Effect of X-rays on the fetus and pregnant women

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Abstract

There are three types of ionizing radiation: alpha (α), beta (β) and gamma (γ). The first two are the so-called corpuscular otherwise called molecular, which have an electric charge, while gamma radiation belongs to the group of electromagnetic radiation. Currently, X-rays are used in diagnostic imaging: ultrasound, computed tomography, magnetic resonance imaging. There are a lot of indications for this type of examination, for example: coronary artery disease, lower limb ischaemia, cranial, pleural or abdominal emphysema, bone, joint diseases or birth defects. Exposure to ionizing radiation at 9-10 weeks after fertilization, it can result in the death of the embryo, and in subsequent periods of development it can cause functional disorders of the bone marrow, kidneys or liver of the fetus. Therefore, the decision to subject a pregnant woman to ionizing rays must be supported by very careful analysis. X-rays are considered very dangerous for both the embryo and the fetus, because they can contribute to chromosomal damage, the development of birth defects in the child, mental retardation, in addition, there is a risk of developing cancer during puberty or as a result of ionizing radiation there may be a miscarriage. Exposure of the embryo or fetus to ionizing radiation may lead to chromosomal damage, birth defects or mental retardation.

There are three ways to protect against ionizing radiation:

1. Shortening the exposure time
2. Using covers
3. Appropriate distance from the irradation place

The use of radiopharmaceuticals in pregnant women must be kept to a minimum, only in cases where diagnostic tests cannot be performed after delivery.

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Introduction

There are three types of ionizing radiation: alpha (α), beta (β) and gamma (γ). The first two are the so-called corpuscular otherwise called molecular, which have an electric charge, while gamma radiation belongs to the group of electromagnetic radiation. This radiation may occur naturally, so called radioactivity or artificial in accelerators (accelerators). One of such devices that accelerate this process is an X-ray tube. Röntgen is considered its creator, who in the 90's of the last century conducted experiments with discharges in expanded gases and thus discovered a new type of radiation. At first, the nature of this emission was unknown, which is why he called them X-rays. The lamp he used for his experiments had two electrodes between which cathodic radiation or an electron beam occurred, which was accelerated by the potential difference that occurred between the cathode and the anode, in collision with the latter gave a picture on a graphic film [1].

Currently, X-rays are used in diagnostic imaging: ultrasound, computed tomography, magnetic resonance imaging. There are a lot of indications for this type of examination, for example: coronary artery disease, lower limb ischaemia, cranial, pleural or abdominal emphysema, bone, joint diseases or birth defects. Contraindications to perform these tests basically do not occur, but one one of the most serious is pregnancy, especially in the first trimester [2]. It is believed that the harmful effects of radiation depend on the child's developmental period and the dose that has been absorbed. Less than 0.1 Gy is considered to be the safest. Exposure to ionizing radiation in the 9-10 week after fertilization may result in the death of the embryo, and in further periods of development may cause functional disorders within the bone marrow, kidneys or liver of the fetus. Therefore, the decision to subject a pregnant woman to ionizing rays must be supported by very careful analysis [3]

Aim

The aim of the article is to show the effect of X-rays on both the fetus and the pregnant woman herself. Is it only harmful? Can there be any benefits from this process?

Radiation exposure of the fetus

X-rays are considered very dangerous for both the embryo and the fetus, because they can contribute to chromosomal damage, the development of birth defects in the child, mental retardation, in addition, there is a risk of developing cancer during puberty or as a result of ionizing radiation there may be a miscarriage [4].

Fetal damage that is caused by radiation can be divided into two types. The first of these are teratogenic abnormalities that cause the fetus to develop abnormally, while the second type is carcinogenic damage that can cause cancer. To avoid these complications, an alternative radiation dose tolerated by the fetus is 0.16 mGy [5].

Teratogen is a factor that is in the external environment and causes a birth defect or increases its incidence in the population. It is currently assumed that they are the cause of about 7% of birth defects that occur in fetuses. Their action depends on many factors:

- Teratogenic agent doses;
- Embryo genotype;
- Mother's genotype;
- The period in which this factor operates.

Exposure of the embryo or fetus to ionizing radiation may lead to chromosomal damage, birth defects or mental retardation. The dose of radiation absorbed by the fetus during diagnostic tests is small and should not be harmful to it, however, it is considered that all such procedures pose a serious threat to the child's development. As an example, we can give a chest radiography performed on a pregnant woman who is in the first trimester of pregnancy. During this procedure, 1R radiation (0.258C / kg) is absorbed by the embryo /

fetus. It is assumed that the risk of fetal damage is low if the radiation dose does not exceed 5R.

Unfortunately, but even small radiation is a risk of gene mutation, therefore it is not possible to determine the dose that would be safe for the child [6].

The degree of embryo or fetal damage depends on the radiation dose taken and the stage of fetal life. We can distinguish three periods of fetal life (Table 1):

1. Preimplantation and early implantation period – this is the emerging period at the time of implantation of the embryo. The most susceptible to X-rays, a dose of 10cGy has already been shown to contribute to the death of the embryo.
2. The period of organogenesis – in this period the organs develop during embryonic development. Exposure to X rays causes serious malformations, e.g. mental retardation, microcephaly.
3. Fetal period – begins after the end of the organogenesis period. During this time x-rays are no longer dangerous for the fetus. The only side effect of radiation on the fetus is a tendency to damage the central nervous system [7].

There is a so-called 10-day rule, which suggests that women of childbearing potential should not undergo pelvic x-rays during the first 10 days of the ovulation cycle. The purpose of this rule is to avoid irradiating the embryo when a woman does not yet know that she is expecting a child [8].

Principles of radiation protection of pregnant women

The definition of radiological protection has been presented in the Atomic Law as: *prevention of human exposure and environmental pollution, and in the absence of prevention of such situations – limiting their effects to a level as low as reasonably achievable, taking into account economic and social factors and health care.*

The Atomic Law also includes a definition of patient radiation protection: *a set of activities and restrictions aimed at minimizing the patient's exposure to ionizing radiation, which will not unduly hinder or prevent obtaining desired and justified diagnostic information or effects medicinal* [9].

There are three ways to protect against ionizing radiation:

1. Reduction of exposure time – the longer the patient is exposed to x-rays, the greater side effects will be observed.
2. The use of covers – they are used not only to protect the patient but also contribute to reducing the genetic consequences of radiation. It should also be borne in mind that those parts of the pregnant woman's body that are not irradiated should be protected by using lead shields that limit the effects of radiation on the fetus.
3. Appropriate distance from the irradiation site – the greater the patient's distance from the

Table 1.
Effect of radiation on the developing embryo / fetus [7]

Duration of pregnancy	Potential Effects
Before implantation	embryo death;
Early implantation 1-8 week	developmental defects of many organs, mental retardation, growth retardation;
8-15 week	mental retardation, microcephaly, skeletal abnormalities and growth inhibition;
15-25 week	unlikely occurrence of serious malformations, mild microcephaly, mental retardation, growth retardation;
> 30 weeks	the main risk is the increased risk of cancer, growth retardation is still possible

radiation source, the lower the exposure to its side effects [10].

The doctor directs a pregnant woman for an examination using ionizing radiation, when other imaging tests do not bring the intended results or are insufficient and is certain that the irradiation procedure brings more diagnostic benefits than side effects for both the child and the mother [11].

Use of radiopharmaceuticals in pregnancy

Conditions for the safe use of ionizing radiation are specified in the Regulation of the Minister of Health of 18 February 2011 on the conditions for the safe use of ionizing radiation for all types of medical exposure, pursuant to art. 33c paragraph 9 of the Act of November 29, 2000 – Atomic Law (Journal of Laws of 2017, item 576). The amendment to the ordinance is contained in the Ordinance of the Minister of Health of November 12, 2015 amending the ordinance on the safe use of ionizing radiation for all types of medical exposure.

The use of radiopharmaceuticals in pregnant women must be kept to a minimum, i.e. only in cases where diagnostic tests cannot be performed after delivery. However, when these preparations are necessary for testing, the dose should be limited to the lowest amount that allows the test to be performed. The dose for the fetus or embryo must not exceed 5 mSv. The patient's medical records must be justified by the supervising or performing physician about the need to perform it. A pregnant woman should be informed of the results of the calculations as well as the risks, including the type and level of risk to the embryo or fetus. When radiopharmaceuticals are used, an increase in the supply of fluids is an essential element and informing the patient of the need to urinate frequently.

Procedures in the field of interventional radiology in pregnant women can only be performed if they are necessary to save the mother's health and life.

The provision in Chapter 3 §15 reads in points 4 and 5 – „Iodine-iodide-iodide iodides for pregnant women 8 weeks after conception may not be used for diagnostic and therapeutic purposes". *If it is necessary to perform an examination or treatment using radiopharmaceuticals in a nursing woman, the physician performing or supervising the examination or treatment is obliged to inform the patient about the need to stop breastfeeding or to temporarily stop feeding, stating the length of this period. The periods of cessation of breastfeeding after administration of radiopharmaceuticals are set out in Annex 9 to the Regulation* [12] (Table 2).

The quality of radiopharmaceuticals is specified in Chapter 3 §16 of this Act and is „*Radiopharmaceuticals are subject to internal quality control tests carried out by health care unit personnel trained in this field*".

Periods of cessation of breastfeeding after administration of radiopharmaceuticals for diagnostic purposes are set out in Annex 9 of the Regulation of the Minister of Health of February 18, 2011:

The document also states that: *after administration of radiopharmaceuticals for therapeutic purposes, complete cessation of breastfeeding applies. If radiopharmaceuticals for which it is not necessary to stop breastfeeding are administered, the child should not be given the first portion of food obtained after administration of the radioactive compounds.*

Radiation therapy during pregnancy

In the case of malignant neoplasms during pregnancy, radiation therapy is an important method of locoregional treatment. In pregnant women, the most common cancers are: breast cancer (51%), hematological cancers (about 26%), and the remainder are cancers in other organ locations.

Despite the fact that treatment with ionizing rays leads to the elimination of cancer cells (the tumor itself, the space that was affected by surgery, metastases), we must remember that this is a process that occurs on a living human body. Complications that occur during this process are associated with the area that has been exposed. In addition to cancerous tissues, it still (although to a very small extent) has healthy structures whose tolerance to ionizing

Table 2.
Cessation periods of breastfeeding after administration of radiopharmaceuticals for diagnostic purposes [12]

Lp.	Isotope	Radiopharmaceutical	Period after administration, in which it is necessary interruption of feeding [Hr.]
1.	^{99m}Tc	HEPIDA and the like, DMSA, DTPA, ECD, phosphonates, gluconates, glucoheptonate, Hm – PaO, MAG – 3, MIBI, red blood cells (in vitro), Technegas, Tetrofosmin, EC, nanocolloid, microspheres (albumin macroaggregates)	0
2.	^{14}C	triolein, glycochilic acid, urea	0
3.	^{11}C, ^{15}O, ^{18}F	FDG, various substances	0
4.	^{51}Cr	EDTA	0
5.	^{121}In	Octreotide, white blood cells	0
6.	^{133}Xe	Gas	0
7.	^{99m}Tc	All other than in No. 1	12
8.	^{123,125,131}I	Jodohipuran	12
9.	^{201}TI	Chloride	48
10.	^{123,125,131}I	Other than hipuran	Complete cessation of breastfeeding complete cessation of breastfeeding
11.	Other	Other served for diagnostic purposes	Complete cessation of breastfeeding complete cessation of breastfeeding

rays depends on the volume and fraction of the dose. When applying radiation to large areas of the body, side effects such as lowering may occur mood, fatigue, weakness, weight loss, hair loss at the irradiation site or pain in the area exposed to rays.

On this basis, we can distinguish two types of radiation reactions: early (acute) and late. The first group is already revealed when radiotherapy begins. They are caused by damage to spore and transient cells in tissues that have a rapid recovery period. An example is the occurrence of anemia, a decrease in the number of leukocytes or platelets in the course of breast cancer. However, the late reaction appears after treatment (up to several months or even years). The time it occurs depends on the dose of radiation, its fractionation method and the type of tissue or organ [13].

Due to the occurrence of pregnancy in cancer patients, it is not possible to irradiate all locations that require this type of therapy. Radiation therapy requires the administration of a very high dose of radiation ranging 104-105 times higher than the doses appropriate for diagnostic radiology, and amounts to 4000-7000 cGy (40-70 Gy). *The amount of a damaging dose that an embryo or fetus will be irradiated depends on the therapeutic apparatus used, the target dose, the size of the irradiation field, the distance from the edges of the fields to the fetus, the technique used and the type of radiation.* The dose can be reduced by reducing the fields and increasing the distance between the field edges and the fetus. Increasing the distance to over 30 cm reduces exposure by 4-20 cGy compared to non-pregnant patients.

Old healing practices indicated the need to terminate pregnancy. Due to the possibilities of modern therapeutic and diagnostic devices, such solutions are no longer necessary. „The use of chemotherapy or radiotherapy or radiological diagnostic tests while maintaining a dose of ionizing radiation taken by the fetus of less than 0.1 and even 0.2 Gy (10-20 cGy), according to Perega et al., Does not increase the risk of congenital malformations. The risk of malformations decreases with more advanced gestational age. Postponing cancer treatment until it is terminated is justified in very few cases" [14].

Conclusions

Based on the analysis we can draw the following conclusions:

- X-rays are not indifferent to our body, so you should not take x-rays too often.
- A measure of irradiation of our tissues is a unit called sievert (Sv). Usually, the dose taken after a single x-ray is thousandths of sievert, i.e. very small amount.
- High doses increase the risk of DNA damage and cancer.
- Opinions on acceptable doses are divided and standards are very different according to different organizations around the world. The rule is not to expose yourself without the necessary necessity.
- When taking an x-ray, the person performing the test gives a protective apron to cover the pelvis to protect the reproductive organs.
- X-rays are strictly contraindicated in pregnant women due to the risk of harmful effects of x-rays on the fetus.
- During the examination, special attention should be paid not only to the dose of radiation, but also to the drugs given to the future mother.
- X-rays contribute largely to birth defects and various types of impairment during fetal development.
- X-ray examination not only brings negative effects, but also positive ones, e.g. in the form of diagnosing cardiovascular disease.

Conclusion

This paper discusses the impact of radiation on a pregnant woman like and on the embryo or fetus itself. By analyzing the impact of radiation doses like and radiopharmaceuticals and the risk associated with it on the occurrence and development of birth defects, chromosomal damage, mental retardation, the appearance of cancer in a child or even the occurrence of miscarriage due to radiation, it is necessary to mention the need for diagnostic tests using this radiation. If the mother's health or life is likely to be lost in exceptional cases such an examination is performed. However, one should also keep in mind the positive aspects of using therapy such as radiotherapy or diagnostic tests. By using radiation, the health and lives of millions of people were saved. By complying with applicable radiation protection rules as and management in accordance with current guidelines, including the selection of the appropriate dose of radiation and radiopharmaceuticals, it is possible to treat a pregnant woman without harming the fetus.

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