Ask EuroSafe Imaging
Tips & Tricks

Paediatric Working Group

Safety and dose aspects of prenatal medical irradiation

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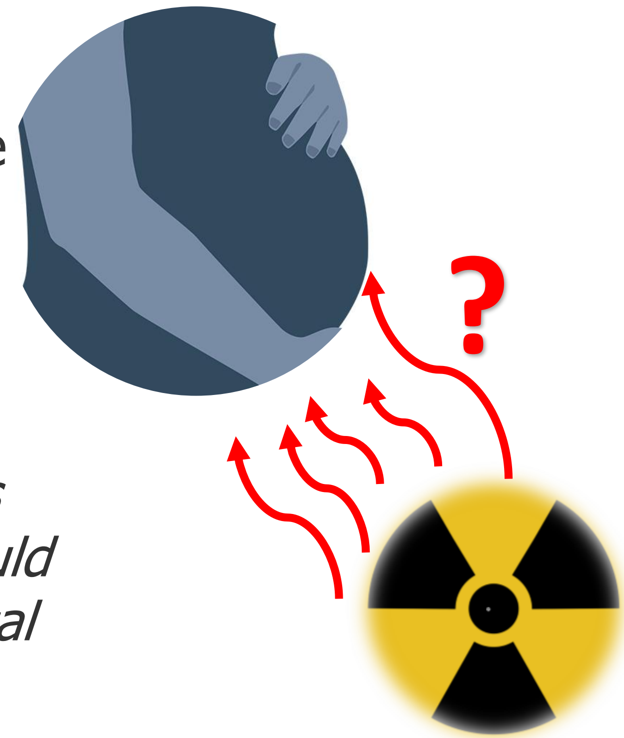
In X-ray diagnostic and interventional radiology, pregnant patients and pregnant medical staff could be exposed to ionizing radiation.

Radiation-related risks for the unborn child are usually small but not negligible. Lack of knowledge on corresponding risks can result in great anxiety and probably unnecessary termination of pregnancies or, contrarily, careless handling with persons concerned.



This presentation is about dose and safety aspects of prenatal medical irradiation. These aspects should be considered by physicians, radiographers, medical physicists and the hospital management when interacting with pregnant patients or pregnant colleagues who are irradiated.

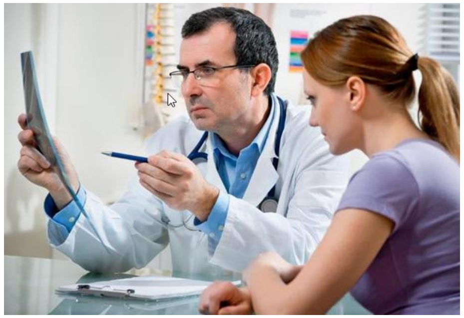
Before any diagnostic or therapeutic procedure …

… it should be determined whether a patient is, or maybe, pregnant; patient questionnaires and advisory notices, posted at several places within the department, should ask for a known or potential pregnancy [1]. Patients aged between 15 and 50 years (or according to national regulations) should be asked actively by the medical staff;

… it has to be ascertained that the procedure for a pregnant patient is indicated, i.e. whether it can be postponed until after the pregnancy or replaced by a procedure without ionizing radiation. The procedure is indicated if the risk for the patient of not performing the procedure is greater than the risk of potential harm to the patient *and* foetus.

Dear patient, please, inform the medical staff before the examination about a known or potential pregnancy.

Before a pregnant patient is exposed to radiation, she …



… has the right to know the potential radiation effects for her unborn child. For high-dose procedures, the thoughts of the patient and her relatives should be considered when deciding for or against the procedure;

… should get information about the efforts of the medical staff to minimize radiation-related risks (see slides #5-6 of this presentation);

… should get further carefully worded information, if desired, e.g. see the information provided in a previous presentation, provided by the Ask EuroSafe Imaging Paediatric Imaging Working Group: "I had X-rays and I didn't know I am pregnant. And now?" (http://www.eurosafeimaging.org/wp/wp-content/uploads/2020/01/I-didnt-know-I-am-pregnant_WPSK_Final_proofread.pdf)

During the exposure of pregnant patients, …

… care should be taken to minimize the dose to the foetus by …

- … preventing direct irradiation of the foetus,
- … increasing the tube voltage (and/or filter thickness) and decreasing the tube current,
- … reducing the number of radiographs and collimating the X-ray beam,
- … reducing the number of CT acquisitions and the CT scan length,
- … reducing the pulse rate, the number of fluoroscopic series, collimating the X-ray beam, using the last-image hold function, and/or tailoring the procedure in fluoroscopy/interventional radiology, and
- … using novel editing image software capable of reducing image noise and novel detectors with high sensitivity …

… as far as reasonably achievable.

In particular in high-dose procedures, e.g., fluoroscopic/interventional procedures or CT examinations …

… of body regions remote from the fetus, such as chest, skull, or extremities, the abdomen of the patient should be protected by an all-around apron (1mm lead-equivalent-thick) as far as it does not impede the procedure: the apron must *not* reach into the primary beam [2]. National regulations should be considered.

… the protocol parameters of the procedure have to be stored,

- … in CT: volume dose index ($CTDI_{vol}$), dose length product (DLP), scan ranges;
- … in fluoroscopic/interventional: dose area product (DAP) and if available: tube/detector positions with respect to patient's body, DAP of single series, entrance skin dose of each series, entrance field size of X-ray image.

After the X-ray procedure …

… a qualified expert (e.g., medical physicist) should make a rough, conservative estimate of the absorbed dose H_u of the foetus.

According to the German Society for Medical Physics and the German Röntgen Society [3], *maximum* equivalent dose of the uterus in conventional radiography (dose per projection) and fluoroscopy are:

Projection	Anterior-posterior			Posterior-anterior			lateral
Patient diameter	17 cm	22 cm	26 cm	17 cm	12 cm	26 cm	36 cm
Radiograph	2 mSv	3 mSv	5 mSv	1 mSv	1.5 mSv	2.5 mSv	4 mSv
Radiograph for digital subtraction angiography	4 mSv	6 mSv	10 mSv	2 mSv	3 mSv	6 mSv	8 mSv
Fluoroscopic series	16 mSv/min	24 mSv/min	40 mSv/min	8 mSv/min	12 mSv/min	20 mSv/min	32 mSv/min

After the X-ray procedure …

… a qualified expert (e.g., medical physicist) should make a rough, conservative estimate of the absorbed dose H_u of the foetus.

According to the German Society for Medical Physics and the German Röntgen Society [2], *maximum* equivalent dose of the uterus in a CT scan series (acquisition) is:

Position of foetus (uterus)	Conversion factor f (has to be multiplied with $CTDI_{vol}$) [mSv/mGy]
partly or entirely in scan region	1.5
in adjoining regions of scan region	0.2
remote from the scan region (skull, neck, upper extremities, lower distal extremities)	0.001

More detailed approximations of H_u

- Another simple, but more detailed approach would be to use conversion coefficients to compute H_u from DAP or DLP or percentage depth dose curves to compute H_u from entrance dose.
- Absorbed dose H_u of the foetus can also be computed by different computer programs:
  - For instance, some modern dose management programs provide approximations of the equivalent dose H_u. However, it should be taken into account that these programs do not provide individual equivalent doses but doses of a reference person (see *http://www.eurosafeimaging.org/wp/wp-content/uploads/2019/11/Paed-Imag_TipsTricks_11_2019_20_final.pdf*).

After the X-ray procedure …

… if the outcome of the rough dose estimation of H_u is smaller than 20mSv, there is no indication for an interruption of the pregnancy; further computations are *not* necessary [3];

… if the outcome of the rough dose estimation of H_u is larger than 20mSv, H_u has to be recomputed in more detail, considering all data available for the individual X-ray procedure, e.g. by using broadly-accepted and validated dose computation programs (see previous slide #9). Usually, a medical physicist performs this more detailed computation [3];

… if the outcome of the more detailed computation of H_u is smaller than 100mSv, there is no indication for an interruption of the pregnancy, otherwise informed decisions should be made based upon individual circumstances, such as the desire of the mother to have the child. Although the risk for negative health effects is not negligible in such situations, the probability of having a healthy child by far outweighs the risks.

After the X-ray procedure …

… the physician who performed the procedure, the patient, and the gynecologist of the patient should be informed about the outcome of the dose estimation;

… there should be a meeting between the patient and physician to discuss the radiation-related risks to the unborn child: the information given to the patient should be more detailed and should be more carefully worded for larger doses H_u. The patient and her relatives should be in a position to reach their own conclusions.

… the outcomes of the dose computation and meeting have to be documented in the patient record.

Radiation-related risks for non-malignant health effects are related to the developmental stage and absorbed dose H_u of the unborn child.

Week of pregnancy	H_u > 100 mSv	Risk coefficient
1^{st} - 2^{nd} week (pre-implantation period)	potential abortion	0.1% / mSv
3^{rd} – 8^{th} week (major organogenesis period)	malformations	0.05% / mSv
9^{th} – 15^{th} week (foetal period)	reduction of intelligence quotient (IQ) (heavy mental retardation for H_u>0.3 Sv)	0.03 IQ / mSv (0.04% / mSv)
16^{th} – 25^{th} week	IQ-reduction (heavily mental retardation for H_u>0.3 Sv)	0.01 IQ / mSv (0.01% / mSv)

Most properly carried out diagnostic and interventional procedures do not result in a measurable increased risk of prenatal death, malformation, or impairment of mental development over the corresponding background incidence. Further information can be found in [4-6].

Radiation-related risks for malignant health effects are related to the developmental stage and absorbed dose H_u of the unborn child .

The risk of the development of carcinogenic effects caused by radiation during pregnancy is assumed to be the same as the risk for small children.

H_u [mSv] (in addition to natural background radiation)	Additional probability [%] to develop a malignant tumor at the age between 0 and 19 years
5	0.3
10	0.4
50	0.6
100	0.9

So far, there is no evidence for heritable effects in humans, due to radiation exposure. Further information can be found in [4-6].

Management of pregnant medical staff.

- Pregnant staff members must declare their pregnancy to the employer as soon as the pregnancy is confirmed.
- Additional protection of the foetus must be considered:
  - Pregnant workers can continue their job, but the compliance with the foetal dose limit of 1 mSv must be ensured.
  - Exposure conditions of the pregnant employee should be reviewed. It could be possible to change the job within the institute to a job with less or no radiation exposure.
  - In fluoroscopy and interventional radiology, the pregnant worker should wear an all-around closed apron (with at least 0.25 mm lead-equivalent-thickness). National regulations should be considered.
  - In addition to the official dosimeter, the pregnant worker should carry a real-time dosimeter at waist level under the apron to permanently monitor and immediately react to any change of the ambient exposure. National regulations should be considered.

The information provided in this Tips & Tricks issue are based on the following documents:

1. Austrian Ministry for Health and Women. Schwangerschaft und Röntgenuntersuchungen. *Leitfaden für die radiologische Praxis.* 2017.

2. Commission on Radiological Protection (SSK). Use of patient radiation protection equipment in the diagnostic application of X-rays on humans. 2018. https://www.ssk.de/SharedDocs/Beratungsergebnisse_PDF/2018/2018-12-13Patient_E.pdf?__blob=publicationFile

3. German Society for Medical Physics and German Röntgen Society. *Pränatale Strahlenexposition aus medizinischer Indikation*. DGMP Report No. 7, 2019, ISBN 978-3-00-064613-3.

4. International Commission on Radiation Protection (ICRP). *Pregnancy and medical radiation.* 2000. ICRP 84, Ann. ICRP 30(1).

The information provided in this Tips & Tricks issue are based on the following documents:

5. International Commission on Radiation Protection (ICRP). *Biological effects after prenatal irradiation (embryo and fetus).* ICRP 90, Ann. ICRP 33(1-2).

6. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). *Effects of radiation exposure of children.* UNSCEAR 2013 Report. Volume II, scientific annex B.