PATIENT EXPOSURES IN SWEDISH DIAGNOSTIC RADIOLOGY*

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1. INTRODUCTION

Reviews (1) or collections (2,3) of articles dealing with medical exposure of patients indicate a wealth of reports in the area. Why should you care to read another one?

A) You are interested in the methods to be used for assessing population exposures. So were we. In particular we paid much attention to the sampling inaccuracy in the mean dose to a small group of patients.

B) You wish to reduce the patient dose. We discuss here realistically possible reductions, and the role of collective radiation risk in assigning priorities for such reductions.

C) You want to know the radiation risk to Swedish patients. Probably not, unless you are Swedish (We are.). But you might be interested in a very broad survey, comparing genetic and somatic doses, encompassing all important types of examinations and a large number of hospitals. If you are of a speculative kind, you might conjecture that some trends may be applicable to your own country.

D) You dream of a simple way of monitoring radiation risk to patients. Sorry, there probably is no such goodie. But we discuss why not and suggest a simple monitoring system indicating long-term cancer risk within a factor of 3 up or down at all but a few types of examinations.

May we have your attention? We then regret that the resticed format prohibits presentation of most of the details. A detailed preliminary report is available (4), giving several references to related studies.

2. WHAT IS THE DOSE TO A SINGLE PATIENT ?

The actual dose to a patient in an x-ray examination depends not only on physical factors such as radiation quality or screen-film sensitivity, but also on factors related to the patient such as his weight, and to the personnel such as the experience of the doctor performing a fluoroscopy. It is extremely difficult to assess the total patient dose unless one resorts to direct measurements on series of patients. We measured doses to about 1000 Swedish patients in 13 hospitals, and additionally several photofluorographic and dental installations. The measurements comprised radiation quality, exposure-area product and doses to a few parts of the body where dosimeters could be placed. Calculations yielded energy imparted as well as doses to the thyroid, mammae, lungs, bone marrow, ovaries and testes. These calculations are based on assumptions about projections, field sizes, patient positioning etc which may be strongly in error as far as the individual patient is concerned. The energy imparted should be subject to the least uncertainty, about ± 15 %. The mean dose to the organ of an individual patient could in many cases be off by more than a factor of two.

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3. WHAT IS THE MEAN DOSE TO A GROUP OF PATIENTS?

When the mean organ dose to a group of patients is assessed the sampling errors tend to be very large, since there are considerable management difficulties in extending the measurements to more than 10 or 20 patients, and the standard deviation of individual organ doses is sometimes above 100 %.

We concluded that we were interested in two types of mean doses to a group of patients. One is the true arithmetic mean which describes the actual irradiation of the group and is relevant e. g. to risk assessment.

The other is the "typical" patient dose which may be more useful in comparative studies. We found that the use of the arithmetic mean of the two middle quartiles as a "typical" dose facilitated significantly, in most cases, the comparison of doses between two groups. The middle quartile mean was closely approximated by the geometric mean. Some care in its employment is required, however, since the arithmetic mean was up to 4 times above the middle quartile mean and proving differences less than a factor of 2 requires considerable effort.

4. POSSIBLE REDUCTION OF PATIENT DOSES

We have compared the arithmetic mean doses to groups of patients examined under different conditions, e. g. at different hospitals (Table 1).

Examination	Ratio of "highest" and "lowest group				
	Energy imparted	Mean absorbed dose to Thyroid	Mammae	Ovaries	Testes
Hip					3.7
Pelvis	3.0				10
Lumbar spine	3.5		6.2	4.3	26
Urography			14		17
Stomach	5.1	8.2	5.0	14	
Colon		4.0		3.5	13
Hysterosalpingography	4.6			3.2	
Gall bladder			11	4.3	>7
Dorsal spine			3.4		
Lung (full size)		6.6			
Lung(photofluorography)	6.0				
Lung plus heart			3.1		
Cervical spine		4.5			
Dental intraoral	23	7.5		>60	>60

TABLE 1. Highest observed ratios of the radiation load to patient groups examined under different conditions e. g. different hospitals or personnel. All patients were not studied for all types of radiation doses. Only ratios of 3 or above are entered.

In principle, it should in most cases be possible for all groups to attain the lowest dose observed for any group. There is little probability that this dose is too low to give sufficient information, since almost all of the radiology is supervised by well trained radiological specialists. Thus it can be safely concluded that there is much room for dose reduction. Often the overall radiation level can be reduced, as indicated by the energy

imparted. Frequently, careful attention to shielding can significantly reduce the dose to various organs involved. Using already available techniques, the energy imparted, thyroid dose, mammary dose and ovary dose to the Swedish population could probably be reduced to about one-half, and the testes dose to less than one-third of the present average level. The collective risk can be used in assigning priorities for this reduction. We have, for instance, given much weight to dose reductions in photofluorography which was very dominant regarding cancer risk.

5. WHAT IS THE RADIATION RISK TO THE SWEDISH POPULATION?

We have estimated the collective doses to the Swedish population from all types of medical and dental examinations in 1974.

A very crude risk estimate (Table 2) based on recent data (1.5) indicates a risk of about 10 radiation induced cancer deaths annually per million inhabitants, and about the same number of individuals born with serious genetically related injuries. (The latter could be a significant overstimate (6).) This would represent an addition of less than 1 per cent to the normal risks.

Organ	Mean annual collective dose per individual, mGy	Assumed number of injuries per million man-gray	Annual harm committment, injuries per million individuals
Thyroid	0.75	1000	0.75
Mammae	0.54	6000	3.2
Lungs	0.64	2000	1.3
Bone marrow	0.92	3000	2.8
Ovaries	0.68		
Testes	0.65		
Whole body	1.00	15000	15
Genetically significant dose	0.4-0.8	15000	6-12

TABLE 2. Estimates of collective dose and risk to the Swedish population from all medical exposures 1974. The injuries referred to are the total number of induced cancers which lead to death, and in the case of genetic injury the total number of future children born with serious genetically related injuries.

A cancer risk estimate along the same lines indicates the following risk of cancer death per million examinations: 10 to 50 at some less frequent examinations such as cardiovascular angiography and further at the following examinations in order of increasing risk: urethrocystography, small intestine, head, stomach, lumbar spine, pelvimetry, lung photofluorography, colon, retrograde pyelography, urography, cerebral angiography and dorsal spine; below 0.1 at single dental exposures and examinations involving femur, lower legs and arms; 1 to 10 at all others. No examinations yielded a risk estimate between 0.1 and 1.

6. MONITORING RADIATION RISK TO PATIENTS

As we have stressed before, any estimates of radiation doses and risks to patients not being based on direct measurements are subject to many errors. The perspective of devoting man-years to patient measurements is, however, discouraging. Can simplified relations relax the measurement burden?

We discuss below two possibilities. For completeness, we also wish to mention without any comments, that the overall mean value of energy imparted to patients per unit film area was 0.39 J/m^2, excluding dental, photofluorographic and image intensifier camera film.

6.1. Exposure-area product and bone marrow dose.

The active bone marrow is distributed over almost the whole body. In a crude approximation it is uniformly distributed over a certain projected body area, and its mean dose can be given as a certain fraction of the entrance dose. The mean marrow dose would then be proportional to the exposure-area product. This approximation seems to bear little relation to reality. Surprisingly enough, detailed calculations at lung exposures and dental exposures yielded a marrow dose within 20 % of that given by the approximation, and cruder estimates indicated an approximation within a factor of 2 at all types of examinations except those involving the lumbar spine, stomach or gall bladder as well as urographies. Crude estimates indicated that at lumbar spine examinations one-half of the constant of proportionality applicable to most examination types would apply, and at urographies one-fifth.

6.2. Energy imparted and cancer risk.

The cancer risk calculated using the assumptions in Table 2 was for each of the various types of examination compared with the energy imparted. (Alternatively, the exposure-area product could be used yielding about the same degree of approximation.)

Examinations of the extremities again seemed to bear relatively little radiation risk. All other types of examinations yielded a risk of 0.0001 cancer deaths per joule, within about a factor of 3 up or down. Any closer tentative risk estimate is hardly justified, bearing in mind the uncertainty of the basic estimates of cancer risk per unit absorbed dose.

In contrast, the ratio of gonad dose and energy imparted extended over a range of 3 decades, as compared to the 1 decade range of the cancer risk ratio. The energy imparted or exposure-area product are thus poor indicators of genetic risk.

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