The Radiation-Dose-Lowering Effect of Landiolol Hydrochloride in Coronary Angiography Using Computed Tomography (DELIGHT), a prospective multicenter study in Japan, has given us valuable information on the utility and safety of the short-acting $\beta_1$-selective blocker landiolol hydrochloride for heart rate control to maintain image quality in coronary computed tomography angiography (CCTA).\textsuperscript{1,2} Then, in this issue of the Journal, Kido et al investigate the reduction in radiation exposure as well as the image quality-improving and heart rate-lowering effects of landiolol hydrochloride.\textsuperscript{3} A total of 219 patients suspected of having ischemic heart disease with heart rate ranging from 50 to 80 beats/min were enrolled to compare image quality and estimated radiation doses. The mean heart rate was significantly reduced from 69.3±7.3 to 59.9±6.4 beats/min (P<0.001) after intravenous administration of landiolol hydrochloride (0.06 or 0.125-mg/kg), and the estimated radiation dose was 4.5±3.2 mSv, calculated according to the formula $k\times$ dose-length product (mGy·cm), $k=0.014$.

CCTA has become the modality of choice for evaluating coronary atherosclerotic lesions in patients who are referred to outpatient’s clinics.\textsuperscript{4,5} The 2 main risks of CCTA are side effects of iodine contrast and radiation exposure.\textsuperscript{6} According to the previous guideline,\textsuperscript{7} the highest dose with invasive coronary angiography occurs on the skin surface where the
X-rays have entered, whereas in CT, the dose in the center of the body is not widely different from the skin surface dose because the trunk is irradiated circumferentially. For this reason, with the same maximum dose, a greater effective dose is produced in CT, where similar doses are irradiated over the entire imaging area, than in invasive coronary angiography, where doses are localized on the skin surface.

In the early days of 16–64-row multidetector CT (MDCT) use, estimated radiation doses were in excess of 15–20 mSv. This high-dose irradiation was caused by retrospective ECG gating and helical overlapped scanning (retrospective-CCTA). To detect coronary artery anatomy on the beating heart, ECG synchronization with the cardiac cycle is important. In the MDCT scanner, time resolution corresponding to shutter speed has been improved by an increase of gantry rotation speed. In the new-generation MDCT, time resolution is achieved to less than approximately 0.2 s. However, a slower heart rate is still required to acquire adequate data. In the initial stages of CCTA, retrospective ECG gating was used. Retrospective-CCTA obtains all phase images of the heart (Figure A). It acquired images throughout the cardiac cycle, allowing later selection of coronary images and functional analysis with the application of retrospective gating.

Prospective ECG gating (prospective-CCTA) allows image acquisition only when the coronary arteries are subject to the least motion, with no image acquisition during the rest of the cardiac cycle. Usually, at 70–80% of the R–R interval, corresponding to the mid-diastolic phase (between rapid filling and atrial kick), the right coronary artery (RCA) and left circumflex artery (LCX), running in the atrioventricular grooves, are stationary. Another advantage of prospective-CCTA is axial (not spiral) scan without overlapped scanning. This ECG-gating method, first developed for electron-beam CT in the 1990s, has been applied to MDCT, resulting in an estimated radiation exposure reduction of 80%. It is necessary to maintain the heart rate between 50 and 60 beats/min to obtain excellent images in prospective-CCTA (Figure B).

On the other hand, a retrospective-CCTA technique has been used that adopts a dose modulation technique that reduces radiation dose by decreasing the tube current in all phases of the cardiac cycle except for the mid-diastolic phase. CCTA using this technique is suitable when the heart rate is higher than approximately 65 beats/min, or when cardiac functional assessment is required. According to the previous study by Hussmann et al., diagnostic image quality was achieved with a low radiation dose of 2.1 ± 0.6 mSv and was promised by a heart rate of less than 63 beats/min. β1-blockers decrease blood pressure and heart rate, lengthening the diastolic phase, and also reducing variations in the R–R interval, providing optimal conditions for coronary artery imaging. Therefore, their effect is beneficial for coronary artery scanning during the diastolic phase. Oral β-blockers have been routinely administered before CCTA, but still the heart rate in the CT laboratory is sometimes too high for obtaining diagnostic-quality scans. Administration of landiolol should be considered when there is insufficient heart rate control even after oral β1-blocker use.

In the assessments of image quality in Kido et al’s study, the percentage of excellent and good image quality was 95% and 93% using the prospective- and retrospective-gated methods, respectively (P = 0.60), and the percentages by artery were 90%, 96%, and 93% in the RCA, left anterior descending artery, and LCX, respectively. In addition, using low tube voltage scan (80–100kV), lower tube current, iterative reconstruction technique, and use of flat-panel decreased the radiation dose while maintaining image quality. The combinations of these improvements in 320-MDCT markedly reduced the median radiation dose from 2.67 mSv to 0.93 mSv with a mean heart rate of 57 beats/min and with a single-heartbeat mid-diastolic-only acquisition (Figure C). Remarkably, in the DELIGHT study using 64–320-slice scanners from several vendor, utilization of low-voltage 100-kV scanning with iterative reconstruction in 45 (20%) patients contributed to a reduction of radiation exposure overall.

In conclusion, adequate heart rate control using short-acting β1-blocker is a favorite method for reducing and maintaining a heart rate less than 60 beats/min in order to perform prospective-CCTA with good image quality, and reduced radiation exposure.

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