

RADIATION PROTECTION IN COMPLEX ENDOVASCULAR INTERVENTIONS

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ABSTRACT

Complex endovascular intervention is becoming increasingly widespread as a minimally-invasive alternative to open vascular surgery. It can be used to treat simple abdominal aortic aneurysms, as well as complex juxtarenal and aorto-iliac aneurysms.

However, it has become increasingly recognized that chronic low-level radiation exposure to the endovascular interventionist is hazardous. We sought to quantify the increase in radiation exposure incurred by complex intervention, as well as define strategies to protect the operating team.

KEYWORDS EVAR; FEVAR; ALARA; endovascular; an aneurysm

Introduction

Advances in expertise and device technology in the field of endovascular intervention have allowed surgeons and interventionists to perform an increasing number of complex procedures. However, with a growing number of complex procedures being performed, there is also a higher radiation dose and thus an increased risk of radiation exposure to both the patient and the interventionist. Indeed, the tribute has recently been paid to Scottish and international endovascular pioneers who have been significantly affected by the effects of chronic radiation exposure radiation. [1]

Complex interventions of endovascular TAAA repair, such as Fenestrated, Branched, and CHIMPS stent-graft insertion, require longer procedural times and thus increase the length of time the patient and operator are exposed to radiation. [2] These are critical interventions that save the patient the morbidity of major open surgery, however, require close fluoroscopic

monitoring during deployment.

Increased radiation can lead to an increased risk of radiation-induced injury, which is divided into deterministic and stochastic effects.[3,4] Deterministic effects are those that occur at a threshold value as a direct result of increased radiation exposure in the short term. Stochastic effects are those that occur years after exposure and have no threshold value.[4] To reduce the injury associated with radiation exposure some interventions can be put in place, such as increased operator education, implementing the ALARA principle, and modifying certain technical risk factors such as magnification mode, C-arm angulation, collimation and the position of the table. The aim of this report is to highlight the growing issue of radiation exposure in complex vascular and endovascular interventions, the short and long term effects, and emphasize the importance of interventions to reduce the associated risk.

Discussion

Complex procedures, in particular, FEVAR and BEVAR have become more common due to the complexity of cases and advances in technology. However, these procedures have increased procedural times and thus lead to increased radiation exposure to the patient and operator.[2] In one study, the dose of an FEVAR was calculated as 6.5Gy, which is above the threshold for deterministic radiation-induced injury.[3] Deterministic injury occurs at threshold levels. A threshold 2-3Gy is considered a risk for skin injuries. For the patient, the risk comprises of inflammatory changes of the skin.[4] Transient erythema due to

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radiation exposure has been reported to occur at a threshold dose of 2Gy.[3] The severity of the injuries increases with the doses, and thus can be minimized by reducing repeated exposure to high doses of the skin. The operator is also at risk of deterministic injury, the most relevant being subcapsular induced cataracts, which has no threshold value. Appropriate use of safety equipment such as shields and lead eyeglasses can reduce the risk.[4] Stochastic injuries do not have a threshold value and include malignant developments. The risk of malignant effects is greater to the operator than to the patient, as the effect of the radiation is cumulative.[4] The patient is mainly at risk by prolonged CT-follow-up, which can be avoided, especially in younger patients, by using alternative imaging modalities whenever possible. Radiation also varies due to the patient and procedural risk factors. Obesity is a risk factor for radiation injury, as a higher radiation dose is required to penetrate the patient's soft tissue.[3] In fact, obese patients, have a risk three times greater than patients with a normal BMI, of skin induced injuries. This higher radiation dose in obese patients also leads to increased exposure to operators.

Some studies have reported a reduction in radiation exposure in complex vascular and endovascular interventions by certain preventative measures. Kirkwood et al. in their study concluded that direct education to vascular surgeons reduced the radiation dose exposure in these complex procedures.[3] Educated use of operating factors and the operator's knowledge of published guidelines during fluoroscopy contribute to a reduction in radiation dose. In the CX Symposium, Barry Katzen stated that simple measures focused on reducing the amount of radiation produced, such as altering fluoroscopy dose, frame rates, and times, and appropriate use of protection, such as lead aprons, eye protection, thyroid shields, and maintaining a safe distance, can all have a profound effect on radiation reduction.[5]

In a report in 2014, it was found that most institutions around the world adopt the ALARA (As Low As Reasonably Achievable) principle, which has shown to be of benefit.[6] In the CX Symposium, Stephen Haulon also stated it should be mandatory for institutions to follow the ALARA principle, to carefully evaluate the risk of exposure to radiation for the patients and operators.[5] The NCSU Radiation Safety Manual contains a comprehensive list of the ALARA principle with some precautions and safety measures to be taken when performing radiological procedures[7]. However, three major principles allow a safe maintenance of radiation dose[8]:

1. **TIME.** This states that by minimizing the time of exposure, it directly reduces the radiation dose to which operators are exposed. This can be done by practicing procedures in a radiation-free simulated setting, which allows the operators to practice different techniques and approaches to reduce radiation exposure.
2. **DISTANCE.** This states that an increase in distance between the operator and the source of radiation can significantly reduce the exposure dose, e.g. by doubling the distance a factor of 4 reduces the exposure dose. This is because the main source of radiation to the interventionist is scattered radiation, which is radiation produced within the patient's tissue after being exposed to the primary X-ray beam, and this scattered radiation decreases in proportion to the inverse squared distance from the radiation source, which is the patient.[11]
3. **SHIELDING.** This states that using the appropriate absorb-

ing materials for the correct radiation source can majorly reduce the exposure dose, e.g. Plexiglas for Beta-emitting sources and lead to X-rays and Gamma-emitting sources.

Fusion imaging in Hybrid rooms is beginning to replace mobile C-arms. Hertault et al. demonstrated that this imaging technique when used by trained operators while applying the ALARA principle, significantly reduced the radiation exposure to the patient and operator.[9] It works by importing the patient's pre-operative images into the angiographic equipment, and then records a 2D/3D dataset by calcium outlines of the vessels or bony landmarks surrounding the vessel, which then forms a fusion volume, which follows the movement of the detector and table.[4,8] The fusion volume can adapt during the procedure if there are any configurational changes. This imaging technique allows for vessel catheterization and graft placement without a need for angiography, reducing the radiation exposure significantly.[8,11]

However, even though mobile C-arms lead to a higher amount of radiation exposure, there are some steps that can be taken with the C-arms to reduce that risk. M.A. Albayati et al. conducted a study that measured the effects of radiation exposure directly to the head during complex EVARs.[2] It was found that the radiation exposure to the head during these procedures was significantly higher, which was inversely related to operator height and C-arm angulation. It was found that C-arm angulations greater than 30 degrees were associated with higher radiation doses, and C-arm angulations less than 20 degrees resulted in a reduction of scatter radiation greater than 3-fold.

Collimation is another method used to reduce radiation exposure, which filters rays, only to allow those parallel to a specified direction through.[10] It avoids overlap of X-ray fields on the patient's skin, and this reduces scatter radiation.[3,10] Haqqani et al. found that the least radiation exposure to the operator was through maximized vertical and horizontal collimation.[9] In turn, collimation has the added benefit of improving image accuracy and limiting radiation exposure to the patient's surrounding tissues.

Conclusion

Radiation exposure in complex vascular and endovascular procedures is a growing issue, especially the stochastic effects on operators. With endovascular therapy becoming more common and the complexity of cases leading to increased operating times, the radiation doses increase, with an increased risk to operators. The CX Symposium highlighted this issue, naming very well-renowned vascular surgeons that had succumbed to the long-term effects of radiation damage in the form of cataracts, brain tumors, carotid artery stenosis and other problems.

It is important for operators to be aware of the dangers of radiation exposure and the ways in which they can rectify the situation.

The evidence explored in this paper report have shown that education of the operators, application of the ALARA principle, fusion imaging, C-arm angulation and collimation, all if applied appropriately and wherever possible, can significantly reduce the radiation dose to which operators and patients are exposed to.

It is essential to apply these techniques and monitor patients and operator doses to ensure an efficient reduction in radiation exposure.

Disclosure Statement

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