# Technical Principles for Interventional Procedures

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**ABSTRACT**

Fluoroscopically guided interventional (FGI) procedures provide alternative means to conventional surgery to alter structure and function in the body. At times, these minimally invasive techniques are preferable to conventional surgery. Procedure goals should be pre-specified including personnel, equipment, time and anticipated results. The consent process requires an explanation of benefits, risks and alternatives. For fluoroscopically guided procedures, this includes a discussion of radiation exposure, dose and risk. It is often assumed that the gravity of the medical situation merits the radiation exposure. However, for many fluoroscopically-guided procedures, there is neither the Class nor Level of Evidence to warrant this assumption. The ALARA (as low as reasonably achievable) principle is central to the medical use of radiation in all patient care [1]. Recognition of ALARA is applicable both to FGI and the overall imaging paradigm.

**INTRODUCTION**

FGI are therapeutic procedures. Radiation exposure to patient and medical staff may be substantial. Effective dose exposure to the patient can exceed 100 millisieverts [2]. Major radiation injury to skin or eye is rare, but prolonged or repeated fluoroscopy to a single area with peak skin dose greater than 15 gray is a sentinel event according to the Joint Commission [3]. Sometimes, such exposures are necessary for the successful treatment of the patient. This requires the judgment of the operating physician and the patient's entire health care team.

Deterministic and stochastic effects of radiation exposure can occur. Deterministic effects are dose-related and can be seen from hours to many weeks after FGI. Deterministic effects generally focus on cutaneous injury. Stochastic effects, particularly neoplasia, are also dose-related but probably uncommon against the greater baseline frequency of fatal malignancy in the United States [2,4].

In children and young adults, consideration of stochastic effects of radiation requires greater attention due to the increased susceptibility to radiation and long life expectancy [5,5].

## RADIATION MANAGEMENT

### Before the procedure

Make sure that the imaging examination is clinically indicated and necessary. Has a similar examination been performed recently or at another institution that would suffice to answer or address the clinical issue in question? Is there an alternative examination, such as MRI or ultrasound, which does not require the use of ionizing radiation? Due to recent concerns about the use of general anesthesia in children that remain unresolved, is there an examination for the pediatric patient that does not require the use of general anesthesia [7]?

Once it is determined that the procedure is necessary, plan the procedure. Ensure that all relevant clinical records, imaging tests and surgical records have been reviewed. Except to answer the clinical question requiring FGI, the procedure is not the time or place to re-answer previously known information about anatomical variations or post-surgical anatomy [8].

As best as possible, the procedure should be carried out in a deliberate and stepwise manner according to the prescribed plan. FGI are commonly coupled with diagnostic evaluation in the same procedure (e.g., catheter angiography). The treatment plan may be altered by imaging findings in the course of FGI. In many cases, the potential findings can be anticipated with scripted, or predetermined, responses. Ancillary staff or equipment should be ordered in advance and available in the procedure room as the procedure commences [9,10].

When possible, meet with the patient, family and close advisors in advance to discuss the proposed procedure, its risks, benefits and potential complications. For FGI, this must include a discussion of potential radiation effects. Good materials are available in print and online to guide clinicians in these discussions [11].

### During the procedure

I was once told by a mentor I respect immensely a quotation commonly attributed to Louis Pasteur: "Chance favors the prepared mind." I believe this to be true and the concept functions on two levels: 1) If the operator anticipates potential responses or consequences, then the operator is better prepared to address these occurrences; and 2) untoward consequences are less likely to occur because the conditions that would permit their occurrence have been anticipated and not permitted.

Work efficiently. Know your assistants and the staff in the room. Maintain sterility, which is not a trivial statement working with large pieces of equipment including fluoroscopic and anesthesia machines.

Always use modern, fluoroscopic equipment that is designed for FGI. Many dose-saving features have been incorporated into these machines, and modern detectors are increasingly efficient. Avoid the use of portable, fixed C-arm fluoroscopes, which cannot be optimized for the lowest patient and staff exposures. New technologies allow reductions in fluoroscopic dose rates without loss of image quality. However, the increasing complexity and expectation of FGI may offset reductions in dose rate due to long procedure length, simultaneous biplane imaging, and rotational imaging for 3-dimensional reconstruction and road-map guidance.

Most FGI systems are highly modifiable. It is important to have close contact with vendor services, medical physicists and biomedical engineering at your institution. There is a tendency for vendor services to optimize imaging on FGI systems to accommodate visual preferences of the operating physicians, often at the cost of higher X-ray tube output. There are important differences between the expectations of physicians in different nations, regions and institutions. From my perspective, image quality involves compromises based on an understanding of X-ray tube output, dose-rate exposure to patient and staff, and imaging needs for diagnosis and safe performance of FGI. In all cases, compromises must be reached between image quality and radiation output [8].

Understanding that high-dose FGI can occur, let's review additional methods to avoid this occurrence [12,13]. Shield patient and staff from any unnecessary radiation exposure using a variety of malleable lead and lead-equivalent panels, sheets and aprons. Keep imaging receptors as close to the patient as possible. Only operate the fluoroscope when imaging of some form of activity is required with the area of interest centered in the detector. Collimate whenever possible. Avoid geometric and electronic magnification when possible.

Learn to use lower frame rates during fluoroscopy and road-map imaging. For example, I routinely use two frames per second during fluoroscopy for diagnostic catheter manipulation and three frames per second during microcatheter manipulation in the cerebral circulation. These functions can be easily selected on some FGI systems but may require setting changes by the vendor in others.

Minimize the use of digital subtraction angiographic (DSA) acquisitions as much as possible. The majority of radiation exposure during FGI comes from DSA image acquisition rather than fluoroscopy. Storing static or sequential fluororadiographic images may suffice to document procedural accomplishments. For vascular procedures, minimize catheter time in the vessels. There is no substitute for training and experience to select the best tools to accomplish a task on the first attempt during FGI.

Both fluoroscopy time and estimated dose area product should be monitored during the procedure. If a procedure approaches or reaches the substantial radiation dose level (SRDL), the operator should consider discontinuation or staging of the planned procedure, if possible.

**After the procedure**

Radiation dose metrics should be recorded in the medical record for each patient [14].

**QA/QI and peer review**

Procedures that reach or exceed SRDL should be included in standard peer-review process. Patients should receive education and counseling detailed separately.

**SUMMARY**

FGI offer the ability to perform minimally invasive procedures to improve patient outcomes, patient satisfaction and reduce length of stay and hospital cost when appropriately selected and properly performed. Careful planning and execution of these procedures using scrupulous technique can reduce procedure risk as well as radiation exposure to the patient and hospital staff.

**REFERENCES**

1. NCRP Report No. 168. Radiation dose management for fluoroscopically-guided interventional medical procedures: National Council on Radiation Protection and Measurements; 2010. Available at: http://www.ncrponline.org/Publications/Press_Releases/168press.html. Accessed September 19, 2014.

2. Stecker MS, Balter S, Towbin RB, et al. Guidelines for Patient Radiation Management. JVIR 2009; 20: S263-S273. Available at: http://www.jvir.org/article/S1051-0443(09)00344-3/fulltext. Accessed October 10, 2014.

3. The Joint Commission. Sentinel event policy and procedures. 2007; Available at: http://www.jointcommission.org/Sentinel_Event_Policy_and_Procedures/. Accessed September 30, 2014.

4. American Cancer Society: Cancer Facts and Figures 2014. Available at: http://www.cancer.org/research/cancerfactsstatistics/cancerfactsfigures2014/. Accessed September 30, 2014.

5. Health risks from exposure to low levels of ionizing radiation: BEIR VII - Phase 2. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. National Academies Press 2006. Available at: http://www.nap.edu/openbook.php?isbn=030909156X. Accessed September 30, 2014.

6. Higson, D, Letters to the editor: Beir Vii-2. J Radiol Prot, 2005. 25(3): p. 324-5. Available at: http://iopscience.iop.org/0952-4746/25/3/L01/pdf/0952-4746_25_3_L01.pdf. Accessed September 30, 2014.

7. Hofacer RD, Deng M, Ward CG, Joseph B, Hughes EA, Jiang C, Danzer SC, Loepke AW, Cell age-specific vulnerability of neurons to anesthetic toxicity. Ann Neurol, 2013. 73(6): p. 695-704. Available at: http://onlinelibrary.wiley.com/doi/10.1002/ana.23892/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false.

8. Duncan JR, Tabriz D, Improving performance during image-guided procedures. J Patient Saf 2014. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24921628.

9. Makary MA, Sexton JB, Freischlag JA, Holzmueller CG, Millman EA, Rowen L, Pronovost PJ, Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. J Am Coll Surg, 2006. 202(5): p. 746-52. Available at: http://bcpsqc.ca/documents/2012/12/SQAN-Teamwork-Communication-Makary-et-al-Operating-Room-Teamwork-among-Physicians-and-Nurses.pdf. Accessed October 10, 2014.

10. Sexton JB, Makary MA, Tersigni AR, Pryor D, Hendrich A, Thomas EJ, Hozmueller CG, Knight AP, Wu Y, Pronovost PJ, Teamwork in the operating room: frontline perspectives among hospitals and operating room personnel. Anesthesiology, 2006. 105(5): p. 877-84. Available at: http://journals.lww.com/anesthesiology/Fulltext/2006/11000/Teamwork_in_the_Operating_Room___Frontline.6.aspx. Accessed October 10, 2014.

11. Image Wisely: Radiation safety information and resources for referring practitioners. Available at: http://www.imagewisely.org/Referring-Practitioners/Articles/Radiation-Safety-Information-and-Resources-for-Referring-Practitioners. Accessed September 30, 2014.

12. Miller DL, Balter S, Dixon RG, et al., Quality improvement guidelines for recording patient radiation dose in the medical record for fluoroscopically guided procedures. JVIR, 2012. 23(1): p. 11-8. Available at: http://www.jvir.org/article/S1051-0443(11)01256-5/fulltext. Accessed October 10, 2014.

13. Radiation protection in fluoroscopy: International Atomic Energy Agency. Available at: https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Posters/fluoroscopy-posters.htm. Accessed September 30, 2014.

14. Balter S, Moses J, Managing patient dose in interventional cardiology. Catheter Cardiovasc Interv, 2007. 70(2): p. 244-9. Available at: http://onlinelibrary.wiley.com/doi/10.1002/ccd.21141/abstract. Accessed October 10, 2014.