A Practical Roadmap to Safer Labs: What to Fix First, Second, and Third

A stepwise approach to reducing radiation risk during fluoroscopically guided interventions, centered on optimizing the imaging system, PPE, and shielding system.

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With the steady increase of fluoroscopically guided interventions (FGIs) in recent years, interventionalists are being exposed to higher doses of radiation, which can increase the lifetime risk of deleterious effects. It is critical for operators to take every opportunity to decrease dose and improve patient and staff safety. There are three vital radiation protection principles that must be considered for any intervention that involves ionizing radiation: time, distance, and shielding.[1] Exposure time should be minimized to only what is necessary to complete the procedure. Both patients and providers should maintain the maximum possible distance from the radiation source, and providers should use appropriate personal protective equipment (PPE) and adequate shielding. Due to case complexity, vascular surgeons experience radiation exposure levels several orders of magnitude higher than other interventional specialties.[2] We have recently reported that level of vascular trainee experience also factors into increased radiation dose.[3] These findings demonstrate the need for optimization of both radiation safety education and operating room setup to improve safety. What do we need to fix first?

FIRST: OPTIMIZE THE SYSTEM

Higher image quality can be achieved with fixed systems compared to conventional portable C-arms because these units are enabled with advanced image processing capabilities.[4,5] Upgrades and updated software versions for radiation unit systems are key to ensuring optimal performance. We have reported significant decreases in radiation dose for both the AlluraClarity system (Philips) and the Clear VD11 PURE platform (Siemens Healthineers), when their respective dose-lowering software was used over the standard manufacturer software.[6,7] Using state-of-the-art, up-to-date units can make a significant dose impact for all individuals within the operating room.

Intraoperative adjuncts for fluoroscopy can also significantly lower dose. Incorporating live-image digital zooming for FGIs significantly reduces radiation dose to both patients and operating staff, as demonstrated in our study that evaluated its use during fenestrated/branched endovascular aneurysm repairs.[8] This technology allows additional reference images for display, which can result in a more comprehensive visualization throughout cases, aid the operator(s) in procedure execution, and provide a safer environment in the room. A second adjunct is image fusion, via a road-mapping tool that can create three-dimensional (3D) vessel images and provide guidance to the operator during FGIs.[9] Another recent technology available for use is FORS (Fiber Optic RealShape, Philips), which uses light reflected along optical fibers enclosed within wires and catheters, allowing a live three-dimensional (3D) reconstruction of endovascular devices.[10] FORS has been proven to work with adequate precision, accurate 3D device registration, and no limitations in workflow or detection for radiation system units.[11,12] One shortcoming of FORS is the limited array of wires and catheters and decreased torque control versus regular catheters, which is set to be improved with a newer catheter hub for upcoming generations of this technology. Within the same spectrum, the electromagnetic-based IOPS intraoperative positioning system (Centerline Biomedical) has been developed. This technology also creates 3D image reconstructions of endovascular devices employed for use and enables the use of 3D maps with preoperative CTA images.[13] A sterile self-adhesive tracking pad is placed in the lumbar zone of the patient and requires a noncontrast-enhanced cone-beam CT scan for verification. With IOPS-compatible guidewires and catheters, off-the-shelf catheters and wires can also be used, ultra-high definition can be obtained, and viewing angles and magnification can be customized to permit visualization from intra-aortic angles. With additional investigation, this can further strengthen the benefits and impact on radiation safety.

SECOND: OPTIMIZE THE PPE

PPE is essential for all team members during FGI. According to clinical guidelines, the standard element that must always be worn is an apron with a thyroid collar and a minimum 0.35-mm lead equivalence.[4] An important consideration for operators lies between comfort and protection given the lifelong performance and volume of FGIs. We have shown that wearing thinner lead can provide similar protection versus thicker lead (86% vs 89% radiation attenuation rates),[14] while alleviating some of the musculoskeletal strain.

Adjunctive PPE has been designed to enhance radiation exposure reduction. The main question is: Which of them actually work? Compared to sleeveless aprons, leaded arm sleeves have demonstrated significant radiation attenuation to the chest wall, optimizing ionizing radiation protection to breast tissue for female operators.[15] Leg wraps have also increased radiation protection during complex FGIs, as the majority of scatter x-rays are to the lower body.[16] Radiation protective gloves have been developed for use during FGIs; initial evidence recommended against their use given the potential increase of scatter radiation to both operators and patients, but we have reported effective hand radiation dose reduction when wearing protective gloves without increasing operator body dose.[17] The use of these gloves should be considered during FGIs when the operator's hand is in close proximity to the beam.

Unfortunately, we have shown that leaded eyewear and leaded surgical caps do not decrease radiation dose to the eye or brain of interventionalists when worn during FGIs. They are ineffective because the x-rays that hit the eye and brain are from angles not attenuated by the cap and glasses.[18,19] The best protection for the operator's head is to pull in the ceiling-mounted shielding. We have developed a patented face shield that significantly decreases both operator eye and brain dose and should be commercially available soon.[20]

THIRD: OPTIMIZE THE SHIELDING

Innovation to reduce radiation exposure has led to the development of next-generation shielding systems. The EggNest Complete system (Egg Medical, Inc.), for example, is composed of a series of shields and covers around and under the table, reducing up to 93% of overall radiation exposure and 98% primary operator radiation dose compared to standard shielding.[21] The Rampart system (Rampart IC) is another novel shielding system that features both a 1-mm lead-equivalent mobile shield plus additional table shields; Crowhurst et al reported a 100% radiation dose reduction for primary operators.[22] Both of these systems have proven to be effective and able to be adapt to operators' workflow. The literature has reported data for simulated settings as well as interventional cardiology/cardiovascular intervention.

New, soon-to-be published multisociety guidelines suggest that these units, as well as other next-generation shielding systems, should be considered standard of care for hybrid operating rooms and catheterization labs.

CONCLUSION

The time is now to protect ourselves from the harmful effects of occupational radiation exposure. The appropriate use of shielding systems, coupled with updated equipment and correctly worn PPE, is the key to a safer endovascular suite for all members of the team. ■

1. Tanenbaum MT, Figueroa AV, Costa Filho JE, et al. A narrative review of intraoperative adjuncts and techniques to minimize radiation during complex endovascular aneurysm repair. JVS Vasc Insights. 2024;2:100058. doi: 10.1016/j.jvsvi.2024.100058
2. Kiang SC, Huh AS, Davis JR, et al. Health Care system-wide analysis identifies high radiation use factors and behaviors in surgery. Am Surg. 2021;87:616-622. doi: 10.1177/0003134820951488
3. Solano A, Shih M, Klein A, et al. Analysis of radiation exposure learning curves for vascular surgery trainees during fluoroscopically guided interventions. J Vasc Surg. 2025;82:267-272. doi: 10.1016/j.jvs.2025.03.178
4. Modarai B, Haulon S, Ainsbury E, et al. Editor's choice - European Society for Vascular Surgery (ESVS) 2023 clinical practice guidelines on radiation safety. Eur J Vasc Endovasc Surg. 2023;65:171-222. doi: 10.1016/j.ejvs.2022.09.005
5. Rehman ZU, Choksy S, Howard A, et al. Comparison of Patient radiation dose and contrast use during EVAR in a dedicated hybrid vascular OR and mobile imaging. Ann Vasc Surg. 2019;61:278-283. doi: 10.1016/j.avsg.2019.04.019
6. Kirkwood ML, Guild JB, Arbique GM, et al. New image-processing and noise-reduction software reduces radiation dose during complex endovascular procedures. J Vasc Surg. 2016;64:1357-1365. doi: 10.1016/j.jvs.2016.04.062
7. Pizano A, Khurram A, Chamseddin K, et al. New imaging technology system reduces patient radiation dose during peripheral arterial endovascular interventions. J Vasc Surg. 2022;76:500-504. doi: 10.1016/j.jvs.2022.03.865.
8. Timaran LI, Timaran CH, Scott CK, et al. Dual fluoroscopy with live-image digital zooming significantly reduces patient and operating staff radiation during fenestrated-branched endovascular aortic aneurysm repair. J Vasc Surg. 2021;73:601-607. doi: 10.1016/j.jvs.2020.05.031
9. Stangenberg L, Shuja F, Carelsen B, et al. A novel tool for three-dimensional roadmapping reduces radiation exposure and contrast agent dose in complex endovascular interventions. J Vasc Surg. 2015;62:448-455. doi: 10.1016/j.jvs.2015.03.041
10. Finnesgard EJ, Simons JP, Marecki H, et al. Fiber Optic RealShape technology in endovascular surgery. Semin Vasc Surg. 2021;34:241-246. doi: 10.1053/j.semvascsurg.2021.10.001

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11. Megens M, Leistikow MD, van Dusschoten A, et al. Shape accuracy of fiber optic sensing for medical devices characterized in bench experiments. Med Phys. 2021;48:3936-3947. doi: 10.1002/mp.14881
12. van Herwaarden JA, Jansen MM, Vonken EPA, et al. First in human clinical feasibility study of endovascular navigation with Fiber Optic RealShape (FORS) technology. Eur J Vasc Endovasc Surg. 2021;61:317-325. doi: 10.1016/j.ejvs.2020.10.016
13. Muluk SC, Elrakhawy M, Chess B, et al. Successful endovascular treatment of severe chronic mesenteric ischemia facilitated by intraoperative positioning system image guidance. J Vasc Surg Cases Innov Tech. 2022;8:60-65. doi: 10.1016/j.jvscit.2021.11.001
14. Solano A, Pizano A, Ramanan B, et al. 0.35-mm lead-equivalent aprons provide similar protection to interventionalists compared to 0.5-mm lead-equivalent aprons during fluoroscopically guided interventions. JVS Vasc Insights. 2025;3:100154. doi: 10.1016/j.jvsvi.2024.100154
15. Ramanan B, Pizano A, Solano A, et al. The addition of a leaded arm sleeve to leaded aprons further decreases operator upper outer quadrant chest wall radiation dose during fluoroscopically guided interventions. J Vasc Surg. 2024;79:948-953. doi: 10.1016/j.jvs.2023.11.042
16. Ramanan B, Pizano A, Timaran CH, et al. Operator lower leg radiation dose during fluoroscopically guided interventions is effectively reduced by wearing lead-equivalent leg wraps. Ann Vasc Surg. 2023;89:161-165. doi: 10.1016/j.avsg.2022.09.031
17. Solano A, Klein A, Siah MC, et al. The use of radiation protective surgical gloves reduces hand radiation exposure without increasing operator radiation dose during fluoroscopically guided interventions. J Vasc Surg. 2025;82:875-881. doi: 10.1016/j.jvs.2025.05.015
18. Kirkwood ML, Klein A, Guild J, et al. Novel modification to leaded eyewear results in significant operator eye radiation dose reduction. J Vasc Surg. 2020;72:2139-2144. doi: 10.1016/j.jvs.2020.02.049
19. Kirkwood ML, Arbique GM, Guild JB, et al. Radiation brain dose to vascular surgeons during fluoroscopically guided interventions is not effectively reduced by wearing lead equivalent surgical caps. J Vasc Surg. 2018;68:567-571. doi: 10.1016/j.jvs.2017.12.054
20. Kirkwood ML, Klein A, Timaran C, et al. Disposable, lightweight shield decreases operator eye and brain radiation dose when attached to safety eyewear during fluoroscopically guided interventions. J Vasc Surg. 2022;75:2047-2053. doi: 10.1016/j.jvs.2021.11.067
21. Riley RF, Kamen J, Tao A, Gomez-Cardona D. Comparative effectiveness of the EggNest complete shielding system to standard shielding in the cath lab. Am Heart J Plus. 2025;54:100543. doi: 10.1016/j.ahjo.2025.100543
22. Crowhurst JA, Tse J, Mirjalili N, et al. Trial of a novel radiation shielding device to protect staff in the cardiac catheter laboratory. Am J Cardiol. 2023;203:429-435. doi: 10.1016/j.amjcard.2023.07.050

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