ON THE EXTENT OF X-RAY EXAMINATIONS IN FINLAND

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Abstract—The annual genetically significant dose of the Finnish population from 2,716,900 X-ray examinations and 80,000 dental exposures carried out in 1963 has been calculated to be 16.8 mrem. The male, female, and foetal contributions to this dose were respectively 4.2 mrem, 8.7 mrem, and 3.9 mrem. The high female contribution observed here is largely due to pelvimetry, hysterosalpingography, obstetrical abdomen, and lower gastrointestinal tract procedures, for which the male contribution only amounts to 5.6% although these examinations account for 42.5% of the total genetic dose. Scrutiny of the contributions of various examinations to the total genetic dose reveals that abdomen and lower gastrointestinal tract account for 26.1% of this dose. Chest surveys cause 6.9% of the genetic dose. This remarkably high proportion is largely due to the fact that approximately 11% of the Finnish population undergoes this survey annually. Although the frequency of mass miniature radiography was very high, about three persons out of ten undergoing this survey annually, its contribution to the genetic dose was found to be not more than 0.9%.

INTRODUCTION

Investigations carried out in the late 1950's in different countries showed that the diagnostic use of X-rays is responsible for the major human-induced exposures of populations. The aim of this work [1] was to find out the radiation burden of the Finnish population due to diagnostic roentgen exposure. This burden is generally expressed in the form of the annual genetically significant dose. This dose formulated by the ICRP/ICRU Joint Study Group [2] is the average of individual gonad doses, each weighted for the expected number of children conceived subsequent to exposure. The fraction of annual genetically significant dose for both sexes caused by class j exposure in age class k can be expressed, for the present purpose, as follows:

$$D^*_{jk} = \frac{N^*_{jk}}{N}\frac{w^*_{jk}}{w}d^*_{jk}\ .$$

where N^*_{jk} = annual number of individuals of age class k, subjected to class j.

N = the total number of individuals in the population,

w^*_{jk} = future number of children expected by an exposed individual of age class k subsequent to a class j exposure,

w = mean child expectancy of the population,

d^*_{jk} = gonad dose per class j exposure of an individual of age class k, and

the asterisk denotes the sex. The classification of examination followed that given in United Nations report No. 17 (A3838) [3] and has been reproduced in Table 1. During analysis of the data some slight inaccuracies in the classification list became apparent. Especially the lumbosacral, lumbar spine, and dorsal spine had been mutually confused as had also the chest and thorax. However, the classification was satisfactory in general.

MATERIAL AND METHODS

Data collection

All X-ray examinations carried out during one month in 1964 in all medical institutions, hospitals and private physician's offices were recorded according to object of examination, age,

Table 1. Gonad Doses in Different Age and Examination Classes (mrem)

	Males		Females	
	< 15 yr	⩾ 15 yr	< 15 yr	⩾ 15 yr
1. Hip and femur (upper third)	90	590	48	20
2. Femur (middle and lower third)	11	92	8	13
3. Pelvic region	139	278	20	80
4. Lumbosacral	7	145	84	260
5. Lumbar spine	191	199	120	727
6. Dorsal spine	108	154	76	113
7. Urography	44	322	468	273
8. Retrograde pyelography	111	153	216	1247
9. Urethrocystography	259	1346	850	850
10. Pelvimetry			520	520
11. Hysterosalpingography			760	760
12. Obstetrical abdomen				113
13. Abdomen (pancreas, spleen, liver)	42	44	720	787
14. Lower gastrointestinal tract (small intestine, appendix, colon)	650	102	1735	1140
15. Upper gastrointestinal tract (pharnyx, oesophagus)	7	25	102	93
16. Cholecystography	7	39	136	136
17. Chest (heart, aorta, lungs)	22	13	8	20
18. Thorax (sternum, ribs, shoulder, clavicle)	40	16	12	20
19. Upper extremities	9	15	8	13
20. Lower leg and foot	16	29	32	13
21. Head and cervical spine	19	16	4	27
22. Fluoroscopy	7	18	56	93
23. Mass miniature radiography	0.2	0.2	0.2	0.9
24. Dental	0.25	0.25	0.05	0.05

and sex. Furthermore, the best possible estimate was requested of the number of examinations carried out in 1963. The total number of mass miniature radiographies (1,205,000) was obtained from the Annual Report of Activities of the Finnish National Anti-Tuberculosis Association,[4] and the number of dental exposures (80,000) was estimated on the basis of the film consumption.

The uncertainty in estimation of the genetic dose is probably mostly due to the uncertainties involved in the measurement of gonad doses. These may be greatly different in different hospitals. In order to gain an idea of this variation, gonad doses were measured in different hospitals. About 2100 fluoro-glass dosimeters were dispatched to 124 hospitals chosen in advance, to be used for measurements of the gonad exposure received by patients undergoing roentgen examination.

Requisite data concerning the structure and birth rates of the population were derived from the *Statistical Yearbook of Finland*[5] and from the archives of the Finnish Central Statistical Office. The number of the Finnish population at the time of the study was about 4,523,300.

Relative Frequency of Examinations

During the control period, 143,320 examinations classified according to object of examination, age and sex were recorded. The resultant chart was utilized in determining the distribution of 2,716,900 examinations carried out in 1963, with respect to various age and examination groups. As regards the distribution of dental examinations, the assumption was made that the share of females was 60% and that of males 40%. The age classes chosen were: under 15 years, 15–19 years, 20–30 years, 31–44 years, and over 44 years. The relative number of examinations N^*_{jk}/N was calculated separately for both sexes and for different age groups.

Child Expectancy

From the birth rates and the probability of death as stated in the *Statistical Yearbook*, the mean child expectancy w was calculated to be 1.316. Assuming that the examination performed has no connection with the patient's child expectancy, the w^*_{jk}/w ratios were calculated for different age and examination classes.

As to foetal exposure, pelvimetry and obstetrical abdomen excluded, it was inferred, taking into account the number of live births, the mean pregnancy time and the number of fertile women, that 6% of the women examined were pregnant.

Gonad Doses

As mentioned before, fluoro-glass dosimeters were used for measurements of gonad doses. In some examination classes the sensitivity of the glass pieces was insufficient. In such instances ionization chamber measurements were performed. Glass pieces were used for measurement

Table 2. Annual Genetically Significant Doses (mrem)

Examination class	Males	Females	Foetal	Total	% of total
1	0.439	0.085	0.005	0.529	3.1
2	0.097	0.007	0.002	0.106	0.6
3	0.370	0.070	0.024	0.464	2.8
4	0.131	0.164	0.068	0.363	2.2
5	0.404	1.079	0.363	1.846	11.0
6	0.295	0.178	0.070	0.543	3.2
7	0.232	0.525	0.078	0.835	5.9
8	0.010	0.126	0.039	0.175	1.0
9	0.104	0.209	0.045	0.358	2.1
10		0.607	1.031	1.638	9.8
11		0.438	0.066	0.504	3.0
12		0.216	0.395	0.611	3.6
13	0.129	1.624	0.719	2.472	14.7
14	0.269	1.199	0.453	1.921	11.4
15	0.012	0.055	0.025	0.092	0.6
16	0.032	0.296	0.130	0.458	2.7
17	0.519	0.531	0.116	1.166	6.9
18	0.146	0.080	0.023	0.249	1.5
19	0.172	0.072	0.012	0.256	1.5
20	0.413	0.180	0.018	0.611	3.6
21	0.258	0.173	0.037	0.468	2.8
22	0.172	0.666	0.149	0.987	5.9
23	0.027	0.106	0.014	0.147	0.9
24	<0.002	<0.001	<0.001	0.003	0.01
Total	4.233	8.687	3.883	16.803	
%	25.2	51.7	23.1		

of skin doses on the testicles and on the back near the ovaries. These doses were used as such as gonad doses for men. In order to work out the female gonad doses from the skin exposures, each examination class was treated separately, employing phantom measurements and considering the position of the ovaries in relative to the primary radiation. In fixing the tissue absorption, the values of Trout *et al.*[6] were used in some cases.

Calibration of the glass pieces was accomplished by using an average kV value in each examination class and assuming the total filtration in all machines to be 2 mm of aluminium, in agreement with Finnish radiation protection regulations.

The gonad doses used in the calculations have been presented in Table 1. Only average doses have been given, although it should be noted that great deviations occur in every examination class.

CONCLUSIONS

The annual genetically significant dose received by the Finnish population from exposure to diagnostic X-rays is found to be 16.8 mrem. In Table 2 the composition of this dose is presented in greater detail. The male, female, and foetal contributions to the genetic dose were 4.2 mrem (25.2%), 8.7 mrem (51.7%), and 3.9 mrem (23.1%), respectively. The high female contribution observed here is largely due to pelvimetry, hysterosalpingography, obstetrical abdomen, abdomen, and gastrointestinal tract procedures, in respect of which the male contribution only amounts to 5.6% although these examinations account for 42.5% of the total genetic dose.

Scrutiny of the contributions of various examinations to the total genetic dose reveals that abdomen and lower gastrointestinal tract account for 26.1% of this dose. Chest surveys cause 6.9% of the genetic dose. This remarkably high proportion is largely due to the fact that approximately 11% of the Finnish population undergoes this survey annually. Although the annual frequency of mass miniature radiography was very high, about three persons out of ten, the contribution of this survey to the genetic dose was found to be not more than 0.9%.

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