MEDICAL RADIATION EXPOSURES IN OCCUPATIONAL STUDIES

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Overview of Occupational Medical Exposure

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Radiologists and radiological technologists are among the earliest occupational groups exposed to radiation. In 1902, only 7 years after the discovery of X rays, excessive occurrences of skin cancer, which was the first solid cancer linked to radiation, were noted among radiologists. In early 1950, excess mortality from leukemia among radiologists began to receive attention, and this, together with the rising concern about the effect of chronic radiation exposure from nuclear weapons tests, led to two landmark cohort studies of radiologists, one in the United Kingdom and the other in the United States. Today, a large number of professional and technical personnel in medicine, dentistry and veterinary medicine are occupationally exposed to radiation while administering various radiological procedures, i.e., diagnostic, therapeutic, interventional and nuclear medicine. The latest UNSCEAR report estimates that, worldwide, there are 2.3 million medical radiation workers—half of the entire workers exposed to man-made sources of radiation. Health risks from radiation exposure in such a large occupational segment of the population are clearly of special concern.

In the literature, there are eight major cohort studies of medical radiation workers: three in the United States and one each in Canada, the United Kingdom, Japan, China and Denmark. Two of these cohorts are exclusively radiologists, while the other six are predominantly radiological technologists. All together, these cohorts include more than 270,000 radiological workers. Radiological technologists typically began their careers when they were in their early 20s and late 30s, whereas radiologists joined the specialty society at somewhat older ages, i.e., in their mid-30s and mid-40s. While most of the cohorts are exclusively or predominately male, two cohorts, U.S. radiological technologists and Canadian medical radiation workers, include large numbers of women, offering a unique opportunity for providing risk data for females, which are lacking in other occupational populations. Because of the availability of professional and specialist society membership rosters and records, follow-up of the medical radiation workers is relatively straightforward. Medical workers are highly cooperative and this facilitates collecting data and biological specimens.

Cohort	Cohort size		Years worked	Years followed up
	Total	Female		
U.S. radiologists	6,500	—	1920–1969	1920–1969
UK radiologists	2,700	—	1897–1979	1897–1997
U.S. radiological technologist	143,000	105,000	1926–1982	1926–1997
U.S. Army radiation techs	6,500	—	1946–1963	1946–1974
Chinese radiological technologist	27,000	5,400	1950–1980	1950–1995
Danish radiotherapy personnel	4,100	3,400	1954–1982	1968–1985
Japanese radiological technologist	12,000	—	NA	1969–1993
Canadian medical radiation workers	73,000	26,300	<1950–1983	1951–1987

Most of the cohort subjects worked during periods of striking historical changes in radiation exposure. This creates a number of dosimetric and analytical problems that need to be addressed. A brief account, which follows, of the historical development of radiation safety standards illustrates the remarkable improvement in radiological protection and concomitant reduction in exposure. During the decades after the discovery of X rays in 1895, radiologists were exposed to such high doses that dermatitis and other radiation-induced injuries were common. The first dose limit was introduced in 1902, which was about 0.1 Gy per day (30 Gy per year!); this was not based on biological data but rather on the lowest observable amount, i.e. fogging of a photographic plate. Many of the subjects in the UK radiologist cohort were pioneering radiologists who were exposed to excessive doses of radiation during this early period. With accumulating evidence of the cancer and cell-killing effects of X rays, the American Roentgen Ray Society recommended in 1924 a tolerance dose of one-hundredth of an erythema dose per month for radiation workers, which is a 10-fold reduction from the one-tenth of an erythema dose per month (about 0.6 Sv per month) that the workers were receiving at that time. In 1934, the U.S. Advisory Committee on X ray and Radium Protection proposed the first formal standard of 0.1 R per day (0.3 Sv/year). The earliest radiologists in the U.S. radiologist cohort and some of the UK cohort worked during this period. One study estimated that radiological workers during the period of 1920–1930 could have been exposed to 100 R per year (1 Sv/year). The conditions must have improved in the late 1930s, since a survey of a large number of U.S. hospitals in 1940 showed that the average exposure ranged from about 0.01 to 0.25 Sv per year, depending upon how well the installations were protected. Levels of exposure may have improved further in the 1950s. Thus, in a 1953 survey of the radiological technologists at the Cleveland Clinic, the usual weekly exposure dose was usually >0.1 R (>0.05 Sv/year) and seldom >0.3 R (>0.15 Sv/year). Large numbers of subjects in the U.S. and Canadian radiological technologist cohorts worked during the period of 1940 through early 1950. In 1957, the International Commission of Radiological Protection recommended a dose limit of 0.05 Sv/year, which led to much lower levels of exposure that exist to this day.

Routine monitoring of radiation exposure was not introduced until 1950. Doses were not measured systematically in earlier years; therefore, the link between the cohort and dose cannot be made. For example, Landauer, Inc., the largest commercial dosimetry provider in the U.S., has

[3] Henry Kelly, Testimony before the Senate Committee on Foreign Relations, March 6, 2002, available on the web at http://www.fas.org/ssp/docs/030602-kellytestimony.htm.

dose information on medical workers only after 1958. Early cohort studies of radiologists and radiological technologists generally demonstrated an excess risk of leukemia and excess risks for some solid cancers (*1*, *2*), but the evidence is based on comparison of the standardized mortality ratios among subgroups working in different periods or between radiologists and other medical professionals working in the same period. In some studies, for example in Canada (*3*), measured doses were available but only for the period after the introduction of monitoring in 1951. Risk values based on such incomplete dose data are likely to be overestimated. In the absence of individual dose information, investigators have used a number of proxy measures. The proxy measures are typically based on work history, e.g., how long the subject worked as a radiological technologist, especially during the early years, and whether the subject administered fluoroscopic examinations and other diagnostic and therapeutic procedures. Data using these proxy measures that must take into account different periods, without dose estimates, clearly have limitations. However, several findings, such as the excess risk of breast cancer, leukemia, skin cancer, and more recently non-cancer diseases,[4] have provided new information on the risks associated with chronic radiation exposure, and they merit further study.

For further study, however, dosimetry is critically important. Currently, efforts are under way in at least three major studies to construct individual dose estimates. Dose reconstruction work carried out for the U.S. radiological technologist cohort will be discussed by subsequent speakers. Briefly, this involves construction of models using film-badge measurement data, extrapolation and modification of the models to earlier periods, and construction of doses for the earliest period using published, largely disconnected, information. These models, along with detailed radiological work history data obtained by questionnaires, are used to estimate individual organ doses. Retrospective dose reconstruction has also been attempted for the Chinese X-ray worker cohort, involving simulation of past working conditions with a phantom, interviewing of subjects for detailed work histories, mathematical models, and verification by chromosomal aberration data (*4*). Reconstruction of early doses is also being undertaken for the Canadian radiation worker cohort.

Medical radiation worker cohorts hold a unique position in radiation studies and offer one of the few chances for obtaining information regarding chronic radiation exposure. The chronic doses received range from a negligibly small to a considerably high level. The subjects represent a healthy working population of both sexes and a wide range of ages. Long-term follow-up is continuing in many studies. The subjects are cooperative and responsive to epidemiological studies and are agreeable to biologically motivated studies of gene–radiation interactions. Together, these open the possibility of gaining critically important insights into health risk of chronic exposure and their underlying mechanisms, about which so little is known at present.

References

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