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Research Paper

Comparison of the dose load of personnel working with angiographic X-ray equipment in different procedures

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ABSTRACT

The present study compares the radiation doses received by the main interventional cardiologist during the angiographic procedures. A comparison was done between the dose load during three procedures–LAD-stenting, LCx-stentingand RCA-stenting. An angiographic X-ray system Philips Allura Xper FD10 (with G-arm) was used for this study. The dose obtained was measured with an X-ray-Gamma Dosimeter 27091. The dose measurements were made for the respective projections of each angiographic procedure and for the operation modes of the equipment used during the respective procedure at three measurement points on the operator's body - head, gonads and feet. The results obtained from the calculations, based on the measured dose values, showed maximum dose load in the procedure that used the radiographic mode of operation for the longest time, namely RCA-stenting. Among the procedures using in general same times of fluorography and radiography, a higher dose load was obtained for the procedure LAD-stenting. Of the three procedures studied, the lowest dose load was obtained for the procedure LCx-stenting.

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Key words: G-arm type angiographic X-ray system, dose load, interventional cardiology, Cardiology Hospital.

INTRODUCTION

In the modern world, the use of X-ray equipment for diagnostic and treatment purposes is increasingly affecting our lives. Because of this, safety is a constant concern when using this type of equipment. This was the motivation for our team to focus the study on the dose load of the staff working with X-ray equipment. The other major reason was the interventional cardiologists' interest in knowing the radiation doses they are receiving during the procedures. We found the following interesting articles on this topic:

Strauss and Seibert (2016) in their study on "Angiographic Equipment Selection and Configuration" discussed how to choose the accessories and the right equipment, depending on the activities for which it is intended to be used.

Patient dose has been discussed by Sadick et al. (2010) in a study on the "Impact of biplane versus single-plane imaging on radiation dose, contrast load and procedural time in coronary angioplasty" and by Mavrikou et al. (2008) in their study on "High patient doses in interventional cardiology due to physicians' negligence: how can they be prevented?.

In a study on "5 Technologies to Reduce Cath Lab Radiation Exposure", the authors discussed the reduction of staff radiation dose from X-ray angiography and long-term back pain due to weight of lead aprons (Fornell, 2016). All aforementioned studies discussed the effective use of the devices in order to reduce as much as possible the dose received by the patient and by the staff working with the equipment.

Continuing the position to reduce the dose received, we performed measurements of the dose received by the first cardiologist-operator during invasive cardiac procedures.

Purpose of the study

The present study is based on the performed dosimetric measurements to make evaluation of the dose load, received by a interventional cardiologist from the scattered X-ray radiation for different angiographic procedures during work with the angiographic system Philips Allura Xper FD10 (Ivanova, 2020; Philips Allura Xper FD10 system specifications, 2017).

Motivation

The specific angiographic procedures require use of different projections where the X-ray tube is pointed at a specific angle to the patient table and to the main cardiologist, performing the procedure. During each procedure, several different projections are used. For each projection, a specific dose load is received by the main interventional cardiologist. In some projections, both fluorography and radiography modes of operation of the X-ray equipment are used and the exposure time for the respective projection and operation mode is different as well. Thus, the total dose load for each specific angiographic procedure is different. All these circumstances inspired us to perform calculations based on the data collected from the measurements and to estimate the dose load that the main operator receives during each specific procedure (Ivanova, 2020).

METHODS

Dosimetric measurement

We measured the dose received by a cardiologist performing an angiographic procedure. Measurements were performed for all of the 9 most commonly used G-arm projections. Each measurement was made at three points on the cardiologist's body: head, gonads and feet and for three different table positions: zero height (according to the default system adjustment), lowest possible position for the respective projection and highest possible position (Ivanova, 2020).

Practical measurements

The practical measurements were made in the Specialized Hospital for Active Treatment in Cardiology (SBALK) Varna, in the Department of Invasive Cardiology (Ivanova, 2020).

Participants

Participants in the dosimetric measurements:

• The first author of this article – a representative of the Medical University and processing the received data,
• Service engineer maintaining the X-ray equipment: the measurements were carried out under the direct and continuous control of the service engineer of the X-ray system,
• Medical physicist - Head of the Radiation Protection Department at the Regional Health Inspectorate, Varna, working with the measuring device;
• Three interventional cardiologists from the Cardiac Hospital who provided information and instructions on the interventional procedures and projections used during the measurements (Ivanova, 2020).

Devices and materials

The study was performed in a procedure room of an angiographic X-ray system with G-arm Philips Allura Xper FD10 (Figure 1). An X-Ray-Gamma-Dosimeter RGD 27091 was used for the dosimetric measurement (Figure 2) (http://www.step-sensor.de/media/main/rgd_27091-manual_.pdf). A 19-liter water bottle was used as phantom (Figure 3) (Ivanova, 2020).

Practical work procedure

The dose measurements were performed for three different patient table positions – zero height (default position set by the factory), highest and lowest position for the respective procedure for the three measurement points – "Head", "Gonads", and "Feet". Figure 4 shows the positions of the three measurement points. Dose evaluation of the first operator was performed for three angiographic procedures: LAD-stenting, LCx-stenting and RCA-stenting.

1. LAD-stenting- The projections shown in Table 1 are used. The total time for the performed procedure 45-90 min. Total time for the basic projection 30 to 60 min: Each of the three mentioned projections can be used as basic projection. The exposure time in pulse fluoroscopy mode for the basic projection is about 10 min. The exposure time in radiography mode for the basic projection is about 2-3 min. Total time for the other projections - 15 to 30 min. The exposure time for these projections in pulse fluoroscopy is about 5 min.

2. LCx-stenting - The projections shown in Table 2 are used. Total time for the performed procedure 45-90 min. Basic projection -30 to 60 min. Each of the three mentioned projections can be used as basic projection depending on the procedure. The exposure time in pulse fluoroscopy mode for the basic projection is about 10 min. The exposure time in radiographic mode for the basic projection is about 2-3 min. Total time for the other projections - 15 to 30 min. Exposure time for these projections in fluoroscopy mode is about 5 min.

Figure 1: Angiographic X-ray system Philips AlluraXper FD10.

Figure 2: X-Ray-Gamma-Dosimeter RGD 27091.

Figure 3: Phantom.

Figure 4: Position of cardiologist in relation to patient table, G-arm, radiation protection shield. Measuring points: head, gonads and steps.

Table 1: LAD-stenting.

AP	$0^0/0^0$
RAO - cranial	$30^0/30^0$
LAO - cranial	$30^0/30^0$
Cranial	30^0

Table 2: LCx-stenting.

AP	$0^0/0^0$
RAO – caudal	$30^0/15^0$
LAO – caudal	$30^0/30^0$
Cranial	30^0

Table 3: RCA-stenting.

AP	$0^0/0^0$
RAO - cranial	$30^0/30^0$
LAO - cranial	$30^0/30^0$
Cranial	30^0

3. RCA-stenting- The projections shown in Table 3 are used. Total time for the performed procedure is about 120 min. First basic projection - LAO 30^0 - about 60 min. Exposure time in pulse fluoroscopy mode is about 10 min. The exposure time in radiography mode is about 2-3 min.

Second basic projection RAO-cranial $30^0/30^0$ - about 30 min. The exposure time in pulse fluoroscopy mode is about 5 min. The exposure time in radiography mode is about 1 min.

Second basic projection - Cranial 30^0 - about 30 min. The exposure time in pulse fluoroscopy mode is about 5 min. The exposure time in radiography mode is about 1 min.

The calculations are done for each of the projections as basic projection and for the remaining two projections as non-basic projections (Ivanova, 2020).

RESULTS

Figure 5 shows comparative diagrams of the received dose load for the whole procedure for each of the three performed procedures, for the three patient table positions and at the three measurement points. The Figure is composed of the diagrams LAD-stenting, LCx-stenting and RCA-stenting. For each of the procedures, the dose received in fluoroscopic and radiographic mode of operation is calculated. The calculations are performed first for 2 min radiographic mode and then for 3 min radiographic mode for the basic projection.

For this reason, "2 and 3 min" values are shown in the diagrams. For the procedures, LAD-stenting and LCx-stentingthe fluoroscopy doses are summed for the respective duration for the three used projections and the 2 min radiographic mode of the basic projection; for the RCA-stenting the doses are summed of the fluoroscopy mode and 1 min radiographic mode for the second and the third projection and 2 min radiography for the first basic projection. In the "3 min" values, for the procedures LAD-stenting and LCx-stenting the doses are summed for the respective duration for the three used projections and the 3 min radiographic mode of the basic projection; for the RCA-stenting, the doses are summed of the fluoroscopy mode and 1 min radiographic mode for the second and the third projection and 2 min radiography for the first basic projection.

By comparing the diagrams of Figure 5, it can be seen that the RCA-stenting procedure shows the highest values of the received dose. This can easily be explained as this procedure runs the longest under X-ray control. The received dose is almost the same for all positions in the patient table. The highest value for the measurement point "Gonads", in all positions of the patient table in the range between 70 and 100 μSv can be clearly seen, more pronounced for the 3-min radiographic mode of the first basic projection.

The lowest value is obtained for the measurement point "Head" , namely about 50 μSv in 3 min radiography mode and about 40 μSv in 2 min radiography mode for the first basic projection RAO – cranial. The largest differences in the dose values are observed for the measurement point "Feet" – in the range 50 to 80 μSv. Because the other two projections, namelyLAD-stenting and LCx-stenting, show almost same exposure time, the dose values will be compared for them (Figure 5).

When comparing the doses obtained at different positions of the patient table, the lowest dose values are observed for the lowest position of the table. This is observed for these two procedures and for 2 min radiography and 3 min radiography in the main projection. In the other two positions of the patient table, there is no clear advantage concerning the dose load. At the highest and zero table position, higher values are indicated by the LAD-stenting. This procedure shows a higher values, in general, as compared with the LCx-stenting procedure.

When comparing the dose load in the different measurement points, the minimum dose is observed clearly outlined for the "Head" point for all procedures. Values equal to and higher than 40 μSv are observed only in the highest position of the patient table for the RAO-cranial projection, when this projection is chosen as basic projection in the LAD-stenting procedure. A lower dose load between 30 and 40 μSv for the measurement point "Head" is observed in the zero position of the patient table for RAO-caudal projection, when this projection is chosen as basic for the procedure LCx-stenting. The lowest dose values for the measurement point "Head" - below 20 μSv - are observed for 2 min radiography and below 30 μSv for 3 min radiography of the basic projection.

The dose load at the measurement point "Steps" is in the range 30 to 50 μSv for 2 min radiography or 40 to 60 μSv for 3 min radiography of the basic projection (Ivanova, 2020).

Most pronounced values were obtained for this measurement point for both projections, namely 60 μSv for LAD-stenting in the basic projection RAO-cranial and for the RCx-stenting with basic projection RAO-caudal. Predominantly, the values for the measurement point "Feet" for all procedures in different projections were measured between 30 and 40 μSv. The lowest value of about 20 μSv was obtained for LAD-stenting in zero position of the table and 2 min radiography for the basic projection LAO-cranial.

The highest dose values for the duration of the whole procedure were obtained for the measurement point "Gonads". The maximum values for all procedures and all patient table positions are between 60 and 70 μSv for 3 min radiography in the basic projection. Three of them are near 60 μSv when the patient table is in the highest and zero position of the procedure LAD-stenting and the highest position of the patient table for the procedure RCx-stenting. The other three are near 70 μSv – for the lowest position of the table for the procedure LAD-stenting and lowest and zero position for RCx-stenting. The lowest values are between 35 and 40 μSv. Here, most of these values are obtained for 2 min radiography for the basic projection for all procedures. Some values about 35 μSv were observed for all positions of the table and the LAD-stenting. About 40 μSv were observed for RCx-stenting.

By comparing the measured values for the different positions of the patient table, for the different projections of each procedure maximum dose values are observed for the main projection.This is due to the fact that in the basic projection, the longest exposure duration is used. In addi-tion, both angiographic modes are used here - fluoroscopy

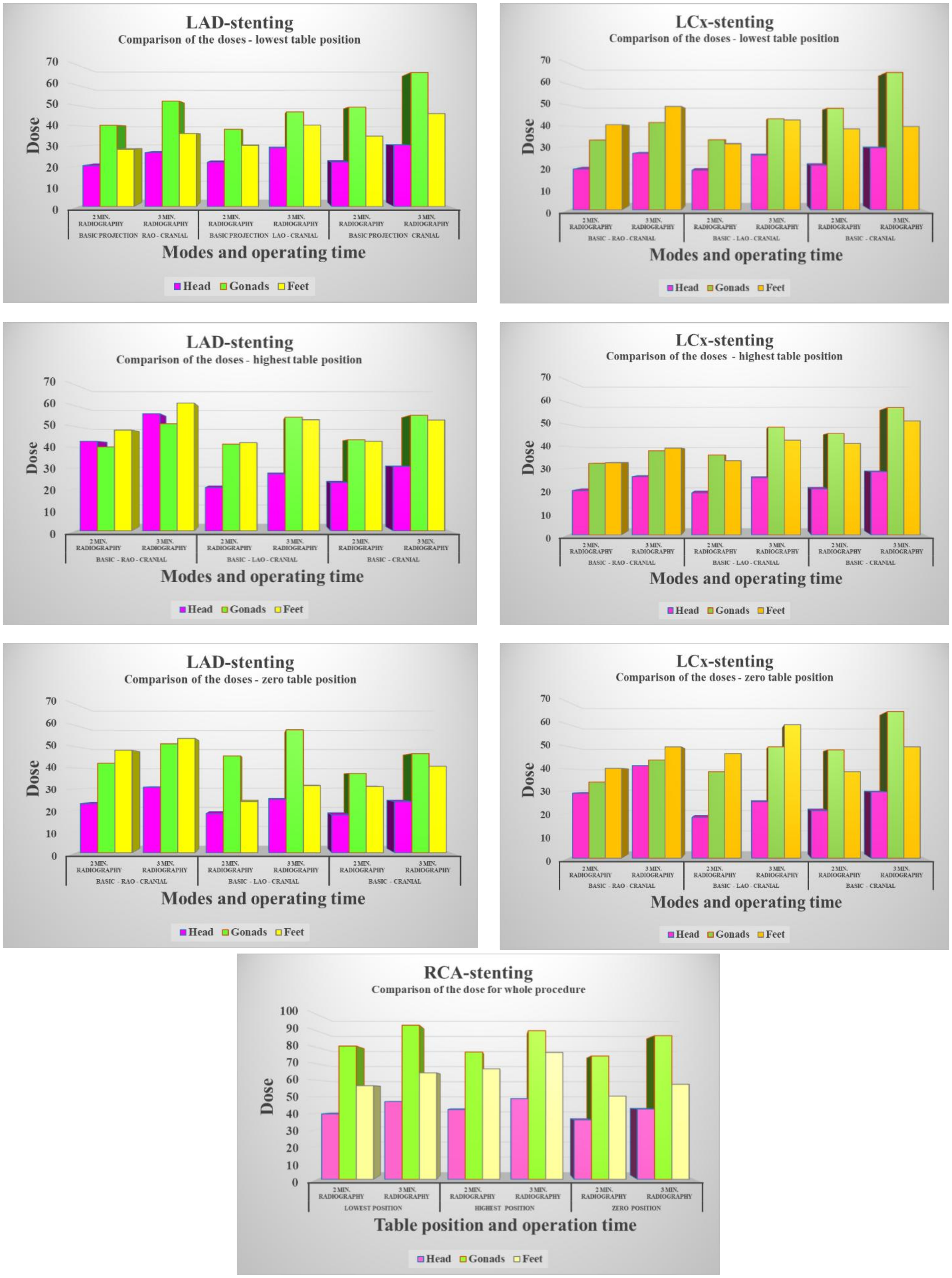

Figure 5: Comparison of the doses received by the first operator, at three points of his body, for the duration of the entire procedure for the three procedures, for different basic projections and in three different positions of the patient table.

and radiography while only fluoroscopy is used during the non-basic operating modes.

The diagrams show greater dose load from the radiography exposure of the basic projection as compared with the fluoroscopy of the same projection, although the fluorography time is 10 min and the radiography time 2 or 3 min. The dose load due to the non-basic projections is minimal because for them also the exposure time is shorter 2.5 min for each basic projection and the used mode is pulse fluorography which is less heavy (Ivanova, 2020).

Conclusions

The results obtained from the calculation of the dose load for the three studied procedures show the following:

1). The highest dose load is obtained for the procedure RCA-stenting because the exposure time for this procedure is the longest:

- Fluoroscopytime 10 min for the first basic projection;
- Radiography time 2 or 3 min for the first basic projection;
- Fluoroscopytime 5 min per each projection for the second and third basic projection;
- Radiography time 1 min per each projection for the second and third basic projection.

The total exposure time for this procedure is 24 min including 2 min radiography for the first basic projection or 25 min including 3 min radiography for the basic projection.

2). Next lower dose load is obtained for the procedure LAD-stenting. Here, the dose load is higher than the dose load for the LCx-stenting even when the total exposure time is the same. The exposure time for both procedures is as follows:

- Fluoroscopy time 10 min for the first basic projection;
- Radiography time 2 or 3 min for the first basic projection;
- Fluoroscopy for the non-basic projections – total exposure time 5 min for both projections.

The total exposure time for this procedure is 17 min including 2 min radiography for the basic projection or 18 min when 3 min radiography for the basic projection is used.

3. The lowest dose load was obtained for the LCx-stenting, which had the same duration of the exposure as the LAD-stenting procedure. By comparing the exposure times of the three examined procedures, the reported difference of 7 min of the procedure RCA-stenting leads to increase of the dose load for this procedure.

The total exposure time for RCA-stenting is 4 min, including 2 min radiography exposure time for the first basic projection or 5 min if the exposure time for the first basic projection is 3 min. For the remaining two projections, the radiography exposure time is 2 or 3 min. These additional 2 min radiography lead to additional increase of the dose load for the RCA stenting as compared with the procedures LAD-stenting and LCx-stenting.

The higher dose for the RCA-stenting is also due to the larger fluoroscopy exposure time during the second and third basic projection. As compared with the two other projections, the fluoroscopy exposure time for the heaviest procedure is about ¼ times longer (20 min for RCA-stenting and 15 min for the other two procedures). Although to a lesser extent due to radiography, the RCA-stenting shows a higher dose due to the longer duration of the fluoroscopy (Ivanova, 2020).

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