Radiation-induced injury in endovascular surgery: How long is too long?

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Vascular surgery has adopted minimally invasive techniques for a large proportion of procedures. Endovascular techniques can allow interventions for patients with comorbidities that make open procedures prohibitive and often are associated with shorter hospital lengths of stay and quicker recovery.[1] However, the use of this technology comes with risks, namely that associated with radiation exposure. Radiation affects everyone in the room during the procedure, including the patient, surgeon, assistants, and staff. Here we focus on a brief review of evidence related to radiation risks to the patient, with suggestions for best practices to minimize these harms.

EFFECTS OF RADIATION EXPOSURE

Radiation exposure is measured in Gray, which is 1 J/kg. Radiation effects of endovascular procedures are broadly grouped into two categories: deterministic effects and stochastic effects.[2] Deterministic effects on cells can be seen once a threshold amount of radiation exposure has been reached[3] and follow a standard dose-response curve.[4] A stochastic effect is due to a random mutation in a cell induced by radiation damage—prolonged exposure is not necessary to induce a stochastic effect, although the potential risk of a stochastic effect increases with additional radiation.[3] This factor can lead to the development of a malignancy, for example, the phenotype of this stochastic effect may take years to become apparent.[2] The best way to decrease both deterministic and stochastic risks is to decrease radiation exposure entirely. However, if the exposure itself cannot be avoided, steps can be taken to reduce the dose and duration of exposure.[5,6]

The threshold level beyond which deterministic effects might be seen is 2000 mGy.[7] These effects may be minimal or transient and can occur anywhere from immediately after surgery up to several weeks later.[8] The most common deterministic effect is skin damage owing to radiation; this damage is generally seen on the back, at the entrance point of the beams.[7] These are difficult to diagnose owing to their occurrence potentially much after the initial exposure.[7] These skin changes can range from erythema to necrosis, with the least severe reactions such as a transient erythema hypothesized to occur at doses of ≥6000 mGy.[8]

The Society of Interventional Radiology reported guidelines for the amount of exposure that should warrant both notification to the surgeon (2000 mGy peak skin dose or 3000 mGy reference point air kerma), as well as thresholds to initiate explicit patient follow-up (3000 mGy peak skin dose or 5000 mGy reference point air kerma).[9] These values should also be mandated institutionally. At our institution, a substantial radiation dose is set at a cumulative air kerma of 5000 mGy, at which point a note is put in the chart and the patient is provided with discharge instructions to check for skin effects on the back for ≤1 year after the radiation exposure. At doses of >8000 mGy, there is an alert that is triggered in the system for a medical physicist to review the case and provide an estimated skin dose, and when this exceeds ,000 mGy, the interventionalist is informed that the patient needs additional follow-up. This is also the case if the peak skin dose exceeds 15,000 mGy in a 6-month period.

METHODS OF MEASUREMENT

There are different ways to monitor radiation exposure, including both indirect and direct methods.[7] Indirect methods include fluoroscopy time, the dose area product, and the cumulative air kerma. Fluoroscopy time is not a good estimate of total radiation exposure, because it does not quantify the dose based on the field size or position or the mode used (ie digital subtraction angiography vs fluoroscopy) and varies based on different models.[7] The dose area product reports the total amount of radiation energy delivered to the patient and is calculated based on the energy of the x-ray beam multiplied by the area of the beam.[7] This metric has been reported to be valuable as a measurement of stochastic risk, but not necessarily of the deterministic skin dose to the patient.[7] The cumulative air kerma is the radiation dose measured at a specific reference point and can provide a better estimate of the skin dose, but does not account for change in body habitus, which can greatly affect the

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The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

J Vasc Surg Cases Innov Tech 2025;11:101680

2468-4287

https://doi.org/10.1016/j.jvscit.2024.101680

total skin dose.[7] Peak skin dose, otherwise known as acute radiation exposure, is usually measured in Gray and is a marker of the deterministic effect.[7] This process adjusts the cumulative air kerma by taking into account patient and table positioning and body habitus.[7] The effective dose is the weighted sum of the mean dose to radiosensitive organs in the body.[4] This takes into account tissue sensitivity and is a marker of the stochastic effect.[7]

RISK FACTORS AND WAYS TO REDUCE EXPOSURE

All radiation-driven interventions are based on the ALARA principle (as low as reasonably achievable). The switch to hybrid rooms rather than using a portable C-arm has resulted in decreased average radiation exposure, in one study decreasing exposure by 40%.[4] Other ways to reduce radiation exposure include minimizing fluoroscopy time where feasible, decreasing use of digital subtraction angiography and magnification, decreasing the distance from the radiation source as well as C-arm angulation, collimating where appropriate, and using antiscatter grids.[3,6]

One of the greatest risk factors for radiation effects is obesity, because higher radiation doses are needed to penetrate increased skin depth.[7] Other risk factors include active tobacco use, diabetes, hyperthyroidism, malnutrition, and any other factors affecting tissue healing or integrity.[7,8] Aspects of the procedure, such as the type and complexity of the operation, are paramount in determining radiation exposure.[6]

FUTURE HORIZONS

There are new methods on the horizon, including electromagnetic tracking and fiber optic shape sensing that can improve the spatial sensitivity of the C-arm, thus reducing the need for prolonged radiation exposure.[5] Electromagnetic tracking uses a magnetic field generator and sensor coils in the tip of the catheter to render a three-dimensional image of the catheter. Fiber optic shape sensing uses optical fibers to create three-dimensional reconstructions without the use of radiation, reducing exposure.[5] Testing and preliminary trials are underway with promising results; however, the significance of these results varies by tool. There are learning curve- and cost-associated limitations related to these new methods, but they represent new horizons in the field of endovascular surgery.

CONCLUSIONS

Radiation is a valuable diagnostic energy, but it has its side effects. The ALARA principle should be strictly adhered to; any radiation use beyond what is necessary is too long. Future investigations into safer ways to perform endovascular procedures are ongoing, to enable procedures that can achieve the same goals as conventional radiation, but with fewer risks.

FUNDING

None.

DISCLOSURES

None.

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Submitted Oct 18, 2024; accepted Nov 7, 2024.