Upgraded tomosynthesis technology for knee evaluation in the presence of metal devices

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INTRODUCTION: Simple radiography is the most frequently used and widely available technology for examining bone pathologies. Computed tomography (CT) can more precisely evaluate such pathologies in multiple planes and three dimensions; however, the radiation exposure is much higher than that in simple radiography. Radiation exposures have two types, natural and artificial. Natural radiation sources are either the Earth or space, and artificial radiation is beneficial to individuals, which involves medicine, pharmacy, engineering, and agriculture. Artificial radiation has been reported to be 3.87 mSv in Japan, although the world annual average of medical radiation exposure was calculated as 0.60 mSv (1). One reason is that CT examinations are frequently ordered in Japan compared with other countries; in Japan, the number of CT scanners per 1,000,000 individuals is the highest globally (2). Therefore, the number of CT examinations for each patient has been considered to be restricted from a standpoint of not increasing artificial radiation exposure and reducing medical expense. Moreover, the diagnostic abilities of both CT and simple radiography have been known to decrease in the presence of metal devices.

Tomosynthesis is a radiographic technology used to evaluate tissues quasi-three-dimensionally with less radiation exposure. Recently, the tomosynthesis technology has been upgraded to decrease metal artifacts. We hypothesized that the upgraded tomosynthesis technology could evaluate bone pathologies with metal devices more precisely, cheaply, and easily. This study aimed to compare the image resolution, examination times, medical expenses, and radiation exposure in the upgraded tomosynthesis technology with those in simple radiography, CT, and the previous version of tomosynthesis in patients with metal devices in their knees.

METHODS: In this study, the different knee conditions of three patients were examined. In the three patients included in this study, the bone union after open reduction and internal fixation with metal devices for commuted patellar fracture was evaluate; the existence of the lower pole patellar fracture after total knee arthroplasty (TKA) was determined, and bone union and prostheses fixation of TKA implants after the simultaneous removal of metal plate and screws of closed wedge high tibial osteotomy and TKA were evaluated. The image resolutions of musculoskeletal tissues with metal devices, examination time, image creation time, radiation exposure, and examination expenses in the Japanese public medical insurance system of simple radiography, CT, and previous and upgraded versions of digital tomosynthesis were compared in these patients. This study was approved by the Institutional Review Board of our institution.

RESULTS: Because of the existence of many metal devices, callus formation and bone union levels were difficult to diagnose using simple radiography. In contrast, CT was more useful for evaluation than simple radiography. In the previous version of tomosynthesis, the image resolution was slightly fussy and the bone condition was difficult to diagnose; however, the bone condition was clearly recognizable in the upgraded version of tomosynthesis (Fig. 1-4). These results were similar in the three patients.

The examination and image creation times were approximately 12–28 min and 5–24 min, respectively, for tomosynthesis; approximately 5 min and 7–10 min, respectively, for simple radiography; and approximately 12–17 min and 12–28 min, respectively, for CT in the three patients.

The medical expenses were approximately 4,240 JPY for tomosynthesis; approximately 2,240 JPY for simple radiography (two directions of one knee); and approximately 15,700 JPY for CT. Thus, tomosynthesis was slightly more expensive than simple radiography but much cheaper than CT.

Regarding medical radiation exposure, the tube voltage was 70 kV, the tube current was 250 mA, and the exposure time was 0.05 s for one exposure of the knee with a size of 30.5 × 25.4 cm in tomosynthesis, and thus, the exposure dose was estimated to be 47.88 mGy for tomosynthesis. Meanwhile, the tube voltage was 66 kV, the tube current was 320 mA, and the exposure time was 0.02 s for one direction of one knee with a size of 30.5 × 25.4 cm in simple radiography, and thus, the exposure dose for two directions of one knee was approximately 0.46 mGy for simple radiography. For CT, the dose index volume was 4.4 mGy and the scan length was 30.5 cm with a size of 30 × 30 cm, and thus, the exposure dose was estimated to be 134 mGy・cm. Therefore, the radiation exposure was much higher in tomosynthesis than in simple radiography; however, that of the radiation exposure in CT was 2.8 times higher than that in tomosynthesis.

DISCUSSION: These technologies showed similar examination and image creation times. The diagnostic ability of the upgraded version of tomosynthesis was better than that of simple radiography and the previous version of tomosynthesis and was similar to that of CT. Moreover, radiation exposure in tomosynthesis was higher than that in simple radiography but was less than that in CT. Despite its useful findings, this study has some limitations. First, the number of cases included in this study was small. Second, this study only considered knee pathologies. However, the upgraded version of tomosynthesis was considered an optimal procedure for evaluating bone pathologies in the presence of metal devices with reasonable radiation exposure.

SIGNIFICANCE/CLINICAL RELEVANCE: CT is one of the best technologies for evaluating bone pathologies; however, because of its high radiation exposure, its usage has been limited. The upgraded version of tomosynthesis can evaluate bone pathologies even in the presence of metal devices with lower radiation exposure.

REFERENCES: 1. Omori Y, J Radiol Prot, 2020. 2. OECD Health Statics, Computed tomography scanner, OECD data, https://data.oecd.org/

Fig.: Evaluation of bone union after open reduction and internal fixation with metal devices for commuted patellar fracture: (1) simple radiography; (2) CT, (3) the previous version of tomosynthesis, and (4) the upgraded version of tomosynthesis.