Radiation Protection in Paediatric Interventional Cardiology in Latin America. Advances of the Regional IAEA program.

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Abstract

The aim of this work is to present the advances of the pilot program on radiation protection in paediatric interventional cardiology launched by the International Atomic Energy Agency in Latin America in 2010. The program objectives and the methodology to collect and process data on patient and staff radiation doses were agreed during a workshop with paediatric cardiologists from 11 Latin American countries. Special attention was given to agree on a common quality control protocol for the x-ray and imaging systems, dosimetric parameters to be collected and a list of the most common procedures.

The preliminary results showed that only 64% of the cardiologists used their personal dosimeters regularly and that only 36% were aware of their personal dose values. During the first step, patient dose data were available in only 5 centers from 4 countries. Median values of kerma area product (KAP) for the five centers (and the full sample of 290 procedures), ranged from 0.7 to 12.5 Gy.cm^2 with a 3rd quartile (for the median values) of 11.3 Gy.cm^2. For fluoroscopy time, median values ranged from 5.3 to 20.8 min.

For the 4 agreed age groups to split the global sample: 0-<1y; 1-<5y; 5-<10y and 10-<16y, the 3rd quartiles of median KAP resulted in the following values: 3.9; 7; 10.5 and 8 Gy.cm^2. This could be considered as an initial approach to diagnostic reference levels, but data from more countries are still missing and the value of 8 Gy.cm^2 need to be reassessed when the sample in this age band will be larger. The impact of procedure complexity on patient dose values needs to be derived in the future. Optimization actions are expected to be started during the next step of the program.

One of the most significant difficulties in auditing and optimizing radiation protection in paediatrics is the relatively low number of procedures and the need to split the samples into 4 age groups.

Keywords: radiation protection, pediatric, patient doses, training, interventional cardiology

1. INTRODUCTION

According to the latest report United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the medical applications of ionizing radiation represent the main-made source of ionizing radiation exposure. Newborn, infants and children, undergo radiological procedures, some of which are high dose procedures such as computed tomography (CT) and interventional procedures (UNSCEAR 2008). The National Council on Radiation Protection and Measurements (NCRP) in USA has determined that medical imaging contributes nearly half of the overall exposure to ionizing radiation in the U.S (NCRP 2009), identifying the interventional radiology procedures as the third largest contributor to collective dose after CT and nuclear medicine (NCRP 2009).

Children undergoing interventional cardiology (IC) procedures, require special attention due to their higher radiosensitivity (Bacher *et al* 2005, Wagner *et al* 2006), which gives a higher probability of cancer when compared with adult patients (ICRP 2007).

The pediatric IC procedures in the regions of Latin America and the Caribbean are performed by medical specialists in pediatric cardiology, who do not often have specific training in radiology imaging and radiation protection (RP) according to the results of the surveys carried out during several training courses organized in the region by the International Atomic Energy Agency (IAEA). Moreover, modern X-ray systems used in pediatric IC are complex to operate because of their numerous setting options and operational modes. Consequently, it is appropriate that the physicians conducting the procedures and other paramedical personnel involved have a clear understanding of the operating characteristics of the X-ray and imaging systems and the practical principles of operational rules for radiation safety.

The problem with some of the procedures in pediatric IC is the re-intervention rate due to the reappearance of the disease. This clearly calls for the establishment of a radiation safety program including patient and staff dose measurements and analysis as well as continuing education in RP and optimization. This program is necessary to guarantee that patient and staff doses are kept at a minimum while ensuring adequate image quality and diagnostic information to guide the procedures.

The IAEA, aware of the situation in Latin America and the Caribbean, has implemented a technical cooperation project entitled “Ensuring Radiological Protection of patients during medical exposures (TSA3), RLA/9/067” (IAEA 2010a). The countries participating in the project are: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela. The first results of this IAEA pilot program were recently published by Vano *et al* 2011.

This paper presents the Advances of the Regional IAEA program on RP in pediatric IC started in 2010.

2. MATERIAL AND METHODS

The pilot program in RP started with a workshop, made in May 2010 at the Luis Calvo Mackenna Hospital in Santiago de Chile. During this workshop, a radiation protection course was imparted to 15 senior interventional cardiologists from 11 Latin American Countries.

The training was carried out over two and a half days with a total of 17 hours of lecturing (including practical and discussion sessions) and partly followed the same pattern as other previous IAEA training activities (Rehani 2007). The seminars and group discussions focused mainly on particular situations and problems the attendants had experienced, but nonetheless considered of general interest by the lecturers and the audience (Vano *et al* 2011).

Parallel to this course, other sessions of the workshop were dedicated to discuss the format and content of questionnaires intended to collect data during the survey to be initiated, such as dosimetric aspects, experience and training in RP of the staff, X-ray system used, number, kind and complexity of the procedures, etc. Some data arrived to be collected prior to the workshop, but they were also completed and discussed during the workshop to avoid any mistakes or inconsistencies.

The participants completed different questionnaires before or during the event to help launch a Latin American network to promote radiation safety in their medical specialty. One referred for example to the use of radiation protection tools and dosimetry (table 1), likewise was agreed that a prospective set of data for a uniform sample of at least 20 clinical cases in the age range of 1-5 years, with demographic data (age and weight), the name of the procedure, together with the dosimetric data (if available), such as: kerma area product (KAP) for fluoroscopy and KAP total (including the cine series) ($Gy.cm^2$), cumulative skin dose (mGy) and time of fluoroscopy (min), should be asked along with the monthly occupational doses during 2010.

Some initial values of dose rate in fluoroscopy and dose per cine frame measured in paediatric X-ray systems in Chile would be used for initial comparison purposes and to help in a rough estimation of patient dose values in countries using X-ray systems without KAP meter. (Vano *et al* 2008, Ubeda *et al* 2010).

3. RESULTS AND DISCUSSION

Table 1 shows the results of the evaluation of the RP tools and dosimetry aspects during the workshop. The preliminary results showed that only 64% of the cardiologists used their personal dosimeters regularly and that only 36% were aware of their personal dose values. Recent surveys regarding dose levels to the lens of the eyes on medical staff have found a significant percentage of lens opacities attributable to occupational radiation exposure when radiological shielding or protection tools have not been used properly (Vano *et al* 2010, Ciraj-Bjelac *et al* 2010), therefore, it is worrying that only such a low percentage of physicians used their shielding tools available (ceiling suspended screens, goggles, etc). It is proved that the use of ceiling mounted leaded glass or lead glass eyewear with side shields reduce radiation exposure to the eyes of the operator by 90% (Thornton *et al* 2010).

Table 1**.** Use of radiation protection tools and dosimetry aspects (Vano *et al* 2011).

Questions	Positive response (%)
Do you use a personal dosimeter?	64
Do you know your radiation dose?	36
Do you use protective ceiling suspended screens?	41
Do you use protection goggles?	55
Do you use under table protective curtains?	36

Table 2, presents initial results of patient doses collected (median values of KAP) for the four typical age ranges (5 centers from 4 countries: Brazil, Chile (2 centers), Colombia and Uruguay). These values were obtained from a relatively small sample (290 procedures) and with no discrimination between the different procedures. The mean values for the age of the patients ranged from 2.9 to 5.7 years in the different centers. Median values of KAP for the five centers (and the full sample of procedures), ranged from 0.7 to 12.5 Gy.cm^2 with a 3rd quartile (for the median values) of 11.3 Gy.cm^2. For fluoroscopy time (median values) ranged from 5.3 to 20.8 min.

Table 2. Summary of kerma-area product (KAP) and fluoroscopy time values; minimum (min), maximum (max), mean, standard deviation (SD), median and third quartiles (3rd Q) for the full sample of diagnostic and therapeutic procedures.

				Kerma-area product (KAP) ($Gy.cm^2$)							fluoroscopy time (min)						
Center	Country	N	Age (mean ± SD)	min	Max	mean	SD	median	3rd quartile	3rd quartile of medians	min	max	mean	SD	median	3rd quartile	3rd quartile of medians
1	Brazil	24	3.8±3.1	0.02	51.3	16.1	13.1	12.5	23.3		6.5	76	24.9	17.7	20.8	30	
2	Chile	35	5.7±4.8	0.3	22.8	3.6	5	1.7	4		1	38.2	13.3	10.8	8.9	18.4	
3	Chile	33	4.1±3.9	0.9	60.8	14.7	14.4	11.3	16.2	11.3	2.7	83.2	22.6	18.3	20.8	25.6	20.8
4	Colombia	72	3.5 ± 4.3	0.1	33.3	1.6	4.1	0.7	1.3		0.7	37.2	8.4	7.5	5.3	10.8	
5	Uruguay	126	2.9±3.7	0.6	60	8.4	8.6	5.6	11		0.8	30.7	7.2	4.9	6	8	

Figures 1 and 2, show as example, some of the results of basic quality controls (characterization) of a X-ray system Siemens Axiom Artis BC, using polymethyl methacrylate (PMMA) thicknesses, to measure entrance surface dose for fluoroscopy and cine modes. We have used to characterize the X-ray systems the protocols agreed during the DIMOND and SENTINEL European programs (Vano *et al* 2005) and adapted in our case, to paediatric procedures (Vano *et al* 2008, Ubeda *et al* 2010).

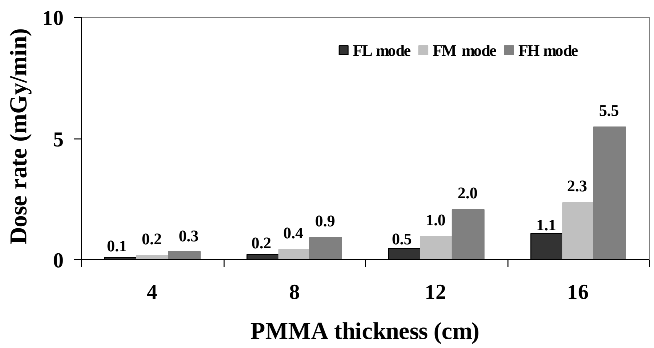

Figure 1. Entrance surface air kerma values. Comparison between fluoroscopy modes: low (FL), medium (FM) and high dose (FH) and different PMMA thicknesses. Field of view 22 cm. Leeds test object (TOR 18FG) at the isocentre.

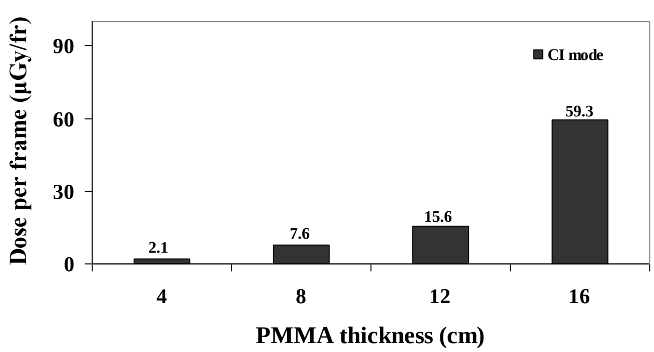

Figure 2. Entrance surface air kerma values per cine frame for different PMMA thicknesses. Field of view 22 cm. Leeds test object (TOR 18FG) at the isocentre.

The characterization of X-ray systems offers a set of useful data to help cardiologists to know the effect of the patient size (when moving from 4 to 16 cm of PMMA) and acquisition mode on patient doses. For example, the increase factors due to patient size are around 18 and 28 for fluoroscopy and cine modes respectively. Furthermore, having the test object at the isocentre, it is possible to evaluate image quality. As part of the program, we have characterized all paediatric X-ray fluoroscopy systems existing in Chile, finding a great variability in the dose values for different operation modes and thicknesses to simulate patients in the different age groups (Ubeda *et al* 2010). It should be noted that in some European surveys, very different values in terms of dose, were also found (Padovani *et al* 2008).

Table 3 shows the results of the median KAP values for all age bands and centers participating in the study.

Table 3. Median values of kerma area product (KAP) by age bands for all centres.
(*) These values need to be reassessed when the sample in this age band will be larger.

	Centre					
Age bands (years)	1 ($Gy.cm^2$)	2 ($Gy.cm^2$)	3 ($Gy.cm^2$)	4 ($Gy.cm^2$)	5 ($Gy.cm^2$)	3rd quartiles ($Gy.cm^2$)
<1	4.8	1.0	6.2	0.5	3.9	3.9
1 - <5	12.5	1.7	11.3	0.6	7	7
5 - <10	13.5	1.7	13.3	0.9	10.5	10.5
10-<16	31.4	5.6	13.8	2.8	8*	8*

The KAP can be used as a measure of the total X-ray energy imparted to the patient which relates to the stochastic effects (e.g., cancer) of radiation (NCRP 2011). The 3rd quartiles of median KAP values in table 3, achieved in our study for the four age bands, were 3.9 $Gy.cm^2$ (<1 y), 7 $Gy.cm^2$ (1 - <5 y), 10.5 $Gy.cm^2$ (5 - <10 y), 8 Gy.cm2 (10-<16 y), respectively. These values could be used as initial diagnostic reference levels to be refined during the IAEA program, but data from more countries are still missing and the value of 8 $Gy.cm^2$ for the age band of 10 - <16y need to be reassessed when the sample in this age band will be larger.

Table 4 presents a comparison of these initial results with others from recent published papers.

Table 4. Comparison between median KAP for pediatric cardiology reported in this work and by others (figures adapted by the authors of this paper). Values in the last column are mean values of the medians from the different centres.

Age bands (years)	Boothroyd *et al* 1997 (Gy.cm^2)	Rassow *et al* 2000 (Gy.cm^2)	Bacher *et al* 2005 (Gy.cm^2)	Martinez *et al* 2007 (Gy.cm^2)	Vano *et al* 2011 (Gy.cm^2)	This paper 2012 (Gy.cm^2)
<1	12	3		1.9	3.6	3.3
1 - <5	24	5	4.1	2.9	8.8	6.6
5 - <10	48	10		4.5	15	8
10-<15	98	18		15.4	23	12.3

The results of this IAEA pilot program show that radiation doses have a very large range (see table 2 and 3), as shown by other pediatric surveys (Papadopoulou *et al* 2005, Onnasch *et al* 2007, Tsapaki *et al* 2008 and Chida *et al* 2010). However, few papers (Boothroyd *et al* 1997, Rassow *et al* 2000, Bacher *et al* 2005, Martinez *et al* 2007 and Vano *et al* 2011) reported radiation dose values by age group, as shown in table 4. In addition, none of them represent an international research program as in this case. In this summary of the median values of KAP, the values of our survey are in the low range of other published surveys with the initial sample of centers involved but the situation could be different when a larger sample will be available. Note that most of the countries to be involved into this pilot program, such as Chile, have not incorporated in its RP legislation (Supreme Decrees 1984, 1985), the implementation of quality assurance programs including the characterization of X-ray fluoroscopy systems, together with the regular evaluation of patient doses.

The impact of procedure complexity on patient dose values needs to be derived in the future. Optimization actions are expected to be started during the next step of the program. One of the most significant difficulties in auditing and optimizing radiation protection in paediatrics is the relatively low number of procedures and the need to split the samples into 4 age groups.

5. CONCLUSIONS

This international action was designed to promote the radiation protection culture in pediatric interventional cardiology in Latin America, establishing the need to implement quality control periodically, as well as the collection and analysis of patient dose values. The initial diagnostic reference levels estimated from the median KAP value for four Latin American countries to the four age bands were, 3.9 Gy.cm^2 (<1 y) , 7 Gy.cm^2 (1 - <5 y), 10.5 Gy.cm^2 (5 - <10 y) and 8 Gy.cm2 (10-<16 y), respectively. The value of 8 Gy.cm^2 for the age band of 10- <16 y, will need to be reassessed when the sample in this age band will be larger.

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