Basic Training Program on the Safe Use of Fluoroscopy

For medical professionals who use fluoroscopy

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KEY POINTS

• The effects of radiation on the conceptus depend on both radiation dose and gestational age.

• Organogenesis is the most critical gestational age. Radiation doses that may result in malformations can be reached during fluoroscopically guided procedures.

• Whenever possible, exposure to the conceptus in utero should be avoided by maintaining the conceptus outside the FOV.

• If the conceptus is not directly irradiated during a fluoroscopic procedure, it is likely that the fetal dose will be less than 50 mGy.

Fetal responses to radiation

<table>
<thead>
<tr>
<th>Gestation stage</th>
<th>Differentiation level</th>
<th>Possible radiation-induced sequelae in humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-implantation</td>
<td>None</td>
<td>Spontaneous abortion/prenatal death</td>
</tr>
<tr>
<td>Organogenesis</td>
<td>Varies from low (gastrula) to high (complete organism)</td>
<td>1. Malformations, increasing in likelihood as dose increases 2. Increased risk of prenatal death</td>
</tr>
</tbody>
</table>

*There is a slight risk for childhood leukemia at all stages, with the strongest evidence indicating a higher risk in the 2nd and 3rd trimesters.
Fetal doses and levels of concern

The likelihood of observing the effects listed in the previous slide depends on the fetal dose, which can be estimated by a qualified medical physicist.

<table>
<thead>
<tr>
<th>Fetal dose</th>
<th>Potential for effects</th>
<th>Likelihood of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50 mGy (&lt; 5 rad)</td>
<td>No effects.</td>
<td>The likelihood of effects decreases with increasing gestational age, with no effects expected at diagnostic doses. Effects are still possible at high doses that can be reached during complex fluoroscopic cases.</td>
</tr>
<tr>
<td>50-100 mGy (5-10 rad)</td>
<td>Potential for effects is uncertain, and if they do exist, are likely too subtle to be observed clinically.</td>
<td>Effects are possible, increasing in likelihood with increasing dose.</td>
</tr>
<tr>
<td>&gt; 100 mGy (&gt; 10 rad)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Childhood cancer

Irradiation *in utero* at any stage of pregnancy has been associated with an increased risk of childhood cancer at doses as low as 10 mGy.*

However, the individual probability of a child developing cancer is still very low, as the background incidence of childhood cancer is small.

In light of this evidence, exposure of the conceptus *in utero* should be avoided if possible.

Follow-up after irradiation of the conceptus

If fluoroscopy of a pregnant patient is deemed necessary, any action taken is based on the gestational age of the conceptus at the time of the irradiation event and the estimated dose to the conceptus*:

– Doses of less than 50 mGy to the conceptus are not currently believed to produce harmful effects. If the conceptus is not directly irradiated during a fluoroscopic procedure, it is likely that the fetal dose will be less than 50 mGy.

– Doses between 50 and 100 mGy to the conceptus have the potential to cause harmful effects, but these effects are probably too subtle to be clinically detectible.

– Detailed investigation by a qualified medical physicist may be required for higher doses, depending on the stage of pregnancy. The dose to the conceptus is not reported by any fluoroscope and must be calculated based on procedural data.


KEY POINTS

• Exploit the 3 Cardinal Rules of Radiation Protection to reduce occupational dose

• Step out of the room during digital acquisition imaging and rotational angiography

• Take one step away from the X-ray beam entrance site prior to beginning a procedure

• Wear personal radiation shielding, however, protective gloves offer little protection and may result in an increase in dose to the patient if used in the field of view.
Personal radiation shielding

This type of equipment consists of several items:

- Apron or vest/kilt combination
- Thyroid shield
- Lead eyewear

Available in a variety of thicknesses from 0.25 to 0.5 mm.

A thickness of 0.35 mm is adequate for most personnel. **Check your state regulations for specific requirements.**

Eye protection

Recent evidence points to a threshold dose for cataract formation that is lower than previously thought.*

However, many personnel who work around ionizing radiation do not experience lens doses high enough to put them at risk for cataracts.

When indicated by occupational doses, lens dose can be reduced by wearing protective eyewear and also by following the other Cardinal Rules of Radiation Protection. In addition to reducing lens dose, eyewear provides the secondary benefit of acting as a splash guard.

Lead eyewear provides excellent protection, however, it does not attenuate all scattered radiation that strikes it, including radiation scattered from the body and head. In addition, the operator is often facing the viewing monitor, which means the side of the head is exposed to the most intense radiation, the area that is typically the weakest point of lead eyewear.

The closer a shield is to a source of radiation, the more effective it is. When used appropriately, a suspended shield blocks the majority of scattered radiation directed at the head and upper body of the operator, including the thyroid and eyes. Use of a suspended shield is recommended if it does not interfere with the goals of the procedure.

Doses that are ALARA are achieved through the use of complementary radiation protection strategies.

Protective gloves

The biggest concern related to the use of protective gloves in the FOV is the likely increase in patient dose rate. Because the AEC system increases radiation output to penetrate the glove, patient dose may increase. Scatter and secondary electron production in the glove itself also contribute to hand dose. These factors imply that the hand dose reduction offered by protective gloves is small.1

Instead of relying on protective gloves or hand creams, develop good habits and keep your hands out of the FOV when possible.2,3 Occasional brief exposure of the hands to the X-ray beam after it has passed through the patient is acceptable. A ring badge can be worn to monitor radiation dose to the hands if concerns arise, however, sterility concerns may need to be addressed.

Wearing protective gloves to reduce contributions to extremity dose from scattered radiation is an acceptable radiation protection practice if the hands do not enter the FOV.

### Kerma area product (KAP)

**Advantages**
- Includes all contributions to patient dose
  - Fluoroscopy
  - Digital acquisition imaging
  - Etc.
- Includes information about practice habits
  - Poor collimation will result in higher KAP

**Disadvantages**
- High KAP* not specific for high risk of skin injury
  - X-ray field size dependence
- Better indicator of risk for stochastic effects than tissue effects

*You may also see KAP abbreviated as $P_{\text{Kx}}$.

### Reference air kerma ($K_{\text{a,r}}$)

**Advantages**
- Preferred metric for assessing risk for skin injury
- Includes all major contributors to peak skin dose (PSD)
- High $K_{\text{a,r}}$ is specific for a higher risk of skin injury
- Low $K_{\text{a,r}}$ is specific for low risk of skin injury
- Display is required by law on all equipment manufactured after June 10, 2006

**Disadvantages**
- $K_{\text{a,r}}$ may overestimate the PSD if multiple, non-overlapping projections are used
- Relationship of $K_{\text{a,r}}$ to the PSD depends on several factors
  - Distance between IRP and skin surface
  - Beam quality and X-ray field size
Peak skin dose compared to the $K_{a,r}$

The PSD is challenging to measure, and the $K_{a,r}$ is often used as a surrogate for the PSD.

The exact relationship between PSD and $K_{a,r}$ depends on many factors, including the position of the patient relative to the IRP and the use of different gantry angles during the procedure.

You can find more information about the relationship of PSD and $K_{a,r}$, including clinical examples, in the Establishing a Patient Safety Program course from FluoroSafety.

Dose metrics and follow-up

Depending on the fluoroscope, one or more of the dose metrics that we have learned about may be available. If $K_{a,r}$ is available, it should be the metric of choice. If any of the thresholds in the table below are exceeded for a study, the irradiated skin site of the patient should be examined between two weeks and one month after the procedure to check for signs of injury.

<table>
<thead>
<tr>
<th>Thresholds for patient follow-up</th>
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<tr>
<td><strong>Dose metric</strong></td>
</tr>
<tr>
<td>Reference air kerma ($K_{a,r}$)</td>
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<tr>
<td>Kerma area product ($P_{ka}$)</td>
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<tr>
<td>Fluoroscopy time</td>
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</tbody>
</table>

Data from NCRP Report No. 168: Radiation dose management for fluoroscopically-guided interventional procedures.
The “Tetrad”

The four most important things to remember before starting a fluoroscopic procedure

Raise the patient table to the highest comfortable working height

Lower the image receptor as much as practicable

Take one step back away from the fluoroscope

Collimate the X-ray field to the area of interest

Also, don’t forget to check the reference air kerma (K_a,r) occasionally!
Dose Reduction Opportunities from the Advanced Training Program on the Safe Use of Fluoroscopy

1. Maintain the patient as far as practicable from the X-ray source. This means raising the patient support to the highest comfortable working level.
2. Maintain the image receptor as close to the patient as practicable.
3. Always use the spacer cone.
4. Use a PA projection whenever possible. Lateral and oblique projections increase patient and operator dose.
5. Remove the grid when performing procedures on small patients (less than 50 lbs).
6. Use the least amount of magnification necessary to perform the procedure.
7. Always collimate to the anatomical area of interest.
8. Use pulsed fluoroscopy instead of continuous fluoroscopy. Ensure that the pulse rate in fluoroscopy mode and the frame rate in acquisition mode are as low as practicable.
9. Become familiar with the vendor-specific dose reduction features of your fluoroscope.
10. Pregnant and pediatric patients require special consideration. Use the pregnant and pediatric patient checklists included in this booklet on every patient, every time.
Pediatric patient checklist

☐ Anti-scatter grid removed if patient weighs less than 50 lbs.
☐ If available, reduced dose pediatric program selected, including pediatric AEC control curve
☐ Lowest practicable fluoroscopic pulse rate and DSA frame rate selected
☐ Use of digital acquisition restricted or eliminated, use Store Monitor/Store Fluoro
☐ Patient as far from X-ray source as practicable
☐ Image receptor as close to the patient as practicable
☐ Lowest magnification practicable selected
☐ X-ray beam collimated tightly to area of interest
Pregnant patient checklist

- Apron positioned on X-ray tube side of patient to identify the level of the conceptus
- Conceptus maintained outside FOV
- Lowest practicable fluoroscopic pulse rate and DSA frame rate selected
- Use of digital acquisition restricted or eliminated, use Store Monitor/Store Fluoro
- Patient as far from X-ray source as practicable
- Image receptor as close to the patient as practicable
- Lowest magnification practicable selected
- X-ray beam collimated tightly to area of interest