XA0101657

RADIATION INJURY OF THE SKIN FOLLOWING DIAGNOSTIC AND INTERVENTIONAL FLUOROSCOPIC PROCEDURES

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Abstract

Many radiation injuries to the skin, resulting from diagnostic and interventional fluoroscopic procedures, have been reported in recent years. In some cases skin damage was severe and debilitating. We analyzed 72 reports of skin injuries for progression and location of injury, type and number of procedures, and contributing patient and operator factors. Most cases (46) were related to coronary angiography and percutaneous transluminal coronary angioplasty (PTCA). A smaller number was documented after cardiac radiofrequency catheter ablation (12), transjugular intrahepatic portosystemic shunt (TIPS) placement (7), neuroradiological interventions (3) and other procedures (4). Important factors leading to skin injuries were long exposure times over the same skin area, use of high dose rates, irradiation through thick tissue masses, hypersensitivity to radiation, and positioning of arms or breasts into the radiation entrance beam. Physicians were frequently unaware of the high radiation doses involved and did not recognize the injuries as radiation induced. Based on these findings, recommendations to reduce dose and improve patient care are provided.

1. Introduction

The number of interventional cardiologic and radiologic procedures performed under fluoroscopy has grown markedly worldwide during the last decade [1]. Advances in interventional techniques have made more complex procedures possible. This trend results in increased fluoroscopy use and is accompanied by a sharp increase in the number of reported skin injuries. We reviewed over 70 case reports of skin injuries that resulted from fluoroscopic procedures [See, for example, reference 2]. More than 90% of cases were reported since 1996. Although the absolute number of injuries may appear very small when compared to the more than 700,000 interventional procedures performed annually [1], skin damage is likely to be under-reported. The main reason is widespread unawareness of this radiation effect and consequent inability of physicians to correctly diagnose it. Radiation damage can be serious. Chronic ulceration and tissue necrosis were documented in about half of all cases. The purpose of our review is to describe these injuries and to investigate common factors related to the patients and their procedures that may have led to the injuries.

2. Skin injuries

Radiation induced skin injury is usually not observed immediately after a procedure, but after a characteristic latent period in which the patient can be free of symptoms. The latent period is most often in the range of 2 weeks to 3 months, but varied in the reviewed case material from a few hours to more than 3 years. Skin injury represents a deterministic radiation effect that requires a radiation dose above a certain threshold. The following radiation skin effects were observed and are given in order of their time of onset (threshold doses are given in brackets). Skin erythema can occur within hours (early transient erythema, 2 Gy) or after 10 days (main erythema, 6 Gy). When a single fixed beam orientation is employed, lesions are typically sharply defined and match the entrance port of the radiation beam (Figure 1). Epilation can be seen after 3 weeks and can be temporary (3 Gy) or permanent (7 Gy). Erythema and epilation are early signs which, when observed, can serve as a warning signal indicating that a certain threshold has been exceeded.

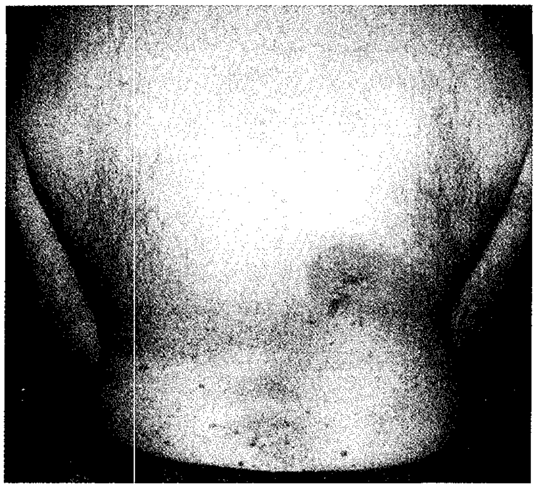

Fig. 1. Well demarcated erythema in large-chested man after PTCA of right coronary artery using stationary left anterior oblique and slightly cranial x-ray beam orientation

After 4 weeks dry or moist desquamation (14 Gy and 18 Gy respectively) can occur. Secondary ulceration (24 Gy) may arise after about 6 weeks, ischemic dermal necrosis (18Gy) after 10 weeks. Prophylaxis against local infection is essential in these cases. Wound healing is typically prolonged and less efficient due to microvascular radiation damage in the dermis, which leads to a relative ischemia. Ulcers which have slowly healed over an extended period of time have a tendency to recur, often provoked by trivial trauma. One of the problems of radiation ulcers is that they can increase in size and depth despite all treatment. Pain control can be a difficult task to achieve. Several cases are known to the authors in which deep tissue necrosis extended to involve muscles and bones. In at least 4 cases deep tissue ulceration was present for more than a year.

In a substantial number of reviewed cases (23%), wound healing could not be achieved despite intensive wound care. Skin grafting finally had to be performed (Figure 2). In a number of cases the initial graft was unsuccessful. Skin grafts are often complicated in these cases by the compromised vascular supply.

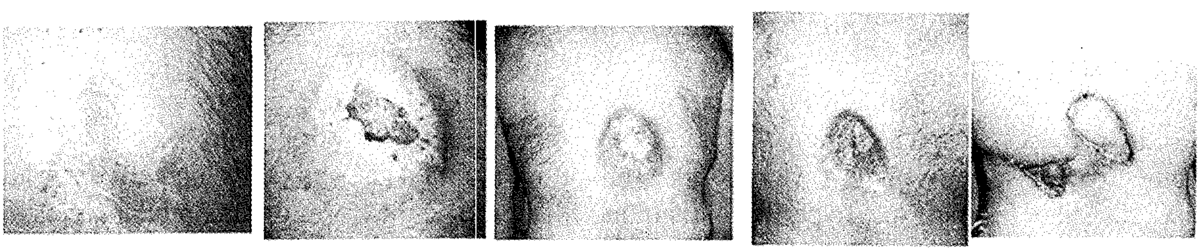

Fig. 2. Progression of injury in heavy-set male following TIPS procedure.
From left to right: injury at 4 months; 7 months; 9 months; 22 months; 23 months.

Late radiation sequela, which can be seen after 3 months to more than a year, are dermal atrophy (10 Gy) and telangiectasia (10 Gy). These, together with areas of hyper- and hypopigmentation, give the skin a poikilodermic appearance. Subcutaneous induration results from a relative increase in the fibrous component of the tissues and can be painful. It may limit motion of it occurs close to a joint (e.g. at the shoulder in cardiac procedures). We noticed radiation skin injuries at the breast in two female patients after interventional cardiac procedures. One patient was only 17 years old. Breast tissue in the adolescent is among the most sensitive tissues for development of radiation induced malignancies. This will significantly increase the patient's statistical risk for breast cancer in the future.

2.1. Which procedures have a potential of skin injury?

Out of 72 reviewed cases of fluoroscopically induced skin injuries, 46 cases (63%) were related to coronary procedures. The majority of these (43 patients) underwent percutaneous transluminal coronary angioplasty (PTCA). The high proportion of this procedure in the total number of reported cases reflects the high number of annually performed cardiologic interventions that far outweigh other interventional procedures (700,000 coronary procedures versus 30,000 other procedures). In decreasing order of prevalence, the location of the skin injury was: right and left scapular or subscapular area, right lateral chest below axilla, midback, and right anterolateral chest. The site of the injury corresponds to the site of the entrance beam and reflects the beam orientation predominately used during the procedure.
A smaller number of skin injuries was caused by cardiac catheter radiofrequency ablation (12 patients), transjugular intrahepatic portosystemic shunt (TIPS) placement (7 patients) and neuroradiological interventions (3 patients). The skin injury involved the back and arm in patients undergoing ablation and the midback and right subscapular area in patients undergoing TIPS procedures. Four patients had other interventions in the abdomen or chest. However, any fluoroscopic intervention has the potential to cause injury if the radiation dose exceeds the deterministic threshold.

2.2. What factors contribute to the injury?

In many reports, a substantial delay occurred between the initial moment the patient presented skin with changes to a physician and the moment the physician made the correct diagnosis. Physicians did not initially associate the injury with radiation from fluoroscopy. Patients were treated in the interim, without success, for a variety of other suspected causes. Meanwhile, some patients underwent a second fluoroscopically guided intervention with additional exposure to the same area. The correct diagnosis was sometimes delayed by several years, in one case the delay was more than 5 years. The latency period between the last intervention and the first appearance of the skin lesion probably contributes to the delay in diagnosis, as the physician is less likely to consider radiation as the etiology.

Several reports originating from radiation therapy literature indicate a correlation between certain diseases and an exaggerated radiation complication after treatment. These include connective tissue diseases (scleroderma, lupus erythematosus, mixed connective tissue disease), diabetes mellitus, hyperthyroidism and the homozygous form of ataxia telangiectasia [3]. Some chemotherapeutic agents are also known to increase sensitivity to radiation [4, 5]. A few reports from interventional work now cite these as probable sensitizing factors for some observed skin reactions.

Long exposure time to the same skin area was the most prevalent factor among the reviewed cases that resulted in skin injuries. Procedures were often difficult or prolonged due to complications, such as arterial dissection.

Extensive use of high magnification or high detailed-mode led to high dose rates. In some cases of skin injury, the physician used these modes exclusively. Cinefluorography is associated with a 10 times higher dose rate per imaging frame than conventional fluoroscopy. High doses can accumulate within minutes during this imaging mode.

Irradiation through thick masses of tissue increases the skin dose. Large patients, common in our study group, are therefore at higher risk for radiation damage. In a similar way, beam angulation increases the tissue pathlength for the x-rays to penetrate and puts the skin closer to the x-ray source. The skin dose, for example, increases by a factor of 4 when 30° cranial angulation are added to a 40° left-anterior-oblique (LAO) projection in a cardiac procedure [6]. Steep beam angles were frequently employed in the reviewed case material and contributed to the reported injuries.

In three cases of radiofrequency ablation procedures, radiation injuries were observed on the arm. In two cases, involving different procedures, skin lesions appeared on the breast. During the procedures these body parts were in the primary radiation beam in close proximity to the x-ray tube, resulting in very high skin doses.

In three cases equipment malfunction or other deficiencies were causative factors for the injuries.

2.3. What can be done to reduce the risk?

Physicians must be able to identify radiation-induced skin injuries in patients. Prior to performing a procedure, a detailed history of prior fluoroscopic interventions and any observed skin effects is essential. If the patient has had such procedures, a brief inspection of the skin is appropriate. The diagnosis of radiation-induced skin injury can often be made based on history and physical examination. Areas of skin injury are usually well defined and occur in typical locations. A skin biopsy may sometimes be helpful in excluding other causes, but should not be performed as part of "routine work-up" as they may result in a nonhealing ulcer.

Interventionalists must keep fluoroscopic on-times to a minimum. Fluoroscopy times or the actual radiation dose should be monitored. Normal values should be established for each procedure. If a procedure is more complicated than expected, or if the fluoroscopy times or radiation dose exceeds a certain limit, consultation with more experienced staff should be sought.

Pulsed fluoroscopy and heavy beam filtration provides imaging at a significantly reduced radiation dose and its use is highly recommended. The dose can be lowered by 50-70% with no perceivable loss in image quality.

Image magnification, high-resolution settings and cineangiography should be used and judiciously and sparingly.
If a procedure proves to be lengthy, the incident beam angle should be varied in order to expose different areas of skin. This will be effective only if the field of view is minimized by

collimation. Otherwise different projections will lead to overlapping radiation fields. General rules of dose reduction must be followed, e.g. the image intensifier should be kept as close to the patient as possible, the distance between x-ray tube and patient should be kept large. If large air gaps between the patient and image intensifier cannot be avoided, the grid should be removed, if possible, as it only adds to additional radiation without effective function.

Extraneous body parts, such as an arm or a female breast, have to be positioned and secured in a way that they will not be exposed in the primary x-ray beam.

Real-time dose monitoring enables the physician to recognize high dose levels and is recommended. The physician can take action to lessen the dose rate early if the dose monitor indicates high radiation levels. Dose monitors also keep track of doses from fluorography and eliminate the need to monitor fluoroscopy time. Increased output due to equipment malfunction can be recognized.

Patients who receive a high skin dose (e.g., in excess of 3 Gy) should be counseled and advised on examining their skin at the proper location. If any skin changes are observed, the patient should contact the physician who performed the procedure.

A good quality control program should be established to assure high standards in dose reduction and image quality.

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