TREAT THE MOTHER FIRST. INITIAL TREATMENT AND IMAGING PRIORITIES IN THE PREGNANT TRAUMA PATIENT ARE THE SAME AS FOR THE NON-PREGNANT PATIENT.

Background

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for pregnant patients. They provide information on the health effects that are likely to occur in the fetus following exposure to ionising radiation during pregnancy and practical guidance as to how and when to prevent or reduce unnecessary fetal exposures when pregnant women are referred for diagnostic medical procedures involving X-rays.

Dose Units

To quantify the possible effects of radiation it is necessary to have some measure of the biological impact of that radiation. We measure the likely detrimental effects of ionising radiation in terms of the Effective Dose measured in units called the Sievert (Sv) or its submultiples the mSv (1Sv = 1000 mSv) and the µSv (1 mSv = 1000 µSv). Typically fetal radiation doses will be quoted in either milli-Grays (mGy) or milli-Sievert (mSv). Noting that if the entire fetus is exposed uniformly to x-rays the two units have equal value.

The Risks

Exposure of the fetus to ionising radiation can potentially lead to two types of adverse health effects:

1. Deterministic effects (tissue reactions) resulting from damage to a number of cells, for which there is a dose threshold before any clinical effect occurs (see appendix 1)
2. Stochastic (cancer) effects which originate from damage to single cells, for which there is no dose threshold but an increased probability of induction as the dose increases. (see appendix 2)
Radiation risk is related to the:
1. Fetal effective dose and Stage of pregnancy.

The greatest risk is during organogenesis. The main risks (although low) are childhood cancer and leukaemia. Most diagnostic radiology procedures pose little risk to the mother or fetus, when compared with other risks throughout the pregnancy. However, interventional radiology procedures involving extended fluoroscopy times, and CT scans of the abdomen or pelvis may result in a significant fetal dose; and an increased risk of cancer.

Ultrasound and MRI:
Ultrasound is accepted as being safe in pregnancy.

MR imaging may be used in pregnant women if other non-ionizing forms of diagnostic imaging are inadequate or if the examination provides important information that would otherwise require exposure to ionizing radiation (eg. Fluoroscopy, CT etc.). There is no clear evidence that exposure to static or low frequency magnetic fields can adversely affect pregnancy outcome. The American College of Radiologists advise that present data has not conclusively documented any deleterious effects of MR imaging exposure on the developing fetus. Therefore, no special consideration is recommended for the first, versus any other, trimester in pregnancy. The fetus may be susceptible to noise during MR scanning, and heating from RF coils (though not from head coils).

Pregnant patients should be informed that, to date, there has been no indication that the use of clinical MR imaging during pregnancy has produced detrimental effects.

Typical Radiation Doses received by the fetus
1. Radiation doses received by the fetus will vary widely depending on equipment used, technique, number of x-rays and maternal and fetal size. As these values are indicative, a more accurate estimate of the fetal radiation dose should be provided by a medical physics expert.

2. Listed below are typical ranges of fetal doses following common diagnostic procedures. The radiation doses have been estimated from surveys conducted in the UK for a range of diagnostic radiology.

<table>
<thead>
<tr>
<th>Group</th>
<th>Examination</th>
<th>Typical fetal dose range (mGy)</th>
<th>Risk of Childhood Cancer per examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low risk</td>
<td>X-ray – Plain Film Skull</td>
<td>0.001 – 0.01</td>
<td>&lt; 1 in 1,000,000</td>
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<td></td>
<td>X-ray – Plain Film Teeth</td>
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<td>X-ray – Plain Film Chest</td>
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<td>X-ray – Plain Film Thoracic spine</td>
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<td></td>
<td>X-ray – Plain Film Breast (Mammography)</td>
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<td></td>
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<tr>
<td></td>
<td>X-ray - CT Head and/or neck</td>
<td></td>
<td></td>
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<tr>
<td>2 Low risk</td>
<td>X-ray – Plain Film Abdomen</td>
<td>0.1 – 1.0</td>
<td>1 in 100,000 To 1 in 10,000</td>
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<tr>
<td></td>
<td>X-ray – Plain Film Barium Meal</td>
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<tr>
<td></td>
<td>X-ray – Plain Film Pelvis</td>
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<td>X-ray – Plain Film Hip</td>
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<td></td>
<td>X-ray / CT Pelvimetry</td>
<td>1 in 10,000</td>
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<td>X-ray / CT Chest and liver</td>
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<tr>
<td>3 Low risk</td>
<td>X-ray – Plain Film Barium enema</td>
<td>1.0 – 10</td>
<td>To 1 in 10,000</td>
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<tr>
<td></td>
<td>X-ray – Plain Film Intravenous urography</td>
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<td></td>
<td>X-ray – Plain Film Lumbar Spine</td>
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<td></td>
<td>X-ray / CT Lumbar Spine</td>
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<td></td>
<td>X-ray / CT Abdomen</td>
<td></td>
<td></td>
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<tr>
<td>4 High Risk</td>
<td>X-ray / CT Pelvis</td>
<td>10 - 50</td>
<td>1 in 1,000 To 1 in 200</td>
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<td></td>
<td>X-ray / CT Pelvis &amp; Abdomen</td>
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<tr>
<td></td>
<td>X-ray / CT Pelvis, Abdomen &amp; Chest</td>
<td></td>
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</tr>
</tbody>
</table>

NATURAL Childhood cancer risk ~1 in 500

* Fetal doses derived from doses to the uterus only apply to early stages of pregnancy when the fetus is small.

Note: the annual dose from background radiation in Victoria is approximately 2 mSv (2 mGy) per annum. As such the fetus receives approximately 1.5 mSv (1.5 mGy) during the gestation period.
The Guideline

Procedure to Avoid Unintentional Irradiation of the Embryo/Fetus

1. All female patients of childbearing age must be queried regarding the possibility of being pregnant.
2. Whenever possible the gonads must be protected during radiological procedures.

Note 1: Where the use of shielding will obscure the desired information relevant to the examination the use of such shielding is discouraged.

Note 2: In some instances (e.g., the covering of the female abdomen during a chest CT scan or plain X-ray examination), the use of lead shielding is more for patient reassurance than for any real physical benefit as the major source of exposure to the abdominal organs is by way of internal scatter.

Procedure if Patient may be Pregnant

The examination may proceed normally if it involves:

- Plain radiography of the extremities and skull;
- Mammography;
- CT of the head or neck; or
- Any other procedure, which is likely to result in an effective dose of less than 1 millisievert to the fetus (e.g. CTPA of the chest).

Diagnostic and interventional radiological examinations causing exposure of the abdomen or pelvis of a woman who is pregnant or likely to be pregnant must be avoided unless there are strong clinical reasons for conducting such examinations.

If it is decided that an X-ray procedure is necessary in a woman who is pregnant or likely to be pregnant then the Radiology Staff must be informed prior to the examination being performed.

If it is decided that an X-ray procedure is necessary in a woman who is pregnant or likely to be pregnant and the embryo/fetus is exposed to the primary beam, the technical factors for the procedure must be:

- Optimized to minimise the dose to the embryo/fetus; and
- Recorded to enable a medical physics expert (see contacts below) to estimate, when required, the dose received by the embryo/fetus and the potential risk to the embryo/fetus.

Procedure if the Embryo/oetus has been Inadvertently Irradiated

1. The dose received by the embryo/fetus and the potential risk to the embryo/fetus from the procedure must be determined by a medical physics expert.
2. The patient must also be queried regarding any other radiological procedures, including Nuclear Medicine procedures, which may have taken place during gestation.
3. The patient must be informed about the magnitude of the radiation dose to the embryo/fetus and counselled about any potential risks.
Risk Communication

Since there is no known threshold for some radiation effects (stochastic effects), when imaging potentially pregnant patients, imaging radiation must be applied at levels as low as reasonably achievable (ALARA), while the degree of medical benefit must counterbalance the well-managed levels of risk.

The pregnant patient should be informed of potential radiation effects that might result from any in-utero exposure. For low dose procedures such as a chest X-ray, extremity x-rays, CT of the brain, cervical spine or chest the only information that may be needed is a verbal assurance that the risk is judged to be extremely low. When fetal doses are above 1 mGy more detailed explanation should be given.

The information should not only include potential radiation risks but also potential alternative modalities as well as the risk of harm from not having the medical procedure. A note of counselling or consent should be included in the record of the patient. This advice must be given before the examination is performed unless there are compelling practical reasons why it has to be delayed until after the examination. An example of such a reason would be the examination of a patient in an emergency situation.

In order to advise the pregnant patient the practitioner responsible for the procedure must:
- Be familiar with the effects of ionising radiation on the embryo and fetus; and
- Be able to communicate the risks to the patient in a meaningful manner.

The Hospital’s Medical Physicist can be consulted and will be able to assist in the estimate of the fetal dose and likely risks associated. The Medical Physicist will provide a detailed report of the effective doses received by both the mother and fetus which can be placed on the patient’s record for future reference.

Contact(s):
If you require any further information and assistance please contact

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Resources & Further Reading (References)

Appendix 1

Deterministic effects of ionising radiation

The principal deterministic effects (tissue reactions) of ionising radiation in the developing embryo or fetus are death, nervous system abnormalities, malformation, growth retardation and abnormal brain development leading to severe mental retardation. Provided multiple high dose procedures are not performed, it is highly unlikely that the fetal effective dose from diagnostic or most interventional procedures will exceed 100 milliSievert, where the threshold for deterministic effects of ionising radiation is believed to occur.

Appendix 2

Stochastic effects of ionising radiation

The stochastic effects resulting from irradiation of the embryo or fetus are the possible causes induction of cancer after birth and of hereditary disease in their descendants. The probability of these effects occurring is considered to be directly proportional to the radiation dose received by the embryo or fetus and is now believed to be fairly independent of the stage of pregnancy after the first three to four weeks of gestation. There is stronger scientific evidence for cancer risks from radiation exposure after the first three to four weeks of pregnancy than for exposures earlier in pregnancy.

A number of large UK based studies conducted in the 1980’s indicated that a fetal dose of roughly 25 mGy was estimated to double the natural rate of childhood cancer. When this doubling dose was applied to the current UK natural baseline risk of childhood cancer incidence of 1 in 500 (2.0 x 10^{-3}), an excess absolute risk coefficient of 1 in 13,000 per mGy (8x10^{-5} mGy^{-1}) was obtained. No new radiobiological or epidemiological evidence has arisen, nor have there been any new assessments of the dosimetry to suggest that a revision of the estimated doubling dose is required.

The fetal doses associated with modern diagnostic medical procedures range from a few microgray (1/1000 of a mGy) to a few tens of milligray, so the associated risks of childhood cancer will range from less than 1 in 1,000,000 to about 1 in 200 (5 x 10^{-3}). Table 1 shows a number of common diagnostic X-ray examinations in four broad groups according to the typical fetal doses and associated childhood cancer risks involved. The actual fetal dose can vary quite considerably from patient to patient for any given type of examination, depending on the imaging equipment available, the examination techniques used and the size of the patient.

Finally, the relationship between the fetal dose and the risk of radiation-induced cancer is not precisely known and could vary by a factor of at least two or three from the figure quoted above of 1 in 13,000 per mGy.

Appendix 3

Advice to Patient

Deterministic Effects

The radiation dose to the embryo or fetus that is likely to result from any diagnostic procedure in current use is well below 100 milligray, where the threshold for deterministic effects of ionising radiation is believed to occur.

Therefore the first three groups in the table 1 should present no risk of causing fetal death, malformation, growth retardation or impairment of mental development.

For procedures listed in group 4 if such examinations are considered to be clinically justified or are carried out inadvertently, the deterministic risk associated with them is still low in absolute terms and termination of the pregnancy would not be justified solely on the basis of the radiation risk to the unborn child.

Childhood Cancer Risk (Stochastic)

For the majority of diagnostic medical procedures, giving fetal doses up to about a milligray (the first three groups in the table 1), the associated risks of childhood cancer are very low (less than 1 in 10,000) and judged to be acceptable when compared with the natural risk (of around 1 in 500). Consequently, all such examinations can be carried out on pregnant women, as long as they have been clinically justified and the dose is kept to a minimum consistent with the diagnostic requirements. The very low risks of childhood cancer from these examinations are certainly not sufficient to justify termination of the pregnancy (particularly in view of the associated risks to the health of the mother). Exposure of pregnant women to the higher dose procedures (the last two groups in the table) lead to fetal doses in excess of a few milligray, and – at the highest doses – may result in a doubling of the childhood cancer risk compared to the natural rate. Consequently, such examinations should be avoided on pregnant women, if this can be achieved without serious detrimental effects to their health. However, if such examinations are considered to be clinically justified or are carried out inadvertently, the childhood cancer risk associated with them is still low in absolute terms (below 1 in 200 and
mostly below 1 in 1000) and termination of the pregnancy would not be justified solely on the basis of the radiation risk to the unborn child.

Alternatively, the risk of NOT developing a childhood cancer could be explained to patient. Throughout most of pregnancy, the unborn child is assumed to be at about the same risk for potential carcinogenic effects of radiation as are children. It has been quoted [ref], the percent likelihood of **NOT developing cancer is 99.93 percent with no radiation exposure** (i.e., all pregnancies have a 0.07 percent chance that the child will develop cancer during childhood). With an in utero radiation exposure of 10 mGy, the chance of not developing cancer is between 99.75 and 99.88 percent. With an in utero exposure of 50 mGy, the chance of not developing cancer is between 99.12 and 99.70 percent. That is, with a uterine radiation exposure of up to 50 mGy the chance of not developing a carcinogenic effect reduces by less than 1%.