

Human  
Subjects

## Paper 3

HEMATOLOGICAL STUDIES ON PATIENTS TREATED BY  
TOTAL-BODY EXPOSURE TO X-RAYS\*

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## 1. INTRODUCTION

The development of chain-reacting nuclear power piles with the resultant intense radiations from the fission process and from the fission products introduced the possibility of accidental or necessary exposure of the entire body of persons to x-rays, gamma rays, and neutrons to an extent *never before thought possible*. The Health Division of the Metallurgical Project was faced with the problem of what changes would occur in individuals exposed to more than the tolerance dose of 0.1 r, on one or more days. It was thought that the blood picture of such individuals would show a rapid and radical change. The literature, however, contained very little information on the effect of x-ray exposure on persons with relatively normal hematological pictures, and such investigations as were reported were rather confusing because of the objectives of the studies. Hence it was considered necessary to study the effects of total-body irradiation with x-rays of varying energy on hematologically normal individuals.

## 2. SELECTION OF SUBJECTS

Patients with diseases requiring therapeutic irradiation of the entire body were selected for observation in this study.

The patients for total-body irradiation were selected by physicians on the staff of the University of California Hospital, who had no connection with the Manhattan Project, and the treatments were administered as part of the normal therapy of these patients. Advantage

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was taken of the fact that patients were receiving such treatment by making numerous blood studies for the Manhattan Project.

The patients with metastatic carcinoma and lymphoma were in the first group studied. They were observed for short periods only because of the probability that their advancing disease would cause blood changes unrelated to the exposure to x-rays.

Table 3.1 — Classification by Age

Age	Men	Women
20-30	3	0
31-40	4	2
41-50	3	3
51-60	1	6
61-70	4	2
71 plus	1	0
Total	16	13

The condition of 29 patients treated between October 1942 and June 1946 was followed for varying periods of time. Thirteen of the patients were women, and sixteen were men. Their ages ranged from 20 to 75 years, as shown in Table 3.1.

### 3. METHOD OF TREATMENT

The patients were placed in such a position that the whole body was exposed in the one x-ray beam at each session. The anterior surface of the patient faced the x-ray tube one treatment day, and the posterior surface faced the tube the next day. The dose in roentgens was measured with a thimble chamber on the skin in the center of the field. Thus the doses referred to in this paper are always roentgens on the skin, including back-scatter. All patients except three received equal fractional amounts at each treatment. The daily exposures were approximately 5, 10, 15, 20, 30, or 50 r, and the total exposures ranged around either 100 or 300 r.

The sum of all daily exposures, regardless of which surface was exposed, is called the "total-body exposure." This method of summation is not the usual way of describing radiation therapy, but it is used here because in occupational exposure, with the individuals moving about, no one surface is exposed continuously. The total radiation to which a person working in a given area was exposed could be known from measurements in that area. However, the amount of radiation received by any part of the body surface could not be determined.

treatment an attempt was made to obtain blood counts two or three times a week for two weeks, then once a week for four weeks, then once every two weeks for the ensuing eight weeks, then once every

Table 3.3—Summary of Treatment Data

Case No.	Volt- age, kv	No. of ex- posures	Duration of treatment, days	Dose per treatment (skin), r	Total- body exposure (skin), r	Whole-body dose (tissue), r	Local treatment, months		Duration of observation from onset, days
							Before	After	
1	200	22	27	15	321	207	8	2	480
2	200	8	58	50	394	264	6		130
3	200	21	24	10 or 20	295	198	5		150
4	100	12	89	30	367	246		1	730
					72				
	200				295				
5	100	10	59	10	291	125		15	840
					104				
	200	18		10	187			19	
6	200	20	25	10 or 20	244	164	5	8 days	36
7	100	3		20	295	140			36
					60				
	200	23	30	10	235				
8	200	19	22	15	302	202	22		74
9	200	14	16	20	300	201			1,180
10	200	15	17	20	307	206			1,100
11	200	15	17	20	300	201			1,200
12	200	15	17	20	313	210			46
13	200	13	15	20	258	173			760
14	1,000	5	5	20	100	68	12	2	79
15	1,000	5	6	20	100	68	3		88
16	1,000	5	6	20	100	68		8	620
17	1,000	6	7	20	120	82		8	37
18	1,000	5	5	20	100	68			660
19	1,000	14	17	20	283	192			600
20	1,000	15	17	20	300	204			21
21	1,000	15	21	20	292	199			560
22	1,000	15	18	20	300	204			560
23	1,000	15	19	20	302	205			420
24	1,000	6	7	20	120	82			510
25	1,000	2	2	20	40	27			2
25	1,000	26	38	10	299	203			350
					259				
	200	4		10	40				
27	1,000	27	40	10	301	204			390
					271				
	200	3		10	30				
28	1,000	47	92	5	298	201			220
					85				
	200	41		5	213				
29	1,000	15	68	5	278	187	6		210
					75				
	200	37		5	203				

four weeks during the entire period of observation. Many patients did not keep all their appointments. During the treatment period each patient was instructed to remain on his regular diet and to take the normal amount of fluid.

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correlated with the quality, the individual fractions, or the total amount of radiation given.

The platelet count did not change significantly during or after treatment in any of the patients.

The sternal-marrow studies that were made on nine of the patients revealed no abnormalities. However, these studies cannot be considered adequate because they were made both before and after treatment on only two patients. On the other seven patients they were made only after treatment.

The prothrombin concentration did not deviate beyond the normal limits in the 11 patients for whom it was determined.

The sedimentation rate of the erythrocytes was determined on 15 patients. No significant deviations from the pretreatment values were observed at any time.

No changes were observed in the icteric index of the 18 patients for whom it was determined before and after treatment.

#### 6. SUMMARY

1. Hematological studies were made on 29 patients who were treated by exposing their whole bodies to x-rays generated by 100, 200, or 1,000 kv. Twenty-six of the patients were observed for sufficiently long periods of time to be of use in this study.

2. Significant changes in the number of blood cells were observed in all the patients, and some of these changes appear to be relatively constant.

3. The most consistent change was a decrease in the absolute number of lymphocytes following treatment, irrespective of the size of the dose and of the physical factors of treatment. This decrease was followed by a return to normal in the posttreatment period.

4. A decrease in the number of nuclear lobes per 100 neutrophils was a consistent finding in the nine patients for whom the lobation index was studied.

5. The number of monocytes varied greatly as a result of exposure to radiation but always returned to normal. The most frequent change was a large increase in numbers during the course of treatment.

6. After the conclusion of treatment, frequently near the thirtieth and sixtieth days, significant deviations in the total white blood cell count and in the counts of the separate types of leucocytes were observed in almost all the patients. In the late posttreatment period similar significant changes were frequent. These were observed at intervals varying most often between 150 and 300 days, and in some patients as late as 680 days.

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7. The erythrocyte counts and the concentration of the hemoglobin occasionally showed a decrease during the course of treatment, followed by a recovery to preirradiation levels in the early posttreatment period. In the late posttreatment period a temporary macrocytic hyperchromic anemia was observed in many of the patients.

No changes in prothrombin concentration, sedimentation rate, icteric index, or platelet count of any of the patients were observed.

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