Radiation Dose and Fluoroscopic Procedures

- Increased use of fluoroscopically guided interventional procedures has raised concerns about the risks of radiation exposure.
- During fluoroscopic procedures, areas of skin receive the highest radiation dose, which occasionally exceeds the threshold for deterministic effects such as skin damage and hair loss.
- Skin effects are usually mild and transient but can be severe, causing pain, requiring multiple surgeries, and/or resulting in permanent disfigurement.
- Interventional radiologists employ a number of techniques to minimize radiation exposure during fluoroscopic procedures.
- Massachusetts law mandates monitoring and recording of radiation dose, cumulative fluoroscopic exposure times, and the number of spot films.
- Mass General Imaging alerts the referring physician if the cumulative dose exceeds 5 Gy, recommending patient follow-up to monitor for signs and symptoms of radiation injury.

Over the past several decades, medical imaging has expanded rapidly, such that the per capita exposure to ionization radiation from medical imaging exceeds that from natural sources of radiation. This growth has led to efforts to monitor radiation doses more closely and to minimize radiation dose. Diagnostic fluoroscopy and fluoroscopically guided procedures are significant contributors to medical radiation exposure.

The biological effects of radiation include deterministic effects and stochastic effects. Deterministic effects, such as skin damage and hair loss, are predictable and evident after a threshold level of radiation has been reached. It is these effects that are of most concern in fluoroscopically guided interventional procedures because the exposure to the skin can be quite high. In contrast, the likelihood of stochastic effects increases with radiation dose but their severity (e.g., induction of malignancy) is independent of radiation dose. Stochastic effects are of greatest concern in children because they are more sensitive to radiation. For adults, the increased risk of developing cancer due to medical radiation is considered to be approximately 0.5%, whereas the lifetime risk of a fatal malignancy in the USA is about 21%. For an average man over the age of 60, the probability of a new radiation-induced malignancy is too small to be statistically significant.

All medical procedures involve some risk that must be weighed against the benefits in each case. It is only appropriate to perform a procedure when the benefits (e.g., increased life expectancy, reduced pain, reduced anxiety, and/or improved functional capacity) exceed the negative consequences (e.g., increased morbidity and mortality, pain associated with the procedure, misleading or false diagnoses).
Management of Risk

For fluoroscopically guided interventional procedures, the risk of radiation exposure is generally accepted. Limiting exposure may do more harm than good because the medical condition being treated and the non-radiation risks of the procedure are generally more deleterious than the risks of radiation. In most procedures, the radiation is well below the dose associated with deterministic effects. However, some procedures are associated with high radiation dose to the skin (Table 1). In addition, skin dose will be higher in larger patients, particularly those who weigh more than 300 lbs. Risks can also be higher for patients with certain medical conditions and those who have recently received a substantial radiation dose at the same site (e.g., from another image-guided procedure or radiation therapy).

<table>
<thead>
<tr>
<th>Table 1. Interventional Radiology Procedures with Potential for High Skin Doses</th>
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<tbody>
<tr>
<td>Embolization (including chemoembolization)</td>
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<tr>
<td>Transjugular intrahepatic portosystemic shunt (TIPS) creation or revision</td>
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<tr>
<td>Vascular stent or stent-graft placement in the abdomen or pelvis</td>
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<td>Complex biliary interventions</td>
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<td>Nephrostomy procedures for stone access and manipulation</td>
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<tr>
<td>Complex, multilevel vertebral augmentation procedures (including vertebroplasty and kyphoplasty)</td>
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A number of techniques are used to minimize radiation dose while obtaining sufficient imaging guidance to accurately and safely perform fluoroscopically guided interventional procedures. These techniques include patient positioning, collimation, limited fluoroscopic time, pulsed fluoroscopy, avoidance of radiation exposure to sensitive organs and tissues, and x-ray beam re-positioning to prevent one area of skin from receiving an excessive dose. During the procedure, the interventionalist is made aware of the cumulative radiation dose and fluoroscopy time.

Massachusetts law requires that the radiation dose during fluoroscopically guided procedures be monitored and recorded and that any dose to the skin >2 Gy be noted in the medical record and reviewed by the institution’s Radiation Safety Committee. The dose is reported as the air kerma at the reference point, which is not the same as the skin dose. All statements of patient dose have some degree of uncertainty and are dependent on factors including patient size and position relative to the beam. In particular, the effect of backscatter from the patient can substantially increase the dose to the skin. Patients also respond differently to radiation due to biological variation and medical history.

If the estimated radiation dose to the skin is <2 Gy, no deterministic effects of radiation are anticipated. If the exposure is in the range 25 Gy, some transient erythema and hair loss at the site of exposure may develop within two weeks and recover in the midterm. At doses of 510 Gy, transient erythema is more likely and may be more prolonged, and hair loss may be permanent at the site of exposure. At doses of 1015 Gy, the skin reaction is likely to be more severe, with the possibility of dry or moist desquamation, which may lead to permanent skin weakness or dermal atrophy.

Institutional policy at Mass General dictates that if the radiation dose (measured as air kerma at the reference point) is >5 Gy during a procedure, the case is reviewed by the radiologist responsible for follow-up and the Radiation Safety Committee is informed of the case. In addition, a letter is sent to the referring physician that documents the skin exposure in Gy, describes possible signs and symptoms of exposure, and plans for patient follow-up (Appendix A - download PDF). On average, approximately five such letters are issued each month at our institution.
Scheduling
Appointments for fluoroscopically guided procedures can be made on ROE (mghroe.org) or by calling 671-726-8396. The procedures are performed on the main campus of Massachusetts General Hospital in Boston.

Further Information
For more information regarding radiation exposure during fluoroscopically guided procedures, please contact Suvranu Ganguli, MD, interventional radiologist, or Bob Liu, PhD, medical physicist, Massachusetts General Hospital (617-726-3093).

We would like to thank them for their assistance and advice for this issue.

References


