A Feasibility Study of the Biological Effects of Fallout on People in Utah, Nevada, and Arizona

United States Department of Health and Human Services, Bureau of Radiological Health

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A Feasibility Study
of the
Biological Effects of Fallout
on People in
Utah, Nevada, and Arizona

Daniel A. Hoffman, Ph.D.
Carolyn W. Harlow, Ph.D.
Michael J. Tully, M.S.
Division of Biological Effects

February 1981
FOREWORD

The Bureau of Radiological Health develops and carries out a national program to control unnecessary human exposure to potentially hazardous ionizing and nonionizing radiations and to ensure the safe, efficacious use of such radiations. The Bureau publishes the results of its work in scientific journals and in its own technical reports.

These reports provide a mechanism for disseminating results of Bureau and contractor projects. They are distributed to Federal, State, and local governments; industry; hospitals; the medical profession; educators; researchers; libraries; professional and trade organizations; the press; and others. The reports are sold by the Government Printing Office and/or the National Technical Information Service.

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WHO Collaborating Center for Standardization of Protection Against Nonionizing Radiations;
WHO Collaborating Center for Training and General Tasks in Radiation Medicine; and
WHO Collaborating Center for Nuclear Medicine.

Please report errors or omissions to the Bureau. Your comments and requests for further information are also encouraged.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The Division of Biological Effects of the Bureau of Radiological Health plans, conducts, and supports experimental and epidemiological research on the biological effects of exposure to ionizing and nonionizing radiation.

An important area of research that has received recent attention by both the division and groups outside BRH is the delayed effects of exposure to low levels of ionizing radiation. In the 1960's a study of school children in three southwestern states was conducted by the Bureau of Radiological Health to examine a possible association between exposure to fallout from nuclear weapons testing and thyroid tumor development. No such association was found, but the post-exposure followup period was short, and the study group was small. The goal of the present study is to determine the feasibility of locating and resurveying the previously studied group of persons exposed to radioactive fallout. The results are expected to be important in deciding whether or not to pursue a full-scale investigation of the original or expanded study group in view of continued concern about the possible health effects of exposure to low levels of fallout radiation.

Moris L. Shore, Ph.D.
Director
Division of Biological Effects
A FEASIBILITY STUDY OF THE BIOLOGICAL EFFECTS OF FALLOUT ON PEOPLE IN UTAH, NEVADA, AND ARIZONA

This is the final report of the analysis of the Utah, Nevada, and Arizona Thyroid Feasibility Study. The report is divided into four sections: (1) Introduction and Background; (2) Analysis of Linkage Study: with the Utah Cancer Registry and Rocky Mountain Cancer Data System; (3) Evaluation of Tracing a Sample of the Original Utah, Nevada, and Arizona Study Groups; and (4) Options for Future Studies.

INTRODUCTION AND BACKGROUND

For a time the thyroid gland was thought to be relatively radioresistant. However, in the last three decades several studies have demonstrated a strong association between external irradiation and the late development of thyroid neoplasia, both malignant and benign (1-6).

Other studies have suggested an association between internally delivered radiation to the thyroid gland from radioactive iodine, primarily 131I, and the appearance of thyroid gland neoplasia in animals and man (7-9). Many of these studies, both of external irradiation and internal 131I exposure, suggest that the rapidly proliferating thyroid gland in infants and children is highly sensitive to the effects of ionizing radiation (9).

During the last half of the 1950s and 1960s, concern developed over population exposures to short-lived radioisotopes and in particular 131I as a consequence of fallout from nuclear weapons testing at the Nevada test site. As the biological pathway of 131I was ascertained and estimates were made of the potential dose to the thyroid glands of young children consuming milk with detectable levels of 131I activity, the possibility was recognized that persons residing in high fallout areas in Utah and Nevada might have been exposed to tumorigenic doses of 131I.

In response to this concern, the Bureau of Radiological Health (then the National Center for Radiological Health), in 1964, initiated a cross-sectional study of children in Utah, Nevada, and Arizona to determine whether exposure to fallout from nuclear weapons testing in Nevada was associated with an increased risk of thyroid neoplasia. Children 11 through 18 years of age, attending school grades 6 through 12 in Washington County, Utah, Lincoln County, Nevada, and Graham County, Arizona, were eligible for inclusion in the study. The exposed study group (N=1,378) consisted of children residing in Washington County, Utah, and Lincoln County, Nevada, prior to January 1, 1960. Two comparison groups were included: (1) children (N=1,313) who moved into these two counties after December 31, 1959 and, therefore, received minimal exposure to fallout; and (2) children (N=2,140) in Graham County, Arizona, where no detectable levels of fallout were recorded.

Physicians, with special training in thyroid gland palpation, examined these children annually from 1965 through 1968 for evidence of thyroid disease. Special attention was given to gland asymmetry, enlargement, and nodularity. The physicians were divided into two teams, and three physicians independently examined the thyroid gland of each child. Children reported to have a thyroid abnormality were referred to a panel of three experienced thyroidologists for further evaluation. In addition, questionnaires were completed for most children in order to elicit relevant medical and demographic information. Laboratory tests were performed on sera from all children referred to the panel and from a sample of children considered to have normal thyroid glands. Estimates of thyroid gland dose from 131I exposure were made.

The data did not demonstrate an increase in the incidence of thyroid neoplasia in the exposed children. However, the sample size of the exposed group was too small to detect anything less than an 18-fold increased risk of thyroid cancer with sufficient statistical probability. In addition, the mean time since exposure was 14 years. Since the minimal latency period for radiation-induced thyroid cancer is at least 15 years, and perhaps greater (9), and thyroid cancer associated with previous irradiation appears as long as 30 years after exposure (10), the children in the original study may not have been followed long enough for the slow-growing thyroid tumors to become manifest if present. Therefore, a second followup of the original study population, with an additional 12 years of risk, would more adequately test the hypothesis of whether fallout exposure to 131I is associated with an increased incidence of thyroid cancer or total cancer in former school children from southwestern Utah and Nevada.

The Utah Thyroid Feasibility Study was conducted in direct response to both legislative and executive concern over possible delayed health effects from nuclear weapons testing at the Nevada test site in the 1950s. The study was initiated in March, 1979, and was completed in August, 1980. The feasibility study was conducted to determine if a second followup of the original Utah, Nevada, and Arizona study groups was possible. Specifically, the feasibility study consisted of two separate tasks: (1) to assess available cancer mortality and morbidity data by linking the original study records with a tumor registry in Utah; and (2) to locate a stratified sample of the original study groups.
EVALUATION OF THE UTAH CANCER REGISTRY (UCR) AND ROCKY MOUNTAIN CANCER DATA SYSTEM (RMCDS) RECORD LINKAGE

A copy of a computer tape containing the names of individuals in the initial BRH study along with other relevant information was sent to UCR/RMCDS in November, 1979. This tape (PHS file) was created during the summer of 1979 by coding and keypunching information from the original study questionnaires.

The PHS file was matched to the UCR/RMCDS files to search for persons in the original study who may have developed and reported a cancer between 1966 and 1978. The files were matched by sex, and month and year of birth. Both last name and first name lists were created within these age and sex categories. The lists were then compared for matches. When possible matches were identified, the abstracts on file in the registry for these cases were examined for detailed information to verify a match. Information used for verification included: parents' names, maiden names, residence at time of diagnosis, place of birth, birth date, and any other information available. When a match could not be determined with data located at the registry, the treating hospital and/or physician was contacted. For deceased persons, death certificates were obtained and reviewed for information which could verify a match between name (maiden name for females), parents' names, and approximate date of birth. The procedure was similar for linkage to RMCDS except that the data coded in this registry was not as complete as that in the UCR.

After searching the UCR/RMCDS files, 62 possible matches were identified and 15 cases were verified as true matches - 12 in Utah, 1 in Nevada, and 2 in Arizona (Table 1). Before the names of these individuals could be released to BRH, authorization was obtained.

Coverage of the UCR/RMCDS registries is 98 percent complete for Utah while for Nevada and Arizona, neither of which has a population-based tumor registry, it is far less complete. Therefore, the findings in Utah cannot be directly compared with those in Nevada and Arizona because of this discrepancy in completeness of ascertainment. Consequently, only those cancers identified in the Utah study group will be discussed.

Of the 12 cases found in the Utah group, 9 were classified as exposed and 3 were unexposed based on the original study criteria (residence in Washington County, Utah, before January 1, 1960, characterized the exposed group; persons who moved into the area on or after January 1, 1960, were the unexposed group). Two of the 12 cases, 1 hydatidiform mole in each group, were excluded because they were not recognized as true neoplasms unless they developed into choriocarcinoma.

Expected numbers of cancers were calculated for the exposed and unexposed groups in the following manner: (1) person-years were calculated, using the cohort approach, over calendar time and within 5-year age groups; (2) the person-years by 5-year age groups were summed over calendar time from January 1, 1953, through December 1, 1978; (3) cancer incidence rates specific for race, sex, and age from the 3rd National Cancer Survey (TNCS) were multiplied by the age-and sex-specific person-years and summed over all age and sex groups for cancer of all sites and of specific sites (11).

The expected numbers of cancers calculated in this manner are subject to several assumptions which would probably make these numbers larger than "true" expectation. First, in estimating the person-years over calendar time and within 5-year age groups, it was assumed that no deaths or loss-to-followup occurred in both the exposed and unexposed groups. This inflates the number of person years and leads to an overestimate of the expected numbers. Second, the rates from the TNCS specific for site, age, race, and sex were used to estimate the numbers of cancers in both groups. The use of these rates could
Table 1. Summary of data of cancer cases of persons in original thyroid study found in Utah Cancer Registry and Rocky Mountain Cancer Data System

<table>
<thead>
<tr>
<th>Case number</th>
<th>Sex</th>
<th>Exposure status</th>
<th>Month, year of diagnosis</th>
<th>Age at diagnosis</th>
<th>Histology and site of tumor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Exposed</td>
<td>01/73</td>
<td>19</td>
<td>Hodgkin's lymphoma</td>
</tr>
<tr>
<td>2*</td>
<td>M</td>
<td>Unexposed</td>
<td>08/73</td>
<td>22</td>
<td>Testicular seminoma</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>Exposed</td>
<td>02/72</td>
<td>18</td>
<td>Testicular teratoma</td>
</tr>
<tr>
<td>4*</td>
<td>F</td>
<td>Exposed</td>
<td>05/71</td>
<td>19</td>
<td>Acute myeloblastic leukemia</td>
</tr>
<tr>
<td>5+</td>
<td>M</td>
<td>Unexposed</td>
<td>04/68</td>
<td>16</td>
<td>Adenocarcinoma of thyroid gland</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>Unexposed</td>
<td>06/76</td>
<td>25</td>
<td>Infiltrating ductal Ca of rt. breast</td>
</tr>
<tr>
<td>7*</td>
<td>F</td>
<td>Exposed</td>
<td>08/75</td>
<td>27</td>
<td>Multiple myeloma</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>Exposed</td>
<td>11/76</td>
<td>23</td>
<td>Ca of parotid gland</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>Exposed</td>
<td>12/78</td>
<td>29</td>
<td>Hydatidiform mole</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>Exposed</td>
<td>12/67</td>
<td>19</td>
<td>Squamous cell Ca of cervix uteri</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>Exposed</td>
<td>04/79</td>
<td>28</td>
<td>Ca of breast</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>Unexposed</td>
<td>03/70</td>
<td>20</td>
<td>Hydatidiform mole</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>Unexposed</td>
<td>01/77</td>
<td>23</td>
<td>Acute myeloblastic leukemia</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>Exposed</td>
<td>1970</td>
<td>22</td>
<td>Hodgkin's lymphoma</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>Unexposed</td>
<td>02/70</td>
<td>19</td>
<td>Argentaffine Ca of appendix</td>
</tr>
</tbody>
</table>

* deceased
+ identified in first study
lead to an overestimation of the expected numbers because the TNCS rates are cross-sectional covering 3 years (1969-1971) and, therefore, do not reflect temporal changes in site specific rates. Furthermore, the cancer incidence rates in Utah tend to be lower than United States rates for all sites and for specific sites. However, according to Dr. Lyon of the University of Utah, the Utah cancer rates for persons less than 30 years of age (as in the study groups) are compatible with the TNCS rates.

Table 2 presents the results of these calculations. The observed number of cancers divided by the number of expected cancers results in an observed/expected ratio (O/E) which is a measure of association between a risk factor and disease. An O/E ratio of 1 indicates there is no difference between the number of cancers observed and the number expected. Ninety-five percent confidence limits for the O/E ratio were calculated using an exact method which assumes the observed number has an underlying Poisson distribution (12).

In the exposed group, there was a total of 8 cancers observed and 7.7 expected (O/E = 1.04) which is not significantly different from 1. In the unexposed group, 2 cancers were observed and 7.5 expected (O/E = 0.27) which is significantly less than 1 (p < .01). For cancers of specific sites, in the exposed group there was 1 cancer of the breast, 1 each for the male and female genital organs and the buccal cavity, 1 leukemia, 1 multiple myeloma, and 2 cases of Hodgkin's lymphoma. The only statistically significant difference occurred for multiple myeloma where 1 case was observed and 0.001 expected (O/E=1000, p < .001). There was no difference between the observed and expected numbers for the combined group of leukemia or cancer of the thyroid gland and female breast, all of which have been associated with radiation exposure. In the unexposed group, there was 1 digestive cancer and 1 leukemia.

The one case of multiple myeloma in the exposed group is interesting for two reasons: (1) multiple myeloma is a very rare cancer in persons under 35 years of age. In the UNCS, only 2 cases were observed in white males and females over a 3-year period (1969-1971) in 9 population-based tumor registries that represented a population of over 10,000,000 persons under the age of 35, and (2) an increased risk of multiple myeloma has been reported in populations exposed to ionizing radiation. These include persons exposed to the atomic bombs in Hiroshima and Nagasaki (13), workers at the Hanford nuclear reactor (14), and radiologists (15). An interesting feature of the case observed in Utah was that the person developed multiple myeloma 22 years after exposure, which is in agreement with the Japanese data where the risk for myeloma in the high exposure group became apparent about 20 years after exposure (13). However, the observation of 1 case in the exposed Utah group should be interpreted with caution because it is only 1 case. It could be a random event and not related to fallout.

In conclusion, the results from UCR/RMCDS record linkage study are subject to several caveats, as discussed previously and should be interpreted with these caveats in mind. The number of observed cancers is, in all likelihood an underestimate of the true number of cancers in both the exposed and unexposed groups because (1) persons who emigrated from Utah and developed cancer elsewhere would not be reported to the UCR/RMCDS registries, and (2) malignancies which may have occurred between 1953 and 1965 in persons who otherwise would have been in the study were probably not identified. Furthermore, differential migration probably occurred in that the unexposed group had all moved into Washington County after 1959 and more of these people may have subsequently left the area. Therefore, the number of cancers observed in the linkage study represents a minimal estimate of the "true" number of cancers in the study groups, with the unexposed group probably experiencing a greater degree of underascertainment than the exposed group. This aspect will be discussed in the evaluation of the tracing study.

While the results of the matching study are open to different interpretations, it is readily apparent that the UCR/RMCDS tumor registries were successfully utilized to match their data files with the PHS file in identifying cases of cancer in the original Utah study groups.
Table 2. Observed (O) and expected (E) numbers of cancers by site with O/E ratios and 95 percent confidence limits (CL) for O/E ratios, Utah study population only.

<table>
<thead>
<tr>
<th>Site (1)</th>
<th>Utah exposed</th>
<th></th>
<th>Utah unexposed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O</td>
<td>E</td>
<td>O/E</td>
<td>95% CL lower</td>
</tr>
<tr>
<td>All sites</td>
<td>8</td>
<td>7.7</td>
<td>1.04</td>
<td>0.45</td>
</tr>
<tr>
<td>Buccal cavity</td>
<td>1</td>
<td>0.2</td>
<td>5.00</td>
<td>0.06</td>
</tr>
<tr>
<td>&amp; pharynx</td>
<td>0</td>
<td>0.4</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Digestive</td>
<td>0</td>
<td>0.2</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Respiratory</td>
<td>0</td>
<td>0.3</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Bone</td>
<td>0</td>
<td>0.3</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Soft tissue</td>
<td>0</td>
<td>0.3</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Melanoma</td>
<td>0</td>
<td>0.4</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Breast</td>
<td>1</td>
<td>0.3</td>
<td>3.33</td>
<td>0.04</td>
</tr>
<tr>
<td>Female genital</td>
<td>1</td>
<td>0.9</td>
<td>1.11</td>
<td>0.02</td>
</tr>
<tr>
<td>Male genital</td>
<td>1</td>
<td>0.5</td>
<td>2.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Urinary</td>
<td>0</td>
<td>0.3</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Brain &amp; CNS</td>
<td>0</td>
<td>0.7</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0</td>
<td>0.7</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Hodgkin’s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lymphoma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>myeloma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leukemia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observed cancers identified in Utah Cancer Registry

Expected numbers based on sex and race-specific incidence rates by 5-year age groups from Third National Cancer Survey.

(1) Excludes two hydatidiform moles, one in each group

Utah exposed = 1,273 persons  Utah unexposed = 1,031 persons
This part of the feasibility study was conducted for the following reasons:

1. To assess the feasibility of locating a large proportion of the original study groups and to evaluate migration patterns in the exposed and unexposed groups.

2. To evaluate the strengths and difficulties inherent in particular location methods and to estimate location costs in a followup of the entire study group.

The tracing was conducted by Equifax Systems Inc. A random sample of 301 persons (about 6 percent of the entire original study group) was selected for tracing. The sample was stratified on sex and State of residence so that there were 6 strata, each containing 50 individuals (one stratum of Utah females had 31). BRH drew the sample and provided identification information for each person to be located. This data included name, sex, birth date, marital status as of 1968, religion, parental names and Social Security numbers, names of siblings, and last known address. The goal was to locate and determine vital status for at least 90 percent of the individuals in each stratum.

Of the 301 persons in the sample, the vital status of 97 percent or 292 persons in the study groups was definitely established. Of the 292 persons traced, 286 were found to be alive and 6 deceased. Death certificates were obtained for the 6 deceased persons. Table 3 presents the location status for each of the 6 strata. There were no differences between the strata in the rate of location. Consequently, in light of the high rate of success in locating the sample, it appears that tracing of the entire study group is feasible.

Table 3. Location status by sex and State of original residence

<table>
<thead>
<tr>
<th>Location status</th>
<th>Sex and State of original residence</th>
<th>Found</th>
<th>Not located</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>#</td>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td></td>
<td>Utah males</td>
<td>48</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Utah females</td>
<td>50</td>
<td>1</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Nevada males</td>
<td>49</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Nevada females</td>
<td>47</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Arizona males</td>
<td>49</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Arizona females</td>
<td>49</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Total males</td>
<td>146</td>
<td>4</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Total females</td>
<td>146</td>
<td>3</td>
<td>151</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>292</td>
<td>9</td>
<td>301</td>
</tr>
</tbody>
</table>

Table 4 presents the distribution, by State and sex, of the final source of information which determined the location and vital status of each person. A significantly greater number of males than females were located through mailed letters (39% versus 23%, p < .03). Conversely, a significantly greater number of females than males were located through field investigations (34% versus 15%, p < .03). The difference between males and females in location sources can be partially attributed to the fact that 86 percent of the women in the study groups were married since the original study, thereby changing their name. This would result in greater difficulty in locating these persons.

Field investigations were the most frequent source utilized to locate persons in the study sample, accounting for 46 percent of those located. It was also the most expensive resource with an average cost per located person of $98. The next most frequently used location resource was the mailed letter. This accounted for 31 percent of located persons with an average cost of $17 per located person. The overall cost per located person was $65.

The exposure status of the persons in the sample was determined after the list of names was received from Equifax. The definition of exposure status has been described previously. The distribution of persons in the sample by exposure status and residence at followup is presented in Table 5. Before describing the results of this analysis, definitions of followup residence status as presented in Table 3 are:

1. Still in same county - this refers to the county of residence in the original study. For example, a person residing in Washington County, Utah, in the original study, and still living in this county on the most recent followup, was classified as "still in the same county".

2. Still in same State - this refers to the State of residence in the original study. For example, a person residing in Washington County, Utah, in the original study, but having moved to some other location in Utah outside of Washington County by the most recent followup, was classified as "still in the same State".

3. Still in 3-State area - refers to the State of residence in the original study. For example, a person residing in Lincoln County, Nevada, in the original study, but found to be living in either Utah or Arizona on the most recent followup, was classified as "still in the 3-State area" (that is in either Utah, Arizona, or Nevada).

4. Left the 3-State area - the person was no longer in the 3-State area and

5. Not located - the current residence could not be determined.

Table 5 demonstrates differences between exposure categories in the residence status. For example, if the analysis is confined to the Utah and Nevada residents, a significantly greater number of exposed persons were still living in the State in which they resided in the original study (70 versus 56%, p < .03) while, conversely, a significantly greater number of unexposed persons had left their original State of residence (38% versus 28%, p < .05). This confirms the initial impression that differential migration occurred between the exposed and unexposed groups and that the unexposed group was more transient. A greater percentage of unexposed than exposed persons in Utah and Nevada could not be located (8% versus 0%). This also reflects the greater mobility of the unexposed group. It appears that the unexposed Arizona group is similar to the Utah-Nevada exposed groups in regard to residence stability. Seventy-one percent of this group still resided in Arizona compared with 70 percent for the Utah-Nevada exposed groups.
The findings from the tracing part of the feasibility study can be related to the results of the linkage study with the UCR/RMCDs. Since coverage for Utah by the UCR is 98 percent complete, only the Utah group will be considered. In the conclusions to the linkage study, it was stated that the numbers of cancers observed represented a minimal estimate of the "true" numbers of cases as a consequence of underascertainment due to emigration of the study groups. It was also felt that the unexposed group experienced a greater degree of underascertainment because they were a more transient population. As seen in Table 5, 75 percent of the Utah exposed group still resided in the State of Utah, and any cases of cancer appearing in this group should be reported to the UCR. Therefore, if the results from the followup of the sample are applied to the entire study group, the degree of underascertainment in the exposed group is approximately 23 percent. This compares with an estimated underascertainment rate of 90 percent in the unexposed Utah group where only 60 percent of the study group sample were still living in Utah. In reality, the level of underascertainment may not be as great as this since 8 percent of the exposed and 20 percent of the unexposed groups moved either to Nevada or Arizona. Partial coverage is provided by the RMCDs registry in these two states, primarily for Las Vegas, Tucson, and Phoenix.

In conclusion, it is evident from the high level of success in the tracing study that it is feasible to locate at least 90 percent of the unexposed and exposed members of the study groups.

### OPTIONS FOR FUTURE STUDIES

Successful tracing of a sample of the original study groups and linkage of the study records with the UCR/RMCDs indicate that a full-scale followup of the entire Utah, Nevada, and Arizona study groups is feasible.

Because of limitations in existing exposure information, definitive epidemiologic studies of these populations cannot be done. Despite these limitations, however, useful and important studies may be possible to determine whether there are detectable health problems in exposed individuals associated with radioactive fallout a quarter century after exposure. If health problems are observed, improved dosimetry will be necessary to investigate the issue and nature of dose-response relationships. The ensuing discussion presents the various strengths and weaknesses of three options concerning continuation of the study.

**Option A:** Conduct a full-scale followup of the original study groups

One approach would be to keep the present study design and perform a second questionnaire survey of the original study groups, accepting the fact that due to the small size of the exposed group a thyroid cancer risk less than 8-fold would probably not be detected (a risk this high or greater is unlikely). The decision to conduct the study with this serious shortcoming would, in all probability, be made on the basis of factors other than scientific merit. One advantage to this approach is that the study population has already been assembled. The results of the feasibility study clearly indicate that these persons can be successfully traced. Although detection of an increased risk of thyroid cancer is unlikely, evaluation of health problems in general (for example, total cancer incidence) is a possibility.

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**Table 4. Final source of information used to determine current residence by sex and state of original residence**

<table>
<thead>
<tr>
<th>Source of information</th>
<th>Utah males</th>
<th>Utah females</th>
<th>Nevada males</th>
<th>Nevada females</th>
<th>Arizona males</th>
<th>Arizona females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone &amp; city directories</td>
<td>52</td>
<td>21</td>
<td>50</td>
<td>30</td>
<td>32</td>
<td>18</td>
<td>132</td>
</tr>
<tr>
<td>Telephone &amp; city directories records</td>
<td>81</td>
<td>27</td>
<td>45</td>
<td>24</td>
<td>42</td>
<td>24</td>
<td>212</td>
</tr>
</tbody>
</table>
| Visitor 
 | 57 | 22 | 49 | 27 | 51 | 27 | 184 |
| Mail | 64 | 25 | 58 | 31 | 61 | 30 | 206 |
| Total | 117 | 55 | 96 | 60 | 91 | 54 | 368 |

* Excludes one unknown source (Nevada = 'a') not stated by contractor

**Table 5. Distribution of persons in Utah, Nevada, and Arizona by exposure status and residence status on followup**

<table>
<thead>
<tr>
<th>State of Residence and Exposure Status</th>
<th>Utah exposed</th>
<th>Nevada exposed</th>
<th>Nevada unexp.</th>
<th>Arizona exposed</th>
<th>Arizona unexp.</th>
<th>Total exposed</th>
<th>Total unexp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still in same county</td>
<td>31</td>
<td>30</td>
<td>22</td>
<td>33.3</td>
<td>3</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Still in same State</td>
<td>15</td>
<td>14</td>
<td>10</td>
<td>21.8</td>
<td>10</td>
<td>9</td>
<td>18.5</td>
</tr>
<tr>
<td>Still in 3-state area</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>13.3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Left the state area</td>
<td>9</td>
<td>14</td>
<td>7</td>
<td>5.0</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Not located</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>11.8</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Decreased</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>60</td>
<td>56</td>
<td>34</td>
<td>36</td>
<td>34</td>
<td>100</td>
</tr>
</tbody>
</table>

* Excludes 10 Utah residents with unknown exposure
Option B: Do not conduct a full-scale followup of the original study groups

There are several reasons for not conducting a second followup of the original Utah, Nevada, and Arizona groups. First, because of the small size of the exposed group, we would not be able to detect anything less than a 3-fold increased risk of thyroid cancer with adequate (80%) statistical probability. This is true even with the addition of 12 years of followup. Since the relative risk for thyroid cancer in the exposed group is estimated to lie between 3 and 6-fold, an observation of no increased risk would be of dubious value. Second, the estimated cost of locating and sending a health questionnaire to the entire original study group (N=4,831), based on the feasibility study, would be $900,000 to $400,000. If thyroid examinations were performed, the estimated costs would be substantially greater. Third, the scientific and public health return for an investment of this size would be questionable, if the present study design is maintained.

Option C: Improve the study design and enlarge the original study groups

Improving the study design, and thereby the chance of obtaining meaningful results, could be done by increasing the size of the study groups. The exposed group could be enlarged by one of two methods. The first involves including other counties in Utah which received substantial fallout exposure such as Iron and Kane Counties. A second method would be to locate those persons who were born in Washington County, Utah, between 1946 and 1959, but whose parents emigrated before the original thyroid study began in 1963. This group accounts for more than one-half of the original estimated exposed group. A feasibility study should first be conducted to determine whether study expansion by these methods is possible since the results of the present feasibility study may not be applicable.

The expense of enlarging the study using these methods would be considerable. The estimated costs would be $800,000 to $1,200,000 assuming the cost estimates derived from the present feasibility study are applicable to the larger study and the time needed to complete the study would be approximately three years. However, a relative risk for thyroid cancer between 3 and 4 would be detected with 80 percent probability if the study was expanded in this manner.

REFERENCES

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FDA 80-8103 X Rays: So You Want To Be In Pictures? (Bookmark).
FDA 80-8108 Positive Beam Limitation Effectiveness Evaluation (GPO 017-015-00163-6, $2.00) (PB 80-169937, md only).
FDA 80-8109 Proceedings of a Workshop on Thermal Physiology (PB 80-187867, $8.00).
FDA 80-8110 Quality Assurance Programs for Diagnostic Radiology Facilities (GPO 017-015-00166-1, $2.50) (PB 80-183338, md only).
FDA 80-8111 Get the Picture on Dental X Rays (brochure).
FDA 80-8116 Chest X-Ray Screening Practices: An Annotated Bibliography (GPO 017-015-00167-9, $3.50) (PB 80-183890, md only).
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FDA 80-8119 Measurements of Emission Levels During Microwave and Shortwave Diathermy Treatments (GPO 017-013-00168-7, $1.75) (PB 80-190772, md only).
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FDA 80-8122 Microwave Hazard Instruments: An Evaluation of the Narda 8100, Holaday HL-1500, and Simpson 380M (PB 80-227820, $6.00).
FDA 80-8124 Optimization of Chest Radiography - Proceedings of a Symposium Held in Madison, Wisconsin, April 30-May 2, 1979 (GPO 017-015-00176-8, $7.50) (PB 80-208317, md only).
FDA 80-8125 Research Into the Biological Effects of Ionizing Radiation in The Bureau of Radiological Health (GPO 017-015-00172-5, $6.00) (PB 80-217268, md only).
FDA 80-8126 Symposium on Biological Effects, Imaging Techniques, and Dosimetry of Ionizing Radiations (July 1980) (GPO 017-013-00175-0, $8.00) (PB 81-112353, md only).
FDA 80-8127 Guide for the Filing of Annual Reports (21 CFR Subchapter J, Section 1002.11) (PB 80-810999, $6.00).
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FDA 80-8130 Nationwide Survey of Cobalt-60 Teletherapy: Final Report (PB 81-101784, $8.00).
FDA 80-8131 Vignettes of Early Radiation Workers: A Videotape Series (flyer).
FDA 80-8133 Hazards from Broken Mercury Vapor and Metal Halide Lamps (Notice of Alert) (pamphlet).
FDA 81-0070 Bureau of Radiological Health Publications Subject Index (supersedes FDA 80-8070, May 1980).
FDA 81-0136 Optical Radiation Emissions from Selected Sources: Part I - Quartz Halogen and Fluorescent Lamps (GPO 017-013-00177-6, $6.50).