

# How concerned are you regarding radiation exposure over a high volume of challenging SFA cases, and what safety measures has your facility implemented?



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*He has stated that he has no financial interests related to this article.*

I am concerned about radiation exposure in general—not only when performing challenging superficial femoral artery (SFA) cases that may involve long fluoroscopy time. The first reason to be concerned about radiation exposure is the patient, although the cumulative risk caused by (repetitive) interventions is not as high as the cumulative risk (high volume) operators are exposed to. My main concern as an operator therefore remains to limit my own exposure as much as possible in order to reduce the stochastic effects of radiation (tumor induction/carcinogenesis and genetic effects) and the deterministic (nonstochastic) effects on the lens of the eye. Exposure to the eye needs special attention, as posterior subcapsular lens changes are dose-related, and one study found these changes in 50% of interventional cardiologists as compared to < 10% in control subjects.<sup>1</sup>

All measures that comply with the “as low as reasonably achievable” (ALARA) principle, which are well known in (diagnostic) radiology, will provide a benefit. The simple act of collimating the x-ray beam and trying to avoid a large field of view will benefit both patient and operator. Also, recent technical developments that use dose-reduction algorithms (software-based image

processing such as Clarity, Philips Medical Systems) and use of new flat detector systems (eg, Q.zen, Siemens Healthcare) can lead to dose reduction of up to 73% and 50%, respectively.

Additional reduction of radiation exposure to the operator can be achieved by lowering scatter radiation, increasing the distance to the x-ray source, and last but not least, lead protection.

Reduction of scatter radiation can be achieved by optimizing the positioning of C-arm and the position of the image intensifier/detector. By increasing the distance to the x-ray source, dose reduction will be exponential. For this reason, I always step out of the room (into the control area) when performing digital subtraction angiography. A phantom study has shown that a 6-second digital subtraction angiography series of 3 frames per second yields an effective dose between 0.91 and 1.46 mSv, as compared to a 6-second fluoroscopic imaging that results in an effective dose between 0.14 and 0.2 mSv. During the procedure, I try to keep as much distance from the C-arm as possible, although this is of course limited by the length of the catheters that are used.

Lead protection consists of protective clothing and the use of lead curtains/shields. Protective clothing should not only include a lead apron (personally, I use a double-thickness, extra-long apron), but also thyroid protection and leaded eyewear. The role of protective helmets/caps still needs to be established. Lead curtains should extend from the side of the table to the floor. Additional shielding can be done by (ceiling mounted) transparent shields.

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Medical imaging procedures in modern health care systems have advanced at an exponential rate over the last 20 years. Endovascular procedures are increasingly becoming more complex, with new emerging technology-driven techniques. Consequently, patients and team members (physicians, fellows, nurses, and techs) are exposed to increased radiation doses during these procedures. Also, there can be significant individual variations in radiation dosage depending on the experience of the interventionist related to technique and habit. The consequences of increased radiation exposure may not manifest for several decades and include an increase in lifetime risks of leukemia and lymphoma, as well as cancers of the thyroid, lung, breast, gastrointestinal track, and brain. Other effects include radiation dermatitis and radiation sickness, infertility, and cataracts.

Our institution has adopted the ALARA principle, which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as is practical. The International Commission on Radiological Protection recommends a dose limit of 1 mSv/year to the general public and 20 mSv/year for radiation workers, averaged over 5 years and not exceeding 50 mSv in any 1-year period. For perspective, modern cardiac interventional procedures incur an average dose of 0.05 mSv per procedure. Our group has limited radiation exposure to patients, operators, and staff by implementing low-dose radiation protocols in the cath lab and operating room. We found that by simply performing an interventional procedure in a low-dose protocol setting, we were effectively reducing the total radiation exposure for any given procedure by tenfold. In addition, we consciously make every effort to minimize fluoroscopy and screening times by refraining from continuous activation of the fluoroscopy machine and instead perform intermittent short exposures only when necessary.

We also limit the use of magnification, as it can incur two to three times the radiation of a normal view, and use collimation whenever possible. Last, multiple barriers are used to reduce exposure from radiation scatter including table-side lead shields and ceiling-mounted mobile acrylic shields, which can reduce radiation exposure to the brain and eye by a factor of 20.

Inappropriate use of protective equipment and poor technique will often lead to unacceptable high radiation

exposure dosages, even during a straightforward interventional procedure. The primary operator should possess the required interventional skills and practice essential safety maneuvers to reduce radiation exposure. Ultimately, the physician in an interventional suite is responsible for the amount of radiation exposure to the patient and coworkers, and it is their responsibility to familiarize themselves with various safety features to maximize radiation protection.

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With the recent publication of studies showing a direct relationship between radiation exposure and health hazards affecting interventional cardiologists, an old subject comes back to life, stronger than ever, as it is now supported with scientific data, which is shaking up the field and leading to very needed behavioral modifications. Currently, thanks to increased awareness of peripheral artery disease, along with the raging epidemic of diabetes and obesity (coupled with the inability to efficiently decrease tobacco consumption), we treat a much larger number of patients with SFA chronic total occlusions (CTOs) and continue to strive to treat longer and more complex lesions.

With the advent of new and improved technologies for the endovascular treatment of SFA CTOs has also come the inherent prolonged exposure to radiation, which affects the operator, the staff, and the patient. Unfortunately, as it is well known, the length of the procedure is directly proportional to the amount of radiation exposure that all of the stakeholders are submitted to.

At our institution, besides following the well-known ALARA principle (well described throughout this article), we have been using extravascular ultrasound to not only guide access but also interventions in the lower extremities, significantly decreasing the exposure to radiation. Patients are prepped in a sterile fashion, and the entire leg is exposed over the sterile field in order for the ultrasound technician to be able to scan up and down the limb as necessary to allow the operators to directly visualize wires, catheters, CTO crossing, atherectomy, and reentry devices.

Extravascular ultrasound also allows us to directly and accurately assess the vessel size to adequately choose the appropriate size balloons and stents.

Beyond the standard radiation safety measures, we are also using zero-gravity lead, lead goggles, extra lead skirts attached to the C-arm to protect the second operator (working from a retrograde tibial position), leaded gloves, table drapes and mobile barriers. Some people are using lead hats, however, we have not embraced those yet...



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At our institution, we perform 1,500 peripheral procedures every year, including 700 SFA cases. In the subgroup of challenging SFA cases, our two main concerns regarding radiation exposure are patient and operating team related.

First of all, the general and well-known radiation protection rules (following the ALARA principle) are strictly applied by all members of the team. Secondly, the core technology of our brand new imaging system (Discovery IGS 740, GE Healthcare) reduces radiation in a substantial way without degradation of image quality. One commonly accepted metrics of detector efficiency is the detective quantum efficiency, which balances dose versus image quality<sup>2</sup> and has to be as high as possible.

Moreover, system intelligence, which automatically compensates for patient size and orchestrates all x-ray parameters (kilovoltage, ampere) provide us with the best possible image quality while keeping the dose as low as possible. Regarding system design, having an intuitive touchscreen at the tableside to define imaging needs helps us optimize exposure during each phase of the case. Having a large display monitor reduces the need for magnification (since the image appears bigger) and thus enables us to follow the recommendation to “use the largest acceptable image detector field of view, with collimation, rather than image magnification.”

Last but not least, patient dose monitoring and awareness during the procedure helps avoid deterministic effects due to local patient peak skin dose. Our system features a tool to visualize the beam trajectory projection in real time on the patient model and estimates the local cumulated dose (Figure 1).<sup>3</sup> This leap in technology has the potential to help us understand how to perform procedures in a safer way.

It is extremely important to benchmark your own radia-



**Figure 1. Dose map. Real-time visualization of cone beam projection and cumulated local dose.**

tion exposure to published references. It helps us move forward and implement advanced imaging capabilities such as two-dimensional roadmapping from previous record acquisition without additional x-rays to reposition the system. Patient dose data have been reported for peripheral procedures,<sup>4</sup> reaching a median dose area product (indicator of stochastic risk) of 46 Gy cm<sup>2</sup> for TASC II type C lesions in the SFA. With modern hybrid operating room equipment, we can benefit from three-dimensional fusion imaging technologies to guide complex aortic and embolization procedures. Hertault and al have recently published on the way preoperative three-dimensional CT angiography fusion with two- and three-dimensional registration helps dramatically decrease the patient dose during complex endovascular aneurysm repair procedures.<sup>5</sup>

The future will show if this technology can also be implemented during the treatment of complex SFA pathology.



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Endovascular treatment of patients with critical limb ischemia makes up a large part of our daily work. These patients often have complex infrainguinal lesions leading to technically difficult procedures and making treatment

challenging and sometimes longer lasting with increased radiation exposure. Therefore, it is obligatory to have well-trained staff who have knowledge of and adhere to radiation safety procedures. Each staff member is responsible for personal monitoring to provide early notice in case the exposure is above the limits. Everyone wears lead aprons with a badge outside of the apron at the collar. Finger rings are worn on the hand where the highest exposure is expected. Leaded eyewear and thyroid shields are also routinely used nowadays. We also routinely use a transparent upper body shield suspended from the ceiling and positioned between the patient and the interventionist.

The physician performing the intervention is responsible for optimizing radiation protection. This means that a difficult procedure should not be extended without a realistic chance for successful revascularization. An experienced interventionist knows when a procedure is not likely to succeed and when to stop a procedure. Furthermore, sometimes it is prudent to reschedule a second attempt for a planned procedure at a later date, perhaps also with the assistance of an even more experienced colleague.

We always try to optimize image quality while minimizing the radiation dose. This goal can be accomplished by pulse fluoroscopy, with attention to the positioning of the image intensifier (it is placed as close to the patient as possible) and only including areas of relevance. Furthermore, we always try to minimize frame rates and the duration of image acquisition. A further important point is to limit digital subtraction angiography only for an accurate diagnosis—especially of the runoff vessels—and for documentation of the final result. Optimal collimation and distance of the image intensifier may not only help to reduce unnecessary exposure, but also improve image quality.

The best radiation protection is guaranteed by a skilled and experienced interventionist using state-of-the-art equipment for a clinically indicated and well-planned procedure.



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As cases become more complex and interventions involving total occlusions seem to be becoming the norm, fluoroscopy times have dramatically increased.

Fortunately, new technology continues to evolve as an alternative to angiography. The challenge is that angiography has been the standard for so many years, and it is what everyone is trained to use. Thus, the time and effort that it takes to adopt new technologies, as well as the added cost to already budget-strapped institutions, has kept angiography the standard. However, if physicians who perform these cases do not take care in addressing their fluoroscopy times, I believe that we will see increasing reports of cancers and other health-related problems in the future.

In our lab, we have adopted several measures, some of which are simple, that have reduced these exposure times. The staff is required to announce to the physician when fluoroscopy times have reached 30 and 60 minutes. Just the simple awareness of the time has reduced total exposure times. We also calculate the acceptable threshold of dye for the case based on creatinine clearance, and this is also announced when the physician is approaching this amount used. This has not only reduced dye-induced renal damage, but has also reduced the amount of images physicians are obtaining.

The use of intravascular ultrasound and optical coherence tomography (OCT) in our lab has had a tremendous effect on my own individual exposure. By routinely using intravascular ultrasound, I can assess the severity of disease without taking multiple angled views. The final interventional result can also be assessed with limited use of angiography.

Newer interventional devices have been developed with OCT for both crossing lesions, as well as atherectomy. Crossing can vary among cases and operators, however, the same standard applies: fluoroscopy needs to be used the entire time that you are crossing. By using OCT crossing devices, I frequently cross long total occlusions with little or no fluoroscopy. Hopefully, in the near future, the same will be done with atherectomy intervention as well. ■

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