Radiation and pregnancy

Joseph Sternberg, M.D., Montreal

Summary: Irradiation during pregnancy may occur either as the result of radioactive pollution of the environment, or during a medical procedure using x-rays or radionuclides. While the former is usually unforeseeable, the latter is known and accepted by both physician and patient.

Recent statistics estimate that about one quarter of pregnant women have had a radiographic experience during the pregnancy, either for obstetrical reasons or in the course of medical and dental examinations. The amount of radiation delivered to the fetus is in the range of one rad or less. Radionuclidic procedures may result in fetal radiocontamination, chiefly after placental transfer and fetal uptake. Radioiodine, radioactive calcium and selenomethionine are dangerous for the fetus, since they cross the placenta freely and are taken up by fetal tissues. The labelled proteins, radiocolloids and some mercury compounds remain in the maternal compartment and therefore can affect the fetus only through their gamma radiation at some distance from the fetus.

The teratogenic effect, the leukemogenic threshold and the lowered resistance to infectious diseases have been demonstrated after irradiation with doses far higher than those encountered during diagnostic applications of ionizing radiation. Statistical data suggest an increase of susceptibility to leukemia in infancy after intra-uterine irradiation at a diagnostic level. Cytogenic analysis may offer valuable data for the establishment of the extent of radiation damage.

Résumé: L’irradiation au cours de la vie intra-utérine peut se produire soit durant la radiocontamination du milieu, soit après un acte médical fait à l’aide des rayons x ou des molécules marquées. Dans le premier cas, l’irradiation se fait sans le consentement du sujet, tandis que dans le second cas, le patient est au courant et accepte le procédé.

Des statistiques récentes indiquent qu’environ un quart des femmes enceintes aux États-Unis ont eu un examen radiologique au cours de la gestation, soit pour des raisons obstétricales, soit pour autres examens médicaux ou dentaires. En général il faut compter la quantité de radiation absorbée par le foetus entre quelques fractions de rad et 1-2 rads. La radiocontamination foetale exige un transfert placentaire et une distribution tissulaire foetale de la molécule marquée. L’utilisation de l’iode radioactif, du calcium ou du strontium marqués, ainsi que la sélénométhionine radioactive, comporte un danger considérable pour le foetus, car ces composés traversent le placenta et sont concentrés dans les tissus foetaux. Par contre, les protéines marquées et les radionucléides restent exclusivement dans le compartiment maternel et peuvent irradier le foetus seulement par leur radiation gamma agissant à travers la paroi utérine.

L’effet tératogénique et leucémogénique, ainsi que la susceptibilité aux infections en bas âge, ont été obtenus avec des doses considérablement plus élevées que celles notées durant les applications diagnostiques de la radiation. Des données statistiques suggèrent une augmentation de la susceptibilité à la leucémie infantile après irradiation in utero pour des radiographies diagnostiques. Les examens cytogénétiques peuvent offrir des informations précieuses pour l’appréciation des radiolésions.

Fashion in medicine is as changing and illogical as in other areas of human endeavour. The recent emphasis placed by mass media upon chemical and biological pollution of the environment seems to have rendered obsolete the concern about radioactive contamination. Yet the problem is far from being obsolete. Nor did it diminish with the temporary lull in the atmospheric testing of nuclear weapons; industrial uses of nuclear energy are steadily growing and diversifying, while biomedical applications of radionuclides develop at an unprecedented pace.

Observations on the effects of radiation during pregnancy are almost as old as medical applications of x-rays. In 1902 Bouillé and Bar reported a severe burn of the abdominal skin after local exposure to x-rays in a pregnant woman. Surprisingly, the report mentions that the woman delivered a set of apparently healthy twins. About the time of World War I, irradiation over the abdominal region was considered a relatively innocuous and convenient procedure for therapeutic abortion; with a dose around 350 R, abortion occurred after three to four weeks. In some cases the fetus survived this assault and was delivered at term with severe developmental defects — stunted growth, microcephaly and mental retardation. This procedure continued to be applied until the late thirties, for we find a report in 1936 presenting statistics of 200 cases performed in a New York hospital.

The advent of World War II and the tragic events in Hiroshima sensitized public opinion against radiation, be it x-rays or fall-out. The children born of women exposed during pregnancy to the nuclear radiation in Hiroshima and Nagasaki exhibited var-
ious degrees of microcephaly and mental retardation similar to those noted after unsuccessful attempts at radiotherapeutic abortion.

In the early fifties the pendulum of public concern swayed to a limit of extreme caution and almost unreasonable fear of radiation. This was understandable at the time, since the menace of world-wide nuclear war loomed in the background of every human activity. Simultaneously, industrial uses of nuclear energy began to acquire importance and medical applications of radionuclides started their spectacular development, to continue with the same momentum until now.

What is the present situation and to what extent must we fear fetal radiation damage when applying a radiation procedure during pregnancy?

The details of the problem have been analysed extensively in recent reviews and symposia. This article stresses only the salient points and offers some guidelines to the clinician.

**Parameters of study**

A semantic clarification is necessary for better understanding of the terms employed in this review. One distinguishes irradiation from radiocontamination in the sense that the former implies the effects of electromagnetic rays (x-rays or y-rays) delivered from a source external to the body and acting simultaneously on the mother and the fetus. Radiocontamination is a more intimate process, since the radiation carrier is first distributed systemically into maternal tissues, reaches and crosses the placenta and is taken up finally by fetal tissues. In this case, not only the y-rays are effective, but also the particulate a- and b-rays, with a shorter range but a markedly higher ionizing power.

The mechanism of radiation damage has by no means been entirely elucidated, but a simplified version distinguishes the "direct hit" which provokes breakage in intracellular bonds, such as in the DNA molecule. Concurrently, the production of free radicals in the irradiated cell inhibits the repair process in the damaged molecule. If radiobiology could find an effective method of repairing the damaged DNA molecule, then a large measure of radioprotection could be offered. Nature shows us that this is possible, since recently a microorganism was found in effluents of high radiation sources. The microorganism, appropriately baptized Micrococcus radiodurans, is capable of repairing rapidly and effectively the damaged DNA molecule (Fig. 1).

Both irradiation and radiocontamination occur as environmental factors, be they natural or man-made. Man receives about 150 to 300 mrad/year.