Dosimetry in Interventional Cardiology Procedures: A Comparison Between Scheduled and Unscheduled Procedures at a Public Healthcare Center in Argentina

Dosimetría en procedimientos de Cardiología Intervencionista: comparativa entre procedimientos programados y no programados en un centro de atención pública de Argentina

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ABSTRACT

Background and objectives. The aim of this study is to analyze the dosimetry administered to patients on our site, compare it with existing literature, and determine whether there are differences between scheduled and unscheduled procedures.
Materials and methods. This retrospective observational study analyzed a sample of consecutive patients who underwent interventional procedures at the Department of Hemodynamics of Hospital Rawson between January 1, 2023, and June 30, 2023. Data on dosimetry were collected using the X-ray angiographic equipment available in their cath lab. Such data were analyzed, compared with current literature, and examined for differences between scheduled and unscheduled procedures.
Results. The mean fluoroscopy times for cardiac catheterization (CC) and for percutaneous coronary intervention (PCI) were 4.31 and 10.56 minutes, respectively. These times are lower than those reported in other studies. However, the mean dose-area product (DAP, in Gy/cm2) in our sample was higher than that reported by other authors, with an average of 65.95 for CC and 135.34 for CC + PCI. When analyzing dosimetry in scheduled versus unscheduled (mostly emergency) procedures, we found that scheduled procedures resulted in lower doses of ionizing radiation in terms of fluoroscopy DAP (p=0.041), exposure DAP (p=0.036), number of sequences (p=0.0209), and number of captured images (p=0.0065).
Conclusions. This study provides insight into the radiation doses administered to patients undergoing interventional cardiology procedures on our site and compares these doses with those reported by other authors. Scheduled procedures are associated with lower doses of ionizing radiation.

Keywords: reference levels, interventional cardiology, radiological protection.

RESUMEN

Antecedentes y objetivos. El objetivo de este estudio es conocer la dosimetría administrada a los pacientes en nuestro centro, agruparlos con las publicaciones existentes en la bibliografía y corroborar si existen diferencias entre procedimientos programados y no programados.
Materiales y métodos. Es un estudio retrospectivo observacional de una muestra de pacientes consecutivos a quienes se les practicaron procedimientos intervencionistas en el Servicio de Hemodinamia del Hospital Rawson desde el 01/01/2023 al 30/06/2023. Se recolectaron datos de la dosimetría administrada y recopilada a través del dispositivo angiográfico de Rayos X del laboratorio de cateterismo. Se analizaron y se relacionaron con datos obtenidos de la bibliografía actual, se compararon procedimientos programados y no programados.
Resultados. El tiempo medio de fluoroscopia fue para CCG y ATC de 4,31 y 10,56 minutos, respectivamente, que son menores que los de las publicaciones de otros autores. La media PDA (Gy/cm2) en nuestra muestra fue mayor a la publicada por otros autores, con una media de CCG 65,95 y en CCG + ATC 135,34. Al analizar la dosimetría administrada a pacientes sometidos a procedimientos programados y no programados (mayormente emergencias) encontramos que los procedimientos programados presentan menores dosis aplicadas de radiación ionizante en términos de PDA de fluoroscopia (p=0,041), PDA de exposición (p=0,036), cantidad de secuencias (p=0,0209) y cantidad de imágenes (p=0,0065) adquiridas.
Conclusiones. Se lograron conocer las dosis administradas a pacientes sometidos a procedimientos de cardiología intervencionista en nuestro centro, se compararon con la informada por otros autores. En los procedimientos programados se administran menores dosis de radiación ionizante.

Palabras clave: niveles de referencia, cardiología intervencionista, protección radiológica.

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INTRODUCTION

Medical radiation from X-rays and nuclear medicine is the largest source of man-made radiation exposure in Western countries, with an effective dose (ED) of 3.0 milliSievert (mSv) per person per year. This is equivalent to the dose administered in 150 chest X-rays[1, 2]. Natural background radiation worldwide is approximately 2.4 mSv. Cardiologists account for approximately 40% of the accumulated ED from medical sources, excluding radiotherapy, in the United States[3]. Furthermore, interventional cardiologists and electrophysiologists can be exposed to occupational radiation levels two to three times higher than imaging specialists[3], and this exposure has increased over the years[3]. In interventional procedures using ionizing radiation, "each patient should undergo the appropriate procedure at the appropriate time, with the appropriate dose."
This study aims to highlight the radiation doses administered to patients in our center, associate them with what has been published in similar studies, and compare the doses administered in scheduled and unscheduled procedures.

MATERIALS AND METHODS

In order to study the dosimetry administered in interventional cardiology and percutaneous procedures, we established the guidelines listed below.
Initially, a review of the current literature on the subject,

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TABLE 1. Aggregated procedures.

1	CC (n=97)
2	Combined CC (n=3): CC + cerebral artery; CC + lower limb vessels; CC + neck vessels
3	CC + PCI (n=37)
4	PCI (n=13)
5	Peripheral angioplasty (n=8): Lower limb peripheral angioplasty + carotid angioplasty
6	Other diagnostic studies (n=91): aortogram (n=1); cerebral artery (n=22); pulmonary artery (n=1); renal artery (n=1); neck vessels (n=1); right heart catheterization (n=12); electrophysiology (n=4); fistulography (n=20); lower limb vessels (n=21); upper limb vessels (n=4); fluoroscopic valvular study (n=1); visceral vessels (n=1).
7	Other treatment procedures (n=18): cerebral embolization (n=3), ablation (n=3), implantable cardioverter-defibrillator (ICD) and resynchronization (n=2); interventions for congenital defects (n=6); inferior vena cava filter placement (n=1); fistuloplasty (n=1); inferior vena cava filter retrieval (n=1); foreign body removal (n=1).

particularly in Argentina, was conducted. The study focused on the only publicly funded healthcare center in San Juan province, Argentina, which has an operational Department of Hemodynamics. Data were collected retrospectively, descriptively, and comparatively from all consecutive cases seen in the cath lab of the aforementioned institution between January 1, 2023, and June 30, 2023. Dosimetry data were analyzed after anonymization. Cases without recorded dose data were excluded. Dosimetry data were extracted from the hospital's Philips® Allura equipment using the Xcelera software, which stores such data as part of the report. General and comparative descriptive analyses were conducted using tests for non-parametric data, discarding classic parametric tests for both scheduled and unscheduled procedures due to sample distribution. For the analysis, procedures were aggregated in the 7 categories described in **Table 1**.

The quantitative variables analyzed were fluoroscopy time, angiographic dose-area product (DAP), air kerma, total number of captured sequences, total number of angiographic images obtained.

Combined diagnostic procedures (item 2) from **Table 2** were excluded, and so were *other diagnostic procedures* (item 6) and *other treatment procedures* (item 7).

Procedures were categorized based on whether they had been scheduled or unscheduled. *Unscheduled procedures* were defined as those not listed on the procedure schedule at least until the day before they were conducted. In most cases, angiographic studies were requested in cases of acute coronary syndrome; these were classified as urgent or emergency procedures. The variables under study were analyzed to determine whether there were significant differences. To that end, we used tests for non-parametric data due to the sample distribution. Specifically, the Wilcoxon rank-sum test was used for non-parametric data distribution. The significance level was set at $p<0.05$.

RESULTS

We determined the mean, median, third quartile (Q3), and standard deviation values for fluoroscopy time, dose-area product (DAP), air kerma (Ka), total number of images, and total number of series. All results are described in **Table 2**.

The mean fluoroscopy times for CC and CC + PCI were 4.31 and 10.56 minutes, respectively. For PCI, it was 12.92 minutes, and for peripheral angioplasty (PA), 14.03 minutes.

TABLE 2. Descriptive analysis of the variables under study

	N	Mean	Median	Q3 (Q75)	Standard deviation
Fluoroscopy time (min)					
CC	86	4.31	2.95	450.2	3.9
CC + PCI	30	10.56	7.07	10.93	11.65
PCI	11	12.92	8.37	20	12.25
PA	8	14.03	7.86	27.65	13.98
DAP (Gy/cm^2)					
CC	86	65.95	48.86	85.74	46.94
CC + PCI	30	135.34	88.58	119.14	156.32
PCI	11	141.85	80.31	257.40	133.42
PA	8	50.43	43.80	90.57	38.160
Air kerma (Gy/cm^2)					
CC	86	0.794	0.596	1.055	0.561
CC + PCI	30	1.775	1.195	2.021	1.736
PCI	11	2.307	1.471	3.792	2.473
PA	8	0.491	0.428	0.772	0.321
Total number of series					
CC	86	8.9	8	10	3.07
CC + PCI	30	19.7	16.5	23.5	11.43
PCI	11	20.36	17	29	10.8
PA	8	20.9	18	36.5	14.2
Total number of images					
CC	86	631.6	578.5	755.75	226.4
CC + PCI	30	1154.07	946.5	1111.5	524.7
PCI	11	1133.7	1036	1322	664.8
PA	8	972.9	811	1158.8	736.3

The table also shows the mean, median, Q3, and standard deviation values for the analyzed variables. The mean DAP (Gy/cm^2) for CC was 65.65; it was 135.34 for CC + PCI and 141.85 for PCI.

The comparison of the mean fluoroscopy times for cardiac catheterization (CC) and PCI (expressed in minutes), CC and CC + PCI with values in other publications is shown in **Tables 3 and 4.**

When comparing whether the procedures were scheduled or not, the analysis on whether there were significant differences ($p<0.05$) was conducted using the Wilcoxon rank-sum test for non-parametric or non-Gaussian distribution data. The outcomes regarding the doses administered to patients in scheduled procedures compared with unscheduled ones are described in **Table 5**. The variables compared were fluoroscopy time, fluoroscopy DAP, exposure DAP, air kerma, total number of series, and total number of images.

DISCUSSION

In interventional radiology, there are three basic principles for the administration and use of X-rays: justification, optimization, and dose limitation. Justification means that the procedure to be performed must provide a benefit to both the patient and society. The principle of optimization, also known as ALARA (as low as reasonably achievable), implies that all exposure should be kept as low as reasonably possible. The dose limitation principle states that radiation doses received by individuals must not exceed the limits established by current legislation.

Based on this, the administered dose range varies greatly for all radiological procedures, since variables such as patient clinical condition, age, weight, and type of X-ray equipment used all play a role[12].

In the comparative analysis of CC, both the fluoroscopy exposure times in minutes for coronary angiography and

TABLE 3. Comparison of fluoroscopy times in minutes and DAP (Gy/cm²) for diagnostic cardiac catheterizations in relation to other publications. *T = Mean fluoroscopy times, expressed in minutes.

Authors	N	T*	Dose-area product (Gy/cm²)		
			Mean	Median	Q3
This study	86	4.31	65.95	48.86	85.74
González-López ***et al***. 2021 (4)	95	5.8	29.1	21.7	38.1
Jungsu ***et al.*** (2015) (5)	361	4.7	67.6	54.7	75.6
Humagain, Maharjan, and Koju (2015) (6)	166	11.4	40.7		
Simantirakis ***et al.*** (2013) (7)	2572	6.0	53.0		
Vano ***et al.*** (2013) (8)	1849	6.5	32		
Georges ***et al.*** (2007) (9)	3600	6.3	63.0		
Tsapaki ***et al.*** (2003) (10)	195	6.5	47.3	39.1	60.4
Broadhead ***et al.*** (1997) (11)	2174	5.7	57.8	45.5	69.9
Zorzetto ***et al.*** (1997) (10)	79	4.9	55.9	52.5	65.6

the DAP values are similar to those reported by other authors in different years, although in some cases they are higher or lower. These comparisons are summarized in **Table 4**[5-9,11,13-16].

Table 4 includes PCI and CC + PCI procedures from our sample as well as those reported by other authors. Compared to other authors, our values for fluoroscopy time are similar. Our DAP values are generally higher compared to those in other studies. There is only one study from 2021; the others are older[5-9, 11, 13-16]. Additionally, we have no reference regarding the complexity level of the procedures or the number of vessels treated in them.

When we analyzed the comparison between scheduled and unscheduled procedures, we found significant differences in fluoroscopy DAP, exposure DAP, air kerma, number of images, and number of captured sequences.

Comparative graphs of scheduled and unscheduled procedures include *boxplots or box and whisker plots*, a graphical representation that provides a summarized view of the statistical distribution of a dataset, its variability, and the presence of outliers. The basic structure of a boxplot includes the elements detailed below. *Rectangle (box)*: it represents the interquartile range (IQR), which spans from the first quartile (Q1 = 25th percentile) to the third quartile (Q3 = 75th percentile). The red line inside the box indicates the median (Q2 = 50th percentile). *Whiskers*: these are lines extending from the box to the most extreme values within an acceptable range; these may vary in length and are used to identify outliers. *Outliers*: they are the individual points beyond the whiskers (red crosses) that may indicate unusual or extreme values in the dataset.

CONCLUSIONS

Our work presents an analysis of differences in dosimetry administered to patients undergoing various procedures at our site. We were able to compare the analyzed data with values observed by other authors in different countries and previous years. We can also infer that these values are higher than the reference levels recommended by the International Atomic Energy Agency[17] *(26.0 Gy/cm2). It is worth noting that, as of today, there are no updated reference dose levels for the procedures analyzed in this study in Argentina, as established by* the nuclear regulatory authority in this country[15]. Additionally, there is no standardized classification

TABLE 4. Comparison of fluoroscopy times in minutes and DAP (Gy/cm²) for therapeutic cardiac catheterizations in relation to other publications. *T = Fluoroscopy time, expressed in minutes.

Authors	N	T*	Dose-area product (Gy/cm²)		
			Mean	Median	Q75
CC + PCI in this study	30	10.56	135.34	88.58	119.14
PCI in this study	11	12.92	141.85	80.31	257.40
González-López ***et al***. 2021 (4)	50	14.6	76.7	63.4	92.4
Simantirakis ***et al.*** (2013) (7)	1899	18.0	129.0		
Georges ***et al.*** (2007) (9)	3600	14.0	100.0		
Tsapaki ***et al.*** (2003) (10)	97	12.2	68.0	58.3	80.7
Broadhead ***et al.*** (1997) (11)	214	12.4	77.9	61.1	100.6
Zorzetto ***et al.*** (1997) (10)	31	12.2	91.8	82.6	104.6

TABLE 5. Comparison of scheduled vs. unscheduled procedures. ***p***-value is considered significant if <0.05 (Wilcoxon rank-sum).

Scheduled	Yes	No	*p*-value
Number of data points (n)	164	58	
Fluoroscopy time (in minutes)			
Mean	9.41	9.16	
Median	4.61	5.13	0.418
Standard deviation	12.54	12.79	
Fluoroscopy DAP (Gy/cm²)			
Mean	33.57	43.8	
Median	13	23.08	0.0402
Standard deviation	55.11	78.5	
Exposure DAP (Gy/cm²)			
Mean	43.40	62.02	
Median	31.78	42.28	0.0360
Standard deviation	47.55	91.63	
Air kerma (Gy/cm²)			
Mean	0.93	1.28	
Median	0.58	0.82	0.0743
Standard deviation	1.16	1.61	
Total number of captured sequences			
Mean	11.78	14.82	
Median	9	11.5	0.0209
Standard deviation	8.74	11.75	
Total number of images			
Mean	674.67	854.75	
Median	582	729	0.0065
Standard deviation	480.92	557.31	

of the different types of procedures for their subsequent assessment based on complexity, complications, and difficulty level.

When performing the comparative statistical analysis of the sample in terms of scheduled and unscheduled procedures, we observed significant differences. Fluoroscopy and exposure DAP, the number of sequences, and the number of captured images were all lower in scheduled procedures, resulting in notably lower administered doses.

As a limitation, our analysis is a single-center retrospective study with a non-parametric sample distribution. It is also noteworthy that there are no updated and published reference dose levels (RDL) for endovascular interventions in Argentina. We believe that this study could serve as a starting point for developing RDL protocols with standardized procedures, categorized by complexity level, to optimize doses for patients and to contribute to the development of a comprehensive quality-of-care plan.

This work presents the dosimetry administered at one of the most updated interventional cardiology centers in Argentina, which means that it is representative of current practi-

ce. It provides significant evidence that, in the studied cohort, unscheduled procedures involve the administration of higher doses of ionizing radiation.

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Ethical responsibilities
In this study, the authors declare that they have followed the study site protocols for data anonymization, analysis, and publication, respecting data privacy and informed consent from patients undergoing these interventions.

SUMMARY OF KEY POINTS

- Regulatory authorities recommend knowing the RDL of one's site and country.
- Argentina lacks updated RDLs.
- There is no data on which procedures administer the highest doses of ionizing radiation in interventional cardiology.
- The analysis of dosimetry administered at our site can be compared with published literature to date.
- In unscheduled procedures, most occurring in cases of ACS, significantly higher doses of ionizing radiation are administered.

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