REVIEW ARTICLE

HIGH RADIATION EXPOSURE AND CANCER RISK WITH 64-SLICE CORONARY CTA: TIME TO REVIEW PATIENT SELECTION CRITERIA AND STANDARDIZATION OF IMAGING PROTOCOLS

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Introduction

The advent of computed tomography (CT) has revolutionized diagnostic radiology. Since the inception of CT in the 1970s, its use has increased rapidly. It is estimated that more than 62 million CT scans per year are currently obtained in the United States, including at least 4 million for children.[1] Current generation multi slice CT (MSCT) like 64-slice machine (able to scan 64 images per rotation), is characterized by its superb spatial and temporal resolution. Coronary CT angiography (CCTA) has emerged as a useful diagnostic method for assessment of coronary stenosis, calcified and non calcified plaques and also for evaluation of patients with chest pain in emergency room. However, potential advantages of CCTA over traditional methods have to be weighed against the radiation exposure of CCTA and the small but potential risk of cancer.

Reasons of High Radiation Exposure with 64-Slice CCTA:

Many of the technical factors that have enhanced spatial and temporal resolution of MSCT also affect the radiation dose receive for CCTA. With 64 slice CT, 64 overlapping 0.6 mm slices with a collimation of 0.6 mm is used with a gantry rotation time of 330 ms and tube current range 500- 900 mA. The resulting volume CT dose index ($CTDI_{vol}$) ranges between 18.8 to 66.4 Gy. This is significantly greater than 16 slices machine owing to reduced collimation and slice thickness with 64-slice CT scanner. To maintain image quality with reduced slice width, the number of photons received by the detector array is usually increased by an escalation in tube current. This results in increase in radiation exposure and effective dose estimate as well. Furthermore, an increase in temporal resolution is achieved by an increase in gantry rotation speed. To avoid a decrease in image quality, the rate of photons received by the detector array must also be increased and therefore, the tube current is further increased, which results in a higher effective dose estimates. Furthermore, with increased number of simultaneously acquired slices, the scanning time of 64- slice CT is reduced, which allows for an increase in the scan length acquired with a single short breath hold.[2]

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Estimation of Radiation Dose by 64-Slice CCTA:

The method proposed by the European Working Group for Guidelines on Quality Criteria in CT[3] for estimation of effective dose of CT angiography has been shown to be reasonably robust and consistent. The effective dose is derived from the product of the dose-length product (DLP) and a conversion coefficient for the chest as the investigated anatomic region. This conversion coefficient (k_0.017 $mSv \cdot mGy^{-1} \cdot cm^{-1}$) is averaged between male and female models.

The PROTECTION I trial (Prospective Multicenter Study On Radiation Dose Estimates Of Cardiac CT Angiography In Daily Practice I), an international, multi-center study (21 university hospitals and 29 community hospitals) includes 1,965 patients undergoing CCTA between February and December 2007. They identified independent predictors associated with radiation dose, which was measured as dose-length product (DLP), which best mirrors the radiation a patient is exposed to by the entire CT scan. Hausleiter and colleagues found that the median DLP of the patients in the study was 885 mGy cm, which corresponds to an estimated radiation dose of 600 chest x-rays. They observed a high variability in DLP between study sites (range of median DLPs per site, 331-2,146 mGy cm). Similarly, mean doses ranged from 8.5 mSv to 43.8 mSv among the participating sites.[4]

Imaging Protocols For Reducing Radiation Exposure:

Different strategies have been employed to reduce radiation exposure associated with 64-slice CCTA. An algorithm referred as ECG dependant dose modulation which modulates the tube current according to ECG during spiral scan (retrospective gating). Cardiac images are sharpest in the mid-diastole due to minimal cardiac motion in this phase of cardiac cycle. This algorithm allows for a high tube current with optimal image quality in mid-diastole, while reducing the tube current by 80% in the remainder of cardiac cycle. However, this algorithm may not be useful in patients with arrhythmia or in patient in whom in whom the best image quality is needed throughout the entire cardiac cycle. Radiation dose can also be reduced by reducing tube voltage (120 KVp to 100 KVp) as it follows the inverse square law. But reducing the tube voltage results in enhanced image noise and quality and this can be minimized by increasing tube current which again increase radiation dose. Therefore, a tradeoff between dose saving and increased image noise has to be made with current cardiac CTA protocols.

Addressing specific dose-reduction strategies, Andrew J Einstein of Columbia University, New York, writes: "Given the strength of evidence supporting it, electrocardiographically controlled tube current modulation (ECTCM) should be widely applied; the evidence for sequential scanning is rapidly accumulating, and it should also be given serious consideration for appropriate patients. Low-voltage scanning should also be considered, perhaps especially for patients who are not obese and at higher risk of radiation-associated cancer, such as children and young women".[5]

Radiation Dose with CCTA and Risk of Cancer:

Ionizing radiation like X-rays when interact with biological material cause excitation and ionization indirectly by creating toxic free radicals and directly by breaking the strands or damaging base of nearby DNA. Fortunately most of the radiation induced damage is rapidly repaired but double strand breaks are less easily repaired and occasional mis-repair can lead to induction of point mutation, chromosomal translocations, and gene fusion, all of which are linked to the induction of cancer.[6]

Most of the quantitative information that we have regarding the risk of radiation-induced cancer comes from studies of atomic bombs survivors of Hiroshima and Nagasaki in 1945. But currently few large scale epidemiological studies of the cancer risk associated with CT scans are underway and results will be available in few years. According to UNSCEAR (United Nation Scientific Committee on Effect of Atomic Radiation) report presented in general Assembly in 2000[7] and Berrington's study[8] published in Lancet in 2004, about 0.4% of all cancers in the United States may be attributable to the radiation from CT. By adjusting this estimate for current CT use, this estimate might now be in the range of 1.5 to 2%.[9]

Summary

The revolution in non-invasive cardiac imaging has taken a giant leap with the invention of 64-slice CT with high spatial and temporal resolution at the cost of significant radiation exposure. The radiation dose to a particular organ depends upon number of scans, tube current and scanning time (mAs), size of patient (BMI), scan range, scan pitch and tube voltage (KVp). ECG controlled current modulation, low tube voltage and sequential imaging are effective strategies for reducing the effective dose estimates. PROTECTION I trial has shown a significant and wide ranged dose estimates (mean doses ranged from 8.5 mSv to 43.8 mSv) among participating sites. Careful selection of CCTA protocols is needed to keep the radiation exposure “as low as reasonably achievable (ALARA)” because of small but non-ignorable life time risk of death from cancer attributable to radiation dose for CCTA. Available clinical data give a thought provoking call to redesign patient selection criteria and standardization of imaging protocols to reduce radiation exposure incurred by CCTA. Failing to this note, will pave the way for non-radiation based imaging modality like cardiac MR angiogram in near future.

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