Clinical usefulness of dual energy CT to detect posttraumatic bone bruise of the knee joint

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Purpose

Traumatic bone marrow lesions can cause subchondral osteonecrosis, articular cartilage degeneration or chronic pain. The purpose of this study was to evaluate prospectively traumatic bone marrow lesions with a dual-energy (DE) computed tomography (CT) for patients with acute knee trauma in comparison with magnetic resonance (MR) imaging.

Methods and Materials

Patient Population

Twenty three patients with an acute knee trauma (11 men; mean age, 47.4 years ± 15.5; age range, 14-72 years) were prospectively enrolled in this study. All patients were referred for CT to rule out fracture on plain radiography or clinical suspicion. And in four patients, bilateral knee CT was performed. Thus final data for analysis were 27 knee joints from 23 patients.

CT protocol

All CT scans were obtained by using a dual-source CT scanner (Somatom Definition Flash; Siemens Healthcare, Forchheim, Germany). This CT scanner is equipped with two x-ray tubes and two detectors rotating with an angular offset of 90°. The author performed a single CT scan of the knee by using following scanning parameters: collimation, 20 X 0.6 mm; pitch, 0.7; rotation time, 0.5 seconds; tube voltages, 80 kVp (tube A) and 140 kVp (tube B); tube current ratio, approximately 1:4 (tube A, 50 reference mAs; tube B, 213 reference mAs); and auto-mA (Care dose, CAREDOSE 4D program, Siemens Medical Solutions).

CT image reconstruction and Postprocessing

The weighted average image was acquired with DE CT scan. It was computed from the 80 kvp and 140 kvp data with ratio of 0.7:0.3 to resemble the contrast characteristics of a single-energy 120- kVp image. Postprocessing was performed by using dedicated workstation equipped with commercially DE postprocessing software (Syngo Dual Energy, version VA34A; Siemens Healthcare). Dual-energy 3-material decomposition algorithm was used to differentiate yellow marrow, and red marrow for image analysis. The Knee VNC application (Syngo Dual Energy, version VA34A; Siemens) and the three dimensional color-coded VNC images were obtained for further analysis (Knee VNC setting of Syngo Dual Energy).
MRI

All MR images were performed by using a 1.5-T unit (Intera; Philips Medical Systems, Best, the Netherlands) with a dedicated knee surface four-element phased-array coil.

Image Analysis

For subjective image analysis, the knee joint was subdivided into 14 anatomic lesions: each medial and lateral femoral plateau, anterior, middle and posterior; medial and lateral tibial plateau, anterior, middle and posterior; patella, medial and lateral facet.

Two radiologists (J.S.K. and K.E.J., who have 25 and 5 years of experience in radiology, respectively) independently reviewed all DE CT images in random order. Both readers were blinded to each other and clinical information. The readers independently assessed the image quality by using a four-point classification system: grade 1, distinct bone marrow lesion; grade 2, less distinct bone marrow lesion; grade 3, equivocal lesion; grade 4, normal bone marrow. Only bone marrow bruises that were within 2 mm distance from the adjacent cortical bone were excluded. This lesion was expected beam hardening artifact [7]. Additionally, the presence or absence of fractures was noted in all patients.

Four weeks later, to avoid any potential recall bias, MR examinations were reviewed by reader 1 as standard of reference. In MR images, definition of bone bruise was areas of poorly marginated signal intensity alteration (decreased signal intensity in T1-weighted image, increased signal intensity in T2-weighted image or both).

Statistical Analysis

For calculation of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy, we determined that grade 1, 2 were positive and grade 3, 4 were negative, and MR imaging served as the standard of reference. Weighted Kappa (#) statistics were used to assess the interobserver agreement for semiquantitative image-quality grades. All statistical analysis was performed by using two softwares (MedCalc; MedCalc Software, Mariakerke, Belgium and SPSS 11.5, Chicago, IL, USA).

Results

MR imaging showed a total of 84 regions with bone bruise; 28 were confined to femoral regions, 46 were in tibial regions and 10 were in patellar regions (Fig 1).

Both grades 1 and 2 lesions were included as positive for bone marrow lesions according to MR images. Reader 1 achieved an overall sensitivity of 63.1%, a specificity of 98.3%,
a PPV of 91.4%, a NPV of 90.3%, and an accuracy of 90.5%; Reader 2 achieved value of 64.3%, 95.6%, 80.6%, 90.4%, and 88.6%. 31 false-negative and 5 false-positive findings occurred with DE CT in reader 1. 13 false-negative and 30 false-positive findings occurred with DE CT in reader 2 (Fig 2, 3). The comparison between 3 compartment of knee, patellar regions, tibial regions show high sensitivity and specificity, but patellar region show low sensitivity and excellent specificity (Table 1).

Table 1. Diagnostic Performance of Color Encoded Virtual Noncalcium DE CT Images for the Detection of Traumatic Bone Marrow Lesions of the Knee Joint

<table>
<thead>
<tr>
<th></th>
<th>TP</th>
<th>FN</th>
<th>FP</th>
<th>TN</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Accuracy (%)</th>
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<tr>
<td>Femoral Reader 1</td>
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<td>2</td>
<td>131</td>
<td>131</td>
<td>55.2</td>
<td>98.4</td>
<td>88.9</td>
<td>90.1</td>
<td>90.7</td>
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<tr>
<td>condyle Reader 1</td>
<td>11</td>
<td>11</td>
<td>122</td>
<td>122</td>
<td>62.1</td>
<td>91.7</td>
<td>62.1</td>
<td>91.7</td>
<td>86.4</td>
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<tr>
<td>Tibial Reader 2</td>
<td>11</td>
<td>3</td>
<td>115</td>
<td>115</td>
<td>75.0</td>
<td>97.4</td>
<td>91.7</td>
<td>91.3</td>
<td>91.4</td>
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<tr>
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<td>12</td>
<td>2</td>
<td>116</td>
<td>116</td>
<td>72.7</td>
<td>98.3</td>
<td>94.1</td>
<td>90.6</td>
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<tr>
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<td>43</td>
<td>43</td>
<td>36.4</td>
<td>100</td>
<td>100</td>
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<tr>
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<td>98.3</td>
<td>91.4</td>
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<tr>
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<td>281</td>
<td>64.3</td>
<td>95.6</td>
<td>80.6</td>
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**Conclusion**

Our study shows that traumatic bone marrow bruise of the knee joint can be diagnosed on color-coded VNC images from DE CT, by using a subjective grading system, with good sensitivity and excellent specificity compared with MR images. This DE CT protocol is only 12% increase in radiation compared with the author's routine single-energy CT protocol. The color-coded VNC technique from DE CT could be useful to detect traumatic bone bruise and used as a screening tool of detecting to predict possibly combined soft tissue injuries.
References


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