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**ADULT LEUKEMIA RISK AND DIAGNOSTIC X-RAYS:
A REANALYSIS OF THE TRI-STATE LEUKEMIA
SURVEY DATA**

by

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ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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Division of Biological and Medical Research

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ABSTRACT

The present study examined adult leukemia risk as a function of X-ray exposure in a data set consisting of 1414 leukemia cases and 1370 controls, using Mantel-Haenszel odds ratio procedures to calculate relative risk for 30 sex/leukemia type/X-ray exposure type categories and between 1 and 6 dose levels (measured as number of films). Risk of contracting pneumonia and heart disease for four time periods prior to leukemia diagnosis is also determined. The main finding is that significant excess risk is restricted to two sex/leukemia type/X-ray exposure type categories, males with acute and chronic myeloid leukemia and more than 40 trunk X-rays. Several sex/leukemia type/X-ray exposure types with risks significantly less than 1.0 were also observed. Association of pneumonia and heart disease with leukemia appear to be the result of a reporting bias in that most significant excess incidence of these diseases in leukemics is within 6 months of leukemia diagnosis. Overall, our results suggest that X-ray related excess leukemia risk is small.

FIN #

A2067

Title

Reanalysis of the Tri-State Leukemia Survey Data and Special Reference to the Leukemogenic Potential of Diagnostic X-Rays

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We would like to express our gratitude to Saxon Graham whose willingness to provide us with a copy of the Tri-State data base made this study possible and to Bruce Carnes, James Collins, and John Viren for many hours of helpful discussion. This study is dedicated to the memory of the late George Sacher whose thoughtful comments will be sorely missed.

EXECUTIVE SUMMARY

The present study reevaluates the adult portion of the Tri-State Leukemia Survey study, a retrospective case control study undertaken in the early 1960's in an attempt to identify environmental factors influencing leukemia risk (Graham et al., 1963).

The body of data collected included 1414 adult leukemia cases, obtained from registries in New York State (excluding New York City), Baltimore, Maryland, and Minneapolis-St. Paul, Minnesota, and a group of 1370 controls chosen for a similar age and sex distribution. Also collected for each case and control were a variety of ancillary variables including ethnicity, occupation, disease history, and radiation exposure history.

Our reanalysis was prompted by three recent papers (Bertell 1977, 1978; Bross et al., 1979) which suggested that the Tri-State data in fact demonstrate that diagnostic X-ray exposure significantly increases leukemia risk and by the subsequent controversy these reports provoked (Ginevan 1980; Boice and Land 1979).

Our reanalysis of these data focused on calculation of Mantel-Haenszel (1959) age-stratified relative risks (age strata \leq 40 years, 41-60 years, 60+ years) for 30 sex/leukemia/X-ray exposure type categories, and between 1 and 6 X-ray exposure categories defined as number of films. Appropriate chi-squared statistics and confidence bounds (Gart, 1971) were also calculated. In addition, the risk of contracting two diseases, pneumonia and heart disease, in several time intervals prior to leukemia diagnosis was determined for the 10 basic sex/leukemia type categories. Finally, total X-ray exposure broken down by time was examined for those males with more than 40 trunk X-rays, and an inspection of ethnicity, occupation, and disease history of two high risk groups identified in the first part of the study was made.

Results of these investigations showed that only two groups, males with acute and chronic myeloid leukemia, exposed to more than 40 trunk X-rays, showed significant excess risk. Most of the risks observed were between 0.5 and 2 and appeared symmetric about 1 (several were significantly less than 1). A second finding of these analyses was that the 2 lowest X-ray exposure categories (1-5 and 6-10 films) showed a general deficiency of leukemia cases. The most probable explanation of this is that leukemics tend to have better medical records than comparable controls.

Evaluations of heart disease and pneumonia showed most excess incidence of both diseases was within 6 months of leukemia diagnosis. This was attributed to a reporting bias.

Evaluations of timing of X-ray exposure in males exposed to more than 40 X-ray films and of disease history, ethnicity, and occupation factors in the two high risk groups identified above show no patterns of significance.

Overall these results agree well with previously published studies (Gibson et al., 1972; Gunz and Atkinson, 1964; Stewart et al., 1962). The pronounced divergence of our work from that of Bertell (1977; 1978) and Bross et al. (1979) appears to be due to faulty analytical procedures and

data selection biases in their studies. Our study, while it does not entirely rule out excess leukemia risks associated with diagnostic X-ray, suggests that such risks are relatively small.

INTRODUCTION

The Tri-State Leukemia Survey (Graham et al., 1963), a retrospective case-control study, was undertaken in the early 1960's in an attempt to identify environmental factors which might affect one's risk of contracting the disease. The body of data collected included 1414 adult leukemia cases, obtained from registries in New York State (excluding New York City), Baltimore, Maryland, and Minneapolis-St. Paul, Minnesota, and a group of 1370 controls chosen via a stratified random sampling procedure for a similar age and sex distribution. Also collected for each case and control was a variety of ancillary variables including ethnicity, occupation, disease history, and, most important to the present study, radiation exposure history.

Studies by the original investigators suggested that males showed an increased risk of both acute and chronic myeloid leukemia with increasing X-ray exposure, but that females did not. Other leukemia types (chronic and acute lymphatic, other leukemias--type unspecified) showed no excess risk with increasing X-ray exposure (Gibson et al., 1972).

Subsequent reanalyses of subsets of this data by workers at Roswell Park Memorial Institute (Bertell, 1977, 1978; Bross et al., 1979) suggested that diagnostic exposures in fact precipitously increase leukemia risk. The last of these studies provoked a critique by Boice and Land (1979) while the first two studies by Bertell received criticism by Ginevan (1980). Both critiques were wide ranging in that they considered not only the studies in question, but also the original Tri-State analysis (Gibson et al., 1972) and two other studies of adult leukemia and diagnostic X-ray (Stewart et al., 1962; Gunz and Atkinson, 1964). The general conclusion of these authors (Boice and Land, 1979; Ginevan, 1980) was that the results of the 3 earlier studies (Gibson et al., 1972; Gunz and Atkinson 1964, Stewart et al., 1962) were consistent in that they showed little excess risk attributable to diagnostic X-ray exposure in leukemics. The results of Bross (1979) and Bertell (1977, 1978) were attributed to faulty analytical procedures and to selection bias in the choice of data and dose metric. [Both Bross et al. (1979) and Bertell (1977, 1978) used arbitrary "rad dose" conversion factors.]

A major finding of our earlier re-evaluation (Ginevan 1980) was that the original Tri-State study (Gibson et al., 1972) used a somewhat idiosyncratic methodology in that overlapping dose categories were employed. A crude regression-based recalculation of relative risk suggested that excess risk was mainly attributable to males over 45 years of age who had received more than 40 trunk X-ray films. This was suggested independently by Boice and Land (1979). Because of this finding and the general controversy which has developed surrounding the adult portion of the Tri-State data, the present study was undertaken.

METHODOLOGY

The first step in our analysis was to obtain a complete breakdown of X-ray exposure by age, type of exposure, sex, and leukemia type. The BMDP-79 program package (Dixon and Brown 1979) was used for this purpose. Eight age intervals (≤ 20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, 71-80 years, > 80 years) and 7 dose intervals (0 films, 1-5 films, 6-10 films, 11-15 films, 16-20 films, 20-40 films, and > 40 films) were used. Breakdowns were conducted (separately for males and females) for controls, chronic myeloid, acute myeloid, chronic lymphatic, acute lymphatic, and other (type unspecified) leukemia. Three types of X-ray exposure were considered: trunk, non trunk (extremities + dental), and total X-ray exposure in number of films. In all cases, all films taken 6 months or more prior to leukemia diagnosis were included. No effort was made to infer radiation dose in rad or rem because of the wide variation among equipment types in dose delivered, and the broad range of organ doses among specific X-ray procedures (USHEW, 1966; Boice and Land 1979).

Upon inspection of these breakdowns a set of rules was developed for combining categories. All analyses were performed using three age strata (≤ 40 years, 41-60 years, 61+ years). Dose strata were determined by the following rule: a dose stratum was lumped with the next lower if it contained less than 5 individuals. Thus, if the group with 11-15 films contained 3 individuals, 16-20 films contained 4 individuals, 21-40 contained 4 individuals, and 41+ films contained 2 individuals, these would be lumped into 2 categories, 11-20 films (7 individuals) and 21+ films (6 individuals).

Once X-ray categories had been combined, summary, age-stratified relative risks were calculated. Two decisions were involved here, the choice of a measure of relative risk and the definition of "exposed" versus "unexposed" categories. The Mantel-Haenszel statistic (Mantel and Haenszel 1959; Mantel 1963) together with 95% confidence limits and a heterogeneity chi squares, which reflects the variation in the odds ratio across the 3 age strata, derived from a procedure suggested by Cornfield (1956) (see also Gart (1971)). These methods were chosen in preference to the Woolf-Haldane log-odds ratio methods (Woolf, 1955; Haldane, 1956; Sheehe, 1966) because the Mantel-Haenszel procedure is less sensitive to sparse data sets (Gart 1962, 1970, 1971; Naylor 1967) and because its small sample properties are better known (Li et al., 1979). Further, the Cornfield error bound procedure is known to give conservative results (Brown 1981). Computational details for the statistics calculated are shown in Table 1. These statistics provide an estimate of the relative risk, the magnitude of its deviation from unity in the form of a chi-squared statistic ($\chi^2_{R.R.}$), error bounds for the central estimate, and a second χ^2 statistic that assesses the uniformity of relative risk across the three age strata (χ^2_{HET}). Computation was performed using a set of BASIC computer programs prepared by the senior author.

In defining "exposed" versus "unexposed" categories it was decided to separately compare each radiation exposure category to the zero exposure category. This procedure was adopted because we felt that it provided a clearer view of the pattern of risk (e.g. does risk increase with increasing dose?) than did the methods used in the original Tri-State study. This point is illustrated

in Table 2. A second set of analyses was also performed using persons with 0-10 films as the unexposed group, to provide an analysis directly comparable to the original Tri-State study (Gibson et al., 1972).

The convention of excluding only those cases with therapeutic X-ray or missing X-ray exposure data, as in the original Tri-State study, was also followed.

This differs from the exclusion rule followed by Bertell (1977, 1978) and Bross et al. (1979) who additionally excluded all those persons with unverified X-ray exposures (unverified exposures being those reported by the study subject or, if subject was a leukemia case who was already dead, a relative that could not be found in the subject's medical records). The problem with this approach is that less than 10% of the exposures reported (as number of films) in the Tri-State data set fall into the unverified category, while exclusion of those with unverified exposure results in loss of over 1/3 of the cases. [Bross et al. (1979) included 206 males with nonlymphatic leukemia; our breakdowns indicate that at least 311 cases were available, if only those with therapeutic exposure are excluded (e.g. see Tables 7 and 8)]. It would seem that loss of one-third of the available data is a rather high price to pay to deal with a source of potential bias confined to less than 10% of the data; the bias is far from one sided (e.g. both leukemics and controls had unverified exposure).

In addition to our calculation of Mantel-Haenszel statistics for the various sex, age, X-ray type, X-ray exposure level, and leukemia type categories, we also examined temporal patterns in the diagnosis of two diseases (heart disease, and pneumonia). The analysis of heart disease was prompted by a claim that it was associated with radiation-induced leukemia (Bross et al., 1979). Pneumonia was examined because preleukemics have been shown to be particularly sensitive to the disease (Kneale, 1971; Stewart and Kneale, 1969) and because it had been hypothesized that preleukemic pneumonia might, in part, account for the excess X-ray exposure attributed to leukemics (Ginevan, 1980). In both diseases the proportion of individuals diagnosed (1) within 6 months of leukemia diagnosis, (2) 7 months-5 years prior to diagnosis, and (3) more than 6 years prior to diagnosis was compared among leukemics and controls using those without the disease as the "unexposed" group. Relative risk statistics were calculated as before using Mantel-Haenszel statistics and the same three age strata.

An evaluation was also made of the timing of X-ray exposure. In this, total X-rays were broken down by three periods: (1) 6 months-1 year prior to diagnosis, (2) 1 year-5 years prior to diagnosis, and (3) greater than 6 years prior to diagnosis. Differences in X-ray exposure pattern between controls and the various leukemia types were assessed. Because of the earlier findings of Gibson et al., 1972, and the results of the present study, this evaluation was confined to males with more than 40 trunk X-rays.

Finally, a detailed examination of two possible high risk groups (males with acute or chronic myeloid leukemia and more than 40 trunk X-rays) identified in this study was made to determine possible factors that might predispose a person to radiation-induced leukemia.

RESULTS

Cross tabulations for all exposure/leukemia types are shown in Tables 4-39. These are provided mainly for the sake of completeness, and to allow the reader to satisfy himself that our results are not particularly sensitive to the choice of age or dose strata. During the production of these mundane breakdowns one of our more interesting discoveries was made. In our initial cross tabulations we discovered excesses of 1 or 2 cases in some exposure categories as compared to published figures (Gibson et al., 1972). This was traced to the fact that we had failed to exclude persons with therapeutic X-ray exposure. We therefore did another analysis excluding such cases, and discovered that we now had deficiencies of between 1 and 3 cases in many categories. This paradox was resolved by an exhaustive case by case examination of the data in question, and rechecking the Tri-State data set code book (Graham, 1980). We discovered that many cases with therapeutic exposure had between 1 and 7 treatments, but the code book indicated therapeutic X-ray was coded as either 0 or 8 (eight or more treatments). Since our data had been checked and rechecked and all the records had been found to be internally consistent (i.e., if a person had therapeutic radiation by one code he had it also on all recodes), it seems probable that in doing the original analysis a programmer decided to exclude cases if the therapeutic variable was greater than or equal to eight. Given the set up of the code book it is a logical thing to do, and it was sheer good luck that we did not repeat the error.

Coding properly for therapeutic X-ray resulted in the loss of about 100 total persons, but had relatively small effects on the subsequent analyses (spot checks were made). This is reasonable given that there is no particular reason to feel that therapeutic exposure should be strongly associated with diagnostic exposure. The breakdown of therapeutic exposure is summarized briefly in Table 3. It is shown that male leukemics had a relative risk of 2.01 while females had a relative risk of 1.06. Since the purpose of the present investigation was the examination of diagnostic radiation effects these data will not be considered further. However, the reader should keep in mind that our values for a particular exposure category will be generally less than those published previously (Gibson et al., 1972). Tables 40-49 show the results of our relative risk by X-ray exposure analysis in 10 sex/leukemia type categories, using those exposed to 10 or less X-ray films as the control group. Of the large number of sex/leukemia type/X-ray exposure categories considered only 3 show a relative risk in excess of 2.0. These are males with acute myeloid leukemia exposed to more than 40 trunk X-rays (Table 40), males with chronic myeloid leukemia exposed to more than 40 trunk X-rays (Table 41), and males with chronic myeloid leukemia exposed to more than 40 total X-rays (Table 41). The last two, however, are hardly independent since the second includes the first. Inspection of table 41 shows that the relative risk of those in the highest total exposure category (2.50) is entirely the result of the extremely high risk shown by those in the highest trunk exposure category (11.41) being diluted by inclusion of non-trunk X-ray exposure.

There are also several categories with relative risks of less than 0.5. Two are not significant owing to small sample size (males with chronic myeloid leukemia exposed to more than 16 non-trunk X-rays [Table 41]; females with other unspecified leukemia exposed to more than 11 non-trunk X-rays [Table 49]), but three others deviate from unity as strongly as do those risks greater than 2. (Males with chronic lymphatic leukemia exposed to between 11 and 20 trunk X-rays [Table 43]; females with chronic lymphatic leukemia exposed to either more than 16 trunk or more than 21 total X-rays [Table 48]).

Turning to the same analyses but using zero X-ray films as the control group (Tables 50-59) we see the same patterns repeated with the additional observation that leukemics tend to be underrepresented in the two additional low exposure categories (1-5 and 6-10 films). (That is, these categories tend to show relative risks of less than unity in most sex/leukemia type categories.)

Our evaluations of heart disease are shown in Tables 60 and 61. The major case-control difference noted is a large excess of heart disease diagnosed within 6 months of leukemia diagnosis. In females, there also seems to be a tendency for leukemics to show an excess of long standing heart disease.

Our pneumonia analysis is presented in Tables 62 and 63. Here we see a strong, consistent excess of risk of pneumonia diagnosis within 6 months of leukemia diagnosis, some evidence of excess risk between 7 months and 5 years prior to diagnosis, and no excess risk of pneumonia 6 or more years prior to leukemia diagnosis.

Table 64 presents breakdowns of total X-ray exposure over time (temporal information for trunk exposure alone was not available) for all males with more than 40 trunk X-rays (the category which includes our only 2 "high risk" groups), broken down by leukemia type. The major finding here is that well over half (58.9-71.3 percent) of diagnostic X-rays were given within 1 year of leukemia diagnosis. There are no striking differences among the different leukemia types, though acute myeloid leukemia does show a significantly different distribution of X-ray exposure by time ($P < .001$), when compared to either the control or chronic lymphatic leukemia groups via a chi-squared test.

The final evaluation carried out was an inspection of the occupation, ethnicity, and disease history of the two "high risk" groups--male acute and chronic myeloid leukemics with more than 40 trunk X-rays. These were compared to males with more than 40 trunk X-rays from the control and chronic lymphatic leukemia groups (the origin of the latter is presumably not radiogenic). The only obvious difference resulting from this comparison was that the 17 individuals afflicted with myeloid leukemia had a history of heart disease which pre-dated their leukemia diagnosis by at least 4 years, as opposed to none of the nine controls and lymphatic leukemia cases. The average age of these seven cases was over 65 years.

DISCUSSION

It is apparent from our extensive consideration of this data set that there is little or no excess leukemia risk that can be attributed to diagnostic X-ray exposure. Only 2 groups (males with acute and chronic myeloid leukemia exposed to more than 40 trunk X-rays) show significant excess risk. This finding is at variance with those of the original Tri-State investigators (Gibson et al., 1972), but the differences are readily explicable. First, as noted earlier, we excluded all therapeutic X-ray exposures, which the original analysis inadvertently failed to do. Second, and more importantly, we analysed non-overlapping exposure intervals. The impact of this may be illustrated by considering that, in the original study (Gibson et al., 1972) males with acute myeloid leukemia and more than 40 trunk X-rays showed a highly significant excess of leukemia and a relative risk of 5.06 ($P \leq .02$). In our investigation, the risk dropped to 4.69 ($P \approx 0.05$) (Table 40). This differential is due, in part, to the fact that 2 of the nine cases originally analysed in this category actually had therapeutic exposure and were thus excluded from our analysis. More significantly, however, all lower exposure categories show a slight deficiency in X-ray exposure compared to the control group. This deficiency is even more apparent if those with 0 X-ray exposure are taken as the control group (Table 50), which makes it exceedingly difficult to seriously propose that X-rays may cause this disease.

Similarly, in the case of chronic myeloid leukemia (Table 51) there is a strong excess risk for males in the 40+ exposure category, but no evidence of any general increase in lower categories. One might argue that here, at least, three of the lower categories show risks in excess of unity, but this ignores the fact that two exposure categories do not (Table 51) and that the second highest risk is shown by those with only 6-10 exposures.

The disagreement of findings of this analysis with those of Bertell (1977 and 1978) and Bross et al. (1979) is more fundamental. It is our opinion that both authors produced selective analyses, designed to support a particular hypothesis, rather than to provide an unbiased evaluation of the data as a whole. Both authors use methodology which is both non-standard and highly questionable. Further, with one exception, both authors restrict themselves to analyses of males with nonlymphatic (chronic myeloid + acute myeloid) leukemia.

The exception itself is worthy of note. Bertell (1978) compares males with females in Table 2. In this she uses rads skin dose, which gives greatest weight to dental X-rays (1 dental X-ray = 6.8 chest exposures or 1.44 abdominal exposures). This makes no sense, as is illustrated in the same paper (Bertell, 1978) by her Table 23 dealing with estimated marrow doses, because dental X-rays involve very little dose to the bone marrow (myeloid leukemias are malignancies of the bone marrow). However, examining the great differences in X-ray exposure and leukemia risk between the sexes shown in our Tables 50, 51, and 53, and Tables 55, 56, and 58, respectively, it is apparent why Bertell's odd scale is necessary. Moreover, this scale is abandoned when consideration is focused only on males (Bertell, 1978, Table 8), for a convention that a dental X-ray = 1/4 of a trunk exposure.

In the case of Bross et al. (1979) work, the contention is made that X-ray exposure is associated with both heart disease and leukemia. Here, too, number of films is converted to "rads" exposure in an arbitrary manner, with the assurance that "The use of other constants would not affect conclusions concerning the shape of the curve" (dose-response is claimed to be calculated). Perusal of the analyses presented here suggests that the choice of exposure types, and constants combining them, would greatly affect any "curve" calculated. More importantly, the classification heart disease--no heart disease is adopted without regard to time prior to diagnosis.

Consulting Table 61 we see that the really striking elevation in diagnosis of heart disease occurs within 6 months of leukemia diagnosis. This is almost certainly a reporting bias (e.g. it is more probable that a sick person who is undergoing intensive medical examination will be found to have heart disease than a person selected at random from the general public). Thus, Bross et al. (1979) included a substantial source of confounding in their study.

Consideration of the 2 "high risk groups" (males with acute or chronic myeloid leukemia and more than 40 trunk X-rays) in our study did show 7 persons with a heart disease history of long standing (more than 5 years prior to diagnosis) and two others with the disease at least 1 year prior to myeloid leukemia diagnosis (all others were free of the disease). None of the nine persons in the two comparison groups (male controls and chronic lymphatic leukemics with more than 40 trunk X-rays) showed any history of heart disease. These data, however, suggest that heart disease predates X-ray exposure. Even the two individuals whose heart disease was diagnosed between one and three years prior to leukemia diagnosis received over 20% of their trunk exposure between 6 months and 1 year prior to leukemia diagnosis. If one accepts the general dictum that a cause must precede its effect, it appears unlikely that X-irradiation causes heart disease (though the converse is both admissible and plausible).

Much better agreement is found between our results and those of two other studies of adult leukemia and diagnostic X-ray. The first of these is Stewart et al. (1962). This study involved 483 cases of nonlymphatic leukemia, as well as 496 cases of lymphatic leukemia, 956 cases of "other cancers," and 956 controls. The study concluded that only nonlymphatic leukemias showed an excess risk of diagnostic X-ray exposure. This excess, which was present to a greater degree in males than in females, was attributable to a very marked excess (1.8 x controls) of persons who had had 10 or more trunk X-rays within 5 years prior to diagnosis of leukemia. The authors originally calculated that some 8% of nonlymphatic leukemias were X-ray induced. Other studies, however, showed that preleukemics have an inordinately high risk of developing infectious diseases (Stewart and Kneale, 1969; Kneale, 1971), such as pneumonia, which would result in an increased rate of exposure to diagnostic X-rays. This finding cast sufficient doubt on the cause-effect relationship that the senior author subsequently retracted her earlier estimate

(Stewart 1973). A later study in New Zealand also considered the possibility of a positive relationship between leukemia and diagnostic X-ray procedures (Gunz and Atkinson, 1964). This study, which included 355 cases of acute leukemia, 78 cases of chronic granulocytic (myeloid) leukemia, 157 cases of chronic lymphocytic leukemia, and 712 controls matched for age and sex, showed a positive relationship between X-rays and chronic granulocytic leukemia. However, all of the excess exposure was attributable to a total of four individuals who had received more than 20 R skin dose during a 10 year period prior to diagnosis. Because the vast majority of leukemia cases showed no excess X-ray exposure, the authors concluded that, at most, 1% of the leukemias were induced by exposure to diagnostic X-ray.

Our findings echo the excess of males over females and the absence of excess risk for lymphatic leukemias found by Stewart et al. (1962). They also parallel the finding that those in the high risk groups have a large number of X-ray procedures within 5 years of leukemia diagnosis. However, this finding must be tempered by the fact that a similar pattern was demonstrated in male controls and male chronic lymphatic leukemics as well (Table 64). As for the speculation that pre-leukemic pneumonia and other infectious diseases may be responsible for the observed excess X-ray exposure in leukemics (Stewart and Kneale, 1969; Kneale, 1971; Stewart, 1973), there is certainly a large excess of pneumonia diagnosed within 6 months of leukemia diagnosis and some indication that there is an excess of pneumonia diagnosed between 7 months and 5 years of leukemia diagnosis. The problem is that these phenomena cut across both leukemia types which show excess risk and those which do not. Thus our investigation does not really support the idea that excess X-ray exposure is caused by pneumonia. However, pneumonia does show a pattern similar to heart disease, and observed excess of this disease to may be due in part to reporting bias.

General agreement is also found between our findings and those of Gunz and Atkinson (1964). It is of particular interest to note that in their study, as in ours, all excess risk was found in a small group of persons with nonlymphatic leukemia. If one accepts the reasonable generalization that 1 trunk exposure = .5 rad skin dose (USHEW, 1966) even the dose cutoffs of their study agree well with ours (20 rads = 40 films).

Another point of interest concerns the observed general deficiency of leukemia cases in the two lowest exposure categories (1-5 and 6-10 films; Tables 50-59). It was suggested to us that this may reflect the fact that X-ray exposure may be underreported for leukemics because in many cases interviewers obtained X-ray histories from relatives of leukemics since the person afflicted had already died. This is true, but it should be remembered that over 90% of the X-ray exposure was verified from medical records and that only about 30% of actual X-ray exposure was mentioned in interviews (Graham et al., 1963). This consideration led Boice and Land (1979) to suggest that leukemia cases might have better records and thus a slight excess in exposure would be expected. If this is in fact the case,

one could explain the observed pattern by the fact that more controls than leukemics tend to be placed in low exposure categories because less of their exposure is recorded.

The final and most important point is what this study says about the adult leukemia risk associated with diagnostic X-ray exposure. It would be inappropriate to try to estimate a doubling dose or excess risk from the two "high risk" groups. First, any such estimate would be an overestimate (Land, 1980). Second, there is the disturbing fact that much of the exposure took place within 5 years of diagnosis which is contrary to the understandings of leukemia latency gained from the atomic bomb survivors (Land and Norman, 1978). In that data, latency following exposure was at least 5 years and increased with decreasing dose. Finally, one can hardly focus on the small group with excess risk while ignoring the groups with significant X-ray deficits. This point is discussed at length by Cohen (1978).

Consideration of the overall pattern of risk observed (which is our basic purpose) suggests that risks are symmetrical about 1.0. However, the results observed are not, on the basis of confidence intervals, incompatible with some small excess leukemia attributable to diagnostic X-ray.

The most that can be said about effects, given the results, is that older males with heart disease (which might in itself cause X-ray exposure) may be at risk if they are exposed to a very large number of X-ray films within a short period of time. However, it should be emphasized that the weight of the evidence examined here suggests that there is little excess adult leukemia risk that can be attributed to diagnostic X-ray exposure in general.

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Table 1. An illustration of Mantel-Haenszel methods for calculation of a pooled relative risk and its associated chi-squared K tables of the form shown below. Also shown are procedures for calculation of an upper bound on the estimate and a heterogeneity χ^2 both of which are developed from a procedure due to Cornfield (1956).

	Case	Control	
Exposed	X_i	$M_i - X_i$	M_i
Unexposed	$N_{1i} - X_i$	$N_{2i} - M_i + X_i$	$N_{1i} + N_{2i} - M_i$
	N_{1i}	N_{2i}	$N_{1i} + N_{2i} = T_i$

Mantel Haenszel Relative Risk (R_m)

$$\text{Take } G_i = X_i^2 - M_i X_i + N_{2i} X_i$$

$$H_i = X_i^2 - M_i X_i - N_{1i} X_i + M_i N_{1i}$$

$$\text{then } R_m = \left(\sum_{i=1}^k G_i \div T_i \right) \div \left(\sum_{i=1}^k H_i \div T_i \right)$$

Chi squared for deviation of R_m from unity (χ^2)

$$\chi^2 = \left(\left| \left(\sum_{i=1}^k G_i \div T_i \right) - \left(\sum_{i=1}^k H_i \div T_i \right) \right| - 1/2 \right)^2 \div \left(\sum_{i=1}^k \left(N_{1i} N_{2i} M_i (T_i - M_i) \right) \div \left(T_i^2 (T_i - 1) \right) \right)$$

For Cornfield upper bound R_c find solution of

$$\frac{(\sum x_i - (\hat{x}_i | M_i; R_c)) + 1/2}{\sum \sqrt{V(\hat{x}_i | M_i; R_c)}} = -Z_{\alpha/2}$$

where $(\hat{x}_i | M_i; R_u)$ is the solution to a quadratic equation, Z_{α} is the normal deviate associated with a two sided $1-\alpha$ percent confidence interval, and

$$V(\hat{x}_i | M_i; R_u) = \left((x_i)^{-1} + (M_i - \hat{x}_i)^{-1} + (N_{1i} - \hat{x}_i)^{-1} + (N_{2i} - M_i + \hat{x}_i)^{-1} \right)^{-1}$$

A method for obtaining this solution is given by Gart (1971). One can also find a heterogeneity chi squared by solving quadratics for $(\hat{x}_i | M_i; R_m)$ and observing that

$$\sum_{i=1}^k \left(\frac{x_i - (\hat{x}_i | M_i; R_m)}{V(\hat{x}_i | M_i; R_m)} \right)^2$$

is asymptotically distributed as a χ^2 variate with $k-1$ degrees of freedom.

Table 2. Alternative methods of defining "exposed" versus "unexposed" populations and their effect on patterns of relative risk (R.R.): an example using hypothetical data.

<u>Data Set</u>	Controls	Cases
Dose level		
0	100	100
1	10	5
2	10	5
3	10	40

Tri-State Survey Method (Gibson et al., 1972)

Dose level 3 versus 0 + 1 + 2

$$\text{R.R.} = (40 \times 120) \div (10 \times 110) = 4.36$$

Dose level 2 + 3 versus 1 + 2

$$\text{R.R.} = (45 \times 110) \div (20 \times 105) = 2.36$$

Dose level 1 + 2 + 3 versus 0

$$\text{R.R.} = (50 \times 100) \div (30 \times 100) = 1.67$$

Method Adopted

Dose level 3 versus 0

$$\text{R.R.} = (40 \times 100) \div (30 \times 100) = 4$$

Dose level 1 or 2 versus 0

$$\text{R.R.} = (5 \times 100) \div (10 \times 100) = 0.5$$

Table 3. A brief analysis of therapeutic X-ray exposure. Shown are breakdowns of therapeutic exposure by sex and age in controls versus leukemics. Also shown are upper and lower 95% error bounds (U.B.; L.B.) and the Mantel-Haenszel statistic for relative risk (R.R.), and chi-squared statistics for relative risk ($\chi^2_{R.R.}$) and heterogeneity (χ^2_{HET}).

	Age	Males			Females		
		≤ 40	41-60	61+	≤ 40	41-60	61+
<u>Controls</u>							
No therapeutic		204	243	203	191	216	251
Therapeutic		5	6	7	11	16	17
<u>Leukemics</u>							
No therapeutic		99	218	491	67	138	318
Therapeutic		8	13	23	3	10	26

Mantel-Haenszel Statistics

	Males	Females
R. R.	2.01	1.06
L. B.	1.13	.66
U. B.	3.90	1.72
* $\chi^2_{R.R.}$	5.64	0.02
† χ^2_{HET}	1.67	0.42
* 1 degree of freedom	$\chi^2 (0.05, 1) = 3.84$	$\chi^2 (0.05, 2) = 5.99$
† 2 degrees of freedom	$\chi^2 (0.01, 1) = 5.02$	$\chi^2 (0.01, 2) = 9.21$

Table 4. Cross Tabulation of Total X-Ray Exposure by Age: Males, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	21	46	25	31	48	31	26	5	233
1-5	11	16	12	17	34	28	13	2	133
6-10	7	9	5	9	17	18	6	1	72
11-15	4	5	2	10	13	13	9	0	56
16-20	4	8	4	2	8	8	1	1	36
21-40	5	6	3	11	14	13	4	2	58
41+	1	1	0	6	12	3	2	0	25
Total	53	91	51	86	146	114	61	11	613

Table 5. Cross Tabulation of Total X-Ray Exposure by Age: Males, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	6	0	3	5	5	4	6	1	30
1-5	5	2	1	0	1	2	0	2	13
6-10	2	0	1	1	0	1	1	1	7
11-15	1	2	1	2	1	0	1	0	8
16-20	1	0	0	3	2	0	0	0	6
21-40	1	0	1	0	2	1	0	0	5
41+	0	0	0	0	0	1	0	0	1
Total	16	4	7	11	11	9	8	4	70

Table 6. Cross Tabulation of Total X-Ray Exposure by Age: Males, Chronic Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	0	3	8	21	44	42	14	132
1-5	0	0	0	4	8	22	22	6	62
6-10	0	1	0	2	6	7	8	3	27
11-15	0	0	1	3	9	3	2	2	20
16-20	0	0	1	1	2	2	6	0	12
21-40	0	0	0	2	5	7	4	3	21
41+	0	0	0	2	1	4	3	0	10
Total	0	1	5	22	52	89	87	28	284

Table 7. Cross Tabulation of Total X-Ray Exposure by Age: Males, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	5	6	3	6	11	17	20	8	76
1-5	3	0	6	3	6	9	7	2	36
6-10	1	2	1	2	4	5	5	0	20
11-15	0	1	4	4	5	4	1	1	20
16-20	0	0	0	1	1	2	0	0	4
21-40	1	1	2	0	6	1	3	1	15
41+	0	0	0	0	5	5	2	0	12
Total	10	10	16	16	38	43	38	12	183

Table 8. Cross Tabulation of Total X-Ray Exposure by Age: Males, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	2	3	1	4	9	12	9	2	42
1-5	0	3	0	4	2	6	4	1	20
6-10	0	1	1	2	2	7	3	0	16
11-15	0	0	1	1	1	5	5	2	15
16-20	0	0	2	1	0	5	1	0	9
21-40	0	0	2	2	1	7	1	1	14
41+	0	0	0	0	2	6	4	0	12
Total	2	7	7	14	17	48	27	6	128

Table 9. Cross Tabulation of Total X-Ray Exposure by Age: Males, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	3	2	2	4	6	9	15	5	46
1-5	0	1	0	2	3	5	5	2	18
6-10	1	0	1	0	3	6	3	1	15
11-15	0	0	1	2	1	1	2	0	7
16-20	0	0	0	0	0	2	2	1	5
21-40	0	0	2	0	3	3	4	3	15
41+	0	0	0	2	1	4	1	0	8
Total	4	3	6	10	17	30	32	12	114

Table 10. Cross-Tabulation of Trunk X-Ray Exposure by Age: Males, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	37	69	31	54	68	39	34	5	337
1-5	12	16	13	16	41	39	10	2	149
6-10	2	3	3	4	16	15	5	2	50
11-15	0	3	1	4	5	6	7	0	26
16-20	0	0	1	4	6	7	2	1	21
21-40	1	0	2	4	7	7	3	1	25
41+	1	0	0	0	3	1	0	0	5
Total	53	91	51	86	146	114	61	11	613

Table 11. Cross Tabulation of Trunk X-Ray Exposure by Age: Males, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	13	3	5	5	6	4	6	1	43
1-5	2	1	1	2	0	2	1	2	11
6-10	1	0	0	2	1	1	0	1	6
11-15	0	0	0	1	2	0	1	0	4
16-20	0	0	0	1	0	0	0	0	1
21-40	0	0	1	0	2	1	0	0	4
41+	0	0	0	0	0	1	0	0	1
Total	16	4	7	11	11	9	8	4	70

Table 12. Cross Tabulation of Trunk X-Ray Exposure by Age: Males, Chronic Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	0	3	13	28	53	46	14	157
1-5	0	0	1	4	13	20	26	8	72
6-10	0	1	0	1	3	6	7	2	20
11-15	0	0	1	0	3	2	1	1	8
16-20	0	0	0	1	1	0	2	0	4
21-40	0	0	0	3	3	6	4	3	19
41+	0	0	0	0	1	2	1	0	4
Total	0	1	5	22	52	89	87	28	284

Table 13. Cross Tabulation of Trunk X-Ray Exposure by Age: Males, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	6	7	6	11	15	23	22	8	98
1-5	4	2	8	4	9	6	8	2	43
6-10	0	1	1	1	4	5	4	1	17
11-15	0	0	1	0	3	2	1	0	7
16-20	0	0	0	0	1	2	1	0	4
21-40	0	0	0	0	4	0	2	1	7
41+	0	0	0	0	2	5	0	0	7
Total	10	10	16	16	38	43	38	12	183

Table 14. Cross Tabulation of Trunk X-Ray Exposure by Age: Males, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	2	5	3	8	10	13	13	2	56
1-5	0	2	2	1	3	7	2	1	18
6-10	0	0	2	2	1	8	6	0	19
11-15	0	0	0	0	0	7	2	2	11
16-20	0	0	0	1	0	3	1	0	5
21-40	0	0	0	2	1	4	1	1	9
41+	0	0	0	0	2	6	2	0	10
Total	2	7	7	14	17	48	27	6	128

Table 15. Cross Tabulation of Trunk X-Ray Exposure by Age: Males, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	4	2	3	6	8	14	16	5	58
1-5	0	1	0	2	3	5	5	4	20
6-10	0	0	3	1	2	2	3	0	11
11-15	0	0	0	0	0	2	3	0	5
16-20	0	0	0	0	2	3	2	1	8
21-40	0	0	0	1	1	3	2	2	9
41+	0	0	0	0	1	1	1	0	3
Total	4	3	6	10	17	30	32	12	114

Table 16. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Males, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	27	54	34	42	76	72	41	8	354
1-5	10	16	10	15	37	21	11	2	122
6-10	5	4	4	9	10	6	5	0	43
11-15	3	4	1	9	4	7	1	1	30
16-20	4	7	1	2	7	1	1	0	23
21-40	4	5	1	5	6	6	2	0	29
41+	0	1	0	4	6	1	0	0	12
Total	53	91	51	86	146	114	61	11	613

Table 17. Cross Tabulation of Nontrunk X-ray Exposure by Age: Males, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	8	0	4	7	7	7	7	4	44
1-5	4	2	1	1	1	1	1	0	11
6-10	1	1	2	1	2	1	0	0	8
11-15	1	1	0	2	1	0	0	0	5
16-20	1	0	0	0	0	0	0	0	1
21-40	1	0	0	0	0	0	0	0	1
41+	0	0	0	0	0	0	0	0	0
Total	16	4	7	11	11	9	8	4	70

Table 18. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Males, Chronic Lymphatic Leukemia.

Number of x-rays.	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	1	3	14	32	64	65	23	202
1-5	0	0	1	1	6	15	15	5	43
6-10	0	0	0	2	8	3	1	0	14
11-15	0	0	1	3	3	3	2	0	12
16-20	0	0	0	0	1	1	3	0	5
21-40	0	0	0	1	2	3	1	0	7
41+	0	0	0	1	0	0	0	0	1
Total	0	1	5	22	52	89	87	28	284

Table 19. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Males, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	7	7	8	8	22	30	28	11	121
1-5	1	0	3	3	6	6	5	1	25
6-10	1	1	2	2	0	4	2	0	12
11-15	0	1	1	2	2	2	0	0	8
16-20	0	0	0	1	1	0	0	0	2
21-40	1	1	2	0	6	0	1	0	11
41+	0	0	0	0	1	1	2	0	4
Total	10	10	16	16	38	43	38	12	183

Table 20. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Males, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	2	4	2	9	14	29	16	5	81
1-5	0	3	0	4	1	15	5	1	29
6-10	0	0	0	0	2	1	1	0	4
11-15	0	0	2	1	0	3	3	0	9
16-20	0	0	2	0	0	0	0	0	2
21-40	0	0	1	0	0	0	1	0	2
41+	0	0	0	0	0	0	1	0	1
Total	2	7	7	14	17	48	27	6	128

Table 21. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Males, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	3	3	3	6	10	18	26	8	77
1-5	0	0	0	0	2	6	2	2	12
6-10	1	0	0	1	3	2	1	1	9
11-15	0	0	2	2	1	0	2	1	8
16-20	0	0	1	0	1	0	0	0	2
21-40	0	0	0	0	0	3	1	0	4
41+	0	0	0	1	0	1	0	0	2
Total	4	3	6	10	17	30	32	12	114

Table 22. Cross Tabulation of Total X-Ray Exposure by Age: Females, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	15	18	23	18	34	49	36	9	202
1-5	14	18	18	33	35	28	18	3	167
6-10	7	19	13	1	10	13	8	1	72
11-15	3	3	3	12	11	11	6	1	50
16-20	3	4	5	6	5	14	0	2	39
21-40	3	8	4	11	12	13	7	1	59
41+	2	1	2	8	7	11	5	0	36
Total	47	71	68	89	114	139	80	17	625

Table 23. Cross Tabulation of Total X-Ray Exposure by Age: Females, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	5	2	2	4	0	4	2	1	20
1-5	1	0	2	0	2	2	0	0	7
6-10	0	0	0	1	0	0	2	1	4
11-15	0	1	0	1	1	1	0	0	4
16-20	0	1	0	0	0	0	1	0	2
21-40	0	0	0	0	0	1	0	0	1
41+	0	0	0	0	1	0	1	0	2
Total	6	4	4	6	4	8	6	2	40

Table 24. Cross Tabulation of Total X-Ray Exposure by Age: Females, Chronic Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	1	1	5	11	33	24	8	83
1-5	0	0	0	2	2	10	11	2	27
6-10	0	0	0	2	2	4	3	1	12
11-15	0	0	0	1	1	5	2	2	11
16-20	0	1	0	1	2	2	4	0	10
21-40	0	0	0	2	1	2	5	0	10
41+	0	0	0	0	0	0	1	0	1
Total	0	2	1	13	19	56	50	13	154

Table 25. Cross Tabulation of Total X-Ray Exposure by Age: Females, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	4	5	3	8	8	8	9	6	51
1-5	0	0	3	4	5	8	7	2	29
6-10	0	1	0	5	4	2	0	1	13
11-15	0	0	1	1	1	2	0	1	6
16-20	0	2	1	0	0	1	2	1	7
21-40	0	0	2	2	3	1	2	0	10
41+	0	0	0	1	1	3	2	1	8
Total	4	8	10	21	22	25	22	12	124

Table 26. Cross Tabulation of Total X-Ray Exposure by Age: Females, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	1	3	3	8	8	10	6	2	41
1-5	0	2	3	2	4	3	5	1	20
6-10	0	0	0	2	2	3	2	2	11
11-15	0	2	0	1	0	4	1	1	9
16-20	0	1	1	1	1	3	1	1	9
21-40	0	0	1	1	1	2	2	2	9
41+	0	1	0	1	1	0	2	0	5
Total	1	9	8	16	17	25	19	9	104

Table 27. Cross Tabulation of Total X-Ray Exposure by Age: Females, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	3	4	4	4	6	16	7	44
1-5	1	0	0	1	3	5	3	2	15
6-10	1	0	0	0	0	2	2	1	6
11-15	0	0	0	1	0	2	2	1	6
16-20	0	0	0	0	1	0	0	0	1
21-40	0	0	0	2	1	1	3	1	8
41+	0	0	0	2	0	1	0	0	3
Total	2	3	4	10	9	17	26	12	83

Table 28. Cross Tabulation of Trunk X-Ray Exposure by Age: Females, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	30	42	42	39	63	73	41	11	341
1-5	14	24	17	33	27	27	16	1	159
6-10	1	4	4	5	4	13	8	1	40
11-15	0	0	2	4	7	7	3	2	25
16-20	1	0	2	5	6	6	2	2	24
21-40	1	1	1	2	7	10	6	0	28
41+	0	0	0	1	0	3	4	0	8
Total	47	71	68	89	114	139	80	17	625

Table 29. Cross Tabulation of Trunk X-ray Exposure by Age: Females, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	6	3	2	4	2	6	5	2	30
1-5	0	1	2	0	1	1	0	0	5
6-10	0	0	0	2	0	0	0	0	2
11-15	0	0	0	0	1	0	0	0	1
16-20	0	0	0	0	0	0	0	0	0
21-40	0	0	0	0	0	1	0	0	1
41+	0	0	0	0	0	0	1	0	1
Total	6	4	4	6	4	8	6	2	40

Table 30. Cross Tabulation of Trunk X-Ray Exposure by Age: Females, Chronic Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	1	1	7	14	37	26	9	95
1-5	0	1	0	3	3	8	11	2	28
6-10	0	0	0	3	1	3	5	1	13
11-15	0	0	0	0	0	5	4	1	10
16-20	0	0	0	0	1	2	1	0	4
21-40	0	0	0	0	0	1	2	0	3
41+	0	0	0	0	0	0	1	0	1
Total	0	2	1	13	19	56	50	13	154

Table 31. Cross Tabulation of Trunk X-Ray Exposure by Age: Females, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	4	7	6	12	13	11	12	7	72
1-5	0	1	3	6	5	11	5	2	33
6-10	0	0	0	0	2	1	0	0	3
11-15	0	0	0	1	0	1	1	1	4
16-20	0	0	1	0	1	0	1	1	4
21-40	0	0	0	1	1	0	2	1	5
41+	0	0	0	1	0	1	1	0	3
Total	4	8	10	21	22	25	22	12	124

Table 32. Cross Tabulation of Trunk X-Ray Exposure by Age: Females, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	1	4	4	12	10	14	7	2	54
1-5	0	2	2	3	4	6	6	2	25
6-10	0	0	0	1	0	3	1	2	7
11-15	0	2	0	0	0	1	1	0	4
16-20	0	0	1	0	1	0	1	2	5
21-40	0	0	1	0	1	1	2	1	6
41+	0	1	0	0	1	0	1	0	3
Total	1	9	8	16	17	25	19	9	104

Table 33. Cross Tabulation of Trunk X-Ray Exposure by Age: Females, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	3	4	7	6	10	17	7	54
1-5	1	0	0	0	1	5	4	2	13
6-10	1	0	0	0	1	1	1	1	5
11-15	0	0	0	1	0	0	2	1	4
16-20	0	0	0	0	1	0	0	0	1
21-40	0	0	0	2	0	1	2	1	6
41+	0	0	0	0	0	0	0	0	0
Total	2	3	4	10	9	17	26	12	83

Table 34. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Controls.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	18	30	31	35	57	80	57	11	319
1-5	12	13	20	23	30	26	13	5	142
6-10	8	13	9	6	7	7	6	1	57
11-15	4	3	2	9	7	9	3	0	37
16-20	1	5	2	0	3	6	0	0	17
21-40	3	7	2	10	8	7	1	0	38
41+	1	0	2	6	2	4	0	0	15
Total	47	71	68	89	114	139	80	17	625

Table 35. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Acute Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	5	2	4	5	1	5	2	1	25
1-5	1	0	0	1	2	1	1	0	6
6-10	0	0	0	0	0	1	2	1	4
11-15	0	2	0	0	0	1	0	0	3
16-20	0	0	0	0	0	0	1	0	1
21-40	0	0	0	0	0	0	0	0	0
41+	0	0	0	0	1	0	0	0	1
Total	6	4	4	6	4	8	6	2	40

Table 36. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Chronic Lymphatic Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	0	1	1	7	14	49	37	10	119
1-5	0	0	0	2	0	4	6	2	14
6-10	0	0	0	1	1	1	2	1	6
11-15	0	1	0	1	2	1	2	0	7
16-20	0	0	0	1	2	0	1	0	4
21-40	0	0	0	1	0	1	1	0	3
41+	0	0	0	0	0	0	1	0	1
Total	0	2	1	13	19	56	50	13	154

Table 37. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Acute Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	4	5	4	12	14	16	15	9	79
1-5	0	0	2	2	2	3	5	1	15
6-10	0	1	0	6	2	1	1	1	12
11-15	0	1	1	0	1	2	0	1	6
16-20	0	1	3	0	0	0	0	0	4
21-40	0	0	0	1	3	1	0	0	5
41+	0	0	0	0	0	2	1	0	3
Total	4	8	10	21	22	25	22	12	124

Table 38. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Chronic Myeloid Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	1	7	7	10	13	16	13	6	73
1-5	0	1	1	0	1	2	2	2	9
6-10	0	0	0	3	2	1	2	1	9
11-15	0	0	0	1	1	2	0	0	4
16-20	0	1	0	0	0	3	1	0	5
21-40	0	0	0	1	0	1	1	0	3
41+	0	0	0	1	0	0	0	0	1
Total	1	9	8	16	17	25	19	9	104

Table 39. Cross Tabulation of Nontrunk X-Ray Exposure by Age: Females, Other (Type Unspecified) Leukemia.

Number of x-rays	Age								Total
	<21	21-30	31-40	41-50	51-60	61-70	71-80	81+	
0	2	3	4	7	6	11	21	11	65
1-5	0	0	0	1	2	1	2	1	7
6-10	0	0	0	0	0	3	2	0	5
11-15	0	0	0	0	0	1	0	0	1
16-20	0	0	0	0	1	0	1	0	2
21-40	0	0	0	0	0	0	0	0	0
41+	0	0	0	2	0	1	0	0	3
Total	2	3	4	10	9	17	26	12	83

Table 40. Male relative risks (R.R.) of acute myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	0.67	0.31/ 1.38	1.01/ 0.94	0.73	0.37/ 1.53	0.54/ 2.35	0.87	0.51/ 1.46	0.21/ 5.23
16 - 20									
21 - 40	0.84	0.31/ 2.11	0.04/ 2.27	1.37	0.70/ 2.70	0.68/ 1.05	0.88	0.45/ 1.67	0.08/ 2.85
41 - +	4.69	1.14/ 16.28	4.84/ 1.54				1.68	0.73/ 3.70	1.24/ 1.19

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 41. Male relative risks (R.R.) of chronic myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	1.72	0.72/ 3.81	1.21/ 3.17	1.37	0.57/ 3.26	0.31/ 2.57	1.25	0.62/ 2.45	0.24/ 1.40
16 - 20	1.03	0.32/ 3.07	0.05/ 0.19				1.47	0.61/ 3.43	0.51/ 0.70
21 - 40	1.66	0.67/ 3.99	0.98/ 0.59	0.47	0.16/ 1.25	2.10/ 7.24	1.25	0.62/ 2.50	0.26/ 0.82
41 - +	11.41	2.68/ 33.81	16.87/ 2.12				2.50	1.04/ 5.41	4.22/ 5.32

55

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 42. Male relative risks (R.R.) of acute lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	1.03	0.34/ 2.88	0.04/ 4.29				1.31	0.54/ 3.08	0.20/ 3.60
16 - 20				0.61	0.25/ 1.46	0.98/ 2.08	1.45	0.53/ 3.89	0.32/ 9.81
21 - 40	1.61	0.52/ 4.62	0.42/ 0.05				0.69	0.26/ 1.76	0.38/ 0.23
41 - +									

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 43. Male relative risks (R.R.) of chronic lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	0.44	0.19/ 0.82	6.50/ 14.37	0.93	0.41/ 2.07	0.01/ 3.94	0.71	0.36/ 1.24	1.45/ 13.16
16 - 20				0.72	0.21/ 2.44	0.07/ 1.90	0.80	0.34/ 1.79	0.18/ 1.33
21 - 40	1.26	0.66/ 2.44	0.36/ 0.49	0.47	0.19/ 1.10	2.91/ 0.38	0.67	0.36/ 1.22	1.62/ 0.83
41 - +							0.75	0.31/ 1.82	0.21/ 0.71

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 44. Male relative risks (R.R.) of other (type unspecified) leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental+ extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	0.79	0.25/ 2.35	0.03 1.32	1.53	0.61/ 3.87	0.66/ 2.37	0.63	0.24/ 1.50	0.91/ 2.24
16 - 20	1.68	0.64/ 4.32	0.85/ 0.13				0.74	0.24/ 2.20	0.10/ 2.55
21 - 40	1.93	0.86/ 4.22	2.33/ 0.57	0.84	0.35/ 1.96	0.05/ 0.58	1.34	0.67/ 2.66	0.52/ 0.50
41 - +							1.86	0.69/ 4.74	1.22/ 9.62

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 45. Female relative risks (R.R.) of acute myelogenous leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	0.73	0.30/ 1.66	0.39/ 1.34	0.95	0.44/ 2.02	0.01/ 8.75	0.53	0.19/ 1.32	1.64/ 0.82
16 - 20							0.86	0.34/ 2.10	0.02/ 4.52
21 - 40	0.94	0.39/ 2.21	0.01/ 0.65	0.73	0.31/ 1.68	0.36/ 2.19	0.77	0.35/ 1.64	0.31/ 0.63
41 - +							0.92	0.38/ 2.16	0.01/ 1.87

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 46. Female relative risks (R.R.) of chronic myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squares statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	1.03	0.45/ 2.30	0.01/ 11.46				1.03	0.45/ 2.31	0.01/ 4.84
16 - 20				0.71	0.36/ 1.37	0.88/ 2.91	1.40	0.60/ 3.19	0.41/ 0.51
21 - 40	1.31	0.56/ 3.03	0.25/ 5.76				0.89	0.39/ 1.97	0.01/ 1.69
41 - +							0.77	0.25/ 2.13	0.10/ 1.25

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 47. Female relative risks (R.R.) of acute lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15									
16 - 20	0.53#	0.12/ 1.88	0.63/ 0.38	0.71	0.24/ 1.96	0.22/ 0.52	0.72	0.31/ 1.63	0.43/ 0.09
21 - 40									
41 - +									

#based on 3 cases

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 48. Female relative risks (R.R.) of chronic lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	1.10	0.46/ 2.55	0.01/ 2.83	0.84	0.31/ 2.10	0.04/ 6.14	0.72	0.33/ 1.55	0.51/ 0.56
16 - 20							0.94	0.40/ 2.14	0.01/ 3.86
21 - 40	0.36	0.16/ 0.84	5.95/ 0.18	0.56	0.23/ 1.29	1.68/ 1.08	0.38	0.18/ 0.78	7.37/ 0.15
41 - +									

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 49. Female relative risks (R.R.) of other (type unspecified) leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}
1 - 5	***	***	***	***	***	***	***	***	***
6 - 10									
11 - 15	0.65	0.22/ 1.81	0.42/ 0.60				0.51	0.20/ 1.23	2.05/ 0.77
16 - 20				0.42	0.16/ 1.06	3.28/ 1.27			
21 - 40	0.91	0.32/ 2.40	0.01/ 1.71				0.75	0.35/ 1.56	0.43/ 2.50
41 - +									

63

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 50. Male relative risks (R.R.) of acute myeloid leukemia by X-ray exposure (numbers of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk				Non-Trunk				Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		
1 - 5	0.94	0.60/1.45	0.04/10.89	0.63	0.38/1.06	3.02/0.06	0.80	0.49/1.31	0.68/2.83		
6 - 10	0.90	0.46/1.73	0.04/1.47	0.89	0.42/1.84	0.03/1.99	0.80	0.43/1.47	0.41/1.63		
11 - 15	0.60	0.26/1.26	1.73/2.21	0.65	0.29/1.39	1.06/1.94	0.78	0.44/1.36	0.67/6.67		
16 - 20											
21 - 40	0.75	0.27/1.93	0.20/3.02	1.23	0.62/2.45	0.22/1.05	0.79	0.39/1.55	0.35/4.53		
41 - +	4.36	1.00/15.88	3.81/0.95				1.48	0.62/3.44	0.53/0.69		

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 51. Male relative risks (R.R.) of chronic myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	R.R.	Trunk		R.R.	Non-Trunk		R.R.	Total	
		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	0.63	0.34/ 1.15	2.13/ 1.90	0.91	0.56/ 1.48	0.08/ 2.69	0.76	0.40/ 1.42	0.60/ 0.43
6 - 10	1.66	0.84/ 3.25	1.99/ 1.32				1.08	0.53/ 2.17	0.01/ 0.18
11 - 15	1.59	0.64/ 3.68	0.72/ 3.26	1.32	0.54/ 3.16	0.22/ 2.99	1.14	0.54/ 2.38	0.04/ 1.35
16 - 20	0.95	0.29/ 2.92	0.03/ 0.23				1.38	0.55/ 3.39	0.28/ 0.82
21 - 40	1.55	0.61/ 3.83	0.62/ 0.40	0.44	0.14/ 1.18	2.49/ 7.35	1.17	0.55/ 2.45	0.07/ 1.07
41 - +	10.40	2.42/ 32.01	14.39/ 2.07				2.27	0.91/ 5.32	2.88/ 4.95

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 52. Male relative risks (R.R.) of acute lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-50, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}	R.R.	L.B./ U.B.	$\chi^2_{R.R.}/$ χ^2_{HET}
1 - 5	0.59	0.27/ 1.23	1.82/ 0.39	0.74	0.35/ 1.55	0.47/ 5.29	0.77	0.36/ 1.58	0.38/ 7.06
6 - 10	1.09	0.48/ 2.45	0.01/ 3.10	1.53	0.67/ 3.68	0.61/ 1.88	0.73	0.28/ 1.84	0.26/ 1.71
11 - 15							1.09	0.43/ 2.70	0.01/ 5.67
16 - 20	1.02	0.36/ 2.74	0.04/ 0.58	0.61	0.24/ 1.48	0.95/ 3.19	1.31	0.45/ 3.62	0.09/ 5.86
21 - 40							0.56	0.20/ 1.47	1.14/ 1.37
41 - +									

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 53. Male relative risks (R.R.) of chronic lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	0.79	0.53/1.18	1.24/0.31	0.63	0.40/0.99	3.96/2.92	0.67	0.43/1.05	3.01/0.94
6 - 10	0.56	0.29/1.04	3.37/5.76	0.73	0.34/1.48	0.66/5.00	0.59	0.32/1.03	3.37/1.86
11 - 15	0.39	0.16/0.73	8.29/17.72	0.83	0.36/1.83	0.12/3.54	0.59	0.29/1.04	3.25/12.60
16 - 20				0.63	0.19/2.16	0.23/2.04	0.66	0.27/1.50	0.82/1.30
21 - 40	1.10	0.56/2.18	0.02/0.66	0.41	0.16/0.98	4.03/0.31	0.55	0.29/1.03	3.49/0.95
41 - +							0.62	0.25/1.56	0.77/0.57

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 54. Male relative risks (R.R.) of other (type unspecified) leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	R.R.	Trunk			R.R.	Non-Trunk			R.R.	Total		
		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$			L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$			L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	
1 - 5	0.62	0.34/1.14	2.28/0.38	0.47	0.23/0.96	4.39/2.67	0.60	0.32/1.16	2.16/0.48			
6 - 10	1.00	0.44/2.20	0.03/8.28	1.10	0.46/2.56	0.01/0.52	0.92	0.45/1.88	0.01/0.16			
11 - 15	0.65	0.20/2.03	0.29/1.08	1.36	0.53/3.42	0.25/1.82	0.55	0.20/1.35	1.53/2.30			
16 - 20	1.42	0.52/3.79	0.27/0.17				0.62	0.20/1.93	0.38/2.39			
21 - 40	1.64	0.70/3.74	1.08/0.47	0.74	0.30/1.74	0.29/0.76	1.16	0.55/2.41	0.06/0.41			
41 - +							1.63	0.58/4.39	0.58/0.50			

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 55. Female relative risks (R.R.) of acute myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk				Non-Trunk				Total		
	R. R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R. R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R. R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		
1 - 5	0.99	0.61/1.61	0.01/4.54	0.45	0.24/0.83	6.72/2.96	0.72	0.41/1.21	1.45/6.89		
6 - 10				0.97	0.46/2.02	0.01/5.40	0.79	0.37/1.63	0.28/9.87		
11 - 15	0.54	0.26/1.12	2.64/0.03	0.77	0.35/1.66	0.28/5.77	0.47	0.16/1.20	2.29/0.75		
16 - 20							0.72	0.27/1.80	0.31/3.17		
21 - 40	0.94	0.38/2.26	0.01/0.57	0.62	0.26/1.43	1.05/2.92	0.64	0.28/1.42	0.97/0.05		
41 - +							0.84	0.33/2.05	0.04/2.89		

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***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 56. Female relative risks (R.R.) of chronic myeloid leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	R.R.	Trunk		R.R.	Non-Trunk		R.R.	Total	
		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	1.01	0.59/ 1.75	0.01/ 3.89	0.29	0.13/ 0.61	11.76/ 4.16	0.60	0.32/ 1.10	2.66/ 3.48
6 - 10	1.01	0.38/ 2.55	0.04/ 1.68	0.64	0.32/ 1.26	1.51/ 6.07	0.94	0.42/ 2.08	0.01/ 5.80
11 - 15	1.05	0.45/ 2.41	0.01/ 10.63				0.86	0.36/ 1.99	0.04/ 6.11
16 - 20							1.16	0.48/ 2.74	0.02/ 1.08
21 - 40	1.41	0.59/ 3.36	0.44/ 4.55	0.59	0.26/ 1.28	1.59/ 4.98	0.74	0.31/ 1.68	0.37/ 3.48
41 - +							0.63	0.20/ 1.81	0.50/ 0.90

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 57. Female relative risks (R.R.) of acute lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	0.37	0.12/1.03	3.55/0.72	0.52	0.18/1.35	1.58/2.25	0.42	0.16/1.10	2.99/0.15
6 - 10							0.66	0.25/1.63	0.62/4.50
11 - 15									
16 - 20	0.45	0.15/1.28	1.97/3.16	0.71	0.28/1.61	0.54/8.68			
21 - 40							0.40	0.13/1.16	2.67/1.44
41 - +									

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***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 58. Female relative risks (R.R.) of chronic lymphatic leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	R.R.	Trunk			Non-Trunk			Total		
		L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	
1 - 5	0.72	0.43/1.21	1.44/0.95	0.33	0.17/0.63	12.57/1.72	0.48	0.28/0.82	7.50/4.76	
6 - 10	0.94	0.44/1.97	0.01/2.32	0.47	0.17/1.25	2.05/0.57	0.62	0.28/1.31	1.40/2.01	
11 - 15	1.00	0.42/2.37	0.04/2.93	0.65	0.24/1.62	0.67/3.71	0.54	0.24/1.19	2.18/1.31	
16 - 20							0.71	0.30/1.60	0.52/1.37	
21 - 40	0.33	0.14/0.78	6.89/0.21	0.43	0.18/0.99	3.93/0.75	0.29	0.14/0.60	12.33/0.28	
41 - +										

***Part of control group

$$\chi^2 (0.05, 1) = 3.84$$

$$\chi^2 (0.05, 2) = 5.99$$

$$\chi^2 (0.01, 1) = 5.02$$

$$\chi^2 (0.01, 2) = 9.21$$

Table 59. Female relative risks (R.R.) of other (type unspecified) leukemia by X-ray exposure (number of films) and their associated 95% lower and upper bounds (L.B.; U.B.). Also shown are chi-squared statistics for the significance of the deviation of the observed relative risks from unity ($\chi^2_{R.R.}$) and heterogeneity chi-squares (χ^2_{HET}) reflecting variability of odds ratios among age strata (≤ 40 , 41-60, 61+ years). Statistics are shown for trunk (chest + abdomen), non-trunk (dental + extremities), and total X-ray exposure. Dark bars indicate exposure interval.

# X-Ray Films	Trunk			Non-Trunk			Total		
	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$	R.R.	L.B./U.B.	$\chi^2_{R.R.}/\chi^2_{HET}$
1 - 5	0.56	0.28/1.12	2.60/4.25	0.28	0.11/0.65	9.88/1.78	0.48	0.24/0.94	4.66/1.87
6 - 10	0.74	0.32/1.66	0.37/0.48	0.53	0.18/1.50	1.13/5.20	0.45	0.16/1.19	2.38/2.15
11 - 15							0.37	0.15/0.92	4.62/1.19
16 - 20				0.32	0.12/0.80	6.33/1.53			
21 - 40	0.59	0.23/1.45	1.09/1.37				0.53	0.25/1.16	2.35/1.93
41 - +									

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***Part of control group

$\chi^2 (0.05, 1) = 3.84$

$\chi^2 (0.05, 2) = 5.99$

$\chi^2 (0.01, 1) = 5.02$

$\chi^2 (0.01, 2) = 9.21$

Table 60. Cross tabulation of heart disease (no disease, within 6 months of diagnosis, 7 months-5 years prior to diagnosis, 6+ years prior to diagnosis) by age (≤ 40 , 41-60, 61+).

Males

	No Disease	Within 6 months	7 months-5 years	6 years +
Controls				
≤ 40	186	1	2	4
41-60	208	1	13	11
61+	154	1	15	17
Acute Lymphatic				
≤ 40	27	0	0	0
41-60	21	0	0	1
61+	15	2	0	4
Chronic Lymphatic				
≤ 40	4	0	0	1
41-60	62	2	5	4
61+	134	16	25	24
Acute Myeloid				
≤ 40	34	0	0	1
41-60	40	2	7	5
61+	61	8	13	9
Chronic Myeloid				
≤ 40	15	0	0	1
41-60	26	1	2	2
61+	50	10	10	10
Other Leukemia				
≤ 40	11	1	0	0
41-60	24	0	2	0
61+	50	9	9	7

Females

Controls				
≤ 40	180	1	1	6
41-60	191	0	7	4
61+	177	3	25	25
Acute Lymphatic				
≤ 40	14	0	0	0
41-60	8	0	1	1
61+	12	0	1	3

Table 60. (continued)

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Chronic Lymphatic

≤ 40	3	0	0	0
41-60	25	1	2	3
61+	88	11	9	12

Acute Myeloid

≤ 40	21	1	0	0
41-60	38	2	0	2
61+	35	6	5	12

Chronic Myeloid

≤ 40	16	0	1	1
41-60	26	2	0	4
61+	30	5	8	8

Other Leukemia

≤ 40	8	0	0	1
41-60	15	0	1	3
61+	36	3	3	12

Table 61. Relative risk (R.R.) of heart disease; diagnosis by 4 diagnosis categories: within 6 months of leukemia diagnosis (6 m), 7 months to 5 years prior to leukemia diagnosis (7 m-5 yr), 6 or more years prior to diagnosis (6 yr +). Acute lymphatic leukemia is excluded for both males and females because of small number problems. Also shown are upper and lower 95% error bounds (U.B.; L.B.) and the associated chi squares expressing deviation of the observed relative risk from unity ($\chi^2_{R.R.}$) and the variation of relative risk among age strata (≤ 40 years, 41-60 years, 61+ years) (χ^2_{HET}).

<u>Males</u>			
	6 m	7 m-5 yr	6 yr+
Chronic Lymphatic			
R.R.	13.97	1.71	1.61
U.B.	64.76	3.08	2.96
L.B.	2.71	0.93	0.89
* $\chi^2_{R.R.}$	15.46	2.92	2.33
† χ^2_{HET}	0.74	0.45	3.68
Chronic Myeloid			
R.R.	19.29	1.76	1.80
U.B.	72.69	3.79	3.85
L.B.	3.59	0.78	0.84
* $\chi^2_{R.R.}$	21.34	1.65	2.12
† χ^2_{HET}	2.12	0.62	0.30
Acute Myeloid			
R.R.	12.22	2.27	1.60
U.B.	51.30	4.38	3.24
L.B.	2.62	1.18	0.79
* $\chi^2_{R.R.}$	15.40	6.24	1.56
† χ^2_{HET}	2.44	1.01	0.67
Other Leukemia			
R.R.	18.91	1.66	0.94
U.B.	81.53	3.71	2.40
L.B.	3.53	0.72	0.35
* $\chi^2_{R.R.}$	20.07	1.21	0.01
† χ^2_{HET}	2.27	0.33	1.81

Table 61. (continued)

Females

Chronic Lymphatic

R.R.	8.16	0.86	1.23
U.B.	38.71	1.88	2.54
L.B.	2.24	0.38	0.60
* χ^2 R.R.	12.88	0.05	0.20
† χ^2 HET	1.08	1.54	5.02

Chronic Myeloid

R.R.	11.73	1.69	2.51
U.B.	48.93	4.01	5.42
L.B.	2.87	0.70	1.19
* χ^2 R.R.	17.48	1.13	6.05
† χ^2 HET	2.32	3.93	2.76

Acute Myeloid

R.R.	12.70	0.75	2.13
U.B.	50.12	2.15	6.36
L.B.	3.37	0.25	1.01
* χ^2 R.R.	21.97	0.10	3.85
† χ^2 HET	0.96	1.45	1.62

Other Leukemia

R.R.	4.53	0.73	2.93
U.B.	26.11	2.29	6.30
L.B.	0.72	0.20	1.47
* χ^2 R.R.	2.15	0.11	9.76
† χ^2 HET	0.21	0.88	2.68

*1 df χ^2 (0.05, 1) = 3.84 χ^2 (0.05, 2) = 5.99

+2 df χ^2 (0.01, 1) = 5.02 χ^2 (0.01, 2) = 9.21

Table 62. Cross tabulations of pneumonia (no disease, within 6 months of diagnosis, 7 months-5 years prior to diagnosis, 6+ years prior to diagnosis) by age (≤ 40 , 41-60, 61+).

<u>Males</u>	No Disease	Within 6 months	7 months-5 years	6 years +
<u>Controls</u>				
≤ 40	162	0	8	23
41-60	186	1	5	38
61+	132	5	5	45
<u>Acute Lymphatic</u>				
≤ 40	23	1	0	3
41-60	17	4	0	1
61+	13	3	2	3
<u>Chronic Lymphatic</u>				
≤ 40	2	2	0	2
41-60	50	3	4	17
61+	125	23	17	36
<u>Acute Myeloid</u>				
≤ 40	30	1	1	4
41-60	39	4	4	7
61+	48	19	7	13
<u>Chronic Myeloid</u>				
≤ 40	12	0	0	2
41-60	24	2	0	3
61+	55	4	4	18
<u>Other Leukemia</u>				
≤ 40	9	0	2	2
41-60	19	1	3	3
61+	46	7	5	15
<u>Females</u>				
<u>Controls</u>				
≤ 40	168	0	0	20
41-60	163	2	6	31
61+	185	1	9	35
<u>Acute Lymphatic</u>				
≤ 40	11	0	0	3
41-60	7	1	0	2
61+	14	1	0	1

Table 62. (continued)

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Chronic Lymphatic				
≤ 40	3	0	0	0
41-60	28	2	1	1
61+	91	7	9	11
Acute Myeloid				
≤ 40	17	2	1	1
41-60	31	7	0	4
61+	42	6	3	7
Chronic Myeloid				
≤ 40	15	0	1	2
41-60	24	1	1	6
61+	34	7	5	6
Other Leukemia				
≤ 40	5	3	0	1
41-60	17	0	1	1
61+	41	2	2	6

Table 63. Relative risk (R.R.) of pneumonia; diagnosis by 4 diagnosis categories: within 6 months of leukemia diagnosis (6 m), 7 months-5 years prior to leukemia diagnosis (7 m-5 yr) 6 or more years prior to diagnosis (6 yr+). Acute lymphatic leukemia is excluded for both males and females because of small number problems. Also shown are upper and lower 95% error bounds (U.B.; L.B.), and the associated chi squares expressing deviation of the observed relative risk from unity ($\chi^2_{R.R.}$) and the variation of relative risk among age strata (≤ 40 years, 41-60 years, 61+ years) (χ^2_{HET}).

<u>Males</u>				
	6 m	7 m-5 yr	6 yr+	
Chronic Lymphatic				
R.R.	6.22	3.30	1.14	
U.B.	27.80	7.63	1.74	
L.B.	2.92	1.37	0.75	
* $\chi^2_{R.R.}$	20.52	7.83	0.31	
† χ^2_{HET}	15.09	0.37	6.72	
Chronic Myeloid				
R.R.	2.97	1.81	0.91	
U.B.	12.28	5.35	1.58	
L.B.	0.86	0.58	0.52	
* $\chi^2_{R.R.}$	2.85	0.76	0.05	
† χ^2_{HET}	2.53	1.73	0.55	
Acute Myeloid				
R.R.	12.16	2.68	0.85	
U.B.	36.15	6.02	1.42	
L.B.	4.67	1.14	0.51	
* $\chi^2_{R.R.}$	37.83	5.32	0.29	
† χ^2_{HET}	0.69	2.50	0.07	
Other Leukemia				
R.R.	4.42	3.83	0.96	
U.B.	16.12	10.32	1.74	
L.B.	1.33	1.54	0.53	
* $\chi^2_{R.R.}$	6.41	9.13	0.01	
† χ^2_{HET}	0.35	0.54	0.48	

Table 63. (continued)

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Females

Chronic Lymphatic

R.R.	10.26	1.78	0.50
U.B.	45.96	4.42	1.02
L.B.	2.12	0.70	0.25
* χ^2 R.R.	11.54	1.19	3.59
† χ^2 HET	0.41	0.39	1.59

Chronic Myeloid

R.R.	16.31	2.78	1.10
U.B.	75.43	7.80	2.11
L.B.	3.54	0.99	0.56
* χ^2 R.R.	21.55	3.74	0.02
† χ^2 HET	2.55	4.57	0.25

Acute Myeloid

R.R.	25.08	1.28	0.75
U.B.	120.89	4.33	1.49
L.B.	7.06	0.35	0.37
* χ^2 R.R.	47.88	0.02	0.51
† χ^2 HET	0.92	8.82	0.32

Other Leukemia

R.R.	18.84	1.16	0.69
U.B.	143.76	4.51	1.58
L.B.	5.18	0.26	0.29
* χ^2 R.R.	29.14	0.01	0.56
† χ^2 HET	8.15	0.12	1.34

*1 degree of freedom χ^2 (0.05, 1) = 3.84 χ^2 (0.05, 2) = 5.99

†2 degrees of freedom χ^2 (0.01, 1) = 5.02 χ^2 (0.01, 2) = 9.21

Table 64. Cross tabulation of total X-ray exposure by time and leukemia type; males with greater than 40 trunk X-rays. Count as % of row total is shown in []. Percent trunk (%T) indicates percentage of total X-rays which were trunk procedures.

Leukemia Type	Time				% T
	6 m-1 yr	1-5 yr	6-10 yr	> 10 yr	
Control	68 [0.185]	179 [0.486]	82 [0.223]	39 [0.106]	93.7
Chronic Lymphatic	30 [0.103]	142 [0.486]	92 [0.315]	28 [0.096]	100.0
Acute Myeloid	67 [0.135]	286 [0.578]	121 [0.245]	20 [0.042]	88.6
Chronic Myeloid	102 [0.132]	398 [0.516]	200 [0.259]	71 [0.093]	77.9
Other Leukemia	31 [0.173]	95 [0.531]	22 [0.123]	31 [0.173]	88.2

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