Semi-automated 3D Distance Mapping of Conventional Non-Weightbearing CT scan with External Rotation Stress demonstrates High Diagnostic Accuracy for Subtle Syndesmotic Instability

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INTRODUCTION:

Ankle sprains account for 40-60% of all athletic injuries. Furthermore, subtle syndesmotic instabilities are often under-diagnosed and pose long-term implications for ankle joint health. Conventional imaging modalities like x-ray, CT, and MRI have limitations in accurately diagnosing these subtle injuries. Weightbearing CT (WBCT) shows promise, but access is still limited. Developing a diagnostic tool based on conventional CT could have significant implications for treating syndesmotic injuries. While previous studies have assessed the diagnostic accuracy of conventional CT in patients with syndesmotic instability, the measurements were obtained manually and only at 1 cm proximal to the tibiotalar joint. Therefore, this study aimed to develop a semi-automated 3D distance mapping algorithm and scan protocol using conventional CT to detect subtle syndesmotic instability.

METHODS:

Forty-five patients with rotational ankle injuries (21 syndesmotic injuries and 24 lateral collateral ligament injuries) were identified from an outpatient orthopedic clinic between September 2018 and April 2021. Diagnoses were confirmed via MRI. Each patient underwent three CT scan protocols: neutral position, 45° external rotation with dorsiflexion and extended knees (Stress B), and 45° external rotation with dorsiflexion and flexed knees (Stress C) (Figure 1A). A firm elastic band maintained knee position during scans. Semi-automatic segmentation was performed using DISIOR Bonelogic 2.0 software, with manual corrections in 3D Slicer. Distance mapping enabled the analysis thousands of measurements over tibiofibular interface and ankle gutters (Figure 1B). The syndesmosis was sectioned at 1 cm, 3 cm, and 5 cm proximal to the tibiotalar joint, and into anterior and posterior regions (Figure 1C). Distances were compared to the contralateral ankle, such that each patient served as their own internal control. Diagnostic accuracy was assessed with ROC curves and AUC, using the DeLong test for comparisons and Youden's J index for cutoff thresholds ($\alpha = 0.05$).

RESULTS:

Patient characteristics in the syndesmosis and LCL groups were similar (Table 1). However, LCL patients had a significantly longer wait after their last sprain before receiving a CT and were significantly more likely to have had more ankle sprains than the syndesmosis group. Significant differences were observed between syndesmotic and LCL injuries at 1 cm, 3 cm, and 5 cm proximal to the tibiotalar joint under stressed positions. The highest diagnostic accuracy was noted at 1 cm and 3 cm within the syndesmotic incisura, with AUC values of 0.91 for Stress B at 1 cm (Figure 1D) and 0.92 for Stress B and C at 3 cm (Figure 1E). In the anterior syndesmotic incisura, AUCs were 0.83 for Stress B and 0.89 for Stress C at 1 cm (Figure 1F), and 0.85 for Stress B and 0.93 for Stress C at 3 cm (Figure 1G), while the AUCs for neutral position at these same heights were 0.54 and 0.6, respectively. AUCs of 0.90 for Stress B and 0.83 for Stress C were observed in the posterior gutter medial to the talus.

Figure 1: (A) Schematic of three CT protocols: neutral position (a & b); 45° external rotation with dorsiflexion and extended knees (Stress B) (c & d); and 45° external rotation with dorsiflexion and flexed knees (Stress C) (e & f). (B) Semi-automatic CT scan segmentation and distance mapping of the Syndesmosis. (C) Sectioning of the Syndesmosis into anterior and posterior regions at 1 cm, 3 cm, and 5 cm, and medial and lateral talar gutters. (D) ROC curves of mean difference within the Syndesmosis at 1cm for neutral (red), Stress B (blue), and Stress C (green) CT protocols. (E) ROC curves of mean difference within the Syndesmosis at 3cm for neutral (red), Stress B (blue), and Stress C (green) CT protocols. (F) ROC curves of Anterior Syndesmosis difference at 1cm for neutral (red), Stress B (blue), and Stress C (green) CT protocols. (G) ROC curves of Anterior Syndesmosis difference at 3cm for neutral (red), Stress B (blue), and Stress C (green) CT protocols.

DISCUSSION AND CONCLUSION:

This proposed automated 3D distance mapping CT algorithm, enhanced by external rotational ankle stress maneuvers, demonstrates high diagnostic accuracy in detecting subtle syndesmotic instability, effectively distinguishing between syndesmotic and LCL injuries. Specifically, the stress positions at 1 and 3cm within the anterior syndesmosis demonstrate a superior ability to differentiate between syndesmotic and LCL injury versus the neutral position, while maintain a very high degree of diagnostic accuracy. Crucially, this study suggests that WBCT may not be essential for diagnosing subtle syndesmotic instabilities, as conventional CT imaging with external rotational stress can achieve high diagnostic accuracy. This finding is particularly important for clinics without access to WBCT, offering a cost-effective and widely accessible alternative. Further validation of this algorithm in larger and more diverse patient populations is warranted to confirm its clinical utility and to establish standardized protocols for widespread adoption. Additionally, integrating this approach into

routine clinical practice could streamline the diagnostic process, reduce the time to diagnosis, and ultimately improve patient outcomes by facilitating timely and appropriate interventions for syndesmotic injuries.

TABLE 1: PATIENT CHARACTERISTICS

CHARACTERISTIC	Lateral Collateral, N=24[1]	Syndesmotic, N=21[1]	p-value[2]
SIDE AFFECTED BY SPRAIN			0.3
LEFT	10 (42%)	12 (57%)	
RIGHT			
AGE	34 ± 11	39 ± 8	0.2
GENDER			0.27
FEMALE	17 (71%)	8 (38%)	
MALE	7 (29%)	13 (62%)	
SPRAIN MECHANISM			0.6
SLIPPED ON STAIRS	5 (21%)	2 (9.5%)	
SPORT	13 (54%)	13 (62%)	
TRAFFIC ACCIDENT	0	1 (4.8%)	
WALKING ON UNEVEN GROUND	6 (25%)	6 (24%)	
ANKLE PAIN ON DAY OF CT	21 (88%)	18 (86%)	>0.9
TIME ELAPSED BETWEEN THE DATE OF THE LAST SPRAIN AND THE CT SCAN (WEEKS)	8.26	2.43	0.05
TOTAL NUMBER OF ANKLE SPRAIN EPISODES	2.04	1.10	<0.001

[1] N (%); MEAN ± SD
[2] PEARSON'S CHI-SQUARED TEST; WELCH TWO SAMPLE T-TEST; FISHER'S EXACT TEST