Acta orthop. scand. 48, 138–142, 1977

TOTAL RADIATION DOSAGE FROM X-RAY EXAMINATIONS IN RHEUMATOID ARTHRITIS AND OTHER CHRONIC SKELETAL DISEASES

A Study of Two Cases

HALLDÓR BALDURSSON & MONICA GUSTAFSSON

Departments of Orthopaedic Surgery and Radiation Physics, The University Hospital, Lund, Sweden.

Young patients with rheumatoid arthritis and other chronic diseases of the skeleton are increasingly being operated on with replacement of major joints. The great number of associated X-ray examinations performed on these patients has caused some anxiety amongst orthopaedic surgeons. Two patients with juvenile rheumatoid arthritis have been studied. An attempt was made to calculate the total radiation dose to bone marrow and gonads. For lack of recommendations for the maximum permissible radiation dose to patients, the dose calculated has been compared with the maximum permissible dose of radiation workers, and with the dose limit for non-occupational irradiation of individuals. The yearly absorbed dose in these two patients is much lower than the maximum permissible dose of radiation workers and only slightly higher than the dose limit for non-occupational exposure of individuals.

Key words: bone diseases; chronic disease; radiation dosage; rheumatoid arthritis

Accepted 13.i.77

Many patients suffer from chronic skeletal disease with an uncertain prognosis as regards cure, although the disease may not greatly shorten the expected life span. Rheumatoid arthritis is a typical example of such a disease.

These patients often undergo repeated orthopaedic operations. Before being operated on, they are usually X-rayed several times in order to follow the pathological changes. Postoperative radiography is often necessary. After total hip or knee replacement, X-ray examinations must be done at intervals for a long time, in order to detect complications, such as infection, at an early stage. The intervals between X-ray examinations vary greatly from one hospital to another.

Some of these chronic diseases engaging the skeleton also cause pathological changes in organ systems other than the locomotor system. Examples of this are renal amyloidosis in rheumatoid arthritis and aortic insufficiency in ankylosing spondylitis.

There may also be adverse effects of the treatment of these diseases, e.g., gastric ulceration may result from administration of antiinflammatory drugs such as corticosteroids and salicylates.

Confinement to bed can predispose the patient to urinary infection and urinary stone formation. The diagnosis and treatment of these changes and complications usually necessitates further X-ray investigations.

Chronic skeletal disease often affects young people and children. These patients are at an early age subjected to a great number of radiological investigations. The chronic nature of their disease, and the prospect of continuing treatment and X-ray investigations of the same patient for many decades, makes knowledge of the accumulated radiation dose important. In addition to the risks of malignancy from radiation, attention has been drawn to the possibility of retarding skeletal growth by irradiation of the growth zones (International Commission on Radiological Protection 1969).

Table 1.

Patient no. 530202 ♀ R.A.	
Onset 1957 at the age of 4 years.	
Operations:	
Removal of kidney stone	1959
Adductor tenotomy	1962
Total hip replacement	1974
Osteotomy of tibia	1975
Patient no. 581002 ♂ R.A.	
Onset 1960 at the age of 1½ years.	
Operations:	
Synovectomy both wrists and several finger joints	1967
Resynovectomy one wrist and several finger joints	1968
Adductor tenotomy	1971
Synovectomy both elbows	1971
Synovectomy of knee	1973

PATIENTS

This study comprises calculations, based on published dose values, of the total radiation dose absorbed by two young patients with juvenile rheumatoid arthritis. They were chosen because of their chronic disease, their youth and the exceptionally high number of X-ray examinations. Both patients have undergone repeated operations (Table 1).

METHODS

Absorbed dose estimation

Radiation absorbed doses in patients from X-ray investigations are often reported. Apart from skin doses, gonad and bone marrow doses are often mentioned. However, we have not been able to find any publications dealing with the subject of this article, i.e., the accumulated radiation doses to patients with chronic skeletal disease.

Two papers by Hashizume et al. (1972 a, b) reporting gonad dose and mean bone marrow dose (local dose to bone marrow averaged over the whole active marrow) were made use of for our calculations. The estimated doses in these reports are based on phantom measurements and are given for one radiograph (or fluoroscopy procedure) in different types of examinations and for four different age groups. In this study, the ages of the patients at the time of the X-ray investigations and the number of radiographs are known. Therefore, Hashizume's data are suitable for our calculations. Registered gonad doses to men in our hospital (Gustafsson 1976) are in reasonably good agreement with the data of Hashizume et al. (1972 a, b).

Considering the number of radiographs kept and the age of the patient at the examinations we thus calculated the gonad dose and the mean bone marrow dose for each patient. The results are given in Tables 2 and 3.

The absorbed dose from fluoroscopy was estimated according to measurements in our hospital of the total absorbed energy (integral dose) to the patient from examinations of the gastrointestinal tract, showing that doses from fluoroscopy and radiography are about equal (Gustafsson 1975).

RESULTS

Estimating that one out of six radiographs taken is discarded because of bad quality or because it did not contribute to the making of a diagnosis, the total absorbed doses will be

Patient number	Mean bone marrow dose (rad)	Gonad dose (rad)
530202	9.3	12.0
581002	5.8	5.3

Table 2. Estimated mean bone marrow dose and gonad dose to patient no. 530202, ♀, from X-ray examinations performed during the period November 1957–October 1975. (—) means less than 10 mrad.

Examination	Number of examinations	Number of radiographs kept	Mean bone marrow dose (mrad)	Gonad dose (mrad)
Heart, lung	23	71	390	140
Cervical spine	8	50	430	—
Dorsal spine	5	19	700	—
Lumbar spine, lumbosacral joints	8	22	920	1460
Hip, pelvis	23	47	1040	2360
Knee, foot	18	74	220	220
Shoulder, arm, hand	10	40	250	—
Urinary tract	31	132	2480	4550
Stomach, abdomen, barium meal	7	36 + fluoroscopy	1140	1310
Others	5	17	150	—
Total	138	508 + fluoros copy	7720	10040

Table 3. Estimated mean bone marrow dose and gonad dose to patient no. 581002, ♂, from X-ray examinations performed during the period June 1965–May 1974. (—) means less than 10 mrad.

Examination	Number of examinations	Number of radiographs kept	Mean bone marrow dose (mrad)	Gonad dose (mrad)
Heart, lung	22	51	290	40
Cervical spine	8	54	460	—
Dorsal spine	2	6	280	—
Lumbar spine	3	12	500	240
Hip, pelvis	4	9	260	1170
Knee, foot	19	122	220	2130
Shoulder, arm, hand	25	121	820	—
Urinary tract	1	14	240	150
Stomach, abdomen	5	36 + fluoroscopy	1660	650
Others	3	9	70	—
Total	92	433 + fluoroscopy	4800	4380

These figures should only be regarded as rough estimates of the real absorbed doses. Recalculations were done from median values of gonad doses reviewed by United Nations Scientific Committee on the Effects of Atomic Radiation (1972) and from bone marrow dose estimations for the United Kingdom (Committee on Radiological Hazards to Patients 1966) and the Netherlands (Weber 1964). The greatest deviation found was a 70 per cent higher mean bone marrow dose calculated from the U.K. data for patient no. 530202. This difference is partly explained by the fact that the U.K. data are not specified for children.

From Table 2, for patient 530202, it can be seen that examinations of the urinary tract contribute about 45 per cent to the estimated gonad dose and about 32 per cent to the mean bone marrow dose, compared with 23 and 13 per cent, respectively, from hip and pelvis examinations. It is also evident that relatively few examinations of the gastrointestinal tract give a high percentage of the absorbed dose.

For patient 581002, stomach examinations make the dominating contribution, 35 per cent of the mean bone marrow dose. The high gonad dose figure in Table 3 for the knee and foot examinations could well be an overestimation, since no dose values were available for examinations of the knee joint.

We also estimated the highest locally absorbed dose in bone marrow. This was done in two ways: 1) by relating the mean bone marrow dose in Tables 2 and 3 to the distribution of active bone marrow in the body (according to Hashizume et al. 1972 b); 2) by using exposure factors and radiation output values according to the International Commission on Radiological Protection (1970) and percentage depth dose factors according to Trout et al. (1952). Method 2) gave a 25–50 per cent higher estimated absorbed dose than method 1).

In patient 530202, the lumbar spine received the highest dose, about 25 rad and in patient 581002 a maximum absorbed dose of 15 rad was estimated for the lower part of the dorsal spine and upper part of the lumbar spine.

Averaged over the period studied, patient 530202 has received about 0.5 rad per year mean bone marrow dose and 0.7 rad per year gonad dose, from X-ray examinations. Patient 581002 has received about 0.6 rad per year to bone marrow as well as gonads.

DISCUSSION

Radiological effects

The main reason for this study was to estimate the absorbed dose in these young patients from their frequent X-ray examinations. When calculating radiation doses in patients we always have the genetic and carcinogenic effects in mind. To calculate an expected risk for these patients of radiation induced cancer we would need dose figures also for breasts, lungs, thyroid and other organs and these data are not yet available.

Another factor of importance in irradiating children is the potential effect on growth when the growth zones receive high doses. The most frequently examined joint in each patient has had 30 to 40 radiographs which should not result in more than 10 rad to the growth zones and probably much less. The minimum stunting dose to children has been estimated to be well above 100 rad (International Commission on Radiological Protection, 1969).

Radiation dose from postoperative X-ray investigations

Another point of interest is how much is added to the total radiation doses by the postoperative X-ray examinations. Assuming that a patient has both hip joints and both knee joints replaced and there is a postoperative follow-up program with five X-ray examinations of each hip and five X-ray examinations of each knee, that would add about 0.5 rad to the mean bone marrow dose, about 1 rad to the female gonad dose and about 5 rad to the male gonad dose. The male gonad dose could be reduced considerably by using an appropriate gonad shield or by pulling the testes out of the radiation field.

Radiation dose comparison

ICRP has not made any recommendations for a maximum permissible radiation dose to patients from X-ray examinations. Instead it is stated that "the level should be as low as is consistent with obtaining the required diagnostic information". (International Commission on Radiological Protection, 1970).

The International Commission on Radiological Protection recommendations for exposure of individuals (International Commission on Radiological Protection, 1966) implies that the maximum permissible dose to radiation workers is 5 rad per year and that no individual should receive more than 0.5 rad per year non-occupationally. Excluded from these yearly doses are natural irradiation and irradiation of a person as a patient. These dose limits are set for planning purposes and at levels considered to result in acceptable risks for radiological effects.

The average yearly doses of 0.5–0.7 rad to gonads and bone marrow calculated for the two patients could also be compared with the mean absorbed dose from natural sources which is about 0.09 rad per year (United Nations Scientific Committee on the Effects of Atomic Radiation, 1972).

Follow-up X-ray investigations

When planning a follow-up program, for instance after total hip replacement, the frequency of the X-ray examinations must be determined. Various factors should be considered; not only the type of operation done and the complications that may arise but also the age of the patient and the total radiation dose. In a follow-up program for young patients it is especially important to minimize the absorbed dose from X-ray examinations. This is done by effective shielding of organs not being examined, by reducing the number of projections and by using the most sensitive X-ray recording system that gives the information required.

ACKNOWLEDGEMENTS

This study, which is part of a project concerning hip surgery in rheumatic diseases, was financially supported by grants from: Riksförbundet mot reumatism, Föreningen för bistånd åt vanföra i Skåne, and Signe och Reinhold Sunds stiftelse.

REFERENCES

Committee on Radiological Hazards to Patients (1966) Final report of the committee. Her Majesty's Stationery Office, London.

Gustafsson, M. (1976) Unpublished data.

Gustafsson, M. (1975) Integral absorbed doses in X-ray examinations of the gastrointestinal tract 1960 and 1974. Paper presented at the Third European Congress of the International Radiation Protection Association, Amsterdam.

Hashizume, T., Kato, Y., Maruyama, T., Kumamoto, Y., Shiragai, A. & Nishimura, A. (1972 a) Genetically significant dose from diagnostic medical X-ray investigations in Japan, 1969. *Hlth Physics* **23**, 827–843.

Hashizume, T., Kato, Y., Maruyama, T., Kumamoto, Y., Shiragai, A. & Nishimura, A. (1972 b) Population mean marrow dose and leukaemia significant dose from diagnostic medical X-ray investigations in Japan, 1969. *Hlth Physics* **23**, 845–853.

International Commission on Radiological Protection (1966) Publication 9: *Recommendations of the International Commission on Radiological Protection*. Pergamon Press, Oxford.

International Commission on Radiological Protection (1969) Publication 14: *Radiosensitivity and spatial distribution of dose*. Pergamon Press, Oxford.

International Commission on Radiological Protection (1970) Publication 16: *Protection of the patient in X-ray diagnosis*. Pergamon Press, Oxford.

Trout, E. D., Kelley, J. P. & Cathey, G. A. (1952) The use of filters to control radiation exposure to the patient in diagnostic roentgenology. *Amer. J. Roentgenol.* **67**, 946–963.

United Nations Scientific Committee of Effects of Atomic Radiation Report (1972) *Ionizing radiation: Levels and effects*. Vol. I.

Weber, J. (1964) Beenmergdosis tengefolge van de röntgendiagnostik. Thesis, Leiden.

Correspondence to: Dr. Halldór Baldursson, Ortopediska kliniken, Lasarettet, 221 85 Lund, Sweden.