Special Article

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X-ray Burns — Painful, Protracted, and Preventable

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ABSTRACT

Very high doses of x-ray may produce deep burns in the backs of patients having fluoroscopically guided cardiac interventional procedures. While these incidents are uncommon they can be prevented by judicious limitation of fluoroscopy and timely repositioning of the x-ray tube. Better education and improved methods for dose mapping should make these distressing complications a thing of the past.

Key words: radiation injury, x-ray burns, percutaneous coronary intervention complications, risks fluoroscopy

Cardiologists are aware that some of their procedures carry a small, but definite risk of inducing cancer, hence the emphasis on minimizing dose when performing fluoroscopy, computed tomography (CT) angiography, and nuclear medicine studies. Both the staff and the patient are exposed to this risk, a fact that is appropriately emphasized during fellowship training. The chance of radiation producing cancer is stochastic, the likelihood of inducing cancer is random and it increases as exposure to radiation increases. There is no threshold below which the cancer risk is zero. For the patient, the effective dose* of radiation for diagnostic coronary angiography is about 5 mSv and for stenting procedures, and for CT angiograms and nuclear scans it ranges from about 10 to 25 mSv for standard protocols.[1–3] In a mixed-age population of individuals each exposed to 100 mSv, about 1% are expected to develop radiation-induced cancer with mortality in about half of them.[4]

On the other hand, cardiologists are very often unaware that excess focal exposure to x-rays can produce deterministic radiation injuries, among which are delayed erythemas (at absorbed doses** to the localized skin area of about 6 Gy) and painful deep necrotic ulcers (at doses in excess of 18 Gy).[5] Deterministic injuries do not occur unless a certain critical level of radiation is delivered. Once the critical level is surpassed, the likelihood of seeing the effect rises rapidly and, as dose continues to accumulate, the severity of the effect as the dose increases. Usually, these occur in the setting of long and complicated percutaneous coronary interventions or electrophysiological ablation procedures where the x-ray beam has been focused mostly on just one entry site (usually the back). Some publications graphically illustrate the typical appearances seen.[6,7]

When fluoroscopy and cineangiography were used only for diagnostic purposes, serious debilitating burns were so rare as to be almost absent. Some cardiologists do recall that mild erythemas that later healed were sometimes seen. However, with greater x-ray use during interventions, the frequency of severe radiation-induced cutaneous injuries is on the rise, appearing in the medical literature and in the courts.[8]

In 1994, the Food and Drug Administration (FDA) issued an advisory to doctors and hospitals alerting them to this problem and suggesting ways to avoid it.[5] Why then is it a surprise to many practicing cardiologists that grotesque and painful ulcers can and do occur?

The FDA advisory seems to have garnered little recognition and, in general, the response of hospitals has been less than diligent, primarily because the warning had no regulatory authority. Additionally, cases are quite uncommon; hence individual doctors were unlikely to have seen a case or to have felt compelled to scour the literature for more information. The most likely source of knowledge for cardiologists is the medical physicist, but communication between the 2 is often poor, being relegated to brief mandatory checks of the fluoroscope performed when the lab is unoccupied. Professional cardiology groups now recommend that interventionalists in training be taught about skin

*Effective dose is a hypothetical whole body dose that is used to assess stochastic risk from the amount of radiation actually delivered.

**Absorbed dose is the concentration of radiation energy deposited locally in tissue and is used to assess deterministic risk to the tissue involved.

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injuries and how to cautiously manage radiation delivery,[9] but no system exists to ensure that they attend the lectures or complete the course work that is entailed.

A further impediment to unmasking this demon of ignorance is the lack of good real-time monitoring of the patient's absorbed x-ray dose. The current standard, cumulated fluoroscopy time, is notoriously unreliable in the face of the many other variables that determine the instantaneous dose output of the fluoroscope and the direction of the beam.[10] While 1 step closer to reality, the dose area product (DAP), directly measured from the x-ray beam as it leaves the x-ray tube, is also a poor surrogate measurement as it aims to assess stochastic risk, not deterministic risk from the absorbed dose at any 1 skin location. Some systems can monitor free-in-air kerma produced at a point along the central axis of the x-ray beam. While more suited to the task of estimating skin dose, this method has other limitations and does not take into account the varying angles of the C-arm; thus doses to specific skin sites cannot be apportioned. Physicians will still have to be trained in the practical application of any new measurements to use them appropriately for procedure management.

Skin dose monitors, attached directly to the skin within the field of view, have been tried but they require careful placement and a commitment by the lab team that is usually reserved for focused teaching or research.[11] Industry has not followed-up on software programs that generate real-time dose-distribution maps because physician interest has been low and the added expense of such an add-on is discouraged by budget-minded administrators. For now, the 1 technique that can be used to record dose to the skin is a self-processing film-like material* but the film must be placed on the table under the patient and is cumbersome to use as a real-time monitor.

Given these concerns, what steps should an interventional cardiologist take to avoid creating a burn? Standard procedures include minimizing fluoroscopy and image acquisition (cine) time and limiting use of special high-dose modes to only times when absolutely needed. One should minimize the patient-to-image intensifier distance while ensuring that a healthy source-to-skin distance is also maintained. Do not allow an arm to enter the field as that will force the automatic brightness control to increase dose output and place the arm at risk for a deterministic effect. Avoid steep oblique and cranially or caudally tilted beam orientations except as a last alternative. Also avoid, as much as possible, orientations that place the spine near the center of the field, because this will additionally increase radiation output. Always remember that simply moving the tube angle will shift the x-ray beam to a new entry site.

In straight-forward routine cases, burns do not occur. It is the unusually long, complicated case, especially when the procedure is in an obese patient or where a single steep beam orientation is used, in which a high dose accumulates. The interventionalist may be focused on other problems (vessel salvage, trying to open a chronic total occlusion, escalating iodinated contrast dose, etc.) and the issue of radiation is not considered. Even when the duration of a difficult procedure is not unusually long, in the large patient with steep beam orientations the absorbed dose to the skin will be far greater. The extreme magnitude of the doses accumulated during these outlier cases has often caught interventionalists by surprise.

The risk of a burn is so uncommon that it rarely needs discussion before the procedure but, should a patient be heavily exposed, some discussion of the possibility of later skin injury is appropriate. While in rare instances some patients show nearly immediate signs of skin injury, the most frequent scenario is that the patient is discharged with absolutely no symptoms of injury, only to develop a rash days to weeks later. For procedures that have potentially delivered unusually high doses, the patient should be advised that injury to the skin may be a complication of the procedure and that the back of the patient should be examined weekly for the next 3 weeks for a rash. The patient should be told where to look for this rash (at the heavily-dosed area where the beam entered the skin) and to call the cardiologist's office to inform him/her. This way the patient will not be surprised by the event and can be referred to a dermatologist for immediate and appropriate treatment with radiation injury as part of the differential diagnosis. All discussions should be documented in the patient's chart.

The cath lab directors should encourage use of available dose-monitoring schemes and maintain vigilance for long fluoroscopy times or high doses and review any concerns with the staff. It would be helpful to include the medical physicist in such dialog and have him or her outline the characteristics of the fluoroscopy machine that influence x-ray output. Continuing education should be used to supplement each user's knowledge base. The American College of Cardiology recently issued a Clinical Competence Statement on Radiation Protection that summarizes much of what is known.[9]

It would be nice to think that new x-ray system strategies and technologies will lessen the risk of burns. However, burns are still being seen with the newer flat panel digital

*Gafchromic Media from International Specialty Products (Wayne, NJ, USA).

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acquisition systems[12] and their use has not regularly translated into lower procedural x-ray doses.[13,14]

As interventionalists, we must push industry vendors for greater transparency, not only in images, but also in quantifying the x-rays we inflict on the patient. As with many other things, it is only through improved data acquisition and better communication that these uncommon but distressing dose-related injuries will be prevented.

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