Beam projections and radiation exposure in transradial and transfemoral approaches during coronary angiography

Ali Tarighatnia*,**,1, Amirhossien Mohammadalian1, Morteza Ghojazade***, Leili Pourafkari****, Alireza Farajollahi*****

*Immunology Research Center, **Department of Medical Physics, ***Liver and Gastrointestinal Disease Research Center,
****Cardiovascular Research Center, *****Medical Education Research Center, Tabriz University of Medical Sciences; Tabriz-*Iran*
1Interventional Cardiology Unit, Aalinasab Hospital; Tabriz-*Iran*

ABSTRACT

Objective: We aimed to compare the operator and patient radiation exposure in standard projections during elective diagnostic coronary angiography procedures via transradial (TRA) versus transfemoral (TFA) approaches.

Methods: In this analytical cross-sectional study, a total of 202 consecutive patients who were candidates for diagnostic coronary angiography were randomized to undergo the procedure via TFA or TRA approaches (101 in each group). Patients with abnormal Allen test and history of coronary artery bypass surgery, valvular heart disease, and unsuccessful coronary angiography were excluded from the study. A single operator performed all of the procedures using a single angiography system. Patient and operator radiation exposure were measured using diamentor and an electronic personal dosimeter, respectively. Each procedure comprised a standardized sequence of projections including four standard views for the left coronary system and two standard views for the right coronary system.

Results: Left anterior oblique (LAO) caudal (50°/30°) and right anterior oblique RAO (30°) projections were associated with the highest and lowest patient radiation exposure, respectively. The operator received a significantly higher radiation exposure in the TRA approach for LAO cranial (for both left and right coronary systems) and LAO caudal (for left coronary system) projections during coronary angiography compared with the TFA approach.

Conclusion: Though a similar amount of patient radiation exposure in each projection was observed among TFA and TRA groups; LAO cranial and LAO caudal projections were associated with a significantly higher operator radiation exposure in the TRA group. These findings need to be considered when choosing the optimal arterial approach for patients scheduled for coronary angiography. *(Anatol J Cardiol 2017; 18: 298-303)*

Keywords: transradial approach, transfemoral approach, radiation exposure, beam projection

Introduction

Interventional cardiologists receive substantial radiation exposure during coronary angiography and coronary interventional procedures. Radiation is associated with potential stochastic and deterministic hazards including malignancy and eye injuries (1, 2).

Radiation dose and beam angulations contribute to the total amount of received radiation (3–5). As multiple projections may be used for optimal visualization of the coronary lesions, the amount of the radiation exposure during fluoroscopy and cine acquisition could vary with beam projection being a determining factor. The goal is to optimize coronary artery visualization while minimizing radiation to both the patient and operator.

Several investigators have focused on optimizing the radiation dose during cardiac angiography procedures (6, 7). Smith et al. (8) have proposed a protocol for different projections to balance the clinical yield as well as radiation risk during coronary angiography.

However, the majority of data has been obtained using phantom models (6, 9, 10) or old generation of angiography systems (7). The introduction of new angiography systems, which are equipped with improved image processing system, as well as the increase in operator experience call for review of the protocol of the coronary angiography procedures, particularly for some projections that are associated with high radiation exposure.

As the transradial approach is gaining more popularity (11–13), it is important to note that most of the studies focusing on the

Anatol J Cardiol 2017; 18: 298-303
DOI:10.14744/AnatolJCardiol.2017.7724

Tarighatnia et al.
Beam projections and radiation exposure *299*

amount of radiation in various projections have been conducted via the transfemoral approach (3, 4). There is only one study in the literature that has examined the radiation dose from different projections during coronary angiography via transradial approach (14).

With regards to the paucity of data in this field, we aimed to evaluate the operator and patient radiation doses in various practical projections in patients undergoing coronary angiography via the transradial or transfemoral approach.

Methods

To determine the sample size, we used the mean comparison formula with 95% confidence and a power of 80%. In this analytical cross-sectional study, we prospectively enrolled 101 consecutive patients who were scheduled for diagnostic coronary angiography via the transfemoral (TFA) or transradial approach (TRA) between September 2014 and August 2015 at the Department of Angiography, Aalinasab Hospital. Exclusion criteria consisted of abnormal Allen test and history of coronary artery bypass surgery, significant left main lesion (as defined by >50%), more than moderate valvular heart disease, unsuccessful coronary angiography and percutaneous coronary intervention procedures. Additionally urgent coronary angiography procedures were not considered for enrollment.

The patients were randomly divided into TRA and TFA groups by using the RandList software1.2 (15) under the code 186207904.

The Ethics Committee of University of Medical Sciences approved this study. A study member approached each patient and obtained written informed consent after complete description of the study.

To avoid any bias resulted by operator experience, all of the procedures were performed by a single experienced interventional cardiologist using a single angiography system (Siemens AG, Muenchen, Germany) (16). The system was equipped with an intelligent flat detector measuring 25x25 cm. The amount of magnification, pulse, and frame rate for fluoroscopy and cine acquisition were set in a similar way for both TRA and TFA groups.

The patient radiation dose was reported as air kerma-area product (KAP) and incident air kerma to provide a more accurate estimate of stochastic and deterministic effects, respectively (17), in accordance with the International Commission on Radiological Units and Measurements (ICRU Report 74) (18). The operator radiation dose was measured using an electronic personal dosimeter (Smart Rad; Model: EV-1, Type GM-Tube, Enviro Korea Co., Ltd) (19). For all the procedures, the dosimeter was attached over the lead apron on the left side in the upper thoracic region at a height of 130 cm. During all the procedures, the operator was protected by personal and structural shields (ceiling suspended lead shield over the patient and pivotal lead shield was mounted along the table (0.5 mm lead equivalent, MAVIG, Munich, Germany). Prior to each procedure, the angiography system was calibrated for consistency and accuracy by quality
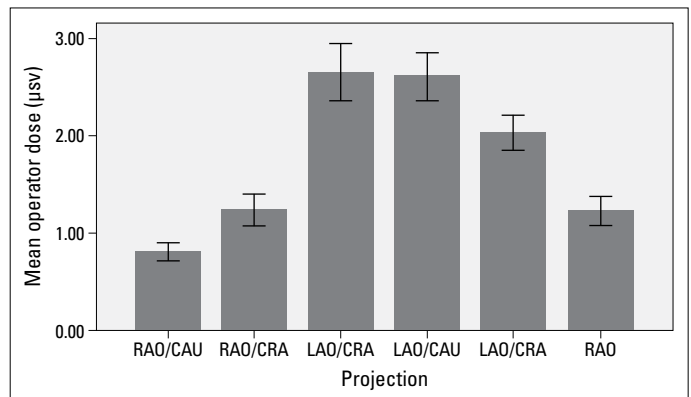

Figure 1. Comparison of operator radiation dose (μsv) in different projections without considering the arterial approach
CAU - caudal; CRA - cranial; LAO - left anterior oblique; RAO - right anterior oblique; TFA - trans-femoral approach; TRA - trans-radial approach

control kit (PTW, Freiburg, Germany). As for TRA procedures, all were performed through the right radial artery. The 6F diagnostic catheter (Judkins 3.5L, 4R; Cordis corporation, Miami, FL) was used for both transradial and transfemoral approaches.

For each procedure, a standardized sequence of projections comprising four standard views for the left coronary system [right anterior oblique (RAO) caudal 20°/25°, RAO cranial 15°/35°, left anterior oblique (LAO) cranial 40°/20°, and LAO caudal 50°/30°] and two standard views for the right coronary system (LAO cranial 30°/15° and RAO 30°) were employed.

The patients' demographic and clinical data were recorded in both TRA and TFA groups.

Data were analyzed using appropriate descriptive statistical methods (means, standard deviations, and numbers and percentages), independent sampled t-test, Mann–Whitney U test, and chi-square test using SPSS 17 (SPSS Inc., Chicago, IL) (20). Kolmogorov–Smirnov test was performed for checking the normal distribution of data. Since variables were not distributed normally, correlations between continuous variables were obtained by Spearman's correlation coefficient test. Statistical significance was set at $p \leq 0.05$.

Results

Demographic and radiation information of patients are demonstrated in Table 1. As shown in Table 1, the demographic data, fluoroscopy time, and patient radiation exposure were comparable for TRA and TFA groups, with no statistically significant difference. Table 2 compares the patients' KAP and incident air kerma at six different projections. As shown, the patient radiation exposure was similar in both groups in different projections.

The operator's mean radiation dose in different projections, regardless of the arterial approach, is shown in Figure 1.

As shown, the operator dose values during coronary angiography from cine acquisition were 0.8±0.66 μsv (RAO caudal), 1.23±1.18 μsv (RAO cranial), 2.64±2.11 μsv (LAO cranial), and 2.60±1.79 μsv (LAO caudal) for the left coronary system and

300 Tarighatnia et al.
Beam projections and radiation exposure

Anatol J Cardiol 2017; 18: 298-303
DOI:10.14744/AnatolJCardiol.2017.7724

Table 1. Comparison of some demographic and radiation data of patients in TRA and TFA groups

	TRA (n=101)	TFA (n=101)	P
Age, years	59.8±10.6	60.5±11.3	0.65
Weight, kg	75.7±12.5	76.4±11.9	0.66
Height, cm	164.6±9.2	166.6 ±9.6	0.13
Sex			
Male	70 (69.3)	67 (66.3)	0.65
Female	31 (30.7)	34 (33.7)	
BMI, kg/m^2	27.7±4.6	28.0±4.2	0.61
FT, min	2.83±0.65	2.93±0.78	0.16
KAP, µGy.m^2	1527.21±101.2	1513.17±93.6	0.84
Incident air kerma, mGy	197.88±15.4	195.31±13.88	0.89

KAP - air kerma-area product; FT - fluoroscopy time; TRA - transradial; TRF - transfemoral. Data are shown with mean±SD and N (%)

2.02±1.3 µsv (LAO cranial) and 1.22±1.1 µsv (RAO) for the right coronary system. Accordingly, LAO cranial 40°/20° was associated with a higher operator radiation dose compared with other projections.

In Table 3, the mean operator radiation exposure in different projections in each arterial approach is shown. As shown, the operator received a significantly higher radiation exposure in transradial approach for LAO cranial (40º/20º) and LAO caudal (50º/30º) during the left coronary angiography and LAO cranial (30º/15º) for the right coronary angiography compared with transfemoral approach. In other projections, the operator received the same radiation dose. These findings are depicted in Figure 2.

Overall, despite the similar patient radiation exposure in both arterial approaches, a higher operator dose was observed in the TRA group.

Discussion

This study evaluated the effect of various standard beam projections on the patient and operator radiation dose in transradial and transfemoral approaches in a group of patients undergoing diagnostic coronary angiography.

The results showed that as depicted in Table 2, LAO caudal (50°/30°) and RAO (30°) projections were associated with the highest and lowest patient radiation exposure (KAP), respectively, compared with other projections.

This was in agreement with the results of studies by Pitney et al. (21) and Farajollahi et al. (3), and contrary to the results of the study by Smith et al. (8), which indicated a higher patient dose (as assessed by KAP) with LAO cranial projection. The differences in the results of these studies may be related to differences in a degree of beam angles.

Table 2. Comparison of patient radiation dose in TRA and TFA groups according to the projection

Projection	KAP, µGy.m^2			Incident air kerma, mGy		
	TFA	TRA	P	TFA	TRA	P
RAO/CAU (20°/25°)	123.16±72.66	144.03±85.48	0.051	19.73±12.58	23.3±14.37	0.056
RAO/CRA(15°/35°)	155.1±81.67	165.59±88.22	0.656	23.88±12.64	25.43±13.67	0.472
LAO/CRA(40°/20°)	266.41±133.52	279.55±127.22	0.770	37.47±18.41	39.05±18.28	0.625
LAO/CAU(50°/30°)	328.49±127.51	354.47±149.09	0.289	51.02±19.22	54.54±22.52	0.227
LAO/CRA(30°/15°)	130.62±89.19	141.81±86.38	0.777	18.14±12.27	19.3±11.97	0.596
RAO (30°)	109.39±57.05	121.76±70.36	0.052	15.07±8.18	16.26±10.06	0.066

CAU - caudal; CRA - cranial; KAP - air kerma-area product; LAO - left anterior oblique; RAO - right anterior oblique; TFA - transfemoral approach; TRA - transradial approach. Data are shown with mean±SD

Table 3. Comparison of operator radiation dose in TRA and TFA groups by projections

Projection	Operator dose, µsv			Operator dose/frame, µsv		
	TFA	TRA	P	TFA	TRA	P
RAO/CAU (20°/25°)	0.69±0.71	0.91±0.60	0.890	0.011±0.011	0.015±0.011	0.891
RAO/CRA (15°/35°)	1.03±1.20	1.14±1.13	0.429	0.018±0.021	0.023±0.018	0.432
LAO/CRA (40°/20°)	2.2±1.74	3.09±2.35	0.049	0.038±0.032	0.051±0.039	0.054
LAO/CAU (50°/30°)	1.96±1.31	3.24±1.98	0.006	0.038±0.026	0.06±0.037	0.006
LAO/CRA (30°/15°)	1.49±0.85	2.56±1.45	0.030	0.032±0.022	0.052±0.032	0.030
RAO (30°)	1.006±0.751	1.44±1.33	0.091	0.021±0.021	0.029±0.038	0.093
Total	8.37±1.09	12.38±1.47	0.001	0.158±0.022	0.23±0.029	0.001

CAU - caudal; CRA - cranial; LAO - left anterior oblique; RAO - right anterior oblique; TFA - transfemoral approach; TRA - transradial approach. Data are shown with mean±SD
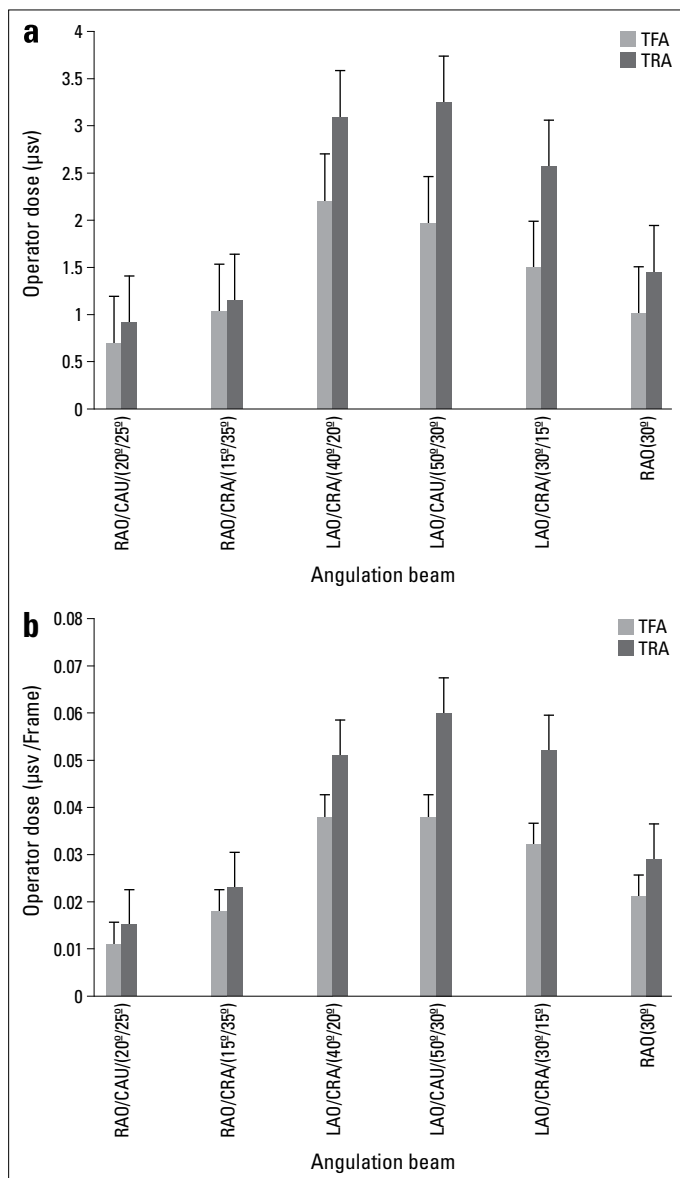
Anatol J Cardiol 2017; 18: 298-303
DOI:10.14744/AnatolJCardiol.2017.7724

Tarighatnia et al.
Beam projections and radiation exposure   *301*

Figure 2. Mean operator radiation dose (a) and mean Operator Dose/ Frame (b) in TRA and TFA groups at differnet projections

CAU - caudal; CRA - cranial; LAO - left anterior oblique; RAO - right anterior oblique; TFA - trans-femoral approach; TRA - trans-radial approach

Likewise, Kuon et al. (6) studied the effect of beam angulations on the radiation dose in phantoms and reported that the RAO (30°) projection resulted in the lowest radiation dose among different projections. This was consistent with our findings.

Also, in the Kuon et al. (6) study, the phantom received the highest exposure in the LAO cranial projection. This finding was not confirmed in our study. However, this could probably be explained by the different design of the studies (human versus phantom study).

There are differences in the anatomy and pathology of coronary arteries between different patients; therefore, human and phantom studies might be substantially different in the results in each area. The LAO cranial projection is generally used to demons-

trate the left main artery and the left anterior descending, diagonal, left circumflex and obtuse marginal bifurcation lesions (22). In addition, this projection is optimal for the assessment of a muscle bridge and for visualizing the reverse flow of the right coronary artery in humans. This could translate to a longer radiation time and an increase in the number of frames in cine acquisition. It is not readily feasible to show this type of pathology in phantom studies. In addition, in cases with slow blood flow, or cut-off of the flow in one of the branches or one or two segments in the coronary arteries, more time is necessary to display newly formed branches, collaterals, which is associated with an increase in cine acquisition time in human studies. Therefore, the amount of the produced and received exposure dose is more realistic and accurate in human subjects compared with phantom models.

In addition, in this study, to estimate skin injuries from radiation, it was shown that the third (LAO cranial 40°/20°) and fourth (LAO caudal 50°/30°) projections (Table 2) might result in more skin injuries in patients compared with other beam angulations in accordance with Agrawel et al. (4) and Varghese et al. (23) results. These two studies, similar to our study, were conducted by new angiography systems. In modern angiography systems, the exposure parameters change during acquisition in different angles to maintain a steady quality of image (4, 5, 21) that in return affects the incident air kerma values.

With an increase in the awareness of potential hazards of radiation for the operator (1), cardiologists need to have sufficient knowledge to be able to make informed decisions regarding their personal safety (5). In addition, simultaneous measurement of the operator and patient radiation doses in different projections is of utmost importance in choosing the optimal approach. There are limited studies about the operator exposure during diagnostic coronary angiography (24, 25), and most of our information comes from studies that have used phantom models (6, 9, 26).

As shown in Figure 1, the results showed that the operator receives the highest mean radiation dose in LAO cranial projection irrespective of the approach. This is in agreement with the reports by Kuon et al. (9) and Pitney et al. (21).

Consistent with our findings, most studies have shown that the transradial approach is associated with increased radiation exposure to the operator during coronary angiography compared with the transfemoral approach (24, 25, 27). It has also been reported that the operator radiation dose increases in the transradial approach due to an increase in the fluoroscopy time.

As in our present and previous study, since fluoroscopy time was similar in both approaches (Table 1), the aforementioned explanation does not seem to hold true. Therefore, other potential explanations should be sought. Accordingly, we compared the amount of radiation associated with each projection in two-by-two comparisons.

We compared the patient radiation exposure as measured by KAP and incident air kerma in similar projections between TRA and TFA approaches (Table 2). We report that these measurements were similar in all of the six standard projections. However, the

302   Tarighatnia et al.
Beam projections and radiation exposure

Anatol J Cardiol 2017; 18: 298-303
DOI:10.14744/AnatolJCardiol.2017.7724

comparison of the operator radiation dose in the six standard projections showed a higher radiation exposure in LAO caudal and cranial projections in the transradial approach (Fig. 2 and Table 3).

To eliminate the effect of radiation time on the amount of operator radiation exposure between different projections, the operator dose was divided by the number of frames in each projection. We found that LAO projections in the TRA group were associated with 1.5–2.5 times increase in the operator radiation doses compared with the TFA approach.

In LAO projections, the operator is in close proximity to the beam entry and receives higher radiation. In other words, the tube leakage and scattered radiation is higher on the left side of the patient than on the detector side. Thus, the difference in operator radiation exposure between the two approaches is attributed to LAO projections. In addition, the distance of the operator from the patient in the transradial approach is less than that in the transfemoral approach, and this is particularly more pronounced in LAO projections.

Overall, it is concluded that with the use of LAO projections in the transradial approach, the operator radiation dose including scattered and leaked beam increases.

Study limitations

This was a single-center study and the sample size was relatively small. Furthermore, percutaneous coronary intervention procedures, which are increasingly performed, were not included.

Conclusion

Despite similar patient radiation dose in all the beam projections in corresponding and two-by-two comparisons, the operator received significantly higher radiation doses in LAO cranial and LAO caudal angulations in the transradial approach compared with the transfemoral approach. Therefore, the operator's higher radiation dose in the transradial approach might be attributed to the higher radiation dose in these projections.

References

1. Klein LW, Miller DL, Balter S, Laskey W, Haines D, Norbash A, et al. Occupational health hazards in the interventional laboratory: time for a safer environment. J Vasc Interv Radiol 2009; 20: S278-S83.

2. Kuon E, Birkel J, Schmitt M, Dahm JB. Radiation exposure benefit of a lead cap in invasive cardiology. Heart 2003; 89: 1205-10.

3. Farajollahi A, Rahimi A, Khayati Sahil E, Ghaffari S, Ghojazadeh M, Tajlil A, et al. Patient's Radiation Exposure in Coronary Angiography and Angioplasty: The Impact of Different Projections. J Cardiovasc Thorac Res 2014; 6: 247-52.

4. Agarwal S, Parashar A, Bajaj NS, Khan I, Ahmad I, Heupler FA Jr, et al. Relationship of beam angulation and radiation exposure in the cardiac catheterization laboratory. JACC Cardiovasc Interv 2014; 7: 558-66.

5. Chambers CE, Fetterly KA, Holzer R, Lin PJ, Blankenship JC, Balter S, et al. Radiation safety program for the cardiac catheterization laboratory. Catheter Cardiovasc Interv 2011; 77: 546-56.

6. Kuon E, Dahm JB, Empen K, Robinson DM, Reuter G, Wucherer M. Identification of less-irradiating tube angulations in invasive cardiology. J Am Coll Cardiol 2004; 44: 1420-8.

7. Partridge JB, Slaughter RE. Radiographic projections for coronary angiography--Implications for digital subtraction angiography. Australas Radiol 1986; 30: 230-5.

8. Smith IR, Cameron J, Mengersen KL, Rivers JT. Evaluation of coronary angiographic projections to balance the clinical yield with the radiation risk. Br J Radiol 2012; 85: e722-8.

9. Kuon E, Empen K, Reuter G, Dahm JB. Personal operator dose in invasive cardiology as a function of body height and tube angulation. Rofo 2004; 176: 739-45.

10. Leyton F, Nogueira MS, Gubolino LA, Pivetta MR, Ubeda C. Correlation between scatter radiation dose at height of operator's eye and dose to patient for different angiographic projections. Appl Radiat Isot 2016; 117: 100-5.

11. Bertrand OF, Belisle P, Joyal D, Costerousse O, Rao SV, Jolly SS, et al. Comparison of transradial and femoral approaches for percutaneous coronary interventions: a systematic review and hierarchical Bayesian meta-analysis. Am Heart J 2012; 163: 632-48.

12. Feldman DN, Swaminathan RV, Kaltenbach LA, Baklanov DV, Kim LK, Wong SC, et al. Adoption of radial access and comparison of outcomes to femoral access in percutaneous coronary intervention: an updated report from the national cardiovascular data registry (2007-2012). Circulation 2013; 127: 2295-306.

13. Yuan DZ, Brooks M, Dabin B, Higgs E, Hyun K, Brieger D. Radial versus femoral access for cardiac catheterisation: impact on quality of life. Int J Cardiol 2015; 178: 91-2.

14. Varghese A, Livingstone RS, Varghese L, Kumar P, Srinath SC, George OK, et al. Radiation doses and estimated risk from angiographic projections during coronary angiography performed using novel flat detector. J Appl Clin Med Phys 2016; 17: 433-41.

15. http://randomisation.eu/index.shtml.

16. https://www.siemens.com/global/en/home.html.

17. Vano E, Gonzalez L, Ten JI, Fernandez JM, Guibelalde E, Macaya C. Skin dose and dose-area product values for interventional cardiology procedures. Br J Radiol 2001; 74: 48-55.

18. Zoetelief J. Patient dosimetry for X rays used in medical imaging. J ICRU 2005; 5: 1-113.

19. http://envirokorea.tradekorea.com/product/detail/P321065/Smart-Rad.html.

20. http://www.spss.com.hk.

21. Pitney MR, Allan RM, Giles RW, McLean D, McCredie M, Randell T, et al. Modifying fluoroscopic views reduces operator radiation exposure during coronary angioplasty. J Am Coll Cardiol 1994; 24: 1660-3.

22. Reis SS, Botelho RV, Abizaid A. A specific angiographic view of left coronary artery bifurcation in the left main percutaneous coronary

Anatol J Cardiol 2017; 18: 298-303
DOI:10.14744/AnatolJCardiol.2017.7724

Tarighatnia et al.
Beam projections and radiation exposure
303

intervention era. J Interv Cardiol 2016; 29: 293-9.

23. Varghese A, Livingstone RS, Varghese L, Kumar P, Srinath SC, George OK, et al. Radiation doses and estimated risk from angiographic projections during coronary angiography performed using novel flat detector. J Appl Clin Med Phys 2016; 17: 5926.

24. Brasselet C, Blanpain T, Tassan-Mangina S, Deschildre A, Duval S, Vitry F, et al. Comparison of operator radiation exposure with optimized radiation protection devices during coronary angiograms and ad hoc percutaneous coronary interventions by radial and femoral routes. Eur Heart J 2008; 29: 63-70.

25. Mann JT 3rd, Cubeddu G, Arrowood M. Operator Radiation Exposure in PTCA: Comparison of Radial and Femoral Approaches. J Invasive Cardiol 1996; 8 Suppl D: 22D-5D.

26. Bienert IRC, Andrade PB, Rinaldi FS, Vilela FDT, Silva PA, Braga JCS, et al. Comparative test of radiological exposure between femoral and radial techniques, development of a protective device and clinical trial design. BMJ Innovations 2015; 1: 103-10.

27. Lange HW, von BH. Randomized comparison of operator radiation exposure during coronary angiography and intervention by radial or femoral approach. Catheter Cardiovasc Interv 2006; 67: 12-6.

Biochemist, MD. Meral Eguz's collections