP view of X-ray.[15] For cases like this, CT scans can be a diagnostic tool for presenting morphologic information as well as providing measured quantitative data to predict a syndesmotic ankle injury.[12,20,21]

Although acquiring quantitative measurements from CT scans may vary on inspectors, it can nevertheless show more insightful spatial anatomic information compared with a plain X-ray. As ankle fractures can result in various patterns and disintegrations of anatomical structures, plain X-ray may thus be insufficient for a comprehensive understanding of the structure. These advantages leverage CT scan as a valuable method for ankle fracture diagnosis, screening, and follow-up.

The question of which diagnostic parameter is most accurate remain controversial.[13,17] Because of the highly individual variations of measurements and discrepancies between image and intraoperative inspections of syndesmotic injuries, several studies have adopted different tools for optimal diagnosis.

However, preoperatively diagnosing a syndesmotic injury of an ankle fracture provides various advantages for predicting overall outcome, enabling advanced preparation. In this study, we found TFO, PFD, FD, APT, and SAS as those with the highest potential in such preoperative diagnosis, regardless of differences among individuals.

The introduction of SAS was a trial to utilize the 2-D image information in evaluating ankle fractures with syndesmotic injury. SAS was introduced with the speculation that a 2-D surface area would stand out better in the spatial comprehension of anatomic structures between the tibia and the fibula.

We believe that SAS ratio can be a useful diagnostic confirmation parameter for syndesmotic injury. Approximately, a >1.555 ratio holds promise as diagnostic information in patients with ankle fractures (Table 3).

Our study can be used not only in making preoperative decisions on whether or not transfixation is necessary, but also to confirm the justification of a postoperative transfixation of ankle fracture as well.

There are some limitations to this study. First, the surgeon who performed diagnostic physical examination (external rotational stress test or hook test), was aware of previous patient information (X-ray measurements and CT scans), including clinical information and radiological examinations. Second, this study did not look into the measurement level. Similar with previous studies, our measurements were performed at 1-cm above the ankle joint line. Further studies will thus require larger cohorts with different levels of measurements and analysis between them. Third, it was possible that the measurements were not precise as this study did not estimate inter- and intra-observer reliability.

Said future studies with larger cohorts, valid parameters, and different measurement levels that also apply volumetric measured values in a 3-D context may provide more information, as in correlative to the actual aspect of syndesmosis in ankle fractures.

Also, this study focused on diagnosis and methods for assessing syndesmotic injury, not clinical outcome. Several studies and literature have already discussed the importance of tibiofibular syndesmotic ligament and its restoration in ankle fracture, while Warner et al.[22] stated that the quality of syndesmotic reduction did not significantly influence clinical outcome. A study with a longer replication period, which would make it possible to correlate the result with the clinical and the functional outcome, would provide surgeons with better suggestions in deciding syndesmotic injury fixation.

Table 1. Patient data.

	Group A (n=20)	Group B (n=50)
Sex (male:female)	14:6	27:23
Mean age (yr)	46.4	52.9
Side of injury		
Right	11	33
Left	9	17
Body mass index (kg/m^2)	24.05	24.69
Height (cm)	167.9	163.32
Duration since trauma till operation (days)	7.57	5.02
Mechanism of injury		
Traffic accident	8	10
Slip-and-fall	7	36
Fall from a height	3	1
Compression	2	3
Involved cortex		
3 cortices	3	4
4 cortices	8	11

Table 2. Ratio of measurements of ankle with syndesmotic injury (injured) and intact ankle (uninjured).

Radiologic reference line	Group	Mean (Injured/Uninjured)	SD	p-value
TFO	A	0.57	0.27	0.001
	B	0.87	0.39	
TFCS	A	1.51	0.87	0.131
	B	1.14	0.53	
AFD	A	1.32	0.47	0.110
	B	1.15	0.51	
PFD	A	1.25	0.52	0.047
	B	1.04	0.29	
AT	A	1.22	0.44	0.178
	B	1.13	0.61	
FD	A	1.78	0.99	0.003
	B	1.12	0.38	
APT	A	1.16	0.27	0.044
	B	1.01	0.18	
Fibular length	A	1.01	0.11	0.104
	B	1.09	0.20	
SAS	A	1.98	0.98	0.002
	B	1.41	0.33	
SAS1.5	A	1.47	0.58	0.125
	B	1.29	0.48	

Group A: treated with transfixation, Group B: not treated with transfixation.
AFD: anterior fibular distance, PFD: posterior fibular distance, AT: anterior translation distance, FD: fibular diastasis, APT: anterior-posterior translation, SAS: surface area of syndesmosis, SAS1.5: surface area of syndesmosis in 1.5 cm above the ankle joint.

Table 3. Absolute value of ankle measurements with syndesmotic injury (injured) and intact ankle (uninjured).

Radiologic reference parameter	Sensitivity	Specificity	Cut-off value
TFO	0.920	0.500	0.52
PFD	0.800	0.600	1.060
APT	0.650	0.580	1.055
FD	0.850	0.460	1.000
SAS	0.650	0.820	1.555

TFO: tibiofibular overlap, PFD: posterior fibular distance, FD: fibular diastasis, APT: anterior-posterior translation, SAS: surface area of syndesmosis.

Table 4. Absolute value of ankle measurements with syndesmotic injury (injured) and intact ankle (uninjured).

Radiologic reference parameter	Area	Standard error	Significance probability	Approximate 95% confidence interval	
				Lower limit	Upper limit
TFO	0.245	0.068	0.001	0.112	0.378
PFD	0.653	0.071	0.047	0.513	0.793
APT	0.655	0.078	0.044	0.501	0.809
FD	0.732	0.067	0.003	0.600	0.863
SAS	0.734	0.069	0.002	0.598	0.869

TFO: tibiofibular overlap, PFD: posterior fibular distance, FD: fibular diastasis, APT: anterior-posterior translation, SAS: surface area of syndesmosis

Figure legends

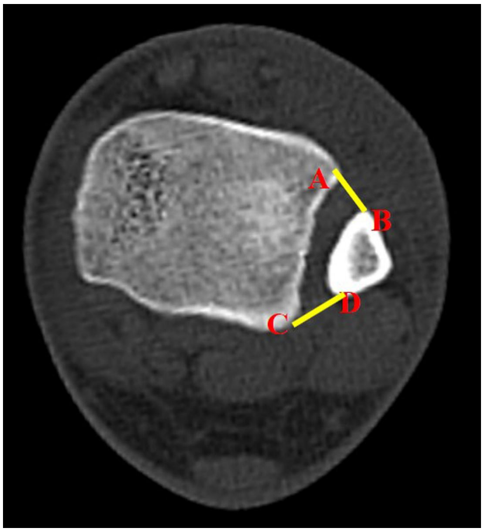

Fig. 1. Axial CT scan images at 1 cm proximal to the tibial plafond; the ankle at neutral position.

5. Conflict of Interest

All authors were involved in this study and the preparation of this manuscript. The material within this manuscript has not been, and will not be, submitted for publication elsewhere.

No source of funding was required for this study or for the preparation of the document. The authors declare that they have no conflicts of interest.

6. Abstract

Valid diagnostic parameters in static bilateral CT scans for predicting unstable syndesmotic injury in ankle fracture

Kwon, Hyuk Jun
Department of Orthopedic Surgery
Keimyung University Graduate School

Background: This study aims to evaluate valid and reasonable parameters for predicting syndesmotic injury in ankle fracture.

Methods: Seventy consecutive patients who underwent preoperative bilateral computed tomography (CT) scans were included in this retrospective study. In the preoperative X-ray, tibiofibular overlap (TFO) and tibiofibular clear space (TFCS) were measured. In the preoperative CT scan, anterior fibular distance (AFD), posterior fibular distance (PFD), anterior translation distance (AT), fibular diastasis (FD), anterior-posterior translation (APT), fibular length (FL), surface area of syndesmosis (SAS), and surface area of syndesmosis at 1.5 cm above the ankle joint line (SAS1.5) were measured. The ratio of the injured side and the intact side were calculated.

Result: Statistically significant differences were found between the ratio (injured/uninjured) of TFO, PFD, APT, diastasis, and SAS of the two groups. The group that required transfixation showed a statistically significant difference, compared with the group that did not require transfixation. Other measurements did not show significant difference. Through a receiver operating characteristic (ROC) curve analysis, SAS was found as the most reasonable ratio of measurement for predicting transfixation (95% confidence interval = 0.598–0.869; cut-off value = 1.555).

Conclusion: Measuring TFO, PFD, APT, diastasis, and SAS from CT scans and comparing them with uninjured side preoperatively can provide surgeons reasonable justification to perform transfixation intraoperatively.

Keyword: ankle fractures, syndesmotic injuries, Computed Tomography

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8. Author Biography

Date of birth : 1991. 02. 24.

Place of birth : Daegu

Graduated from Keimyung University School of Medicine Schools

Resident of Keimyung University Dongsan Hospital, Department of Orthopedic Surgery