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3

Radiation hazards in pregnancy and methods of prevention

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The incidence of malignancy in pregnancy is low and most commonly occurs in breast, gynaecological, skin and haematological sites. The management of pregnant cancer patients is complex requiring a multidisciplinary approach to ensure the welfare of both mother and baby. Foetal radiation exposure, both diagnostic and therapeutic, must be kept to a minimum. Following the description of the deterministic and stochastic effects of foetal radiation exposure doses, radiotherapy should be avoided in the first and early second trimester. This chapter describes the possible diagnostic techniques and treatment for the common malignancies in pregnancy; some case studies indicating supradiaphragmatic radiotherapy may be safe later in pregnancy. Pelvic radiotherapy for gynaecological malignancies is not appropriate.

The incidence of malignancy in pregnancy is low – 0.02–0.1%. The most common malignancies are breast, skin including melanoma, gynaecological (uterine, cervix and ovarian) and haematological [1].

Treating pregnant women with cancer involves balancing the care of the mother, whilst ensuring the health of the foetus. This may lead to complex ethical, religious, psychosocial and medical conflicts of interest. Thus, these women need to be managed by a multidisciplinary team, including clinical and medical oncologists, surgeons, obstetricians, neonatologists and paediatricians, specialist nurses and psychologists. Management must to be determined on an individual case-by-case basis.

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In the past, the accepted approach was to terminate the pregnancy irrespective of the stage of the pregnancy. Based on evidence supporting the safe use of some treatments during the second and third trimester, changes have been made to this blanket policy.

The overriding principle of all radiation is that it should be 'as low as reasonably achievable' (ALARA) as the effects of radiation are cumulative. Foetal exposure to radiation, whether for diagnostic or therapy purposes, is no exception and needs to be carefully considered.

Radiation effects are described as either 'deterministic' or 'stochastic'. Deterministic effects show a cause and effect relationship such that a threshold is set below which the effect will not occur. Once the threshold has been exceeded, however, the severity of the effect will increase in a linear fashion with increasing dose. Stochastic describes radiation effects that occur by chance, for example, induction of cancer. There is no threshold dose, and risk increases in a linear quadratic relationship with dose.

Deterministic radiation effects on a foetus include congenital malformation, mental retardation, lower intelligence quotient, microcephaly, neurobehavioral disorders leading to increased risk of seizures and growth retardation, foetal death and lastly increased cancer risk [2]. A threshold dose of 0.1 Gy has been reported as the dose a foetus may be exposed to. The risks are unclear between 0.05 and 0.1 Gy and considered negligible below 0.05 Gy.

The evidence for the effects of radiation on foetal development originates predominantly from animal studies and nuclear accidents, like the Chernobyl disaster. The developing embryo is at its highest risk during the implantation stage. In the zygotic stage, a dose of 0.1 Gy is sufficient to cause preimplantation death in mice [3]. An 'all-or-none phenomenon' has been described, such that exposure of 0.15–0.2 Gy at preimplantation can cause embryonic death, and thus failure to implant. However, there is no increase in malformations in those surviving embryos [2].

Radiosensitivity decreases as the embryo develops. Most malformations occur during the period of organogenesis, which occurs about 3–7 weeks post implantation. During this period, there is also a high risk of growth retardation of the foetus. The brain develops between the 8th and 15th week post implantation. Irradiation during this period can result in mental retardation and impact on cognitive function. Doses under 0.1 Gy are unlikely to lead to cognitive impairment, whereas doses above 0.3 Gy would affect higher functioning [4]. Doses between 0.1 and 0.49 Gy have been reported to a 6% incidence of mental retardation [5].

During the second trimester (between 16 and 25 weeks), although the risks are similar to those of the first trimester, including malformations, growth and mental retardation, sterility, cataracts and malignancy, there is a reduced risk. One study reported mental retardation to be 2% with a maximum of 0.49 Gy [6]. Miller et al. reported that small head size was seen in two out of 30 children exposed to doses below 0.1 Gy, and 2 out of 44 children exposed to 0.1–0.5 Gy after exposure in utero in the second trimester during the atomic bomb [7].

Lastly, in the third trimester, there is a lower risk of malformation and mental retardation. Miller et al. reported small head size in three or 39 children receiving below 0.1 Gy in utero in the third trimester and one in 50 receiving between 0.1 and 0.5 Gy [7]. Stovall et al. did report that although the risks of mental retardation and malformation were negligible, doses exceeding 0.5 Gy did result in growth retardation [8].

There has been conflicting evidence as to the risk of malignancy after radiation exposure in utero. In 1975, Bithell and Stewart found that there was an increase in all types of childhood malignancy after radiation exposure in utero in the Oxford Study of childhood cancer, whereas other studies have not found such an association [9–12]. The Oxford review describes a risk of 6.4% of carcinogenesis per Gray of foetal radiation exposure. However, a recent study investigating the sequelae of atomic bomb survivors found the risk of adult-onset malignancy was greater in children exposed to radiation compared to foetal exposure [13]. Another study quoted an increased additional risk of 0.06% to the 20% lifetime risk of developing a fatal malignancy after an exposure to 0.01 Gy as a foetus [14].

A recent Swedish population-based cohort study was carried out comparing the development and school grades of children exposed in utero to pelvic X-ray and those that were not. Although an initial univariate analysis surprisingly found that children exposed in utero had higher school grades, when mothers' education and social class, gender of child, birth order and birth position were taken into account no statistical association was found (point estimate (PE) 1.4; 95% confidence interval (CI) −0.1–2.8) [15].