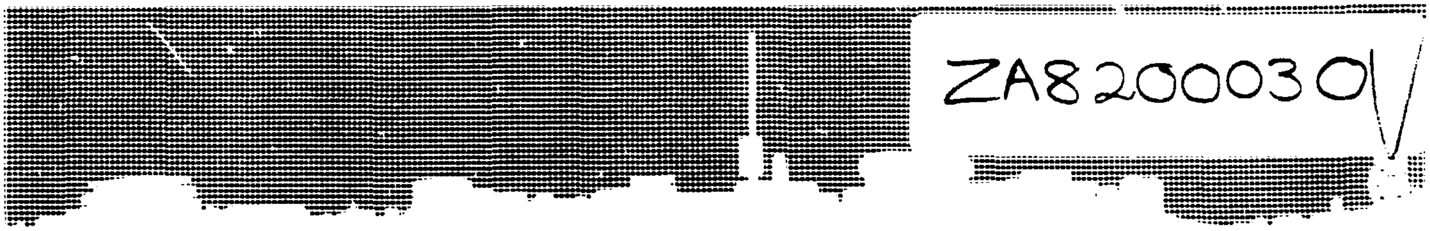

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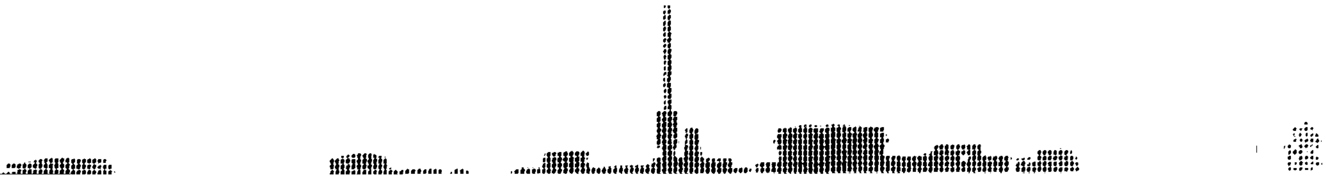

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CONTENTS

SAMEVATTING

'n Voorval betreffende die verlies van 'n iridium-192 radiografiese bron en die gevolglike ernstige oorblootstelling van 'n derde party word beskryf. Aspekte van gesondheidsfisika, veral dié wat met dosismeting verband hou, word toegelig en word vergelyk met resultate wat met chromosoomafwykingsdosismeting verkry is. Die mediese waarnemings en behandeling word ook beskryf.

ABSTRACT

An accident, involving the loss of an iridium-192 radiographic source and the subsequent serious overexposure of a third party, is described. Health physics aspects, particularly dosimetrical aspects are addressed and compared with results obtained by means of chromosome aberration dosimetry. Details are provided on the medical observations and treatment of the patient.

ACKNOWLEDGEMENTS

The expert assistance of Mrs J.I. Feather with the physical dosimetric calculations is gratefully acknowledged.

An abbreviated version of this report was presented as a poster at the 5th Congress of the International Radiation Protection Association, Jerusalem, 9 – 14 March 1980, and was published in the proceedings Radiation Protection, Pergamon Press, Oxford (1980) p. 64 – 67.

1. INTRODUCTION

Industrial radiography in South Africa has grown since 1948 to the present use of, *inter alia*, 130 iridium-192 sources with strengths of up to 7,4 TBq (200 Ci) by 29 firms. Although this field of application remains the main cause of overexposure[1] in the use of radioisotopes, only two persons suffered clinically observable injury in South Africa before this incident which occurred in 1977. Studies on and observations of the one person who suffered acute overexposure, included physical dosimetry, chromosome aberration studies and medical surveillance and treatment.

2. THE INCIDENT

On Saturday morning, 8 January 1977, a 248 GBq (6,7 Ci) ^{192}Ir source fell out of its container during radiography at a construction site. This was not noticed by the radiographer because of a faulty monitor, and he subsequently left the construction site without being aware that the source was not safely stored. About three hours later a construction supervisor, A, picked up the bright metallic object, which he assumed to be a component of a mobile crane, and placed it in the left breast pocket of his shirt. Subsequently, he travelled home in a small bus with six other occupants who alighted at various points along the route, with A reaching his home after 40 min where he sat down to watch a television program. About 40 min later he became nauseous and vomited. He removed his shirt, placed it in a cupboard and went to bed.

The next morning he removed some money and the source from the shirt and placed them in the drawer of his bedside table. The family spent the rest of the day away from their home, retiring at 20h00 with A immediately next to the bedside table and his six-year-old son sleeping between him and his wife. On Monday he left for work at 06h00 while his wife and son remained at home.

The loss of the source was discovered at 11h30 on the Monday, whereupon a search was instituted by the firm with the aid of radiation monitors. As the search proved fruitless, a replica of the source capsule was shown to the workers on site which resulted in subsequent identification and recovery of the source from A's bedside table at 15h45. The loss of the source was reported to the Atomic Energy Board, the regulatory authority in respect of the use of radionuclides, at 13h45.

3. HEALTH PHYSICS

Due to the serious nature of the accident, A was admitted to hospital for observation and his family as well as his colleagues were immediately placed under medical supervision. Subsequent dosimetric calculations indicated that in addition to his family, only three colleagues (X, Y and Z) needed to remain under medical observation, but that at no stage was any member of the public at large exposed to a level that warranted surveillance.

Although statements were obtained from A, his superiors, colleagues and the industrial radiographer, it was extremely difficult to reconstruct the accident in detail. It could, however, be established with a fair amount of accuracy that the source remained in his pocket for about two hours and 40 min, whilst its position in relation to the body (it was a loose-fitting shirt) could not be determined accurately. From the information provided by A it was decided to base the dosimetric calculation on the assumption that for 33 % of the time of exposure, A spent in a sitting position with the source approximately 60 mm from his body, whereas the source capsule was considered to be in contact with his skin in the standing and prone positions. Isodose curves were calculated using the shielding program PELSHIE[2], assuming a point source irradiating the body, which was considered to be equivalent to a slab of water. The results are presented in Fig. 1.

Significant simplifying assumptions had to be made for the calculation of the equivalent whole-body dose, which was estimated to have been 1,33 Gy (133 rad).

Since that time, the calculations have been repeated and the new isodose curves were compared with experimental results obtained by way of thermoluminescent dosimetry measurements on an Alderson Rando phantom. The equivalent whole-body dose was also recalculated by a more refined technique(3). The body was approximated by a cylinder 600 mm long with a radius of 150 mm, with the source situated on its surface. See Fig. 2. Since the dose D(r) is, by approximation, only a function of the distance (r) from the source, the integrated dose could be calculated by the use of the following formula:

$$D = \frac{\int_0^{2R} D(r)\, A(r)\, dr}{\int_0^{2R} A(r)\, dr}$$

where $A(r) = 2\pi r^2 - 4r^2 \int_0^{\sin^{-1}\left(\frac{r}{2R}\right)} \sqrt{1 - \frac{4R^2}{r^2}\sin^2\theta}\; d\theta$

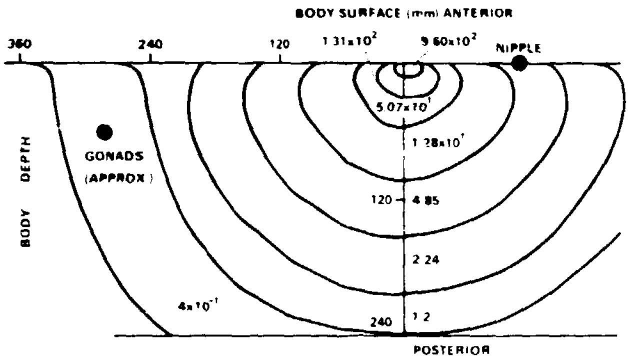

Fig. 1.

Isodose curves in Gy (Patient A : 1,83 m; 85 kg)

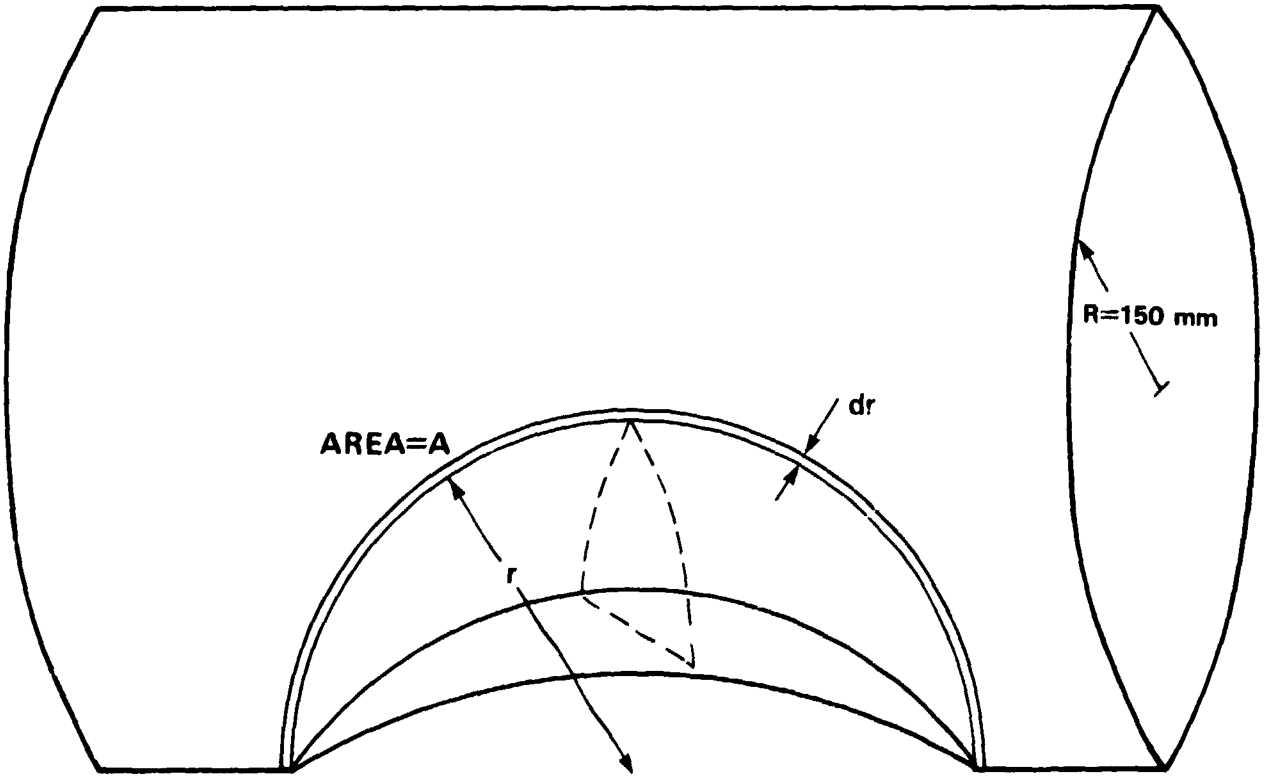

Fig. 2.

Model for refined dose calculations

This integral was evaluated numerically and produced an equivalent whole-body dose of 1,06 Gy (106 rad). This value compared well with that obtained by way of chromosome aberration dosimetry, namely 1,16 Gy.

Although the eventual biological effects were underestimated during the initial clinical examinations, the physical dosimetry led to A being kept under close medical observation as well as the decision to carry out studies by chromosome aberration dosimetry.

4. CHROMOSOME DOSIMETRY

On 31 January, 23 days after the incident, 10 ml blood samples from six people were placed in sterile heparinised specimen tubes and despatched by air to the National Radiological Protection Board in England. Their lymphocytes were cultured following a routine technique which has been described in full by Purrott and Lloyd[4]. In brief, several replicate "mini" cultures were made for each person. These consisted of 4,0 ml Eagles' Minimal Essential Medium, 1,0 ml calf serum, 0,75 ml phytohaemoglutenin and the buffy coat derived from 1,0 ml of blood. The cultures were incubated at 37 °C for 48 h with colcemid being added for the final three hours. Orcein-stained metaphase spreads were examined for the presence of unstable chromosome damage, namely dicentrics, centric rings and acentric aberrations. Details of the criteria used in this analysis have also been described by Purrott and Lloyd[4].

The aberrations found and the resulting estimates of dose together with their 95 % confidence limits, based on scoring statistics, are presented in Table I.

TABLE I
ABERRATIONS AND DOSE ESTIMATES

	No. cells	Dicentrics	Centric rings	Acentrics	Dose in Gy	95 % Confidence limits	
						Lower	Upper
A	1 000	86	2	60	1,16	0,98	1,33
Wife	500	2	–	10	0,17	0,02	0,40
Child	500	1	–	3	0,10	0,02	0,34
X	500	–	–	1	–	–	0,26
Y	500	–	–	3	–	–	0,26
Z	500	–	–	5	–	–	0,26

The estimates of dose were available on 4 February, five days after the samples were taken. They are equivalent whole-body doses and were made by referring the yields of dicentric aberrations to the dose response curve $Y = 1{,}57 \times 10^{-4}\ D + 5{,}0 \times 10^{-6}\ D^2$. This curve had been previously produced by *in vitro* irradiation of blood with cobalt-60 γ-rays[5].

The cytogenetic method provided estimates of whole-body dose in agreement with the tentative calculations but did not permit quantitative estimates to be made of the absorbed dose to specific parts of the body. Following a uniform exposure, the distribution of aberrations amongst the cells is expected to be Poisson, so that the ratio of variance to mean $\frac{\sigma^2}{y}$ is 1,0. A test described by Papworth[6] compares the difference from unity of the measured $\frac{\sigma^2}{y}$ with the standard error in $\frac{\sigma^2}{y}$. In the case of a Poisson distribution, that ratio, designated by u, is expected to be a standard normal deviate. For the distribution of the total chromosome aberrations in patient A, as shown in Table II, the value of u is 14,9, providing a clear indication that his exposure was not uniform.

TABLE II
ABERRATION DISTRIBUTION AMONGST
1 000 SCORED CELLS

	0	1	2	3	4	5
Observed	890	86	16	4	2	2
Poisson	862	128	9,5	0,5	–	–

5. MEDICAL OBSERVATIONS

The dosimetric evidence was confirmed by subsequent medical examinations which revealed clinical evidence of radiation injury only in patient A. The patient developed slight nausea and loss of appetite within hours after exposure, a condition that lasted for only about 24 h. ECG studies done at one week, six weeks and 18 months after exposure did not reveal any abnormalities. Blood pressure remained constant. Examinations of urine at weekly intervals gave normal results. The patient's wife gave birth to a full-term normal baby about a year after the incident. Mentally the patient became depressed, being unable to do his normal work because of his injured left hand. No shortness of breath or infection occurred during this follow-up period. Chest X-rays done at monthly intervals were within normal limits and no fibrotic changes were observed.

5.1 Laboratory Studies

Full blood counts as well as the sedimentation rate were determined, the first at two-day intervals and then at weekly intervals. The haemoglobin, white-cell count, as well as the differential white-cell count remained within normal limits. The only abnormality was a change in the sedimentation rate which was normal on day three and rose to 50 (NV 0-9 Wintrobe) on day nine. Twenty-four days after exposure it was back to normal. Liver and kidney function remained within normal limits.

5.2 Local Reactions

The thumb and index finger of the right hand started with an erythema reaction on day 18, that developed into a wet dermatitis on day 20, but this healed completely within the next 10 days. Clinical estimation of the radiation dose was difficult but judging by the reactions[7], about 10 Gy (1 000 rad) were delivered to the distal section of the fingers.

The thumb and index finger as well as the middle finger of the left hand started with an erythema on day four, which developed into a wet dermatitis as well as blister formation after ten days. The hand was very painful and on day 20 the full skin thickness was shed. The healing of the fingers was very slow and incomplete and after three months they were covered with atrophic skin that tended to break down repeatedly after minor trauma. This required amputation of the thumb, index and middle finger after 24 months. The dose was estimated at over 50 Gy (5 000 rad).

Two days after exposure, erythema developed over about 180 cm^2 of the anterior chest wall. This progressed to wet desquamation on day six, followed by necrosis in the centre. Healing started from the periphery and two months after exposure there was a 60 cm^2 (80 mm x 150 mm triangle) necrotic area surrounded by slightly atrophic depigmented skin, which was very painful. The necrotic area remained unchanged and excision and pedicle skin graft was required 18 months after the incident. By means of the Strandqvist method[8], the central necrotic part was estimated to have received between 50 and 100 Gy (5 000 and 10 000 rad). The adjoining area received between 10 and 22,5 Gy (1 000 and 2 250 rad). This is in remarkable agreement with the dosimetric calculations, especially as the source was not stationary.

Figures 3 and 4 illustrate the clinically observable radiation injuries after 17, 24, 37, 100, 220 and 1 139 d.

6. CONCLUSION

This accident has highlighted the inherent weakness of pneumatic radiographic equipment. Consequently, the further use of such equipment in South Africa has been prohibited. A system of logsheets has also been introduced whereby the radiographer must personally certify in the logbook that the source has safely returned to the source container and that the source container has been locked up in an approved storage place. Although the use of monitoring equipment during radiographic procedures has always been a requirement, the importance of monitoring is now stressed in that the Board's amended conditions particularly provide for the procedures to be followed. Each industrial radiographer must also be issued with a code of practice for the handling, use, conveyance and storage of sealed sources as well as explicit written instructions on the procedures to be followed in the event of an accident or emergency.

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Day 17

Day 24

Day 37

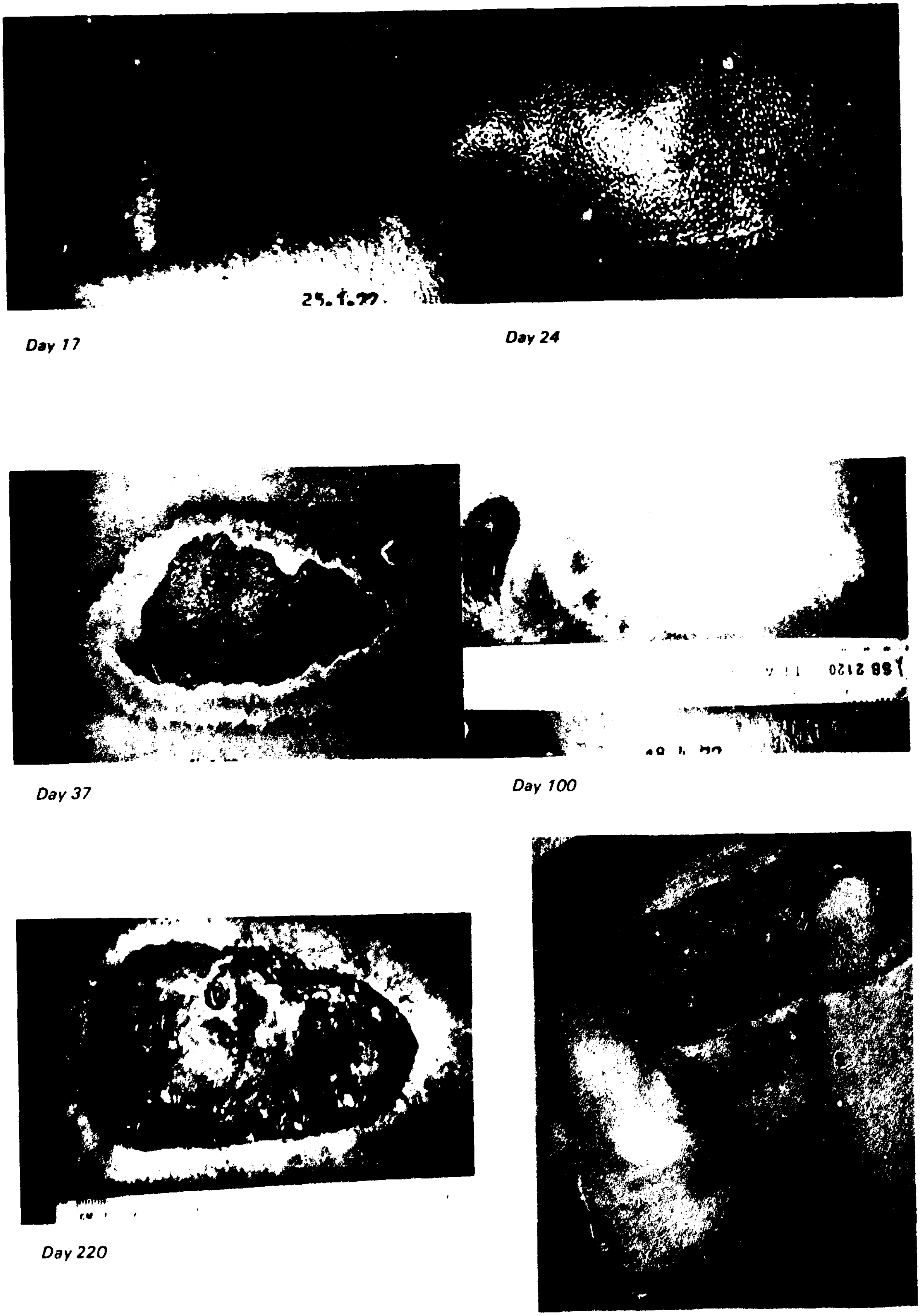
Day 100

Day 220

Day 1 139

Fig. 3.

Clinically observable radiation injuries to the hands after 17, 24, 37, 100, 220 and 1 139 days.



Day 17

Day 24

Day 37

Day 100

Day 220

Day 1 139

Fig. 4.

Clinically observable radiation injuries to the chest, after 17, 24, 37, 100, 220 and 1 139 days.