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Research Paper

Comparison of radiation doses during coronary interventional procedures performed using different angiographs

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ABSTRACT

Heart disease has become one of the main civilization diseases, also in Poland. They mainly concern the working population. Interventional radiology methods are preferred currently for the treatment cardiac disorders. This study was conducted to assess the importance of technological solutions in angiographs used in such procedures for radiation risk to adult patients. Four different angiographs currently offered by main producers, that is: Allura Clarity and Azurion (both made by Philips), Artis Zee (Siemens) and Infinix X (Canon -preveiously Toshiba) were compared. X-ray doses were measured at the same exposure conditions using thermoluminescent dosemeters manufactured by LADIS Laboratory (Krakow, Poland). During the patient's exposure, he imitated the anthropomorphic adult human phantom (CIRS, USA). The doses absorbed in the volumes corresponding to particular organs and body parts were evaluated. Having obtained them, the effective doses were also computed according ICRP recommendations. Statistically significant differences were observed in the doses when the particular angiographs were used. For example: in the heart from 7.8 to 14.5 mGy, in the lungs from 5.6 to 17.2 mGy, in the liver from 0.4 to 14.4 mGy. Value of the effective dose differs from 1.4 to 8.9 mSv. The observed differences can be explained by a diverse action of automatic exposure control for the compared angiographs resulting in different dynamics of dose increasing. It should be noted that the dose differences were found despite the fact that the "patient" was the same and the same exposure conditions.

Key words: Heart disease, patients, angiographs, radiation doses.

INTRODUCTION

Heart disease has become one the main civilization diseases, also in Poland. They mainly concern to the working population. Interventional radiology methods are preferred currently for the treatment cardiac disorders. As consequence, coronary angiography (CORO) following percutaneous coronary intervention (PCI) is the most frequently performed interventional procedure in cardiology with more than 200.000 procedures performed yearly in Poland (2013) (Ochala et al., 2014). Hence, IC procedures are significant medical source of ionizing radiation for world population with impact of about 10% into mean effective dose per capita (Cornetto et al., 2016).

The level of radiation risk in IC procedures is highly dependent on the clinical condition and physiology of patient but also on the technical quality of imaging equipment (that is, angiographs). When a long-time X-ray exposure is necessary, the relatively high doses for both patient and operating team are recorded in consequence.

Table 1: Absorbed doses (in mGy) and effective dose (in mSv) for adult patient and air kerma (in mGy).

	Angiograph			
	Artis Zee	**Allura Clarity**	**Azurion**	**Infinix X**
Effective dose [mSv]	8.89±2.07	5.19±1.92	1.81±0.68	1.39±0.71
Absorbed organ doses [mGy]				
Lungs	17.20±7.32	12.82±6.50	6.28±2.03	5.56±3.64
Heart	14.52±6.37	13.82±6.43	8.25±2.32	7.87±3.16
Liver	14.42±7.27	5.87±3.61	1.38±0.82	0.37±0.26
Stomach	24.77±11.65	9.59±4.31	0.71±0.39	0.38±0.32
Kidneys	31.45±4.47	5.68±4.05	1.20±0.60	0.24±0.13
Ribs	24.8±23.10	7.84±4.30	6.32±4.71	2.47±1.01
TH spine	26.04±15.55	22.71±7.31	5.98±1.94	6.64±5.63
L-S spine	17.92±13.04	3.80±3.52	1.31±0.54	0.12±0.02
Shoulder	7.88±0.30	9.17±1.03	2.46±0.30	4.12±0.15
Red bone marrow (total)	9.39±2.74	5.52±1.66	3.92±1.41	2.95±0.92
Entrance Air Kerma (in reference point) [mGy]				
	531.1 (10 frames/s)	210.0 (15 frames/s)	97.0 (7.5 frames/s)	81.9 (10 frames/s)

The aim of this study was to evaluate the importance of technological solutions in angiographs used for coronary angiography following percutaneous coronary intervention (CORO+PCI) for radiation risk to adult patients. For this purpose, the doses obtained in these procedures performed under control of four different angiographs currently offered by main producers, that is: Allura Clarity and Azurion (both made by Philips), Artis Zee (made by Siemens) and Infinix X (made by Canon - previeously Toshiba) were compared.

METHODS

X-ray doses were evaluated experimentally using thermoluminescent (TL) dosemeters manufactured by Ladis Laboratory (Krakow, Poland). During the patient's exposure, he imitated the anthropomorphic adult human phantom (CIRS, USA). All the exposures were performed in a routine fashion, according to the same "standardized" working schedule being elaborated on the basis of direct careful observation of real patients' treatment. The scheme of projections together with their duration (that is, chronometry) and the current-voltage parameters were recorded. For this purpose, the procedures without any specific clinical complications were taken into consideration and patients who underwent them were adults of standard body size.

RESULTS

As regard the result of the measurements, the doses absorbed in the volumes corresponding to particular organs and body parts were evaluated. Having obtained them, the effective doses (as a measure of future health effects probability) were also computed according ICRP recommendations (ICRP, 2007).

The exposure conditions for all dosimetrically evaluated procedure were as follows:

1) Radiography: 2 times at about 80 kV (mAs -set automatically) at LAO-20^0 and SID=100 cm,
2) CORO- pulsed fluoroscopy:

a) RAO 20/CAUD 30 : 20 s,
b) LAO 40/CAUD 2 : 18 s,
c) LAO 4/CRAN 37 : 21 s,
d) LAO 30/CAUD 40: 22 s;

3) PCI - pulsed fluoroscopy LAO 40/CAUD 20: 9.5 min;
4) Acquisition (fluorography): 5-6 s projections according CORO-2(a,b,c,d) and 20 s according PCI -*3.*
The results of measurements performed at above parameters are shown in Table 1 where the following values are given:

- Doses absorbed in the organs situated in body volume

Table 2: Maximal values of absorbed doses (in mGy) recorded in organs covered by primary X-ray beam.

	Angiograph			
	Artis Zee	**Allura Clarity**	**Azurion**	**Infinix X**
	Absorbed organ doses [mGy]			
Lungs	49.0 - 68.7 w: 16-19	57.5 w: 16	20.8 w: 16	32.6-46.5 w: 15-16
Heart	27.5 w:18	18.1-22.2 w:17-18	13.3 w:13	12.2 w:15
Ribs	51.5 w:17	13.7 w:17	19.7 w:17	3.3 w:17
Thoracic spine	46.5 w:17	30.5 w:17	8.3 w:15	13.4 w:15

("w" means the number of phantom' slice where the dose was registered.)

cover by primary X-ray beam,
- Effective dose and
- Air kerma in the reference point.

The last quantity is measured automatically by angiographic system and displayed on the monitors.

Table 1 shows absorbed doses (in mGy) and effective dose (in mSv) for adult patient and air kerma (in mGy).

Table 2 shows maximal values of absorbed doses (in mGy) recorded in organs covered by primary X-ray beam. Table 2 shows also the information about the number of phantom slices in which the high doses were registered. It should be noticed that for all angiographs the maximal dose values were measured in the same part of the given organs, with differences not exceeding 1-2 phantom slices, what means 2.5-5.0 cm.

This compliance is the proof of repeatability of geometrical pattern of exposure during all measurement sessions which results are presented in this study.

SUMMARY

The obtained results were statistically analyzed using non-parametric Wilcoxon' test sum of rank (in wider version Mann-Whitney-Wilcoxon). The statistical probe was completed from dose values obtained during exposure performed the given angiograph. The compared probes were independent and had the same number of elements. Value of test statistic (W) was calculated as sum of ranks and critical value at assumed significance level was checked in the appropriate statistical tables (Zieliński, 1972).

As the result, the following relationships among the dose values for adult patients in CORO+PCI procedures under control of compared angiographs were found:

1) Artis Zee - Allura Clarity : differ at significance level $\alpha = 0.02$,
2) Artis Zee - Infinix : differ at significance level $\alpha = 0.02$,
3) Artis Zee -Azurion : differ at significance level $\alpha = 0.02$,
4) Allura Clarity - Infinix : differ at significance level $\alpha = 0.02$,
5) Allura Clarity - Azurion : differ at significance level $\alpha = 0.05$,
6) Infinix - Azurion : do not differ significantly.

It should be noted that the dose differences were found despite:

- the same "patient" (that is, antropomorphic phantom),
- the same angles of projections, time of X-ray emission and distance to focus of X-ray tube.

The observed differences can be explained by a diverse action of automatic exposure control (AEC) for the compared angiographs resulting in different dynamics of dose increasing. Additionally- an automatic change of filtration in dependence on thickness of examined object (patient) is implemented in Artis Zee and Infinix. As consequence, when a part of the spine or the ribs are covered by primary X-ray beam, the intensity and penetrability of radiation becomes higher and doses for deep organs placed on directory of primary beam are also higher.

As a result, for angiographs with such high dynamics of AEC system better quality of images for big-size patients is

easier to obtain, although the angles of particular projections should be set very carefully. Size of primary beam area is also important for dose level.

Another important parameter is frequency of X-ray pulses: it was 15 frames/s for Allura Clarity, 10 frames/s for Artis Zee and Infinix and 7.5 frames/s for Azurion. The higher frequency means higher doses as well to patient as to operating team.

Characteristic feature of exposure in interventional radiology procedures is the possibility of high irradiation of relatively small areas of patient' body (dependently on procedure type).

For IC procedures, this problem concerns of course the whole heart, but also part of the lung (mainly right one), part of TH-spine and the ribs. The dose for these parts can be really high, even if average absorbed doses for the organs /body parts are quite acceptable and organ remains undamaged.

However, the high doses should be absolutely avoided for children having 2-3 times higher susceptibility for induction of biological health effects of irradiation.

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