RADIATION EXPOSURE DURING CARDIAC CATHETERIZATION PROCEDURES

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INTRODUCTION

For some time there has been an increased interest in more information about radiation exposure during cardiac catheterization because of: (i) relatively high doses to workers and patient, (ii) rapid increase of numbers of examinations, (iii) introduction of new procedure-types (e.g. Percutaneous Transluminal Coronary Angiography, PTCA) and (iiii) introduction of new techniques (e.g. Digital Subtraction Angiography, DSA).

This paper reports about a study on the exposure to medical personnel and patient in two major hospitals[*,**] in the Netherlands. The total number of cardiac catheterization procedures in both hospitals amounts to circa 3000 per year (approximately 10% of all cardiac procedures c.q. 20% of all PTCA procedures in the Netherlands). This study is related to 1300 cardiac examinations.

CARDIAC CATHETERIZATION PROTOCOL

The catheterization team usually consists of one cardiologist performing the catheterization, one sterile assistant, one or two circulating assistants and personnel behind lead glass walls. Regularly, a cardiologist trainee is involved too. Sterile assistance is performed by a member of staff of the catheterization laboratory (hospital A) or by a cardiologist (hospital B). In hospital A, the sterile assistant stays opposite of the investigator on the left side of the patient. In hospital B, investigator and sterile assistant stay both on the right side of the patient. All personnel in the vicinity of the patient wear aprons (0.5 mm lead equivalent). Thyroid collars and lead eyeglasses are not used. In hospital B, most of the time a lead apron, attached to a framework, is positioned aside the patient table between cardiologist and patient. Protective shields are not used in hospital A. Hemiaxial views are obtained with rotation and angulation of the C arm in hospital A and with rotation of the U arm and table movements in hospital B. Usually, catheterizations are performed with a femoral approach. Characteristics about these hospitals are given in table 1.

DOSIMETRY

Individual dosimetry was carried out during circa 1000 procedures in hospital A and 250 procedures in hospital B. Combinations of filmbadge dosemeters and TLD dosemeters were worn by cardiologists and staff on the forehead, on the collar (outside apron), on the sternum (inside apron), the unshielded back, the tibia and wrists and indexfingers of both hands. All dosemeters were replaced every two weeks. In total 2000 dosemeters were distributed. Job dosimetry was performed with electronic personal pocket dosemeters worn in the breast pocket of lead aprons during 120 procedures in hospital A.

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Ambient dosimetry was carried out with integrating dosemeters, placed in 10 different positions in each laboratory. An antropomorph phantom was used in several series of exposure rate measurements in the laboratories during fluoroscopy and cineangiography in simulated cardiac procedures.

Using a Diamentor (PTW Freiburg) with a flat transmission ionisation chamber attached to the X-ray tube housing, independent measurements were made of the exposure-area product XAP (expressed in R•cm²) during both fluoroscopy and cineangiography in 200 examinations.

In addition, data were recorded about procedure type, team composition, patient data (weight, length and sex) and fluoroscopy time and cineangiography.

TABLE 1 DESCRIPTIVE DATA OF THE DEPARTMENTS OF CARDIOLOGY

	hospital A	hospital B
cardiologists/trainees	12	8
members of staff	9	12
procedures (1986):		
= total	2000	1200
= CAG	950	700
= PTCA	750	40
= EPS	-	250
= DSA	-	30
radiodiagnostic equipment	Philips Poly Diagnost; Maximus M200 gen.; C-arm with parallellogram support	Siemens Cardioscoop Pandoras generator U-arm
image intensifier	6½ and 9 inch	6½ and 9 inch
cine filmspeed	50 frames/s	50 and 25 frames/s

RESULTS: PATIENT EXPOSURE

Dose assessments for patients can be based on exposure-area product XAP measured with a Diamentor system [NR86]. Measurement results of XAP are given in table 2. The mean XAP for all cardiac procedures is circa 6100 R•cm². The relative contribution of fluoroscopy amounts to circa 40% per examination. The mean XAP-value per unit time is 3.8 R•cm²/s during fluoroscopy (range 0.4 to 9.3). During cineangiography at 50 frames/s, mean XAP per unit time is 63 R•cm²/s. (range 26 to 134). Differences in XAP-values per unit time during CAG and PTCA were statistically not significant.

TABLE 2 EXPOSURE-AREA PRODUCT XAP [R•cm²] PER EXAMINATION

	all procedures			CAG			PTCA		
	fluor.	cine	total	fluor.	cine	total	fluor.	cine	total
mean	2800	3500	6100	1900	3300	5000	3400	3700	6800
cv (%)	100	55	70	100	53	68	93	56	64
minimum	120	430	400	120	540	700	280	450	1200
1st quar.	820	2200	3300	560	2200	3000	1300	2300	3800
median	1900	3000	4800	1200	3000	4200	2300	3100	5500
3rd quar.	3500	4600	7700	2500	4100	6700	4300	4600	8900
95th %	9900	7300	15200	7500	6800	12700	10800	8100	17300
maximum	13800	8900	24000	8700	8900	16500	12000	8800	18800
sample size	169	170	209	79	81	98	71	70	84

Linear regression analysis of the measurement results showed that XAP per patient can be approximated with a formula in which fluoroscopy time is expressed in minutes and filmlength in meters (regression coefficient = 0.9):

$$XAP = 255 \bullet \text{Fluoroscopy time} + 60 \bullet \text{Filmlength} \quad (1)$$

Statistics about fluoroscopy time and filmlength during circa 1300 examinations are given in table 3. Mean fluoroscopy time during PTCA is about twice as long as during CAG-procedures. The difference in filmlength is negligible. Using these recorded data about fluoroscopy and cineangiography the distribution of XAP was calculated for 1300 procedures. This distribution is not significantly different from the distribution of measured XAP values (table 2).

Analysis of variance showed that differences in fluoroscopy and cine time between individual cardiologists in hospital B was not statistically significant. On the other hand, these differences were quite large in hospital A. During CAG mean fluoroscopy time varied between 5 and 16 min; mean cine time between 47 and 69 seconds. During PTCA mean fluoroscopy time ranged from 10 to 24 min and mean cine time from 50 to 67 seconds for different cardiologist.

TABLE 3 FLUOROSCOPY TIME AND CINE FILMLENGTH

	Fluoroscopy time (min) Hospital A			Fluoroscopy time (min) Hospital B		Filmlength (meters*) Hospital A			Filmlength (meters*) Hospital B	
	all	CAG	PTCA	all	CAG	all	CAG	PTCA	all	CAG
mean	11	7.7	15	10	7.7	59	57	61	49	48
s.d.	10	7.5	11	9	5.3	24	21	27	16	19
1st quartile	4.3	3.4	7.6	5	4	45	46	45	40	40
median	8.0	5.3	12	7	6	56	55	57	48	45
3rd quartile	15	9.3	19	12	9	70	68	72	50	50
95th percentile	33	23	36	30	18	101	90	110	75	90
maximum	66	59	66	63	42	243	216	243	120	120
sample size	1041	503	388	226	120	1031	502	387	124	79

*: Using a 35 mm camera at a filmspeed of 50 frames/s, one second of cine angiography corresponds with a filmlength of circa 1 meter.

RESULTS: OCCUPATIONAL EXPOSURE

Using General Linear Model procedures, dosimetry measurements were related to working conditions. Personnel dose data were fitted with XAP-values, totalized per monitoring period. XAP-values were calculated with formula (1) from fluoroscopy and cineangiography data about those examinations in which each person participated. Resulting estimates of organ dose equivalents for workers are presented in table 4 (normalized to XAP = 1000 R•cm^2). Jobdosimetry showed that mean dose equivalents of the cardiologist's eyes varied between 10 and 50 microsievert per 1000 R•cm^2 for different cardiologists.

Typical mean values for the dose equivalent of the eyelens for CAG procedures are 0.2 mSv for investigators and circa 0.05 mSv for assistants. During PTCA procedures, these estimates are circa 25% higher.

Using filmbadge dosemeter data the overall effective energy of scattered radiation in vicinity of patient was estimated at 35 keV.

TABLE 4 ORGAN DOSE EQUIVALENT TO WORKERS [microsievert] PER EXPOSURE-AREA PRODUCT XAP OF 1000 R•cm²

tissue	hospital A			hospital B		
	I	II	III	I	II	III
eye	30	10	10	20	10	3
thyroid	25	5	5	20	7	2
trunk (front)	-	-	-	-	-	-
trunk (back)	1	0.5	0.8	-	-	-
tibia	30	20	2	35	20	3
left hand	25	5	5	15	10	3
right hand	5	7	5	7	7	3

I = investigator ; II = sterile assistant ; III = circulating assistant

DISCUSSION

Using the method of dosimetry index described by Huyskens [Hu88], personnel dose data were evaluated. In hospital A the dosimetry index for investigators varied between 30 and 50% ; for members of staff of the catheterization laboratory between 10 and 20%. Due to a lower workload, the dosimetry index for cardiologists in hospital B was less than 25%. For members of staff in hospital B, the dosimetry index was only a few percent. For cardiologists and staff the dosimetry index for the eye is higher than any other dosimetry index. Using dosimetry index for classification of working conditions, it is concluded that cardiac catheterization procedures are to be classified as working condition A.

Calculated XAPs were compared with XAP-values of some common types of X-ray diagnostic examinations as reported by NRPB [NR86]. Ratios of mean XAP for cardiac procedures and mean XAP for diagnostic procedures are: chest 120; abdomen 10; lumbar spine 5 and barium enema 1.5.

The smaller amount of filmlength in hospital B is a result of a lower filmspeed during coronary angiography recordings (25 frames/s instead of 50 frames/s) [Ja85]. However, the expected reduction is partly compensated by taking more cine recordings per examination.
This study confirmed that during LAO-views (rotating the X-ray tube towards the investigator) radiation exposure to the investigator is much higher (10 times or more) than during RAO-views. LAO-views should be replaced as much as possible by RAO-views.
It was concluded that lead aprons of 0.35 mm lead equivalent, protecting a larger part of the body are to be preferred.

This study confirms that the practice of cardiac catheterization needs adequate individual dosimetry and intensive radiation protection managment.

REFERENCES:

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