Low dose computerized tomography examinations of coronary occlusive disease

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Abstract: Background: The aim of this study was to present an original technique of low-dose coronary computerized tomography angiography (CCTA) for the evaluation and early diagnosis of coronary occlusive disease (COD) and to compare from this technique of CCTA with those resulting from the latest conventional angiography and multidetector computerized tomography units. Methodology: The study included 820 CCTA exams of patients with COD (average age 61 +/- 7 years), with a follow-up exam in 204 male (39%) and 62 female (20%) patients with hemodynamically insignificant coronary occlusion. Exams were performed using a 64-slice computerized tomography (CT) unit using electrocardiography (ECG)-triggering and individual settings (voltage of the x-ray tube and effective tube-current) based on each patient’s body mass index. Exponential dose for each exam was defined. Results: There was a statistically significant progression in the number of patients in whom occlusion of one of 3 coronary arteries occurred in hemodynamically significant occlusive disease (occlusion of more than 50% of lumen) - 60 of 204 males and 12 of 62 females (p<0.0001 and p<0.001). The mid-effective radiation dose during CCTA exams was 1.9 +/- 0.7mSv (range of 0.9 to 3.9 mSv). Conclusion: Prospective ECG-triggering allowed for low-dose CCTA exams while still enabling high diagnostic accuracy in evaluating patients with COD. The technique used in this study resulted in 2 times less the exponential dose than conventional angiography.

Keywords: Radiobiology • CT dosimetry • Coronarography • Early diagnostics • Occlusive disease

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1. Introduction

In the past 120 years medicine, in addition to other fields of biology, have been using x-rays in their methodology. However, x-rays are also known to have negative biological effects related to ionization of living tissue (malignant tissue alteration). As a result, an entire medical discipline is now devoted to understanding and protecting patients from such negative effects. Research in this area has become particularly important in the past 20 years because of the common use of CT units in clinical practice.

The potential for biologically adverse effects from exposure to x-rays during CT scans have raised concern especially in relation to genetic neoplastic diseases and other illnesses [1]. CT scanning is the source of approximately 2/3 of the overall dose of radiation in the US and that proportion is increasing [1]. On 19th June 2007, the New York Times reported that “from 1980-2006 the overall dose of ionizing radiation derived from clinical examinations has increased by about 600% and it’s still increasing”. Radiation from medical and dental scanning has resulted in approximately 700 cases of cancer per year in Great Britain and 5600 cases per year in the US [2]. Given this risk, the ALARA (as low as reasonably achievable) principle is widely accepted in medical and biological societies wherein every effort is made to lower radiation doses while...
maintaining a high level of sensitivity for CT exams, so. Finally, biotechnology has become the main technical preoccupation in development of new generation- CT units [1,2].

Coronary occlusive disease (COD) is the leading cause of mortality in the world. In more than 40% of cases it is asymptomatic, while in 35% of cases it presents with atypical symptoms prior to myocardial infarction [3,4]. Incidence of morbidity is increasing in most European countries [3,5]. In Serbia hypertension is one of the leading causes of death from heart disease [5]. Prevention most often includes elimination of risk-factors, but early diagnosis of COD is difficult [4].

For diagnosis of COD, CT exams of the heart are revolutionary for several reasons:

a. Non-invasive and diagnostically sensitive exams enable evaluation of coronary status, as well as further evaluation and monitoring of changes in the level of occlusion, with reductions of the lumen of up to 50% (i.e. occlusive lesions that are not indication for revascularization).

b. CT exams allow determination of calcium score indices as reliable predictors of atherosclerosis progression and coronary occlusion.

Multidetector CT (MDCT) exams of the heart have been used in clinical practice since 2005, when 64-slice MDCT units were developed. In terms of minimizing potential effects of radiation, CCTA is a high-risk exam, because patients are subjected to high exponential doses (approximately 1.5 times higher than conventional coronarography) [5]. Until 2010, exponential radiation doses in standard protocols for 64-slice MDCT heart exams ranged from 7-15 mSv and Ca-score indices ranged from 1.5-3 mSv, depending on the manufacturer and type of unit. The main reasons for such high doses is the high energy of x-rays generated in x-ray tubes of high thermal capacity, the small slices used (0.625 mm) and the powerful generators (70-100 kW).

The aim of this study was to establish optimal technological solutions that minimize radiation dose levels during CT exams of the heart when diagnosing and screening for coronary occlusions.

2. Materials and Methods

A total of 820 patients were given CCTA exams between 2010 and 2012, including 510 males and 310 females, with an average age of 61 years (+/-7 years). All subjects had borderline results on ergometry and had atypical symptoms (e.g. fatigue, occasional headaches). None of the subjects had stenocardia and chest pain. In terms of risk-factors for coronary occlusive disease, 68% of the patients (85% of males and 52% of females) had three associated risk-factors (hypertension, obesity and physical inactivity). Only 15% of the subjects had fewer than two risk-factors.

Follow-up exams were performed on 204 (39%) male and 62 (20%) female patients for which hemodynamically insignificant occlusive lesions (stenosis up to 50%) were found in one or several loci on one of three marginal coronary arteries (LAD, LCX, RCA) during the first exam. These follow-up CCTA scans were performed 12 months after the first scans. For this group, the levels of hemodynamically insignificant occlusions in the CCTA exams were separated into four categories (20-30%, 30-40%, 40-50%, >50%).

Prior to CCTA scanning, all patients received 2.5 mg of isosorbid-dinitrate sublingually and, depending on their blood tension values, metoprolol intravenously (2-20 mg) in order to reach 65 mm Hg during scanning. Omnipaque 370 contrast agent (GE Healthcare, Buckinghamshire, UK), at a flow rate of 5 mL s⁻¹, was injected into an antecubital vein through an 18-gauge cannula. Bolus tracking was performed within a region of interest placed into the ascending aorta, and image acquisition was started 4 s after signal density reached a threshold of 120 Hounsfield units (HU).

All CCTA examinations were performed with a LightSpeed VCT scanner (GE Healthcare) and prospective ECG triggering using a commercially available protocol (Snapshot Pulse, GE Healthcare) and the following scanning parameters: slice acquisition of 64 x 0.625 mm, the smallest x-ray window (only 75% of the RR-cycle), z-coverage of 40 mm with an increment of 35 mm, and a gantry rotation time of 350 ms [6-10]. Voltage of the x-ray tube (important for controlling the exponential dose) was set individually depending on each patient's body mass index as follows: 100-120 kV for BMI up to 25 kg/m², 120-150 kV for BMI over 25 kg/m². Effective tube-current was also set individually according to the following: 450 mA for BMI up to 23 kg/m², 500 mA for BMI 23-25 kg/m², 550 mA for BMI 25-28 kg/m², 600 mA for BMI 28-30 kg/m², 650mA for BMI over 30 kg/m². However, patients that needed between 650 and 800 mA were not included in the study.

Effective doses from CCTA were calculated as the product of the dose-length product (DLP) times a conversion coefficient for the chest (k ¼ 0.017 mSv/mGy cm) [9]. Bearing in mind the heterogeneity of populations, various statistical methods for data analysis and processing were used: average values, standard deviations (SD), variation coefficients, nonparametric tests, χ² tests, ANOVA tests, and Z-tests for independent correlations (for specific parameter among groups). Statistic significance was defined at a level of probability