Coronary Computed Tomography with Lower Radiation Dose

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Imaging of the heart structures, including the coronary arteries, using computed tomography is technically challenging. In order to obtain accurate diagnostic images of a constantly moving structure consisting of chambers that do not contract simultaneously and may change in position because of respiration movements, "freezing" of the heart in the same contraction phase and location for repeat scans is mandatory. Due to improvements in the temporal and spatial resolution of CT, especially after the introduction of the 64-row multidetector, CT has emerged as a non-invasive diagnostic tool for evaluation of the coronary arteries. Scan times are in the order of several seconds (usually 5–12 seconds), thus even patients with severe pulmonary disease or congestive heart failure can hold their breath for the required length of scan time.

The use of coronary CT angiography is constantly increasing, with well-established data confirming its accuracy in various clinical indications in the cardiac vasculature [1]. The indications include diagnosis or exclusion of various coronary pathologies [2], and newer indications such as open heart reoperations [3] and the "triple rule-out" CT angiography protocol in the evaluation of acute chest pain [4]. Additional benefits of CCTA are extracoronary findings, which are frequently detected and sometimes even more important than the coronary disease itself [5].

However, these improvements in spatial and temporal resolution significantly increased the radiation dose. Consequently, concern about exposure to ionizing radiation and its potential risk of cancer is limiting its use by health care providers [6,7]. The radiation levels are derived from the need to scan small structures, to overlap the four to five slices needed to cover the entire heart with the 64-MDCT, to use high kilo voltage for penetrating the surrounding structures in order to differentiate between the small coronaries and their surroundings, and to assess the atheromatous plaque structure. The effective radiation dose for CCTA has been estimated at 6.4–27.8 mSv in several reports [8]. The international Prospective Multicenter Study On RadiaTion Dose Estimates Of Cardiac CT AngIOgraphy I (PROTECTION I) study, the largest observational study on radiation dose estimates of cardiac CT so far, determined the radiation dose of CCTA, as well as the effect of different strategies to reduce the dose in clinical practice. The median dose-length-product of 1965 CCTA examinations was 885 mGy x cm, which corresponds to a median estimated effective radiation dose of 12 mSv. However, a large variation in dose between study sites was observed, indicating a large potential to reduce the dose for individual sites [9].

The conventional CCTA protocols are retrospective gating algorithms that cover the entire cardiac cycle during the scan. The continuous scan, using a low helical pitch, enables selective reconstruction of the data at any time point (phase) in the cardiac cycle and produces cine images of the cardiac movement. Every possible strategy should be used to reduce radiation exposure associated with CCTA. CT radiation protection and dose reduction have become an important focus of attention and new dose-saving algorithms have been developed [10-18].

Body mass index-based kV and tube current should be used to reduce radiation dose whenever possible [10]. Additional reduction can be achieved by other means such as tube voltage, with a reduction from 120 to 100 and even 80 kVp, and tube current modulation, i.e., lower radiation by 40% to 80% during 60%–80% of the cardiac cycle, where the heart movement is higher and the image quality inferior. Lower kV and tube current (e.g., 100 kV and 450 mA) are often sufficient to obtain diagnostic image quality in slim patients (BMI less than 25 kg/m^2). Scan length to the minimum necessary and dual energy scanning further reduce the radiation [11]. Recent MDCT scanners are equipped with prospective gating capabilities. New prospective electrocardiograph triggering algorithms, like Step and Shoot (S&S) mode, are based on the ability to scan only at predefined times during the cardiac phase when the heart is moving minimally (phase 75–80 mid-diastole). With this protocol, only during one-seventh of the cardiac cycle is the X-ray turned on and the heart scanned; in the remaining cycle the X-ray current is off. The partial radiation enables a radiation dose reduction by

CCTA = coronary CT angiography

MDCT = multidetector CT

BMI = body mass index

70% from 10–14 mSv to 2–4 mSv on the 64-slice MDCT [15]. The new MDCT with 256 and 320 detector rows offers a scan of the entire heart in one rotation during one beat, which means less exposure time (one second), no need for slices overlapping, and less contrast media. Durmus et al. [16] reported radiation exposure of 2.0–3.3 mSv with the 320 MDCT, which contains all the phases. New combinations of various protocols based on the patient's BMI, heart rate and MDCT protocols resulted in radiation reduction to even less than 1 mSv on CCTA [17,18].

Acute chest pain suggestive of acute coronary syndrome is a frequent complaint in the emergency department. If the clinical examination and initial cardiac workup suggest that a patient is having myocardial ischemia, the patient will usually be urgently referred for invasive coronary angiography and revascularization. In stable patients without evidence of ST elevation and ongoing myocardial ischemia, an initially conservative approach is sometimes considered. Cardiac risk stratification of this subgroup of patients who are at low and intermediate risk for coronary artery disease is recommended before discharge, and imaging is necessary to exclude ischemia as an etiology. Non-cardiac etiologies of chest pain include aortic dissection, aortic aneurysm, pulmonary embolism, pericardial disease, and lung parenchymal disease. Non-invasive cardiac imaging in patients who are at low and intermediate risk for coronary artery disease may increase confidence regarding the safety of discharge from the emergency department. In addition to risk stratification, non-coronary etiologies for chest pain can be established with CT imaging.

"Triple rule-out" CT angiography is a protocol tailored for such patients; it simultaneously evaluates coronary artery disease, pulmonary embolism, and aortic dissection in a single imaging examination. The average radiation dose of "triple rule-out" using prospective gating on a 64-slice MDCT was 9.2 ± 2.2 mSv, and in another study the radiation dose of dedicated CCTA using prospective gating was less than 3.0 mSv (1.1–3.0 mSv) in patients with lower BMI [19].

In the previous issue of *IMAJ*, Goitein et al. [20] presented their image quality results for accurate diagnosis utilizing prospective gated CCTA in acute chest pain evaluation compared to retrospective gated images. They reported a reduction of the mean effective dose from 17.2 mSv in the retrospective 64-slice CCTA to 3.8 mSv with prospective 64-slice CCTA algorithm without impairment of the overall diagnostic quality.

CCTA is expected to be used more widely for patients with non-specific acute chest pain because it can be performed with lower radiation exposure. Use of the recently released 128,256 and 320 detector row MDCT and further advances in temporal resolution of MDCT scanners may increase the number of patients who can undergo radiation-sparing prospectively gated CCTA examinations and achieve a sufficient imaging quality.

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