PhD Thesis Title: Optimisation of radiation dose, image quality and contrast medium administration in coronary computed tomography angiography

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Abstract:

Radiation dose and contrast medium administration are two major concerns in coronary computed tomography angiography (CCTA). This study aimed to assess the radiation dose and risk of radiation-induced cancer associated with different prospectively ECG-triggered CCTA protocols, and to optimise the radiation dose, image quality and contrast medium administration with an improved retrospectively ECG-triggered CCTA protocol. The study is divided into four phases whereby the phases that involved patients' recruitment were approved by the Institutional Ethics Committee (Medical Ethics No: 989.35). Firstly, radiation dose received from prospectively ECG-triggered CCTA using different generations of CT scanners was assessed through organ doses measurement in a standard female adult anthropomorphic phantom. The measured organ doses were used for the estimation of lifetime attributable risk (LAR) of cancer incidence in different sex and age. Secondly, a low tube voltage (100 kVp) protocol was developed for retrospectively ECG-triggered CCTA and tested in 30 patients. The radiation dose and image quality were compared to the routine 120 kVp protocol. Then, a personalised contrast volume calculation model based on patient characteristics and test bolus parameters was developed and validated in 30 recruited patients. Finally, an improved retrospectively ECG-triggered CCTA protocol was developed using the combination of 100 kVp and personalised contrast protocol and validated in 30 recruited patients. Among the prospectively ECG-triggered CCTA protocols, the highest effective dose (H_E) was received from 2 × 32-detector-row dual-source CT (DSCT) scanner (6.06 ± 0.72 mSv). Although the heart is the organ of interest in CCTA imaging, the highest radiation dose was received by breasts and lungs (4 to 8 times higher than heart). The estimated LARs were generally low for all cancers (less than 0.02 to 113 cases per 100,000 population). For patient's body mass index (BMI) less than 30 kgm^{-2}, using automatic tube current modulation, statistically significant ($p < 0.05$) radiation dose reduction (37.8 %) and higher vessel contrast enhancement (VCE) were achieved at 100 kVp. A strong linear relationship was found between VCE and contrast volume ($r = 0.97$, $p < 0.05$). Age, sex,

body surface area (BSA) and peak contrast enhancement (PCE) at test bolus were found to be significant predictors for VCE ($p < 0.05$). A personalised contrast volume calculation model was then developed by applying these factors. The model successfully reduced the total iodine dose (TID) while achieving optimal VCE and image quality at 120 kVp compared to the routine contrast protocol (9.8 %, $p < 0.05$). When combining both the low tube voltage (100 kVp) and personalised contrast protocol, optimal VCE and image quality were achieved with statistical significant ($p < 0.05$) radiation dose (33.8 %) and TID reduction (43.9 %) compared to 120 kVp. The radiation doses and LAR for cancer incidence from a prospectively ECG-triggered CCTA are relatively low and depend on the scanner model and imaging protocol. This study successfully developed a scanning protocol using low tube voltage (100 kVp) and personalised volume calculation that optimise radiation dose, image quality and contrast medium administration for retrospectively ECG-triggered CCTA.

References to author publications that relate specifically to the dissertation:

1) **Tan SK**, Yeong CH, Ng KH, Abdul Aziz YF, & Sun Z. “Recent Update on Radiation Dose Assessment for the State-of-the-Art Coronary Computed Tomography Angiography Protocols.” *PLoS One*. 2016; 11(8): e0161543.
2) **Tan SK**., Yeong CH., Aman RR., Ng KH., Abdul Aziz YF, Chee KH, & Sun Z. “Low tube voltage prospectively ECG-triggered coronary CT angiography: A systematic review of image quality and radiation dose.” *Br J Radiol*. 2018; 91: 20170874.
3) Givenchi S, Safari MJ, **Tan SK**, Md Shah MNB, Sani FBM, Azman RR, Sun Z, Yeong CH, Ng KH, Wong JHD. “Measurement of coronary bifurcation angle with coronary CT angiography: A phantom study.” *Physica Medica: European Journal of Medical Physics*. 2018; 45:198-204.