AIR KERMA RATES MEASUREMENT IN AN INTERVENTIONAL CARDIOLOGY SUITE

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Abstract. In Interventional Cardiology (IC), the assessment of the radiation that the physicians are exposed to is extremely important because the irradiation is not uniform and the received doses are substantially high. During the procedure, the radiation control is complex and there are several reasons for the high exposure levels. It is necessary to perform dosimetric assessments in different parts of the physicians’ body and in different specific points of the examination room. By analyzing this information it is possible to determine the probable causes and to provide recommendations, aiming at optimizing the radiological protection. This work had the following objectives: to assess the exposition levels at representative points of critical anatomical regions of the physicians’ body who perform IC examinations; to provide means to implement personal monitoring procedures; and to make them aware of the radiation risks. Measurements of air kerma rates were performed in 45 points around the examination table, along the room. Such measurements were made in the conditions frequently used in coronary angiography and coronary angioplasties procedures: adult patient phantom; RAO, LAO and AP incidences; fluoro and digital modes; 13cm and 17cm magnification modes; frequencies of 30f/s (fluoro) and 15 f/s (digital); typical field size used during examinations. Data were obtained at the lenses, chest, hands, gonads and knees levels. For AP incidence, the lowest contributions for scattered radiation and a more homogeneous distribution of radiation were observed. The highest air kerma rates were obtained during digital acquisition mode and for LAO incidence on interventional radiologists, anaesthesists and nurses. The most critical anatomical regions were the knees and gonads. Air kerma rates of about 7,8mGy/h were registered in some places. At physicians’ hands position, rates of about 5mGy/h were reached. In several points and levels measured (workload ≈ 6 examinations/day), this air kerma rates would produce a higher dose than the annual limits. This work shows the need to implement additional protection devices; to elaborate safety guidelines; to train staff on radiological protection, and to implement the use of additional dosemeters attached to critical points.

KEYWORDS: Interventional cardiology, fluoroscopy, radiation protection, air kerma rates, occupational exposure, workplace analysis.

1. Introduction

The interventional doctors' radiation exposure in hemodynamics is an issue of great concern, once the received doses are greater than those received in conventional radiology [1]. Due to the expected high levels of such exposure, it is necessary to perform dosimetric evaluations, monitoring different parts of the body (usually, the worker's exposure is not even), as well as specific points in the examination room. By analyzing this information it will be possible to identify its probable causes and implement the recommendations and practice codes.

Some of the reasons for the high level of radiology on the interventional doctors are: faults in an X ray equipment component, inappropriate use of the equipment and technology, acquisition of too many images, being exposed too long. Due to the scattering of the radiation beam through the different thickness of the patient, to the different modes of operation and to the angulations of the C-arm, different rates of scattered radiation are generated [2]. Not wearing the appropriate protection accessories can also increase the doses received by the staff. In addition to that, the interventional techniques have been applied by radiology non-specialized physicians who, most of the times, have not had proper training in radiation protection [3, 4, 5].

This work aimed at evaluating the air kerma rates in critical parts of the bodies of the radiologists who perform coronary angiography (CA) and coronary angioplasties (PTCA) procedures, when its incidences were most significant.

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2. Material and Method

The work has been developed in an Interventional Cardiology Room in an important hospital of Rio de Janeiro, Brazil. The procedures were performed with a Siemens (Coroskop HIP- T.O.P) X-ray equipment, the range of tube voltage was 50 – 125kVp. The system has an automatic exposure control, three fields of view, 13,17 and 23cm, fluoroscopic and digital image acquisition modes. The equipment filters 0.2mm copper permanently during fluoroscopy. In the digital image acquisition mode, if the image quality is not good enough, the filter is immediately withdrawn from the beam's path.

The most frequent conditions of irradiation in the C-arm projections during CA and PTCA procedures were simulated. A plastic box containing 20 l of water was used as a thorax phantom. It was placed on the exam table, with the center of the phantom at the X-ray equipment isocenter. The projections were:

**Right Anterior Oblique RAO (+35°):** fluoroscopic and digital acquisition modes.
**Left Anterior Oblique LAO (-35°):** fluoroscopic and digital acquisition modes.
**Antero- Posterior, AP (cranial 0°/caudal 0°):** fluoroscopic and digital acquisition modes.

For all cases: intensifier-focus distance = 1,00 m; table position: vertical + 2; horizontal + 40; diagonal – 3; field of view = 13cm; field of irradiation size on the surface of the simulator = 49,5 cm².

The electrometer used to measure the exposure in the different points inside the procedure room was a Radcal 9015 with a 10x5-1800cc ionisation chamber. In order to identify the measurements points, a system of coordinates was defined, with points marked on the floor with a separation of 60cm between them. In the coordinate system, the lines parallel to the table's bigger axis were denominated A,B,C,D and E and the lines perpendicular to the bigger axis were denominated 1,2,3,4 and 5 and -1,-2,-3 and -4.(Fig.1). Point 1A corresponds to the position of the table command, where the interventional doctor stays during the procedure. In each point, air kerma rate was measured in different heights from the floor. The heights measured were: 1,60m, to simulate the eye height (lens); 1,30m (thorax); 0,85m (gonads); 0,50m (knees). Measurements were also taken at 1,00m high, in the areas around the examination table to simulate the upper extremities. The total measurements were 134 for the RAO, 138 for the LAO and 156 for the AP.

**Figure 1:** Sketch of the room, coordinates system definition and identification of the measurement points.
In order to estimate the exposure of the interventional doctor in a part of their body during a real procedure, the equivalent dose in the lens and in the hands were calculated from the air kerma rates values measured in the 1,60m and 1,00heights. It was simulated a case in which the interventional cardiologist performs 10 angiographies, working 5 days a week and 50 weeks a year. This was calculated using the most frequent projections, the number of images and the average values of fluoroscopic current and time.

3. Results

The air kerma rate values (µGy/h) were classified in numbered bands, each of them being colored in shades of gray. As an example, the results of the measurements of the air kerma rates taken in the points shown in Figure 1 are presented in Figure 2 for the RAO (+35°) projection, as a plan of the room with the numerical values at each point. The values measured have an associated uncertainty of 16%.

3.1 Right Anterior Oblique Projection, RAO (+35°)

The air kerma rates were lower in the fluoroscopic mode than in the acquisition mode due to the different currents used (fluoro ≈15mA, acquisition mode ≈600mA). The distribution of the air kerma rates in both modes follow the same pattern in all points of the room. The points with greater variation are those closer to the patient, due to the fact that the contribution of scattered radiation is more significant for the positions close to the X-ray tube. In the acquisition mode, the rates reached, in many cases, values 4 or 5 times higher than in the fluoroscopic mode, demonstrating the importance of the reasonable use of image acquisition. The rates were higher next to the X-ray tube, left of the patient.
**Figure 2:** Air kerma rates distribution in the different heights of the points in the examination room (digital acquisition and fluoro modes) for the projection RAO (+35°).
The air kerma rates in the fluoroscopic mode reached values of 1943µGy/h (point 1D) and 2130µGy/h (point -1E), at gonad height. At 1.60m (eye lens), the greater air kerma rates were measured in points -1E, 1D and -1A, points near the X-ray tube and the area where the anesthetist and the nurses usually walk around. In the digital acquisition mode, due to the geometry, the areas with the greatest rates are the ones where the anesthetist and the nurses stay (points 1D, 2D, -1D, -2D, -3D). Values such as 7181µGy/h at point 1D (gonad height) and 7081mGy/h at the same point (knee height) were registered. The relation between the values of air kerma rates measured in opposite points (e.g. right and left of the patient, points 1A and 1D), might reach up to a factor 4.

In Figure 3 it is shown the profiles for the points where the medical staff is more likely to be working, for instance, 1A, 2A, 3A, 1D, 2D and 3D.

**Figure 3:** Air kerma rates profile for points 1A (interventional cardiologist), 2A (assistant cardiologist), 3A and 1D (anesthetist), 2D (nurses) and 3D, for RAO (+35°), digital acquisition mode.

### 3.2 Left Anterior Oblique Projection, LAO (-35°)

The air kerma rates measured in the fluoroscopic mode were almost homogeneous and lower than the air kerma rates in the acquisition mode. This values reached 1240µGy/h (point 1A) at knee height, and 1848µGy/h (point 1D), knee height. At 1.60m (lens), the higher aire kerma rates were measured at points 1D and 1A.

In the digital acquisition mode, values such as 3602µGy/h (hands), 5690µGy/h (gonads) and 5677µSv/h (knee) at the point 1A, were measured. The air kerma rates reached, again, values 4 or 5 times higher than in the fluoroscopic mode.

### 3.3 Antero- Posterior Projection, AP (cranial 0°/caudal 0°):

The scattered radiation follows the same pattern in both sides of the examination table; that is, the interventional doctor and the anesthetist, who are in symmetric position in relation to the X-rays tube, are exposed to similar intensity of air kerma rates. This happens because the X-ray beam is underneath the examination table, without any angulation. Among the three projections studied, the AP geometry is the one that presented the smallest air kerma rate measured. This can be explained by the fact that the path made by the primary beam in the phantom is shorter than in the other projections, as a result there is less scattering.

In the fluoroscopic mode, the maximum values measured were 861µGy/h (hands), 685µGy/h (gonads) and 574µGy/h (knee), at point -1D (close to the anesthetist). In the same mode, at point -1A, close to...
the interventional doctor when the access is brachial, the corresponding values were 254µGy/h, 368µGy/h and 391µGy/h. These values are reasonably low, if compared with the ones measured in digital acquisition mode, which were of 5000µGy/h at some points.

### 3.4 Additional Considerations

It was clear that the exposure of the body of the ones who operate the equipment is not even; it varies in intensity and distribution according to the person's position in relation to the patient, to the techniques used, to the time of exposure, to the fields of view used, etc. Therefore, the air kerma rates measured at each point are an attempt to estimate the doses received by the medical staff. Individual exact values of the levels of exposure are not possible to be determined.

A comparison of the air kerma rates for the different access modes was made. For the femoral access, the interventional doctor stands at point 1A, and for the brachial access, at point 2A. In Figure 4, it is shown a comparison of the rates measured at point 1A and 2A, for all the heights and for the three projections, in the digital acquisition mode. The staff that performed the work through the brachial access were more exposed to radiation than those who performed the procedures through femoral access, due to their proximity to the X-ray tube in all the angulations of the C-arm.

**Figure 4** Comparison of the air kerma rates for the different access modes (interventional cardiologist position).

![Figure 4](image)

The calculated values for the equivalent doses were: lens = 293mSv/year and hands = 400mSv/year. The estimated value for the lens is higher than the annual limit of 150mSv/year [6]. It is recommended that the interventional doctor wears lead glasses to perform the procedure. Although the estimated value for the upper extremities in this simulation is not higher than the annual limit (500 mSv/year), it is still considered high. So, it is recommended that the interventional doctors wear protective gloves and keep their hands away from the primary X-ray beam.

Although the air kerma rates (µGy/h) measured in the digital acquisition mode are higher than those in the fluoroscopic mode (µGy/h), the calculated equivalent doses are significantly higher when projected for the annual limits (mSv/year), due to the long fluoroscopy times involved in the procedures.
4. Conclusion

From the air kerma rates values obtained in the points inside the room, it is possible to identify the places with the highest levels of exposure, where it is not desirable for the staff to stay during the procedures. In some cases, as in the LAO for the hands and lens, the air kerma rates measured could be higher than the equivalent dose limits. It can happen when the projection for the obtained values in air kerma for the annual equivalent doses is made. The oblique incidences are considered the most critical to the irradiation of the staff.

The work allows the staff to be aware of the expected levels of exposure in some parts of the body, as well as it suggests means of protection against radiation for the different geometries of the equipment. In points identified as critical, it is important to implement additional protection devices and dosimeters. The doctor that performs the procedures must wear protection for the face and lens. It is important to call the attention of the protective clothes manufacturers to the size and length of the lead aprons, due to the measured values of air kerma rates in the knee area.

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REFERENCES