DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY: A STRATEGY FOR INTRODUCING DIAGNOSTIC REFERENCE LEVELS TAKING INTO ACCOUNT THE NATIONAL PRACTICE

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ABSTRACT

Diagnostic reference levels (DRLs) are difficult to define in the case of X-ray examinations involving fluoroscopy particularly those performed in angiography and interventional radiology due to the large variability between examinations: fluoroscopy duration, number of images, image quality required. In order to tackle this problem a nation-wide dosimetric survey was performed in Switzerland involving five university hospitals, aiming at establishing a set of DRLs for eight types of examinations performed in diagnostic and interventional radiology. Each centre was requested to provide information on the patients and the technical data related to 20 examinations for each type. From the data collected, the distributions of the dose-area product, the number of images and the duration of fluoroscopy were established. A large variability of the technique was found. A set of DRL values was then determined using the 3rd-quartile method. These results will be sent to the radiologists to be analysed accompanied with some proposals for dose reduction.

1. INTRODUCTION

X-ray examinations involving fluoroscopy, particularly those of the digestive system, angiography and interventional examinations contribute significantly to the total collective dose due to medical exposure even if their frequency is relatively low. A recent survey on the exposure of the Swiss population by X-ray imaging indicated that this contribution amounts up to 29% [1]. Moreover, these types of examinations, which deliver effective doses to the patient of the order of few mSv to few tens of mSv, can lead to extremely high entrance surface doses, up to a few Gy, leading to a significant risk of deterministic effects.

Several international bodies address seriously the issue of radiation protection of the patient and the radiologist for dose-intensive examinations. The International Commission on Radiological Protection (ICRP) dedicated one of its publications to the means and methods to set up in order to prevent the lesions that may be induced by interventional radiology [2]. Similarly, the European Directive 97/43 Euratom states in its article 9 that "Member States shall ensure that appropriate radiological equipment, practical techniques and ancillary equipment are used for the medical exposure […] involving high doses to the patient, such as interventional radiology, computed tomography or radiotherapy." [3]

In Switzerland the Federal Office of Public Health set up in early 2000 with the collaboration of the University Institute of Applied Radiation Physics a working group on the optimisation of radiation protection in the case of dose-intensive X-ray examinations (*Optimierung des Strahlenschutzes bei dosisintensiven Untersuchungen in der Radiologie* – OSUR). Several medical associations concerned by the issue were invited to take part in this working group: general practitioners, radiologists, cardiologists, radiographers, medical physicists. One of the main issues addressed by the working group relates to diagnostic reference levels (DRLs), whose definition, establishment and implementation have become in recent years of central importance in the management of radiation

doses delivered to the patient in diagnostic and interventional radiology. In fact, several international, regional and national bodies showed an increasing interest for this subject [3-6], a great number of papers were dedicated to DRLs and several scientific meetings and journals included DRLs in their priority topics [7].

The International Commission on Radiological Protection (ICRP) introduced the term "DRL" for the first time in 1996 [8], specifying that it is advisory, set by professional bodies, apply to dose to patients or intake of pharmaceutical, and call for local review if consistently exceeded.

The ICRP compiled in 2001 different sets of DRLs proposed at the international level [4]. The data presented in the ICRP report covers fifteen radiographic views for adult patients, and for paediatrics in a few cases, three fluoroscopy examinations, ten CT examinations, mammography and five dental examinations.

The DRLs apply exclusively to diagnostic and interventional examinations (X-ray and nuclear medicine) - radiotherapy being outside their scope, and in priority to the most common types of examinations. The ICRP underlines in its publication 73 (paragraph 104) that: "Diagnostic reference levels should be related only to common types of diagnostic examination" [8], whereas the European Commission declares in its publication 109 (paragraph 14) that: "DRLs are applicable for standard procedures in all areas of diagnostic radiology, both in radiodiagnostics and nuclear medicine. They are, however, particularly useful in those areas where a considerable reduction in individual or collective doses may be achieved or where a reduction in absorbed dose means a relatively high reduction in risk: i) frequent examinations, including health screening; ii) high-dose examinations such as CT and procedures which require long fluoroscopy times, such as for interventional radiology; and iii) examinations with more radiosensitive patients, such as children." [5] The EC publication adds that: "However, it should be recognised that it is rather more difficult to establish DRLs for CT, interventional radiology and groups of children than it is for more frequent, less complex exposures. Therefore priority could be given to the more simple and frequent examinations".

Even if it is difficult to deal with DRLs in the case of complex X-ray examinations, their use is important for such dose-intensive examinations since it provides guidance for proper dose management.

It is recommended to use easily measurable quantities to establish DRLs. Table 1 presents the quantities commonly used for the various radiological modalities.

Table 1. *Dosimetric quantities used in this work to establish the DRLs*

Modality	Dosimetric quantity	Abbreviation	Unit
Radiography	Entrance surface dose, per view	ESD	mGy
	Dose-area product, per examination	DAP	mGy.cm^2
Mammography	Air Kerma at the breast surface, per view	ESAK	mGy
Fluoroscopy	Dose-area product, per examination	DAP	mGy.cm^2
Angiography	Dose-area product, per examination	DAP	mGy.cm^2
et interventional	Number of images, per examination	–	–
radiology	Fluoroscopy duration, per examination	–	min
Computed	Weighted CT dose index, per slice or rotation	$CTDI_w$	mGy
tomography	Dose-length product, per examination	DLP	mGy.cm
Dental radiology	Entrance surface dose, per view for intra-oral examinations (apical, bitewing)	ESD	mGy
	Dose-width product for OPG	DWP	mGy.mm

In general, DRLs are based on dosimetric surveys. The widely used 3rd-quartile method prescribes the use as a DRL of a dose value corresponding to 75% of the dose distribution established by the survey. In the absence of a dose distribution, another method has been suggested consisting in multiplying the average dose by a factor 1.5 [7,9].

In 2002 the OSUR working group launched a study to investigate the situation of fluoroscopy in Switzerland. The aim of this study was to study the technique used to perform eight common types of examinations involving fluoroscopy in five university hospitals performing the bulk of the dose-intensive examinations, and to collect dosimetric data in order to establish DRL values for the eight types of examinations investigated.

2. METHOD

The study covered the following five Swiss hospitals: University Hospital of Lausanne (CHUV), University Hospital of Geneva (HUG), Inselspital of Bern (ISB), Kantonsspital of Basel (KSB) and University Hospital of Zürich (USZ). In what follows these hospitals will be referred to using the codes CE1 to CE5 to guarantee data anonymousness. The investigation covered the eight types of examinations (four diagnostic and four interventional) proposed by the OSUR working group after a long internal discussion and a wide consultation with the practitioners of the participating centres. These eight types of examinations that will be denoted EX1 to EX8 are presented in table 2.

Table 2*. The eight types of examinations investigated*

Type of examination	**Code**
Diagnostic	
Barium meal	EX1
Lower limb angiography	EX2
Cerebral angiography	EX3
Barium enema	EX4
Interventional	
Hepatic embolisation	EX5
Biliary drainage and stent insertion	EX6
Cerebral embolisation	EX7
Iliac dilatation and stent insertion	EX8

Each centre was asked to register 20 examinations for each of the eight types. This represents a good compromise between the statistical quality and the duration of registration. The centres were requested to fill in a questionnaire and provide information on the examination (fluoroscopy duration, number of images, dose-area product, difficulty of the case), on the patient undergoing this examination (age, gender, height and weight), and on the practitioner performing the examination (medical specialty, number of years of experience, number of examination already performed).

Moreover, the 18 fluoroscopy units used in the five healthcare providing centres were characterised. One DAP-meter was found to give a dosimetric indication a factor of two higher than the reference value. An adequate correction was applied in this case.

RESULTS AND DISCUSSION

The response rate was good since 571 examinations were registered after a few reminders. This presents 71.4% of the total of 800 that would have been expected in an ideal case and corresponds to an average of 114 examinations per centre and 71 examinations per type.

Table 3 shows a summary of the collected data for the example of cerebral angiography as an illustration. The ranges and mean values among the five centres are given for all the quantities investigated.

Table 3. *Data concerning the patient and the examination for cerebral angiography (EX3)*

Centre		CE1	CE2	CE3	CE4	CE5
Number of examinations		14	20	20	21	16
Diameter of Image intensifier	17-22 cm (%)	7	10	0	-	100
	23-28 cm (%)	71	20	5	-	0
	29-34 cm (%)	21	50	95	-	0
	35-40 cm (%)	0	20	0	-	0
DAP (Gy.cm2)	minimum	47	48	48	8	3
	maximum	316	996	232	149	147
	mean	131	208	83	69	39
Fluoroscopy duration (s)	minimum	312	160	240	120	120
	maximum	5,100	4,260	2,160	1,740	1,080
	mean	1,379	966	584	592	370
Number of images DSA	minimum	59	5	215	32	103
	maximum	285	441	770	588	5,486
	mean	182	233	403	201	2,583
Number of series DSA	minimum	3	4	10	5	2
	maximum	16	376	31	20	15
	mean	9	60	19	9	6
Difficulty of the case	easy (%)	29	15	0	29	0
	normal (%)	57	40	90	71	88
	complex (%)	14	45	10	0	13
Gender of the patient	M (%)	43	50	39	48	56
	F (%)	57	50	61	52	44
Age of the patient (a)	minimum	45	21	22	30	40
	maximum	91	79	69	71	77
	mean	64	52	53	53	54
Height of the patient (cm)	minimum	153	158	152	158	158
	maximum	184	197	187	182	185
	mean	169	173	172	171	173
Weight of the patient (kg)	minimum	55	52	51	43	58
	maximum	103	86	95	90	98
	mean	75	70	74	73	78

Figure 1 shows the inter centre variability of the fluoroscopy mean duration for the five types of examinations. It can be noticed that for some types there is a high variability, whereas for others the variability is relatively low.

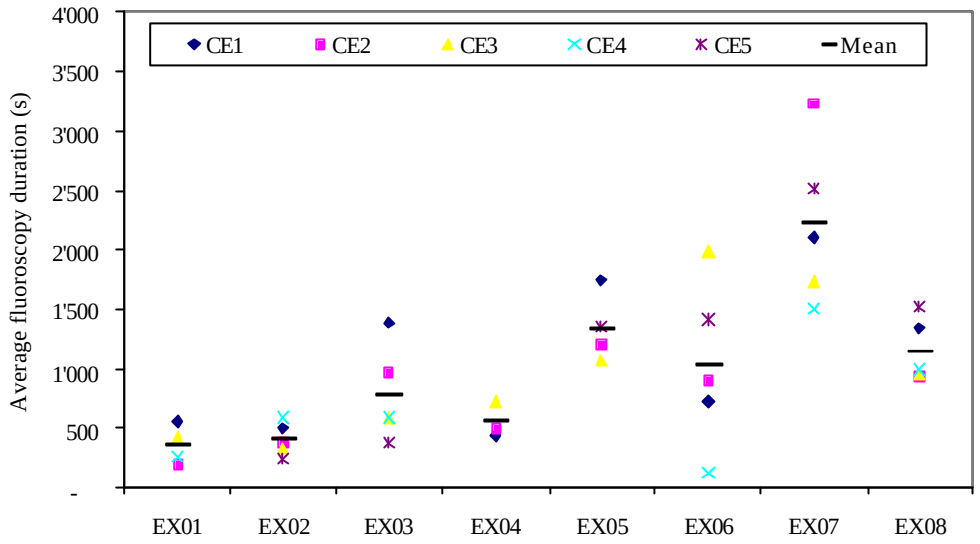

Figure 1. *Inter centre variability of the fluoroscopy duration*

Table 4 presents the correlation between the fluoroscopy duration and the degree of difficulty of the examination type. One can see that there is a direct correlation since the fluoroscopy duration increases with the difficulty of the examination. It is of the order of 350 to 750 s for diagnostic examinations which are on average complex in 10-20% of the cases, and goes up to around 1100 to 2100 s for interventional examinations which are on average complex in 40-74% of the cases.

Table 4. *Correlation between the fluoroscopy duration (T in s) and the degree of difficulty of the examination type (in %)*

Type of examination	Number of cases	T average	Easy (%)	Normal (%)	Complex (%)
Barium meal (EX1)	88	351	19	64	17
Lower limb angiography (EX2)	94	395	16	76	9
Cerebral angiography (EX3)	91	754	14	69	16
Barium enema (EX4)	40	470	15	70	15
Hepatic embolisation (EX5)	70	1321	6	54	40
Biliary drainage and stent insertion (EX6)	56	1267	21	34	45
Cerebral embolisation (EX7)	58	2191	2	24	74
Iliac dilatation and stent insertion (EX8)	72	1149	3	51	46

Figure 2 shows an example of the distributions established from the data collected in this study. It relates to the DAP and concerns cerebral angiography.

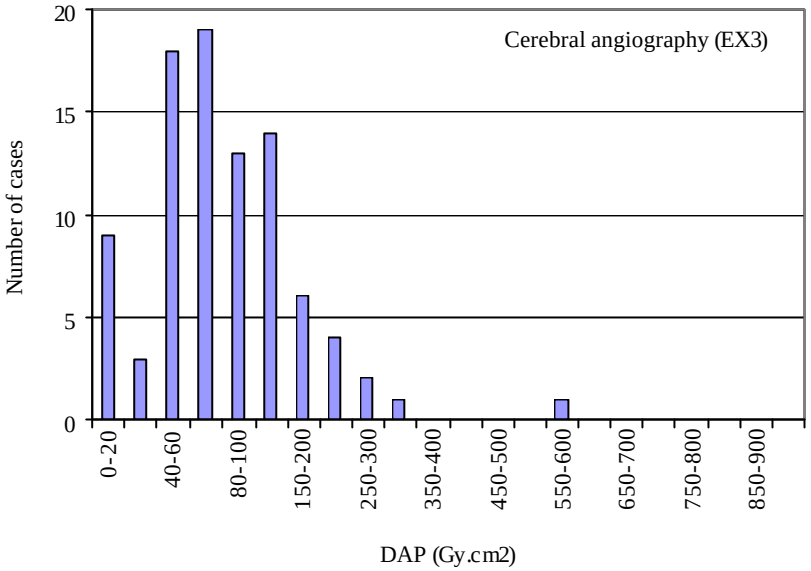

Figure 2. *Distribution of the DAP for cerebral angiography*

The DAP results obtained for all the eight types of examinations, as established from the corresponding distributions, are summarised in table 5. Minimal, maximal, mean and 75-percentile values of the DAP are given. The 75-percentile value corresponding to the DRL is compared to DRL values reported in the literature.

Table 5. DAP values for the eight types of examinations investigated.

Examination type	EX1	EX2	EX3	EX4	EX5	EX6	EX7	EX8
Number	89	94	91	41	70	56	58	72
Minimum	3	8	3	20	54	5	24	36
Maximum	441	747	996	564	1,703	1,375	1,345	1,122
Mean	67	178	107	114	463	244	335	344
75-percentile	87	226	124	142	629	312	352	431
75-percentile /Mean	1.30	1.27	1.16	1.25	1.36	1.28	1.05	1.25
Literature	25[4]	36[10]	100[11]	60[4]	120[11]	100[11]	-	-

The differences between DRL values can be high, particularly for complex examinations such as those performed in interventional radiology. These differences are due to several factors such as a difference in the definition of the type of examination and in the technique among the centres.

The 75-percentile to mean ratio varies from 1.05 to 1.36 with an average value of 1.24. This shows that for this type of examinations, if the DRLs were to be established from mean dose values, then a factor of 1.24 rather than 1.5 should be applied.

The differences between the 75-percentile values established in this work and the DRLs reported in the literature can reach a factor of 5. This should be analysed by the radiologists to see if these discrepancies are justified.

Table 6 presents the established DRL values based on the present study for the 8 investigated types of examinations

Table 6. DRL values based on the present study for the 8 investigated types of examinations (increasing order)

Examination type	DAP (Gy.cm2)
Barium meal (EX1)	100
Cerebral angiography (EX3)	120
Barium enema (EX4)	150
Lower limb angiography (EX2)	200
Biliary drainage and stent insertion (EX6)	300
Cerebral embolisation (EX7)	350
Iliac dilatation and stent insertion (EX8)	450
Hepatic embolisation (EX5)	650

CONCLUSION

This study allowed the collection of data concerning 571 examinations corresponding to eight types. In general all the participating centres give comparable average doses, except one centre for which the doses are a factor 2 lower than the average of the centres. This investigation showed a strong correlation between the fluoroscopy duration and the degree of difficulty of the examination. The dosimetric data base set up in this work will allow the establishment of national DRL values for the eight types of examinations investigated. There is a large variability of the dose for such examinations related to the degree of complexity of the examination, the experience of the practitioner, and to differences in the definition of the examination and in the technique used. This constitutes a difficulty in applying the DRL concept. Of course such a concept cannot be applied to a specific examination, but it is highly recommended to perform a check after each ten examinations to see if in average the DRL is exceeded systematically or not, and to take the appropriate measures if necessary. The 75-percentile values established in this work were found to be higher that the DRLs reported in the literature, sometimes by a factor of 5. This might be due to the fact that the survey covered university hospitals exclusively, where the proportion of “heavy” cases might be relatively high and where there is a high number of junior radiologists undergoing their training. Unfortunately the participants in this survey did not answer the questions related to the number of years of experience and number of examination already performed by the radiologist, but a different study performed at a local Swiss hospital showed a correlation between the years of experience and the dose delivered during a complex X-ray examination. This issue should prompt a discussion between the participating radiologists.

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