

*Interviews with a sample of the population in Buffalo, N. Y., revealed that 40 to 50 percent of the adult population had received one or more diagnostic X-ray examinations during the preceding 12-month period; 2.5 to 8.0 percent were therapeutically exposed to X-rays during their lifetime.*

## Diagnostic and Therapeutic X-radiation in an Urban Population

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**D**URING 1956, a sample of the population of Buffalo, N. Y., was interviewed to determine the frequency and distribution of selected characteristics as a basis for planning epidemiological studies of cancer. Among the characteristics studied was the extent to which persons were exposed to X-rays in diagnostic examinations and to X-rays or radium in therapeutic procedures.

Since recent discussions of population exposures to ionizing radiation have pointed up the need for precise information of this type, data on examinations and therapy are being reported separately. These data may assist in planning more intensive studies in other geographic areas. In addition, this study should be of interest to those concerned with the distribution of such exposure in the population and its relation to the distribution of leukemia.

### Method of Study

Data were obtained by interviewing all persons 18 years of age and older in a sample of households and of persons living in lodging houses in Buffalo. Residents of hospitals, convents, dormitories, and other institutions were excluded. Thus, those interviewed represented

the noninstitutionalized population of Buffalo. In both the households and lodging houses, the samples were selected so that they resulted in a uniform sampling fraction of 1 in 75.

For the household sample, addresses were selected systematically from the Buffalo City Directory of 1956, supplemented by a list of new addresses obtained from the building permits issued by the Buffalo Bureau of Buildings. To take care of omissions from the directory, the "half-open interval method" was used; addresses thus obtained were added to the original lists (1). Separate area sampling studies indicated that a small percentage of addresses were missed by these means.

For lodging houses, a list was obtained from the Erie County Health Department, where lodging houses are registered, and a probability

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sample was drawn maintaining the same sampling fraction.

When the selection of the sample was completed, the addresses were arranged by socioeconomic status. The socioeconomic status of the population was estimated from information on census tracts in Buffalo published by the Bureau of the Census in 1950. The census tract comprises a neighborhood of between 3,000 and 6,000 persons who are relatively homogeneous with regard to such characteristics as median monthly rental, occupational status, and extent of home ownership. The census tracts in Buffalo were ranked according to the median monthly rental as determined in the 1950 census and then assembled into halves so that approximately 50 percent of the city's population fell into each half. The median monthly rental was considered a valid index of relative socioeconomic status because of its high correlation with other indexes such as family income, years of school completed, and occupation.

For white persons in the sample, each address was assigned to its census tract; the assignment determined whether it fell into the upper or lower socioeconomic group. The non-whites were dealt with separately because of their small numbers; however, a large majority of them were in the lower socioeconomic group.

Use of the 1950 census data for assignment of addresses in 1956 might be questioned, but from our knowledge of areas in the city and the social changes that have taken place since 1950, it seems reasonable to expect that those assigned to the lower group are in general of lower socioeconomic status than those assigned to the upper group. In any event, the 1950 census data are the best available for this purpose.

Addresses from both socioeconomic strata were assigned randomly to interviewers.

A total of 4,456 adults were interviewed. About 11 percent of the adults in the selected sample were not interviewed for various reasons: some refused; some were too ill; and others were not at home despite repeated visits by interviewers. To the extent that these 11 percent differ from the 89 percent interviewed, the information obtained is not representative of the population of Buffalo.

As part of the interview, respondents were

asked if, during the preceding 12 months, they had had X-ray or fluoroscopic examinations of the chest, stomach, bowel, teeth, or other part of the body. Each part was specifically mentioned by the interviewer. If a "yes" answer was received, the interviewer then asked the number of times each part was examined. Each respondent was also asked, "Have you ever had any X-ray or radium treatments?" If the respondent replied, "Yes," he was asked what part of the body was treated, when he received treatment (month, year), and for what reasons treatment was given.

In planning the study, it was thought that information on examinations occurring prior to the previous year would be faulty because of defective recall. On the other hand, it was thought that treatment might be sufficiently vivid in a person's lifetime so that it would be less affected by errors of recall, except for treatment received during childhood. Information obtained by interviews is of course subject to error; this will be discussed more fully later in this report. With respect to the possibility of error, it should also be noted that the information about the individual was obtained directly from the person concerned, not from another family member.

In making comparisons among the various groups in this study, differences in their age composition were taken into account by using the direct method of age adjustment commonly employed in routine vital statistics practice (2). The standard population used for age adjustment was the total sample. The rates presented for these groups are adjusted for age and are directly comparable. The numbers in the groups in the tables vary slightly as a result of the variation in the percentage of "don't know" or omitted answers for individual items.

### **Age, Sex, and Race Distribution**

In table 1, the age-specific percentages of persons who stated they had had diagnostic X-ray examinations and X-ray or radium treatments are presented by race and sex. It is notable that between 40 and 50 percent of the population were exposed to one or more diagnostic X-ray examinations during a 12-month period. In general, among adults men were examined more

**Table 1. Percentage of persons who had one or more diagnostic X-ray examinations during 12 months preceding interview, and of those who had X-ray or radium treatments during lifetime, by age, sex, and race**

Age (years)	Examinations				Treatment			
	White		Nonwhite		White		Nonwhite	
	Men (N=1,766)	Women (N=2,051)	Men (N=170)	Women (N=225)	Men (N=1,793)	Women (N=2,068)	Men (N=172)	Women (N=227)
18-19.....	74.4	66.2	100.0	53.3	16.3	9.2	0	6.7
20-29.....	59.3	53.3	63.3	52.3	4.7	8.8	0	1.5
30-39.....	50.7	38.1	65.1	55.6	8.6	9.9	2.3	1.6
40-49.....	51.2	35.6	57.1	31.0	7.3	9.5	4.8	6.9
50-59.....	34.1	34.3	40.7	31.4	6.0	14.2	3.7	2.9
60-69.....	32.3	25.2	57.1	21.4	5.6	11.2	0	0
70 and over.....	24.0	17.7	50.0	0	3.1	9.5	0	0
All ages.....	45.9	37.2	58.2	44.4	6.5	10.5	2.3	2.6

frequently than women, whereas women were treated more frequently than men. For both men and women in each racial group the frequencies of diagnostic examinations were highest in the younger ages; they decreased with advancing age.

This last finding is surprising, for one would

expect that since the frequency of illness increases with age, diagnostic X-ray examinations would be more frequent in the older age groups. A possible explanation for this age variation would be that young adults are more conscious of health and consequently obtain more X-ray examinations than older adults.

**Table 2. Distribution of conditions for which X-ray or radium treatments were given, by sex**

Condition for which treatment was given	X-ray <sup>1</sup>				Radium <sup>2</sup>			
	Men (N=109)		Women (N=188)		Men (N=10)		Women (N=43)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Acne.....	8	7.3	23	12.2				
Allergy.....			5	2.7				
Arthritis.....			10	5.3				
Backache.....	6	5.5	7	3.7				
Bursitis.....	16	14.7	24	12.8				
Infections, fungus.....	7	6.4						
Infections, skin, sinuses, others.....	17	15.6	19	10.1				
Injuries.....	10	9.2						
Menstrual problems.....							11	25.6
Miscellaneous <sup>3</sup> .....			25	13.3	7	70.0	3	6.9
Muscle aches.....	15	13.8						
Pelvic conditions, general.....			8	4.3				
Pelvic conditions, other.....							11	25.6
Skin conditions, including dermatitis.....	27	24.8	34	18.1				
Thyroid disease.....			8	4.3				
Tumors, including cancer.....	3	2.8	16	8.5	3	30.0	18	41.9
Warts.....			9	4.8				

<sup>1</sup> Percentages calculated from total number in group receiving X-ray treatment.

<sup>2</sup> Percentages calculated from total number in group receiving radium treatment.

<sup>3</sup> Miscellaneous conditions for which radium treatment was received include deafness and spine injuries.

This seems likely since, as will be noted later, a vast majority of X-ray examinations are of the chest, and probably many of these were part of mass population surveys.

It is also possible that the increasing use of diagnostic X-rays over the past decades is reflected first in the younger age groups, who may have been more likely to accept such innovations and to continue the practice. Therefore, the percentage of exposed individuals in the older ages may increase in the future. The age distribution may also reflect increases in pre-employment physical examinations and membership in health insurance plans.

More of the nonwhites than of the whites had received diagnostic examinations; this is particularly true for the men, among whom this difference is present for all age groups. For the women, the difference between the races is less marked and is not consistent for all ages. Age-adjusted rates for white and nonwhite women are similar.

About 8 percent of the white population and about 2.5 percent of the nonwhites have received X-ray or radium treatments, or both, during their lifetime (table 1). In general, women were more frequently treated.

The frequencies of conditions for which X-ray and radium treatments were given, at least insofar as the respondent was able to recall, are presented in table 2. It is impossible to evaluate the reliability of such information in the absence of medical records. It is of some

importance that many of the conditions for which treatment was received in the past may not be so treated now.

### Socioeconomic Distribution

Age-adjusted frequencies of X-ray examination by part of body examined and by race and sex are shown in table 3. For the white population, frequencies are shown also for the lower and upper socioeconomic groups. In view of the current concern over the association of leukemia with ionizing radiation and the observation that leukemia is more frequent in the upper socioeconomic classes than in the lower, exposure to diagnostic and therapeutic X-ray or radium treatment was analyzed to see if it varied in these socioeconomic groups in a manner consistent with the variation in leukemia (3, 4).

From table 3 we note that a large majority of X-ray examinations were of the chest; this is true for both races and both sexes. For all organs examined, men were more frequently examined than women. Also, the frequency of examination is consistently higher for the upper socioeconomic groups for both sexes and for all organ sites. From our knowledge of the social patterns of medical care this is not unexpected.

Comparisons of the white with the nonwhite groups reveal some interesting differences. The frequency of examination of the chest, stomach, and bowel is higher for nonwhite men than

**Table 3. Age-adjusted percentages of persons who received one or more diagnostic X-ray examinations during 12 months preceding interview, by site of examination, sex, race, and socioeconomic group**

Site of examination	White men			White women			Nonwhite <sup>1</sup>	
	Upper group (N=978)	Lower group (N=801)	Both groups (N=1,779)	Upper group (N=1,152)	Lower group (N=909)	Both groups (N=2,061)	Men (N=172)	Women (N=226)
Chest.....	39.5	35.8	37.9	29.1	24.3	26.8	49.5	31.4
Stomach.....	6.6	5.4	6.1	5.6	5.4	5.5	8.9	6.0
Bowel.....	4.4	3.6	4.0	3.4	2.2	2.9	5.1	2.2
Teeth.....	11.8	6.5	9.4	12.4	6.3	9.6	4.8	3.7
Other.....	8.9	7.4	8.2	7.2	6.2	6.7	6.5	4.4
All sites.....	49.6	41.7	46.0	41.8	32.9	37.7	57.9	37.6

<sup>1</sup> The small number of nonwhites in this study prevented any meaningful distinction between upper and lower socioeconomic groups.

**Table 4. Frequency distribution of all diagnostic X-ray examinations during 12 months preceding interview, by sex, race, and socioeconomic group**

Number of examinations	White men						White women						Nonwhite			
	Upper group		Lower group		Both groups		Upper group		Lower group		Both groups		Men		Women	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0	493	50.8	463	58.2	956	54.2	679	59.3	609	67.1	1,288	62.8	71	41.8	125	55.6
1-4	422	43.5	308	38.7	730	41.4	416	36.3	270	29.8	686	33.4	89	52.4	94	41.8
5-9	40	4.1	16	2.0	56	3.2	36	3.1	21	2.3	57	2.8	9	5.3	5	2.2
10-14	8	.8	5	.6	13	.7	11	1.0	4	.4	15	.7	1	.6	1	.4
15-19	4	.4	0	0	4	.2	2	.2	2	.2	4	.2	0	0	0	0
20 and over	4	.4	3	.4	7	.4	1	.1	1	.1	2	.1	0	0	0	0

for white men in the upper socioeconomic group, whereas the reverse is true for the other examinations. Similar white-nonwhite differences are observed for the women except for examination of the bowel. The higher frequency of chest examinations for the nonwhite group may be explained by the higher incidence of tuberculosis among nonwhites or their increased use of public health facilities, such as county hospitals and health department clinics.

The respondents were also asked to tell the number of diagnostic examinations they had received during the year. For both sexes in the white population, about 4 percent had 5 or more examinations during the year; the upper socioeconomic group had more examinations than the lower (table 4). No information was obtained concerning the number of films taken during these examinations. Consequently, estimates of exposure based on frequencies were rather crude. In future studies of a similar nature, this information should be obtained in more detail in order to estimate more accurately the X-ray exposure experience of a population.

During a lifetime, women of both races received X-ray or radium therapy more frequently than men, and the white population of both sexes received more than the nonwhite (table 5). For both sexes, the white upper socioeconomic group had almost twice the frequency of the white lower group.

Thus, the upper socioeconomic group received both more diagnostic and more therapeutic

X-ray than the lower group, which is consistent with the socioeconomic distribution of leukemia.

#### Distribution by Religion

Recently, MacMahon and Koller reported the interesting observation that the incidence of leukemia among Jewish residents in Brooklyn, N. Y., was about twice that of the non-Jewish residents (5). They considered the possibility that the Jewish population may have been exposed to more X-radiation since there is evidence that Jews receive more medical care than other religious groups in Brooklyn. Despite the fact that the data from Buffalo and Brooklyn may not be comparable, the X-ray exposure experience in Buffalo was analyzed by religious groups to see if the same variation prevailed.

Since the total number of Jews in our sample was relatively small and since the majority

**Table 5. Age-adjusted percentages of persons who received X-ray or radium treatments during lifetime, by race, socioeconomic group, and sex**

Race and socioeconomic group	Men		Women	
	Number	Percent treated	Number	Percent treated
Total white	1,793	6.5	2,068	10.5
Upper group	981	8.5	1,157	12.6
Lower group	812	4.2	911	7.7
Total nonwhite	172	2.0	227	2.6

**Table 6. Age-adjusted percentages of persons who had one or more diagnostic X-ray examinations during 12 months preceding interview and of those who had X-ray or radium treatments during lifetime, in upper socioeconomic group, by religion and sex**

Religion and sex	Number of respondents	Percent examined	Number of respondents	Percent treated
<i>Jewish</i>				
Men.....	59	54.1	61	13.6
Women.....	65	55.5	65	20.5
<i>Protestant</i>				
Men.....	341	46.8	347	9.4
Women.....	426	43.6	432	12.9
<i>Catholic</i>				
Men.....	536	49.4	537	7.3
Women.....	634	39.7	640	12.5

of them were in the upper socioeconomic group, comparison by religion was limited to the upper socioeconomic group (table 6). For both sexes, Jews had more diagnostic X-ray examinations and more X-ray therapy than the other religious groups. The differences were not large with regard to examinations, but the therapeutic procedures were almost twice as frequent among Jews as among non-Jews. The importance of this observation lies in its consistency with the distribution of leukemia by religion. A possible explanation for the frequency of therapy among Jews may be that the Jewish group was in a relatively higher socioeconomic segment of the upper socioeconomic group. Unfortunately, the number of Jews was too small to permit further study.

### Discussion

The results of the present study can be considered from two viewpoints. First, they provide some idea of the frequency of exposure of an urban population to diagnostic and therapeutic radiation. Second, they indicate that the frequencies of such exposure are related to several characteristics of the population found previously to be associated with the distribution of leukemia.

In evaluating the estimates of exposure several points must be borne in mind. The estimates may be minimal since, as has been mentioned, some individuals may not have been able to recall all their exposures to X-rays. On the other hand, some may have overestimated the frequency of diagnostic X-ray examinations: the data were obtained for a period of 12 months preceding the interview and there may have been a tendency for some to state that they had been X-rayed during the past year even though the exposure actually occurred earlier. Such a phenomenon has been observed in morbidity surveys (6). It is therefore difficult to determine the validity of these estimates without medical records. This particular objection does not apply to the frequency of therapeutic procedures. The respondents were asked to provide information on therapy during their lifetime and the only error would lie in underestimation, although it is possible that some individuals may have experienced non-X-ray procedures (such as diathermy) which they erroneously thought were X-ray procedures, or they may have confused diagnostic with therapeutic radiation.

Keeping these difficulties in mind, it still appears that this particular urban population was exposed to a large amount of diagnostic and therapeutic radiation. The frequencies seem so large as to indicate a definite need for repeating similar and more detailed population surveys specifically designed to reveal the extent of exposure. In such studies, it would be essential to establish procedures for determining the validity of the estimated frequencies.

The second point of interest in these results was the distribution of X-ray exposure in different segments of the population. Diagnostic examinations were more frequent among non-whites than whites, men than women, persons in the upper socioeconomic group than those in the lower, and among Jews than non-Jews.

Some of these differences are consistent with the distribution of leukemia in the population. For example, leukemia mortality is higher among persons in the upper socioeconomic group and among Jews. Consistency with regard to sex and racial differences is difficult to evaluate.

Sex differences in leukemia mortality are not large, the male-female ratio being about 1.1 to 1.2. The sex differences in frequency of diagnostic and therapeutic X-ray procedures revealed that men had more X-ray examinations than women, and the women had more X-ray therapeutic procedures than men. Perhaps a balancing of these two might result in a total excess exposure of women, particularly since total dose for treatment is probably greater than for diagnostic examinations.

Leukemia is more frequent among whites than among nonwhites; again, the difference is not large. MacMahon and Koller think that this difference is a result of the greater frequency of diagnosis of leukemia among whites than among nonwhites rather than a difference in the true incidence of the disease (5). Frequency of diagnostic and therapeutic X-ray procedures disclosed that nonwhites had more diagnostic but much fewer therapeutic exposures than whites. As with sex differences, perhaps total exposure was greater among whites than among nonwhites.

In contradistinction to the sex and racial differences in the frequency of leukemia, the Jewish and non-Jewish and the socioeconomic group differences are of a larger order of magnitude. Thus, the large differences in X-ray exposure by religion and socioeconomic groups are consistent with large differences in the frequency of leukemia between these segments of the population. While the findings have not been analyzed in a more refined quantitative manner (a procedure not warranted by these data), their consistency points up the need for further study of the relationship of leukemia to the above-mentioned population groups, of radiation exposure to the same groups, and of the association of leukemia with exposure to ionizing radiation.

### Summary

During 1956, a probability sample of the adult population of Buffalo, N. Y., was interviewed on the frequency of diagnostic X-ray examinations during a preceding 12-month period, and of X-ray or radium therapy during a lifetime. About 50 percent of the adult population had had one or more diagnostic X-ray

examinations during the 12-month period. Male members of the population had such examinations more frequently than the female members of both races, and for both sexes the nonwhites had received examinations more frequently than the whites. Individuals of both sexes in the upper socioeconomic group received X-ray examinations more often than those in the lower group.

Analysis of the frequency of therapeutic procedures revealed that about 8 percent of the white population had received such exposure during a lifetime compared with 2.5 percent of the nonwhite population. Women of both races had a higher frequency of such treatment than men. For both sexes of the white population, the upper socioeconomic group had such procedures more frequently than the lower group.

The frequency of both X-ray examinations and therapeutic procedures was higher among the Jewish members of the population than among the non-Jewish members. The distribution of X-ray examinations and therapeutic procedures by religion and socioeconomic group was similar to the distribution of leukemia.

Studies are needed in other geographic areas to obtain more detailed information concerning exposure to therapeutic and diagnostic radiation than was possible in the present investigation.

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