RADIATION INJURY FROM ANALYTICAL X-RAY EQUIPMENT

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1. INTRODUCTION

During the last two decades there has been a considerable increase in the use of analytical X-ray equipment in research centres and industries in India. The energy range of X-rays generated by these machines is less than 25 Kev and these X-ray tubes are provided with negligible inherent filtration. As a result, the exposure rates near the tube windows are extremely high. Most of these low energy radiations will be absorbed within the first few millimetres of tissue (1). If the absorbed dose to the skin is sufficiently high, there is a distinct possibility of formation of significant dermatitis, which if present for sometime, can lead to skin cancer.

Several reports of injury caused by radiations from X-ray analytical equipment have been reported (2). This paper presents two cases of inadvertent acute exposure to low energy radiation from X-ray crystallography units. The paper also analyses the possible causes of these accidents. Based on our experience accumulated during the radiation protection surveys of such X-ray analytical equipment, several measures to avoid recurrence of such incidents and also to reduce radiation hazards in routine work are recommended.

2. CASE I

This is a case of radiation burn in the inner forearm of the right hand caused by acute exposure from an X-ray crystallography unit. The incident occurred on August 9, 1974.

2.1. History

Mr. N, aged 37 years and his colleague were working with an X-ray crystallography unit. The unit has two beam windows at 180^{o} to each other and both were 'ON' simultaneously. It is intended that whenever only one beam is used the other should be closed by inserting a lead shutter. On the forenoon of the day of this incident, it was told that Mr. N had closed the beam on the right side as only the left beam was used. After lunch, the work was resumed and while manipulation of the experimental set-up, both hands were used. The work was continued

for about 15 minutes when it was suddenly realised that the shutter of the right beam was not present and that the inner forearm of the right hand was receiving radiation exposure from the direct beam.

A blood count, taken on the next day was found to be normal and there were no biological symptoms during the first week. After about 14 days, an elliptically shaped wound of major and minor axis 5 and 3 cm respectively, had developed. The wound was 5 mm deep. As per the prescription of the local physician, antibiotic ointment was applied on the wound which healed after about three months.

Corresponding to the wound area, a white elliptical patch still remained when observed in January 1976. Mr. N had no other symptoms at this time and no numbness in the affected region. Pigmentation has started from the fringes to about 2 mm inside this area. Surrounding the white patch an area of about 20 cm x 5 cm from the centre of the forearm towards the ankle has a darker appearance. There was epilation in this area initially with no subsequent hair growth. Mr.N recalled that he was holding his right hand in a stationary position at about 45^{o} to the beam for nearly 2 to 3 minutes and that this particular exposed region had developed into a wound subsequently. The elongated shape of this patch is in conformity with the oblique incidence. The regions which got exposed during the remaining time when the hand was not stationary might have got lesser dose resulting only in charge of skin colour.

2.2. Dosimetry

The dosimetry was performed by reconstructing the incidence. Mr. N's right hand would have been at about 15 cm from the window of the tube through which the beam was emerging. The exposure rate was measured at this place using a calibrated soft X-ray ionisation chamber and found to be 4,444 R per minute. Considering the Roentgen-to-rad conversion factor as 0.9 for skin, the dose rate would be 4000 rads per minute . For an exposure time of 2-3 minutes, the skin dose would have been 8,000 to 12,000 rads.

3. CASE II

3.1. History

This was a case of severe skin reaction on the inner three fingers of the left hand reported in July, 1972. Mr. K, aged 36 years, noticed some changes in the skin of his fingers and experienced burning sensation associated with pain in the fingers. He developed blisters on the left index finger and raised patches on the middle and ring fingers. During this acute phase, the patient was given oral antibiotics and skin ointment containing antibiotics and hydrocortison. A clinical examination early in August, 1972 revealed a healed scar of about 1 1/2 cm x 1 cm on the medial aspect of the left index finger while raised patches of 2 x 1 cm with slight depigmentation were seen on the middle and ring fingers. Marked pigmentation was noticed on the distal phalanges extending to the middle phalanges on the left hand and on the index finger on the right hand.

An investigation established that Mr. K was in the habit of holding a 5 cm fluorescent screen strip in the beam to locate its position and size, and to align the camera. The image on the screen due to

uncollimated beam is brightly visible even at a distance of one meter without darkening the room, whereas the small image due to a collimated beam could be observed only in close proximity in a darkened room. Mr.K used to remove the collimator during alignment and replace the collimator into the camera with the beam still 'ON'. In this process, his left hand fingers, particularly his index and middle fingers were in the direct beam. The diameter of the beam at the finger position was about 3 cm.

3.2. Dosimetry

The exposure rate was measured to be about 22,000 R per minute at 25 KV and 20 mA. It was established by mock exercises that in the process of inserting the collimator into the camera, Mr.K's fingers were in the direct beam for 3-4 seconds in each of the 4 or 5 occasions when he used the new unit after installation. These operations would have resulted in a dose in the range of 4000-6500 rads to the index finger. The thumb had been shielded by the index finger and no dermatitis was seen on the thumb. The dose to the middle and ring fingers on the left hand was estimated as 1000 rad. He also used to hold the fluorescent screen with his right hand and this explains the pigmentation seen on the right index finger.

4. RADIATION SAFETY

A significant reason for such indents is the low standard of radiation safety features built into many of the X-ray analytical equipment(3,4). In this connection 59 X-ray analytical units of different makes as seen in Table 1 were studied. Of these, 52 units are used for crystal structure determination, 3 for thermal expansion study, 2 for study of diffraction from metals and alloys and 2 for studies of soils and clays. 56 of these had manual control, 2 automatic and 1 semi-automatic. 38 units had single targets and 21 had multitargets. The availability of radiation safety features is detailed in Table 2. A majority of these units do not have interlocking systems or radiation barriers.

It is to be pointed out that in both the incidents discussed here, the units were of the same make. No distinctive warning light which will glow when the X-ray beam is 'ON' was interlocked to the high tension. Also, electrical or mechanical interlocks which will ensure that the shutter will be in position for blocking any unused beam were absent. Incorporation of the above features in addition to a radiation alarm monitor and an interlocking device to prevent the entry of any part of the body into the direct beam and education of the working personnel regarding awareness of radiation hazards will definitely help to reduce unnecessary exposure from X-ray analytical equipment.

TABLE 1. Number of X-ray analytical units of different manufacturers

S.No.	Manufacturer	No. of units
1.	Radon House (Indian make)	31
2.	Philips	19
3.	General Electric	3
4.	Rich Seifert	3
5.	Picker	1
6.	Ray Max	1
7.	Other	1
	Total	59

TABLE 2. Availability of radiation safety facilities

S.No.	Radiation safety facility	Available	Not Available
1.	Beam trap	45	14
2.	Safety shutters	46	13
3.	Temporary shielding	54	5
4.	Interlocking system	15	44
5.	Barrier	14	45
6.	Lead glass for viewing	44	15
7.	Warning indicators	38	21
8.	Radiation symbols	30	29
9.	Radiation survey instruments	19	40
10.	Film badge service	16	43

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