

Transition from image intensifier to flat panel detector in interventional cardiology: Impact of radiation dose

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ABSTRACT

Flat panel detector (FPD) technology in interventional cardiology is on the increase due to its varied advantages compared to the conventional image intensifier (II) systems. It is not clear whether FPD imparts lower radiation doses compared to II systems though a few studies support this finding. This study intends to compare radiation doses from II and FPD systems for coronaryangiography (CAG) and Percutaneous Transluminal Coronary Angioplasty (PTCA) performed in a tertiary referral center. Radiation doses were measured using dose area product (DAP) meter from patients who underwent CAG ($n = 222$) and PTCA ($n = 75$) performed using FPD angiography system. The DAP values from FPD were compared with earlier reported data using II systems from the same referral center where the study was conducted. The mean DAP values from FPD system for CAG and PTCA were 24.35 and 63.64 Gy cm^2 and those from II system were 27.71 and 65.44 Gy cm^2 . Transition from II to FPD system requires stringent dose optimization strategies right from the initial period of installation.

Key words: Cardiology; flat panel; image intensifier; radiation dose

Introduction

An increased man-made radiation exposure-risk from the use of high-dose imaging modalities such as computed tomography and angiographic suites is now being observed in many health-care centers with over 3.6 million diagnostic examinations performed annually worldwide.^[1,2] Interventional procedures are performed by cardiologists, radiologists, endovascular surgeons, operation theater staff, etc., due to the well-known benefits in medicine. However, it is crucial for the referring clinician and the interventionalist (radiologist/cardiologist/clinician in the operation theater) to assess the potential benefit-risk ratio for various interventional procedures as some of

the procedures involve a high radiation exposure due to prolonged fluoroscopic screening.

All interventional cardiological procedures are invariably performed using dedicated fluoroscopy and angiography suites equipped with either image intensifier (II)-based or flat panel detector (FPD)-based systems. The II-based systems have been used for fluoroscopy for more than two decades. On the other hand, the FPD-based systems for medical imaging emerged in the 1990s initially for two-dimensional (2D) projection X-ray image, and subsequently for a “real-time” fluoroscopy sequence.^[3] Interventional angiography suites equipped with II or FPD have the potential to impart high radiation doses to patients if optimization strategies are not well-implemented. Stringent optimization involves orientation of staff, consistent restriction of frame rates during image acquisition, using low dose settings, judicious use of magnification, etc.^[4] It is also necessary to understand the potential risks due to radiation from different interventional procedures. For this reason, it is necessary that one should be knowledgeable in the magnitude of radiation dose associated with each intervention. This can be achieved by measuring real-time doses using devices such as a dose area product (DAP) meter. Most of the newer angiography machines are equipped with a DAP meter fitted on the collimator assembly of the machine. DAP is particularly a useful method for assessing and comparing the radiation dose from screening procedures and acts as a surrogate for

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radiation risk.^[5,6] Entrance surface dose (ESD) is also used for measuring radiation doses. From the dose descriptors, it is possible to estimate organ doses as well as effective doses for each procedure.

Radiation doses from interventional procedures have been widely reported in literature, with more emphasis on doses from II-based systems. However, there are only a few reports on radiation doses from FPD systems as it may be a transition period from II to FPD for most of the interventional users. Some patient and phantom-based studies reported in literature state that doses from FPD are higher than II systems.^[7-10] Few other studies report that radiation doses from FPD are lower than II systems.^[6,11,12] In comparing conventional and digital systems, very few studies are found in literature and these are contradictory.^[13] Hence, it is not clear whether FPD imparts lower radiation dose than II and whether there would still be a need to further optimize doses in the newer FPD systems. The recent digital modalities have shown improvement in dose optimization and noise reduction techniques.^[14] The purpose of this article is to review and compare radiation doses from II and FPD-based systems in interventional cardiology in a tertiary referral center that has introduced FPD system recently. It is anticipated that this information will be useful for those performing cardiological interventions and for those who are on a transition from II to FPD.

Materials and Methods

The study was approved by the institutional review board (IRB No. 8805). Cardiovascular interventions were performed using two dedicated catheterization labs, each equipped with Philips Allura FD10 flat panel system (Netherlands). The dose area product (DAP) values for Coronary Angiography (CAG, $n = 222$) and Percutaneous Transluminal Coronary Angioplasty (PTCA, $n = 75$) procedures performed during a one year period 2012–2013 were prospectively recorded using a built-in calibrated DAP meter (transmission ionization chamber). The PTCA procedure was invariably performed by a senior interventionalist assisted by two junior cardiologists, while the CAG was performed either by the senior interventionalist or by junior cardiologists. For a similar comparison of clinical protocols adopted in the institution, DAP values from CAG and PTCA performed using Philips Integris H3000 and H5000 II-based systems (Netherlands) reported earlier^[15,16] were compared to those from FPD system currently studied. All the X-ray systems were on periodic QA programs and conformed to the manufacturer's specifications.

The II and FPD systems had low-, normal-, and high-dose settings, respectively, for fluoroscopy. These machines incorporated a total filtration of 2.5 mmAl with possibility of selecting spectral filters such as 0.1 mm, 0.2 mm, 0.4 mm Cu for dose reduction. During the course of the study, low

dose setting with 0.4 mm Cu filter was invariably selected during fluoroscopy. In the earlier work using II-based system, a 23-cm image intensifier format (IIF) was used during fluoroscopic screening in CAG and PTCA procedures for tracing the path of the catheter from the region of arterial puncture and to the screening of the cardiac valve region. A 17-cm IIF was used for the oblique, caudal, cranial, and lateral projections delineating the coronary anatomy.^[16] In the FPD system, 25 cm fluoro format was used during screening and 20 cm was used for other projections to delineate coronary anatomy.

Results and Discussion

A transition from II to FPD system for a catheterization lab would require adequate justification in terms of radiation dose, image quality, maintenance, and investment. It has been reported that the FPDs designed specifically for fluoroscopic purposes provide superior image quality and dose efficiency compared to the II systems, except at the lowest fluoroscopic dose levels.^[3] Prieto *et al.*, reports that even after upgrading to the FPD from II, significant increase in patient doses were observed though the fluoroscopic time and number of images remaining the same in both cases during the initial transition period.^[17] As only a few studies on radiation doses are available for FPD systems; more work is required on optimization strategies in the FPD systems.

Table 1 shows the DAP values and fluoroscopic time duration for II and FPD systems from the referral center where the study was conducted. The DAP values for II-based systems represented in Table 1 is from the use of optimized protocol as reported in the previous published article from the same referral center where the study was conducted. Prior to optimization in II systems, the doses were above 50%; however, it was possible to optimize dose by halving the entrance dose rates by selecting 0.4 mm Cu filtration (generally recruited in pediatric protocols) during fluoroscopy. Selection of 0.4 mm Cu filtration did not suffer significant loss of image quality; however, tube potentials were increased from 80 kVp to 103 kVp during fluoroscopy.^[15,16] In the FPD system, tube potentials ranged from 90 kVp–110 kVp when 0.4 mm Cu filtration was selected with low dose settings during fluoroscopy. Having adhered to the same optimization strategies in both systems, doses were similar owing to the fact that further optimization is warranted in FPD system. Bogaert *et al.* reported DAP values of 31 and 33 Gy cm^2 from CAG with the use of II and FPD system, respectively. They have also reported that the total DAP from fluoroscopy and cine for II and FPD are not significantly different and the image quality from FPD is better than II in cine mode with no difference in the imaging performance in fluoroscopy mode.^[18]

Tables 2 and 3 shows DAP values for CAG and PTCA procedures from various studies in literature. The

arithmetic mean DAP and fluoroscopic time duration using II system as reported in literature was 39 Gy cm^2 for 6.6 min and 61.2 Gy cm^2 for 17 min for CAG and PTCA respectively [Table 2]. With the use of FPD, mean DAP and fluoroscopic time duration were 28.4 Gy cm^2 for 7 min and 61 Gy cm^2 for 18.05 min for CAG and PTCA, respectively [Table 3]. From Tables 2 and 3, radiation doses from FPD were significantly low for CAG but were similar for PTCA when compared to II systems. It should be noted that time duration for CAG and PTCA was not available for some reported studies in Tables 2 and 3. Wide variation of doses is observed from these studies which may be attributed to the angiographic system used, time duration of the procedure and work environment. Doses of the order of 492 Gy cm^2 were recorded in PTCA procedure from FPD system which was higher than the II systems.^[17] Chida *et al.*, conducted studies from various II and FPD system and the average entrance doses of cine angiography and fluoroscopy in FPD systems were not significantly different. Though FPDs possess good detective quantum efficiency, they did not inherently reduce the radiation dose.^[10] Jensen *et al.*, observed that patient doses from FPD were lower than II systems; however, the eye lens doses for radiologists were higher in FPD than in II due to the use of high filtration and recruitment of high tube potentials.^[11] In our study, high tube potentials were recruited when low dose settings involving high filtration were selected, which may have the potential to increase staff doses.

It is prudent to adopt stringent optimization measures in FPD as the dose may be higher than the II systems as reported by Prieto *et al.*^[17] and Stratis *et al.*^[32] Dose reduction is possible in either II or FPD systems. During the initial stages of our study, the doses from FPD were similar to the II system though high filtration was used. Kuon *et al.* reports that it is possible to achieve mean DAP of 6.2 and 10.4 Gy cm^2 for CAG and PTCA procedures performed using II system.^[23] They further report that the reduction of doses was by influencing the quality of fellowship training, consistent restriction to mean values of 171 frames per CAG, 165 frames per PTCA, low-level fluoroscopy, training in the use of fluoroscopy-free blind positioning to the region of interest, restrictions to achieve lower II entrance dose for

adequate image quality.^[4] From Tables 1 and 3, the mean DAP for CAG from FPD were higher than those reported by Kuon *et al.* Tsapaki *et al.*, reported the doses from FPD were increased by 35% compared to II when fluoroscopy levels were changed from low to high mode^[35]; they also recorded a minimum DAP value of 6.1 and 14.3 Gy cm^2 for CAG and PTCA, respectively, with the use of low dose fluoroscopy settings in FPD.^[13] Dekker *et al.*, reported that the new generation FPDs incorporated with good image processing and noise reduction techniques resulted in reducing patient doses by 43% without compromising image quality and staff doses by 50% during electrophysiological interventions.^[14] Though FPD has reduced entrance dose rates, it does not automatically reduce radiation doses in clinical practice.^[27] Further work is necessary to study the possibilities of dose reduction in FPD so as to be implemented in the clinical set up. The patient dose and image quality in any newer modality needs to be permanently monitored and transition from II to FPD requires careful attention.^[33]

Conclusion

This is a preliminary study as the institution where the study was conducted recently moved from II to FPD-based systems. Though radiation doses for cardiological interventions from FPD were similar to the II-based system achieved after optimization, the advantages of FPD in terms of good image uniformity, improved patient imaging accessibility due to smaller size, absence of geometric distortion/veiling glare or vignetting make the FPD superior to the II systems.^[3] To achieve improved patient dose reduction, it is advisable to strictly adhere to low dose protocols with high filtration in FPD systems. In addition, more attention for staff doses is warranted especially for interventionalists when this stringent patient dose reduction is employed. It is recommended to follow stringent dose reduction strategies right from the period of initial installation when there is a transition from II to FPD systems. Further studies are required to develop dose optimization in FPD, though use of high filtration is already in place.

Table 1: Fluoroscopic time and dose area product values from II and flat panel detector (FPD)-based systems from cardiological interventions

Examination	Image intensifier			Flat panel detector		
	No. of cases	Mean fluoro time (mins) (range)	Mean DAP (Gy cm^2) (range)	No. of cases	Mean fluoro time (mins) (range)	Mean DAP in (Gy cm^2) (range)
CAG	28	3.96 (0.4–10.2)	27.71 \pm 2.49 (12.6–68.9)	222	3.89 (0.45–10.37)	24.35 \pm 14.48 (2.21–83.48)
PTCA	5	17.72 (7.9–24.8)	65.44 \pm 42.78 (22.3–109.5)	75	12.49 (3.51–25.5)	63.64 \pm 39.4 (13.32–191.41)

The data for fluoro time and DAP for II system is from the previous studies^[15,16]. DAP: Dose area product, CAG: Coronaryangiography, PTCA: Percutaneous transluminal coronary angioplasty

Table 2: Radiation doses from cardiological interventions performed using image intensifier-based systems

Examination	Studies in literature	No. of cases	Mean fluoro time (min) (range)	Mean DAP (Gycm ²) (range)	
CAG	Zorzetto <i>et al.</i> ^[19]	79	4.9	55.9	
	Betsou <i>et al.</i> ^[20]	29	9.8	30.4	
	Fransson ^[21]	65	4.4 (0.7-25.8)	62.6 (4-147.1)	
	Katritsis <i>et al.</i> ^[22]	16	8.6	27.27	
	Kuon <i>et al.</i> ^[23]	112	-	6.2	
	Mc Fadden ^[24]	8	8.25 (2-21)	43.47 (22.05-93.3)	
	Kuon <i>et al.</i> ^[4]	982	5.9	36.3	
	Tsapaki <i>et al.</i> ^[25]	195	-	47.3 (9.9-160)	
	Sandborg <i>et al.</i> ^[26]	40	4.6	38	
	Trianni <i>et al.</i> ^[27]	-	4.3	31.2	
	Karamatskidou <i>et al.</i> ^[28]	20	-	49 (18-107)	
	Bogaert <i>et al.</i> ^[18]	-	-	31	
	Pantos <i>et al.</i> ^[29]	9 100	4.7 (0.3-57)	39.9	
	Prieto <i>et al.</i> ^[17]	698	11.4 (1.1-61.1)	33.7 (1.6-322.3)	
	Ahmed <i>et al.</i> ^[30]	382	5.2 (0.16-5.35)	20 (3-81)	
	PTCA	Zorzetto <i>et al.</i> ^[19]	31	12.2	91.8
		Betsou <i>et al.</i> ^[20]	12	21	37.6
		Fransson <i>et al.</i> ^[21]	24	8.2 (2.5-20.9)	47.9 (3.2-100.6)
		Katritsis <i>et al.</i> ^[22]	10	21.1	35.76
Van de putte <i>et al.</i> ^[31]		-	-	115.23	
Kuon <i>et al.</i> ^[23]		46	-	10.4	
Mc Fadden ^[24]		-	21.4 (9-46)	122.07 (10.14-357.01)	
Kuon <i>et al.</i> ^[4]		50 2	18.1	36.6	
Tsapaki ^[25]		97	-	68 (7.7-378)	
Trianni <i>et al.</i> ^[27]		-	11.4	52.1	
Karamatiskidou <i>et al.</i> ^[28]		10	-1	40 (16-115)	
Pantos <i>et al.</i> ^[29]		5294	5 (1.4-172)	78.3 (1.6-69.2)	
Prieto <i>et al.</i> ^[17]		376	23.7 (3.4-110.2)	65.7 (10-226.2)	
Ahmed <i>et al.</i> ^[30]		46	17.6 (2.4-55.2)	56.5 (9.5-210.6)	

DAP: Dose area product, CAG: Coronaryangiography, PTCA: Percutaneous transluminal coronary angioplasty

Table 3: Radiation doses from cardiological interventions performed using flat panel detector-based systems

Examination	Studies in literature	No. of cases	Mean fluoro time (min) (range)	Mean DAP (Gycm ²) (range)
CAG	Tsapaki <i>et al.</i> ^[13]	100	4.1 (1.3-39.4)	27.7 (6.1-78.1)
	Trianni <i>et al.</i> ^[27]	-	-	33.4
	Bogaert <i>et al.</i> ^[18]	-	4.4	33
	Stratis <i>et al.</i> ^[32]	108	-	24 (4-102)
	Dragusin <i>et al.</i> ^[33]	122	-	16.3
	Tsapaki <i>et al.</i> ^[34]	177	11.85 (1.25-74.7)	34*
	Prieto <i>et al.</i> ^[17]	342	7.6 (0.5-46.4)	35.8 (5.7-65.8)
PTCA	Tsapaki <i>et al.</i> ^[13]	100-101	12.7 (3.2-39)	51.1 (14.3-154.9)
	Trianni <i>et al.</i> ^[27]	91	10.7	66.9
	Stratis <i>et al.</i> ^[32]	159	28.6 (2.41-107.1)	54 (9-332)
	Dragusin <i>et al.</i> ^[33]	702	-	32.7
	Tsapaki <i>et al.</i> ^[34]	-	-	80*
	Prieto <i>et al.</i> ^[17]	-	20.2 (2.3-161.2)	112.6 (28.5-492.1)

*Median DAP values. DAP: Dose area product, CAG: Coronaryangiography, PTCA: Percutaneous transluminal coronary angioplasty

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