Artigo Original

FULL CHARACTERIZATION OF THE X-RAY SYSTEM IN ORDER TO EVALUATE PATIENT DOSE IN INTERVENTIONAL CARDIOLOGY

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Abstract. The purpose of the present paper is to evaluate interventional radiology x-ray system performance in order to analyze its influence on patient dose. Entrance air kerma rate in fluoroscopy modes and air kerma per image in cine modes were measured at the entrance of PMMA slabs (10 to 30 cm) in two interventional x-ray systems. Air kerma evaluation was performed in all image intensifiers (II) diameters and in all fluoroscopy and cine modes used in the clinical practice with an ionization chamber. High and low contrast resolution was evaluated for all PMMA thickness, II and modes, with two quality image tests (NEMA XR 21 and Leeds TOR-18FG). Significant differences were found in air kerma rate and air kerma per image in both x-ray systems for comparable II and modes. For example, for 24 cm PMMA thickness in fluoroscopic high dose mode, in one x-ray system delivers 0.49 mGy/s and the other one 1.87 mGy/s. However, differences in image quality were not significant. In the same conditions described above, Leeds test showed: 0.032 (low contrast) and 1.25 lpmm (spatial frequency). In addition, when phantom thickness increase, image quality decreases in x-ray systems, but in one of them, the difference is high. Results show that patient dose and image quality depend on the x-ray system characteristics. Due to this it is essential to perform a complete evaluation of the x-ray system in order to help interventional cardiologists (radiologists) to learn possibilities of dose reduction with no lose of image quality.
Keywords: image quality, patient dose, interventional cardiology.

1. Introduction

The importance of fluoroscopy guided Interventional Radiology (IR) is well known. In some cases it is the only therapeutic possibility for the treatment of a disease. In others offers a therapeutic option in which associated risks or health care costs are reduced. IR enables evaluation of the patient´ pathology; guide its treatment and result. This has been increased the frequency, nature and complexity of IR. In turn, patient dose may also increase and cause radiation injuries as reported in many references (Vañó et al., 1998; Wagner et al., 2000).

The proceedings of the International Conference on the Radiological Protection of Patients (Malaga, March 2001) include a specific recommendation, with respect to interventional procedures: "to explore the possibility of establishing guidance (reference) levels" (GL) (IAEA, 1996). GL are a powerful tool for self assessment of performance because it enables radiology departments to compare their doses values and image information with those from other departments. (Vañó et al., 2001).

Patient dose depends on the experience of the radiologist or cardiologist, protocols followed, clinical complexity of the procedures and adequate use of the various technical parameters of the x-ray system.

Since 2002, Chile, Spain, Italy, United Kingdom and Uruguay are developing an IAEA Project with the objective of exploring the possibility of obtaining GL in IR.

Due to the close relation between patient dose and image quality it is necessary to perform the full characterization of the x-ray system in order to obtain complete information on dose levels and high and low contrast resolution (Martin, 1997). Results improve the possibility of taking corrective actions to optimize IR practice.

This study provides an evaluation of the interventional radiology x-ray system performance in order to analyze its influence on patient dose.

2. Material and methods

The research was performed in 2003 in two IC centers of Uruguay (the university hospital and a private hospital). In the former (UH) the x-ray system is a Picker CV-PRO (installed in 1997) and in the PH is a Philips Integris BH 3000 Biplane Version 2 (installed in 1996). Operation modes of both x-ray units are summarized in Table 1.

Table 1. Operation modes of the x-ray systems. [1]Image intensifier, [2]Pulsed rate per second, [3]Low, Medium and High.

	II diameters (cm)[1]	Fluo modes[2] (pr/s)	Cine modes (frames/s)	Dose modes
Picker unit (UH)	14,18 and 21	3.5, 7, 15 and 20	15 and 30	L, M and H[3]
Philips unit (PH)	14,17 and 23	12.5	12.5 and 25	L, M and H

Dose (incident air kerma, Ki) rates (fluoroscopy) and dose (Ki) per image (cine) were measured at the entrance of 25 cm x 25 cm polymethyl methacrylate slabs (PMMA) with an ionization chamber. Despite the fact that copper is usually used in constancy tests to simulate patient or projection thicknesses, PMMA was chosen to perform the characterization of the x-ray systems because it is more similar in attenuation and backscatter properties of patients than copper. In order to simulate the more frequent patient thicknesses in clinical conditions (projections) 16, 20, 24 and 28 cm PMMA thicknesses were used (with TOR-18FG Leeds test) and 5, 10, 20 and 30 cm (with NEMA XR 21 test). For all of them and for all operation modes and possible combinations, Ki rate and Ki per image and image quality were evaluated simultaneously. The test image plate was positioned in the isocenter of the system gantry and in the middle of the phantom thickness and was taken in account in the total phantom thickness. All measurements were performed with the couch and mattress to reproduce clinical conditions.

Ki was measured with the Radcal ensemble: 10 x 5 – 6 E (Series Number 91-0619, calibration certificate number 13406, given by Radcal Corporation, date 20/04/01) and the electrometer Model 9015S (Series Number 9294, calibration certificate number 13406, given by Rad. Cal Corporation, date 20/04/01). Lectures were corrected with calibration factors (taking into account chamber factor in the range of x-ray energies, temperatures and pressures).

Image quality was evaluated with both test objects. High and low contrast resolution were always assessed by the same two observers standing at the usual clinical distance to the monitor of the IC room. In both fluoroscopy and cine modes the evaluation was performed while the image was live. In addition, cine mode images were stored in CD-ROMs at the UH and in VHS the PH. Therefore, further image quality evaluations were possible.

It is important to note that constancy tests with copper slabs (at least four 1 mm copper slabs of more than an area of 20 x 20 cm) and Leeds image plate must be performed before the full characterization of the x-ray system. The constancy test is a quick test to obtain the baseline of the performance of the equipment. Besides, must be performed quarterly and after major changes in the equipment or when malfunction is suspected (Martin, 1997).

3. Results and discusion

It is impossible to show here all the results obtained (all operation modes, all II diameters and with both quality image tests). Then, will be only summarized some of them in order to demonstrate the importance of the full characterization of the x-ray system to help interventional cardiologists to improve their practice, using the low possible dose with the adequate image quality.

Significant differences were found in air kerma rate and air kerma per image in both x-ray systems for comparable II and modes (Figures 1 to 4). However, differences in image quality (low and high contrast) were not so significant (Tables 2 and 3). In addition, when phantom thickness increases image quality decreases in both x-ray systems, but in the Philips unit the decrease is higher than in the Picker unit.

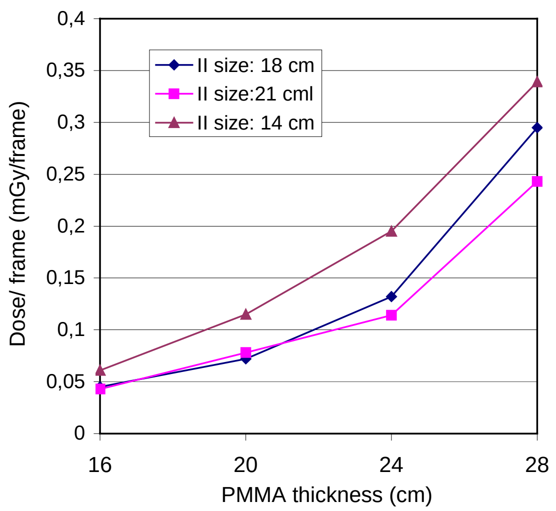

Figure 1. Dose (Ki) per frame for different image intensifier diameters in 15 frames/s cine mode in the Picker unit (university hospital).

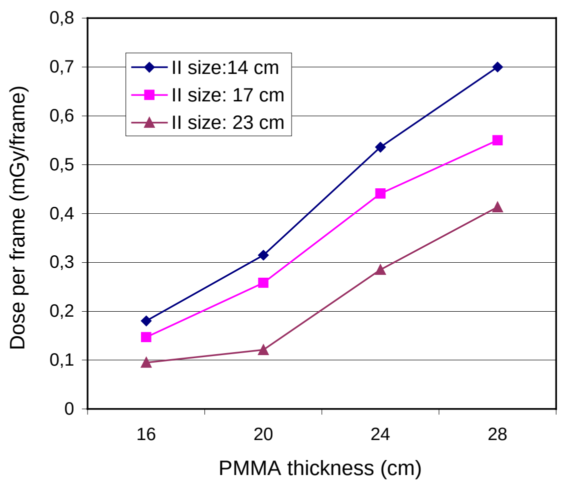

Figure 2. Dose (Ki) per frame for different image intensifier diameters in 25 frames/s cine mode in the Philips unit (private hospital).

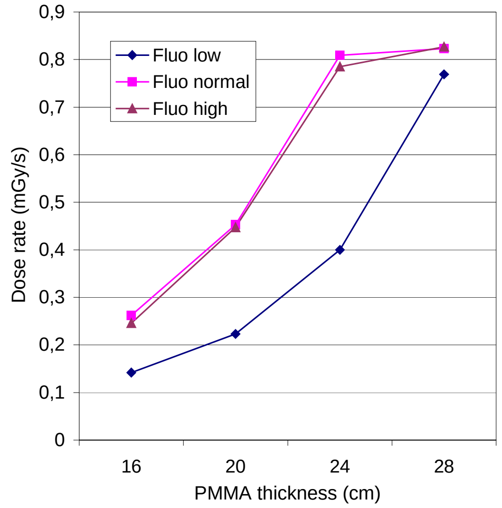

Figure 3. Dose (Ki) rate for different PMMA thickness in fluoroscopic mode (15/s) and 14 cm image intensifier diameter in the Picker unit (university hospital).

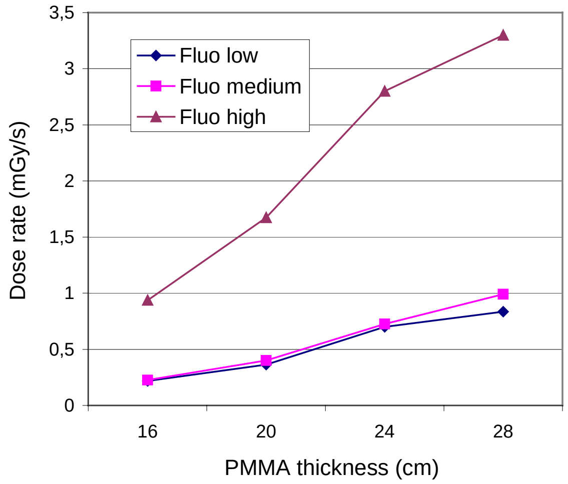

Figure 4. Dose (Ki) rate for different PMMA thickness in fluoroscopic mode (12.5 / s)and 14 cm image intensifier diameter in the Philips unit (private hospital).

Table 2. Characterization of both x-ray systems for 24 cm PMMA for fluoroscopy modes, with Leeds test.

	II size (cm)	Fluoroscopy mode	kV	mA	Dose rate (mGy/s)	Low contrast (circles)	Contrast	High contrast (spatial frequency) lpmm
Picker CV-PRO	14	Medium (15 /s)	120	1.7	0.81	12	0.027	1.80
	14	High (15 /s)	120	1.7	0.79	12	0.027	1.80
	21	Medium (15 /s)	118	1.7	0.49	11	0.032	1.25
	21	High (15 /s)	120	1.7	0.49	11	0.032	1.25
Philips Integris BH Version 2	14	Medium (12.5 /s)	107	10.5	0.73	11	0.032	1.80
	14	High (12.5 /s)	99	25.3	2.80	14	0.017	1.80
	23	Medium (12.5 /s)	80	14	0.47	11	0.032	1.25
	23	High (12.5 /s)	77	27.5	1.87	11	0.032	1.25

Table 3. Characterization of both x-ray systems for 24 cm PMMA for cine modes, with Leeds test.

	II size (cm)	Cine acquisition mode (frames/s)	kV	mA peak	Dose/ frame (mGy/ frame)	Low contrast (circles)	Contrast	High contrast (spatial frequency) lpmm
Picker CV-PRO	14	15	120	500	0.20	15	0.015	2.00
	18	15	103	500	0.13	13	0.022	1.60
	21	15	103	500	0.11	13	0.022	1.40
Philips Integris BH Version 2	14	25	79	860	0.54	16	0.013	2.24
	17	25	75	802	0.44	15	0.015	1.80
	23	25	67	633	0.29	16	0.013	1.40

Results are closely related with patient dose of both IC centers. Doses are lower in the UH although is an educational center. Mean total dose in Coronary Angiography in the UH was (20.2 ± 14.4) Gy.cm^2 and in the PH (63.0 ± 34.5) Gy.cm^2. For Percutaneous Transluminal Coronary Angioplasty: (31.9 ± 26.5) Gy.cm^2 in the former, and (100.9 ± 65.9) Gy.cm^2 in the latter.

4. Conclusions

Patient dose and image quality depend on the x-ray system characteristics. Due to this it is essential to perform a complete evaluation of the x-ray system in order to help interventional radiologists to learn possibilities of dose reduction with no lose of image quality.

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References

International Atomic Energy Agency (1996), International Basic Safety Standards for protection against ionizing radiation and for the safety of radiation sources. *Safety Series* No. 115*,* Vienna, International Atomic Energy Agency.

Martin M. (1997), Fluoroscopy system evaluation. *Proceedings of the 1997 AAPM Summer School of The expanding role of medical physicists in diagnostic imaging*. p 219-230.

Vañó E., Arranz L., Sastre J.M., Moro C., Ledo C., et *al*. (1998) Dosimetric and radiation protection considerations based on some cases of patient injuries in interventional cardiology, *Brit. J. Radiol.* 71, p. 510-516.

Vañó E., Fernández J. M., López L.., Ten J. L., González L.., Guibelalde E. (2001), The use of constancy checks to optimize patient dose in interventional radiology systems. *International Conference on radiological protection of patients in diagnostic and interventional radiology, nuclear medicine and radiotherapy.* Vienna, International Atomic Energy Agency, Contributed paper IAEA –CN 85-196.

Wagner L. K., Archer B. R. and Cohen A. M. (2000), Management of patient skin dose in fluoroscopy guided interventional procedures. *JVIR* 11, p. 25-33.