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## Patient exposure to X-ray radiation during abdominal aorta and lower limb digital subtraction angiography

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### Summary

**Background:**

The main aim of this study was to find out what is the risk caused by ionizing radiation during digital subtraction angiography (DSA) for abdominal aorta and lower limb examinations.

**Material\Methods:**

The study is based on a large group of patient data subjected to a complex analysis of fluoroscopy time, exposure time, air kerma values, and dose-area product (DAP). Measurements were performed on 449 patients with intra-arterial (IA DSA) contrast administration.

**Results and Conclusions:**

Median DAP value for fluoroscopy was 5.4 Gy-cm<sup>2</sup> and for exposure 51.7 Gy-cm<sup>2</sup>. On exposure the patients received 94% of the total DAP although this examination takes only 0.1% of the total examination time. For this reason, small changes in the exposure time may result in a considerable reduction in the radiation received by the patient. There was good correlation between DAP values and the fluoroscopy time ( $r=0.78$ ), while the correlation between DAP and the exposure time was much poorer ( $r=0.39$ ). It was also found that gender was a differentiating factor neither both fluoroscopy ( $F[1, 449]=0.01, p>0.05$ ) nor exposure time ( $F[1, 449]=0.42, p>0.05$ ).

**Key words:**

dosimetry • radiation • dose

**PDF file:**

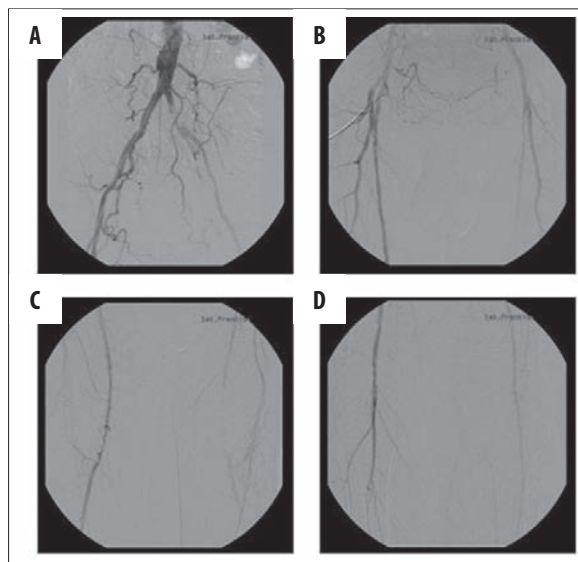
<http://www.polradiol.com/fulltxt.php?ICID=866865>

### Background

Ionizing radiation (IR) can affect all biological systems, resulting in the modification and destruction of cellular components and modifications of DNA. These are the main causes of radiation-induced damage to cells and hence organs and tissues [1]. A single X-ray beam has the ability to cause irreparable damage to cells with the possibility of deleterious effects. This leads to the concept that the effects of exposure to X-ray, no matter how small the dose, are cumulative over the lifetime of a patient [2].

Digital subtraction angiography examination (DSA) provides the possibility of diagnosing such complex pathologies in the vascular system as peripheral arterial occlusive disease (PAOD), carotid artery pathology, aneurysms, various tumors, renal-vascular hypertension, and cerebral and hepatic artery pathology. Fluoroscopy (real-time images: coater introduction procedure) and exposure (x-ray pictures taken during the injection of contrast medium) are the essential medical procedures for angiographic radiology.

According to "The National Protocol for Patient Dose Measurements in Diagnostic Radiology" [3], for examinations involving fluoroscopy the most appropriate dosimetric quantity is the dose-area product (DAP), which has been mainly used as an indicator of the patient's irradiation dose [4–19]. DAP measurements using a flat X-ray transition ionization chamber have been accepted as a suitable dosimetric technique for angiographic examination. DAP measurements are commonly used to assess the effective dose for evaluation of stochastic risk. Modern devices (e.g. the Philips Integris Allura) are designed for the simultaneous measurement of DAP and air kerma during fluoroscopy and exposure. DAP has the advantage of being constant at any distance from the tube focus, so wherever DAP is measured, it reflects the air kerma radiation field size product at the patient's skin. The DAP is also useful in estimating the effective dose via calculation of the total energy imparted to the patient, which can be used to calculate the stochastic risk [20]. The purpose of routine measurements and controlling of dose area product (or entrance dose) is to help to achieve an overall reduction in the radiation received by patients undergoing medical radiological examinations.



**Figure 1.** Sample images obtained from IA DSA. (A) bifurcation of abdominal aortic, (B) iliac arteries, (C) femoral arteries, (D) bifurcation of popliteal arteries.

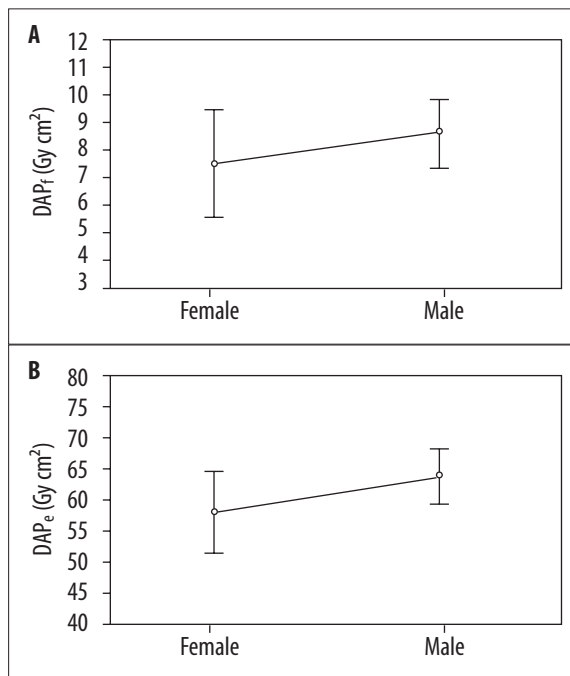
## Material and Methods

Between May 2006 and October 2007, 449 patients were subjected to digital subtraction angiography (DSA) of the abdominal aorta and lower limbs. This number included 312 males and 137 females (age range: 16–97 years, mean age  $\pm$ SD: 63.6 $\pm$ 12.48 years). Figure 1 presents sample images obtained as a result of intra-arterial DSA. In general, indications for DSA of the abdominal aorta and lower limbs included clinical symptoms of PAOD, acute lower extremity ischemia, aneurysms of peripheral vessels, traumatic ischemia, and vascular malformations.

DSAs were performed on a Philips Allura system with the use of ionic radiation. Intra-arterial DSA was carried out by Seldinger's method. After puncturing the common femoral artery, a 5F straight catheter with side holes (Balton, Warsaw, Poland) was introduced on a guidewire into the abdominal aorta. Used were 0.025–0.035 Teflon coated "J" guidewires (Balton, Warsaw, Poland) and 0.035 hydrophilic coated guidewires (Cook Inc. USA; Terumo Corp, Tokyo, Japan). The latter were applied in cases of advanced lesions in the iliac and femoral arteries. The most frequent kV value was 80 and speed was 3.0 fps. The preferred projection in the analyzed angiography procedure was A-P (anterior-posterior).

A straight catheter was positioned into the distal segment of the abdominal aorta. Contrast medium was injected with the use of an automatic syringe (Medrad). For each series, a dose of 15–30 ml of contrast agent was injected at a rate of 10–20 ml/sec. Four to six series were performed, depending on clinical indications. All procedures were performed using non-ionic contrast media manufactured by Nycomed, Schering, Pharma, Altana (Bracco) and Tyco in concentrations of 350–370 mg/ml.

The results were analyzed using STATISTICA 6.0. ANOVA (Fisher's analysis of variance) was used to evaluate the sig-



**Figure 2.** Mean DAPf (fluoroscopy) (A) and DAPe (exposure) (B) values for male and female patients.

nificance of differences between males and females. The level of statistically significant differences was set at 5%. Correlation analysis was performed to find and describe relations between DAP and the times of fluoroscopy and exposure.

## Results

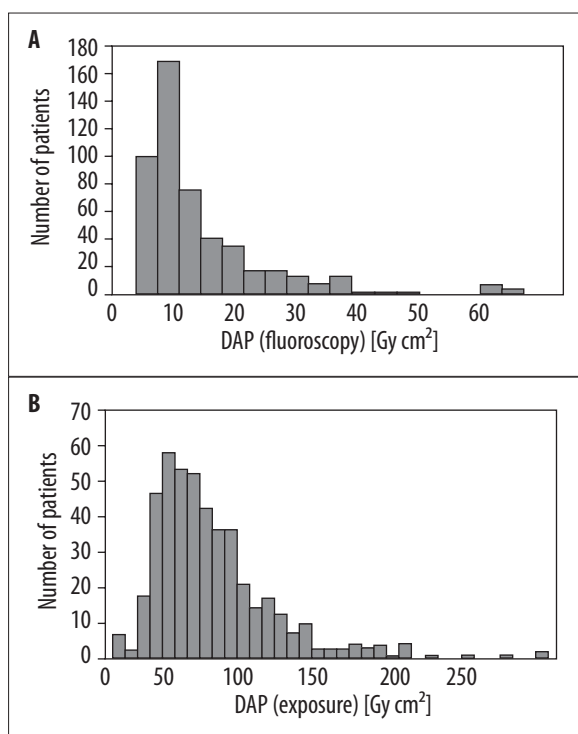
Comparison of the patients' DAP values for males and females was made and is presented in the following figures. It was found that the mean values of both DAPf (fluoroscopy) and DAPe (exposure) were higher for males; however, analysis of variance (ANOVA) indicated no statistical differences ( $F[1, 449]=1.25, p>0.05$ ;  $F[1, 449]=3.09, p>0.05$ ) (Figure 2AB). Gender also was not a differentiating factor for fluoroscopy ( $F[1, 449]=0.01$ ) or exposure time ( $F[1, 449]=0.42, p>0.05$ ). It should be emphasized that in this study the air kerma value for none of the patients exceeded 1 Gy.

Analysis of the data is presented in Table 1. Mean (median) total DAP was 68.62 (58.9) Gy-cm<sup>2</sup> and mean (median) fluoroscopy time and exposure time were 135.29 (102) s and 111.31 (78) ms, respectively. The patients received 88.25% of the total DAP under exposure (not in fluoroscopy), although exposure takes only 0.1% of the total examination time. The greatest number of patients were examined over 100–150 s (on fluoroscopy) and over 80–170 ms (on exposure). The highest values were 1728 s and 1489 ms for fluoroscopy and exposure, respectively. During fluoroscopy the majority of patients were exposed to doses from 5 to 15 Gy-cm<sup>2</sup>, while for exposure the values were greater, from 40 to 80 Gy-cm<sup>2</sup>, see in Figure 3.

There is good correlation between DAP values and fluoroscopy time ( $r=0.78$ ), while the correlation between DAP

**Table 1.** Air kerma, DAP, and exposure times for 449 patients in IA DSA lower limb examination.

	Median	Mean value	Standard deviation	Minimum value	Maximum value
Air kerma (fluoroscopy) [mGy]	21.66	32.15	45.2	1.73	644.47
Air kerma (exposure) [mGy]	127.82	154.87	98.94	4.6	805.67
Air kerma (total) [mGy]	159.19	187.02	122.05	24.59	883.98
DAP (fluoroscopy) [Gy cm <sup>2</sup> ]	5.4	8.19	11.1	0.2	122.3
DAP (exposure) [Gy cm <sup>2</sup> ]	51.7	60.43	37.48	0.8	302.1
DAP (total) [Gy cm <sup>2</sup> ]	58.9	68.62	42.49	5.6	311.2
Fluoroscopy time [s]	102.0	135.29	135.42	18.0	1728.0
Exposure time [s]	78.0	111.31	151.7	6.0	1489.0
Age	63.0	63.59	12.48	16.0	97.0

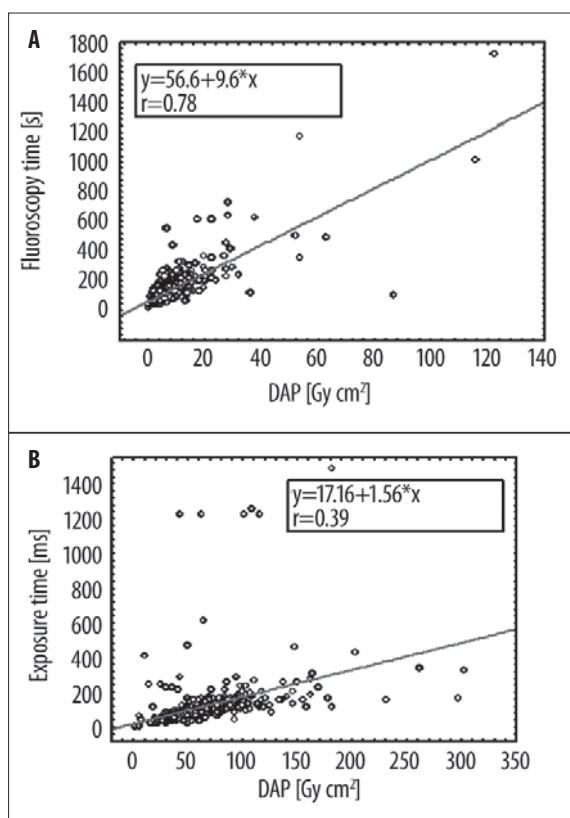


**Figure 3.** Histogram of DAP received by the patients on fluoroscopy (A) and exposure (B) applying IA DSA.

and exposure time is much poorer ( $r=0.39$ ) (Figure 4). Correlations between air kerma and the times of fluoroscopy and exposure are characterized by  $r=0.88$  and  $r=0.54$ , respectively. No correlation between patient age and the DAP he/she received was found.

**Discussion**

There are many parameters in digital subtraction angiography (DSA) that can affect the patient's dose. Some of these are equipment design (calibration), the patient's characteristics, experience of the radiologist (some examinations were made by untrained young radiologist), and the complexity of the procedure [8]. The DAP can be reduced when properly trained people operate the equipment [20].



**Figure 4.** Relation between DAP and the times of fluoroscopy (A) and exposure (B) during digital subtraction angiography.

Another important factor that can affect patients' doses is proper cooperation between the doctor and patient.

Monitoring radiation doses in fluoroscopy can serve several purposes. Patient dose monitoring allows comparison among users within and outside an institution. Knowledge of patient doses can assist the medical staff in the direct care of individual patients [20]. It is likely that exposures vary significantly between training institutions and those involving only private practice medicine due to the difference in experience of the radiologist. For all these reasons it is not possible to establish internationally accepted refer-

ence dose levels for angiographic examinations as for simple radiographic examinations [21].

Results of studies of DAP to date have been obtained for small populations of patients from all areas of interventional radiology. For example, Sapiin et al. [22] conducted a study on 7 patients, Cruces et al. [23,24] on 35 and 31, and Vano et al. [25] on 40. The above authors obtained mean DAP values from 30 to 109.4 Gy-cm<sup>2</sup> as a result of their examinations. The aim of this study was a complex analysis of all exposure parameters determining patient dose during DSA on a large population of patients with PAOD, aneurysms, and other peripheral vascular disorders. Several clinically important observations can be made on the basis of these results. The most important is that the patient receives 94% of the total DAP on exposure, although this examination takes only 0.1% of the total examination time. For this reason, small changes in the exposure time may

result in a considerable reduction of the radiation received by the patient.

## Conclusions

The results obtained support several important conclusions. First, the correlation between DAP and exposure time was much better than that between DAP and fluoroscopy time. Second, the correlation between air kerma and exposure time was much better than that obtained for DAP and exposure time. Moreover, the correlation of fluoroscopy (exposure) time and air kerma was better than that of DAP and examination time. Third, the actual dose received by the patient also depends on the experience of the medical staff involved, i.e. the radiologist, radiographer, and nurse. A reduction in the number and duration of exposures reduces the radiation dose in direct proportion. Finally, there is absolutely no correlation between patient age and the dose received.

## References:

- Boyle P, Krewski D, Ashmore J et al: Radiation epidemiology and national dose registers. *Eur J Cancer*, 1997; 33: 1-2
- Dewey P, George S, Gray A: Ionising radiation and orthopaedics. *Current Orthopaedics*, 2005; 19: 1-12
- Institute of Physical Sciences in Medicine, National Radiological Protection Board and College of Radiographers. National protocol for patient dose measurements in diagnostic radiology. Chilton, UK: NRPB, 1992
- Ad den Boer A, de Feijter P, Serruys P et al: Real-time quantification and display of skin radiation during coronary angiography and intervention. *Circulation*, 2001; 104: 1779-84
- Ashleigh RJ, Hufton AP, Razzaq R et al: A comparison of bolus chasing and static digital subtraction arteriography in peripheral vascular disease. *Br J Radiol*, 2000; 73: 819-24
- Betsou S, Efstathopoulos EP, Katritsis D et al: Patient radiation doses during cardiac catheterization procedures. *Br J Radiol*, 1998; 71: 634-39
- Bor D, Sancak T, Olgar T et al: Comparison of effective doses obtained from dose-area product and kerma measurements in interventional radiology. *Br J Radiol*, 2004; 77: 315-22
- Bor D, Toklu T, Olđar T, et al: Variations of patient doses in interventional examinations at different angiographic units. *Cardiovasc Intervent Radiol*, 2006; 29: 797-806
- Bakalyar DM, Castellani MD, Safian RD: Radiation exposure to patients undergoing diagnostic and interventional cardiac catheterization procedures. *Cathet Cardiovasc Diagn*, 1997; 42: 121-25
- Broadhead DA, Chapple CL, Faulkner K et al: The impact of cardiology on the collective effective dose in the North of England. *Br J Radiol*, 1997; 70: 492-97
- Efstathopoulos E, Karvouni E, Kottou S et al: Patient dosimetry during coronary interventions: A comprehensive analysis. *Am Heart J*, 2004; 147: 468-75
- Faulkner K, Love HG, Sweeney JK et al: Radiation doses and somatic risk to patients during cardiac radiological procedures. *Br J Radiol*, 1986; 59: 359-63
- Fransson SG, Persliden J: Patient radiation exposure during coronary angiography and intervention. *Acta Radiol*, 2000; 41: 142-44
- Interventional Radiology. Edited by Wilfrido R. Castañeda-Zuñiga, Williams & Wilkins, 1997
- Katritsis D, Efstathopoulos E, Betsou S et al: Radiation exposure of patients and coronary arteries in the stent era: a prospective study. *Catheter Cardiovasc Interv*, 2000; 51: 259-64
- Zorzetto M, Bernardi G, Morocutti G et al: Radiation exposure to patients and operators during diagnostic catheterization and coronary angioplasty. *Cathet Cardiovasc Diagn*, 1997; 40: 348-51
- Van de Putte S, Verhaegen F, Taeymans Y et al: Correlation of patient skin doses in cardiac interventional radiology with dose-area product. *Br J Radiol*, 2000; 73: 504-13
- Vano E, Goicolea J, Galvan C et al: Skin radiation injuries in patients following repeated coronary angioplasty procedures. *Br J Radiol*, 2001; 74: 1023-31
- Vano E, Gonzalez L, Ten JI et al: Skin dose and dose-area product values for interventional cardiology procedures. *Br J Radiol*, 2001; 74: 48-55
- Shrimpton PC, Wall BF, Jones DG, Fisher ES: The measurement of energy imparted to patients during diagnostic X-ray examinations using the Diametor exposure-area product meter. *Phys Med Biol*, 1984; 29: 1199-208
- European Commission (1996) European guidelines on quality criteria for diagnostic radiographic images Luxembourg: EUR 16260-EN Office for Official Publication of the European Communities, 1996
- Sapiin B, Ng KH, Abdullah BJJ: Radiation doses to patients undergoing interventional radiological procedures in selected hospitals in Malaysia. Retrospective study. *J HK Coll Radiol*, 2004; 7: 129-36
- Cruces R Ruiz, Garcia-Granados J, Diaz Romero FJ, Hernandez J: Estimation of effective dose in some digital angiographic and interventional procedures. *Br J Radiol*, 1998; 71: 42-47
- Cruces R Ruiz, Perez-Martinez M, Martin-Palanca A et al: Patient dose in radiologically guided interventional vascular procedure: conventional versus digital systems. *Radiology*, 1997; 205: 385-93
- Vano E, Arranz L, Sastre JM et al: Dosimetric and radiation protection considerations based on some cases of patient skin injuries in interventional cardiology. *Br J Radiol*, 1998; 71: 510-16