(4) An Accident of Exposure to an ^{192}Iridium Source in Chiba, Japan (September 1971) : Angiopathy 22 Years After Exposure

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Abstract

A follow-up study was performed for an accidental overexposure to a high dose of γ-rays from an ^{192}Iridium source in 1971, and the latent effects on one of the victims were studied. The average absorbed dose of the whole-body was estimated to be 1.33 Gy, the absorbed dose to the fingers was 26-90 Gy Necrosis and atrophy of the right fingers have gradually developed and necessitated the amputation of two of his fingers. An examination of his angiogram showed that these delayed effects were mainly caused by angiopathy.

I. Introduction

Radiation such as X- or γ-rays has characteristic abilities to penetrate materials and to expose film. Radiography, one of the techniques utilizing these characteristics, is widely used for non-destructive testing in industry, because it can be used to examine products without damaging them. Examination of weldjoints on metallic plates is a very common application of radiography. Earlier, radium was primarily used as the source for radiography, but recently, X-rays, ^{192}Ir, ^{60}Co, ^{137}Cs, and ^{170}Tm are frequently employed for non-destructive testing.

Since 1966, when the first nuclear reactor started operation in Japan, we fortunately have not had any radiological accidents that required medical care for the people involved. However, several accidents have occurred at industrial facilities using radiography with ^{192}Ir, ^{60}Co, and others. The workers suffered injuries from high doses of irradiation.

In September 1971, a radiological accident occurred at an industrial radiation facility in Ichihara City, Chiba, 50 km southeast of Tokyo. Six construction workers were accidentally exposed to γ-rays from an ^{192}Ir source and developed the acute radiation syndrome Twenty-two years after the accident, one of them developed angiopathy that caused necrosis and atrophy of the bone in his right hand

The present report will describe a follow-up study on one of the workers treated for accidental overexposure in the 1971 incident, which was previously described, and detail the clinical features of this individual.

II. Case History

The accident occurred at a shipyard in Ichihara City, Chiba, Japan. This industrial city faces Tokyo Bay and constitutes a part of the Keiyo industrial area (Figure 1). There are many factories or facilities including shipyards in this area. In one of these shipyards, radiography was employed as non-destructive test. Radioactive iridium-192 (^{192}Ir) was used as the radiation. The rod-shaped ^{192}Ir source element was held in the top portion of a pencil-like stainless source holder. The ^{192}Ir source had an activity of 5.26 Ci, the dose rate on the surface of the source was 250 R/min-Ci and the absorbed dose rate was 1 Gy/min. This holder was connected to a custody box with a cable, and was shielded in the box when not in use.

On September 17, 1971, an operator who was engaged in the non-destructive testing by means of such an ^{192}Ir source at the shipyard forgot to confirm that the source holder was in the custody box at the end of his work. The ^{192}Ir source holder was somehow disconnected from its cable; the source was left on the ground without a shield. It was not noticed until September 20, 1971 that the source was missing; the operator could not find the source holder in the box when he tried to start a radiographic examination. Throughout the three days, the facility remained unaware of the loss of the holder containing the ^{192}Ir source. On September 23, the management of the shipyard reported the loss of the source to the authorities.

The initiating events:

At 15:45 on September 18, a construction worker (YS) employed by a subcontractor of the shipyard found "a 17-cm-long pencil-like piece of stainless steel" on the ground in the shipyard (Figure 2) He picked it up out of curiosity without knowing that it was radioactive. He put the source between his belt and trousers and took it to his apartment by car. In the car, his right hip contacted the source for 10 minutes and his left hip for 30 minutes. In the evening, five of his friends visited him and they watched television together. Not knowing what the holder was, they touched it by their hands in turn Thus, this radiological accident occurred With the holder somewhere in the room, all of them were in the room for at least one or two hours, and two of them (patients SH and YS) stayed there overnight. In the following three days, they were in and out of the room. Figure 3 shows the length of their stay in the room. On September 25, the accident was realized; SH knew through the news media that the ^{192}Ir source was lost and notified the authorities that he might have handled the source holder at his friend YS's. The authorities tried to find the source in the room or the neighbourhood, but they failed. On September 26, the wife of the manager of the apartment found the source in the garden.

III. Dosimetric Calculations

Dose estimation for the six persons exposed to ^{192}Ir γ-rays were performed by various techniques. The principal techniques used were as follows:

- determining thermoluminescence from the jewels of their wrist watches
- a reconstruction on the basis of exposure time to the ^{192}Ir source and the location of the source
- biological estimate

Physical estimate

1) Absorbed dose of whole body

Three persons, YS, SH, and MI, had watches on their wrists when exposed to the ^{192}Ir source. Their watches contained either 21 or 25 jewels These jewels (rubies) were carefully removed from each of the watches and their thermoluminescence intensities were measured. The dose rate of the source (5 26 Ci) was calculated to be 2.17 roentgens per hour (R/hr) at a distance of 1 m from the source. The duration of stay of each person and location of the source in the room was reconstructed Figure 4 shows the location of the source and the postures of the six persons on the night of September 19, 1971. The estimate dose of exposure for each person is shown in Table 1

2) Skin dose of the fingers

The exposure dose rate on the surface of the source was 250 Ci/min-Ci and the absorbed dose rate was 13 Gy/min (conversion factor; 0.0095 Gy/R). If a person held the source in his hands for 2 to 7 minutes, his fingers would have an absorbed dose of 26 to 91 Gy.

Biological estimate

1) Absorbed dose of whole body

Chromosomal analyses were performed on the cultured lymphocytes and bone marrow cells from individuals. The yield of dicentrics plus rings in the peripheral blood lymphocytes was 0.0015 to 0.1367 per cell. Based on these results, the total body absorbed dose was equivalent to 0.098 to 1.24 Gy of ^{60}Co γ-rays and 0.156 to 1.52 Gy of high energy X-rays (Table 1).

Table 1. Estimated Absorbed Dose

Case	Corresponding dose (Gy) ^{60}Co g-rays	high energy X-rays	Physically estimated doses (Gy)
SH	1.24	1.52	1.33
YS	0.4	0.54	0.5
KJ	0.26	0.37	0.1
MK	1.22	0.19	0.25
TS	1.09	0.172	0 13
MI	0.98	0.156	0 15

IV. Clinical Findings

All six people were hospitalized at the National Institute of Radiological Sciences (NIRS, Chiba City); four patients SH, MK, MI, and TS on September 26, YS on September 27, and KJ on October 11. The clinical symptoms observed in these individuals are summarized in Table 2. No gastrointestinal symptoms such as anorexia, nausea, vomiting, and diarrhea were observed in any of the cases during their hospital courses. None of them showed any psychological disturbances.

Table 2. Symptoms Observed After Initial Exposure

	Prodromal symptoms	Skin lesions	Bone marrow suppression	Gonadal suppression
SH	+	++	+++	+
YS	-	+++	+	+++
KJ	-	+	+	+
MK	-	-	+	+
MI	-	-	-	+
TS	-	-	-	+

Prodromal symptoms

One person, SH, had symptoms of anorexia and nausea without vomiting three hours after the initial exposure (on Day 1); however, these symptoms were not observed at the time of admission (on Day 9) No prodromal symptoms of radiation exposure were manifested in the other 5 cases.

Bone marrow suppression

The most severe bone marrow suppression was observed in patient SH. His hematological data on admission showed a moderate suppression; the number of leukocytes was 3,300/μL and that of platelets was 240,000/μL. However, the leukocyte count decreased thereafter; on Day 32, his platelet count was 15,000/μL and on Day 30, his leukocyte count reached its lowest level (800/μL).

Gonadal suppression

The number of sperm was decreased for 3 months or more after the initial exposure in all patients; azoospermia was noted in YS in March 1972, and oligospermia was observed in the other five individuals between December 1971 and January 1973. All cases showed normal levels of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) shortly after exposure. However, FSH levels increased in the cases who received 0.122 Gy or more, and the FSH level remained elevated for more than 400 days after exposure in case YS.

Skin lesions

At the beginning of October 1971, about 40 days after the initial exposure, radiation burns were manifested in SH, YS, and KJ. In the case of YS, who found the holder and took it home, severe radiation burns on his hip and right hand were noted. The lesions on the buttocks were caused by contact with the radioactive source, and the estimated absorbed dose was 30 Gy on the right and 90 Gy on the left. The dermatitis-contained necrotic ulcer was resistant to treatment and had to be surgically removed in March (on Day 124). The skin lesions on the hand improved with recovery of hematopoietic system. A patient TJ developed erythema on his right hand, and this skin lesion was healed in about forty days The radiation burns observed in case SH were most remarkable; the details will be described in the following section.

V. Radiation Burns 22 Years After Exposure

On October 2, 1971, SH developed erythema with swelling in the palm and fingers of both hands. In several days, blisters appeared. These skin lesions were the most severe of all the cases. However, these radiation burns were healed by antiseptic treatment in December. After discharge, repeated erosions or ulcers appeared, and contracture of some of the fingers (right index finger, the middle finger, and the right thumb) gradually developed resulting in limited finger motility. In 1976, an atrophy of the phalanges was observed. One day in 1993, he came to our institute; he was referred to us because he had right finger pain with repeated infection The skin of the right index finger and medial finger was infected and necrotic, the right thumb was severely atrophied, and the inter phalangeal joints of the index finger and the middle finger were contracted (Figure 5) Radiographic examination showed a severe atrophy of the proximal phalanx of the thumb, and the distal phalanx could not be recognized (Figure 6). The peripheral bones were also significantly reduced in density. Furthermore, angiography was performed on the right brachial artery The angiogram showed a complete occlusion of the palmar digital and dorsal pollical arteries and the narrowing of a radial index artery; the right fingers were mainly fed through the superficial palmar arch by the ulnar artery Progressive necrosis and repeated infection eventually necessitated the amputation of his two fingers. His second toe was transplanted as the thumb in the right hand.

VI. Conclusion

Acute radiation burns are characterized by a severe initial reaction that processes from erythema to necrosis, and exposure to large doses of γ-rays is known to cause delayed effects including fibrosis or necrosis The case presented in this follow-up study developed necrosis and severe bone atrophy on his hand 22 years after exposure to ^{192}Iridium. Angiography showed that these delayed effects were caused by gradually-developed angiopathy. This report may provide useful information for the diagnosis, therapy, and prognosis of the delayed effects of high-dose exposure to γ-rays.

References

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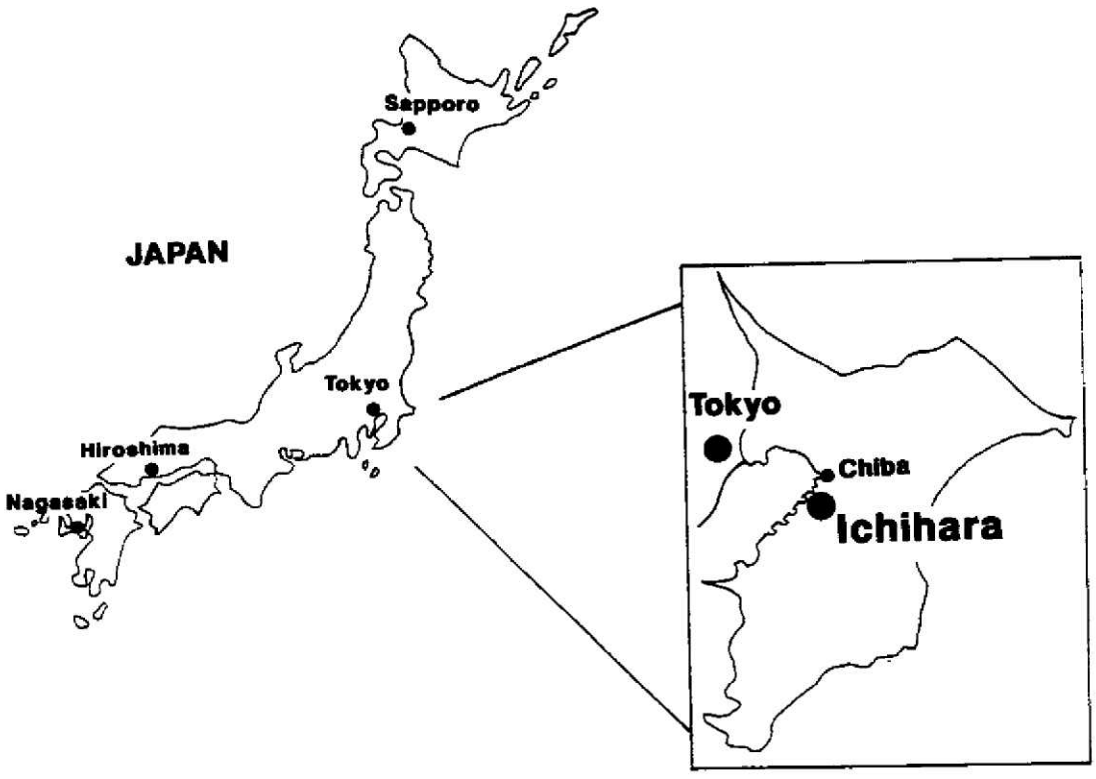

Fig. 1 The industrial city Ichihara is located at 50 km southeast of Tokyo and faces Tokyo Bay.

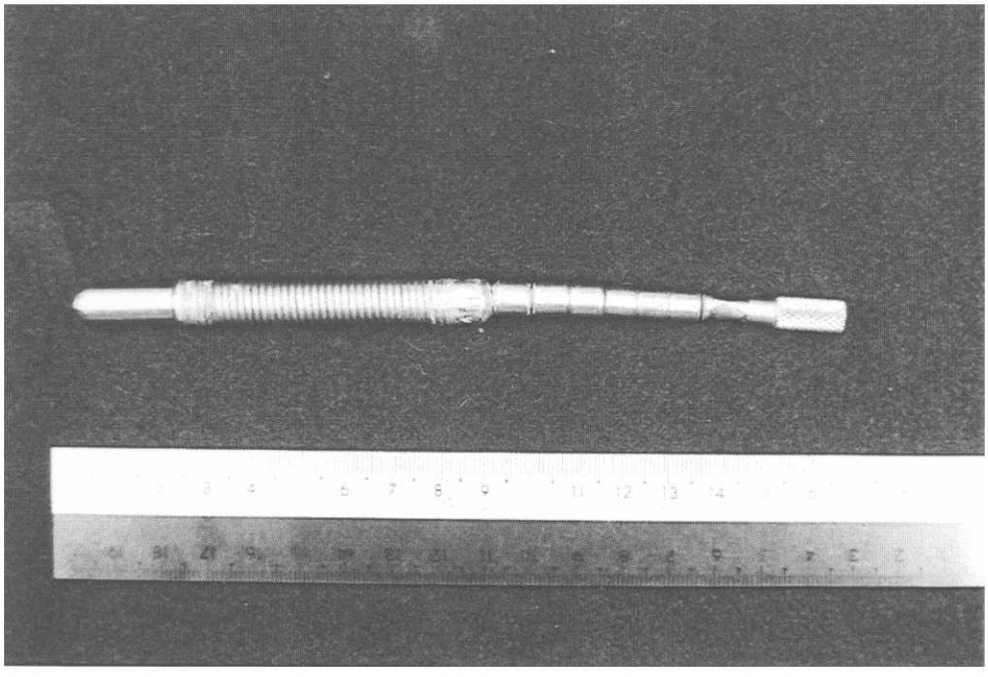

Fig. 2 A picture of the radioactive ^{192}Ir source. "A 17-cm-long pencil-like piece of stainless steel" was found on the ground in the shipyard. The arrow points the rod-shaped ^{192}iridium source element. By courtesy of Dr Hirashima.

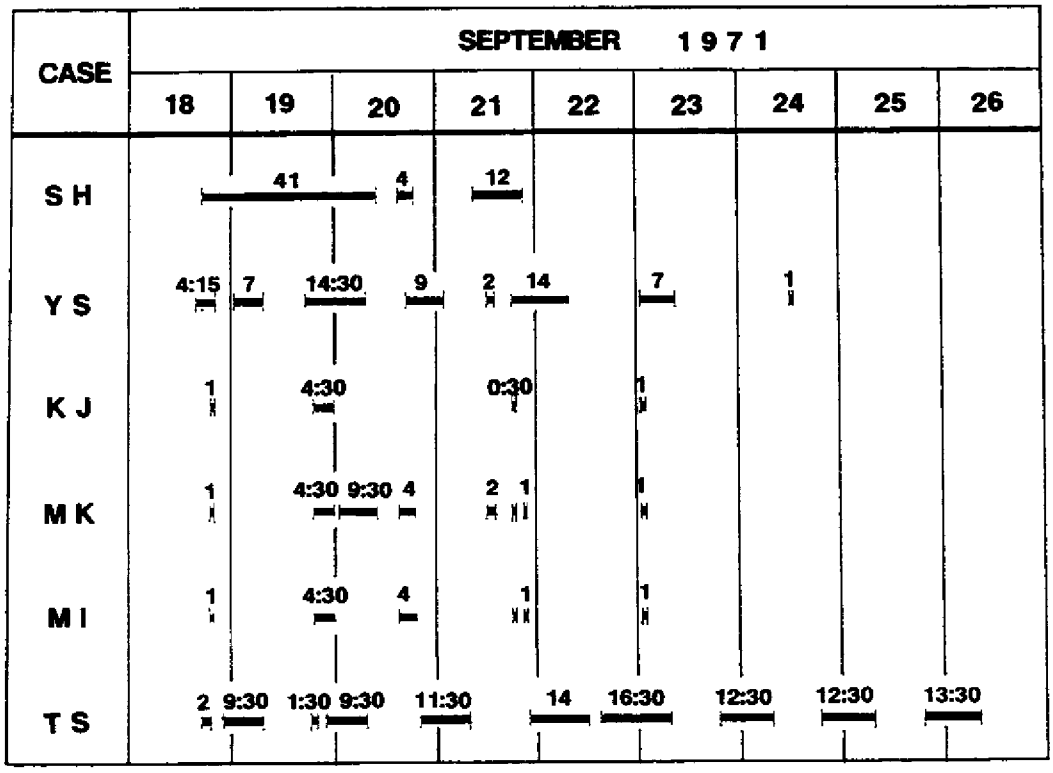

Fig. 3 The length of stay of six persons in the room with the radioactive ^{192}Ir source. Patient SH stayed in the room for 57 hours. Adapted from Hashizume et al. 1973.

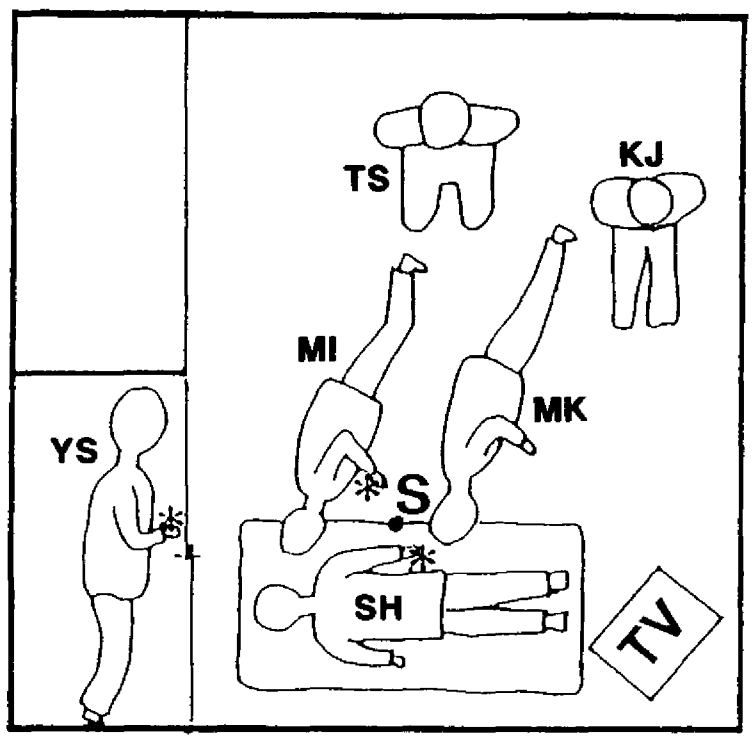

Fig. 4 The location of the source and the postures of six persons on the night on September 19, 1971. The mark "S" points the source and the mark * points wrist watches. Adapted from Hashizume et al. 1973.

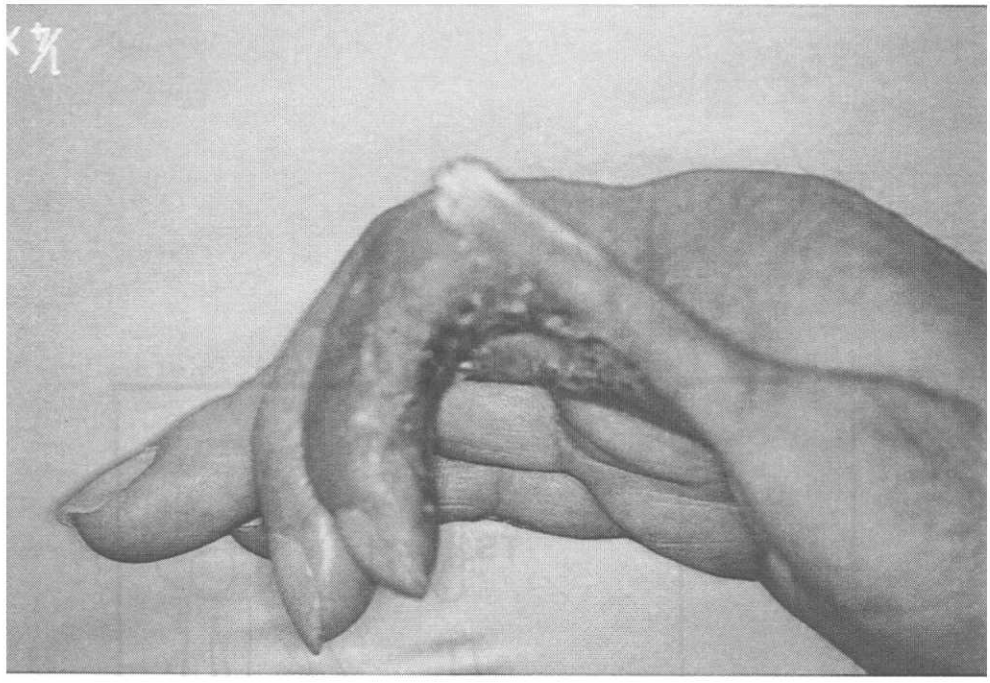

Fig. 5 A photograph of the right hand in 1993 before amputation (patient SH). The skin of the right index finger and middle finger was infected, necrotic, and the right thumb was severely atrophied. The inter phalangeal joints of the index finger and the middle finger were contracted.

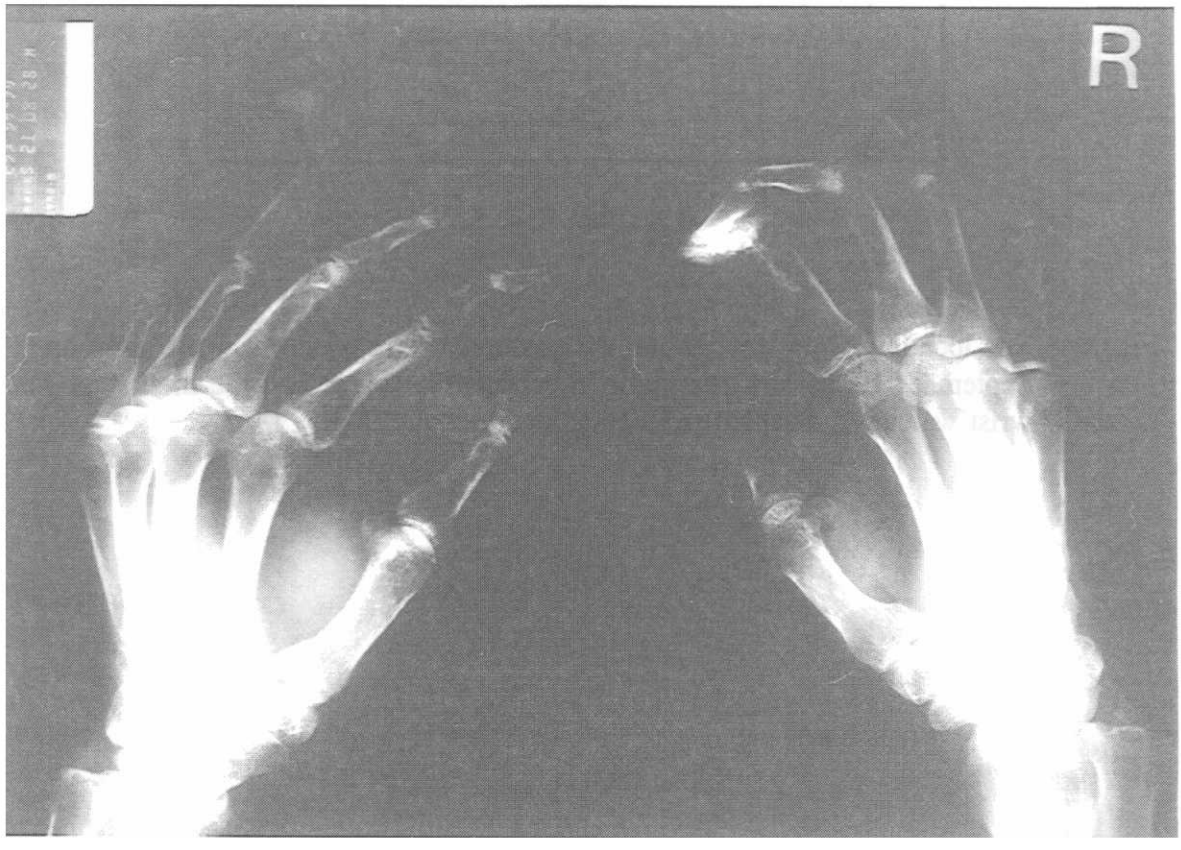

Fig. 6 A plain roentgenography of hands (patient SH). The distal phalanx could not be recognized and the peripheral bones were significantly reduced in density.