234

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RECORDED TESTIMONY ON

THE BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

Conducted by

SPECIAL SUBCOMMITTEE ON RADIATION

JOINT COMMITTEE ON ATOMIC ENERGY

22 - 26 June 1959

by

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234

Representative Holifield. He holds the rating of senior navigator, and was recently awarded the Legion of Merit for his contribution in the area of radiation research. He is a past director of the Health Physics Society of America. He is an author of two Air Force training textbooks and approximately 50 scientific papers on radiobiology, weapons effects and nuclear physics. I believe he is Director of Medical Research for the United States Air Force School of Aviation Medicine and Chief of the Department of Radiobiology, if I read this right.

Col. Pickering, will you please come forward?

STATEMENT OF COL. J. E. PICKERING, USAF, SCHOOL OF AVIATION MEDICINE, RANDOLPH AIR FORCE BASE, TEXAS.

Col. Pickering. Thank you, sir.

Representative Holifield. Col. Pickering, you might just give us your background and your specific experimental work in this field of effects from protracted exposure very briefly.

Col. Pickering. Mr. Chairman, I can be very brief in my remarks in summarizing the experimental data. I had planned to use some slides to illustrate the results.

Representative Holifield. I think we want to see those slides. I understand that they are very revealing. I believe we will go ahead with that, even if we have to carry one of our witnesses over until tomorrow.

Col. Pickering. Yes, sir. The topic upon which I was asked to speak was the experimental effects of protracted or long term radiation. In following up on Dr. Harris' remarks, I would like to go from the 60 day acute effects to those effects which we see over a period of weeks, months and up to and

including eight years of post-radiation in animal experimentation.

I would like to address my remarks to the experimental evidence that we have accumulated and to preface my remarks by stating that nearly ten years ago there was concern, as there is today, for some of the long term effects of ionizing radiation. Much of the information we did glean from the casualties from the Hiroshima-Nagasaki, from many of the laboratory experiments, and certain of the accidental exposures that Dr. Harris referred to. The point in question was not the initial rather large amount of ionizing radiation, but really what are the effects of small doses delivered over extremely long periods of time.

For illustrative purposes, I would like to state that experiments begun some 8 years ago were designed to measure the effects of a quarter of a roentgen per hour, one roentgen per hour, 4 roentgens per hour, delivered over 16 hours at one time, and fractionated over seven day intervals for extended periods of time. One of the experiments which I should like to refer to was begun at the Oak Ridge National Laboratory seven years ago, in which the dose rates which I just spoke of were used. One of the points of extreme concern at this time was, what are the effects or threshold doses which might produce cataracts, shortening of life span, increased incidence of leukemia, perhaps temporary sterility, and the question which I cannot answer, the genetic effects of these doses.

I would like to illustrate by the first slide, one of the points that came from this series of experiments. One of the things that is seen, contrary to the information which Dr. Harris referred to in the acute experiments, is that the effects are much less pronounced in the doses which we have studied.

In looking at doses with a total of 30, 120 and 500 roentgens delivered once a week for a period of six months, we did not find a mature cataract at all (Fig. 1). This is the lens of an experimental animal's eye with only a very few vacuols, and something that would certainly not involve a detrimental effect (Fig. 2).

Representative Holifield. Was this whole-body radiation?

Col. Pickering. Yes, sir.

Representative Holifield. What animal was it?

Col. Pickering. This was the small primate.

Representative Hosmer. The interval was weekly?

Col. Pickering. Yes.

Representative Hosmer. The total dose was 500?

Col. Pickering. Yes, sir, the highest dose used. If you will go to the next slide, please.

Representative Hosmer. Did you mean 500 a week or a total dose?

Col. Pickering. A total dose of five hundred over a period of months.

Representative Holifield. What would this show?

Col. Pickering. This shows that there were no mature cataracts. This is one of the first points for which we had concern.

To answer your specific question, animals were exposed as controls, 0 dose, others exposed to a total dose of 30 roentgens, another group to 120, and a third group 493, over a period of six months in their exposure, they have shown at the end of five years only a very few opacities. There is no indication to date that these will develop into mature cataracts.

In further looking at the animals and studying the hematological response, we do not find at this date any demonstrable severe biological damage.

In the early days, there were changes in the white blood cell picture. These animals have also been exposed to a performance situation in which an attempt was made to study their motor and sensory perception. In no instance have we found that there is a performance decrement when these total doses have been administered over a fractionated period of time in which the interval of exposure was once every seven days.

It should be emphasized that this work was done under water in the swimming pool reactor at Oak Ridge and there was some concern that we could not make accurate dosimetric measurements. Consequently, a second series of large long term experiments were set up using a synthetic type reactor with neutrons (Po-Be) and gamma rays (Co^{60}) and an in-air exposure made.

In these instances beginning in 1954, and through to the present date, they were exposed in two different situations. Rather than once a week, they were exposed either every fourth day or every 12th day. They were exposed in each of the exposure days for a period of 16 hours. They were exposed at three different dose rates; a quarter of a roentgen per hour, a half roentgen per hour, or one roentgen per hour. This permitted total doses of the neutron-gamma of approximately 78, 156, 316 and 616 rep. (Fig. 18).

It is of interest to note that one group was exposed 40 successive times, another group 20 times, which gives us an overlap of dose where the points are asterisked, using twice as many doses and half the dose rate.

We would obviously, therefore, accumulate the same dose as one with twice the dose rate.

Representative Holifield. Were these experiments on mice?

Col. Pickering. These are on small primates, the rhesus monkey. Again six years post-radiation we have not found in these animals mature cataracts.

Again just a few opacities. There are no blood changes now that are biologically damaging. We have found no instance of leukemia nor have we determined any shortening of life span from the administration of these doses of radiation to date.

To contrast this with the remarks of Dr. Harris, the next slide, when we speak of an acute dose of 5 to 7 hundred rep. of neutrons delivered to (fig 3) the lens of the eye this is the effect that can accumulate in 13.5 months. A mature cataract. If you will, from the next slide I can show you in acute exposures that the biological effects can be produced. We have produced in many instances a mature or near mature cataract (Fig. 4).

The point here, however, that I would like to make for the committee is that in no instance, whether it be acute radiation exposure or the protracted exposure, have we seen any biological effects that were serious below a total dose of 200 roentgens. On that point I would like to continue my discussion.

Representative Holifield. Could I ask you at that point to relate this to the background radiation which is generally conceded to be around 7 roentgens over a life time of 70 years, and the amount of radiation which has been testified to before this committee as an average of something less than a roentgen from the bomb test buildup of radiation? Then in view of the fact that you are now talking about experiments that relate to 200 roentgens, would you have any comment on whether you can obtain any kind of detectable biological damage with a dose rate as low as 7 roentgens over a 70 year period?

Col. Pickering. Sir, I can only answer what our data substantiates, that is to date; and I realize this is only the eighth year of perhaps a 25 year life span animal, we do not find demonstrable biological effects. There are other points which will come out in just a moment that may permit an inference in this regard.

Testimony

Representative Holifield. When you answered that question, were you speaking of somatic damage and genetic damage?

Col. Pickering. Somatic damage. I have no data nor am I qualified to speak on the genetic phases.

Representative Holifield. You are speaking on the physical damage to the body cells.

Col. Pickering. That is correct. If we observe these animals in the next slide, over the entire period over which they have been exposed, one group being exposed every fourth day, the exposures lasting for nearly 200 days, you can follow the blood picture. Let us concentrate on the highest dose represented by the lower line. We find that there is a drop in the leukocyte count during the interim of radiation exposure, but post-radiation it returns to what we must conclude from our experience is the normal blood picture (Fig. 5).

Four years later we have not found a demonstrable damage at these doses. That is not to say that ten years from now it will not be manifest. As of 4-6 years post-radiation they do not yet exist.

Representative Holifield. How does that compare to the life span of man with respect to the animal you are using?

Col. Pickering. I am sure that all of us have reasonable doubts. If we take man, whose life is perhaps 70 years, we believe the small primate has a life expectancy of 20 to 22 years. I am not inferring here that you can use a factor of three and scale from monkey to man. I am not certain we know that. That is about the life span, sir, one to three. At the time these experiments were going on, opportunity presented itself to look into another type of radiation experiment. For some time and beginning prior to

1951, but my remarks are specific from 1951 to date, radiation had been used in certain select cancer patients as a possible therapeutic agent. It was possible in conjunction with the M. D. Anderson Cancer Hospital to conduct some work in the therapeutic administration of ionizing radiation and to get a feeling for the numbers, that Mr. Hosmer was getting from Dr. Harris, these involved 263 patients. Obviously this is not a large population but it is a group of individuals that were treated.

There were two points that become interesting in this opportunity. It was possible to study effects from, if you will, a fractionated exposure where individuals received 15, 25 or 50 roentgens. One group received this as a total immediate dose. Another group received it in five equal doses. The same for the 25. One 25 r dose within a few minutes. Another one over a period of hours. And also the same for the 50 roentgens.

These individuals in addition to being followed clinically were studied for psychomotor performance. There were tests administered using the two-hand-coordinator and the rotary pursuit which had tremendous statistical significance in terms of the tests, since they had been tried on many thousands of flying cadets. The individuals who received radiation exposure were taught to work these devices. The idea was that if these types and doses of radiation did produce a performance decrement, perhaps it would be manifest at certain dose levels. Since radiation therapy was not widely used, small doses were used first in the therapeutic management of these cancer patients.

The first experiment which I have described here on the board in terms of a performance decrement permits the following conclusion. There was not evidence of a psychomotor decrement among the individuals who received these doses of radiation, whether it was administered over a period of a few

minutes or over a period of a day in five different fractions of dose. In addition there were no clinical evidences of radiation effects.

Representative Hosmer. For the purpose of the record when you were talking with these, were you talking about all of them or the 15 roentgens?

Col. Pickering. I am talking here of some 200 patients.

Representative Hosmer. Were you talking about all those doses or just one?

Col. Pickering. I would like to combine all of the doses whether they be in single shot or whether they be in the integrated or protracted dose.

Representative Holifield. This was whole-body radiation?

Col. Pickering. Yes, sir. There was no decrement in the performance nor in the clinical observations of these patients. There were no suggestions of biological damage. An opportunity presented itself to look at some of the patients three years post-radiation. I think you should understand that most of these patients were terminal cancer patients, and that there would not necessarily be the whole group alive at the end of three years. At the end of three years in this follow-up study, 30 per cent of these patients were alive, and that is perhaps about as significant a survival as among those who did not receive any radiation treatment.

Progressing, then, from this experiment, it became possible to study other patients, and these now are the 263 to which I referred earlier, who were given doses from a control group of zero to 200 roentgens whole-body x-radiation. The dose scale went from 25 to 50 to 75, 100, 150, 175, and 200 roentgens.

Again these individuals were followed in terms of performance decrement. In the next slide, one of the things that one sees, looking now at the rotary pursuit, and perhaps you would be interested in what it is, it is a

disk like the turntable on a record player, and one is required to follow a dot with a pointer, and to stay on the dot as it goes in its eccentric motion. The control group represents, as you see, a curve, a learning curve (Fig. 6).

These individuals became better as the days progressed. It was possible to study the individuals four days prior to the administration of radiation, and in this particular instance daily for ten days post-radiation. In all instances you see that there is a learning. There is perhaps what one might choose to call a possible decrement at 175 to 200 roentgens in this particular instance, but as the number of patients have increased, we cannot prove this to be statistically significant, and perhaps it is associated with the severity of the disease.

I must point out to the committee that this is one point about which there is some question (200 r). In any event, we did not find a performance decrement in these psychomotor tests and in the clinical observations the individuals below 175 roentgens did not demonstrate any significant biological damage. However, having been followed each day in their blood picture there is the one point to which Dr. Harris referred. There is after the initial rise a drop post-radiation in the lymphocyte count. This drop was manifest in all doses from 100 to 125 to 200 roentgens (Fig. 7).

In observing these patients for a period of several months, there were three other points that perhaps are worthy of the committee's attention. First the nausea and vomiting that is frequently associated with exposure to ionizing radiation was not sufficiently severe so as to preclude the nutrition of the patient. Secondly, there was an increased bleeding tendency. Thirdly, these individuals when compared to other cancer patients who were untreated had essentially the same life expectancy. If one plots the curve of some 200

individuals stricken with lung cancer and their survival time and compares individuals with the same disease who received 200 roentgens of whole-body radiation, their survival time is identical. So again perhaps all I am trying to say is that radiation did not contribute to an earlier death, whether or not it relieved the condition of cancer, I am not qualified to say.

This study led to an interesting point which I think may come out in the next slide. We have had the opportunity to observe neutron and gamma radiations as it has affected the response of small primates; further, there have been opportunities of studying the acute effects from among the Japanese, the nuclear accidents at Los Alamos, the Marshallese and the administration of therapeutic x-radiation in the treatment of certain select cancer patients. If one plots the white blood cell response in all of these types, here is neutron-gamma radiation, beta radiation, x-radiation, delivered over different time periods and different energy spectrums, the response is not too different, and the minimum depression is about four to five weeks (Fig. 8).

The only reason for showing this is that we would like to feel that as one goes into a long term animal program much information can be taken from the human acute responses that do occur to guide us in the long term effects, since we do not have chronically exposed human beings at the present time.

Representative Holifield. Colonel, you will be interested to know that this committee was responsible for raising the appropriation from $2 million to $3 million in the last authorization bill for the purpose of helping in the facilities for experiments on animals along the radiation line.

Col. Pickering. Yes, sir. Speaking for our own School we are grateful to you. If I may continue, moving now from the small primate or the monkey, through the human portion, I would like to go to another series of experiments

that are illustrative of this fractionated exposure to radiation and a few of the statements which we may make.

Choosing another specie now, our concern to see if there are specie differences and further, if one can relate them, from monkey to man, studies were begun on rats. They were given one tenth of a roentgen per hour for 8 hours, or if you will, .8 of a roentgen per day. They were begun on this radiation at age four months and irradiated to age 16 months. They were exposed every day for 12 months, and followed. We can conclude this, since it has been published and it is of considerable concern, these animals lived longer than the control animals. This effect of extremely small doses of radiation over extended periods of time has produced an increased survival time over control animals receiving no exposure, in Dr. Carlson's laboratory, also at Los Alamos, in England, and many other laboratories. It is a point that bears considerable additional work because this could be most important.

Representative Holifield. Is this an indication, then, that in the cases of small doses of radiation that it is apparently beneficial, rather than deleterious?

Col. Pickering. I do not feel, sir, that I am personally qualified to say. However, that suggestion has been made by many outstanding scientists. Dr. Mole has demonstrated that certain of the data comparable to that which I have just referred, below 10 roentgens per week, the data can be fitted either with a straight line or a curve, and suggests, just as you have asked, that there may be a threshold.

Representative Holifield. I know one of the facts brought out by Dr. Russell in his mass experiment with mice at Oak Ridge was that the same amount of radiation given over a longer term in smaller doses but cumulative

produced much less damage. I think less damage by a factor of four than the same amount given in one mass dose at one time.

Col. Pickering. That is correct. There are other investigators who have reported the same. I endeavored to review the literature for you in my prepared introduction so I would not get into controversy with other individuals. Dr. Hardin Jones perhaps will have a different opinion in the morning, and I think he has very good merit to his remarks.

The experimental evidence to date in these experiments indicates beyond any question of a doubt that the irradiated animals outlived the controls because the irradiated animals are alive in fact, and the control animals are dead.

Representative Holifield. Isn't this some evidence that if we want to be intelligent and weigh these factors that we cannot jump to conclusions either way on some of these things, because we simply do not have as yet enough data to actually prove the case at either extreme.

Col. Pickering. As I continue your question will be answered, sir.

Representative Bates. Is there any correlation between extended life in areas which have high natural background radiation? Have any figures been worked out on that?

Col. Pickering. I think Dr. Teller and Dr. Pauling have fringed on this. I am not qualified to talk about it. They have discussed people living in Denver or the Tibetan mountains. I don't know whether that is germane to your question.

Representative Bates. That is my question.

Col. Pickering. I don't know the answer. I don't know that anyone does.

Representative Bates. You have statistics.

Representative Hosmer. Perhaps the Colonel is wondering whether it is a good idea to live longer or not.

Representative Holifield. Proceed, Colonel.

Col. Pickering. Moving then from monkey, man, and rat, to the burro. Reference this particular information which I shall give, I must qualify it; this is information over which we have cognizance by request but did not do the work. All other information given to this time we have had primary cognizance and are speaking from our experimental data. A band of burros were exposed at Oak Ridge National Laboratory about nine years ago. There is one particular group in this band of burros that is of interest to us. They were exposed to dose rates of 25 r per week to a total dose of 350 r. The animals involved were 20 in number. To date that group of animals are still alive. They do not show any demonstrable hematologic damage. There are some corneal opacities, but there are as many in the controls as in the experimental animals. So again if you will keep in mind, the doses here and the rates, it will permit me to go very shortly to the only conclusion I would like to make.

Moving from the burro experiments, exposures have been conducted in mice by one of our contractors. We have chosen dose rates of one third, one, and 3 rep per hour (gamma radiation). They have been fractionated in dose so that they were exposed either once a day, another group every three days, or a third group once every nine days, to look at fractionation.

In addition one group was exposed for 18 days, another group for 54 days, and a third group for 162 days. If you will, this is protraction of time by a factor of three. These experiments in terms of longevity, as the dose accumulates, show greater mortality, and the greatest mortality exists in

the fractionation of every ninth day of radiation. They are about two years post-radiation and are being followed.

Coincident with this experiment, a gamma ray experiment was another one done with neutrons, where the assumption was made that the neutron may be biologically more damaging. We assumed that it perhaps may be five times as damaging. Therefore, the dose rates were one fifteenth, one fifth and three fifths of a roentgen/hr. The intervals were identical.

A point of extreme interest here, mortality accumulated faster in the neutron exposed animals at the 3 day interval than the other two intervals. So one sees in these experiments on both protraction and fractionation effects, that neutrons and gammas are not necessarily the same. It leads to the point that I would like to make, as has already been suggested to the committee, even though there are a considerable series of experiments that are giving us evidence on the effect of long term radiation, there are many more that need to be done.

In summary, the point I would make is, I think, demonstrated on the last slide. From the evidence we have from among our own experiments, I think my opening remark is still the remark I must stand by. We do not see detrimental biological effects in animals that have been exposed for a period of five to eight years post-radiation below 200 roentgens. On this basis we are trying to develop our so-called dose vs. clinical effect chart. Below 200 r we need surveillance, there is slight hematopoietic damage, with a drop in leukocytes. We have it from human data on 200 individuals and several hundred small primates, from a colony of nearly a thousand. Although this is not large, it is a large experimental colony to maintain for perhaps 20 years.

With that, those will be my conclusions. To date in the fractionation of dose over the time periods we have available, and the eight years post-

radiation, we do not see demonstrable detrimental biological effects in terms of mature cataracts, we have not demonstrated an increased incidence of leukemia in the small primate, we have not found a shortening of life span that is attributable to ionizing radiation. These animals are in a breeding colony and whether or not they are temporarily sterile is not manifest, and we are not qualified to study the genetic effects.

Representative Bates. Colonel, how many specimens did you use in this example that you have on the board?

Col. Pickering. 17,000 mice.

Representative Bates. 17,000?

Col. Pickering. Yes, sir.

Representative Bates. For the nine group?

Col. Pickering. That was for the whole total experiment.

Representative Bates. For the nine day group, how many did you use?

Col. Pickering. Approximately one third.

Representative Bates. This was consistent.

Col. Pickering. Yes, sir. As the analysis of variance has now been made in the gamma ray experiments, the mortality increases at the nine day fractionation period in mice. In neutrons, the mortality is greatest in the three day fractionation.

Representative Bates. Do you know of any reason that would account for that?

Col. Pickering. No, sir, I don't. I believe the investigators who are with us in this program will take this as their next research step.

Representative Bates. You did not have many deviations from the man.

Col. Pickering. There are deviations, but this finding is statistically

significant. By analysis of variance it is a fact on this specie in that laboratory. We based our normal survival time on accepting several thousand animals in January and several thousand animals in July and looking at their normal survival, choosing the worst situation, winter in Chicago, and so on.

Representative Bates. The nine is gamma and three is the neutrons?

Col. Pickering. That is correct.

Representative Hosmer. You don't have much of a quarrel with Dr. Harris, do you?

Col. Pickering. No, sir, I don't. I have two more points that came from the other questions, and I can be exceedingly brief on them. One is on the LD 50. Information that we have available that Dr. Harris alluded to, but graciously did not discuss, in a study trying to reconstruct, if I may use that phraseology, Hiroshima and Nagasaki, to look at dose distributions and perhaps better evaluate the data which is available, small primates were exposed two years ago in the weapons effects programs and to date doses of up to 532 rem have not produced an LD 50-30. That is a poor way to state it. (fig. 9)

Representative Holifield. Will you say what the LD is?

Col. Pickering. I think it is above 532.

Representative Holifield. Lethal dose?

Col. Pickering. Lethal dose, 50 per cent, 30 days. I base that on having a portion of these animals very much alive in the laboratory today two years post-radiation. So at least for a two year post-radiation period this does not kill 50 per cent of the small primates used. These were adolescent primates.

Representative Holifield. Was that given in one dose?

Col. Pickering. Yes, sir.

Representative Holifield. 532 roentgens in one dose?

Col. Pickering. This was at a weapons effect test. This spectrum of dose extended from somewhere around 1632 to 135 roentgens.

Representative Bates. Colonel, you said it didn't kill 50 per cent. What per cent did it kill?

Col. Pickering. I can tell you. In this particular 532 r group I have the data. There were 8 animals per point and there are six survivors. It killed 25 per cent.

Representative Bates. Haven't many people used the range of 4 to 600?

Col. Pickering. Yes, sir.

Representative Bates. So that would fit in somewhere with that experiment.

Col. Pickering. That is right. The last point is with reference to retinal burns, Mr. Holifield. In the experiments which were conducted, I can state the following, and I appreciate your earlier remarks that these are open hearings and not classified. There was a news release that retinal burns did occur in the eyes of animals. That is indeed factual. They occurred in the eyes of animals to distances of approximately 300 nautical miles.

Representative Holifield. Burns occurred in the eyes of animals to distances of 300 nautical miles?

Col. Pickering. Yes, sir.

Representative Holifield. What type of animals?

Col. Pickering. They were pigmented rabbits.

Representative Holifield. How is this blink time reaction in that case as compared to human beings?

Col. Pickering. Comdr. Fugitt is here, and he has the Armed Forces Special

Weapons release. Suffice it to say and I am sure he would agree with this, that the greatest percentage of the thermal efficiency of the weapon was delivered well inside the blink reflex of the animals. The rabbit has a blink reflex of 200 to 250 milliseconds and the thermal contribution for the most part was delivered in a few milliseconds.

Representative Holifield. In other words, as far as blink reflex is concerned, the human being would have no more protection than the rabbit has?

Col. Pickering. On those particular tests, that is correct.

Representative Holifield. These were high tests over Johnston Island, were they not?

Col. Pickering. Yes, sir. I am referring to the Atomic Energy and Department of Defense release in the Washington Post last week.

Representative Holifield. That would have had to be slant range, would it not?

Col. Pickering. Yes, sir.

Representative Holifield. Is there any of this material in this field classified.

Col. Pickering. The details are classified, and they were written and published by our group.

Representative Holifield. If it has been published it is not classified. You mean it is unclassified.

Col. Pickering. It is published in the classified literature of special weapons.

Representative Holifield. I see. It is written up but it is not declassified to the public yet.

Col. Pickering. No, sir. That is why I prefaced my remarks.

Representative Holifield. Are there any further questions of the Colonel? If not, Colonel, you have given us very valuable testimony today, and we appreciate having it very much. This will cause us all to do some studying, I am sure.

(The statement of Col. Pickering follows:)

Representative Howell. Dr. Newell, we will have to carry you over until tomorrow, sir. We will start with you as the first witness in the morning.

We meet tomorrow morning in the Old Supreme Court Room. It will be a different room in the Capitol Building. The committee stands adjourned.

(Thereupon at 5:20 p.m., a recess was taken until Wednesday, June 24, 1959, at 10 a.m.)

RADIATION CATARACT EXPERIMENTS
A. CHRONIC (PHASE II)

RADIATION TYPE AND SOURCE	DATE OF EXPOSURE	TOTAL DOSE			EARLIEST LENS OPACITIES (MONTHS)	DEGREE OF OPACIFICATION	TIME POST-RAD	POSSIBLE FUTURE PROGRESSION
		GAMMA	NEUTRON	RATIO				
REACTOR SOURCE (PHASE I)	OCT 52	0	0					
		25	0.74	1/34				
OAK RIDGE		107	3.0	1/36				
		493	11.8	1/42	30	<1+	5YRS	ARRESTED
SYNTHETIC SOURCE PoBe AND Co^{60} (PHASE II)	APR 54	0	0					
		70	8.2	1/9				
		*140	16.4	1/9				
RADIOBIOLOGICAL LABORATORY-USAF		**140	16.4	1/9				
		*284	32.5	1/9				
		**280	32.5	1/9				
		557	62.0	1/9	9	<1+	45 MOS	ARRESTED

*EXPOSURE INTERVAL EVERY 4 DAYS FOR 40 EXPOSURES
**EXPOSURE INTERVAL EVERY 12 DAYS FOR 20 EXPOSURES

Figure 1

Figure 2

RADIATION CATARACT EXPERIMENTS
B. ACUTE (PHASE III)

RADIATION TYPE AND SOURCE	DATE OF EXPOSURE	TOTAL DOSE	EARLIEST LENS OPACITIES (MONTHS)	DEGREE OF OPACIFICATION (OCT 1955)	TIME POST-RAD	POSSIBLE FUTURE PROGRESSION
FAST NEUTRONS (A) 14 MEV COCKROFT-WALTON ACCELERATOR	15 JAN 1953	250 75 21 6 1.75 .75	13 16-1/2	2-3+ <1+	5 YRS 5 YRS	ARRESTED " IMPROBABLE " " "
(B) "	4 NOV 1953	850 250 75	6-1/2 14 19-1/2	4+(MATURE 20 MONTHS) 2-3+ 1+	4 YRS 4 YRS	ARRESTED IMPROBABLE
(C) "	26 MAY 1955	150 50 15		1+	30 MO	IMPROBABLE
THERMAL NEUTRONS LASL	23 JUL 1953	7500 2500 825	DIED IN 16 WEEKS 9-1/2 14-3/4	4+(MATURE 30 MONTHS) 2+	53 MO 53 MO	ARRESTED
GAMMA 12 MEV AUSTIN, CO^{60}	30 MAR 1954	3000 2000 1000 500 250	9-10 MO 9-10 MO 9-10 MO 22 MO	4+(MATURE 30 MONTHS) 4+(MATURE 30 MONTHS) 3+ 30 MO <1+ 30 MO	45 MO 45 MO 45 MO	PROBABLE IMPROBABLE

Figure 3

Figure 4

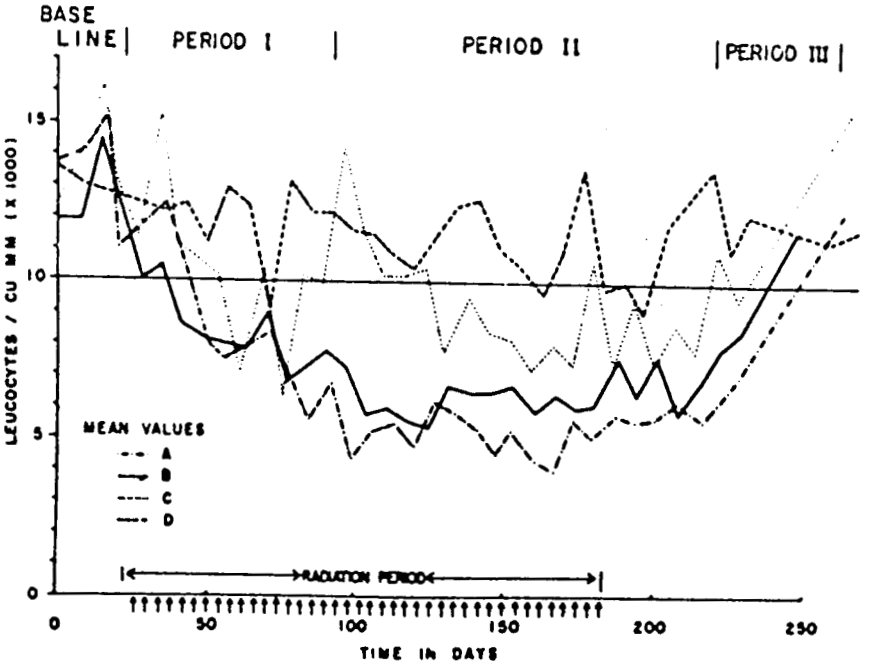
BASE LINE
PERIOD I
PERIOD II
PERIOD III
LEUCOCYTES / CU MM (X 1000)
15
10
5
0
MEAN VALUES
A
B
C
D
RADIATION PERIOD
0
50
100
150
200
250
TIME IN DAYS

Figure 5

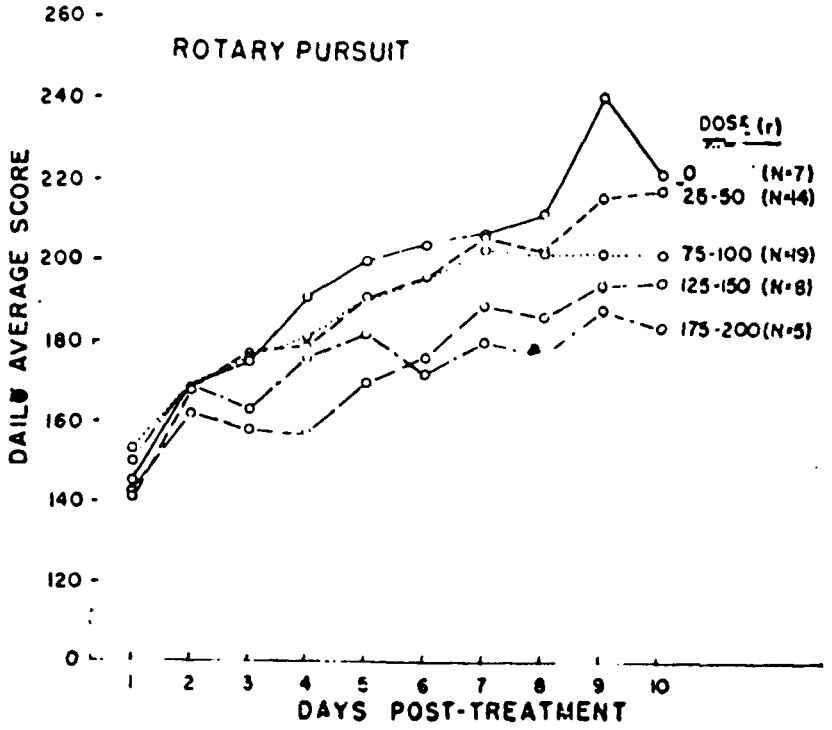
ROTARY PURSUIT
DAILY AVERAGE SCORE
260
240
220
200
180
160
140
120
0
1
2
3
4
5
6
7
8
9
10
DAYS POST-TREATMENT
DOSE (r)
0 (N=7)
25-50 (N=14)
75-100 (N=19)
125-150 (N=8)
175-200 (N=5)

Figure 6

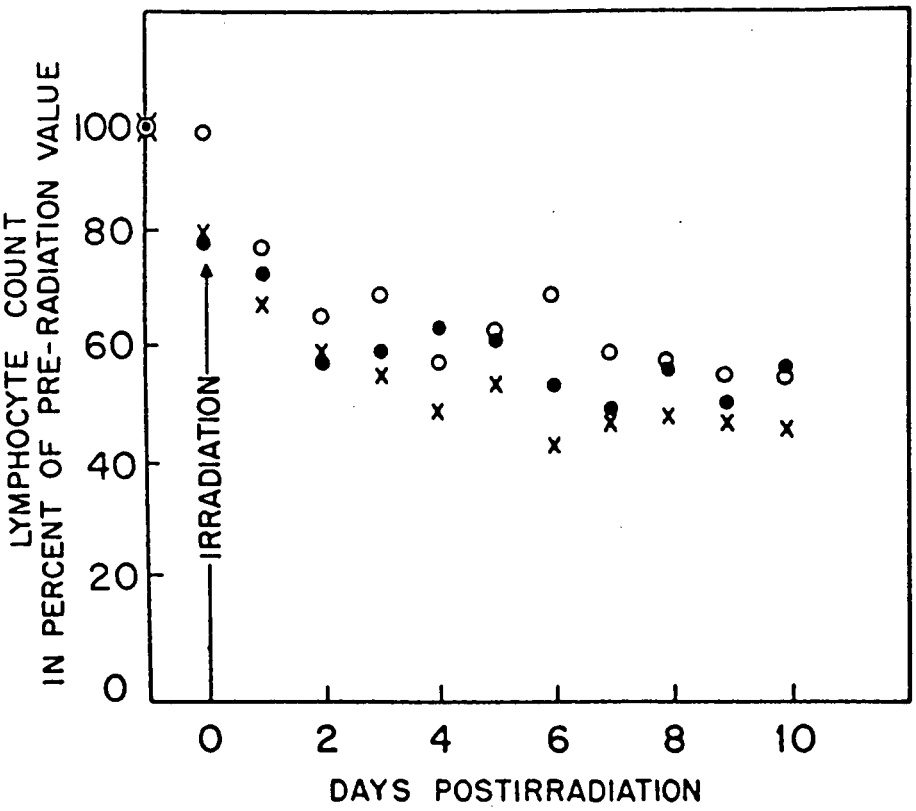
LYMPHOCYTE COUNT
IN PERCENT OF PRE-RADIATION VALUE
100
80
60
40
20
0
IRRADIATION
0
2
4
6
8
10
DAYS POSTIRRADIATION

Figure 7

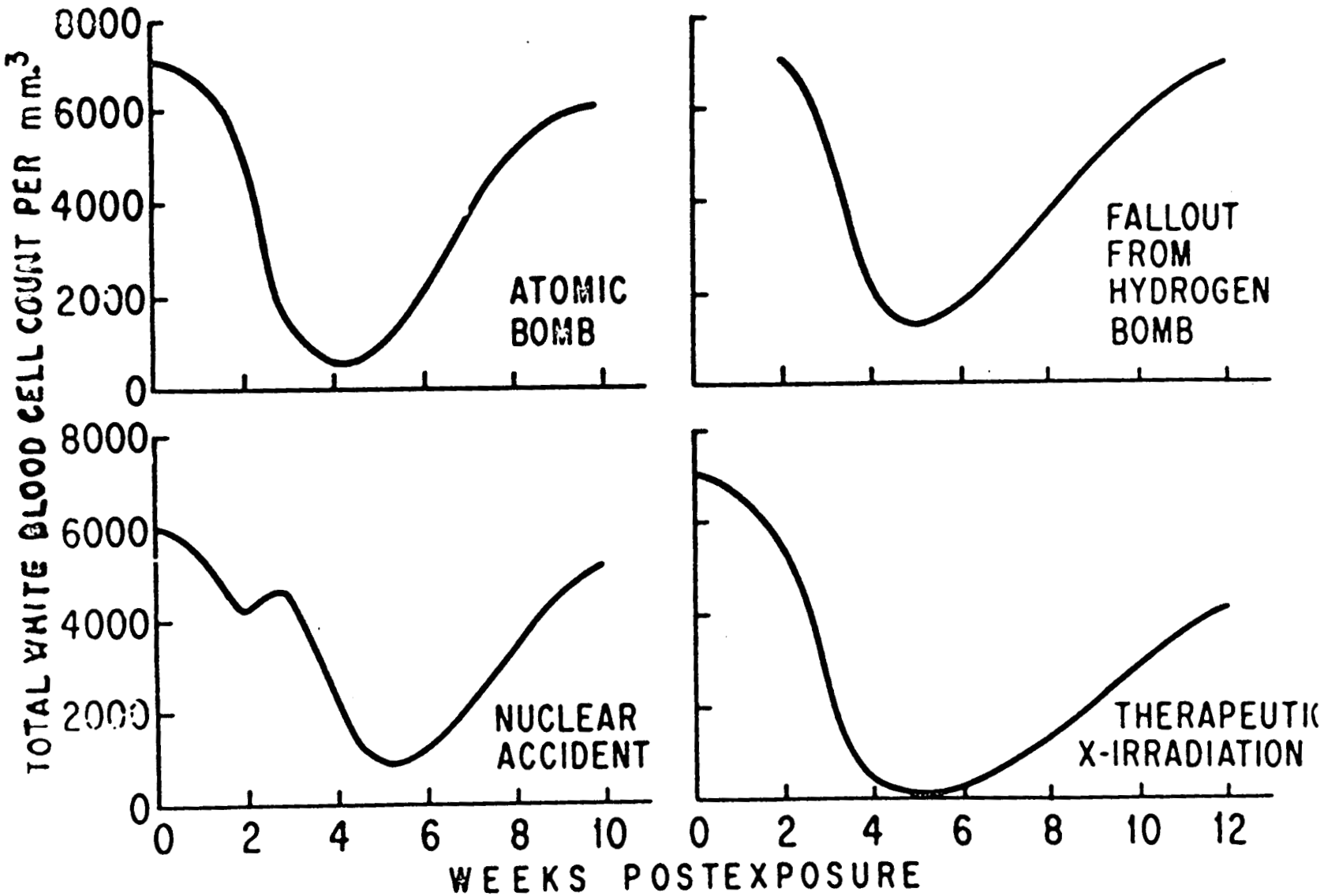

FIGURE 4

Similarity of the leukocyte response in persons exposed to various types of penetrating ionizing radiation. Origin of data is explained in text.

Figure 8

MORTALITY

Group	Dose, γ rep	Dose, on^1 rep	Rem	Survival time hr	Survivors	Group	Dose, γ rep	Dose, on^1 rep	Rem	Survival time hr	Survivors
A	562	495	1602	188	0	A	322	286	923	325	0
B	480	436	1396	203	0	B	276	253	807	318	2
C	434	391	1255	213	0	C	252	211	695	357	6
D	395	351	1132	276	0	D	242	185	631	346	5
E	355	315	1017	327	0	E	204	158	536		8
F	320	252	849	356	0	F	187	127	454	549	7
G	285	202	709	423	0	G	169	114	408		8
H	245	213	692	409	3	H	151	103	367		8
I	225	152	544	462	6	I	129	86	310		8
J						J	119	77	281	632	7
Control	0	0	0	0	8	Control	0	0	0	0	8

Figure 9