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Research Article

The Comparison of Radiation Exposure between Application of Ultra-low Dose Radiation Settings and Conventional Radiation Settings in Coronary CTO Intervention

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ABSTRACT

Introduction: The purpose of this study is to measure the cumulative doses and dose-area products exposed in chronic totally occluded coronary (CTO) interventions performed under ultra-low dose radiation procedure.

Materials and Methods: 47 patients were included to our study. Three experienced CTO operators and team were performed these procedures, one of whom was working with ALARA principles (Operator Group 1, 31 (66%) patients), the remaining operators were working in standard cine mode (Operator Group 2, 16 (34%) patients). Total fluoroscopy time, number of cineangiographic runs, cumulative dose, the dose area product were reviewed for each procedure. ALARA (As Low As Reasonably Achievable) modifications were used by Operator 1, such as reduced pulse width and exposure dose, filter protection, a longer lines for Y connector, pedaling technical as well as low frame rate.

Results: Comparison of total fluoroscopy time and the number of cineangiographic runs were not significant. But, on the other hand, cumulative doses and dose area products were significantly lower for the Operator Group 1 ($p<0.001$ for both parameters). Mean dose area product of CTO procedures were lower than reference levels in the literature in operator Group1.

Conclusion: Besides frame rate and fluoroscopy time, the usage of ALARA principles resulted with low radiation exposure compared with conventional techniques during CTO interventions. All catheterization laboratories should strictly apply ALARA principles.

Keywords: Radiation exposure; Chronic total occlusion; Ultra-low dose radiation procedure; ALARA principles

Abbreviations: ALARA: As Low As Reasonably Achievable; CTCA: Computed Tomography Coronary Angiography; CD: Cumulative Dose; CTO: Chronic Total Occlusion; DAP: The Dose Area Product; ESAK: The Entrance Surface Air Kerma; FT: Fluoroscopic Time; GY: Gray; MSCT: Multi-slice Computed Tomography; SPSS: Statistical Package for the Social Sciences

INTRODUCTION

CTO interventions are the one of the more difficult procedures amongst cardiological interventions [1]. One of the main limitations for coronary CTO is high radiation exposure [2]. It has been well established that total radiation exposure mainly depends on the frame rate [3]. In addition to that extensive radiation reducing set-up can be applied over it to reduce exposure more efficiently [4,5] Three different measure are recently used during interventions: (a) the entrance surface air kerma (ESAK), measured in Gray (Gy), which means the radiation energy released at the point where the X-ray beam enters the patient's skin; (b) the dose area product (DAP), measured in Gy.cm^2, which represents the product of the dose in air within the X-ray beam and the beam area and; (c) the fluoroscopic time (FT), measured in minutes [6-8]. The ESAK is used to measure the deterministic risk to the patient such as skin injury, while the DAP is used to measure the stochastic risk of the patient, which involves the likelihood of developing malignancies or genetic defects in the future. FT does not include cine acquisition imaging and is therefore inadequate to assess

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patient radiation [9,10].

The methods for reducing radiation during CTO interventions included preoperative and intraoperative strategies:

a) Pre-procedural strategies: Patient selection without risk factors like recent radiation exposure is the mainstep [10,11]. And if it is possible, previous images must be evaluated prior to procedure for planning. Also computed tomography coronary angiography (CTCA) is a useful tool for CTO pre-procedural planning. Although the contribution of multislice CT (MSCT) is approximately 19 mSv. Finally, CTO team, which include doctors, technicians and nurses should be educated about radiation safety prior to procedures [12,13].

b) Intra-procedural strategies: Staff radiation dose should be closely monitored regularly with dosimeters [9]. Protective 0.5 mm lead aprons, thyroid shielding, shin leg covers and radiation-specific glasses can stop up to 95% of the scattered radiation and should be worn by all CTO team members [10]. CTO interventions with below and above table mounted shielding and the recently developed Trinity Radiation Protection system [14]. All CTO operators should be familiar with and apply the ALARA principle, which means using all relevant methods and strategies in order to minimize radiation dose. Radiation exposure should be closely monitored at any time during the procedure. A dose of 10 Gy ESAK is as a threshold at which a CTO operator should stop the procedure [15].

Adjusting the distance between the patient and the X-ray tube by positioning the table at a higher level can result in significant reduction of radiation dose [16]. Higher magnification increases the patient's dose and should only be utilized in special circumstances [16]. Moreover, all CTO operators should be familial with undergoing procedures at lower framing rates per second (fps) (6.0-7.5 fps instead of 15 fps) and using pulsed fluoroscopy mode rather than the digital cine mode storage. Altering the beam angulation during the procedure by rotating the X-ray tube more than 40° can reduce the patient's skin dose and minimize irradiation of a particular portion of the patient's skin [17,18]. Steep angles have been linked to higher radiation doses due to penetration through more layers of tissue and should therefore be avoided [16]. Collimation decreases scatter radiation and the overall dose received by the patient. The use of additional copper filters reduces primary beam exposure and can enhance focused visualization [15].

MATERIALS AND METHODS

The Institutional Ethics Committees of Medical Park Izmir hospital/Turkey approved the study protocol. The study was conducted according to the latest version of Helsinki Declaration. All subjects were informed and signed written consent prior to their enrollment. All 47 patients, aged 62, 4 ± 12 and 40 (85, 1%) male, were selected based on prior angiographic images and clinical findings from 2017 to 1019. The mean age of the study group was 62, 4 ± 12. Duration of CTOs was between 1, 5-10 years. All procedures were performed by experienced operators; each of them performed about 500 CTO procedures between from 2005 to 2019. Patients divided two groups (31 (66%) and 16 (34)) based on patients selection after informed consent and lesion anatomical resemblance in prior images. All operators informed about operation prior to procedure and all of them, together, decided techniques and devices for procedures. All procedures performed with same angiography device (Siemens Artis Zee VC14H) with same CTO team except operators. Total fluoroscopy time, number of cineangiographic runs, Cumulative dose (CD, mGy), the dose area product (DAP, Gy cm^2) were reviewed for each procedure. Three operators were performing these procedures, one of whom was working with ALARA principles (Operator Group 1), the remaining operators were working in standard cine mode (Operator Group 2). 31 (66%) of the interventions were performed by Operator 1 and the remaining 16 (34%) by the other operators. All possible radiation reducing modifications were used by Operator 1, such as pulse width (5.0 ms) Kv and exposure dose (0.10 mGyf^1), setting for copper filter protection, shielding, a longer line for Y connector, pedaling two seconds after contrast injection techniques as well as low frame rate (7.5 f s^{-1} for cine and fluoroscopy). All procedures were completed successfully by operators. The counts of used wires, balloons and stent were similar for two groups. All measurements of total fluoroscopy time, number of cineangiographic runs, cumulative dose(CD, mGy), the dose area product (DAP, Gy cm^2) were compared statistically.

Statistical analysis: The statistical package SPSS (Statistical Package for the Social Sciences, version 17.0, SSPS Inc, Chicago, Ill, USA) was used for statistical analysis. Continuous variables were expressed as means ± standard deviation. Categorical variables were expressed as the total number (percentage). Analysis was performed using Student *t*-test. Categorical data were compared against a chi-squared distribution. A p value <0.05 was regarded as significant.

RESULTS

Comparison of total fluoroscopy time and the number of cinegraphic runs were not significantly different (p=0.21 and p=0.31, respectively). But, on the other hand, cumulative doses and dose area products were significantly lower for the Operator Group 1 (p<0.001 for both parameters). Mean dose area product of CTO procedures (44.3 ± 34.9 Gy cm^2) were lower than reference levels in the literature [15] (252 ± 234 Gycm^2) in operator Group 1 (Table 1).

DISCUSSION

Radiation safety is an important matter for both CTO teams and patients. We try to evaluate importance of using ALARA principles [19]. Our study showed that, if operator and other CTO team take in consideration of radiation safety pre and intra operative [20]. Radiation exposure with ALARA principles will be considerably low compared to conventional techniques especially in low pulse with and low frame rate [21,22]. But doing the procedure

Table 1: Comparison of groups' radiation exposure.

Groups		Cumulative dose of the patients CD (mGy)	Fluoroscopy Time dk	Number of cinegraphic runs	Dose Area Product DAP (Gy/cm^2)
Group 1 (ALARA principles)	N:31	571.8 ± 468.7	35.9 ± 18.4	51.7 ± 19.5	44.3 ± 34.9
Group 2 (Conventional principles)	N:16	1833.9 ± 1495.4	28.7 ± 24.6	20.9 ± 17.8	128.0 ± 82.6
p-Value		p<0.001	p=0.21	p=0.31	p<0.001

with these techniques requires operator experience. Guide wire, balloon and stent manipulation is rather difficult in limited cine and fluoroscopic guidance.

There are some ongoing debates about CTO procedures' profit and loss. Because of that CTO interventions are not be complicated during procedure [23]. Also stent, balloon and device selection should be based on angiographic images [24]. Operators, especially inexperienced, need more images consequently more cine and fluoroscopy time and increased radiation exposure.

In our study we compared two kinds of procedures; one is with ALARA principle with ultra-low pulse with and low frame rate, other is conventional method. Even if, all procedures were performed experienced operators and team. We noticed, when operators did not use ALARA principle had some bias to need more images, increased pulse with and frame rate . Also ALARA principle using operators and other team members could be more compatible with radiation safety and cautions. We believed that only think about ALARA principles during procedure can cause low radiation exposure moreover other special exposure settings, adaptive copper filter, longer line and pedaling techniques can cause rather decreased radiation exposure.

Our study showed that all experienced operators should be pay attention to adhere ALARA principles besides frame rate and fluoroscopy time which are commonly using strategies for lowering radiation exposure. Even only think about working with these principles can reduce radiation exposure. Also operation planning with evaluation of prior images and decides for selections of devices before procedure were useful strategies. As a result of this Comparison of total fluoroscopy time and the number of cineangiographic runs were not significant. Moreover group 1 had reduced radiation exposure by means of strict usage of ALARA principles by experienced operators.

CONCLUSION

Besides frame rate and fluoroscopy time, above mentioned ALARA principles and protective techniques like special exposure settings, adaptive copper filter, longer line, shielding and pedaling techniques have been shown to be seriously effective on radiation protection. All radiation exposure lowering techniques should be routinely used in catheterization laboratories to be reduced deterministic and stochastic effects of radiation exposures.

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