Effect of Changes in Technical Parameters in Radiological Safety

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Abstract. This work analyzes the generation of secondary radiation that affects the professionals of health during interventional X ray procedures in first level hospitals. The research objectives were, on the one hand, to quantify the amount of radiation and to compare it with norms in force with respect to magnitudes, and on the other hand to evaluate the elements of protection used. The measurements will help to improve the radiological safety, to assess the eventuality of risks and, in the last term, to the possibility of norms modification for the improvement of the protection, especially that of the personnel who daily make a certain amount of interventional procedures guided by radiation, like angiographic cine applications, using continuous or pulsed fluoroscopy. The motivation of the study is in the suspicion that present interventionism is made with a false sensation of safety, based only in the use of lead apron and protection elements incorporated in the equipment by the manufacturer, nevertheless not always the health personnel are conscious that an excessive proximity with the tube and the patient body becomes a risky source of secondary and scattered radiation. The obtained results allow us to demonstrate the existence of conditions of risk, even possible iatrogenic events, in particular when the procedures imply the use of certain techniques of radiographic exploration, thus reaching the conclusion that the radiographic methodology must be changed in order to rationalize so much?. In order to achieve this we propose modifications to the present norms and legislation referred to the radiological safety in Chile.

1. Introduction
The specialist in the use of radiation on the patient with diagnostic purposes is denominated in Chile Medical Technologist and his concern is the suitable management of the equipment and the patient to obtain the best images with the fewest possible affectations by the use of ionizing radiation, another professional obviously related to X rays is the radiologist physician who interprets the results and in certain cases he participates in the management of the patient in exploratory studies that he requires himself to make, both professionals have by formation and its daily practical individual, a sufficient knowledge about the safety and the elementary measures to avoid affectation by the direct or secondary radiation generated by bounces in objects or the own patient. Nevertheless at the present time other kinds of professionals works with X rays, cardiologists, angiologist and urologist that implant pacemakers, introduce catheters, install Stents, make PTCA manoeuvres, measure urinary fluometry and in general carry out interventionist procedures in the middle of the fluoroscopic radiation or process of x ray cine, which implies them, to remain during certain time exposed at certain levels of direct radiation and in greater level to secondary radiation coming from the equipment or from the patient.

The investigation tries to analyze the effects not only on the patients, but on the personnel who works with X rays in cardiac interventionist procedures, called Working Exposed Personnel (WEP).
2. Method and instruments
For the Research we use a phantoms (simulator of patient), who emulates the reflection and absorption characteristics of X radiation of the torso of an adult and a modern C arm for angiographic equipment (2004) Siemens ARTIS DF installed in Dr. Gustavo Fricke, Hospital, Viña del Mar, with multipulse x-rays Generator provided with computerized loading tube and automatic exposimeter. The equipment used is type DR, (Digital Radiology), that include flat panel (it gives to digital output when receiving radiation), without CCTV, and can give continuous operation: Máx. 125 kV, 24 mA. and maximum levels of exposure: 125 kV, 640 mA; 80 kV, 1000 mA.

During the investigation the “patient” was radiated from diverse usual projections in angiographic procedures, with several techniques and ways of generation from fluoroscopy levels.

Figure 1. Schematic representation of the equipment, the location of the radiation meter is to 130 cms. to floor.

The measurements were made with an instrument Victoreen Model 450P with pressurized ionization chamber, calibrated with Cesium 137 in October 06/2006.

In general it was tried to obtain results about:
- Evaluation of the effects after modifying the technical parameters of exploration.
- Evaluation of the efficiency of the elements of radiological safety.
- Evaluation of the levels and form of X rays dispersion at surrounding space.
- Evaluation of the radiation levels to which the WEP in their jobs is exposed.

One settles down as fundamental parameter, the radiation detection to 130 Cms. of height from the ground.

This length was standardizes using a Mayo table, whose elevation was regulated so that the center of the ionization chamber was located to the wished height (1.3mts.). Radiation in each point is measured that forms squares of 50 Cms by side.
Figure 2 Drawn into squares of measurement to 50 Cms.

From the ample data obtained by the measurements, information relative to three significant aspects was obtained:

A) The relative to the distribution of the secondary radiation in a single plane, by means of iso-exposure curves; and the form in which the modification of some parameters of exploration generates changes in the detected levels of radiation, affecting of form differentiated to the participants in the interventionist processes.

B) The relative to the way as the level of exhibition to secondary radiation by effect of four concomitants factors is modified to consider.

C) The relative to the protective effect that offers the elements of shield (with lead lenses and lead aprons) for the medical and paramedic personnel. The values of the measurements are given in format of exposition rate (mR/h) in all the cases, and because the type of study was necessary to use exposure instead absorbed dose (mR instead mGy). [1]
The obtained data in paragraph A) allowed studying the exposition to radiation over two medical and paramedical workers [2]; the results of these measurements appear in another publication. In this paper the results of the measured aspects in B) are analyzed solely, that is to say to quantify as changes the secondary radiation by usual radiographic technical factors and in C) that is to say, to quantify as it operates the protection by elements of shielding.

3. Results

For safety and advantage, the investigation without patients (use of phantoms) allows making changes in the modality of the studies without taking care of the dose optimization [3].

The first part of the study generates iso-exposure curves that show to the distribution of the radiation according to the position assumed by the X-rays tube and the flat-panel detector.

Three angiographic projections were analysed; antero-posterior (AP), left anterior oblique (LAO) and lateral (LAT 90). [4]

The second part of the study, the measurement of the generated levels of Secondary Radiation from the modification of the technical parameters for the angiographic exploration, is focused in AP projection. The acquisition of this information is obtained without varying the position of the C arm, and the following parameters were modified:

1) Distance between flat-panel and phantom.
2) Height of the table with respect to the floor.
3) Variations in the size of Field of View.
4) Variation of the number of pulses per second of the radiation from the multipulse generator.

3.1 Discussion on the protection

In order to determine the efficiency of elements of radiological safety, measurements were made that serve to evaluate the efficiency of the apron with lead to 50 and 100 cm of isocenter. The justification of this consists to determine the magnitude of the attenuation of radiation to different distances from the source.

In order to evaluate the efficiency of the protection with lead lenses; only a measurement to 50 cm of isocenter was made.

| Measurement | Distance flat panel phantom 30 Cms | Distance flat panel phantom 15 Cms |
|-------------|----------------------------------|----------------------------------|
|             | mR/h    | KV  | mA  | mR/h    | KV  | mA  |
| Measurement 1 | 23  | 66  | 81  | 22  | 66  | 66  |
| Measurement 2 | 23  | 66  | 80  | 21  | 66  | 67  |
| Measurement 3 | 23  | 66  | 82  | 22  | 66  | 68  |
| Average      | 23.67 | 66  | 81  | 21.67 | 66  | 67  |

Distance of the detector to isocenter = 50 Cms.
Field of View Size = 25 Cms.
Pulses of fluoroscopy = 15 puls/sec
| Table 2. Radiation based on the distance between the table and floor |
|---------------------------------------------------------------|
| Distance flat panel phantom 30 cms | Distance flat panel phantom 15 cms |
| mR/h | KV | mA | mR/h | KV | mA |
|------------------------------------|---------------------------------|
| Measurement 1                      | 23 | 66 | 81 | 22 | 66 | 66 |
| Measurement 2                      | 23 | 66 | 80 | 21 | 66 | 67 |
| Measurement 3                      | 23 | 66 | 82 | 22 | 66 | 68 |
| Average                            | 23 | 66 | 81 | 21.67 | 66 | 67 |

Distance of the detector to isocenter = 50 Cms.
Distance flat panel table = 24 Cms.
Distance flat panel X ray tube = 93 Cms.
Pulses of fluoroscopy = 15 puls/sec
Field of View Size = 25 Cms

| Table 3. Radiation based on Field of View size |
|-----------------------------------------------|
| FOV size 16 Cms | FOV size 25 Cms |
| mR/h | KV | mA | mR/h | KV | mA |
|-----------------------------------------------|
| Measurement 1                      | 30 | 58 | 175.8 | 14.5 | 58 | 82.2 |
| Measurement 2                      | 31 | 58 | 174.6 | 14 | 58 | 82.2 |
| Measurement 3                      | 32 | 58 | 175 | 14.3 | 58 | 82.2 |
| Average                            | 21.67 | 58 | 175.1 | 14.27 | 58 | 82.2 |

Distance of the detector to isocenter = 100 Cms.
Distance flat panel table = 24 Cms.
Distance flat panel X ray tube = 101 Cms.
Pulses of fluoroscopy = 15 puls/sec
Height of the table = 104 Cms

| Table 4. Radiation based on the fluoroscopy pulses |
|--------------------------------------------------|
| Fluoroscopy pulses 30 p/sec | Fluoroscopy pulses 10 p/sec |
| mR/h | KV | mA | mR/h | KV | mA |
|-----------------------------------------------|
| Measurement 1                      | 57 | 66 | 134.9 | 20 | 66 | 92 |
| Measurement 2                      | 56 | 66 | 140 | 20 | 61 | 92 |
| Measurement 3                      | 47 | 66 | 139.6 | 20 | 66 | 92 |
| Average                            | 21.33 | 66 | 138.17 | 20 | 64.3 | 92 |
Distance of the detector to isocenter = 50 Cms.
Distance flat panel table = 22 Cms.
Distance flat panel X ray tube = 97 Cms.
Size of the Field of Vision = 25 Cms
Height of the table = 104 Cms

Table 5. Evaluation of lead apron at 50 Cms from isocenter

|                         | Without lead apron | With 0.25 mm lead | With 0.5 mm lead |
|-------------------------|--------------------|-------------------|-----------------|
|                         | mR/h   KV   mA    | mR/h   KV   mA    | mR/h   KV   mA  |
| Measurement 1           | 22   58     87.5  | 2.1   58     83.2 | 1.05  58     83.2 |
| Measurement 2           | 21   58     88.3  | 2     58     82.2 | 0.98  58     82.3 |
| Measurement 3           | 21   58     88.5  | 2.1   58     83.2 | 0.87  58     83.2 |
| Average                 | 21.33 58     88.1 | 2.07  58     82.87 | 0.97  58     82.87 |

Size of the Field of Vision = 25 Cms
Distance flat panel table = 24 Cms.
Distance flat panel X ray tube = 101 Cms
Pulses of fluoroscopy = 15 puls/sec.
Height of the table = 104 Cms

Table 6. Evaluation of lead apron at 100 Cms from isocenter

|                         | Without lead apron | With 0.25 mm lead | With 0.5 mm lead |
|-------------------------|--------------------|-------------------|-----------------|
|                         | mR/h   KV   mA    | mR/h   KV   mA    | mR/h   KV   mA  |
| Measurement 1           | 9     58     87.5  | 0.73  58     83.2 | 0.25  58     83.2 |
| Measurement 2           | 8.9   58     88.3  | 0.73  58     82.2 | 0.26  58     82.2 |
| Measurement 3           | 8.9   58     88.5  | 0.8   58     83.2 | 0.23  58     83.2 |
| Average                 | 8.93  58     88.1 | 0.75  58     82.87 | 0.24  58     82.87 |

Size of the Field of Vision = 25 Cms
Distance flat panel table = 24 Cms.
Distance flat panel X ray tube = 101 Cms
Pulses of fluoroscopy = 15 puls/sec.
Height of the table = 104 Cms
Table 7. Evaluation of the lead lenses

|                     | Without lead lenses | With lead lenses |
|---------------------|---------------------|------------------|
|                     | mR/h                | KV               | mA   | mR/h | KV | mA |
| Measurement 1       | 20                  | 58               | 87.5 | 15   | 58 | 91.8 |
| Measurement 2       | 22                  | 58               | 88.3 | 15.6 | 58 | 91  |
| Measurement 3       | 21                  | 58               | 88.5 | 17.5 | 58 | 91.53 |
| Average             | 21                  | 58               | 88.1 | 15.87 | 58 | 91.53 |

Distance of the detector to isocenter = 50 Cms.
Distance flat panel table = 24 Cms.
Distance flat panel X ray tube = 101 Cms.
Size of the Field of Vision = 25 Cms
Height of the table = 104 Cms
Pulses of fluoroscopy = 15 puls/sec

4. Conclusions

1) During the angiographic exploration the variation of the height of the flat-panel becomes necessary with respect to the patient or the examination table.

These variations indeed generate changes in the level of radiation as much for the patient as for the WEP. The obtained results allow demonstrating, like others international studies, [5] that if we increased the distance of the flat-panel in 17 cm. the radiation also will increase. If we expressed this variation in percentage we would obtain that the modification of the distance in 17 cm. generates an increase of a 6.1% in the secondary radiation in 50 cm. of isocenter.

The explanation to this situation corresponds to that the increase of the distance between the receiver and the tube, must be compensated by an increase of the tube current, as is observed in the corresponding data table with the intention of being able to maintain an image diagnoses optimal during the study. Therefore, the recommendation is to reduce to the minimum the distance between the flat-panel (or image intensifier) and the patient, because this aid to reduce the radiation emitted by the source.

2) Another element that habitually shows variations within the angiographic studies is the height of the table of exploration with respect to the ground.

By means of this study it is possible to be determined that, an elevation of 15 cm. in the height of the examination table generates an increase of the secondary radiation in a 13.84% at 1 meter of distance of isocenter. Therefore, it is inferred that the increase of the height of the table generates an increase in the radiation emitted by the C arm equipment. In this case also an increase in the current of the tube takes place.

3) The variation of the size of the exploration field is very useful to magnify the image and to be capable to appreciate small structures within the anatomy of the patient. Unfortunately this modification also generates changes in the radiation levels. During the diminution of the size of the field of vision of 25 to 16 cm. an increase of a 117% in the secondary radiation takes place in 1 meter of distance of isocenter. This value is very important if we considered that during the angiographic
procedures the small sizes of field are used by a period of time superior to those of greater size specially in the positioning of Stents.

4) The technological advance has allowed that the efficiency of the x-rays tube increases. That means a significant reduction of the radiation. The C arm used for this study include three modalities of fluoroscopic radiation 10, 15 and 30 pulses per second. Being 15 pulses/sec. The modality used by default during all the procedures. From this one the modifications of the parameters were analyzed. First verification: if we increased to the double the number of pulses per second (of 15 to 30 pulses/sec.), the radiation is increased in a 82% to 50 cm. of isocenter. Second verification: if we reduce the pulse frequency to 10 pulses/sec. The radiation diminishes in a 32% to 50 cm. of isocenter.

It becomes necessary then, the verification of the amount of radiation generated in x-rays equipment that has only continuous fluoroscopy. Situation that would be necessary to analyze by means of another research.

5) One of the most interesting points of the present study is the demonstration of the level of effectiveness obtained using lead protection. Within the area of work of the WEP in the laboratories of hemodynamic studies, the protection using lead aprons becomes indispensable. Nevertheless, many X ray workers do not know the safety level that this one provides to them.

When verifying the values obtained after the measurements with and without shield protection with lead in a same point, is possible be inferred that the use of this type of shield indeed reduces the degree of exposition to the secondary ionizer radiation.

The measurements were made in two different points, to 50 cm and 100 cm respectively. The reason is to be able to evaluate if the efficiency of the attenuation is the same if the distance is increased.

I. First position, to 50 cm. of isocenter:

It was possible to be verified that the posterior side of the apron equivalent to 0,25 mm of lead reduces the radiation in a 88%. Whereas the frontal part equivalent to 0,5 mm of lead reduces the radiation a 96%.

II. Second position, to 1 meter of isocenter:

With the same way, for 100 cm. of isocenter distance, was determined that the posterior side of the shield with lead apron reduced a 92% of the secondary radiation. Whereas the part equivalent to 5 mm Pb diminished it in a 97%.

The attenuation of the secondary radiation provided by the lead aprons is similar, specially to greater distances and is equivalent to lead of 5 mm. Nevertheless, the use of these elements to a smaller distance of 50 cm. or directly in front of the primary beam of radiation it would generate an uncertain efficiency of protection provided by those safety elements; this study cannot be able to determinate that efficiency.

As general conclusions of the research in relation to the generation of secondary radiation and the forms of protection, can be determined that the iso-exposure curves, allow to appreciate that the hottest point is always included within the diameter of isocenter and the x-rays tube. Is important to emphasize that the distribution of the radiation levels, follows the movement of C arm. Always the most elevated levels of radiation are in zones near the flat-panel and secondly near the x-rays tube.

5. Recommendations

Is important to use lead protector hanging of the ceiling and additional shielding to the aprons, like lead lenses (they reduce the radiation in 97%). To reduce number of x ray projections and adjust the LAO projection to 50/35, providing a smaller degree of caudal approach and left angled.

Select fluoroscopy with the smaller number of pulses for suitable image (15 pulses instead of 30). To propose changes in procedures for interventionism work in angiography, defining new parameters, preferred projections, better use of protection elements towards the best safety of the patients and the personnel going consequently towards the change of the present legislation [6], [7].
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