Radiation Safety for Interventional Spine Procedures

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Myth: The dose of radiation used in performance of interventional pain procedures is inconsequential, and few measures are required to maintain radiation safety.

Fact: Radiation exposure at any dose carries some risk for both the patient and the healthcare team. Mitigation strategies for radiation exposure are governed by the principles of ALARA (as low as reasonably achievable). Adoption of simple and inexpensive tactics may reduce radiation exposure by more than 90%.

Fluoroscopic guidance is essential for the safe performance of interventional spine procedures (1), but the use of fluoroscopy introduces risks of radiation exposure. Those risks come in two general forms: deterministic and stochastic. Deterministic effects are dose-dependent effects resulting from rapid cell damage or death caused by ionizing radiation when molecules, stripped of their electrons, become free radicals that cannibalize their neighbors. However, deterministic effects are not related to the typical doses encountered in diagnostic or interventional radiology. Stochastic radiation risk refers to the chance that any ionizing radiation may induce damage to cellular DNA ultimately leading to cancer. Radiosensitivity is highest in undifferentiated and actively proliferating cells such as bone marrow, and least in muscle and brain. Epithelial and endothelial cells have intermediate sensitivity.

Controversy exists regarding radiation exposure risks from interventional spine procedures. The average annual background radiation exposure from natural sources for persons living in the United States is estimated to be 3 mSv. By consensus, measurable harm thresholds from radiologic exams are estimated to occur in the range of 50 to 100 mSv, below which exposure harm is considered speculative (2,3). Radiation exposures incurred during spinal injections are orders of magnitude less than background exposure and are measured in µSv (4). However, models based on the linear no-threshold theory estimate there is significant cancer risk even for doses extrapolated to near zero (5). This model maintains that no dose of radiation is safe.

Several important radiation safety principles apply to spine interventions. Foremost, physicians should always consider whether a proposed procedure has a high likelihood of success and whether it is warranted. Thereafter, if a fluoroscopically-guided intervention is performed, all prudent measures to reduce radiation should be implemented.

On the part of the physician, technical skill should be developed first through didactics and expert mentoring until efficiency is mastered, so as to minimize procedure time on patients. Physicians should be aware that certain features place patients at higher risk for developing cancer as a consequence of medical imaging: pregnancy, younger age, high body mass index (BMI), and female gender (6-9). Higher levels of radiation exposure occur routinely when lateral views or oblique projections are used, and during imaging of dense tissue volume as in patients with a high BMI. High exposure levels also arise during continuous fluoroscopy; high dose (boost), magnification (when conventional image intensifier equipment is used but not in fluoroscopy units utilizing flat panel detectors); and digital subtraction angiography (DSA). Review of previous imaging may identify anatomic variations that could modify or obviate the interventional plan.

For individual cases, specific practice measures can be routinely applied. Although only some of these measures have been quantified for validity, the face validity of the other measures seems self-evident.

Displacement

- Maximize the distance between the operator and the X-ray beam. Radiation decreases in proportion to the square of the distance from the source. Stepping back one meter during imaging may reduce exposure to scatter to the operator by 90%.
- When practical, the operator should stand on the image intensifier side of the table during lateral and oblique views (10).
- Maximize the distance between the X-ray tube and the patient by positioning the image receptor closer to the patient.
Shielding

- Shield with lead. The majority of radiation exposure for personnel comes from scatter. Only 1% of the X-rays incident on the patient reaches the image-recording device, and the rest are either absorbed by the patient or scattered throughout the room. Shielding with lead or lead equivalents may reduce scatter exposure by more than 50%. Personal shielding with lead aprons and thyroid shields are paramount. Leaded eyewear is recommended for conditions of heavy exposure. The use of lead skirts surrounding the fluoroscopy table and lead portable barriers placed between the X-ray source and personnel have demonstrated value.

Imaging technique

- Orientate the beam before acquiring the first image, in order to eliminate the need for repeated adjustments (11).
- Collimate the beam to reduce the field of exposure to the minimal number of landmarks required to complete the procedure safely. The collimator uses lead shutters to confine the X-ray beam to a narrow area. This reduces both the volume of tissue in the patient exposed to radiation and the scatter of radiation from the patient.
- Use pulsed fluoroscopy. Continuous fluoroscopy acquires images at 30 frames per second, which is near the flicker fusion threshold for the human eye (24 Hz). Reduction of the acquisition rate incrementally results in a less robust image, but experienced operators have found that image quality is acceptable at rates of eight frames per second. Use of slower image acquisition rates is termed “pulsed fluoroscopy”. Implementation of pulsed mode can significantly reduce radiation exposure.
- Use intermittent needle advancement and last image hold. After each advancement of the needle, remove the hands from the field and step back before checking the position of the needle. Quick looks of 0.2 seconds produce an image of equal brightness and contrast as continuous exposure. Hold the image. Plan any adjustments by considering the held image. Progress towards the target can be assessed by comparing with the previously held image. This protocol avoids unnecessary exposure of the patient to continuous radiation while the physician works out what to do next.

- Consider the implications of the automated brightness control feature. A radio-dense object placed within the X-ray beam triggers the X-ray unit to work harder to try to penetrate the object. This results in higher doses of X-rays emanating from the tube. Lead hand shields, leaded gloves, lead shielding, and metal instruments should not be positioned within the active beam as they may defeat the other radiation mitigation maneuvers employed (12).

Dosimeter badges

Elapsed “on” time tabulated by the fluoroscopy unit is only an approximation of the effective dose calculation because it does not take into consideration collimation, differences between various C-arm machine models, and other radiation dose management strategies. Monitoring dosimetry badge readings remains the critical endpoint (4). Use of dosimeter badges by all personnel is mandatory.

Digital Subtraction Imaging

For procedures carrying a risk of inadvertent intra-arterial injection, some physicians have argued that DSA is superior to continuous real-time fluoroscopy for detection of intravascular needle placement (13,14), but the superiority of DSA over conventional fluoroscopy in differentiating intra-arterial from intravenous placement is unproven. Given that use of DSA results in significantly higher radiation exposure, physicians should always consider whether the use of DSA is worth the increased risks associated with the incremental X-ray exposure (4). The Spine Intervention Society, as a member of the Multi-society Pain Workgroup, agreed that it was premature to recommend DSA for routine use (15).

Conclusion

Ionizing radiation has potential for harm at any dose. An understanding of radiation physics coupled with equipment safety training improves patient care. Strategic implementation of radiation mitigation tactics involving technique modifications and equipment changes may reduce exposure for the patient and the healthcare team by up to 97% (16).
References