Computed Tomography Staging of Osteonecrosis of the Femoral Head

Beomseok Lee, MD
Consultant Surgeon
Department of Orthopedic Surgery
Gwangmyeong Sungae Hospital
Gwangmyeong, South Korea

Jae-Young Lim, MD
Clinical Fellow
Department of Orthopedic Surgery
Chung-Ang University College of Medicine
Seoul, South Korea

Dong Min Lee, MD
Resident
Department of Orthopedic Surgery
Gwangmyeong Sungae Hospital
Gwangmyeong, South Korea

Jung Wee Park, MD
Clinical Fellow
Department of Orthopedic Surgery
Seoul National University Bundang Hospital
Seongnam, South Korea

Young-Kyun Lee, MD
Associate Professor
Department of Orthopedic Surgery
Seoul National University Bundang Hospital
Seongnam, South Korea

Yong-Chan Ha, MD
Professor
Department of Orthopedic Surgery
Chung-Ang University College of Medicine
Seoul, South Korea

Kyung-Hoi Koo, MD
Professor
Department of Orthopedic Surgery
Seoul National University Bundang Hospital
Seoul National University College of Medicine
Seongnam, South Korea

ABSTRACT

Introduction: Osteonecrosis of the femoral head (ONFH) usually affects patients younger than 50 years and frequently leads to collapse of the femoral head and subsequent osteoarthritis of the hip. Joint-preserving procedures are attempted in the early stages without collapse, while total hip arthroplasty (THA) is done during more advanced stages with femoral head collapse or a fracture in the necrotic portion. Thus, accurate staging of the disease is mandatory to decide therapeutic strategy. The purpose of this study is to determine the prevalence of occult fracture in the necrotic portion among osteonecrotic femoral heads, which were classified as Association Research Circulation Osseous (ARCO) stage 1 or 2 on radiographs.

Materials and Methods: A preoperative computer tomography (CT) scan was routinely performed to obtain an adequate cup position in patients undergoing THA at our institution. Radiographs and CT scans of 308 patients, who underwent unilateral THA due to ONFH from January 2011 to December 2014, were assessed by two orthopedic surgeons to compare the stage based on simple radiography and that based on CT scans.
Results: Among the 308 hips, which were classified as stage I or II lesions on simple radiography, fracture inside the necrotic portion was seen in 63 hips (20.5%) on CT scans. Fifty-nine of the 63 patients were followed for two to five years. Further collapse of the femoral head occurred in 41 patients, and 36 of them underwent THA during the follow up.

Conclusion: In this study, 20.5% of hips classified as ARCO stage I or II on simple radiography were found to be ARCO stage III on CT imaging. When a joint-preserving treatment is considered for early stage ONFH, CT examination is necessary for more precise staging of the disease.

### MATERIALS AND METHODS

The design and protocol of this retrospective study were approved by the institutional review board at the authors’ hospital. Given the retrospective nature of this investigation and the use of anonymized patient data, requirements for informed consent were waived.

### PATIENT SELECTION

In our department, preoperative computed tomography (CT) scan was routinely performed in patients undergoing THA to obtain an adequate cup position. From January 2011 to December 2014, 565 patients underwent THA due to ONFH at our hospital. Among them, 87 patients, who had previous THA on the opposite hip, 23 patients, who had bilateral THA, and 86 patients, who had unilateral ONFH, were excluded. Hip radiographs, anteroposterior view, and frog-leg view of the remaining 369 osteonecrotic hips (369 patients) were reviewed. Fifty hips with definite collapse (≥2 mm) and/or subchondral fracture (crescent sign), and 11 hips with inadequate quality of CT scan, were excluded. This left 308 osteonecrotic hips (308 patients) which were subjects of this study.

### IMAGING PROTOCOLS OF CT SCANS

CT images were acquired using a 16-channel (MX8000 IDT, Philips Medical Systems, Best, the Netherlands) or 64-channel (Brilliance 64, Philips Medical Systems, Best, the Netherlands) multidetector CT system with the standard acquisition protocols as follows. For 16-channel CT: rotation speed, 0.75s per rotation; current, 240mA; voltage, 120kVP; and collimation, 2.5mm. The field of view at acquisition was 15 cm, with a slice thickness of 1.0mm at increments of 0.5mm (50% section overlap). For 64-channel CT: rotation speed, 0.75s per rotation; current, 300mA; voltage, 140kVP; and collimation, 0.625mm. The field of view at acquisition was 30 cm, with a slice thickness of 0.67mm at increments of 0.33mm (50% section overlap). This high-resolution isotropic CT volume enabled image reformation in any desired plane without degradation of image quality. Coronal, sagittal, and axial images were reconstructed using the Rapidia 2.8 workstation (Infinitt Co. Ltd., Seoul, South Korea). Radiation dosages were recorded from the

### Table I

<table>
<thead>
<tr>
<th>Stage 1: A band lesion of low-signal intensity is seen around the necrotic area on MRI scans. No changes are seen on plain radiographs</th>
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<tbody>
<tr>
<td>Stage 2: Subtle signs of osteosclerosis, focal osteoporosis, or cystic change can be identified in the femoral head on plain radiographs. Still there is no evidence of subchondral fracture.</td>
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<tr>
<td>Stage 3: Fracture in the subchondral portion is seen on plain radiography or by computed tomography or tomograms</td>
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<tr>
<td>Stage 4: There is osteoarthritis of the joint with accompanying joint space narrowing, acetabular changes, and finally destruction of the joint</td>
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</tbody>
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DICOM header information that was incorporated into the scanner software program and ranged from 2.55 to 7.75mSv.

Osteonecrotic lesions were staged according to the ARCO system (Table I). 11

**RADIOLOGICAL EVALUATION**

Two orthopedic surgeons assessed radiographs and CT scans independently. Both observers were blinded to clinical data of each patient. The presence and location of fractures in the necrotic portion were assessed on axial, coronal, and sagittal CT scan images through the femoral head according to the method of Yang et al. 12

After the THA, follow-up radiographs were taken at postoperative six weeks, three months, six months, one year, and annually thereafter. Progression of ONFH was defined as a head collapse >2mm. 13

Both observers performed two measurements at a four-week interval to determine inter- and intra-observer reliability on CT evaluation using the Kappa coefficient method. These were interpreted as follows: 0.00, poor; 0.00–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and >0.80, almost perfect agreement. 14

When there was a disparity in the evaluation of femoral head collapse or the presence of fracture in the necrotic portion, the final decision was made by consensus.

**RESULTS**

The intra-observer reproducibility of CT evaluation was almost perfect in both of the two observers (k=0.83 and 0.84, respectively), while the inter-observer reproducibility was moderate (k = 0.72).

Among 308 hips, which were stage I and II on simple radiography, fracture was seen in the necrotic portion on CT scan in 63 hips (20.5%). Thus, these 63 hips were classified as ARCO stage-3 lesions by CT findings.

In these 63 osteonecrotic femoral heads, fracture appeared in two major locations: the deep necrotic region near the underlying necrotic-viable interface (39 femoral heads) and the subchondral region (15 femoral heads). In nine femoral heads, the fracture involved both regions.

These 63 patients included 41 men and 22 women. Their mean age was 54.6 years (range, 23–72 years) and their mean body mass index was 24.0 kg/m$^2$ (range, 18.5–31.1 kg/m$^2$). The risk factors of ONFH were alcohol abuse in 25, steroid use in 14, and unidentified in 24 (Table II). 15,16

Fifty-nine patients were followed for two to five years after arthroplasty with serial radiographs. During the follow-up period, no medical or surgical treatment was done. In 18 patients, the femoral head did not collapse until the latest follow up. The remaining 41 patients had radiographic progression, and 36 of them underwent THA (Fig. 1A–C).

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**Table II**

<table>
<thead>
<tr>
<th>Table II</th>
<th>Sixty-three patients with fracture in the necrotic portion on CT</th>
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</thead>
<tbody>
<tr>
<td>Male: female</td>
<td>41: 22</td>
</tr>
<tr>
<td>Age (years)</td>
<td>54.6 (range, 23–72)</td>
</tr>
<tr>
<td>Body mass index (kg/m$^2$)</td>
<td>24.0 (range, 18.5–31.1)</td>
</tr>
<tr>
<td>Risk factors of osteonecrosis</td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>25</td>
</tr>
<tr>
<td>Steroids</td>
<td>14</td>
</tr>
<tr>
<td>Unidentified</td>
<td>24</td>
</tr>
</tbody>
</table>

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Figure 1. A 40-year-old man who had osteonecrosis on the left femoral head. (A) The necrosis is classified as Association Research Circulation Osseous stage 2 on radiography. (B) Computed tomography scan of the same patient revealed a concealed fracture at the necrotic margin inside the reactive rim. (C) The lesion was progressive and the patient underwent total hip arthroplasty one year later.
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This retrospective study was designed to detect occult fractures in the osteonecrotic femoral head, which were missed on simple radiographs, and to determine the fate of femoral heads with the occult fractures. The principal finding was that 63 of 308 (20.5%) hips classified as ARCO stage I and II based on simple radiography were confirmed as stage III on CT. Of 63 hips, 41 (65.1%) progressed to further collapse of the femoral head and 36 of them underwent THA during the follow-up period of two to five years.

Therapeutic strategies of ONFH are decided by the stage of the disease and the presence of the occult fracture changes in the therapeutic strategies. Early diagnosis of ONFH and accurate staging are important to establish an appropriate treatment strategy to obtain satisfactory results.17

Detection of subchondral fractures of the femoral head is important to assess prognosis and treatment options for ONFH. Although MRI is most sensitive to diagnose ONFH, it has a limited value in the detection of subchondral fractures.

Stevens et al.17 compared the sensitivity of unenhanced radiography, CT, and MR imaging in revealing subchondral fractures in 45 subjects with stage I and stage II ONFH. Compared with CT, MR imaging had a sensitivity and specificity of 38% and 100%, and unenhanced radiography had a sensitivity and specificity of 71% and 97%, respectively.

Yeh et al.18 conducted a prospective study to determine the accuracy of MRI in the detection of subchondral fracture in 28 hips with early-stage ONFH. The MR images were reviewed by a musculoskeletal radiologist and a general radiologist. The diagnoses of the two readers were agreed in only 57.5% (16/28 diagnoses). Seventeen of the 28 MR imaging readings (60.7%) made by the musculoskeletal radiologist, and 15 of the 28 (53.5%) made by the general radiologist, agreed with those of the CT standard.

The present study has several limitations. First, it is a retrospective study from one tertiary referral hospital and might have an inherent selection bias. Second, sample size was small and we did not correlate the extent of the necrotic area with further collapse.

CONCLUSION

In this study, 20.5% of hips classified as ARCO stage I or II on simple radiographs were found to be ARCO stage III on CT imaging. CT examination is necessary for more precise staging and to decide therapeutic strategies of ONFH. 31

AUTHORS’ DISCLOSURES

The authors have no conflicts of interest to disclose. Beomseok Lee and Jae-Young Lim contributed equally to this work as first authors.

REFERENCES