Over-exposure Cases on the Extremities in Radiological Accidents

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ABSTRACT

In a decade, we have treated from medical and radiological viewpoints five males who were over-exposed to direct beam of X-ray on their extremities when they had handled X-ray analysis machine during research or maintenance. All workers except one had worn personal dosimeters on the chest, but not on fingers or wrists. The estimated absorbed dose of the epidermis of the skin performed by a reconstruction of events ranged from 15 to 300 Gy. The causes of accidents in all cases were mishandling of safety system of machine. Clinical syndrome of radiation burn of the skin appeared in all cases and these clinical signs were very useful indicators to estimate dose of each individual.

INTRODUCTION

One of the most important purposes of radiological protection is preventing the deterministic effects of radiation. However, there were some cases of radiation injuries, particularly the radiation burn on hands and faces, quite recently. In a decade, we have treated five male workers over-exposed to X-rays on their hands with radiological and medical cares (1,2,3). Detailed analysis of these accidental subjects from viewpoints of radiological protection is important to prevent further accidental cases in future.

SUMMARY OF INDIVIDUAL CASES INCLUDED IN THIS PAPER

The exposure conditions of each subject are shown in Table 1. Physical properties of irradiated radiation are shown in Table 2. All individuals are male engineers or students. Causes of over-exposure were misusage of safety system of X-ray analytical machine and shortage of sufficient knowledge and perception on radiation safety in workers themselves.

Table 1 Summary of over-exposure by X-ray analytical equipment

Subject	Occupation (age)	Time	Distance	Area	Dose
A	engineer (30)	5 sec	3 cm	50 cm^2	200 Gy
B	engineer (20)	2 sec	0	4 cm^2 x 2	300
C	student (22)	20-30 sec	6	4 cm^2 x 2	8
D	student (23)	100-150 sec	5	2 cm^2 x 3	30-300
E	engineer (20)	4-5 sec	10	20 cm^2	300

Table 2 Physical properties of exposed radiation from X-ray analytical equipment

Subject	Voltage	Current	Additional filter	Effective energy
A	50kV	20mA	-	10 keV
B	50	30	-	10
C	30	20	-	9
D	50	50	-	9
E	40	200	-	10

ESTIMATION OF ACCIDENTAL EXPOSED DOSE

Four cases were wearing personal dosimeters on the trunk when they were clearly exposed, but as irradiated areas were limited to only a part of the body, the dosimeters did not include exposed direct beam of X-rays. Therefore, their dosimeter recorded zero. One case, a college student, did not wear personal dosimeter because he was not registered as a radiation worker. In all cases, personal dosimeters on the wrist or finger were not worn; thus, in all cases, the doses to the exposed parts of the hands were not given by personal dosimetry. So we estimated dose by reconstruction of events after each accident. The detailed information of exposed time, distance, shielding and source strength were taken from interview of both subject and radiation safety officer immediately after exposure. Exposure doses were measured with the following equipment in the experiment of the reconstruction;

Ionizing chamber : CAPINTEC Model 192 (probe volume;6cc)
Thermoluminescence dosimeter : $CaSO_4$, BeO

The estimated absorbed dose of epidermis of each case by reconstruction are shown in Table 1. Each estimated dose had uncertainty factor 2 to 3, because exposed times at the accident were equivocal. We considered that the clinical manifestations on the skin after accidents were the most valuable indicators for dose estimation. We did not perform biological estimation of dose, that is analysis of chromosome aberrations and hematological examination of circulating blood; because irradiated area was a very restricted volume, we considered that dose could not be detected by these biological analyses.

CLINICAL SIGNS AND TREATMENT

Acute and chronic syndromes of the radiation burns appeared in all subjects with some period of latency. Typical acute syndromes that appeared in each case were erythema, dry and wet desquamation, dermal oedema, blister and erosion. These acute syndromes disappeared in two or three months after exposure and chronic syndrome appeared after 9 or 18 months after events. In one case, chronic syndromes appeared without a break from acute syndromes. Typical chronic syndromes in all cases were ulcer, necrosis, hyperplasia, telangiectasis, pigmentation, dis-pigmentation and atrophy. The points of medical care of subjects were cleaning of the exposed area and giving it a good rest. Four cases were treated with non-surgical conservative therapies and one case was treated with surgical skin graft therapy.

Clinical manifestations, particularly the length of latencies of acute syndromes, were very useful information for dose estimation in individuals not wearing personal dosimeter. The times of appearance of each acute syndrome in individuals are shown in Fig.1.

ADMINISTRATION ACTION

(1) Improvement of safety equipment

All equipment was provided with safety lock system. However, many workers frequently ignored these safety systems while operating the machine. At the time of accident, the functions of safety systems were not effective in any of the cases reported in this paper. Then deep defense systems of safety were introduced.

(2) Creation of a formal management structure and operational guidance

New effective organizations for radiation protection and manuals of good practice expressed in clear terms were prepared in all institute after the accidents.

(3) Training and skill for radiation workers

Special training and skill were performed to establish a safety-based attitude in everyone concerned with operations of X-ray analytical machines in each institute. There were many types of machine and various techniques of utilization of X-ray analytical machine; thus, details of training concerning safety and protection depended on the type and technique of operating machine and degree of worker's skill.

(4) Lay-off from radiation work

All cases were permitted the subsequent employment in the same duties of radiation work from clinical and radiological consideration; however, the duties of all cases were modified from radiation work to non-radiation work as required by each individual.

DISCUSSION

(1) Biological dosimetry of very small part of the skin

Analysis of chromosome aberration in peripheral lymphocytes has usually been performed in accidental cases, but, in the cases where the irradiated area or volume is very small, chromosome analysis does not detect irradiation dose. Then, other biological dosimetric system must be investigated; particularly useful indicators under the dose range are the appearance of clinical manifestation, that is erythema and epilation. Now we research growth retardation of hair after over-exposure of skin as a biological indicator (4).

(2) Dose estimation of very low energy of X-ray

In cases of irradiation by X-ray analytical machine, the energies of radiation were very low, under 10 keV. The response of present dosimetric equipment, TLD, depends on energy of exposed radiation. The equipment is over-responsive in these energy ranges. Then, we employed a method of two kinds of TLDs, which are different in effective atomic number, to correct X-ray energy response.

(3) Shortage of knowledge of radiation safety and protection of workers

Our previous studies made it clear that the understandings of managers and workers for radiation protection were lacking. The most important aspect of radiation safety and protection is the close links between managers and workers. All persons concerned with radiation work must have appropriate knowledge of safety of radiation.

CONCLUSION

We have treated five male workers who were over-exposed to X-rays on their hands with doses from 8 to 300 Gy. The experience of detailed analysis of these subjects suggested that it is important to practice appropriate pre-operational and periodical education and training for workers on radiological safety and protection.

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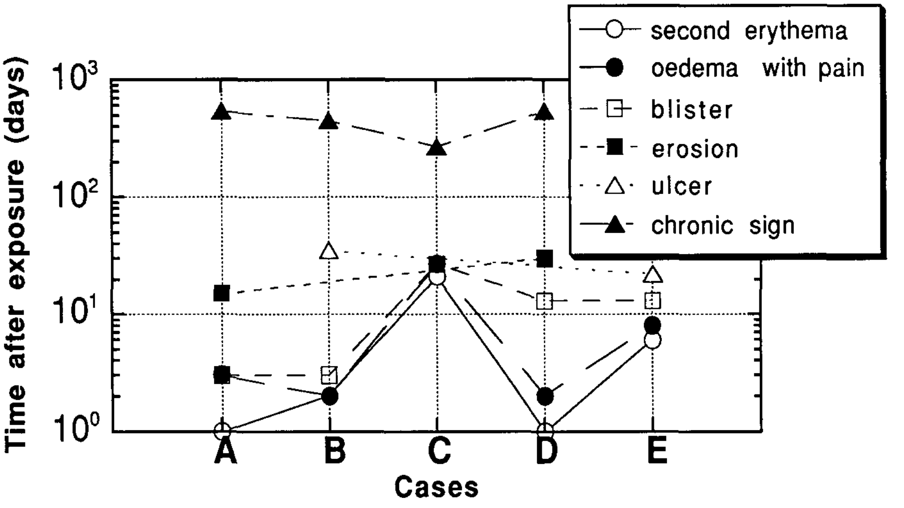

Fig.1 Clinical manifestation of each case.