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BLOOD CHANGES IN HUMANS FOLLOWING TOTAL BODY IRRADIATION

Written by

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Introduction

A major problem facing the Manhattan Project was the protection of workers against damage resulting from either acute or chronic exposure to external radiation. It was anticipated that the total dose sustained by personnel and the rate of administration could vary widely. Further, there was the problem of assessing the damage, either transitory or permanent, which might arise from such exposures. The problem of detecting evidence of damage following exposure to total body radiation led to this study.

Both the experimental(1)(2)(3)(4) and clinical(5)(6)(7) evidence pointed to the blood-forming organs as some of the most radiosensitive tissues in the body. When this study was undertaken, the work previously done on this subject indicated that changes in the blood-forming organs and in the hematological constituents of the peripheral blood were a good index of exposure of the whole body to radiation, whether chronic as seen in occupational exposure(6)(8) or acute as in radiation therapy(9)(10). The responses of this system can be readily, although indirectly inferred by serial determinations of the absolute numbers and ratios of the various cellular elements of the blood. The major changes observed in the peripheral blood and reported in the literature are epitomized in the following paragraphs.

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After acute exposure to large amounts of radiation, a precipitate fall had been noted in the absolute number of lymphocytes together with a transient, marked increase in the number of neutrophiles, followed by a marked decrease in their numbers. The time necessary for the return to normal of both lymphocytes and neutrophiles was prolonged, and roughly proportional to the amount of radiation received by the subject. Depressions in the number of platelets had been described by some investigators(9)(11) but was not a constant finding. Alterations in the number of red blood cells and in the amount of hemoglobin were not usually noted.

After exposure to chronic (occupational) radiation, the number of lymphocytes was variously described as being increased or decreased. The number of neutrophiles was commonly said to be decreased. Increase of the number of monocytes has been described. Thus, although the total white blood cell count could be within the normal range, the relative numbers of the various elements might vary markedly. Alterations in the hemoglobin value or in the number of red blood cells and platelets were usually described as a relatively late result of persistent exposure to low levels of radiation.

Because of the dependence which was being placed on certain persistent deviations of the elements in the peripheral blood, it seemed expedient to reinvestigate in man, both here and elsewhere(12)(13), the effects of total body radiation.

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To be added as 2nd paragraph, page 5, under "Material":

The people used in groups I and II were individuals to whom the medical profession could offer no treatment that was at all specific or known to be helpful. The x-ray exposures that were given had as reasonable a chance as, or even a more reasonable chance than any other known type of treatment of doing the patients some good. Since this manuscript is concerned only with the effects on the blood, the clinical condition of the patients is not discussed at any length.

Material

Three general groups are used for the persons who were subjected to radiation during this study. The first group consisted of eight persons who had neoplasms which could not be cured but still were not extensive enough to influence general health. This group was given total body irradiation in single exposures, with doses of 27, 60, and 120. The second group consisted of three persons who had illnesses which were generalized and chronic in nature. They were given total body irradiation in multiple exposures, with total doses of 100, 300, and 500. The third group consisted of three normal volunteers from the personnel of the Metallurgical Laboratory. Insofar as is known, they had no abnormalities. This group was given total body irradiation in three divided doses to a total of 21 r.

Methods

Laboratory Examinations. The changes in the peripheral blood cells were studied. The tests included determination of the hemoglobin in g%; hematocrit in cc per 100 cc; numbers of red blood cells, white blood cells and platelets per mm^3; and estimation of the number and percentage of the various elements of the white blood cells. The differential was commonly based on 500 cells. The normal values for this laboratory are given in Chapter IV of this volume.

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In most of the cases studied at the Billings Hospital special biochemical studies on blood, urine, and feces were also performed. These will be reported in detail elsewhere in this series (Schwartz, Vol. 20-1). In one case serial bone marrow biopsies were performed.

The physical factors involved in the treatments are given in Table I. The first group of 8 patients was treated with 400 KV x-rays, the treatment being given with the patient seated in a light wooden chair with either the right or left side of the body toward the x-ray tube. All of the body, except the feet, was included in the field. The dose was measured by a Victoreen Integron, checked in each instance by determinations with a Victoreen r meter, using a 25 r ionization chamber. The ionization chamber was placed in the breast pocket of the patient's dressing gown.

The patients in the second and third groups were treated with 200 KV x-rays through somewhat smaller fields. Two fields were used anteriorly and two posteriorly to cover the entire person while lying down. The dose given to each of the two fields was considered as the dose to the whole body. The roentgens per treatment varied from 7 to 100. In group two, the treatment was given in from 2 to 30 days. In group three, the treatments were always given in 3 days.

In calculating the dose administered to the patients in groups two and three the amount received by the anterior surface was added to that received by the posterior surface and was called the "total body exposure". For example, exposure of each of the anterior and posterior fields to 20 r was interpreted as an exposure of the patient to 40 r. We are aware that this is contrary to usual clinical practice, but felt

Table I.

Physical Factors Used.

Case	Date	KV	Ma	Filter mm	HVL mm cu	TSD cm	Field in cm	r/min (skin)	Time min/Rx	r/Rx (skin)	Total r (skin)
1	3-19-43	400	5	3 Cu	5	320	77 x 92	1.0	60	60	60
2	3-19-43	400	5	3 Cu	5	320	"	1.0	60	60	60
3	4-17-43	400	5	3 Cu	5	320	"	1.0	60	60	60
4	4-17-43	400	5	3 Cu	5	320	"	1.0	60	60	60
5	6-4-43	400	5	5 Cu	7	320	"	0.45	60	27	27
6	6-26-43	400	5	3 Cu	5	320	"	1.0	120	120	120
7	8-27-43	400	5	3 Cu	5	320	"	1.0	120	120	120
8	9-11-43	400	5	3 Cu	5	320	"	1.0	120	120	120
9	11-26 and 11-27-43	200	20	1 Cu 1 Al	1.5	150	80 x 40	5.2	21.6	107	
	12-16 to 12-20-43	200	20	1 Cu 1 Al	1.5	150	"	5.2	14.0	73	506
10	10-10 to 11-12-44	200	20	1 Cu 1 Al	1.5	150	75 x 55	5.0	2.5	12.5	300
11	11-13 to 11-21-46	200	20	1 Cu 1 Al	1.5	150	80 x 45	5.0	2.5	12.5	100
12	10-16 to 10-18-44	200	20	1 Cu 1 Al	1.5	150	"	5.0	1.5	7	21
13	10-30 to 11-1-44	200	20	1 Cu 1 Al	1.5	150	76 x 46	5.0	1.5	7	21
14	11-20 to 11-22-44	200	20	1 Cu 1 Al	1.5	150	"	5.0	1.5	7	21

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justified in doing so because the worker exposed to occupational radiation may receive radiation from any direction, but usually only from one direction at a time. His maximum permissible level of exposure is not 100 mr to each body surface, but a total of 100 mr to all surfaces. Consequently, the addition of the doses to the anterior and posterior body surfaces seems to best approximate the situation of the worker.

Results

Group I.

Case I. A 53-year old white male | with carcinoma of the epiglottis and extensive bilateral cervical metastases was given local radiation therapy to the affected areas between November, 1942 and January, 1943. His general condition was good but regrowth of the cervical lymph nodes showed his outlook to be hopeless. Therefore, on March 19 1943 he was given a total body exposure of 60 r.

Figure 1 and Table II show the hematological response. They show that the white blood cell count dropped immediately following the treatment, the decrease being transient. The major effect of the treatment was found to be on the lymphocytes which decreased in number immediately following the treatment, the reduced level persisting throughout the 157 days of observation. The elements of the blood did not show any alterations which were attributed to the effects of the radiation.

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Table II.

Hematological Studies in Case I.

Time		Hgb gms %	RBC M/mm³	WBC/mm³	Poly %	Poly Abs	Lymph %	Lymph Abs	Mo %	Eos %	Bas %	Plat/mm³
Pre Rx	Post Rx											
0		15.9	4.56	6400	61	3904	36	2304	0	2	1	270,000
	1h	--	--	6100	79	4909	20	1220	0	1	0	---
	3h	--	--	4700	76	3572	16	752	6	1	1	---
	5h	--	--	3700	76	2812	19	703	3	2	0	---
	1d	--	--	5000	81	4050	15	750	2	1	1	---
	2d	--	--	5500	75	4125	23	1265	1	1	0	---
	3d	--	4.50	5600	78	4368	21	1176	0	0	0	230,000
	4d	--	--	5100	72	3672	19	969	7	1	1	---
	8d	16.0	4.66	5000	72	3600	25	1250	1	1	1	200,000
	15d	15.7	5.36	6000	80	4800	17	1020	2	1	0	---
	29d	14.6	4.95	5200	74	3848	22	1144	2	1	1	180,000
	46d	--	--	5900	73	4307	18	1062	7	1	1	210,000
	58d	--	--	5000	65	3250	24	1200	8	2	1	210,000
	72d	---	--	6200	76	4712	17	1054	5	1	1	---
	86d	--	--	6500	76	4940	15	975	7	1	1	260,000
	115d	--	--	5800	77	4466	18	1044	4	1	0	---
	143d	--	--	10,500	80	8400	11	1155	7	1	1	220,000
	157d	--	--	7100	80	5680	12	852	0	0	0	103,000

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Figure 1. Case I . Responses of blood elements following a single exposure of the entire body to 60 r.

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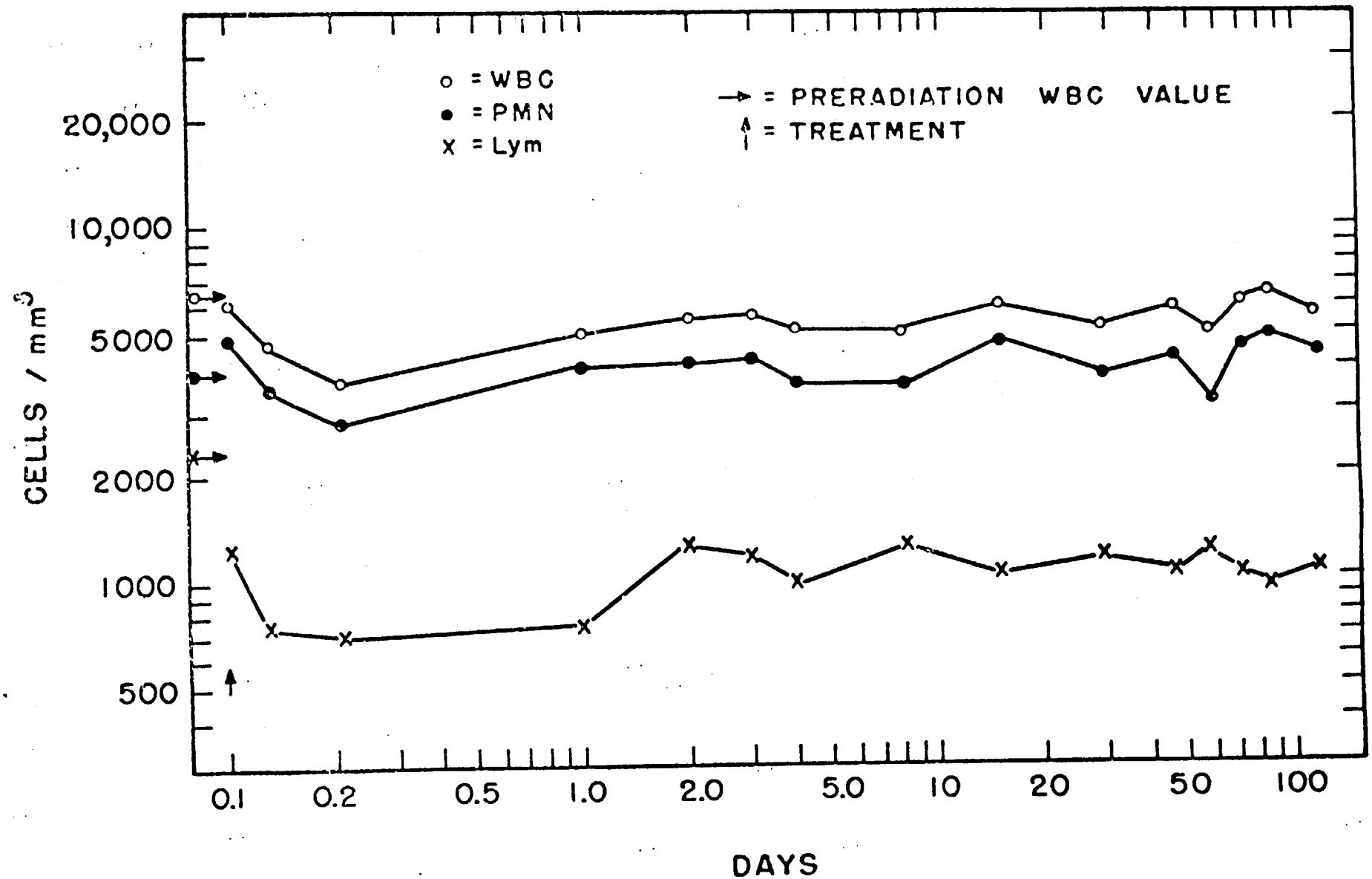

Figure 1.

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Case II. A 75-year old white male was found to have a carcinoma involving the right tonsillar pillar and fossa, the right lateral pharyngeal wall, the base of the tongue, and the floor of the mouth. No palpable lymphadenopathy was noted. Between December, 1942 and February, 1943, 7200 r through a single right lateral cervical portal was given. On March 19, 1943 his general condition was fair but response to treatment showed that cure was not to be expected. A total body exposure to 60 r was given. The results of the hematological studies are to be found in Table III and Figure 2. The total white blood cell count increased immediately following the completion of the x-ray exposure. The duration of the increase was only a few hours. The lymphocytic values increased for 3 hours and then fell below the initial level, the decrease persisting throughout the 151 days of observation. The platelet count dropped moderately from the 29th to the 71st day. The other elements of the blood studied did not show any significant change.

Case III. A 59-year old white male was found in December, 1942, to have a squamous cell carcinoma of the epiglottis, with metastases to the right cervical region. Local x-ray therapy was given during January, 1943. On April 17, 1943 the primary lesion was apparently healed, but the mass in the right cervical region was still present although reduced in size. On that date 60 r of total body radiation was given.

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Table III.

Hematological Studies in Case II.

Time Pre Rx	Time Post Rx	Hgb gms %	RBC M/mm³	WBC/mm³	Poly %	Poly Abs	Lymph %	Lymph Abs	Mo %	Eos %	Bas %	Plat/mm³
0		12.5	3.68	6300	52	3276	44	2772	1	2	1	330,000
	1h	--	--	8200	67	5544	28	3296	2	2	1	---
	3h	--	--	10,300	60	6180	35	3605	1	3	1	---
	5h	--	--	5800	62	3596	33	1904	2	2	1	---
	1d	--	--	5900	66	3894	25	1470	5	3	1	---
	2d	--	--	7000	64	4480	28	1960	5	3	0	---
	3d	13	3.50	5500	67	3685	24	1320	6	3	0	220,000
	4d	--	--	5600	69	3814	22	1232	5	3	1	---
	8d	13	3.82	5200	66	3432	28	1456	2	3	1	266,000
	15d	14	3.65	5100	65	3315	25	1275	9	1	0	365,000
	29d	13.6	4.00	5600	68	3808	29	1624	2	1	0	120,000
	45d	--	--	6400	65	4485	27	1863	6	2	0	150,000
	57d	--	--	5700	64	3648	27	1539	6	2	1	140,000
	71d	--	--	5400	66	3564	26	1404	5	1	2	150,000
	85d	--	--	6500	64	4160	27	1755	6	2	1	220,000
	120d	--	--	8000	73	5840	21	1680	5	1	0	---
	151d	11.7	3.82	5100	72	3672	21	1021	5	2	0	120,000

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Figure 2. Case II : Responses of blood elements following a single exposure of the entire body to 60 r.

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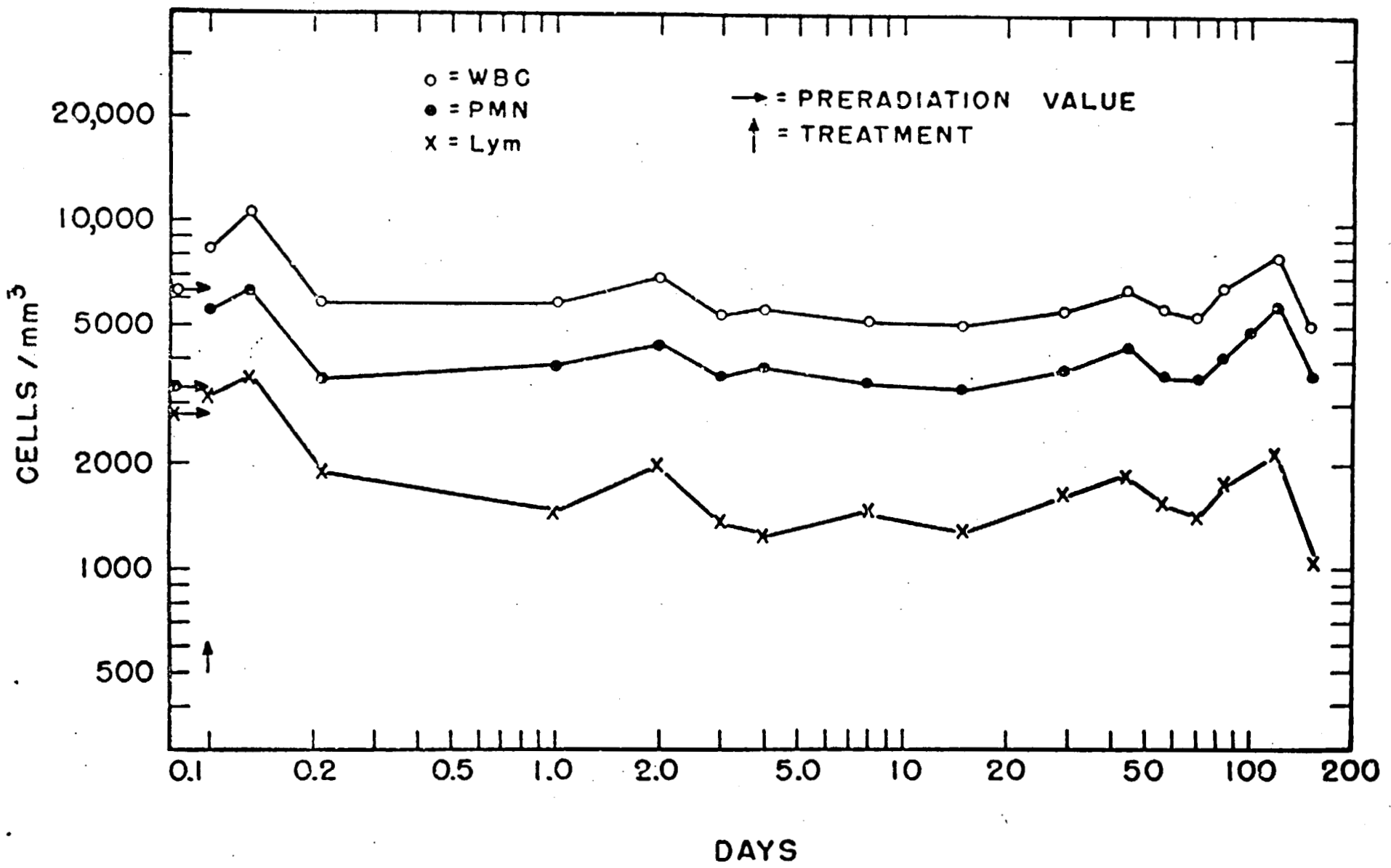

Figure 2.

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The hematological data are given in Table IV and Figure 3. The total white blood cell count decreased during the first few hours following the completion of treatment; thereafter no significant alteration was seen. The lymphocytic values decreased sharply immediately following the treatment. The values returned to pre-radiation levels approximately two weeks after the completion of the treatment. No other abnormalities were attributed to the effects of the radiation exposure.

Case IV: A 72-year old white female gave a history in January, 1942, of a mass in the right breast for the past 5 years. Examination revealed a carcinoma of the right breast with metastases to the right axilla and supraclavicular region. Local radiation therapy was given to the right breast and axilla in January, 1942. On April 7, 1943, 60 r of total body radiation was given. At that time the local disease and metastases were uncontrolled, but no other metastases were noted and her general condition was fair.

The results of the hematological studies are given in Table V and Figure 4. A mild, transient decrease in the number of lymphocytes in the circulating blood is shown. No other effect of the exposure is seen. The increase in number of white blood cells on the 56th and 154th days was associated with acute upper respiratory infections.

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Table IV.

Hematological Studies in Case III.

Time		Hgb	RBC	WBC/	Poly		Lymph		Mo	Eos	Bas	Plat/mm^3
Pre Rx	Post Rx	Gms %	M/ mm^3	mm^3	%	Abs	%	Abs	%	%	%	
0		16.8	4.70	8900	65	5184	28	2492	3	4	0	360,000
	1h	--	--	7900	61	4819	35	2765	1	3	0	---
	3h	--	--	5200	69	3588	26	1152	2	3	0	---
	5h	--	--	5400	74	3976	21	1134	1	4	0	---
	2d	--	--	6000	76	4560	18	1080	2	2	0	300,000
	3d	--	--	6700	75	5025	19	1263	4	2	0	300,000
	5d	--	--	8200	62	5084	23	2296	8	2	0	220,000
	7d	--	--	6000	62	3720	31	1860	3	4	0	220,000
	16d	--	--	6300	71	4473	23	1449	3	2	1	280,000
	49d	--	--	7400	66	4884	26	1824	4	3	1	230,000
	56d	--	--	8100	68	5508	24	1944	5	3	0	350,000
	167d	16.4	4.26	9400	67	6308	21	1974	6	6	0	200,000
	181d	15.9	4.39	5500	68	3740	32	1760	5	5	0	180,000
	196d	15.8	4.31	8400	73	6132	22	1848	0	4	0	210,000
	209d	17.0	4.35	9200	72	6624	19	1748	4	5	0	---
	223d	16.8	4.33	6600	65	4290	31	2046	2	2	0	---
	289d	14.5	4.40	6800	65	4420	34	2210	1	0	0	398,000
	363d	14.5	4.00	8400	65	5460	28	2352	1	6	0	253,000
	377d	14.9	4.23	7750	70	5425	20	1550	2	8	0	207,000
	391d	16.5	5.42	7900	62	4898	27	2133	4	5	2	224,000
	3d	14.9	4.75	11,500	59	6844	30	3480	3	6	2	---

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Figure 3. Case III . Responses of blood elements following a single exposure of the entire body to 60 r.

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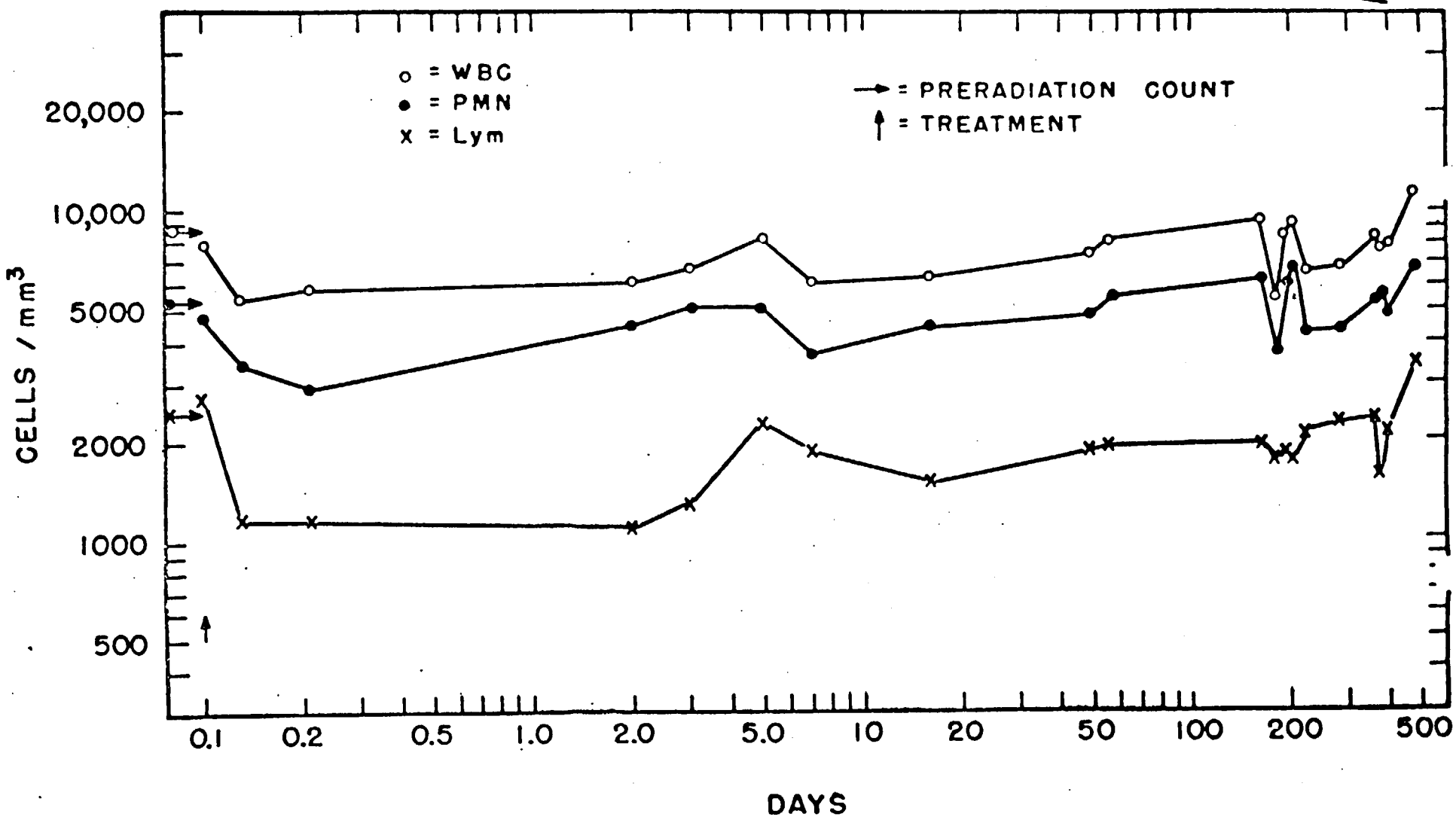

Figure 3.

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Table V.

Results of Hematological Studies in Case IV.

Time		Hgb gms %	RBC M/mm^3	WBC/mm^3	Poly		Lymph		Mo %	Eos %	Bas %	Plat/mm^3
Pre Rx	Post Rx				%	Abs	%	Abs				
17d		14.0	4.23	7400	69	5106	28	2072	3	0	0	176,000
2d		13.5	4.34	7800	58	4524	36	2808	6	0	0	255,000
0		13.5	4.22	8400	65	5460	29	2436	4	1	1	220,000
	1h	--	--	7800	74	5772	20	1560	5	1	0	---
	3h	--	--	7700	70	5390	23	1771	7	0	0	---
	5h	--	--	8300	60	4980	32	2656	7	1	0	---
	1d	--	--	8600	67	5762	23	1978	9	1	0	---
	2d	--	--	6800	72	4896	22	1496	6	0	0	240,000
	3d	--	--	7000	72	5040	23	1610	4	1	0	190,000
	5d	--	--	8100	61	4941	35	2835	3	1	0	160,000
	7d	--	--	6200	66	4092	29	1798	4	1	0	195,000
	12d	14.0	4.25	9900	61	6039	32	3168	6	1	0	160,000
	16d	--	--	6900	70	4690	25	1725	5	0	0	180,000
	21d	--	--	7100	68	4828	27	1917	4	1	0	190,000
	28d	--	--	6200	69	4278	26	1592	4	1	0	140,000
	42d	--	--	6600	57	3762	36	2376	6	1	0	180,000
	56d	--	--	14,000	83	10,820	15	2100	2	0	0	185,000
	70d	--	--	9800	66	6468	29	2842	4	1	0	125,000
	84d	--	--	7900	63	4977	31	2449	5	1	0	220,000
	112d	--	--	7200	59	4248	37	2664	4	0	0	260,000

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Table V. (cont'd)

Results of Hematological Studies in Case IV.

Time		Hgb Gms %	RBC M/mm^3	WBC mm^3	Poly		Lymph		Mo %	Eos %	Bas %	Plat/mm^3
Pre Rx	Post Rx				%	Abs	%	Abs				
	140d	--	--	7500	59	4425	38	2850	3	0	0	270,000
	154d	14.5	3.82	11,500	71	8165	27	3105	2	0	0	400,000
	168d	--	--	6300	68	4284	27	1701	4	1	0	220,000
	182d	--	--	6500	70	4550	26	1690	3	1	0	163,000
	207d	--	--	7400	67	4958	29	2146	3	1	0	205,000

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Figure 4. Case IV . Responses of blood elements following a single exposure of the entire body to 60 r.

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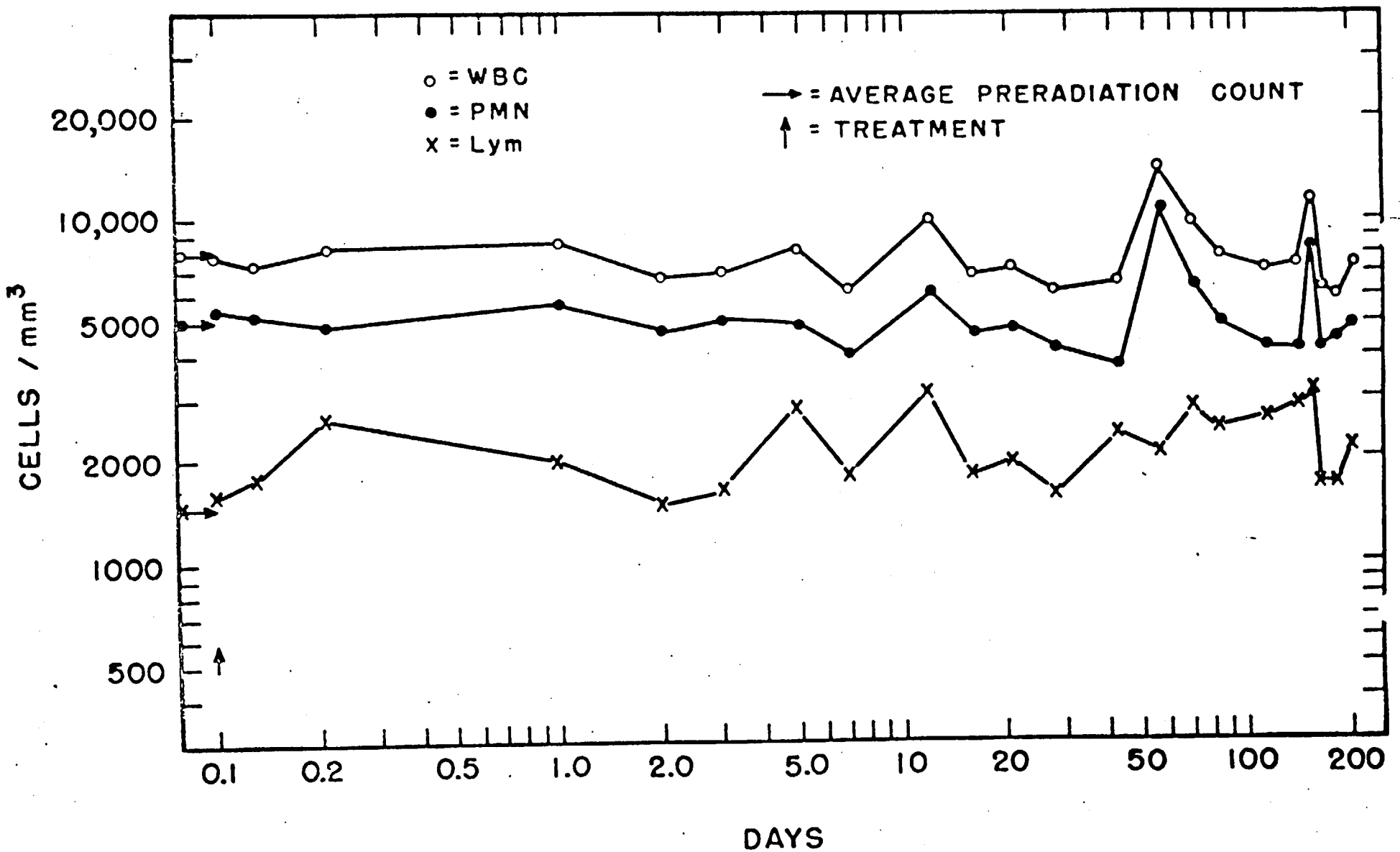

Figure 4.

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Case V. A white male | , aged 57, showed in October, 1942 an advanced carcinoma of the epiglottis involving the left subglottal region. In that month, 6500 r was given to the left cervical region, but the local lesion was not controlled. Metastatic lesions were noted subsequently in the cervical lymph nodes. Tracheotomy was done in April, 1943. On June 4, 1943, 27 r total body radiation was given. His general condition at that time was good.

The results of the hematological studies are given in Table VI and Figure 5. The total white blood cell count increased slightly following the treatment and a slight leukocytosis is noted throughout the 174 days of observation.

Case VI. A 61-year old male , in January, 1939 had a carcinoma of the left hemilarynx with fixation of the larynx. During January and February, 1939, 4050 r was given to the lesion through a single field. On June 26, 1943, 120 r total body radiation was given. The patient's general condition was good, although the local disease was uncontrolled at that time.

The results of the hematological studies are given in Table VII and Figure 6. The 24 and 48 hour platelet counts are depressed. The post-radiation lymphocytic values are all distinctly lower than the pre-radiation value. This effect persisted throughout the period of study, and is the dominant post-radiation change.

Case VII. A 65-year old white male | was found to have a transitional cell carcinoma of the larynx, which was treated with x-rays in May and June, 1943. The local disease was uncontrolled, however. On August 28, 1943, 120 r total body radiation was given.

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Table VI.

Results of Hematological Studies in Case V.

Time		Hgb	RBC	WBC/	Poly		Lymph		Mo	Eos	Bas	Plat/mm^3
Pre Rx	Post Rx	gms %	M/mm^3	mm^3	%	Abs	%	Abs	%	%	%	
0		11.9	4.28	9600	73	7008	19	1824	5	2	1	---
	1h	--	--	9800	75	7350	18	1764	4	3	0	---
	3h	--	--	10,600	78	8268	18	1908	3	1	0	---
	5h	--	--	12,500	78	9750	15	1875	4	2	1	---
	1d	--	--	11,000	72	7920	18	1980	8	1	1	---
	2d	--	--	11,000	74	8140	17	1870	6	2	1	340,000
	3d	--	--	12,200	75	9150	17	2074	5	2	1	350,000
	4d	--	--	11,000	75	8250	18	1980	4	2	1	335,000
	8d	--	--	9900	75	7525	17	1693	5	1	2	400,000
	15d	--	--	9100	70	6370	24	2184	5	1	0	240,000
	21d	--	--	9500	67	6375	19	1805	4	3	1	300,000
	35d	--	--	8400	73	6132	20	1680	5	2	0	375,000
	49d	--	--	10,400	66	6864	23	2392	7	4	0	225,000
	63d	--	--	7300	63	4599	25	1825	9	3	0	213,000
	77d	--	--	7700	72	5544	18	1386	6	2	1	210,000
	91d	--	--	9000	71	6390	20	1800	6	2	1	270,000
	119d	11.5	4.40	10,800	77	8346	14	1572	6	3	0	310,000
	133d	11.2	4.26	8200	78	6396	18	1476	2	2	0	270,000
	147d	12.4	3.91	14,900	91	13,559	9	1241	0	0	0	320,000
	160d	12.4	3.64	10,400	70	7280	19	1976	6	4	1	320,000
	174d	11.8	3.59	10,600	75	7950	17	1802	4	3	1	380,000

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Figure 5. Case V , Responses of blood elements following a single exposure of the entire body to 27 r.

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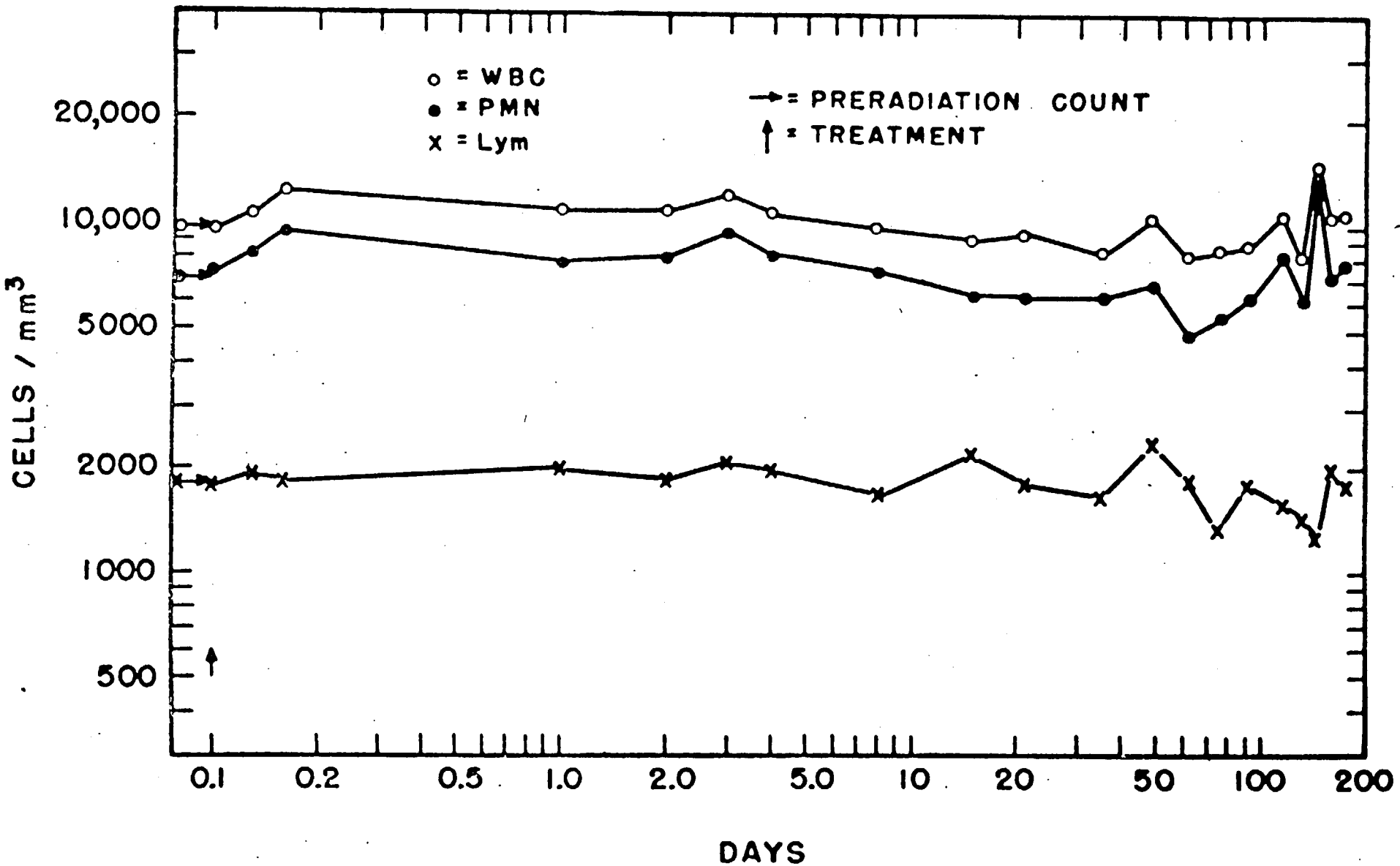

Figure 5.

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Table VII.

Results of Hematological Studies in Case VI.

Time		Hgb	RBC	WBC	Poly		Lymph		Mo	Eos	Bas	Plat/mm^3
Pre Rx	Post Rx	gms %	M/mm^3	mm^3	%	Abs	%	Abs	%	%	%	
0		15.2	4.50	9400	76	7144	21	1974	2	1	0	203,000
	2h	--	--	9900	73	7227	23	2227	3	1	0	---
	4h	--	--	7370	77	5621	18	1314	3	2	0	---
	6h	--	--	8050	71	5680	24	1920	4	1	0	---
	1d	--	--	7300	75	5475	19	1387	5	1	0	70,000
	2d	--	--	8670	82	7052	15	1290	3	0	0	140,000
	3d	--	--	7070	73	5183	22	1562	4	1	0	244,000
	4d	--	--	8480	85	7225	10	840	4	1	0	218,500
	7d	--	--	6400	74	4736	22	1408	3	1	0	261,000
	14d	--	--	8100	77	6237	18	1458	3	2	0	135,000
	21d	--	--	9800	81	7938	15	1470	3	1	0	---
	28d	--	--	6900	74	5106	19	1311	5	1	1	176,000
	56d	--	--	7400	77	5998	16	1184	3	1	1	120,000
	70d	--	--	8400	78	6552	18	1512	3	1	0	230,000
	98d	--	--	5000	70	3500	21	1050	4	3	1	230,000
	113d	14.9	4.39	5200	71	3692	23	1206	4	2	0	290,000
	127d	14.7	4.20	6100	80	4880	18	1098	0	2	0	153,000

1066796

DOE/HQ

Figure 6. Case VI . Responses of blood elements following a single exposure of the entire body to 120 r.

1066797 DOE/HQ

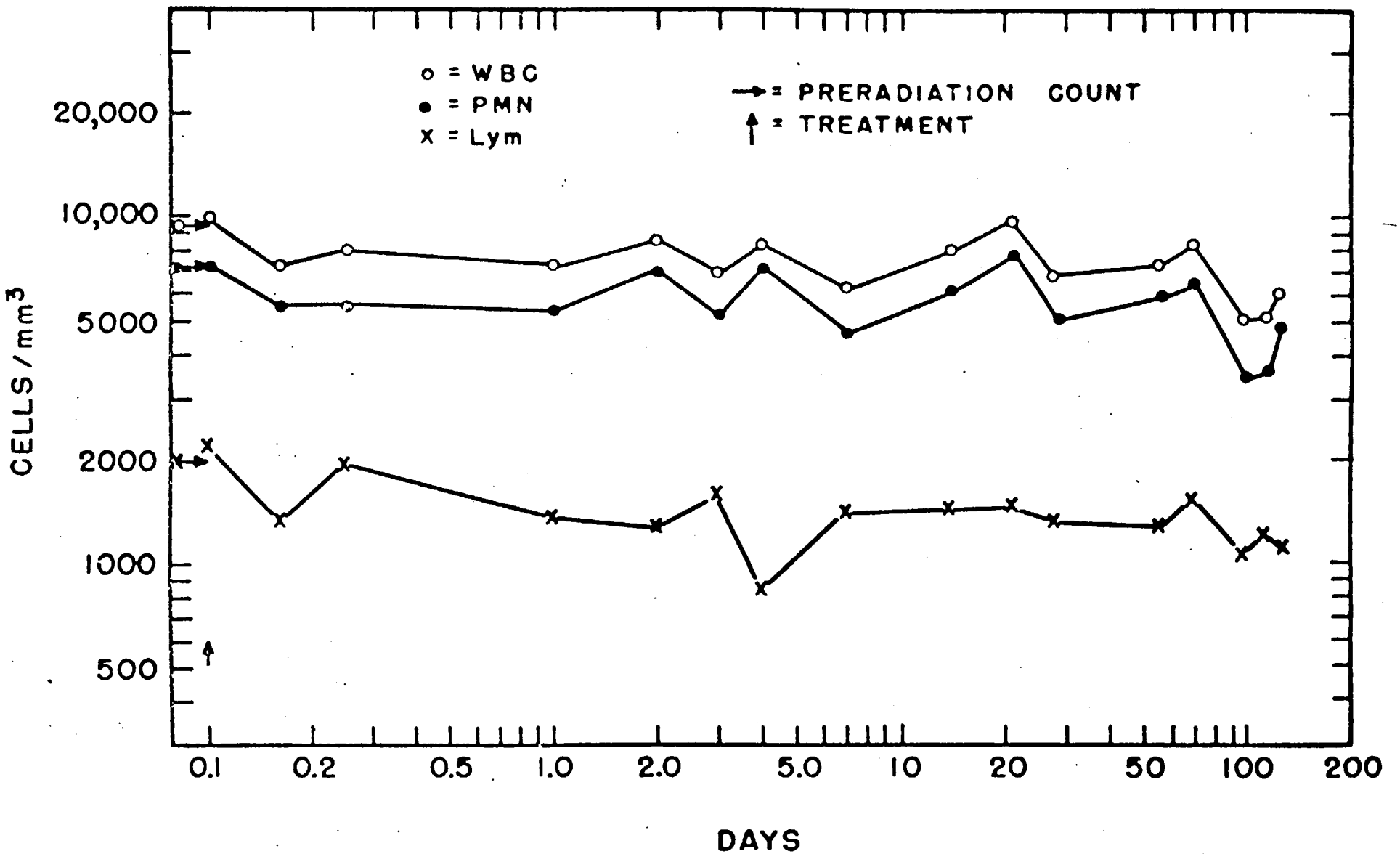

Figure 6

1066798

DOE/HQ

The general condition was fair at the time of the exposure. The laryngeal lesion was infected.

The results of the hematological studies are presented in Table VIII and Figure 7. Leukocytosis due to an elevation in the number of neutrophiles was present throughout the period of observation and was marked on the 49th (last) day. The lymphocyte count was very low on the 35th day. A decrease in the numbers of red blood cells and in amount of hemoglobin is noted.

Case VIII. A 54-year old white male first seen in August, 1943 showed a squamous cell carcinoma of the epiglottis and base of the tongue together with bilateral cervical adenopathy. On September 11, 1943, 120 r total body radiation was given. The hematological studies are given in Table IX and Figure 8.

The total white blood cell count was slightly high throughout the period of observation, due to an increase in the number of neutrophiles. The platelet counts from the second to the fourteenth day were elevated above the pre-irradiation values.

The Arneth counts (Table X) do not show any significant alteration. Arneth counts were done also on other cases in Group I with similar results.

Group II.

Case IX. A 73-year old white male had a squamous cell carcinoma of the dorsum of the right hand with widespread metastases. He was given 502 r total body radiation in six treatments between November 26 and December 20, 1943.

1066799

DOE/HQ

Table VIII.

Results of Hematological Studies in Case VII.

Time		Hgb	RBC	WBC	Poly		Lymph		Mo	Eos	Bas	Plat/mm^3
Pre Rx	Post Rx	gms %	M/mm^3	mm^3	%	Abs	%	Abs	%	%	%	
0		13.6	4.49	14,700	79	11,760	15	2205	5	1	0	---
	1h	--	--	14,900	80	11,920	13	1937	6	1	0	---
	3h	--	--	14,400	78	11,232	14	2016	5	2	1	---
	5h	--	--	15,700	83	13,031	12	1884	4	0	1	---
	1d	--	--	12,900	82	10,578	11	1419	6	1	0	---
	4d	--	--	12,700	85	10,795	13	1651	2	0	0	---
	7d	--	--	12,200	77	9,394	17	2074	5	1	0	310,000
	35d	12.3	4.16	11,100	90	9,990	6	666	4	0	0	270,000
	49d	12.2	4.01	23,700	85	20,145	11	2607	4	0	0	237,000

1066800

DOE/HQ

Figure 7. Case VII , Responses of blood elements following a single exposure of the entire body to 120 r.

1066801

DOE/HQ

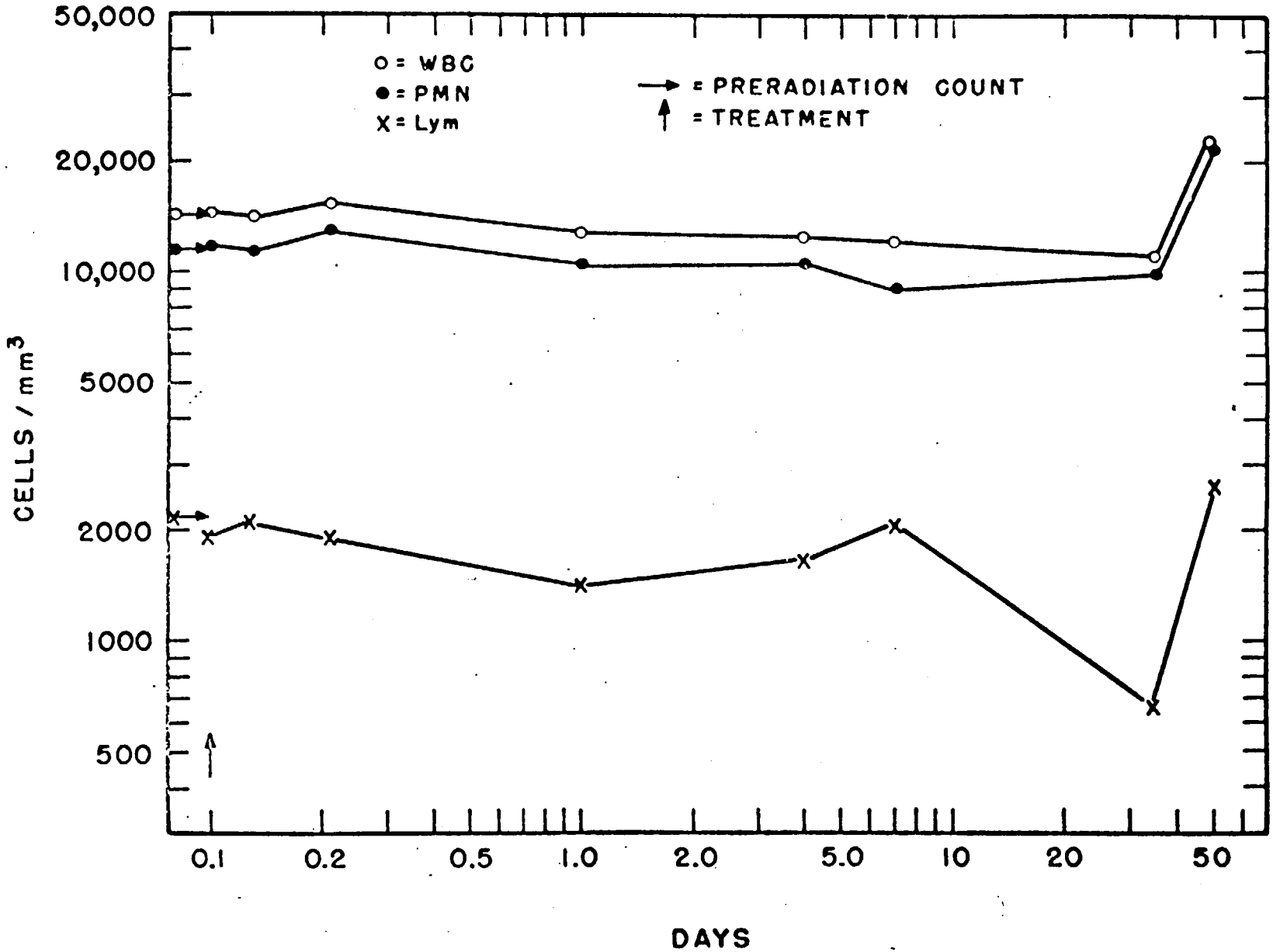

Figure 7.

1066802

DOE/HQ

Table IX.

Hematological Findings in Case VIII.

Time		Hgb gms %	RBC M/3 mm^3	WBC/ mm^3	Poly		Lymph		Mo %	Eos %	Bas %	Plat/mm^3
Pre Rx	Post Rx				%	Abs	%	Abs				
7d		12.6	3.64	13,900	76	10,564	19	2641	5	0	0	301,000
0		--	3.80	11,000	65	7150	24	2640	10	0	1	170,000
	2h	--	3.81	14,500	74	10,730	18	2610	6	1	1	370,000
	4h	--	--	11,900	76	9044	16	1904	7	1	0	350,000
	6h	--	4.15	13,400	75	10,050	20	2680	4	1	0	300,000
	1d	--	4.11	11,700	78	9126	15	1755	5	2	0	310,000
	2d	--	--	12,900	81	10,449	13	1677	5	1	0	530,000
	4d	--	--	12,400	85	10,064	12	1488	2	0	0	500,000
	8d	13.0	4.01	10,300	85	8755	13	1399	2	0	0	480,000
	15d	12.3	3.98	11,900	80	9520	14	1666	6	0	0	500,000
	39d	12.5	3.80	11,000	71	7810	24	2640	4	1	0	370,000
	50d	10.6	3.57	15,700	89	13,973	11	1727	0	0	0	220,000

1066803

DOE/HQ

Table X.

Arneth Counts in Case VIII.

Time		Arneth Count					Total Number Lobes
Pre Rx	Post Rx	1	2	3	4	5	
0		9	44	34	11	2	253
	2h	10	39	42	8	1	251
	4h	12	34	43	11	0	258
	6h	9	43	36	12	0	251
	1d	6	35	43	14	2	269
	2d	13	34	33	19	1	266
	4d	12	38	43	7	0	245
	8d	19	34	42	5	0	233
	15d	16	44	32	8	0	232
	39d	18	40	35	6	1	232
	50d	17	42	34	7	0	231

1066804

DOE/HQ

Figure 8. Case VIII — Responses of blood elements following a single exposure of the entire body to 120 r.

1066805

DOE/HQ

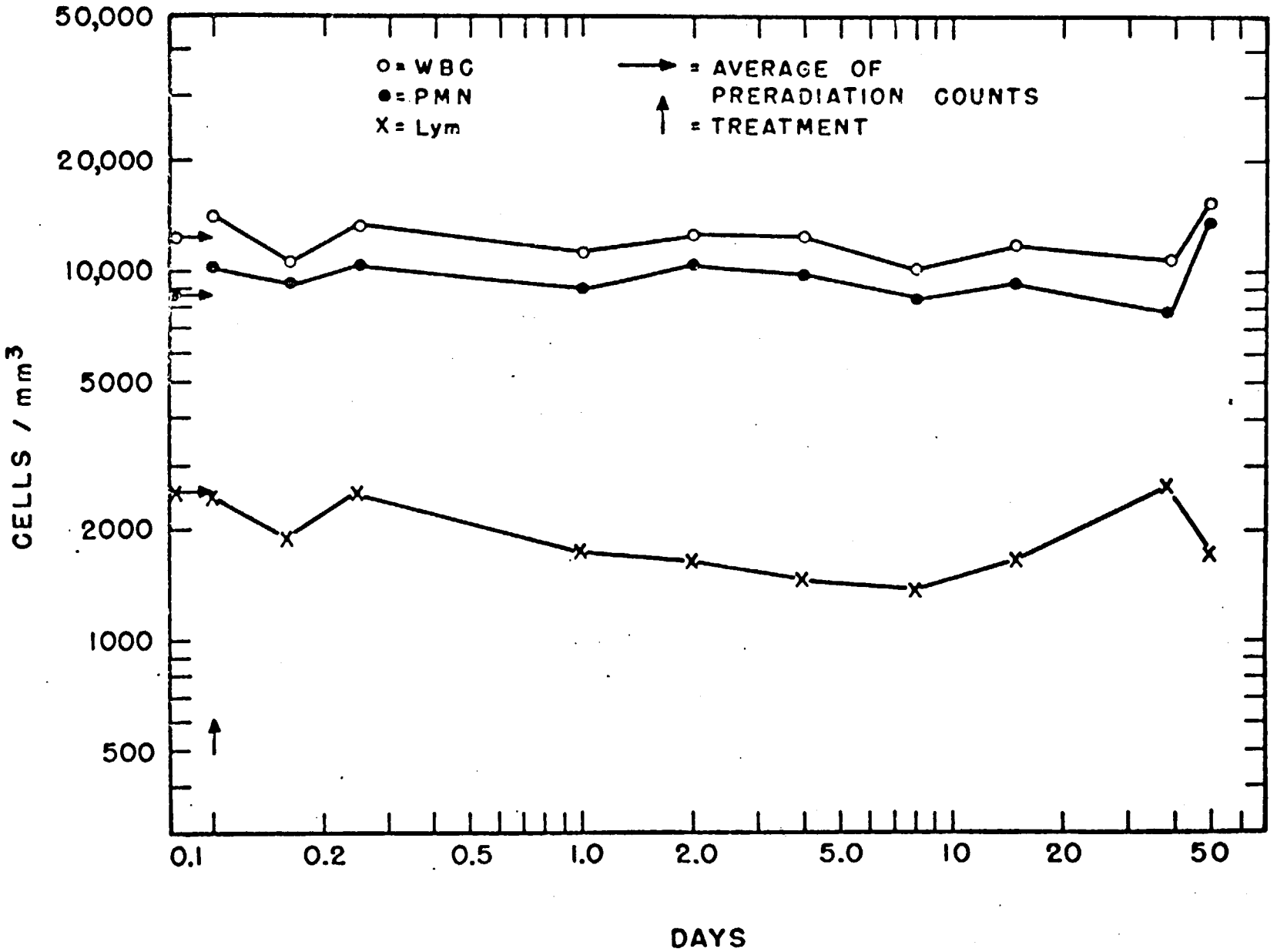

Figure 8.

10bb80b

DOE/HQ

The first and second treatments were given on November 26 and 27, and the third to the sixth treatments were given on December 16, 17, 18, and 20.

Transient nausea and vomiting were noted after the first two treatments and again after the sixth. Because of the condition of the patient (see Figure 9), 3750 cc of citrated whole blood was given to him between the 26th and 30th days. His general condition was poor for one week after the completion of the treatments. The clinical recovery was preceded by an increase in the white blood cell levels.

The hematological data are presented in Table XI and Figure 9. The total white blood cell count was somewhat depressed by the first two treatments, the general level falling by about 2,500 cells per mm^3. A profound effect was noted following the third and subsequent treatments; the total white blood cell count dropped steadily from the 18th day to the 31st day at which time it reached a low of 350. The polymorphonuclear cell reactions closely paralleled that of the total white blood cell count. The lymphocytes were markedly reduced in numbers after the first two treatments and did not approach to pre-radiation levels until the 50th day after therapy was begun. Of the blood elements studied, the lymphocytes were affected the earliest and the longest.

Case X. A 67-year old white female had had chronic rheumatoid arthritis since 1941. No previous radiation therapy is known. Total body irradiation to a total of 300 r was given in 33 days in October and and November, 1944. No marked change in the course of the disease was noted during or after the treatments.

1066807

DOE/HQ

Table XI.

Hematological Studies in Case IX.

Time Pre Rx	Time Post Rx	WBC/mm³	Poly %	Poly Abs	Lymph %	Lymph Abs	Mo %	Eos %	Plat/mm³
3d		7800	72	5616	26	2008	0	2	280,000
30h		9200	79	7268	18	1656	3	0	190,000
24h		7750	67	5159	25	1925	2	6	223,000
15h		7200	69	4968	23	1656	5	3	190,000
	* 0	7350	60	4396	27	1971	3	1	160,000
	* 2h	8800	65	5720	28	2464	4	3	200,000
	4h	7950	75	5925	23	1817	1	1	190,000
	6h	7550	79	5925	20	1500	0	1	185,000
	18h	8600	75	6450	18	1528	5	2	200,000
	* 20h	7350	74	5402	22	1606	3	1	180,000
	2d	8300	84	6972	14	1162	0	2	190,000
	3d	4700	80	4136	10	470	0	2	200,000
	3d	6900	89	6141	10	690	1	0	---
	4d	5900	72	5251	12	590	0	0	220,000
	5d	5200	79	3744	17	624	1	6	210,000
	6d	5550	77	4345	22	935	0	3	230,000
	8d	5550	79	4235	17	1210	2	1	200,000
	13d	5550	79	4345	17	935	2	2	230,000
	17d	4800	85	4080	13	624	1	1	180,000
	18d	6400	85	5440	15	960	0	0	200,000
	19d	4500	81	3881	18	810	1	0	180,000
	20d	3090	86	2580	11	335	2	1	150,000
	* 20d	3860	82	3157	16	608	2	0	---
	* 21d	3600	85	3060	14	504	0	1	---
	* 22d	3400	83	2822	15	570	1	1	180,000
	23d	2700	84	2268	13	351	1	2	170,000
	* 24d								
	26d	1250	84	1050	12	150	0	4	230,000
	27d	1000	51	510	36	360	0	13	---
	28d	500	--	--	--	--	-	--	160,000
	31d	350	--	--	--	--	-	--	150,000
	32d	350	--	--	--	--	-	--	150,000
	33d	350	30	105	70	245	-	--	---
	34d	400	--	--	--	--	-	--	190,000
	36d	1550	70	1085	30	465	0	0	150,000
	38d	1100	74	814	24	260		2	200,000
	42d	3000	87	2610	12	360	0	1	110,000
	47d	5500	91	5005	8	440	0	0	120,000
	50d	9000	84	7560	16	1440	0	0	100,000

* Days on which radiation was given.

1066808

DOE/HQ

Figure 9. Case I. Responses of blood elements following exposure of the entire body to 502 r in divided doses.

1066809

DOE/HQ

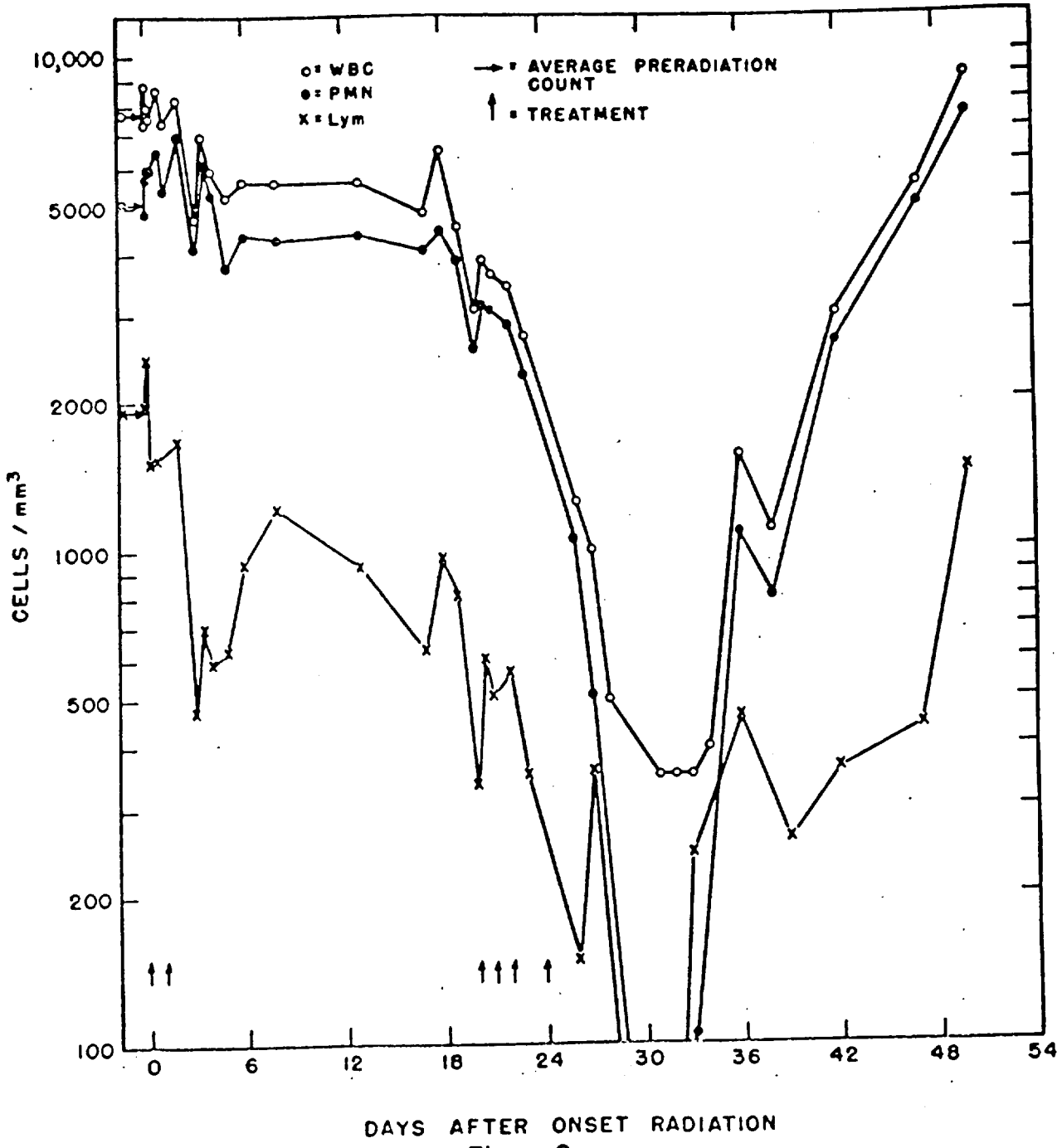
o = WBC
● = PMN
x = Lym
→ = AVERAGE PRERADIATION COUNT
↑ = TREATMENT
10,000
5000
2000
1000
500
200
100
CELLS / mm³
0
6
12
18
24
30
36
42
48
54
DAYS AFTER ONSET RADIATION

Figure 9.

The hematological data are given in Table XII and Figure 10. The total white blood cell count began to decline about 20 days after the treatments were begun. The depression was maximal approximately 50 days after the beginning of therapy and persisted until approximately the 80th day.

The polymorphonuclear cells, their maturity measured by the number of lobes in the nucleus (Arneth count), showed a shift to the more immature forms. The total number of lobes began to decrease by the 15th day after the exposures began, the low point being reached on the 63rd day after the treatments were begun. Recovery was slow; pre-irradiation values were not yet attained when the studies were terminated on the 83rd day, when the patient was discharged from the hospital.

The absolute lymphocyte count fell shortly after the treatments began and remained low throughout the period of observation. The average of the absolute number of lymphocytes in the pre-radiation period is 3220 cells per mm^3. Eight days after x-ray therapy was begun, the lymphocyte value had dropped to approximately one-third of the pre-radiation value. For the remainder of the period of treatment, the number of lymphocytes varied, but usually was low. The period following treatment was characterized by a persistent lymphopenia. The last three recorded lymphocytic counts averaged 1661, approximately 50 per cent of the pre-radiation value. The pre-radiation value is abnormally high and is probably a reflection of the chronic infectious process. The post-radiation value may be

1066811

DOE/HQ

Table XII.

Hematological Findings in Case X.

Time		WBC/mm³	Poly		Monocytes - %	Eosinophiles - %	Basophiles - %	Arneth Count						Lymph		RBC - x 10⁶/mm³	Hgb - gms %	Hct - cc/100 cc	Platelets x 10³/mm³
Pre Rx	Post Rx		%	Abs										%	Abs				
16d		8450	51	4310	6	1	1	5	48	37	10		252	41	3465	4.72	15.5	-	161
14d		8950	54	4833	2	2	1	10	45	38	7		242	41	3670	4.63	14.0	40	188
9d		7800	56	4368	5	2	0	12	44	36	8		240	37	2886	4.81	14.3	42	148
7d		8300	47	3901	5	2	1	13	45	37	5		234	45	3735	4.65	13.5	40	208
5d		8050	51	4106	4	1	1	4	45	45	6		252	43	3462	4.63	13.8	43	198
2d		6450	62	3999	3	2	0	18	42	35	4	1	228	33	2789	4.30	12.6	41.5	155
*0d		7250	67	4858	4	3	0	12	47	34	7		236	35	2539	4.31	12.4	40.5	185
	* 1d																		
	2d	7300	48	3504	5	3	0	10	37	46	7		250	44	3212	4.41	13.4	41.5	187
	* 3d																		
	4d																		
	5d	5800	56	3248	4	0	1	15	39	37	9		240	39	2262	4.14	12.7	41.5	203
	6d																		
	7d	6050	49	3259	4	4	0	9	42	43	6		242	43	2195	4.20	12.9	-	114
	* 8d																		
	* 9d	5450	60	3270	5	3	0	7	44	44	5		247	32	1036	4.19	13.0	40.5	182
	*10d																		
	11d																		
	*12d	6850	61	4179	4	2	0	11	47	39	3		234	33	2261	4.48	13.0	40.0	200
	*13d																		
	*14d	6450	62	3999	4	2	1	8	48	35	9		245	31	2600	4.12	13.7	40.5	201
	*15d																		
	*16d	5800	61	3538	9	5	0	17	52	30	1		215	25	1450	4.33	13.5	41.0	196
	17d																		

* Days on which radiation was given.

1066812

DOE/HQ

Table XII (cont.)

Time			Poly					Arneth Count						Lymph					
Pre Rx	Post Rx	WBC/mm^3	%	Abs	Monocytes-%	Eosinophiles - %	Basophiles - %	1	2	3	4	5	Total	%	Abs	RBC - x 10^6/mm^3	Hgb - gms %	Hct - cc/100 cc	Platelets x 10^3/mm^3
	18d																		
	19d	7200	67	4824	4	2	1	30	50	19	1		191	26	1872	4.34	13.3	40.5	225
	*20d	6300	62	3906	5	2	0	38	45	17			179	30	1890	-	-	-	-
	21d	6350	73	4636	9	2	1	44	35	20	1		178	13	826	4.22	12.9	40.0	202
	*22d	9950	74	7363	6	2	1	43	45	11	1		170	16	1594	-	-	-	202
	*23d	9650	77	7431	9	2	0	44	43	12	1		170	12	1158	4.13	13.0	40	198
	*24d	7800	84	6552	4	2	0	35	46	19			184	10	780	-	-	-	-
	25d																		
	*26d	4850	69	3347	4	3	0	44	40	15	1		173	24	1164	4.05	12.6	39.5	186
	*27d	6150	70	4305	6	4	0	45	38	15	2		174	20	1230	-	-	-	-
	*28d	5400	71	3834	7	3	0	44	47	8	1		168	19	1026	3.90	12.0	39	177
	*29d	5750	70	4025	8	2	0	40	43	16	1		178	20	1150	-	-	-	-
	*30d	4550	68	3094	8	4	0	55	34	10	1		157	20	910	3.90	12.6	39.5	162
	*31d	4950	72	3570	4	4	0	42	8				158	20	990	-	-	-	-
	32d																		
	*33d	4350	69	3001	8	3	0	64	31	4	1		142	20	870	3.82	12.5	39.0	148
	34d	6950	75	5210	3	2	0	55	36	9	1		155	20	1390	-	-	-	-
	35d	4050	68	2760	4	5	1	53	40	7			154	22	891	3.89	12.2	38.5	142
	36d	5950	72	4290	5	4	1	50	36	14			164	18	1070				
	37d	4150	72	2980	4	4	0	52	39	9			157	22	914	3.82	11.9	37.5	121
	40d	3600	60	2160	3	10	0	49	41	9	1		162	27	973	3.63	11.8	35.0	
	42d	4050	60	2430	6	12	0	61	36	3			142	22	892	3.51	12.1	37.0	88
	44d	3100	55	1710	6	16	0	56	37	7			151	22	683	3.46	11.1	34.5	60
	47d	2850	56	1600	3	14	0	58	37	5			147	27	780	3.62	11.5	31.5	58
	49d	3000	54	1620	7	12	0	62	27	10	1		150	27	810	3.79	12.0	37.0	62

* Days on which radiation was given.

1066813

DOE/HQ

Table XII (cont.)

Time			Poly		Monocytes - %	Eosinophilic - %	Basophilos - %	Arneth Count						Lymph		RBC - x $10^6/mm^3$	Hgb - gm %	Hct - cc/100	Platelets x $10^3/mm^3$
								Arneth Count											
Pre Rx	Post Rxq	WBC/mm^3	%	Abs				1	2	3	4	5	Total	%	Abs				
	51d	3500	50	1750	10	10	0	64	33	3			139	30	1050	-	11.3	35.0	155
	54d	2500	40	1000	4	3	1	52	44	4			152	52	1300	3.90	11.8	41.0	15
	56d	3150	52	1612	6	8	0	52	43	5			153	34	1054	3.66	11.4	-	158
	58d	3100	34	1054	10	9	1	55	40	5			150	46	1426	3.53	11.5	35.0	117
	61d	2850	45	1260	7	4	1	68	24	8			140	43	1204	3.49	10.9	30.0	44
	63d	2600	55	1430	9	3	2	80	16	4			124	31	806	3.94	11.6	31.0	164
	65d	2700	48	1296	9	1	1	60	32	8			128	41	1107	3.35	11.5	36.0	201
	68d	3000	55	1680	8	2	1	55	34	11			156	33	990	3.75	11.6	35.0	169
	70d	3400	45	1530	9	2	1	74	18	8			134	43	1462	3.42	11.6	30.0	163
	72d	3550	57	1995	7	3	0	59	35	6			147	33	1155	3.35	11.7	35.0	168
	77d	3750	58	2146	6	2	0	53	35	10	2		161	34	1258	3.39	11.3	33.5	186
	79d	3700	57	2109	8	4	1	54	34	12			158	30	1110	3.31	11.2	33.0	189
	82d	4800	63	3024	7	2	0	57	34	9			152	28	1344	3.21	11.5	35.0	184
	86d	5100	50	2550	6	6	1	47	36	15	2		172	35	1836	3.24	10.9	33.5	199
	89d	5350	65	3445	7	4	0	51	35	13	1		164	24	1272	3.25	11.5	33.0	191
	93d	5200	48	2496	44	8	0	49	35	15	1		168	40	2080	3.33	10.7	35.0	181
	96d	4800	59	2832	3	8	0	50	39	10	1		162	28	1344	3.38	10.9	34.0	214
	100d	6100	53	3233	2	4	1	34	49	17			183	30	1830	3.45	11.0	30.5	183
	105d	4950	53	3089	5	3	0	43	41	13	1		170	26	1274	3.38	10.4	34.0	139
	112d	5900	60	3590	6	4	0	35	45	19	1		186	30	1770	3.84	11.0	35.0	145
	119d	6200	62	3844	5	4	0	33	47	18	2		209	29	1798	3.31	10.9	30.0	140
	126d	5900	61	3599	7	5	0	37	41	19	3		188	24	1426	3.84	11.3	37.0	134

1066814

DOE/HQ

Figure 10. Case X : Responses of blood elements following exposure of the entire body to 300 r in divided doses.

1066815

DOE/HQ

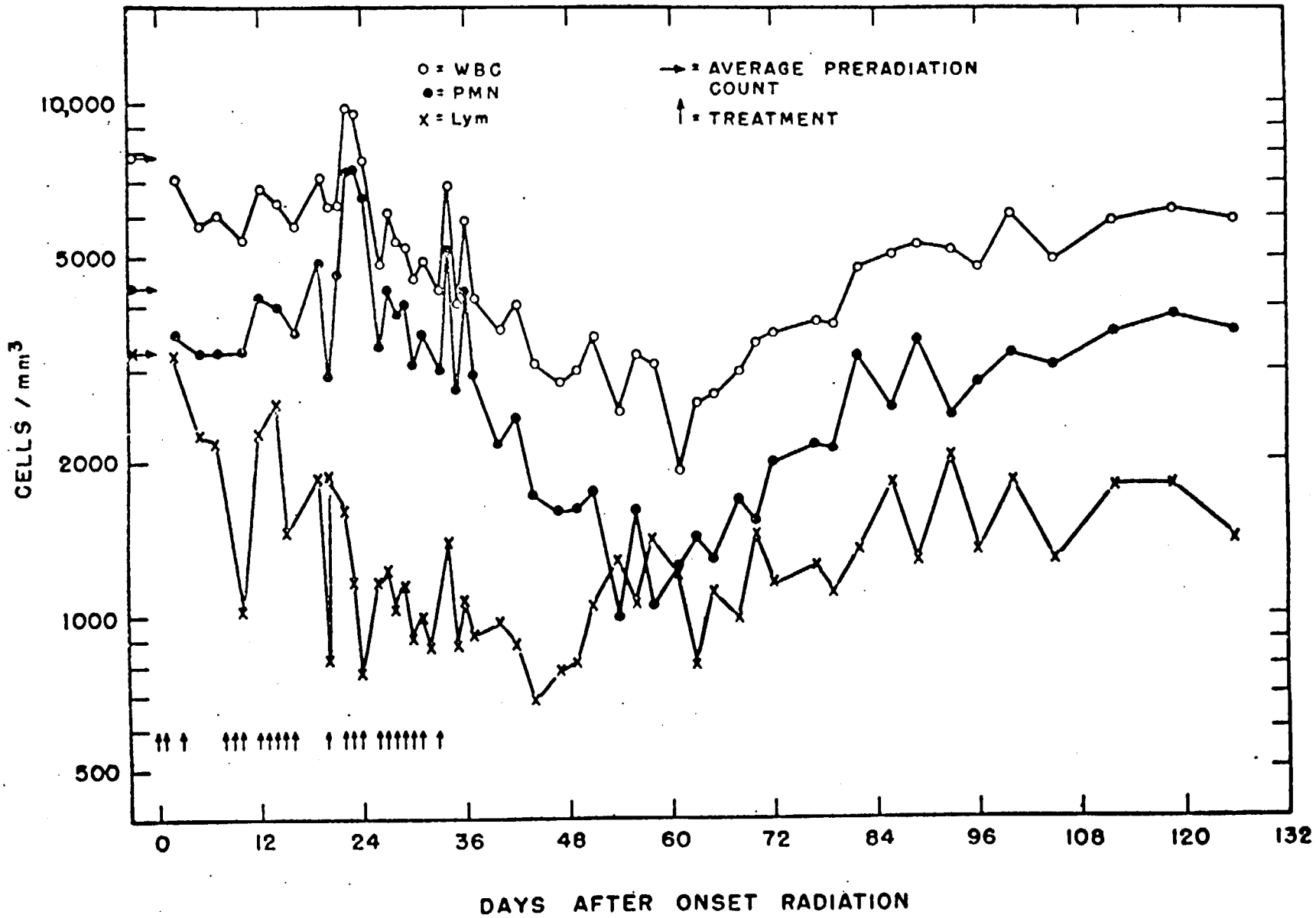

Figure 10.

106681b

DOE/HQ

Table XIII.

Results of Bone Marrow Differentials in Case X.

	9-23-44	10-5-44	11-2-44	11-13-44	11-21-44
	%	%	%	%	%
Myeloblasts	1.3	1.6	0.6	0.8	0.15
Promyelocytes	2.6	1.4	0.4	0.2	0.5
Myelocytes: Neutrophiles	17.0	15.1	16.0	10.2	5.5
Basophiles	1.0	1.6	1.8	2.2	1.0
Eosinophiles	0.2	0	0	0.2	0
Metamyelocytes	16.5	13.6	16.0	12.4	3.6
Stabs	6.8	8.6	32.6	6.0	1.5
PMN Neutrophiles	15.0	19.4		34.6	39.3
PMN Eosinophiles	1.8	1.6	1.6	1.0	8.8
PMN Basophiles	0.26	0	0	0	0
Lymphocytes	11.6	13.8	7.1	8.6	18.5
Plasma Cells	0.4	0.4	0.6	0.4	0.86
Monocytes	0.3	0	0.6	0.4	2.7
Reticulum Cells	0	0	0	0	0
Megakaryocytes	0	0	0	0	0
Proerythyroblasts	0.2	0	0	0.2	15.5
Erythyroblasts	24.9	22.9	21.3	24.8	
Megaloblasts	0	0	0	0	0

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lower either as a direct effect of the radiation or as an indirect effect resulting from improvement in the general condition of the patient, which clinically, however, was not marked.

Bone marrow studies revealed that the relative number of promyelocytes, neutrophilic myelocytes, and metamyelocytes decreased during the period of observation (see Table XIII). This decrease was matched by an increase in the relative numbers of stab forms, polymorphonuclear neutrophiles and eosinophiles.

Case XI. A 25-year old white female with a history of pain and stiffness of the joints of four years duration was first seen in 1941. Local radiation therapy to the left knee was given in October and November of that year. In nine days in November, 1945, eight treatments of total body radiation were given, to a total of 87.5 r. For some time prior to treatment the patient had been confined to bed because of her arthritic lesions. Her general condition, which was poor, was unchanged during and following her total body irradiation.

The hematological data are given in Table XIV and Figure 11. The total white blood cell count, always low, was further depressed during the ten days following the completion of the treatments. Subsequently, other periods of depression in the total white blood count were noted, the most marked being on the 94th day. The absolute number of neutrophiles roughly paralleled the total white blood cell counts. The number of lobes in the polymorphonuclear cells showed a definite decrease, which was most marked on the thirty-fifth day after treatment was begun; the rise to pre-radiation levels was prolonged. The absolute number of lymphocytes fell transiently during and intermittently following the irradiation period, returned to more normal values

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Table XIV.

Results of Hematological Studies in Case XI.

Time			Poly		Lymph					Arneth Count									
Pre RX	Post RX	WBC/mm^3	%	Abs	%	Abs	Monocytes - %	Eosinophiles - %	Basophiles - %	1	2	3	4	5	Total	RBC x 10^6/mm^3	Hgb gms %	Hct cc/100 cc	Platelets x 10^3/mm^3
14d		5200	52	2704	44	2288	2	1	1	4	44	38	13		259	4.45	15	43	205
12d		5420	48	2592	47	2533	4	1	0	15	47	34	4		227	4.41	14.5	42	186
10d		5300	49	2597	46	2438	4	1	0	14	50	28	7	1	231	4.42	14.7	44.5	195
8d		5150	59	3009	36	1836	4	1	0	28	38	26	8		214	4.48	14.9	44.5	196
6d		5300	51	2703	42	2225	3	3	1	21	43	28	6	2	265	4.35	14.9	44	183
4d		5100	58	2958	34	1734	6	2	0	35	46	16	3		137	4.48	14.5	44	208
1d		5350	55	2915	38	2014	4	2	1	32	40	24	4		200	4.54	14.9	45	188
0*																			
	1*d																		
	2*d																		
	3*d	7100	65	4615	28	1988	7	0	0	40	31	22	6	1	197	4.25	14.4	43	163
	4*d																		
	5 d																		
	6*d	4500	59	2655	34	1530	5	2	0	33	46	18	3		191	4.05	14.6	43	184
	7*d																		
	8*d	3750	73	2701	23	851	3	0	0	29	43	24	4		203	4.45	14.6	42	150
	10 d	4250	64	2688	29	1218	6	1	0	28	40	25	5	2	213	4.33	14.1	43	198
	13 d	4050	68	2720	26	1040	6	0	0	25	37	29	8	1	223	4.21	14.9	44	146
	15 d	3250	64	2048	27	864	8	1	0	25	42	29	4		212	4.26	14.8	41.5	155
	17 d	3850	56	2128	40	1520	3	1	0	35	40	17	8		198	4.37	14.2	42	194
	20 d	4650	65	2990	32	1472	2	1	0	44	32	16	8		188	4.35	14.5	43	108
	23 d	6700	62	4134	32	2144	5	0	1	35	42	16	7		195	4.22	14.0	41	174

* Days on which radiation was given.

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Table XIV (cont.)

Time			Poly		Lymph					Arneth Count									
Pre Rx	Post Rx	WBC/mm³	%	Abs	%	Abs	Monocytes - %	Eosinophiles - %	Basophiles - %	1	2	3	4	5	Total	RBC x 10⁶/mm³	Hgb gms %	Hct cc/100 cc	Platelets x 10³/mm³
	25d	4950	62	3038	32	1468	4	2	0	24	46	28	4	-	216	-	14.2	44	137
	28d	4200	70	2940	27	1134	3	0	0	36	41	21	2	-	189	4.54	14.0	44	130
	30d	6600	64	4224	32	2122	3	1	0	32	43	24	1	-	194	4.41	14.1	42.5	114
	32d	4550	63	2835	30	1350	6	1	0	52	28	16	4	-	172	4.55	14.9	42	100
	35d	4100	68	2788	22	902	8	2	0	44	39	15	2	-	175	4.20	14.5	42.5	112
	37d	3550	58	2030	35	1255	4	3	0	64	28	8	-	-	144	4.31	14.4	41.5	84
	39d	4000	63	2520	29	1160	5	2	1	58	29	9	4	-	159	4.40	14.9	41.5	117
	44d	3100	50	1550	38	1178	10	1	1	39	45	12	3	1	182	4.14	14.9	41	115
	46d	3150	48	1492	43	1333	7	2	0	46	45	8	1	-	164	3.79	14.2	39	129
	49d	3600	56	2016	39	1404	5	0	0	37	38	21	4	-	197	4.40	14.1	42	89
	53d	3700	60	2220	34	1258	5	1	0	39	40	16	3	-	185	3.92	13.5	42	123
	56d	3850	53	2014	38	1444	8	1	0	34	50	16	-	-	182	4.13	12.6	39	131
	60d	4050	57	2280	37	1480	5	1	0	31	44	23	2	-	196	3.88	13.5	40	125
	63d	4900	63	3087	30	1470	6	1	0	40	40	19	1	-	181	3.81	13.0	41	159
	67d	4500	52	2340	42	1890	4	2	0	37	39	23	1	-	188	3.72	12.5	39.5	137
	72d	4850	60	2880	32	1536	6	2	0	26	35	29	8	2	225	3.93	12.1	40	159
	79d	3450	90	3060	8	272	0	[illegible]	0	[illegible]	31	22	3	1	[illegible]	3.74	11.5	36	113
	86d	2950	68	1972	27	783	2	3	0	31	52	13	4	-	190	3.74	11.7	36	70
	93d	1700	34	578	46	782	12	7	1	48	48	4	-	-	136	3.89	10.6	33	58
	100d	3700	75	2775	20	740	4	1	0	41	40	18	-	-	175	3.52	11.1	32.5	40
	107d	3475	69	2397	25	872	3	2	1	23	52	25	-	-	202	3.58	12.2	35	108
	114d	3350	69	2311	22	737	7	2	0	18	40	33	9	-	232	3.85	11.4	36	132
	121d	6650	66	4389	24	1596	8	2	0	9	40	42	9	-	251	3.63	11.5	36	136
	128d	6275	62	3890	26	1631	7	4	1	16	48	28	8	-	228	4.03	12.2	39.5	176
	134d	4400	59	2596	31	1364	4	5	1	19	50	25	6	-	218	3.98	11.6	37.5	-

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Figure 11. Case XI. Responses of blood elements following exposure of the entire body to 87 r in divided doses.

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between 17th and 30th days, and then fell to low values again between 80th and 120th days. The hemoglobin, hematocrit, and red blood cell values declined steadily throughout the period of observation. The platelet count was depressed from the 38th to the 50th days, recovered to more normal values transiently, and was again depressed from the 87th to the 108th days. Normal values were again recorded before the study was terminated.

Group III.

The three persons forming this group were young male volunteers who were chosen to receive total body irradiation because they were normal in every known respect. A total of 21 r was given to each of the subjects.

Case XII. A 35-year old white male, received 3 doses of total body irradiation of 7 r each on October 16, 17, and 18, 1944. The results of the cellular hematological studies are given in Table XV. No evidence is seen of alterations in the elements of the blood reported here. It will be seen that the total white blood cell counts, the percentage and the absolute number of neutrophiles fluctuate more than in Cases XIII and XIV.

Case XIII. A 23-year old white male, was given 7 r total body radiation per day on October 30, 31, and November 1, 1944. The results of the cellular hematological studies are given in Table XVI. No evidence of alteration in the elements of the blood reported here is noted.

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Table XV

Hematological Findings in Case XII,

Time		WBC/ mm^3	Poly		Lymph		Mo	Eos	Bas	Arneth Count					
Pre Rx	Post Rx		%	Abs	%	Abs	%	%	%	1	2	3	4	5	Total
4d		10,100	61	6161	34	3434	3	1	1	12	30	34	22	2	272
3d		13,400													
2d		10,300													
1d		10,450													
*0		15,600	75	11,700	21	3276	3	0	0	4	18	56	18	4	300
	* 1d	9,500	53	5,035	42	3990	2	2	1	8	28	42	22	0	278
	* 2d														
	3d	7,200	59	4,248	37	2664	4	0	0	4	22	56	16	2	290
	4d	9,950	71	7,065	25	2488	3	1	1	6	36	44	10	2	260
	5d	10,230	64	6,560	31	3178	3	2	0	10	34	32	22	2	272
	6d	10,600	66	6,996	28	2968	2	1	0	16	34	39	11	0	245
	7d	9,150	63	5,765	30	2745	7	0	0	16	32	46	6	0	242
	9d	8,330	56	4,676	33	2755	9	2	0	14	48	36	2	0	226
	13d	13,950	74	10,323	18	2511	6	1	1	8	38	42	12	0	258
	16d	12,000	64	7,680	23	2760	7	5	1	6	42	43	9	0	252
	20d	18,650	82	15,293	13	2425	5	0	0	4	36	49	12	0	271
	23d	13,300	87	12,003	8	1104	4	1	0	6	36	44	14	0	266
	26d	10,600	64	6,784	25	2650	10	1	0	10	24	44	22	0	278
	29d	9,900	53	5,247	36	3564	8	2	1	4	22	50	20	4	258
	32d	9,600	56	4,816	33	2838	7	4		10	28	40	17	5	284
	40d	10,600	61	6,466	26	2756	9	4		4	30	54	12	0	274
	47d	9,950	66	6,567	24	2388	7	2	1	9	21	44	19	0	257
	54d	12,350	65	8,027	27	3335	6	3		4	28	46	20	2	288
	69d	11,850	66	7,821	27	3199	6		1	3	28	54	8	2	263

* Days on which radiation was given.

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Table XVI.

Hematological Findings in Case XIII.

Time		WBC/ mm^3	Poly		Lymph Lymph		Mo	Eos	Bas	Arneth Count					
Pre Rx	Post Rx		%	Abs	%	Abs	%	%	%	1	2	3	4	5	Total
4d		6000	54	3240	41	2460	4	1	0	10	36	40	14	0	258
3d		5200	44	2288	42	2184	10	4	0	12	36	46	6	0	246
2d		5750	58	3335	36	2070	4	2	0	8	28	52	12	0	268
0*															
	*1d	6450	58	3741	39	2516	2	1	0	4	39	49	8	0	261
	*2d	5900	58	3422	40	2360	2	0	0	0	0	0	0	0	0
	3d	6800	56	3808	38	2584	5	1	0	8	26	43	19	4	285
	4d	5400	60	3240	35	1890	4	1	1	8	28	40	22	2	282
	5d	5250	67	3518	28	1470	3	1	1	6	22	46	20	2	278
	6d	4700													
	8d	5450	47	3107	36	1962	6	1	0	6	16	62	14	2	228
	10d	6250	48	2875	43	2688	9	0	2	8	30	50	12	0	216
	13d	5550	48	3296	25	1288	6	5	0	4	26	42	26	2	296
	18d	5150	0	2215	43	2215	11	2	1	6	14	42	30	6	316
	20d	6100	48	2928	37	2257	12	2	1	3	33	48	13	3	280
	24d	6250	48	3913	33	2061	7	1	0	6	31	48	17	0	280
	27d	5950	47	2856	40	2380	9	1	2	4	32	50	14	2	284
	30d	4950	47	2822	36	1782	7	0	0	6	33	46	15	0	270
	34d	6950	47	3823	36	2502	5	3	1	8	26	56	8	0	260
	41d	6200	47	3286	39	2418	4	3	1	8	38	48	8	0	256
	43d	5750	56	3220	37	2128	6	1	0	8	36	36	18	0	260

* Days on which radiation was given.

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Case XIV. A 23-year old white male [redacted], an employee of the Metallurgical Laboratory, volunteered to receive 7 r total body radiation per day on November 20, 21, and 22, 1944. The results of the cellular hematological studies are given in Table XVII. None of the fluctuations observed in the various cellular elements of the blood are felt to be due to the effects of the radiation given to the subject.

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Table XVII. (cont.)

Time		WBC/ mm^3	Poly		Lymph		Mo %	Eos %	Bas %	RBC x 10^6/ mm^3	Hgb gms %	Ret %	Arneth Count					
Pre Rx	Post Rx		%	Abs	%	Abs							1	2	3	4	5	Total
	28d	4400	54	2380	40	1760	5	1	0	--	--	0.4	0	17	54	76	17	159
	29d	4100	54	2220	38	1560	6	1	1	--	--	0.4	0	23	66	57	18	150
	30d	4350	59	2560	38	1650	7	1	0	--	--	0.6	0	18	60	80	15	162
	31d	5500	63	3460	29	1600	7	1	0	--	--	0.9	1	21	70	78	19	173
	32d	4400	57	2500	34	1500	9	0	0	--	14	0.5	0	[illegible]	[illegible]	69	[illegible]	[illegible]

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Discussion

Group I. The most remarkable feature of the hematological studies of the eight patients receiving single doses of x-rays is the lack of any uniform persistent effect on the elements of blood. Prior to the onset of this study it seemed likely that one should see a marked effect on one or more of the cellular elements of the blood following exposures of perhaps 60 r of total body radiation. It was because of the lack of this effect that it was decided to increase the dose in Cases VI, VII, and VIII to 120 r. However, no marked uniform effect was noted as a result of the increased dose.

The lymphocytes showed the only uniform response of any of the blood elements that were studied in this group. In every instance but one (Case V) there was a drop in the number of the lymphocytes in the peripheral blood during the first four days. In Cases I, II, V, and VIII the lymphocyte level was somewhat lower throughout the period of study following irradiation than before. Arneth counts were done on six of the eight cases in this group. No change in either the total number of lobes per 100 cells or in the percentage of cells with a given number of lobes was noted.

Clinically, no deliterious effect which was attributed to the treatment was noted by the patient during the periods of observation. Particularly, no radiation sickness was induced in any of these patients. Indeed, one patient spontaneously remarked that the treatment made him feel decidedly better, and wanted to know if he could have some further treatments.

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Group II. The three cases of this group differ in all respects except that they received multiple doses. Case IX, who received the largest total dose (500 r) reached a low in both polymorphonuclears and lymphocytes on the 28th to 34th days after starting treatment but apparently recovered after transfusions. Case X reached a low in polymorphonuclear count on the 53rd day after starting treatment and thereafter a gradual rise occurred.

Case XI had relatively small numbers of all the blood elements and so is not easy to group with Cases IX and X. A low point in polymorphonuclear and lymphocytic values was reached about the 50th day, followed by a gradual rise toward normal values. Recovery of the lymphocytes was slower than for the polymorphonuclear cells.

The marked, though transient depression in the neutrophile, lymphocyte, and platelet counts noted in Case XI about 100 days after the onset of therapy, is interesting in the light of the findings of R. S. Stone and B. V. A. Low-Beer[12] who feel that their cases indicate that this drop may be a delayed result of the x-ray exposures.

Group III. No evidence of change in the cellular elements of the blood was noted in any of these cases. It will be remembered that the individuals were all normal males insofar as could be demonstrated. These cases were of particular interest to us inasmuch as they indicated that acute exposure to far more than the maximum permissible level of 0.1 r per working day could not be expected to

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produce diagnostic changes in the elements of the peripheral blood which were studied.

From the practical point of view, these studies should have been extended to include the examination of individuals subjected to from 0.1 to 1 r per day x-ray exposure for long periods of time. For obvious reasons these studies were not undertaken with humans. Since, however, the data discussed above checks in a general way with experimental data on animals with comparable rates and amounts of exposure[14] it is perhaps reasonable to assume that the animal data obtained at low levels of exposure for protracted periods of time are applicable, at least approximately, to the effects which might be seen in humans. These data are presented in Volumes 22-A and B of this series and summarized in a paper in this volume.

Summary

1) Results of examinations of elements of the peripheral blood in fourteen individuals following exposure to total body radiation are presented. The individuals are divided into three groups: Group I consists of eight individuals who were irradiated with x-rays at one sitting; Group II consists of three individuals who were irradiated with x-rays in divided doses; and Group III consists of three normal individuals who were irradiated with x-rays by 3 doses of 7 r each.

2) In Group I the most persistent abnormality noted was a diminution in the number of lymphocytes shortly after the completion of the treatment.

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Summary - (con't)

3) In Group II depression in the lymphocytic count was also the most marked single change.

4) In Group III no alterations were noted in the elements of the peripheral blood which were studied.

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