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RADIATION AND HEALTH

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RADIATION AND HEALTH[1]

EDITORIAL

The Western Journal of Medicine

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radiation because the exposures are so small. The issue of this scientific dispute may never be resolved--it may be beyond the abilities of science and mathematics to decipher (4).

What are some of the radiation doses from common X-ray procedures?

The radiation doses from X-ray examinations are limited to defined regions of the body; the radiant energy absorbed by the tissues is generally much the same wherever the procedure is done in the United States (5). For a chest X-ray examination, the dose to the bone marrow in the thorax--the important target tissue--is about 10-20 mrad (0.1-0.2 mGy)[1] per projection. For the hip and upper femur, the dose is about 75 mrad (0.75 mGy). And for dental radiography, a complete mouth examination may involve 10 mrad (0.1 mGy) to the bone marrow. Mammography today ranges about 1-5 rad (0.01-0.05 Gy), but new techniques permit this to be reduced to only half-a-rad to the breast per examination. A barium enema is a "high-dose" examination--the average is close to 1 rad (0.01 Gy), but it could be as high as 3 rad (0.03 Gy). Special radiological procedures, such as angiography of the abdomen, may be as low as 400 mrads (0.04 mGy), but could be much higher. CT scans of the brain may be as high as 4 rads to the portion of the brain exposed; but the new CT units have decreased this to the range of about 1 rad or 0.01 Gy. X-ray pelvimetry to the pregnant mother ranges from 600 mrad to (6 mGy) about 1 rad (0.01 Gy); the fetus receives a dose of about half this amount.

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1 In the new system of international units, 1 Gy (gray) = 100 rad, and 1 Sv (sievert) = 100 rems.

Are the epidemiological studies on radiation carcinogenesis in human populations valid?

The epidemiological evidence is compelling--cancers arising in a vareity of organs and tissues and transmitted genetic effects are the principal late effects in poplations of exposure to low levels of ionizing radiation (2,3,6-8). Since the late 1940s and early 1950s, it has been postulated that there may be no threshold level of exposure to ionizing radiation below which risks of injury are entirely lacking. At the same time, however, it has been recognized that the risks of exposure at levels of natural background can be estimated at the present time only by interpolation between levels of health effects observed at high doses and dose rates and spontaneous levels of the same effect. The assumption of a linear, no-threshold dose-response relationship (linear hypothesis) has generally been considered to provide a conservative approach to risk estimation for low dose and low dose rate exposure, because the effect per unit dose for low-LET radiations (e.g., X-rays and gamma rays) has usually been observed in biology and medicine to decrease with decreasing dose and dose rate (7).

There are several reports that have been published, some recently, seeming to indicate degrees of carcinogenic radiation effects at low doses in man that would be incompatible with the linear hypothesis being conservative. This would lead to claims that low-level exposure, in fact, may be more hazardous per unit of absorbed dose that at high doses and dose rates. These data and claims, therefore, suggest that this dose-response relationship at low doses does not lead to conservatism, but may even underestimate the effects of low doses and low dose rates. However, each of these epidemiological studies

provide data which have been heavily criticized for serious statistical and methodological difficulties and, individually or collectively, are not scientifically convincing enough to argue against either the conservatism of the linear hypothesis or the present estimation of risk of cancer-induction in human populations exposed to low levels of ionizing radiation (3,7). They stand apart from, and in disagreement with, the large body of epidemiological evidence that convincingly demonstrate the carcinogenic and hereditary effects that might occur in man after exposure to low doses and low dose rates.

Are there any contraindications to diagnostic X-ray examinations?

There are no contraindications to any medical examination; rather, there are indications for a clinical examination. X-ray procedures, however, have an unwanted byproduct of the examination that is of no benefit to the patient, viz., ionizing radiation which is absorbed by the cells and tissues of the body. A good rule, therefore, is never to expose a patient to unnecessary radiation, and to expose the patient only to that amount of radiation which provides the diagnostic radiological information.

There are, however, special circumstances to consider, since there is a benefit to be gained for the patient's health, and this is invariably associated with the risk of radiation injury resulting in an increase probability of delayed or late health effects occurring in that patient. Probability is the mathematical chance of something occurring; risk is when that probability is associated with a detriment, such as ill-health. When the benefit strongly outweighs the risk, then we are not as concerned--as for example, radiation exposures attendant in specialized procedures, such as examination of the coronary arteries in a patient with cardiovascular disease,

or computerized tomography of the brain in a patient with a suspected cerebral hemorrhage. In these cases, the benefit/risk ratio is high.

On the other hand, there are occasions when the benefit to the patient of a diagnostic radiological procedure is small or even negligible, and the attendant risk of radiation exposure, though equally small, may relatively become high, that is, the benefit/risk ratio is low or the risk may even be greater than the potential benefit. The best examples here are the mass screening X-ray examinations, e.g., chest photofluorography for tuberculosis or lung cancer in asymptomatic populations, and screening mammography in females with extremely low breast cancer risk, such as women under 35 years of age without a history of breast cancer risk factors. That is why the American College of Radiology recommends that such mass X-ray screening programs of asymptomatic populations which result in low diagnostic yields should be discouraged.

Is there potential harm from diagnostic radiation exposure in medicine?

There is always potential harm that can result from exposure to ionizing radiation such as X-rays. Ionizing radiation has several injurious effects, such as cataracts of the lens of the eye and impairment of fertility, but three late or delayed health effects stand out as those of greatest concern--carcinogenesis, or cancer induction; teratogenesis, or developmental abnormality of the newborn; and mutagenesis, or genetically-related ill-health occurring in descendants of exposed individuals (9). Scientists now believe that exposure to ionizing radiation--because of the structure and function of the important living molecules, the DNA molecules within the cell, and the manner in which energy is deposited in the molecular structure--increases the

probability of such deleterious health effects. And further, as the dose of radiation increases above low levels, the risks of these deleterious effects increases in exposed human populations. However, these events at the biophysical level of the cell are extremely rare, due primarily to the efficiency of repair of radiation injury (7). Even when they do occur, and a lesion results in the DNA molecular structure, the cells and tissues have an enormous capacity to repair the radiation damage, so that no residual injury results (7). Since such health effects, if any, are so rarely seen under low-level radiation, and since the health effects induced by radiation are indistinguishable from those occurring naturally, it follows that their existence can be inferred only on the basis of a statistical excess above that natural incidence in the exposed populations (3). Thus, at the dose levels of diagnostic radiological exposure normally encountered in radiological procedures in the United States, it follows that there is only a very slight probability of increased deleterious health effect resulting from diagnostic radiation exposure of about 100 million Americans each year.

Is X-ray exposure during pregnancy especially dangerous?

If there are indications for examination of the fetus or pelvis, where pelvimetry or obstetrical abdomenal examination will provide the diagnostic information, then X-ray examination can be carried out safely (10). However, circumstances exist where a series of X-rays are obtained for diagnosing ill-health in the mother and, on occasion, there is no knowledge that a pregnancy exists, then each situation is weighed according to the benefits and risks, inevitably, the risk to the fetus. There are two delayed health

effects of concern. The first is developmental abnormality in the newborn, resulting from radiation teratogenesis during the first trimester when the fetus is unusually susceptible to radiation injury (8). Here, teratogenesis is strongly dependent on the stage of gestation at which exposure occurs. Evidence from the Japanese atomic bomb survivors suggests decrease in head size associated with mental retardation has occurred from exposure in utero to dose levels below 10 rads (0.1 Gy) (3). The second delayed health effect is cancer-induction, notably leukemia, resulting from X-ray doses in the range of 1-2 rads (0.01-0.02 Gy), following exposure in utero during the last trimester (3). One study (11) strongly suggests this conclusion, with another 10 or so which tend to support the findings of this study. However, evidence is mounting that suggests too many biases exist in the one positive study and, in fact, certain of the findings on childhood cancers might prove to be spurious (12). The controversy is not settled, but the introduction of ultrasound pelvimetry as the primary method of examination of the fetus and the pregnant abdomen is making the conclusion of the controversial study somewhat academic.

The "ten-day rule" is a recommendation that X-ray examination of the female abdomen be taken only during the ten-day interval between the onset of the patient's menstrual period and the tenth day thereafter. It is based on the fact that the woman cannot reasonably be pregnant during that interval. This "rule" is only a suggestion to decrease the probability of exposing a developing embryo or fetus unsuspectingly. The idea has been popular in some medical centers in Great Britain but not in the United States, although it has been recommended in clinical radiology.

However, the evidence that radiation exposures at levels of diagnostic radiology can induce cancer in the developing fetus, particularly the findings

among the atomic bomb survivors (13), remains somewhat controversial. There are a number of arguments for and against the conclusion that such low doses are carcinogenic in the fetus. However, there has been some reticence to accept a "ten-day rule" in clinical practice. Some radiologists have argued that such a requirement would disrupt the patient scheduling in a large, busy X-ray department. Others have argued that ten days is not precise--it may be necessary to cover a fourteen-day period, since ovulation occurs in the majority of women during the 14-day interval. Perhaps the most compelling argument against deferring an X-ray examination of the abdomen for a period of time until the woman is not pregnant is that the condition that warranted the examination may no longer exist. It is good practice not to expose the pregnant uterus to X-rays unknowingly or unnecessarily--but if the patient is acutely ill, the benefits of the examination may far outweigh the very small potential risk to the embryo.

What can we conclude?

In the evaluation of epidemiological surveys and laboratory animal data, national and international advisory committees on radiation and health carefully review and assess the value of the available scientific evidence for estimating the risks of the health effects in human populations exposed to low-level radiation (4-9). The present scientific evidence and the interpretation of available epidemiological data can draw those necessary conclusions on which to base scientific public health policy for radiation protection standards (14). Based on the radiation risk estimates derived, any lack of precision does not minimize either the need for setting responsible public health policies, or the conclusion that such risks are extremely small when

compared with available alternative options, and those normally accepted by society as the hazards of everyday life. When compared with the benefits that society has established as goals derived from the necessary activities of medical care, it is apparent that society must establish appropriate standards and seek appropriate controlling procedures which continue to assure that its health needs and services are being met with the lowest possible risks.

In one-third century of inquiry, embodying among the most extensive and comprehensive scientific efforts on the health effects of any environmental agent, much of the important information necessary for determination of radiation protection standards is now available to decision-makers for practical and responsible public health policy. It is now assumed that any exposure to radiation at low levels of dose carries some risk of deleterious health effects. However, how low this level may be, or the probability or magnitude of the risk at very low levels of dose, still are factors which are not known and may remain so. Radiation and the public health, when it involves the public health, becomes a broad societal problem and not solely a scientific one, and to be decided by society, most often by men and women of law and government. Our best scientific knowledge and advice are essential for the protection of the public health and for the effective application of new technologies in medicine. Unless man wishes to dispense with those activities which inevitably involve exposure to low levels of ionizing radiations in medicine, he must recognize that some degree of risk to health, however small, exists.

REFERENCES

1. Hendee WR: Editorial, Real and perceived risks of medical radiation exposure, WJM, this issue
2. International Commission on Radiological Protection: Recommendations of the International Commission on Radiological Protection, ICRP Publication 26, Pergamon Press, Oxford, 1977
3. National Research Council: Committee on the Biological Effects of Ionizing Radiation, The effects on populations of exposure to low levels of ionizing radiation, Natl Acad Sci, Washington, DC, 1980
4. Fabrikant JI: Epidemiological studies on radiation carcinogenesis in human populations following acute exposure: nuclear explosions and medical radiation, Yale J Biol Med 54: 457-469, 1981
5. Klement AW, Miller CR, Minx RP, Shleien B: Estimate of ionizing radiation doses in the U.S. 1960-2000, Washington, DC, U.S. Environmental Protection Agency, ORP/CSD 72-1, 1972
6. National Council on Radiation Protection and Measurements, NCRP report No. 43, Review of the current state of radiation protection philosophy, NCRP, Washington, DC, 1980
7. National Council on Radiation Protection and Measurements, NCRP report No. 64, Influence of dose and its distribution in time on dose-response relationships for low-LET radiations, NCRP, Washington, DC, 1980
8. United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and effects of ionizing radiation, United Nations, New York, 1977
9. Fabrikant JI: The BEIR-III report: origin of the controversy, AJR 136: 209-214, 1981

10. The selection of patients for X-ray examinations: the pelvimetry examination, HHS Publ (FDA) 80-8128, USDHHS, PHS, FDA, BRH, Rockville, MD, July 1980

11. Kneale GW, Stewart AM: Mantel-Haenszel analysis of Oxford data. 1. Independent effects of several birth factors including fetal irradiation, J Nat Can Inst, 56:970-883, 1976

12. Boice JD Jr, Land CE: Ionizing radiation, In Schottenfeld D and Fraumeni JF Jr (Ed): Cancer epidemiology and prevention, Chapter 3, pp. 231-253, Saunders, Philadelphia, 1982

13. Beebe GW: The atomic bomb survivors and the problem of low-dose radiation effects, Amer J Epidemiol 114: 761-783, 1981

14. National Research Council: Federal research on the biological and health effects of ionizing radiation, National Academy Press, Washington, DC, 1981

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