Radiation Exposure, Effects, and Safety Measures for Vascular Operators

Radiation-related damage to DNA, advice regarding protective equipment, the promise of radiation-free imaging systems, the status of the upcoming ESVS radiation protection guidelines, and what future studies should address.

With Bijan Modarai, PhD, FRCS

One of your primary areas of study has been the effects of radiation exposure to operators during endovascular procedures, with specific focus on whether and how their DNA might be damaged or altered.[1] What led you to explore this particular effect of radiation exposure?

Vascular surgeons are performing a significant volume of increasingly complex x-ray–guided endovascular procedures. This carries a cumulative lifetime burden of chronic low-dose radiation that often commences as a young trainee. Whether this exposure remains within safe limits is determined solely by physical dosimetry, but dose data are often incomplete and do not account for individual variability in sensitivity to radiation. When I became interested in this area a few years ago, there was anecdotal evidence of an increased frequency of malignancy in high-volume operators but without any mechanistic insights as to why this may be the case. Radiation-related DNA damage had been measured in radiation-exposed workers (for example in the nuclear industry), and I wondered whether we could use the same techniques to find evidence of biological sequelae of exposure in endovascular operators.

On a practical level, how is DNA damage observed and measured?

This involves taking a small blood sample and processing it to allow detection of DNA damage in circulating lymphocytes, which are exquisitely radiosensitive cells. Processing involves staining the cell for a molecular marker of acute DNA damage/repair known as γH2AX, which increases in expression immediately after radiation exposure. Alternatively, the lymphocytes can be isolated, cultured in a dish, and probed for chromosomal markers of chronic DNA damage, which include chromosomal aberrations such as dicentrics. These aberrations reflect the cumulative effects of radiation exposure over several years.

What are the potential effects of this DNA alteration?

The majority of acute radiation-induced DNA damage sustained is successfully repaired by the cell; however, occasionally, a misrepair occurs, producing chromosomal aberrations that are responsible for a phenomenon known as genomic instability. Genomic instability is a characteristic of most cancer cells and is therefore associated with malignancy. What is less well known is the cancer risk associated with the extent of DNA alteration that we observe in radiation-exposed workers.

How would you briefly summarize your findings to date?

A few years ago, we studied the aforementioned markers of acute DNA damage in endovascular operators and found that immediately after performing aortic repair, γH2AX expression was significantly raised in their lymphocytes, returning to normal the following day. We did not see any response in operators who carried out open aneurysm repair. More recently, we have obtained samples from high-volume endovascular operators, analyzed their lymphocytes for evidence of chronic DNA damage, and found that chromosomal aberrations are detected at a significantly higher level compared with a matched cohort of radiation-naive surgical colleagues. It is important to acknowledge the contribution of the clinical and nonclinical scientists at King's College London, United Kingdom Health Security Agency and Brunel University. In particular, two of my clinical research fellows, Tamer El-Sayed and Mohamed Abdelhalim, for their outstanding work to accrue these important data.

Have you explored potential fetal or reproductive effects?

We have not looked at this specifically. Large cohort studies would be required to decipher any ill effects to the fetus and reproductive organs. It is imperative that pregnant operators promptly contact their institution's medical physics expert to instigate protective measures to minimize any exposure to the fetus in the operating room. Thankfully, the published literature suggests that with adequate protection, the radiation exposure to the fetus is very low during x-ray–guided procedures.

How have your findings affected your own approach to practical radiation protection? What advice do you share with colleagues with regard to protective lead and other shielding equipment?

The evidence of acute DNA damage in endovascular operators was a stark finding and unexpected. One interesting detail we noted was that there was no increase in γH2AX in operators who wore leg lead shielding. This suggests a significant, preventable exposure to lymphocytes and other tissues in the unshielded leg. Now, I always perform endovascular procedures with protective leg lead shielding. Our more recent findings of greater than expected chronic DNA damage and genomic instability in high-volume operators is also alarming, irrespective of whether a proven link to cancer risk exists or not. With this in mind, I would urge colleagues to ensure maximal personal lead garment protection and optimal fixed shielding use, including optimal positioning of ceiling-mounted lead shields, for example. We should all be cognizant of the ALARA (as low as reasonably achievable) principle (ie, aiming to carry out each and every procedure with the minimum amount of radiation possible). For example, this refers to avoiding excessive C-arm angulation, minimizing digital subtraction angiography, configuring settings on imaging systems appropriately, and accepting a lower image quality when it does not impact the safety of the procedural workflow.

What do you predict for the future of imaging systems in their capabilities for protecting operators and other staff?

The community, including manufacturers of imaging systems, are increasingly aware of the risk of deleterious effects associated with radiation exposure, and this is reflected in the pace of innovation in this space. The latest imaging systems now incorporate dose reduction software; this has led to incremental dose savings, and I hope it becomes standard of care in the next few years. Uptake of image fusion to aid navigation, particularly during complex aortic procedures, is increasing. I predict that, in time, definitive studies will demonstrate a radiation-sparing value for this adjunct, not only for aortic procedures but for other endovascular interventions, and that its use will become more ubiquitous. Other radiation-sparing modalities such as intravascular ultrasound are also likely to find more use in the endovascular operating room.

Finally, I believe that we are witnessing the dawn of technologies that will allow intervention with minimal reliance on x-ray guidance. One of the truly exciting prospects is the FORS (Fiber Optic RealShape) technology (Philips), which uses pulses of light to visualize devices and circumvents the need for fluoroscopic navigation.

You and colleagues from the European Society for Vascular Surgery (ESVS) have been working on guidelines for radiation protection. What is the status of the guidelines at this time?

We are currently working on the final draft and expect the ESVS guidelines for radiation protection to be published very soon. My Co-Chair, Professor Stéphan Haulon, and I are incredibly grateful to the team of experts, which includes not only vascular surgeons but radiation scientists, for their hard work to help us compile the guidance. These are the first radiation protection guidelines to be published by any vascular society, and the team has risen to the challenge of producing this document de novo. The guidance outlined will be instrumental in promoting better radiation safety during endovascular procedures and will help provide the information required by colleagues when they liaise with their institutions to ensure provision of optimal resources.

In what ways is standardization of radiation safety particularly challenging?

Awareness of the importance of radiation safety varies, as do the resources available to initiate safety measures. Another contributing factor is that legislation, including rules pertaining to training in radiation safety, differs from country to country. These are all reasons why a guidance document from ESVS is timely.

What additional studies are underway, and what studies are most needed next?

We are continuing studies aimed at assessing the biological significance of radiation exposure in operators. We now also have an additional focus on patients who undergo endovascular aortic repair given the recent debate surrounding whether radiation exposure during repair and that associated with subsequent surveillance imaging puts patients at increased risk of malignancy.

Most needed are prospective studies that aim to link lifetime radiation dose to biological markers of radiation exposure and major health outcomes in operators and patients. The current techniques required for carrying out assays of biological markers such as γH2AX and chromosomal aberrations are specialized and labor intensive. Developing high-throughput, validated assays would pave the way for one day using biological dosimetry as an adjunct to the physical dosimetry that currently guides safe exposure limits. ■

1. El-Sayed Tamer, Patel AS, Cho JS, et al. Radiation-induced DNA damage in operators performing endovascular aortic repair. Circulation. 2017;136:2406-2416. doi: 10.1161/CIRCULATIONAHA.117.029550

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