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Diagnostic Radiology

Radiation Registry of Physicians[1]

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ABSTRACT—Preliminary findings for the original group of approximately 7,900 specialists given a Radiation Registry of Physicians questionnaire are presented. The questionnaire was developed for the purpose of studying the biological effects of prolonged exposure to ionizing radiations among radiologists and comparable specialists. The study population is the total living membership of the American College of Radiology and the College of American Pathologists as of December 1961 and thereafter. The questionnaire furnished information about personal characteristics, possible exposures to ionizing radiations or other health hazards, and reproductive and family histories.

INDEX TERMS: Education • Epidemiology • Radiations, surveys • Radiations, Injurious Effects, as result of diagnostic procedures • Radiations, Injurious Effects, in physicians, radiation personnel, etc. • Radiology and Radiologists

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THE HISTORY of the Radiation Registry dates back to 1959, when an *ad hoc* Committee on the Follow-up Study of Radiologists was convened by the Division of Medical Sciences of the National Academy of Sciences–National Research Council (NAS-NRC). In December 1959, this committee, stimulated by the interest of committee chairman Shields Warren (13), unanimously voted to approve the establishment of registries for collecting data on radiologists and suitable comparison groups as a resource for future studies, recognizing that this was one of the few available means of gaining knowledge regarding the long-term effects of ionizing radiations in man (1, 3, 5, 6, 12).

Because of the studies of survival among radiologists then being conducted at the Johns Hopkins University School of Hygiene and Public Health by Raymond Seltser and Philip Sartwell (9, 10), the NAS-NRC initiated the Registry project as part of the existing Johns Hopkins activity, thus creating a new, more comprehensive Registry project which was to be supervised by a standing committee of the NAS-NRC. In 1960, development of the Registry at the Johns Hopkins University began as a pilot venture with modest expenditures of personnel and funds. Plans for the long-term cooperation of the participating colleges of medical specialists and their membership were worked out, and procedures for data collection, processing, maintenance, and analysis were developed. Registers were established at the participating colleges and a central statistical unit was set up at Johns Hopkins. Financial support came from the Public Health Service and the Atomic Energy Commission.[2]

In July 1968, the Registry project and responsibility for its operation were transferred to the Bureau of Radiological Health of the Public Health Service, where a Central Registry Unit is maintained. The Radiation Registry of Physicians now operates jointly with the American College of Radiology (ACR), the College of American Pathologists (CAP), and the NAS-NRC. The original plans for the Registry envisioned the involvement of at least two other specialty societies, the American College of Physicians and the American Academy of Ophthalmology and Otolaryngology. Subsequent discussions led to the decision to initiate the project with the ACR and CAP, with the idea that other societies might be invited to participate if experience showed this to be desirable. It was felt that broader participation would be easier to secure if it were demonstrated that the two "pilot" registers could be operated successfully.

It is important to clarify at this point what is meant by the terms *register* and *registry* in this re-

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port. The term *register* is defined as a listing of persons or the accumulated body of recorded data regarding those persons, whereas a *registry* is defined as the organization and process involved in the support, maintenance, and operation of a register. A single radiation registry, therefore, represents an organization which can support several registers. This is more than mere semantics. Even though the ideal research design calls for the collection of data in an identical fashion for both "cases" and "controls" in a study, the development of a registry program calls for a certain amount of improvisation. Thus the two colleges participating in the Registry program are each operating separate registers, which must be evaluated separately.

The Radiation Registry was clearly defined at its inception as an attempt to establish a long-term follow-up of radiologists and comparison groups "designed to disclose such effects on life expectancy, morbidity and related characteristics as may be the result of exposure to radiation." The interest of the Registry program covers the entire gamut of biological effects of ionizing radiations. It may be said that one of its aims is the collection of data on the variables of today which may serve as indicators of the radiation effects of tomorrow.

METHODS

The basic source document of the Radiation Registry of Physicians is an eight-page, self-administered questionnaire which is mailed to members of the two colleges and returned to the respective college offices. The questionnaire has been designed to furnish information about such personal characteristics of the Registry group as age, sex, marital status, place of birth, and information regarding professional career; gross descriptions of possible exposures to ionizing radiations, including type of x-ray work, years of occupational exposures of various types, and personal exposures to diagnostic and therapeutic radiation procedures; personal exposures to other health hazards, including tuberculosis and cigarette smoke; reproductive histories which might facilitate evaluation of possible genetic effects of radiation exposure (including a history of miscarriages, stillbirths, congenital anomalies, maternal x-ray exposures, or other conditions during pregnancy); and a family history, including a survival record of parents, siblings, spouse, children, and grandchildren (including both family and respondent histories of specific conditions thought to be related to radiation exposure, such as leukemia, skin cancer, etc.).

The questionnaires remain the property of each of the respective colleges. However, they are forwarded to the Central Registry Unit in the Bureau of Radiological Health for processing and coding after they have been checked by the college offices. Elaborate precautions have been taken to safeguard the confidential nature of the completed questionnaires. All members of both colleges have been assigned Registry Code numbers which constitute the only identifying mark on the questionnaire. The responsibility for assigning the Registry Code number rests with the Central Registry Unit, and numbers are now assigned to all new members each year on the basis of cards forwarded from the college offices. The individual respondent does not sign his name, and numerous procedures have been developed to prevent individuals who need access to the questionnaires from also obtaining access to the code book which identifies the individual.

Each questionnaire, with its related documents, is kept in an individual file identified by a study number. No names are ever attached or related to the completed questionnaire. Each college, as well as the project officer in the Central Registry Unit, has a single master log of the study number assigned to an individual. The colleges maintain alphabetical files and the central unit keeps a numerical log. The Central Registry Unit also maintains current files of names and addresses of all members of the two college registers.

After the questionnaires have been forwarded to the Central Registry Unit, the information is coded and punched on IBM cards for storage and use in analysis. The identifying data on each respondent are immediately coded and punched so that current lists of respondents and nonrespondents are always available. A detailed coding system has been developed to generate a minimum of 11 IBM cards from each questionnaire. The coding system is based on experience derived during the first few years of the study, when detailed studies were conducted on a 10% sample of questionnaires as they were received by the Statistical Unit at Johns Hopkins. Repeat mailings of questionnaires are made to nonresponding members, and several other methods have been used or are being contemplated by the colleges to improve the response rate.

RESULTS

The data generated by the Radiation

Registry are classified as cross-sectional, retrospective, and prospective or longitudinal. Examples of these three types of data are given below.

I. Cross-Sectional Data

A. Composition of the Total Radiation Registry Population: The total population included in the Radiation Registry comprises all U. S. physicians who were members of the American College of Radiology (ACR) and the College of American Pathologists (CAP) in December 1961 (later changed to Jan. 1, 1962) and all those who subsequently became members of the participating colleges. By March 1970, the Radiation Registry included 7,090 members and former members of the American College of Radiology and 5,678 members and former members of the College of American Pathologists. It is an important aspect of the Registry operation that once individuals have been enrolled into the Registry, future follow-up will be attempted regardless of whether they retain their college membership or not. This has not posed a problem as yet, but it will involve extra work in tracking down individuals who drop out of a college for any reason. However, this does not represent a major problem when dealing with physicians, since they are followed continuously by the American Medical Association through its directory department.

Of the ACR members, 4,741 represent individuals enrolled in the original Registry program in December 1961; 3,115 of the CAP members were in the original group. The additional 2,349 ACR and 2,563 CAP registrants represent new members. Most of the material analyzed thus far has dealt exclusively with the original registrants.

B. Response of the Original Registry Group: When the questionnaires were returned by the original group of respondents, two peaks were notable: one covering the initial six-month period of mailing and follow-up requests and a second peak which reflects the intensive clean-up campaigns carried out first by the ACR and then, one year later, by the CAP. Somewhat different techniques were used by the two colleges, for a number of reasons. The most effective results were obtained by the American College of Radiology, which employed its local councillors in a combined telegraph and telephone campaign and achieved an overall response rate of 89.2%, compared to 77% for the CAP. The ACR response rates were at the same high level in all geographic regions of the U. S.; there was more variation by region in the CAP response rates, but these differences are not remarkable.

C. Response of New Members: The Registry is a dynamic instrument which needs continued follow-up efforts to maintain satisfactory response rates. The new members taken into the ACR in 1962 attained response rates similar to the overall response of the original group, but considerably fewer of those who were enrolled in 1963 responded. The same is essentially true for new CAP members, whose 62% response is similar to that of the original group one year previously.

D. Age Distribution of Respondents and Nonrespondents: TABLE I shows the importance of age as a variable in response to this program. There is a rather consistent inverse relationship between the age of the members and the level of response, which is to be expected. In view of the fact that future initial questionnaires will be filled out by relatively younger men, the prognosis for continuing improvement of the level of response in this program seems excellent.

Comparison of responses in the current Registry project with the response levels attained by a previous study carried out by Macht and Lawrence in 1951 (4), in which the follow-up activities were limited to one follow-up letter, reveals that the response rates have been consistently higher for respondents of all ages despite the longer questionnaire used in our study. Many radiologists did not respond to the 1951 survey but have responded to the current project either spontaneously or as the result of the persistent follow-up efforts of the college officials. There is an important difference in the orientation of these two studies, begun ten years apart. The 1951 survey was a well-conducted

TABLE I: PERSONAL DATA: QUESTIONNAIRE RESPONSE ACCORDING TO AGE

Age (1961)	Yr. of Birth	Radiologists (ACR) Total Sent	Radiologists (ACR) No. Returned	Radiologists (ACR) % Response	Pathologists (CAP) Total Sent	Pathologists (CAP) No. Returned	Pathologists (CAP) % Response
≥77	<1884	67	44	65.7	38	19	50.0
72–76	1885–89	97	79	81.4	44	27	61.4
67–71	1890–94	158	126	79.7	74	48	64.9
62–66	1895–99	211	175	82.9	135	93	68.9
57–61	1900–04	332	298	89.8	197	153	77.7
52–56	1905–09	547	498	91.0	278	212	76.3
47–51	1910–14	787	707	89.8	426	320	75.1
42–46	1915–19	869	800	92.1	525	410	78.1
37–41	1920–24	1,132	1,032	91.2	776	606	78.1
32–36	1925–29	528	487	92.2	529	435	82.2
27–31	1930–34	13	13	100.0	93	82	88.2
TOTAL		4,741	4,259	89.8	3,115	2,405	77.2

study designed to collect retrospective data on congenital abnormalities among the offspring of radiologists and comparison groups of physicians. It is unlikely that any investigator initiating a similar study today could expect to do much better in terms of the degree of cooperation elicited from groups of busy practicing physicians. Although the methodology used in the Radiation Registry initially is identical to that of the 1951 survey (*i.e.*, a self-administered questionnaire), the information generated on congenital abnormalities among offspring is really incidental to the basically longitudinal orientation which is the hallmark of an ongoing Registry program.

Information obtained regarding some of the descriptive variables of respondents is useful not only in checking the comparability of the two participating college memberships but also for the intelligent analysis of information generated by other sections of the questionnaire. These descriptive variables deal with sex (more female pathologists), marital status (more unmarried respondents in the CAP, consistent with its younger membership), birthplace (more foreign-born females than males, and more foreign-born CAP members), location of the medical school from which the respondent graduated (no marked differences between the two colleges), region of residence (no important differences), and current professional status, whether active or retired (roughly the same proportion of retired respondents in both colleges).

Another piece of cross-sectional information deals with the individual's willingness to participate in a controlled trial of dosimeters. As a result of response to this question, we now have access to a roster of 2,975 radiologists who have volunteered for studies aimed at quantitating the current level of occupational risk involved in different types of x-ray practice. This is an example of another possible by-product of the Registry program.

A major problem with which the Registry project must come to grips is the matter of "incomplete response." Even though an individual is listed as a respondent, in a number of cases only portions of the questionnaire were completed. This was rather alarming when first recognized; however, we have found that this incomplete response is seen almost exclusively in a limited number of the items dealing with retrospective data. The information of a cross-sectional nature and the type of data which will be needed for longitudinal studies have usually been answered by an overwhelming proportion of the respondents; for these items, the incomplete response levels are usually less than 5%, which seems low enough to prevent a serious bias from being introduced into future statistical analyses. Specific areas in which the incomplete responses are significant enough to cast doubt upon the usefulness of the derived data will be mentioned later.

II. Retrospective Data

The type of information most readily generated from this questionnaire survey is, quite understandably, retrospective in character. We present a few findings dealing with such information simply to illustrate some of the features of these data. Many of the more interesting items of information have not yet been processed and tabulated.

A. Factors Other Than Irradiation: The problem of the effect of initial selection factors on radiologist survival was examined. It has been suggested that physicians who are in poor health are more apt to choose a sedentary type of practice or one which is primarily hospital- or office-based rather than one which involves house calls. One reason for choosing pathologists as a comparison group was that the same factors which influence the choice of radiology as a

specialty might operate in the choice of pathology as a field of specialization. We found a slight but unimpressive excess of radiologists who gave a history of having chosen their specialty as a result of illness. This seems to bear out the relative comparability of these two college memberships in regard to this factor of "initial unfavorable selection."

Preliminary analyses thus far have revealed no remarkable differences in factors which might influence the comparability of the two groups of medical specialists, such as smoking habits, prior experience with tuberculosis, or urban-rural residence.

B. Nonoccupational Radiation Exposure: There may be an important preventable occupational hazard of the field of radiology, *i.e.*, an excessive exposure to nonoccupational diagnostic x rays. The crude data show only that a greater proportion of radiologists have been subjected to medical diagnostic x-ray procedures (exclusive of routine chest films and dental x-ray examinations). If these data are valid and hold up on more refined analysis, the classical type of occupational exposures to irradiation may be found to be less important than the exposures which are "indirectly occupational" in view of the radiologists' greater accessibility to x-ray equipment. Some previously obtained preliminary data indicate that there is considerably more x-rav exposure among radiologists' families than among pathologists' families. This type of data will always be suspect in view of the possibility that radiologists may give a better history of radiation exposures, since they would remember the procedures better. This is an excellent illustration of the advantages of collecting such data for future use rather than relying on the retrospective survey.

C. Possible Effects of Irradiation: Some of the possible genetic effects of irradiation, which might be detected from the data accumulated on the responding members of the two participating colleges, were examined. One of the most interesting of these is the possible effect of paternal radiation exposure on the sex ratio of offspring. One proposed hypothesis has been that the presence of radiation-induced dominant lethal changes in the x chromosomes of the father would be expected to kill off the female offspring but not the male, resulting in an excess of male births. (Conversely, inasmuch as the male derives its only x chromosome from the mother, maternal radiation-induced damage to the x chromosomes should result in the death of the male offspring. The reverse is not necessarily true in the female offspring if the lethal gene is recessive, since the female also possesses an x chromosome from the father.)

TABLE II: REPRODUCTIVE HISTORY: SEX OF OFFSPRING

	Radiologists (ACR)	Pathologists (CAP)
Total live births	10,905	4,306
Total offspring*	11,034	4,400
Males	5,009	1,881
Females	4,521	1,908
Not stated	1,504	611
Sex ratio (% males)	0.52	0.49

* Includes multiple births

Some preliminary sex ratio data derived from the Registry experience were compared with those of previously published studies reported by Newcombe dealing with the effects of paternal radiation exposure (7). For this purpose, all radiologists in the Registry were regarded as "exposed"; a much more refined analysis will be needed in order to separate out those offspring born prior to the father's entrance into the field of radiology. However, even taking this into account, these data represent a group of exposed fathers considerably larger than any reported previously, including the Atomic Bomb Casualty Commission group (8). The difference in proportion of male births between radiologists and pathologists is consistent with the previously stated hypothesis (TABLE II). The data have been broken down by family size, which demonstrates that the proportion of male offspring decreases among responding pathologists' families as the family size increases; this is not true for the radiologists' families. The magnitude

TABLE III: REPRODUCTIVE HISTORY: CONGENITAL ANOMALIES REPORTED

Type of Anomaly	Radiologists		Pathologists	
	No.	Rate/1,000 Pregnancies	No.	Rate/1,000 Pregnancies
Heart and blood	56	5.1	30	6.8
Muscles and joints	40	3.7	17	3.9
Bones and cartilage	154	14.1	86	19.7
Gastrointestinal tract	31	2.8	16	3.7
Genitourinary tract	68	6.2	23	5.3
Central nervous system	21	1.9	22	5.0
Sense organs	99	9.1	45	10.3
Developmental arrest	50	4.6	21	4.8
Others	225	20.6	82	18.7
TOTAL	744	68.1	342	78.2

of the sex ratio shift is impressive for all three classes of family size (as measured roughly by the number of reported pregnancies).

In order to check this information more closely, we decided to look at the data on sex of offspring as reported in two separate parts of the questionnaire. In addition to questions dealing with reproductive history, there is also an item dealing with family history which asks for the current survival status of all children, as well as the year of birth and sex of each child. We felt that the tabulations should be roughly comparable for these two sections, although one might expect a slightly greater number of offspring reported in the section on family history. When the sex ratio data determined from these two sources were compared, the total number of liveborn offspring was indeed comparable for both sections of the questionnaires returned by the radiologists. However, there was a remarkable excess of some 2,000 pathologist offspring reported under the family history but missing from the reproductive history. The explanation for this is contained in the "unknowns," representing questionnaires in which the section on reproductive history was not completed. This was true for 32% of the responding pathologists, in contrast to 11% for the responding radiologists. The reason for this specific deficiency in the completeness of the questionnaires has not yet been determined. There is evidence that a number of men felt that they obviously did not have a "reproductive history," since they had never been pregnant! If this is the case and the section was omitted as a result of improper questionnaire design, a specific questionnaire dealing exclusively with this subject might be used to obtain the data. If, on the other hand, there is a general reluctance on the part of pathologists to furnish this type of information, the potential of the Registry program in the area of elucidating possible genetic effects of irradiation will be seriously limited. At any rate, in view of the large proportion of pathologist offspring for whom data are missing, we must be extremely cautious in interpreting the sex ratio data at this time.

The data on congenital abnormalities have not yet been completely tabulated. However, the level of completeness of response is apparently excellent in this area, with only 3.6% of the pathologists and 4.3% of the radiologists omitting the question. At present, there are 744 "congenital anomalies" of all types among the offspring of radiologists and 342 such anomalies among the offspring of pathologists (TABLE III).

Data on reported miscarriages and stillbirths show a remarkable similarity between the two groups. Information was derived from the same section on reproductive history previously used to provide sex ratio information, and it is interesting to speculate why the large group of "nonresponding" pathologists did not seem to influence these results. Possibly the factors influencing the failure to complete this section of the questionnaire may not be related to pregnancy history or sex of offspring in any way; the nonrespondents to this question might actually be a representative sample of the entire responding group. If this is the case, the sex ratio data presented above would reflect the true situation.

There are certain well-known limitations inherent in the use of a self-administered questionnaire to obtain retrospective data of this type. The memory factor becomes important in evaluating the validity of certain types of data: the older the respondent, the less likely that he or she will remember all of the details requested in the reproductive, personal, or family history. On the whole, however, there is a considerable advantage in having respondents who are all qualified specialists and completely familiar with the language. Notwithstanding the general deficiences in this method of obtaining information, an unusual body of data has been obtained with re-

spect to the probable high level of reliability of the information on the initial questionnaire.

It must be recognized that these types of data could have been collected without establishing a registry, as was done in the previously cited surveys. Therefore, the expense and time of maintaining an ongoing registry operation must be justified on grounds other than the types of information available from the retrospective or historical approach.

III. Prospective Data

The real justification for establishing a radiation registry is related to the longitudinal or prospective studies and analyses which are possible only if such a registry has been established and is maintained. It is sometimes difficult to keep this fact in mind, since the cross-sectional and retrospective data are readily available for analysis and discussion, whereas there is very little to show for the longitudinal aspect of the registry even after a number of years.

A. Factors Other than Irradiation: Data are not yet available, but in time there will be longitudinal information on the smoking practices of members of the two specialty groups.

B. Nonoccupational Radiation Exposure: Through updating the questionnaire and obtaining information on new members, there will be an opportunity to determine nonoccupational exposure as the members go through life. Special studies can be carried out to validate any marked differences that appear between the two groups. The suggestive differences observed so far will be tested.

C. Occupational Radiation Exposure: No valid data are yet available on quantitative estimates of x-ray exposures. The data to be obtained from repeat questionnaires and special dosimetric studies will offer opportunities to study trends in the use of x rays by different generations of radiologists and other physicians.

D. Possible Effects of Irradiation: The data which can be potentially generated longitudinally from the Radiation Registry should provide information on both somatic and genetic late effects of ionizing radiations.

Survival is the most straightforward and perhaps most valid information which can be derived from the Registry. Since basic age data are available on all college members regardless of whether they return the questionnaire or not, it will be possible to derive age-specific death rates for the members of these two specialties as the years progress.

A later study by Seltser and Sartwell (11) indicated that the type of occupational exposures to radiations used by radiologists prior to 1940 had an effect on survival. That study was based entirely upon reconstruction of membership rosters of various specialty societies and follow-up for survival status of all individuals who had ever been members of those societies. It was not possible to investigate other factors which might have influenced survival, such as smoking habits or pre-existing illnesses which might have selectively biased the composition of the specialty groups being studied.

Estimates based on current mortality rates of radiologists indicate that of the 4,200 original respondents from the American College of Radiology register, 1,450 would be expected to die within the next twenty years. Of these deaths, 250 would occur during the next five years, with an additional 300 deaths during the subsequent five years, 400 deaths during the third five-year interval, and another 500 deaths during the fourth five-year period. If the mortality analysis for this sizable group could be correlated with information recorded in the Radiation Registry files, there would be an opportunity to draw inferences with considerably greater confidence than was possible when such information was not available. As a result of the procedures developed during the radiologist mortality study at Johns Hopkins, there is an excellent mechanism available for review of all deaths of American physicians. At present, all American Medical Association death records are sent from Chicago for review and radiologist and pathologist deaths can be detected. This will be especially helpful in determining

TABLE IV: CAUSE OF DEATH

Classification	ICD No.*	Radiologists			Pathologists		
		Respondent (%)	Non-respondent (%)	Total (%)	Respondent (%)	Non-respondent (%)	Total (%)
All causes		236(100.0)	74(100.0)	310(100.0)	90(100.0)	68(100.0)	158(100.0)
Heart	401.1–443	109(46.2)	25(33.7)	134(43.2)	49(54.4)	27(39.7)	76(48.1)
Cancer	147–203	46(19.5)	11(14.8)	57(18.4)	14(15.6)	8(11.8)	22(13.9)
Leukemia	204.0–204.4	2(0.8)	2(2.7)	4(1.3)	1(1.1)	3(4.4)	4(2.5)
Vascular lesions of the central nervous system	330–334	19(8.1)	6(8.1)	25(8.1)	6(6.7)	7(10.3)	13(8.2)
Accidents	816.0–836.0	7(3.0)	6(8.1)	13(4.2)	6(6.7)	2(2.9)	8(5.1)
Chronic nephritis	592	2(0.8)	...	2(0.6)	...	...	...
Pneumonia	490–493	5(2.1)	3(4.0)	8(2.6)	...	2(2.9)	2(1.3)
Diabetes	260	1(0.4)	...	1(0.3)	...	1(1.5)	1(0.6)
General arteriosclerosis	450	2(0.8)	1(1.4)	3(1.0)	1(1.1)	1(1.5)	2(1.3)
Cirrhosis of the liver	581.0–581.1	1(0.4)	...	1(0.3)	...	1(1.5)	1(0.6)
Suicide	970.2–978	2(0.8)	1(1.4)	3(1.0)	3(3.3)	2(2.9)	5(3.2)
Hyperplasia of the prostate	610	1(0.4)	...	1(0.3)	...	...	...
Hernia and intestinal obstruction	561.0–561.5 and 570.0–570.5	5(2.1)	1(1.4)	6(1.9)	...	...	1(0.6)
Diseases of the circulatory system	465–466	3(1.3)	1(1.4)	4(1.3)	...	1(1.5)	1(0.6)
All other causes		26(11.1)	12(16.2)	38(12.3)	8(8.9)	7(10.3)	15(4.5)
Unknown	795.5	5(2.1)	5(6.8)	10(3.2)	1(1.1)	6(8.8)	7(4.5)
Total admissions		4,295(100.0)	482(100.0)	4,741(100.0)	2,405(100.0)	710(100.0)	3,115(100.0)
Total deaths		236(5.5)	74(15.4)	310(6.5)	90(3.7)	68(9.6)	158(5.1)

* ICD (International Classification of Diseases, World Health Organization)

TABLE V: CANCER DEATHS REPORTED JAN. 1962–APR. 1968

Classification	ICD No.	Total No. of Cancer Deaths	Radiologists			Pathologists		
			Respondents	Nonrespondents	Total	Respondents	Nonrespondents	Total
All neoplasms		87	48	13	61	15	11	26
Digestive	150–159	26	11	4	15	7	4	11
Respiratory	160.0–165	14	10	2	12	1	1	2
Male genital organs	177–179.9	11	9	1	10	...	1	1
Urinary	180–181.8	7	5	1	6	...	1	1
Skin	190.0–191.9	3	1	...	1	2	...	2
Brain and central nervous system	192–193.9	3	1	1	2	...	1	1
Other	140.0–148 194–199	8	4	1	5	3	...	3
Lymphoma	200.0–203	7	5	1	6	1	...	1
Leukemia	204.0–204.4	8	2	2	4	1	3	4

survival status of nonrespondents. The participating colleges are also a source of reports of deaths, since survival status is reviewed annually for all active dues-paying members. As of April 1968, there had been 468 deaths among the original Registry members; the specific causes of death are shown in TABLE IV.

It may be estimated that of the expected deaths from *cancer and leukemia* occurring among the 4,200 responding radiologists, 200 may be due to cancer, of which 15–20 may be due to leukemia. Investigation of these cases could be carried out using the case-control method of study, since it would be possible to employ both matched pathologists and other radiologists for comparison purposes. The cancer deaths by type among the original groups of radiologists and pathologists as of April 1968 are given in Table V.

In addition, recent studies indicate a suggestion of an across-the-board effect on mortality from most major causes of death. Cause-specific data therefore may be most important for determining possible effects of irradiation on other major diseases as well.

In regard to *genetic effects*, it is anticipated that the data on sex ratio and congenital abnormalities among offspring of radiologists and pathologists will be more valid on a longitudinal study basis than on a retrospective basis. Many new members of both colleges represent young families still in their child-bearing years. Data collected on these groups should accumulate rapidly during the coming years. It should also be possible to investigate second-generation effects of radiation exposures by conducting special studies of the fertility patterns of the offspring and looking for congenital malformations among the grandchildren. More than 1,670 grandchildren have been reported by ACR members and 690 by CAP members. Forty-six congenital anomalies have been reported thus far in ACR grandchildren (2.8%) and 23 in CAP grandchildren (3.3%).

SUMMARY

This is the first report of the Radiation Registry of Physicians, conceived and gradually established during the past decade. The Registry was developed as a vehicle for the long-term follow-up of radiologists and comparable medical specialists for the purpose of studying biological effects of prolonged exposure to ionizing radiations. The study population is comprised of the total living membership of The American College of Radiology and the College of American Pathologists as of December 1961 and thereafter. The basic source of information is a detailed, self-administered questionnaire handled confidentially by the two colleges; the processing of data is done separately in a central registry unit of the Public Health Service.

To date, the principal types of tabulated data available are cross-sectional and retrospective; longitudinal data, except for some survival figures, have not yet been generated. The future production of longi-

tudinal data is the primary goal of the Registry. Important as cross-sectional and historical data are, they can be gathered by survey techniques without the need for registries. The collection of longitudinal data on an ongoing basis offers the advantage of reliability of current data as compared with recollected data, as well as the opportunity for soundly based prospective studies.

Because the Registry includes total population groups, it can serve as a frame for sampling subgroups of radiologists or pathologists for intensive study. Sampling on a known probability basis, even if it involves only small numbers, provides the basis for the use of conventional statistical tests and evaluation.

There are already many suggestive leads from the data concerning the nonoccupational use of irradiation by radiologists and their families, the diminished occupational exposure of younger radiologists, and possible alterations in the sex ratio of offspring. The Registry is not designed to yield quantitative dosimetric information, but this weakness could be overcome by studying samples of practices and exposures and relating these to the study of population exposure to x rays in the United States which was carried out in 1964 (2) and repeated in part in 1970.

The feasibility of developing a physician registry which may prove useful in delineating biological effects of occupational exposure to ionizing radiations has been demonstrated. The existence of the Registry poses a challenge to those responsible for establishing safety standards in the radiation field. A number of studies might employ appropriately drawn samples of physicians for intensive studies of dosimetry and related areas. Such studies would have the advantage of yielding a maximum amount of information economically. However, the Registry's major contribution is the opportunity for longitudinal follow-up of responding physicians and the compilation of increasingly relevant and useful data over the years with adequate opportunities for the validation of such data.

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REFERENCES

1. Court Brown WM, Doll R: Expectation of life and mortality from cancer among British radiologists. Brit Med J 2:181–187, 26 Jul 1958
2. Gitlin JN, Lawrence PS: Population exposure to x-rays, U.S., 1964. Public Health Service Public. No. 1519. Washington, D.C., Govern Print Off, 1964
3. Lewis EB: Leukemia and ionizing radiation. Science 125:965–972, 17 May 1957
4. Macht SH, Lawrence PS: National survey of congenital malformations resulting from exposure to roentgen radiation. Amer J Roentgen 73:442–466, Mar 1955
5. March HC: Leukemia in radiologists. Radiology 43:275–278, Sep 1944
6. March HC: Leukemia in radiologists in a 20 year period. Amer J Med Sci 220:282–286, Sep 1950
7. Newcombe HB: Genetic effects in populations, with special reference to studies in man, including ABCC results. Radiat Res 16:531–545, Apr 1962
8. Schull WJ, Neel JV: Radiation and the sex ratio in man. Science 128:343–348, 15 Aug 1958
9. Seltser R, Sartwell PE: Ionizing radiation and longevity of physicians. JAMA 166:585–587, 8 Feb 1958
10. Seltser R, Sartwell PE: The application of cohort analysis to the study of ionizing radiation and longevity in physicians. Amer J Public Health 49: 1610–1620, Dec 1959
11. Seltser R, Sartwell PE: The influence of occupational exposure to radiation on the mortality of American radiologists and other medical specialists. Amer J Epidem 81:2–22, Jan 1965
12. Ulrich H: The incidence of leukemia in radiologists. New Eng J Med 234:45–46, 10 Jan 1946
13. Warren S: Longevity and causes of death from irradiation in physicians. JAMA 162:464–468, 29 Sep 1956

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Date September 4, 1945

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Subject Post-War Biology Program

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From H. J. Curtis

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September 4, 1945

To: R. S. Stone

From: H. J. Curtis

Re: Post-War Biology Program.

Summary.

As the principal objectives of the biological research of the Metallurgical Project approach attainment, a new goal should be established for the conduct of the work. This goal should be dual, and should include both work on the practical problems associated with nucleonics and work in pure research aimed broadly at the attainment of fundamental knowledge. The science of nucleonics has furnished biology with important new tools in the form of various kinds of radiation. The potentialities of these tools are not clearly seen, chiefly because they have never been looked for. A program should be initiated to consider these questions, and such a program should include research in cancer, aging, biochemistry, physiology, and bacteriology.

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Introduction.

I am writing this letter in response to your recent letter requesting suggestions for a post-war biology program. I have talked a good deal recently with Dr. Raper, Dr. Henshaw and others, so this letter will be an attempt to reflect the views of all of us. I have also drawn heavily on previous communications on this subject, so the present views do not necessarily represent a change from previous views; indeed, I have found that our views on this subject have changed remarkably little during the past three months. However, many of them have become crystallized so they can be more precisely stated.

At the present time it appears that the greatest contribution which the science of nucleonics can offer to the science of biology is in the field of radioactive tracers. Following your suggestion, I am omitting discussion of this important field.

Objectives of Research Program.

In considering a program of research in biology, it is pertinent to consider first the objectives. We feel there should be two, namely, 1) a better understanding of the hazards involved in the nucleonics profession and 2) a better understanding of certain other biological problems which can be attacked more satisfactorily by the methods of nucleonic biology than by any other. This distinction is quite similar to the distinction commonly made between developmental and pure research. In a great many cases the problems arising from these two objectives would be indistinguishable, but it is important to establish clearly these two objectives.

Considering the first of these objectives, I think it is safe to say that by the time our present experiments are complete, we will have reached a turning point in the biology program. Most of the experiments have been aimed directly at determining toxicities and setting tolerance doses, and this work should constitute a rather complete survey of the entire field. It is impossible to predict

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[redacted]

the outcome of these experiments, but present indications are that they will substantiate most of our early predictions. However, they will tell us very little about the fundamental nature of the action of radiations on tissues, and very little about the validity of the concept upon which all currently accepted radiation tolerance values are based. However, these could be used as a basis for a protection program and the nucleonics industry would involve no more risk than, say the manufacture of tetraethyl lead. I would be the last to advocate a cessation of research on lead poisoning, and by the same token feel that research on radiation injury should continue. Such research will continue in a sporadic way in various institutions just as research in lead poisoning has unless a well organized program is undertaken. I believe such a program is justified on the grounds of protection of the valuable personnel, the difficulty in diagnosing radiation injury, lack of knowledge of the fundamental mechanisms involved in radiation injury, or the ever-present possibility of the discovery of new radiations or new products. If there is to be a program in radiation injury then nucleonics laboratories, being more concerned than any other single institution in the country, should undertake it.

Turning now to the second objective, namely, the applications of the ideas and techniques of nucleonics to biological problems, I feel that if a research center for nucleonics is to be established, it would be a grave mistake to omit fundamental research in biology. I will not enter into a discussion of the merits of pure research, but would like to quote from Bush in "Science, the Endless Frontier". 'The striking advances in medicine during the war have been possible only because we had a large backlog of scientific data accumulated through basic research in many scientific fields in the years before the war', and again, 'progress in combating disease depends upon an expanding body of new scientific knowledge - - progress in the war against disease results from discoveries in remote and unexpected fields of medicine and the underlying sciences.' Indeed, I would go so far as to say that if only developmental research in biology can be justified, then I feel that no biological program at all should be undertaken in connection with the nucleonics program.

[redacted]

In establishing a program of research, the two objectives would be closely associated, and in fact, probably each individual would be working toward both goals simultaneously.

Research Facilities.

There are research facilities which have been uncovered by the Metallurgical Project which offer tremendous possibilities. We have devoted ourselves during the war entirely to developmental research in biology, so the problems of this field can be rather clearly forseen; but the field of pure research is untouched and therefore the problems cannot be as clearly stated. It is safe to say that they, none-the-less, ultimately will be far more important. The facilities peculiar to this field are almost entirely in the nature of radiations, and therefore, problems should center around the effects of radiations on biological material and materials of interest in biology. Radiations now available or under consideration are as follows:

a) Thermal Neutrons: These are available at Clinton, 105, in pure form at intensities of $nv = 3 \times 10^8$ and contaminated with other radiations at $nv \sim 2 \times 10^{12}$. At Argonne CP - 3, $nv \sim 10^{12}$. At Clinton 105B (proposed) $nv \sim 2 \times 10^{14}$ contaminated and $nv \sim 10^{11}$ in pure form suitable for animal exposure.

b) Beta Rays: Sources have been developed on the project by activation of phosphorus containing plaques having surface intensities of 15000 r/hr., and with the completion of the proposed Clinton 105B pile values at least 10 times as strong should be available. These sources could be shipped, but for research purposes could best be used near a production pile.

c) Gamma Rays: Piles themselves act as excellent sources of gamma rays and the following maximum intensities may be obtained. Clinton 105, ~ 30,000 r/min; Hanford 105B, ~ 150,000 r/min; Clinton 105B (proposed), ~ 3,000,000 r/min. In addition, activated tantatum sources of 100 curies are available at Clinton, and larger ones could easily be made. Fission products can be

separated to give very intense sources. Energies conveniently available are ~ 1 Mev, but special isotopes can be developed to give stronger or weaker radiations.

d) Fast Neutrons: These radiations are readily available at Clinton in pure form for animal exposures at intensities of about 3 n/min, (1.7 Mev average energy). Inside the Clinton 105 pile, the intensity nv ~ 10^{12}. In the Clinton 105B (proposed) unit there will not be very ready access to fast neutrons, but indirectly, it should be possible to obtain them in pure form at intensities of about 300 n/min. By means of velocity selectors, it should be possible to obtain relatively mono-energetic neutrons having energies between 1.5 Mev and thermal in intensities considerably below these values. These velocity selection methods may prove to be extremely valuable research tools, as indicated below.

e) Fission Recoils: These radiations will be available chiefly in the liquid in homogenous piles, but enormous energies are available (about 75 Mev) and reactions might be energized in this way which could not be achieved by any other method.

f) Very High Energy Radiations: The betatron and the large cyclotron offer the possibility of exploring entirely new fields, and the investigation of the biological effects of these radiations should be considered in formulating a program of biological research.

From this discussion of research facilities, it would appear that research, in nucleonic biology, should take place in the neighborhood of one of the present or proposed piles. However, this is not necessarily the case, since a small experimental pile such as has been operated at Los Alamos for some time, might profitably be constructed at a number of research center and used to produce most of the radiations listed above in intensities great enough to be satisfactory for experimental work. This could be done very easily, given about 500 g. of either U^{239} or Pu^{239}. The advice and stimulation which could be obtained by close association with a scientific group working on closely associated problems in physics and chemistry is a factor which should not be overlooked.

Research Problems.

It is impossible to tell where a program of research may lead, but at the present time there are a number of specific problems which need attention, and these might be used as a starting point.

1) Cancer: Our present research program is showing that many of the agents associated with nucleonics are even more carcinogenic than we had feared, and that cancer induction probably is the greatest hazard of this profession. We do not know, and our present program will not tell us, all that must be known about this hazard if persons working in this profession are to be protected as well as they could be. Research here should include, especially, work on beta rays and slow neutrons, since these radiations are not as well understood biologically as others. There are some indications that they may have very interesting carcinogenic action which should be investigated not only from the purely protective point of view but for cancer research. They can be worked on conveniently only in the presence of a pile.

The cancer problem should be attacked first by a careful comparison between the above radiations and x-rays and ultraviolet radiations, since the latter are comparatively well understood. On the basis of this comparison, further work could be contemplated. No stone should be left unturned in a search for the cause and cure of cancer.

2) Aging: One of the most important problems of the present time is the one of aging. We have found that following irradiation, there is a significant loss of vitality, and that animals die prematurely in a state of atrophy. Thus irradiated animals resemble in most respects old animals. We should determine as soon as possible whether or not any of the radiations of the project are more effective for studying the general problem of aging than x-rays which may be obtained elsewhere. This problem is of paramount importance for workers in nucleonics.

3) Radiation Induced Biochemical Reactions: It has long been known that radiations produce destructive chemical reactions, such as the decompostion of water. However, certain construc-

tive reactions can be energized by radiations, and the possibilities seem quite inviting. For example, methane can be irradiated, with or without other added constituents, to form a wide variety of organic compounds. This field is only beginning to be explored from the chemical point of view, but the possibilities for the production of new biochemical materials will excite the dullest imagination. The production of one drug similar to sulfanilamide would be ample reward for the expenditure of many millions of dollars.

That this is no idle dream, will be realized by considering the fact that biochemical synthesis depend upon extremely delicately controlled reactions, and small changes in conditions mean the difference between success and failure. For example, the male and female sex harmones are almost identical chemically, yet produce quite different physiological effects. A small alteration in environment will change one into the other. Radiation chemistry offers the possibility of very localized, specialized and precisely controlled energizing of reactions. For example, epithermal neutrons having an energy of 9 ev will break simple C-H bonds, whereas it requires 30 ev neutrons to break simple C-C bonds. Bonds of different strengths could be broken by neutrons having different energies. This technique could be used not only for the production of specific chemical reactions, but for the investigation of bond strengths which would be invaluable for different types of synthesis. Once methods of synthesis were worked out, there should be no serious difficulty in making fairly large quantities of material even for medical use, Dr. Burton, of the Chemistry Division is even enthusiastic about the commercial production of such things as synthetic rubber and plastics by means of radiation energized chemical reactions.

Such a program as this should be started immediately, but significant results should not be expected for at least five years. Research may even have to start with inorganic chemistry and gradually work up to the complex reactions of physiological chemistry.

4) Genetic Effects: One of the most important branches of applied biology is the one of biological synthesis. In past years it was customary to search the world over for organisms which would make a desired end product. Recently, however, there have been many successful attempts to produce mutations in organisms for the purpose of obtaining another organism to manufacture a specific product.

For example, mutations produced in P. Notatum have recently increased penicillin production markedly. This field is just beginning to open up, and the possibilities are tremendous. It is impossible now to say whether any of the above radiations will prove more useful in this regard than x-rays but, considering that a 20% increase in mutation efficiency undoubtedly would be welcomed, the chances of some success seem particularly bright. At the other extreme one sees the possibility not only of increasing enormously the mutation efficiency but of producing selective mutations.

Geneticists are, of course, extremely interested in any agent which is capable of producing mutations, and will therefore unquestionably demand that the research possibilities of these tools be investigated.

An initial program should investigate the difference between x-rays and the various radiations listed above for at least two organisms and then proceed on the basis of these results.

5) Detection of Radiation Injury: From the project point of view, this is one of the most important problems. Considerable research on the project so far has revealed only that the blood count is a poor indication of radiation damage. However, enough work has been done so that it appears that a further frontal attack on this problem is useless, and the problem should be reopened only after significant advances have been made in the problem of the mechanism of radiations injury, as outlined below.

6) Mechanism of Radiation Injury: This problem is of paramount importance from the protection point of view, and significant advances must be made in it before the problems of detection and therapy can be undertaken effectively. This problem should be attacked by means of a) mammalian biochemistry, since it offers the possibility of finding the effects of radiations on the various chemical systems of the body; b) mammalian physiology, since a study of changes in function due to radiation should eventually lead to important practical discoveries; and c) cellular physiology and biochemistry, since the primary damage from radiation is to individual cells. All of these approaches have been used somewhat on the project and all have yielded valuable information. They should be continued, but the problem is very complex and results should not be expected too soon.

7) Bacteriology: There are a number of practical as well as fundamental problems in this connection which could profitably be investigated, such as the use of the pile for the pasteurization of milk, sterilization of vaccines, blood plasma, etc., and it has even been suggested that a pile be used for sewage disposal. It is entirely possible that radiations may selectively kill one strain of bacteria leaving others intact, may kill bacteria leaving proteins undenatured, or may even be used as a method for identification of bacterial strains. In short, we have here a physical agent, like heat, capable of accurately controlled selective destruction of matter. It would be extremely surprising if some applications in bacteriology were not found.

8) Therapy of Radiation Injury: At present there is no known specific treatment for radiation injury. It is unthinkable that some sort of treatment cannot be devised if the problem is actively pursued, particularly in connection with the problem of the mechanism of radiation injury. Considering the number of persons working with radiations both inside and outside the nucleonics program, and considering the patients being treated daily with x-rays and radium, the importance of this problem cannot be over emphasized. Its solution will not come from directed research, but will be a result of some of the work on other radiation problems.

9) Time Factors in Radiation Injury: In setting up the present biological program it was felt to be impossible to cover adequately the entire field of time-intensity relations so two extremes were chosen; small daily doses until death, and a single large dose. This is certain to be an inadequate covering of the field and when these results are complete and analyzed, a new program should be initiated to cover the gaps which are sure to be seen.

This problem is closely related to that of regeneration and recovery, which has been studied only casually on this project. It is of prime importance in the definition of tolerance and should be considered in connection with time factors.

10) Maximum Allowable Doses: So far no work on the project has thrown very much light on the fundamental postulates of this important question, but some relevant results will come from the chronic program now in progress. It is reasonably safe to assume that the answer to this question will come from the studies on cancer and aging as outlined above.

The application of these results on lower animals to corresponding problems for man is extremely difficult and liable to error. The only reasonable approach is by means of a comparative study using various animals, and leading finally to carefully conducted experiments on man.

11) Partial Body Irradiation: Most of the project studies with external radiations have been on animals whose entire body has been exposed to the radiation. In practice, this sort of exposure usually is not encountered, so it is of interest to know what differences can be expected. Is it possible, for example, to allow a greater exposure to the hands than to the total body? And if, for example, one had were to receive a very high dose of radiation, what is the prognosis and what treatment should be undertaken? This problem may be attacked in connection with those of cancer and therapy.

12) Internal Radiations: With the exception of plutonium and possibiy polonium, it appears that in general, the hazard on this project from ingested radioactive materials has not been very great. From a practical point of view, if an area is so badly contaminated with fission products that there is danger from internal radiations, there will be at least a ten fold greater danger from external radiations. Work with plutonium should continue, since it appears to be a significant industrial hazard.

There have been many interesting possibilities brought forward on the project in connection with internal radiations both in academic biology and in medicine, but these may be considered properly under radioactice tracers.

Research Program.

In order to attack successfully the above problems, it will be necessary to establish a biological laboratory in connection with one or more of the proposed research centers for nucleonics. Depending on the availability of scientists, a research program might be organized at one or more laboratories as follows:

1) A chronic study group, consisting of about three men for studying the problem of cancer, aging, tolerance doses, and time-intensity factors.

2) A genetics group, consisting of about two men.

3) A physiology group, consisting of about two men, to study the problem of mechanism of injury, detection of injury, etc.

4) A biochemistry group, consisting of about three men for studying the uses of radiations in biochemistry.

5) A bacteriology group, consisting of about two men, for studying the applications of nucleonics in bacteriology.

6) In addition, there should be space for several men who may have specific ideas along these lines. Also, provisions should be made for graduate students, professors on leave, etc.

In addition to these men, there should be technicians and helpers as needed.

This program includes only these things for which a definite need can be forseen. It has been our experience on the project that as work progresses more problems are uncovered than are solved, so in planning a program considerable expansion should be anticipated.

I do not mean to imply by this proposed organization that I feel that the work should be carefully planned, coordinated and directed. Virtually the only direction which should be placed on the program is in the hiring of the senior personnel.

I would like to re-emphazize the fact that we need here a research program aimed at the attainment of fundamental ideas, and not merely the application of old ideas to new situations. For that very reason it is extremely difficult to outline a program and impossible to predict what results may follow. It is necessary then to guide our actions solely by past experience. In the past it has been found that fundamental ideas very seldom come from directed research, but have come from individuals working without restrictions. There has been an increasing tendency in this country to organize everything, including research, and the success of the industrial laboratories is given as the reason

for organizing all research. The leaders of our industrial laboratories realize that in the long run they would be lost without continued fundamental research by universities and similar institutions, and that no industrial type laboratories even seriously attempt to do fundamental research. Dr. O. E. Buckley, president of Bell Telephone Laboratories, has said recently ("The New York Times", 8/25/45) "...'pure' or basic research directed at understanding nature's laws and expanding our area of scientific knowledge is almost wholly a function of universities and endowed pure research institutes ... one sure way to defeat the scientific spirit is to attempt to direct inquiry from above. All successful industrial research directors know this, and have learned by experience that one thing a 'director of research' must never do is to direct research, nor can he permit direction of research by any supervisory board ... successful research goes in the directoon in which some inquiring mind finds itself impelled. True, goals are set, goals of understanding in the case of fundamental research, and goals of practical accomplishment in the case of applied research."

Dr. Bush in his report, "Science, the Endless Frontier" has entered a strong plea for pure research, and has outlined a way in which this can be accomplished in this country. Research in nucleonics is exactly the same as research in other fields and I see no reason for separating it from the rest. Each should be used to strengthen the other. Therefore, if a national nucleonics program is to be considered, it would be well to consider the pure research involved as a part of the whole national research program.

I am confident that science is on the threshold either, of its greatest victory or its greatest defeat. Now is the time for our scientific leaders to employ their keenest vision and to set their sights high.

H. J. Curtis

jr