Skin and Non-Solid Cancer Incidence in Interventional Radiology using Biological and Physical Dosimetry Methods

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1. Introduction

Interventional radiology has been extended during last years, increasing the necessity of developing radiation protection procedures, not only for patients, but for radiologists and radiology assistants [ICRP 2000]. In the past, radiation injuries of patients exposed to fluoroscopy and other interventional techniques have been analysed as deterministic effects of radiation exposures [Vanagunas et al. 1990, Vano and Gonzalez 2004]. However, medical staff is exposed to low levels of ionizing radiation which are fractionated in time, therefore suspicious to develop stochastic effects such as skin and non-solid cancer incidence (leukaemia, lymphomas and/or myelomas).

Factors affecting doses are dependent on exposure time, field size, technical characteristics of radiation equipment, patient size, examination type, operation mode, complication of examination or staff experience [Kottou et al. 2005]. Some indicative values for effective or equivalent dose per interventional technique found in the literature are shown in Table 1.

Interventional technique	**Effective/equivalent dose**	
	Doctor (μSv)	**Patient (mSv)**
Cardiology	0.5 - 18.8	8.3 per hour
Cerebral embolization	-	2.5 – 10.5
ERCP (Endoscopic retrograde cholangiopancreatography)	Lens (eye) - 340	7.3 (mean to whole body)
	Thyroid - 300	
	Hands - 440	
CT fluoroscopy	7-48	-
Neuro interventional procedures	3.7 ± 2.3 (mean ± SD)	11.3 (mean)

Table 1. Some indicative values for effective or equivalent dose per interventional technique

Staff (radiologists and assistants) receives doses from scattered radiation, but many are not aware of this fact, due to a lack of formation and education on radiation protection practices. In some countries, cumulative radiation doses to the hands, eyes, and thyroid may restrict the number of procedures that interventionists can undertake and there have been reports of radiation injuries to clinicians, including cataracts [Shrimali et al. 1972, Vano et al. 1998a, 1998b]. Additionally, staff doses can be considerably increased if inappropriate x-ray equipment practices or inadequate personal protection items are used (i.e. lead apron, shielding panels…) [ICRP 2000].

Biological dose estimation based on analysis of dicentric chromosomes in solid stained metaphases has provided the most reliable method, being used widely for this purpose. This methodology has been used not only to assess acute doses but also to evaluate protracted and fractionated doses like those received occupationally. For past or chronic exposures, an alternative to the conventional use of dicentrics is the analysis of AST (apparently simple traslocations). After an exposure to ionizing radiation, translocations are induced at a frequency similar but stable to that of dicentrics [Barquinero et al. 1999], whose yield remains relatively constant over time [Lloyd et al. 1998, Lindholm et al. 2002]. Translocations are chromosomic aberrations which can be detected easily by fluorescence in situ hybridization (FISH), and their analysis is a valuable tool in cases of old or longterm exposures, due to their stability [IAEA 2001, Edwards et al 2005].

The objective of this study is the estimation of stochastic effects derived from low dose and low LET dose rate in a specific population group of the Radiology Department of the Hospital La Fe (Valencia), based on physical and biological dosimetry. These subjects have been selected due to the clinical observation of radiation injuries such as aged skin, telangiectasia in nasal region or radiodermitis. Effective doses are generally absorbed in skin, lymphatic fluid and blood, and consequently there is an associated risk to induce a skin and a non-solid cancer, which must be estimated.

2. Materials and methods

2.1 Study population

The subjects under study is a group of nine radiologists from the radiology department of the Hospital La Fe (Valencia), three females and three males with ages ranging from 43 to 58 years old. The groups were exposed to direct and scattered X-ray radiation over a period of 8–28 years, being routinely monitored with film badges or thermoluminescence dosimeters (TLD's). Procedures used by the group of radiologists were endoscopic retrograde cholangiopancreatography, pneumatic dilatation, and insertion of nasoenteric tubes or prosthesis in the gastrointestinal tract.

Table 2 shows employed radiological techniques, common irradiated corporal zone, years of employment, estimated time per patient for each technique and mA - min per year for each worker.

Case	Sex	Age	Years of employment	Ionizing radiation expositions	Radiological techniques	mA·min per year
1	m	56	22	Radiology Endoscopy	Ballon angioplasty/stent Chemoembolization Biopsy TIPS Thrombolysis Aortic endoprosthesis Angioplasty	4800 8000 660 1980 528 1485 6000
2	m	43	8			
3	f	45	13			
4	f	58	25	Radiology Endoscopy	Endoscopy retrograde cholangiopancreatography (ERCP) Digestive stents dilatation	12000 54.45
5	f	57	27			
6	m	54	28	Radiology	Artrography Mielography	1625 1300

Table 2. Interventional procedures and techniques in group of study

Physically recorded doses have been obtained from film badges placed on the wrist and thermoluminescence dosimeters (TLD's) placed near the chest. Biologically recorded doses have been obtained by extrapolating the yield of translocations to their respective dose–effect curves. Chromosome aberrations were detected by fluorescence in situ hybridization (FISH). Table 3 shows a description of the group of nine radiologists and the estimation of the physical and biological effective doses, where Σ_i is the accumulated dose during all professional activity [Montoro et al 2005].

Case	Age	Years	Sex	Physical doses (mSv)				Biological doses (mSv)
				TLD		Wrist		AST
				$\bar{d}\ [d_{\min}, d_{\max}]$	Σ_i	$\bar{d}\ [d_{\min}, d_{\max}]$	Σ_i	
1	56	22	m	3.27 [0,14.8]	75.2	76.1 [0,238.1]	988.9	546 [236-940]
2	43	8	m	2.82 [0,7.1]	21.3	90.1 [60.7,122.1]	450.6	46 [0-289]
3	45	13	f	4.48 [0.3,26]	60.2	64.7 [7.8,169.9]	776.0	99 [0-376]
4	58	25	f	8.91 [0,48.7]	228.1	103.7 [49.8,152.1]	201.9	596 [73-1710]
5	57	27	f	4.67 [0,21]	115.2	25.9 [-,-]	25.9	166 [8-440]
6	54	28	m	3.69 [0.8,13.8]	105.8	9.0 [0,167.4]	216.6	441 [179-773]

Table 3. Physically and Biologically recorded Doses with 95% Confidence Limits. Estimated doses for total apparently simple translocations (AST) using the dose-effect curve: $Y = (0.86 \pm 0.13) \times 10\text{-}2 + (6.57 \pm 1.06) \times 10\text{-}2\ D + (4.15 \pm 0.55) \times 10\text{-}2\ D^2$

2.2 Risk of exposure induced cancers (REIC)

There are different indicators when evaluating the associated induced cancer risk to people exposed to ionizing radiation. These indicators are adequate to make comparisons and to be included in quality controls assessment. One of these estimators is the excess absolute risk for cancer incidence, EAR, defined as the excess probability of developing a cancer after an exposure to ionizing radiation, where is a set of covariates, such as sex, age-of-exposure, attained age, effective dose or latency period.

The UNSCEAR Reports present a large group of cohorts and case-control studies of risk estimates for solid and non-solid cancers after exposures to ionizing radiation. The most important source of radio-induced cancers is the Radiation Effects Research Foundation Life Span Study, which links the Japanese atomic bomb survivors and the Hiroshima and Nagasaki tumor registry data for 1958 through 1987 [UNSCEAR 2000]. However, this report includes only detailed models for risks of solid cancer mortality and incidence (except skin cancer) based on age-at-exposure and attained age.

A risk model based on average EAR per person-year-sievert (PYSv) from external low-LET exposures has been introduced for transporting risks from the Japanese population to the exposed population. Table 4 shows the average excess absolute risk (EAR) for cancer incidence in males and females.

		EAR (10^4 PYSv)$^{-1}$
		Male / Female
Solid cancer	Skin cancer	0.89 / 0.72
Non-solid cancer	Leukaemia	3.35 / 2.29
	Hodgkin's disease	0.04 / 0.04
	Non-Hodgkin's lymphoma	0.73 / -0.20[a]
	Multiple myeloma	0.26 / -0.08[a]

Table 4. Average excess absolute risk (EAR) for incidence cancer (104 PYSv)-1 from the Life Span Study cohort (UNSCEAR 2000 report)

The risk of exposure-induced cancer (*REIC*) is defined as the probability that an individual suffers a radio-induced cancer, not necessarily fatal, over all of his or her life. The REIC is estimated as

$$REIC = \left(\sum_{j=e+L}^{M} s_{1j} EAR_j \right) \tag{1}$$

where e is the age-at-exposure, L is the latency period and s_{1j} is an estimator of the survival function, that is

$$s_{1j} = \prod_{i=e}^{j} \left[1 - \lambda_{all}(i) \right] \tag{2}$$

The baseline mortality function per male and female has been obtained from INE database (www.ine.es), assuming an additive model for epidemiology from EAR of the Life Span Study cohort. The excess absolute risk has been transported to the population of the Valencian Community through the baseline mortality function λ_{all}, using the software RADRISK. This software has been developed on Matlab 7.0, based on the software SCREENRISK which is used for estimating the breast cancer incidence and mortality in the Valencian Breast Cancer Screening Program [Ramos et al. 2005].

3. Results

Effective doses obtained from the wrist dosimeter have been used for estimating the skin cancer incidence, whereas TLD's and biological doses have been employed for estimating non-solid cancer incidences.

Tables 5 and 6 show the risk of exposure-induced cancer derived from physically recorded doses and biologically recorded doses. As observed, there is an appreciable increment in the cancer incidence due to exposed radiation in some cases, especially for skin cancer and leukemia. The REIC for induced non-Hodgkin lymphomas and multiple myeloma is negligible for females, derived from the negative EAR trend from the UNSCEAR 2000 report.

Case	Sex	Age	Wrist dosimeter	TLD dosimeter			
			Skin Cancer	Leukemia	Hodgkin's disease	Non-Hodgkin's disease	Multiple myeloma
1	m	56	5.39	1.54	0.01	0.33	0.12
2	m	43	2.38	4.25	0.00	0.09	0.03
3	f	45	4.36	1.07	0.01	< 0	< 0
4	f	58	1.10	3.98	0.06	< 0	< 0
5	f	57	0.15	2.15	0.03	< 0	< 0
6	m	54	1.45	2.67	0.03	0.58	0.20

Table 5. Risk of exposure-induced cancer (REIC) per 1000 for non-solid cancer incidence derived from physically recorded doses (wrist and TLD dosimeter)

Case	Sex	Age	Leukemia	Hodgkin's disease	Non-Hodgkin's disease	Multiple myeloma
1	m	56	11.21	0.13	2.44	0.87
2	m	43	0.91	0.01	0.20	0.07
3	f	45	1.77	0.03	< 0	< 0
4	f	58	10.40	0.18	< 0	< 0
5	f	57	3.11	0.05	< 0	< 0
6	m	54	11.14	0.13	2.42	0.86

Table 6. Risk of exposure-induced cancer (REIC) per 1000 for non-solid cancer incidence derived from biologically doses

4. Discussion and conclusions

The discrepancies observed between the physically recorded doses and the biologically estimated doses due to that physical dosimetry is low estimated because of radiologists did not always wear their dosimeters or that the dosimeters were not always in the radiation field, which implies a possible partial-body exposure.

These results are in accordance with DIMOND report which states that staff doses in interventional procedure are highly dependent on radiation protection measures taken (Peer et al 2003). Unfortunately the dosimeters are not placed on the same worker's point in every hospital (i.e. chest dosimeter is placed commonly on belt) and are not used every day by misleading for the majority of interventionists.

Suitable theoretical and practice education and training for the personnel in radiology (and cardiology) is necessary. Training in radiological protection for patients and staff should be an integral part of the education for those professionals using interventional techniques. Risks and benefits, including radiation detriment, should be taken into account when new interventional techniques are introduced.

Other non-solid cancer incidence is negligible, but it has been considered that is derived from the hypothesis of constant excess-absolute risk (EAR) over the life of the radiologist. Future work will include a more complex model for estimating EAR, based on attained age or age-at-exposure applicable to non-solid and non-melanoma skin cancer.

Despite all uncertainties transporting risks, the average radiological detriment, expressed as the risk of exposure-induced cancer (REIC) is appreciable for some cases and some cancer incidence, such as skin cancer and leukaemia.

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