Evaluation of Severely Calcified Coronary Artery Using Fast-Switching Dual-kVp 64-Slice Computed Tomography

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Figure. (A) Maximum-intensity projection (MIP) image generated by single-kVpeak (kVp) computed tomography (CT). (B) MIP iodine-density image generated by fast-switching dual-kVp CT. (C) MIP calcium-density image generated by fast-switching dual-kVp CT. (D) Conventional coronary angiography (CAG). The significant stenotic regions in the left anterior descending artery and diagonal branch (B, arrows) are clearly demonstrated in the MIP iodine-density image generated by fast-switching dual-kVp CT, which corresponded well to the CAG findings (D, arrows). These findings could not be evaluated on the MIP images generated by single-kVp CT (A) due to severe calcification.

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The introduction of 64-slice computed tomography (CT) has enabled non-invasive evaluation of coronary artery stenosis with a high degree of accuracy. A large number of studies, however, have found that the presence of severely calcified plaques is the most frequent reason for false-positive or false-negative evaluation, limiting the clinical usefulness of 64-slice CT.^{1–8} Dual-kVpeak (kVp) CT allows material decomposition between calcification and iodine.⁹ CT system parameters, however, for instance gantry rotation speed, data sampling speed, and X-ray tube power output, have not been sufficient for routine clinical use.

Recently, fast-switching dual-kVp technology, dynamic switching between 80- and 140-kVp X-rays in <0.5 ms, which uses simultaneous dataset acquisition at both energies in one gantry rotation, has been developed. Because of the extremely small time difference, the acquisition datasets at 80 and 140 kVp are treated as coincident projection data both temporally and spatially. Use of this fast-switching dual-kVp technology has recently been enabled in 64-slice CT by the development of a garnet crystal scintillation detector with ultra-fast optical response, and of a high-voltage generator with ultra-fast tube voltage switching. In addition, the data acquisition system of that CT allows data sampling at more than 2.5-fold in one gantry rotation compared with a conventional 64-slice CT, hence, data acquisition that maintains in-plane spatial resolution and flux balance between 80 and 140 kVp is achieved. The fast-switching dual-kVp data acquisition enables attenuation measurements to be mathematically transformed into density (or amount) for 2 basis materials in projection data space. This projection-based process corrects for multi-material beam hardening effects, which provides accurate material decomposition in material density units. Generally, water and iodine are selected as the basis material pair. The respective pair of desired material density images (iodine and calcium) can be generated by transformation of these 2 basis material density images in the material decomposition process.¹⁰ Because this technology has not yet been applicable to clinical cardiac scanning, we applied this technology to ex vivo human heart specimens.

An ex vivo human heart specimen was taken from the clinical anatomy laboratory of Keio University after institutional review board approval. The specimen, after being put into a chest phantom (Kyoto-kagaku, Japan), was scanned using high-definition CT (HDCT; Discovery CT750 HD, GE Healthcare, WI, USA) in both the single-kVp (120 kVp) and fast-switching dual-kVp (80 and 140 kVp) helical scanning modes, immediately after injection of a mixture of iodinated contrast medium (Iohexol; Daiichi-sankyo, Japan) and polyethylene glycol (CT value: 350 HU at 120 kVp) into the ostium of the left coronary artery. The radiation dose estimated for the fast-switching dual-kVp helical scanning mode was 14 mSv, which is within the range used in conventional coronary CT angiography (8–18 mSv).¹¹ Conventional coronary

angiography (CAG) was also performed using a flat-panel digital detector system (Innova 3100, GE Healthcare) as the reference standard for the coronary artery stenosis findings.

In the single-kVp CT image it was difficult to evaluate the degree of stenosis in the left anterior descending artery, diagonal branch or left circumflex artery, where severely calcified plaques existed (Figure A). Iodine-density and calcium-density images were generated from fast-switching dual-kVp CT data (Figures B, C). The significant stenotic regions were clearly demonstrated in the iodine-density image (Figure B, arrows), which corresponded well to the CAG findings (Figure D, arrows).

Although the present study was limited by not having been conducted on a beating heart, we conclude that fast-switching dual-kVp technology may be useful for the evaluation of severely calcified coronary arteries and may overcome the limitations of conventional CT.

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