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Review paper

Clinical perspective on diagnostic X-ray examinations of pregnant patients – What to take into account

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ABSTRACT

Imaging during pregnancy has increased in frequency. Radiation protection is extremely important although tissue reactions of the conceptus, requiring a threshold dose of around 100 mGy, are unlikely in the diagnostic use of X-rays and stochastic effects of cancerogenesis have a rather low risk (around 10^{-4}/mGy for childhood cancer due to in utero exposure). This article will review the risk depending on dose and phase of pregnancy and the exposure by frequent examinations; it will then concentrate on the duties of an imaging department: screening for pregnancy, examination justification, planning and optimization, patient information, counseling, involving the patient in the decisions, and managing the situation of pregnant staff members. Typical flowcharts of investigating frequent clinical questions will finally be presented and critically discussed.

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Utilization of imaging during pregnancy has increased over the years, more for CT than for the other modalities [1,2] which explains the even more important increase of dose to the pregnant population. This article will review the known risks of exposure to ionizing radiation and assess exposure levels by X-ray examinations performed during pregnancy in order to support the justification process. We will then derive the prominent duties of a department for patient information and counseling, decision taking, management actions as well as the policy regarding occupationally exposed pregnant staff members. Options to choose the best clinical diagnostic pathway in several important clinical scenarios will finally be presented.

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1. Risks depending on the dose and the phase of pregnancy

According to the International Commission on Radiological Protection (ICRP), "prenatal doses from most correctly performed diagnostic procedures present no measurably increased risk of prenatal or postnatal death, developmental damage including malformation, or impairment of mental development over the background incidence of these entities; life-time cancer risk following in utero exposure is assumed to be similar to that following irradiation in early childhood" [3]. However, there is no safe level: the ALARA (As Low As Reasonably Achievable) principle requires that we use diagnostic methods without ionizing radiation whenever they are equivalent in reaching the diagnosis to those with radiation. Before ionizing radiation can legally be used, a medical diagnostic imaging examination has to be justified; this means that its diagnostic benefits for a specific patient in the specific clinical situation must exceed its risks; it is unique for the situation of a pregnancy that there are both benefits and risks to two individuals, the mother and the growing child. While the benefits have to be assessed individually, this section will concentrate on the knowledge of risks to the conceptus, the term used for the embryo/fetus. Of course, the risks to the mother are part of the justification as well, such as the proliferating breast gland that is more sensitive to radiation, or the metabolic adaptations to as well as anatomical changes of the pregnancy that may predispose to certain diseases (e.g. venous thrombosis), modifying indirectly the risks or benefits of a diagnostic imaging procedure.

Knowledge of risks to the conceptus is limited and often has a wide range of uncertainty. Furthermore, biological risk models may be derived from animal experience, and even where human data are available, they often reflect a special population (e.g. atomic bomb victims). Thus, ranges of confidence are quite large, as is often the case in radiation protection. Effects may be either stochastic (cellular mutation, with no threshold and a probability of damage proportional to the dose; e.g. by cancer induction) or deterministic (multicellular injury, now preferentially called tissue reactions, e.g. malformations), with a rather high threshold. Background radiation to the mother during pregnancy is about 2.3 mSv, and 0.5–1.0 mSv of these will reach the uterus [4]. Table 1 summarizes the risks of additional ionizing radiation to the conceptus. According to McCoullough et al. [5], while the natural risk for malformations at birth is 4%, 100 mGy of conceptus dose will only slightly reduce the proportion of children without a malformation from 96% to 95.8%, and similarly, the natural rate of 99.93% of children without a cancer during childhood will just marginally decrease to 99.07%; together, 95.93% of children will have neither a malformation nor a childhood cancer after 0 mGy, and 94.91% after 100 mGy.

In summary, after implantation of the conceptus in utero exposure by less than 100 mGy has no proven deterministic risks but the stochastic risk of cancer induction, although small, is estimated to exist and to increase in proportion to the dose (Table 1). Deterministic risks have a threshold of around 100 mGy even during the most sensitive phase of organogenesis. The consensus is that abortion because of intrauterine exposure to ionizing radiation should not be considered at conceptus doses of less than 100 mGy (for doses >100 mGy see Section 3.4 below).

2. Radiation exposure by diagnostic and interventional examinations

The ALARA principle means that ultrasonography (US) and magnetic resonance imaging (MRI) and any non-imaging diagnostic examinations have to be considered before we use X-ray imaging or nuclear medicine methods. Of course, the risks of alternative methods avoiding ionizing radiation are to be considered as well, such as those of contrast agents used for MRI. When ionizing radiation is appropriate, lower exposure is preferred to higher exposure as long as imaging quality is adequate to answer the clinical question. Table 2 summarizes radiation doses to the conceptus by different diagnostic X-ray examinations, showing that doses in most cases are unlikely to exceed 50 mGy. Some general rules apply to the uterine and – consecutively – the fetal dose:

1. The anatomic area exposed to direct radiation is the most important factor predicting the uterine dose.

Table 1
Risks of ionizing radiation to the conceptus.

Conceptus dose (mGy)	Phase of pregnancy: week [w] after conception						
	w1	w 2	w 3-8	w 9-15	w16-18	w 19-25	w 26-38
≥250		†	organ malformation	(organ malformation)	severe mental retardation		
≥200			growth retardation				
			most sensitive teratogenic phase				
≥100	†			IQ reduction	IQ deficit not detectable		
			small head size [$]				
				severe mental retardation			
≥50	(†)	risk uncertain / too subtle to be detected					
<50	no additional risk						
0	baseline risk for malformation: 4%						
stochastic risk	heritable effects have not been shown in humans						
	radiogenic risk for childhood cancer ~1 x 10^{-4}/mGy *						
0	baseline risk for childhood cancer: ~1.5-2 x 10^{-3}						

[†] Death/abortion (animal studies: preimplantation ≥50–100 mGy, postimplantation ≥250 mGy).
[$] Threshold for animals, human incidence 0.05–0.1% (no threshold).
[*] The risk for childhood cancer by in utero exposure has been estimated to be ~1.7×10^{-4}/mGy in the 1st trimester and ~0.4×10^{-4}/mGy in the 2nd/3rd trimester, averaging at ~1×10^{-4}; doubling of baseline risk by around 25–50 mGy (4,5,11,12,15,20).

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