

# Characterization of Bone Marrow Edema Patterns among Patients with Segond Fracture in the Setting of Acute Anterior Cruciate Ligament Injury: A Comparative MRI Study

Sharif Garra, Zachary Li<sup>1</sup>, Naina Rao<sup>2</sup>, Lully Vargas<sup>3</sup>, Jordan Eskenazi<sup>4</sup>, Erin F Alaia, Michael J Alaia<sup>1</sup>, Eric Jason Strauss, Laith M Jazrawi<sup>5</sup>

<sup>1</sup>NYU Langone Orthopedic Center, <sup>2</sup>NYU Langone, <sup>3</sup>NYU Langone Medical Center, <sup>4</sup>NYU Langone Health, <sup>5</sup>Center For Musculoskeletal Care

## INTRODUCTION:

The incidence of Segond fracture ranges from 2%-29% and its presence is considered to be indicative of a higher energy mechanism compared to an isolated anterior cruciate ligament (ACL) injury. While several prior studies have investigated the anatomic distribution of bone edema on magnetic resonance imaging (MRI) following ACL injury, there has been limited characterization of bone edema among patients with a concomitant Segond fracture. The purpose of this study is to investigate the anatomic distribution of bone marrow edema on MRI among patients who sustained a Segond fracture compared to those with an isolated ACL tear.

## METHODS:

A retrospective study was performed on patients who presented with an acute isolated ACL tear following a sports activity injury between 2012 and 2022. Inclusion criteria were patients aged 18 to 40 years old at the time of injury and had an injury which occurred during participation in sports activity. Exclusion criteria were the following: 1) previous ipsilateral knee surgery or history of ACL injury; 2) ACL reconstruction was performed more than 90 days after the day of injury; 3) unknown date or mechanism of injury; 4) MRI obtained more than 30 days after injury. Two blinded readers (a musculoskeletal radiologist and a senior orthopaedic resident) reviewed all knee MRIs to assess bone marrow edema using the Whole-Organ Magnetic Resonance Imaging Score (WORMS). The area of each subcompartment was scored based on the WORMS bone bruise subscale from 0-3: 0 (no marrow abnormality), 1 (abnormality <25% of subregion area), 2 (25%-50%), or 3 (>50%). Patients' demographics, sports activity at injury, and type of meniscus injury were collected from the patient charts. Bone edema was compared between groups using Pearson's Chi squared testing. Bivariate linear regression was used to evaluate the relationship between each compartment and medial or lateral meniscus injury.

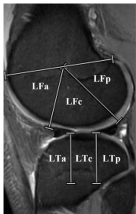
## RESULTS:

There were 522 patients in the final analysis, of which 28 patients (5.4%) were identified to have a Segond fracture. Overall, the mean age was 28.2 ± 5.9 years, the cohort was 54.3% males, and the mean BMI was 25.1 ± 4.0, and there were no significant differences in demographics comparing those with and without Segond fracture (p>0.05). The Segond group demonstrated significantly greater rates of WORMS grades 2 and 3 in the central lateral femoral condyle, as well as the anterior, central, and posterior lateral tibial plateau. Furthermore, the Segond group demonstrated significantly greater rates of WORMS grades 2 and 3 in the central medial femoral condyle and the anterior medial tibial plateau. Bone edema at the central lateral femoral condyle (R=0.034, p=0.019) and central tibial plateau (R=0.093, p=0.033) were significantly correlated with lateral meniscus tears, while the edema in the posterior medial femoral condyle was correlated with medial meniscus tears (R=0.127, p=0.004).

## DISCUSSION AND CONCLUSION:

Patients who present with ACL tear and a concomitant Segond fracture demonstrate significantly more extensive bone marrow edema in both the medial and lateral compartments of the knee compared to patients with an isolated ACL tear. These findings suggest that the Segond fracture may be indicative of a higher energy injury mechanism, and a potentially serious injury.

Figure 1. Subdivision of the lateral compartment of the knee in the sagittal view based on the WORMS scale. LFA, lateral femoral condyle anterior; LFC, lateral femoral condyle center; LFP, lateral femoral condyle posterior; LTA, lateral tibial plateau anterior; LTC, lateral tibial plateau center; LTP, lateral tibial plateau posterior.



**TABLE 1**  
Comparison of Bone Edema Distribution between Patients with and without Segond Fracture

	Segond Fracture (n=28)	Isolated ACL Tear (n=494)	p-value
<b>Lateral compartment edema, n (%)</b>			
Anterior LFC	1 (3.6)	1 (0.2)	0.105
Anterior tibial plateau	4 (14.3)	6 (1.2)	0.001
Central LFC	18 (64.3)	17 (3.4)	<0.001
Central tibial plateau	9 (32.1)	11 (2.2)	<0.001
Posterior LFC	1 (3.6)	4 (0.8)	0.242
Posterior tibial plateau	27 (96.4)	200 (38.8)	<0.001
<b>Medial compartment edema, n (%)</b>			
Anterior MFC	1 (3.6)	4 (0.8)	0.242
Anterior tibial plateau	2 (7.1)	4 (0.8)	0.637
Central MFC	2 (7.1)	3 (1.0)	0.449
Central tibial plateau	1 (3.6)	3 (0.6)	0.199
Posterior MFC	0 (0.0)	2 (0.4)	1
Posterior tibial plateau	17 (60.7)	200 (42.4)	0.076
<b>Central knee edema, n (%)</b>			
Lateral femur	14 (50.0)	101 (20.3)	<0.001
Lateral tibial plateau	14 (50.0)	50 (10.1)	<0.001
Central tibial plateau	9 (32.1)	31 (6.3)	<0.001
Medial femur	1 (3.6)	2 (0.4)	0.113
Medial tibial plateau	2 (7.1)	9 (1.8)	0.113

\*Values assessed as p=0.2 or <0.05 using the Whole-Organ Magnetic Resonance Imaging Score (WORMS) edema abnormality subscale.  
Abbreviations: LFC, lateral femoral condyle; MFC, medial femoral condyle.

**TABLE 2**  
Comparison of Bone Edema Distribution between Patients with and without Segond Fracture

	Segond Fracture (n=28)	Isolated ACL Tear (n=494)	p-value
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