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Doses to Patients from Diagnostic Radiology in France

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DOSES TO PATIENTS FROM DIAGNOSTIC RADIOLOGY IN FRANCE

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Abstract - The major results are reported of a 1982 national survey in France to establish the collective effective dose equivalent associated with the main types of radiological examinations practiced annually in this country (except nuclear medicine, C.T. scans, dental radiology and mass chest screening). It describes the methodology followed in achieving dose measurements either on an anthropomorphic phantom or directly on the patient and highlights the importance of the radiological procedures (number of x-ray films, fluoroscopy screening time, etc.) on the received patient organ doses. Estimate of the collective effective dose equivalent associated with the radiological practice is 86,000 person-sievert i.e. an individual effective dose equivalent of 1.58 mSv y^{-1}; the Genetically Significant Dose figure is 0.29 mSv and finally the collective red bone marrow dose due to 45 million x-ray exams practiced in France (1982) is 40,300 person-sievert, i.e. 0.74 mSv per inhabitant.

INTRODUCTION

In many countries medical exposure of patients represents the greatest man mad contribution to the collective dose imparted to the population.

In France, as in other countries, it is generally considered that medical exposur equals approximately half the exposure from natural sources of ionizing radiation, an much effort should be devoted to its reduction. A useful tool for achieving such efforts i knowledge of the radiation doses received by patients undergoing general x-ra examinations. Many publications have already investigated the various aspects an levels of such radiation sources, and both United Nations Scientific Committee on th Effects of Atomic Radiation (1982) and the Advisory Committee on the Biologica Effects of Ionizing Radiations (NA82) have published very extensive reports on thi subject.

As far as France is concerned, the last available assessment of gonadal doses and of the consequential genetic risks of diagnostic radiology examinations was carried ou on a national scale longer than 30 years ago by Reboul et al. (1957). Since then, numerous studies dealing with dosimetry of certain categories of x-ray examinations have been performed (Aubert 1981, Costa et al. 1981, Fauré et al. 1983, Laval-Jeantet and Weill 1977, Manens et al. 1984), but none evaluated the collective dose received in France. Furthermore, since 1957 both diagnostic imaging techniques and medical practices have changed considerably, and new dosimetry technologies also have been introduced and applied in diagnostic radiology.

Considering this, a survey was conducted on a national scale in France by Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire (CEPN) and Institut National de la Santé et de la Recherche Médicale (INSERM) in 1982 . The main objectives of this survey were : to learn about the staffing and facilities for diagnostic radiology; to establish the frequency of x-ray examinations and the age and sex distribution of patients; to ascertain current levels of exposure for patients; and to evaluate the radiation risks from the various radiological procedures.

This paper reports the main results of this survey and describes (a) the assessment

of the collective effective dose equivalent associated with the different types of radiological examinations practiced in France in 1982, (b) the distribution of collective patient doses absorbed in particularly radiosensitive organs, (c) the genetically significant dose (GSD), and (d) the most frequently used radiographic exposure parameters.

MATERIAL AND METHODS

a) The National CEPN-INSERM Survey (1982)

Detailed methodology used in carrying out the 1982 survey of the radiological activity in France has already been published elsewhere (Fagnani et al. 1985a, Fagnani et al. 1985b, Fagnani et al. 1985c). To summarize briefly, the survey was conducted in two separate phases (the survey excluded dental radiology, mass chest screening practices, Ministry of Defense Hospitals, independent fluoroscopy units, C.T. scanners and nuclear medicine). Initially, about 500 radiology departments, private clinics and offices practicing diagnostic radiology were selected throughout the country by a stratified sampling procedure (average sample rate of 1/10); the stratification was based on a rough evaluation of their annual x-ray film consumption. All the necessary information about the provision of staff and facilities for diagnostic radiology in terms of numbers of radiologists, radiographers and x-ray sets available was finally gathered in 386 public hospitals and private practices that actually participated in the survey. In a second phase, in order to estimate the total number of x-ray exams annually practiced in France, broken down by age and sex of patients, a questionnaire was sent to a sub-sample selected among the x-ray sets (549 out of 1,372) that equipped the 386 radiological departments mentioned above. Technical data about each of 13,000 x-ray examinations such as the number of films, the fluoroscopic screening time, the x-ray beam projection, the applied potential (kVp), the tube current (mA) and the exposure time (s) were thus collected over a specified one week period in June 1982.

Table 1 hereafter summarizes the data base used for the survey and gives the

response rates, broken down by the activity sector, associated for the two phases.

As one can notice, the rather high response rate figures obtained in both phases reflects a very good acceptability of the survey although it involved important mobilization of manpower and time from already hard-pressed staff in diagnostic x-ray departments. In particular, it must be pointed out that information requested by questionnaires during the second phase was supplied by almost 75% and 60% of the x-ray units, respectively, installed in the public hospital and in the private sector.

In all, 45.4 million x-ray examinations were estimated for France in 1982 by extrapolating the weekly figures taking account of the seasonal radiological activity variations.

b) Dosimetry

Concerning the dose evaluation problem, measurements were performed either on an anthropomorphic phantom * or directly on the patient by using thermoluminescent dosimeters (lithium borate pellets) which previously were calibrated with a standard source of ^{60}Co. The energy dependence and linearity between thermoluminescence and dose were checked and found satisfactory.

The general protocol used in measuring doses associated with the x-ray diagnostic procedures in France is hereafter described.

1. Adult phantom dosimetry

In the case of the measurements on the phantom, three major problems were to be solved.

a) Selection of the parameters to be used in experimental measurements.

Almost 1,500 configurations, expressed in terms of combination of physical and anatomical parameters such as kVp, mAs, film size, x-ray beam projections and centering point position were actually observed in the survey. In order to limit the number of experimental measurements, this number was reduced by considering the following two criteria: either the relative low frequency in the actual practice, or the likely low contribution to the collective population dose (limb x-rays were not included);

in doing so, the configuration number falls into 37, as showed in the Table 2.

It can be noticed that, in order to complete the set of the dosimetric measurements showed in Table 2, two extra configurations have been considered for the simulation of the fluoroscopy radiation mode. The so-called "thoracic scanning" was thus related to the following exams: head and neck, chest, stomach and gall bladder; while the so-called "abdominal scanning" was related to the rest. This enabled us to cover in a more realistic manner the radiological practice, and to add useful information about the dose associated with fluoroscopy.

b) Selection of a representative x-ray table.

This point concerned the selection of an x-ray table considered representative of the most routinely operating x-ray equipment in France, on which dosimetry measurements were to be performed. For practical reasons, 17 different x-ray tables, remote controlled, conventional and specialized ones, installed in five hospitals which participated in the dosimetry survey were selected. Free in air exposure variations were checked as a function of kVp, mAs and quality of the detector (standard film and rare earth screen film) by using ionization chambers and TLDs. For the same kVp and mAs values, exposures were found to range by a factor of 1 to 3, depending on the x-ray equipment considered. Finally, the selected x-ray table, having the closest values of technical parameters (filtration, HVL etc.) as compared to the average was a model made by Compagnie Générale de Radiologie (C. G. R.).

c) Organ dose assessment methods.

One problem related to the selection of particularly radiosensitive organs inside the Rando-man phantom. Keeping in mind that the objectives of the dosimetry study were the evaluation of the effective dose equivalent associated with a given x-ray examination, i.e. the assessment of the dose received by all the organs recommended by the ICRP, two different procedures were followed in measuring organ doses.

- Concerning lenses (6 TLDs), lungs (57 TLDs), testes (6 TLDs), ovaries (9TLDs), mammary glands (9TLDs) and thyroid (3 TLDs), TLDs were inserted into the corresponding organ positions and systematically irradiated 30 times to obtain significant dose values, especially at different points outside the primary beam. This

was repeated as many times as the number of the configurations considered (see Table 2). In addition to those dosimeters, three TLDs were also attached to the phantom's surface at the center of each x-ray field, in order to assess the entrance skin dose.

- Concerning the red bone marrow, the bone surface and the "remainder" organs, the estimation of doses was mainly based on the entrance skin dose measurements carried out for each radiograph. This has been achieved through Monte Carlo calculations using standardized x-ray field size and positions, corresponding to the 37 configurations, and an idealized mathematical phantom (MIRD) representing the patient (Jones and Wall 1985). To be coherent and also to validate this procedure, a comparison between the Rando phantom dose and the MIRD dose has been carried out in terms of factors relating organ doses to the entrance skin dose for a wide range of x-ray field sizes, positions and projections (Benedittini et al. 1985). Comparative organ dose data are shown in Table 3. As one can notice, CEPN conversion factors, derived from the experimental measurements carried out on a Rando phantom, are generally lower than the correspondent calculated MIRD conversion factors. Nevertheless, reasonable agreement is obtained between the two sets of organ dose conversion factors when the beam sizes are the same. In those cases, the National Radiological Protection Board (NRPB) and CEPN factors agree to within 30% for all except the abdomen exam in A/P projection, the chest exam in P/A projection and the skull exam in A/P projection.

2.Patient Dosimetry for children

In order to complete the previous set of dosimetry measurements, carried out exclusively on an adult Rando phantom, some in-vivo measurements were also performed on a sample of young patients (less than 10 years old) for a limited number of x-ray examination types. In accordance with the strategy adopted for assessing both somatic and genetic risk associated with the radiological practices, the following five common types of x-ray examinations were considered as the most representative ones: pelvis, intravenous urography, abdomen, lumbar spine and barium meal.

Measurements were then carried out on patients undergoing the selected examinations by using TLDs attached to the patient's skin. Thyroid, gonads (only for the boys) and lung doses were estimated directly from skin dose measurements: one TLD over the thyroid, one TLD over the testes and two TLDs, respectively, on the front and back of the thorax. Doses for other organs were, as in the case of the adult patients, deduced from measurements of entrance skin dose (including backscatter) per radiograph using Monte Carlo conversion factors adapted to a pediatric phantom (Kereiakes and Rosenstein 1980).

RESULTS

(a) Frequency of x-ray examinations

The CEPN-INSERM survey indicated that 45.4 million x-ray examinations were performed in France in1982. This corresponds to 820 examinations per thousand head of population. Figures of 23.9 million x rays and 21.5 million x rays were obtained respectively for male and female patients. Table 4 shows the weekly figures and the annual numbers of x-ray examinations broken down in 30 different categories. The first general comment concerns the thorax examination number, which, as mentioned above, does not include the mass screening practices, and represents 34% of all x rays in France. The other most important examinations practiced in 1982 are limbs (22%), skull (9%) and pelvis-hip (7.5%).

Concerning the number of x-ray examinations practiced in France detailed by the corresponding activity sector, almost 61% of all examinations are carried out in public hospitals, 16% in the private for profit clinics and 23% in the private offices.

Regarding the age and sex distribution of patients, Figure 1 shows the annual frequency of diagnostic radiology exams by age and sex per 1000 patients of each age class. The first obvious remark concerns the shape of the curve which follows similar patterns of the "U" curve of the general medical consumption. For the first age class, (patients aged less than 1 year) the mean number of x rays all together, ranges from 2.2 to 3 per inhabitant and per year; while beyond the age of 60 years this value

falls into a range of 1 to 1.5. One can also notice that male patients are examined more frequently than the female, all age categories together, except in the case of the very young patients (less than 1 year old). In the latter, a reverse situation is observed, almost 3,000 x rays are annually performed per 1,000 girls against 2,200 x rays per 1,000 boys. One of the most important reason for that being the high number of pelvic x-ray examinations taken for diagnosing the congenital hip dysplasia: two thirds of all French girls and one quarter of all French boys actually undergo such an examination in the first year of life; the higher rate for girls reflecting their higher susceptibility to this pathology (Lefaure et al. 1986).

(b) Examination Organ Dose Estimates.

The entrance skin dose measurements carried out for each radiograph belonging to the previously mentioned CEPN configurations have allowed the estimation of doses to all the major radiosensitive organs for each complete x-ray examination.

Table 5 shows the mean values of the total organ doses observed for each examination category involving the mean number of radiographs and the fluoroscopy screening time given in Table 6.

Values are expressed in terms of absorbed dose to ICRU muscle (International Commission on Radiation Units and Measurements 1970), apart from those for breast, which are calculated assuming a tissue composition of 50% water and 50% fat.

As far as the "remainder organs" are concerned, figures represent the mean of the doses to the additional five most irradiated radiosensitive organs not otherwise specified in Table 5. (International Commission on Radiation Protection 1977).

A comment on the Table 5 concerns the range of the gonad doses which vary from 0.03 mSv for a complete examination of the thorax to 5 mSv for a lumbo-sacral spine exam. In this respect, two examinations seem to be the most irradiating ones: the abdominal angiography, which also delivers the highest dose to the total body all examinations considered, and the barium enema.

As far as the breast doses are concerned, the following three radiological

procedures have to be mentioned as the most important ones: barium meal (36.43 mSv), thoracic angiography (10.01 mSv) and thoracic spine (9.98 mSv). In particular for barium meal, which necessarily involves the use of contrast media, a large number of films and frequently fluoroscopy, the breast dose value seems particularly high. Although it is difficult to precise effect of radiographic technique used in carrying out this examination on the radiosensitive organ such as the breast, it might be thought that it is not necessary for the breast to be directly irradiated during a barium meal. However, because of their anterior position in the body, the doses to this organ depend not only on the degree of field collimation but also on whether the radiation is predominantly AP or PA.The rather high proportion of remote control fluoroscopy units with under-couch image intensifiers operating in France probably leads to more AP projected x-ray beams in this examination and hence large breast doses.

In general, it can be argued that the complexity of the radiographic technique used in performing a given examination, (film number, type of projection, fluoroscopy...) is largely responsible for the highest doses estimated in the context of the methology followed. This is clearly illustrated by the thyroid dose values for a cervical spine exam and for a conventional cerebral angiography. In the latter, the number of x-rays, the fluoroscopy used for selective arterial catheter placement, (see Table 6) lead to a thyroid dose of about 160 mSv, whilst the dose to the same organ for a cervical spine is more than ten times lower i.e. 10 mSv.

As far as the red bone marrow doses are concerned, considerable variations are also apparent in comparing the mean values of dose obtained with those reported by different authors for some particular examinations (Bengtsson et al. 1978; Shleien et al. 1977; Shrimpton et al. 1986). Discrepancies of up to a factor 10 between the mean doses for a given examination were found, probably due less to differences in radiographic practice than to important differences in the dosimetric technique employed. Similar discrepancies also occur in dose data reported for other organs.

Regarding the remainder organ doses, their contribution to the effective dose equivalent has been found to range from 40% for a conventional cerebral angiography to about 90% for a cholecystography. This was assessed by applying the ICRP

weighting factors which were mainly defined for occupational exposures ar populations and may not be an appropriate indicator of risk for patients undergoi diagnostic radiological procedures.

Concerning the effective dose equivalent to patients having x-ray examinations, n surprisingly, the largest mean values are associated with the 'complex' examinatior (angiographies, intravenous urography, barium meal). Conversely, the figure from th survey for a chest examination, the most frequent of all radiological procedure conducted in France, is 0.28 mSv. Mean effective dose equivalent values for eac examination are presented graphically in Figure 2.

Although there are currently no recommended limits for the doses which patient may receive from medical radiological examinations, it can be pointed out that 11 % c the x rays annually performed in France result in higher effective dose equivalent than the limit of 5 mSv that any member of the public may annually receive from a other artificial sources of exposure, and the corresponding percentage of th examinations the dose of which is over 2 mSv (mean exposure due to the nature background in France) is about 48 %.

Collective Dose Estimates

The collective effective dose equivalent estimates obtained in combining botl examination frequencies and the indivual effective dose equivalent mentioned above are presented in Table 7 for each examination category.

As it can be noticed, from the collective point of view, the most important examination is, by far, the IVU which leads to a collective exposure of about 20,500 person-sievert, the corresponding values for lumbar spine, barium meal and barium enema being closely equal to 8,000 person-sievert. Regarding the use of fluoroscopy technique, its contribution to the collective dose ranges from 3% for thorax to 70% for thoracic angiography, with an average figure of 15%. Finally, the total collective effective dose equivalent received by patients who undergo diagnostic radiology examinations in France in 1982 is about 86,000 person-sievert, i.e. 158 person-sievert

per million inhabitants.

Table 9 compares some collective effective dose equivalent values, expressed in person-sievert per million inhabitants, only for those countries where such estimates are available.

As it is showed, there are significant differences in doses for the studied countries: for instance the British collective dose per 10^6 inhabitants is six times lower than the French one. However three different factors may help to explain those discrepancies. The first one is the number of examinations carried out per 1000 people in each country (450 in Great Britain (Hughes and Roberts 1984), 665 in Italy (Padovani et al. 1987), 825 in France and 977 in Japan (UN82)); the second one is the type of the radiological techniques used in performing the same type of examination (fluoroscopy is less frequently used, about 10 times less, in Great Britain than in Italy or in France (Contento et al. 1987)); finally the pathology which the radiologists are seeking may have an impact on the collective exposure (for instance barium meal exams which are quite often carried out in Japan (International Agency For Research on Cancer 1982).

The Genetically Significant Dose (GSD)

The GSD is an index of the presumed genetic impact of radiation exposure on the whole population. It has been defined by UNSCEAR as "... the dose which, if received by every member of the population would be expected to produce the same total genetic injury to the population as do the actual doses received by the various individuals". In fact, many of the x-rayed individuals may have life and child expectancies quite different from the general population because of the effect of their medical condition. Due to a lack of specific data on this subject, it has been assumed that persons who undergo radiological examinations have the same future child expectancy as the general population.

The previous results concerning both frequencies and gonadal doses associated with each examination type have then been combined with child expectancy of the patients to obtain the GSD. The total GSD to the population of France due to the

diagnostic radiology examinations in 1982 is estimated to be 295 µSv. The male and female contribution to the GSD are 30.2% and 69.8%, respectively. Figure 3 shows to which extent the various examination types contribute to the total GSD.

It can be seen that the main contributors to the GSD are examinations of the urinary system and pelvis which acount almost 60% of the total GSD. The following table 10 gives the breakdown of the total GSD for each sex as a function of the radiological technique used. Overall, fluoroscopy accounts for only 10%, while radiographic examinations contribute 90% of the GSD. It may be pointed out that more than 50% of the GSD is due to the exposure of the less than 30 years old female population; while the irradiation of the less than 1 year old children represents 16% of the total GSD. Comparison of radiological protection practices in France with those of some other industrialized countries on the basis of the GSD values is showed in Figure 4. It appears that the French GSD is similar to other developed nations. It is also clear from these data that the GSD can vary between countries by a factor 3 or more.

CONCLUSION

The intention of this paper has been to highlight the major results of a national survey carried out in France in 1982 on the doses received by patient undergoing diagnostic x-ray examinations. The main conclusions of this study are the following :

- As far as the Genetically Significant Dose is concerned, the figure obtained from the survey represents approximately 14% of the total GSD from natural background.
- Concerning the ICRP "remainder organs" their contribution to the effective dose equivalent associated with each examination category must be stressed. In particular, in almost 60% of the examinations considered, doses received by these organs represent more than 40% of the effective dose equivalent.
- Over 80% of the routine examinations yearly carried out in France have effective dose equivalents that are more than the average per caput annual dose of 2 mSv due to the natural background radiation in France.
- Estimate of the collective effective dose equivalent associated to the radiological

practice is 86,000 person-sievert i.e. an individual effective dose equivalent of 1.58 mSv per year (1.48 for females and 1.70 for males).

- Finally, there have been few comprehensive publications of organ dose data for diagnostic radiological procedures, which probably reflect the difficulties of achieving suitable dose estimates for many organs. Comparison of our organ dose data with results from similar surveys indeed indicates large discrepancies for certain organs and examinations, which must be due at least in part to the differences in dosimetric technique used. Although higher levels of patient exposure have been reported for France, without comparison of the image quality as well as the patient doses, it is difficult to verify whether optimal conditions have been applied in other countries. The introduction of quality assurance programs in diagnostic radiology, which is being encouraged in Europe by the Commission of the European Communities, might certainly help to establish and maintain optimal procedures in this field.

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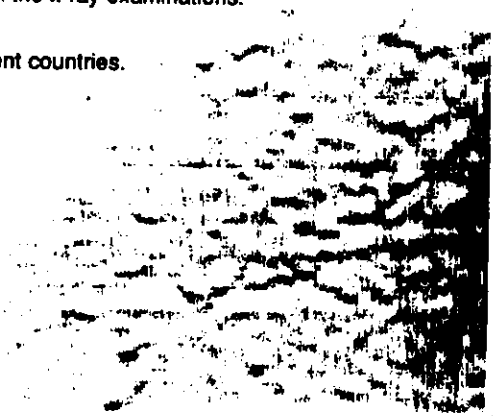

Table 1. Data base and response rates of the CEPN national survey (France 1982).

	PUBLIC HOSPITAL	PRIVATE CLINICS	PRIVATE OFFICES	TOTAL
x-ray Dept. *	1,478	1,047	2,433	4,958
Sampled x ray Dept. (1st phase)	157	81	199	437
Mean Sample Rate (%)	10.6	7.7	8.2	8.8
Actual number of x ray Dept. participating (1st phase)	137	76	173	386
Mean Response Rate (%) (1st phase)	87.3	93.8	86.9	88.3
x-ray sets installed in the participating Dept.	787	215	310	1,372
Sampled x ray sets (2nd) phase	241	101	207	549
Response Rate (%) (2nd) phase	74	59.4	61.6	66.8

* Excluding dental radiology, mass chest screening, Ministry of Defense hospitals, independent fluoroscopy units, C.T. scanners and nuclear medicine.

Table 2. Selection of 37 combinations of physical and anatomical parameters for dose measurements

EQUIVALENT FILM SURFACE CATEGORY / CENTERING POINT	400 cm²	600 to 800 cm²	1,200 cm²	1,600 cm²
ILIAC CREST		A/P kVp: 65 mA: 300 s : 0.3		A/P kVp: 70 mA: 300 s : 0.5 LAT kVp: 70 mA: 300 s : 0.3 OBL - A/P kVp: 70 mA: 300 s : 0.4
HEAD		A/P kVp: 75 mA: 300 s : 0.4 P/A kVp: 75 mA: 300 s : 0.3 LAT kVp: 80 mA: 300 s : 0.3 OBL - A/P kVp: 80 mA: 300 s : 0.4		
XYPHOID BONE		A/P kVp: 60 mA: 200 s : 0.3 LAT kVp: 70 mA: 250 s : 0.25 OBL - A/P kVp: 65 mA: 200 s : 0.3	A/P kVp: 60 mA: 300 s : 0.25	
CHEST			A/P kVp: 110 mA: 300 s : 0.02 LAT kVp: 110 mA: 300 s : 0.06 OBL kVp: 110 mA: 300 s : 0.06	A/P kVp: 110 mA: 525 s : 0.01 P/A kVp: 110 mA: 400 s : 0.01 LAT kVp: 120 mA: 300 s : 0.04 OBL kVp: 120 mA: 300 s : 0.04
PELVIS		OBL - A/P kVp: 65 mA: 300 s : 0.4	A/P kVp: 65 mA: 600 s : 0.16 LAT kVp: 65 mA: 300 s : 0.3 OBL - A/P kVp: 65 mA: 300 s : 0.3	
PUBIS		A/P kVp: 60 mA: 300 s : 0.3 LAT kVp: 80 mA: 300 s : 1 OBL - A/P kVp: 80 mA: 300 s : 0.6	A/P kVp: 110 mA: 300 s : 0.08	
CERVICAL SPINE	A/P kVp: 60 mA: 350 s : 0.17 P/A kVp: 60 mA: 300 s : 0.2 LAT kVp: 60 mA: 300 s : 0.2 OBL - A/P kVp: 60 mA: 300 s : 0.2	A/P kVp: 60 mA: 350 s : 0.17 LAT kVp: 80 mA: 300 s : 0.2 OBL - A/P kVp: 80 mA: 300 s : 0.2		
LUMBAR SPINE		A/P kVp: 70 mA: 900 s : 0.1 LAT kVp: 70 mA: 300 s : 1 OBL kVp: 70 mA: 300 s : 0.9		

Table 3. Comparative organ dose data between CEPN and NRPB (JO86)

ORGANS	PROJECTIONS	ANATOMICAL LANDMARK		FILM SIZE		CONVERSION FACTOR *		RATIO
		NRPB	CEPN	NRPB	CEPN	NRPB (1)	CEPN (2)	(1)/(2)
OVARIES	LATERAL	ABDOMEN	ILIAC CREST	36x43	36x43	0.04	0.057	0.7
	A/P	ABDOMEN	ILIAC CREST	36x43	36x43	0.15	0.08	1.81
	A/P	PELVIS	ILIAC CREST	36x43	30x40	0.116	0.053	2.18
	LATERAL	PUBIS	PUBIS	36x43	24x30	0.056	0.054	1.04
	A/P	PUBIS	PUBIS	30x40	30x40	0.26	0.23	1.13
	LATERAL	LUMBAR SPINE	LUMBAR SPINE	30x40	24x30	0.019	0.013	1.46
LUNGS	A/P	CHEST	XYPHOID BONE	36x43	24x30	0.23	0.2	1.15
	A/P	CHEST	CHEST	36x43	35x35	0.39	0.41	0.95
	LATERAL	CHEST	CHEST	36x43	35x35	0.21	0.3	0.7
	P/A	CHEST	CHEST	36x43	36x43	0.46	0.32	1.44
	A/P	CHEST	CHEST	36x43	36x43	0.39	0.31	1.26
	LATERAL	CHEST	CHEST	36x43	36x43	0.25	0.28	0.89
	A/P	LUMBAR SPINE	LUMBAR SPINE	30x40	24x30	0.013	0.01	1.3
HEAD	LATERAL	HEAD	CERVICAL SPINE	24x30	18x24	0.029	0.016	1.81
	A/P	HEAD	CERVICAL SPINE	24x30	24x30	0.03	0.018	1.67
	A/P	HEAD	HEAD	24x30	24x30	0.05	0.035	1.43

* Expressed as absorbed dose in the organ relative to the entrance skin dose.

Table 4. Breakdown of x-ray examinations (sample and total population) (France 1982)

EXAMINATIONS	OBSERVED NUMBER	ANNUAL ESTIMATED NUMBER (10^6)	%
CERVICAL SPINE	396	1.26	2.8
THORACIC SPINE	301	0.95	2.1
LUMBAR SPINE	643	1.84	4.1
SACRO-LUMBAR SPINE	226	0.69	1.5
PELVIS-HIP	919	3.39	7.5
ABDOMEN	422	1.59	3.5
IV UROGRAPHY	797	1.97	4.3
HYSTEROGRAPHY	62	0.18	0.4
CHOLECYSTOGRAPHY	266	0.67	1.5
SKULL	1076	4.02	8.9
BARIUM ENEMA	375	0.84	1.9
BARIUM MEAL	458	1.12	2.5
THORAX	3537	15.48	34.1
LIMBS (INFERIOR & SUPERIOR)	2543	10.04	22.1
MAMMOGRAPHY	150	0.26	0.6
CEREBRAL ANGIOGRAPHY	61	0.14	0.3
THORACIC ANGIOGRAPHY	63	0.13	0.3
ABDOMINAL ANGIOGRAPHY	37	0.07	0.2
INFERIOR LIMBS ANGIOGRAPHY	13	0.03	<0.1
PHLEBOGRAPHY	64	0.15	0.3
OBSTETRICAL ABDOMEN	125	0.32	0.7
PYELOGRAPHY	26	0.06	0.1
TOTAL	12591	45.35	100

Table 5. Organ doses by x-ray examination category (mSv).

EXAMINATIONS	GON	BRE*	RBM	LUN	THY	BON	REM	EFF
CERVICAL SPINE	0.14	0.01	0.43	0.82	10.37	3.01	2.56	1.35
THORACIC SPINE	0.21	9.98	1.45	1.34	0.94	3.47	3.21	2.24
LUMBAR SPINE	1.32	0.13	1.41	3.21	0.29	4.09	12.42	4.72
LUMBO-SACRAL SPINE	5.01	0.04	2.88	1.79	0.07	3.33	9.55	4.73
PELVIS-HIP	1.28	0.03	0.81	1.17	0.01	1.02	3.41	1.59
ABDOMEN	0.99	0.05	0.74	2.67	0.03	2.35	6.16	2.56
IV UROGRAPHY	3.92	0.27	2.99	11.67	0.21	8.82	25.53	10.42
HYSTEROGRAPHY	3.77	0.03	3.98	0.59	0.06	2.47	11.38	4.78
CHOLECYSTOGRAPHY	1.18	0.25	2.63	0.62	0.08	5.19	21.91	7.21
SKULL	0.03	0.01	0.61	0.35	5.66	3.56	3.29	1.35
BARIUM ENEMA	4.95	0.13	4.14	10.79	0.11	7.56	22.72	9.96
BARIUM MEAL	0.98	36.43	3.99	5.25	7.06	9.32	8.82	6.73
THORAX	0.03	0.16	0.22	0.64	0.42	0.44	0.44	0.28
CEREBRAL ANGIOGRAPHY	2.14	0.07	2.84	10.98	159.32	19.41	16.54	12.33
THORACIC ANGIOGRAPHY	1.74	10.01	2.14	13.49	19.94	4.26	5.27	5.01
ABDOMINAL ANGIOGRAPHY	4.89	0.52	4.81	11.03	0.75	33.45	54.07	20.24
INFERIOR LIMBS ANGIOGRAPHY	4.32	0.08	2.73	6.05	0.08	9.61	24.05	9.88
PHLEBOGRAPHY	4.49	0.19	2.71	6.16	0.51	15.29	28.11	11.11
OBSTETRICAL ABDOMEN	2.11	0.03	1.88	0.95	0.06	1.71	6.34	2.83
PYELOGRAPHY	1.83	0.09	4.53	0.55	0.08	6.13	15.81	5.91

* For female patients only.

GON : Gonades; BRE : Breast; RBM : Red Bone Marrow; LUN : Lung; THY : Thyroid; BON : Bone Surface; REM : Remainder Organs; EFF : Effective Dose Equivalent.

Table 6. Mean number of radiographs and fluoroscopy screening time by examinat category.

EXAMINATIONS	MEAN NUMBER OF FILMS	FLUOROSCOPY SCREENING TIME (s)
CERVICAL SPINE	3.7	53
THORACIC SPINE	4.3	33
LUMBAR SPINE	4.8	47
SACRO-LUMBAR SPINE	4.8	82
PELVIS-HIP	2.2	26
ABDOMEN	2.4	34
IVU	10.7	83
HYSTEROGRAPHY	4.9	96
CHOLECYSTOGRAPHY	5.7	73
SKULL	3.2	29
BARIUM ENEMA	9.5	187
BARIUM MEAL	9.5	267
THORAX	1.5	17
CEREBRAL ANGIOGRAPHY	46	482
THORACIC ANGIOGRAPHY	24.2	455
ABDOMINAL ANGIOGRAPHY	37.7	302
INFERIOR LIMBS ANGIOGRAPHY	14.3	78
PHLEBOGRAPHY	10.1	182
OBSTETRICAL ABDOMEN	3.4	53
PYELOGRAPHY	5.2	75

Table 7. Collective Effective Dose Equivalent by examination category (France 1982).

EXAMINATIONS	COLLECTIVE EFFECTIVE DOSE EQUIVALENT (person-sievert)	FLUOROSCOPY PERCENTAGE (%)
CERVICAL SPINE	1,680	18
THORACIC SPINE	2,100	16.5
LUMBAR SPINE	8,580	13
SACRO-LUMBAR SPINE	3,400	7
PELVIS-HIP	5,350	3
ABDOMEN	4,120	6.5
IV UROGRAPHY	20,580	11.5
HYSTEROGRAPHY	810	17
CHOLECYSTOGRAPHY	4,860	34.5
SKULL	4,990	10
BARIUM ENEMA	8,210	21.5
BARIUM MEAL	7,460	31.5
THORAX	4,110	3
CEREBRAL ANGIOGRAPHY	1,760	15
THORACIC ANGIOGRAPHY	680	70.5
ABDOMINAL ANGIOGRAPHY	5,590	34
INFERIOR LIMBS ANGIOGRAPHY	260	15
PHLEBOGRAPHY	940	37
OBSTETRICAL ABDOMEN	930	8
PYELOGRAPHY	370	24

Table 8. Comparison of the effective collective dose equivalent (person-sievert per 10^6 inhabitants).

FRANCE (1982)	G. B. (1983)	JAPAN (1979)	ITALY (1983)	POLAND (1976)	SWEDEN (1977)
1,580	220	1,314	848	511	452

Table 9. Breakdown of the total GSD by age and sex as a function of the radiological technique used. (μSv)

	RADIOGRAPHY			FLUOROSCOPY			TOTAL	
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	GSD	%
CERVICAL SPINE	0.7	0.3	1.0	0.1	0.3	0.4	1.4	0.5
THORACIC SPINE	0.8	6.2	7.0	0.1	0.2	0.3	7.3	2.5
LUMBAR SPINE	2.4	10.4	12.8	1.1	0.8	1.9	14.7	5.0
SACRO-LUMBAR SPINE	1.0	3.1	4.1	2.0	0.9	2.9	7.0	2.4
PELVIS-HIP	32.0	51.0	83.0	0.5	0.7	1.2	84.2	28.5
ABDOMEN	5.0	13.0	18.0	0.1	0.2	0.3	18.3	6.2
IV UROGRAPHY	17.0	67.0	84.0	2.5	1.5	4.0	88.0	29.8
HYSTEROGRAPHY	-	2.0	2.0	-	0.2	0.2	2.2	0.7
CHOLECYSTOGRAPHY	0.9	3.0	3.9	1.1	0.4	1.5	5.4	1.8
SKULL	0	0	0	0.5	0.9	1.4	1.4	0.5
BARIUM ENEMA	3.8	10.4	14.0	3.7	0.9	4.6	18.8	6.4
BARIUM MEAL	3.9	9.2	13.1	1.6	1.3	2.9	16.0	5.4
THORAX	2.8	1.8	4.6	0.2	0.4	0.6	5.2	1.8
CEREBRAL ANGIOGRAPHY	0.4	0.6	1.0	0.1	0.4	0.5	1.5	0.5
THORACIC ANGIOGRAPHY	0	0.1	0.1	1.5	2.1	3.6	3.7	1.3
ABDOMINAL ANGIOGRAPHY	0.8	0.9	1.7	0.9	0.4	1.3	3.0	1.0
INFERIOR LIMBS ANGIOGR.	0	0	0	0	0	0	0	0
PHLEBOGRAPHY	0.3	1.3	1.6	0	0	0	1.6	0.5
OBSTETRICAL ABDOMEN	-	12.8	12.8	-	1.1	1.1	13.9	4.7
PYELOGRAPHY	0.8	0.6	1.4	0.8	0.6	1.4	1.5	0.5
TOTAL	72.6	193.1	265.7	16.6	12.7	29.3	295	100

Fig. 1 Annual frequency of diagnostic radiology exams by age and sex per 10(patients of each age class (France 1982)

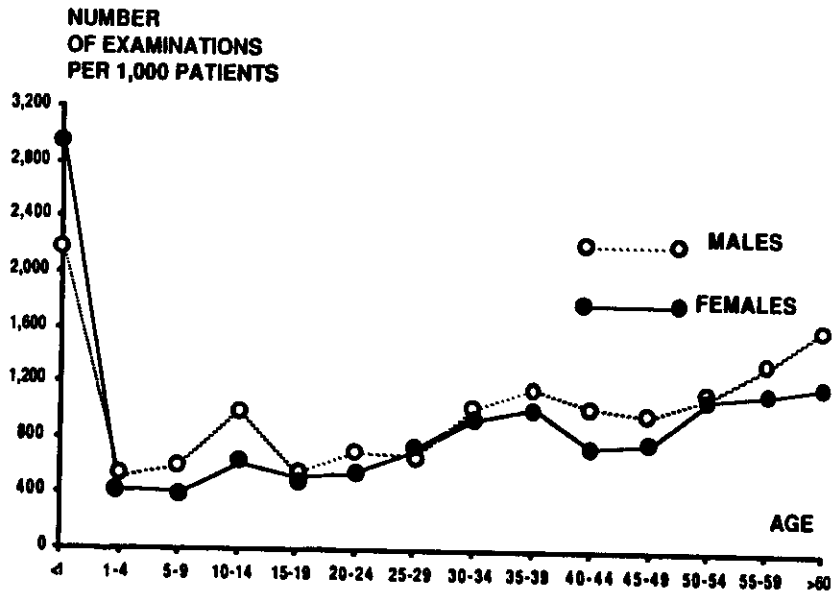

Fig. 2 Mean effective dose equivalent values for each examination type. (France 1982)

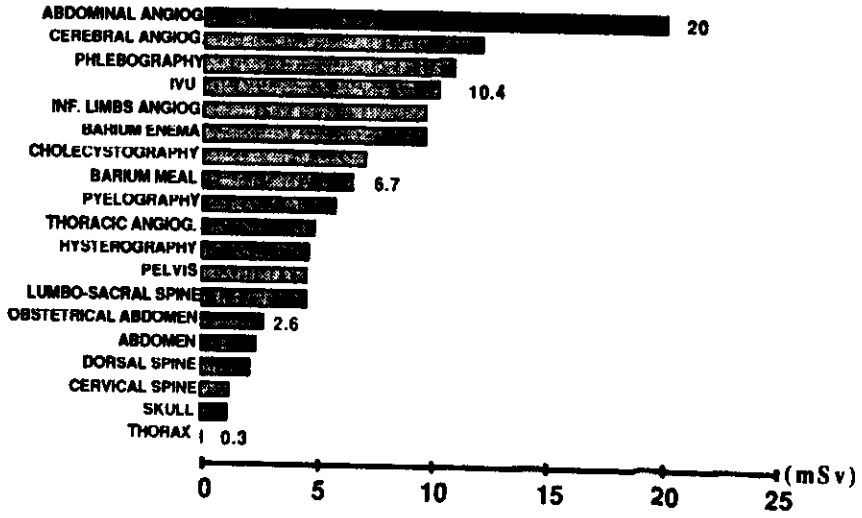

Fig. 3 Relative contribution to the GSD from the x-ray examinations.

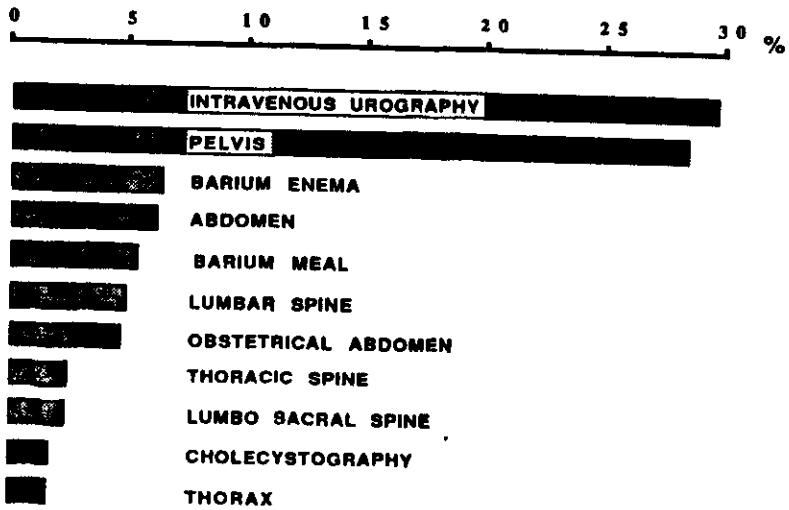

Fig . 4 Genetically Significant Dose in different countries.