Spinal Bone Bruise: Can Computed Tomography (CT) Enable Accurate Diagnosis?

Domin Na, MD, Suk-Joo Hong, MD, PhD, Min A Yoon, MD, Kyung-Sik Ahn, MD, PhD, Chang Ho Kang, MD, PhD, Baek Hyun Kim, MD, PhD, Yeonggul Jang, BS

Rationale and Objectives: The study aimed to evaluate the usefulness of dual-energy computed tomography (DECT) before and after calcium subtraction in the diagnosis of spinal bone bruise.

Materials and Methods: Among the patients who visited our emergency department between January 2013 and July 2014 who underwent both spinal DECT and magnetic resonance imaging, 38 patients (men:women = 25:13; mean age: 55.6 years, range: 28–82) were included. The patients were divided into two groups, those with and without acute spinal compression fracture, based on magnetic resonance imaging findings. In the fracture group ($n = 22$), the ratio of Hounsfield unit (HU) values was calculated between the fracture level and the next normal inferior vertebra in the DECT before and after calcium subtraction. In the non-fracture group ($n = 16$), the ratios of HU values were calculated between two normal adjacent vertebrae. The mean HU ratios were compared between the two groups.

Results: The mean HU ratio was higher in the fracture group (calcium subtraction: before: 1.57 and 1.59; after: 1.74 and 1.76) than the non-fracture group (before: 1.07 and 1.08; after: 1.07 and 1.07) ($P < 0.001$). The mean HU ratio between before and after calcium subtraction images was different only in the fracture group ($P < 0.05$). There was no significant difference in the area under the curve, sensitivity, specificity, positive and negative predictive values, and accuracy (before: 0.846, 87.5%, 81.2%, 87.5%, 81.2%, 85%; after: 0.865, 91.7%, 81.2%, 88%, 86.7%, 87.5% in high energy) between the images before and after calcium subtraction.

Conclusion: The HU ratio between the fractured and next normal vertebra was diagnostic for spinal bone bruise on DECT images both before and after calcium subtraction.

Key Words: Spinal fracture; compression; bone marrow; contusion; dual-energy CT.

INTRODUCTION

Vertebral compression fractures are very common and are associated with decreased quality of life and increased mortality. Patients with a diagnosed vertebral compression fracture have 15% higher mortality rates than those without (1,2). Thus, accurate diagnosis and appropriate treatment are important for the improvement of mobility and function (3). However, the determination of a recent fracture is sometimes challenging, such as when the fractures are occult bone lesions (often referred to as bone bruises), which may not be revealed by conventional radiography, or when patients have multiple compression fractures of variable chronicity (4,5).

Acad Radiol 2016; ■:■■–■■

From the Department of Radiology, Korea University Guro Hospital, Korea University College of Medicine, 148, Gurodong-ro, Guro-gu, Seoul 08308 (D.N., S.-J.H., M.A.Y.); Department of Radiology, Korea University Anam Hospital, Korea University College of Medicine, Seoul (K.-S.A., C.H.K.); Department of Radiology, Korea University Ansan Hospital, Korea University College of Medicine, Gyeonggi-do (B.H.K.); Severance Biomedical Science Institute, Yonsei University Health System, Seoul, Republic of Korea (Y.J.). Received January 3, 2016; revised June 15, 2016; accepted June 16, 2016. **Address correspondence to:** S.-J.H. e-mail: hongsj@korea.ac.kr

http://dx.doi.org/10.1016/j.acra.2016.06.006

In acute vertebral compression fractures, such as those due to trauma, bone marrow lesions commonly present a "bone bruise" pattern, which is histologically heterogeneous in nature and associated with microtrabecular fractures of cancellous bone, hemorrhage, and swelling of the marrow with or without substantial disruption of the adjacent bone or overlying articular cartilage (6,7).

Bone bruise lesions can be seen on magnetic resonance imaging (MRI) as an area of low signal intensity on T1-weighted images (WI) and high signal intensity on fluid-sensitive sequences in the marrow (6,8). Therefore, MRI is the most favored imaging modality in determining treatment location (9,10). Unfortunately, contraindications to MRI might be more commonly encountered in an aging population, and examination requires a longer period of time than computed tomography (CT), which might be difficult to sustain when a patient is having back pain (11).

In the study that analyzed the effectiveness of multidetector row computed tomography in detecting the occult fractures compared to MRI, the sensitivity of this CT technology in detecting occult vertebral fractures using Hounsfield unit (HU) measurement was 92.7% (12). However, CT has still less accurate diagnostic performance than MRI (11,13). Despite its lower sensitivity for finding marrow abnormalities, CT presents several advantages as compared to MRI: It is more readily available, requires a shorter examination time, and is able to depict subtle cortical fractures (11). However, the depiction of bone marrow abnormalities on CT is impeded by overlying cancellous bone (4,6). Although bony structures can be easily removed on single-energy CT images by an automatic subtraction process (14), this does not permit bone marrow to be visualized because the delicate trabecular structures surrounding the bone marrow are not resolved.

The advent of dual-energy computed tomography (DECT) has improved the ability of CT to characterize and differentiate various body substances according to material decomposition (15,16). In several studies, investigators demonstrated the ability of DECT to depict bone marrow and posttraumatic bone bruises of the knee, ankle, and vertebrae using virtual non-calcium images by a three-material decomposition approach (5,17,18). Also, Bierry et al. have demonstrated the ability of DECT to detect trauma-related bone marrow abnormalities in vertebral compression fracture in both qualitative (visual) and quantitative analyses (11). Nevertheless, quantitative analysis may be limited because the HU values might vary according to patient age, pathologic or osteoporotic conditions, or vertebra level. Therefore, we hypothesized that there would be a limitation to the diagnosis of bone bruises using absolute HU values.

In this study, we aimed to evaluate the benefit of the HU ratio, which is calculated from calcium subtraction images reconstructed from DECT, in the diagnosis of bone bruise in patients with acute spinal compression fracture, as compared to conventional CT images (DECT images before calcium subtraction) and correlated with spinal MRI.

MATERIALS AND METHODS

Patients

This study was approved by our institutional review board. Among the patients who visited our emergency department between January 2013 and July 2014, 139 consecutive patients who had undergone DECT because of suspected spinal trauma were enrolled. Among them, a total of 46 patients who underwent both spinal DECT and MRI were included. Eight patients were excluded because of the following reasons: three patients had severely bursting vertebral fractures, one patient had a negative HU value after subtraction and we assumed it was because of a kind of error, and four patients did not have available DECT data because of a software problem. Therefore, a total of 38 patients were included; we divided them into two groups, the fracture group and the non-fracture group, on the basis of spine MRI findings. The fracture group consisted of 22 patients who had 24 vertebral bodies with acute compression fractures (2 patients had 2 lesions) in the thoracolumbar spine (5 thoracic and 19 lumbar spine). The non-fracture group consisted of 16 patients who did not have any acute compression fractures in the spine (7 cervical, 2 thoracic, and 7 lumbar spine). The flowchart of the study

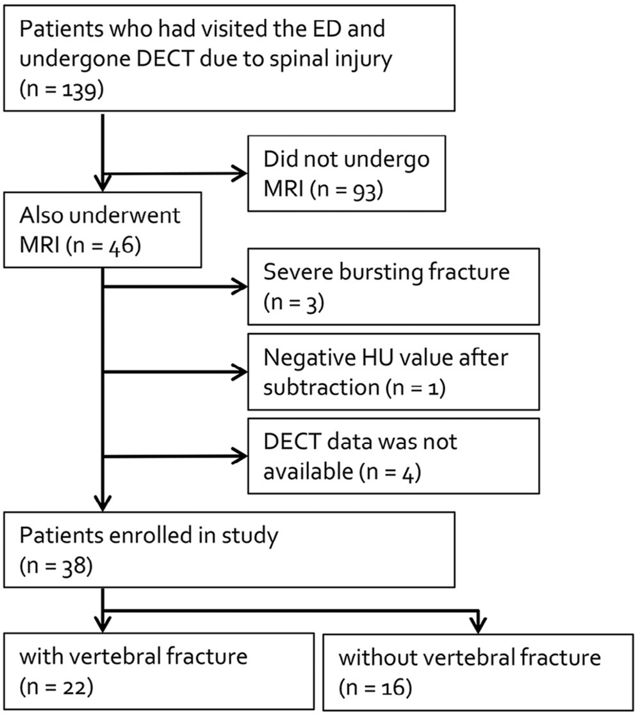

Figure 1. Flowchart of the study population.

population is depicted in Figure 1. There were 25 men and 13 women, with a mean age of 55.6 ± 15.4 years and age range of 28–82 years. The mean interval between DECT and MRI was 2.5 days (range: 0–14 days).

CT Protocol

All CT scans were obtained using a 320-row detector CT scanner (Aquilion ONE; Toshiba, Tokyo, Japan). Dual-energy scan mode was used in a helical (80-row for Aquilion ONE), volume or wide volume scan mode, with the following protocols: collimation, thickness 0.5 × 80 mm, helical pitch (HP) 8.0, rotation time 0.5 ms, craniocaudal scan direction. Tube voltages were set at 100 kV and reference at 320 mA for the low energy scan, and at 135 kV and reference at 100 mA for the high energy scan.

CT Image Reconstruction and Post-processing

Two different image sets were acquired from each DECT scan at 100 kVp and 135 kVp. Post-processing was performed using custom-made software (in-house dual-energy analysis software). The purpose of this program is the separation of the bone from the image using a calcium material axis in the energy map. The material axis is a constant value of the material, which means that the ratio of the HU values falls between 135 kVp and 100 kVp in the energy map. In addition, the value of calcium is 0.82, which was provided by the Aquilion ONE Console DE software based on the experience from a previous study, in which DE spectra were acquired at 100 kVp