Radiation Safety During Interventions of Coronary Chronic Total Occlusion

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Abstract: During percutaneous coronary interventions (PCI) for chronic total occlusion (CTO), prolonged procedures increase the risk of excessive radiation exposure. These situations harbor a major concern to protect patients and personnel in the cardiac interventional laboratory (CCL). Important questions regarding radiation safety for interventional cardiologists performing PCI for CTO lesions are discussed and concrete applications are suggested.

Keywords: Chronic total occlusion, radiation safety, percutaneous coronary intervention.

INTRODUCTION

During percutaneous coronary interventions (PCI) for chronic total occlusion (CTO), prolonged procedures increase the risk of excessive radiation exposure. These situations harbor a major concern to protect patients and personnel in the cardiac interventional laboratory (CCL). Important questions regarding radiation safety for interventional cardiologists performing PCI for CTO lesions are listed in Table 1.

MECHANISM OF RADIATION EXPOSURE

Initially, the radiation is emitted from the generator towards the patient. Most of the rays penetrate through the patient's body and reach the image intensifier. However, when hitting the patient's body from below the table, a significantly small amount of radiation reflect towards the personnel. Then after emerging from the patient's body, a small amount of radiation scatters towards the personnel. Finally, the third source of radiation is direct leakage from the generator. Therefore, of the various positions of the image intensifier, the largest radiation exposure to personnel standing on the right side of the patient are the left anterior oblique (LAO) cranial position or any steep caudal position.

PATIENTS AT RISK

Factors leading to higher radiation exposure include male gender, high body mass index (BMI), complex anatomy and lesions such as CTO. The median cumulative skin radiation dose is 1.5 Gray (Gy), a unit of absorbed radiation, with a

Table 1. Radiation safety questions for interventional cardiologists.

1.	What is the acceptable radiation dose for chronic total occlusion procedures?
2.	How do you program x-ray equipment in order to minimize the amount of radiation?
3.	How can you adjust capturing and storing pictures to maintain the appropriate radiation level?
4.	In what ways can you reduce the radiation exposure in obese patients?
5.	What type of follow-up do you plan to generate for potential radiation injury?

range 0.34 Gy to 4.5 Gy [1]. Generally, heavier patients and steep angles tend to increase radiation levels.

RADIATION INJURIES

The cumulative dose at which skin injury is likely is approximately > 10 Gy. The skin damage can occur after exposure to radiation (fluoroscopy time) for >120 minutes. However, the fluoroscopy time by itself is much less specific than the air kerma dose expressed in Gy, as it takes into consideration the various patient factors as described above. Skin damage usually occurs a few weeks after PCI. The skin eruption is usually characterized by an atrophic rectangular plaque on the left upper back. This is presented as mottled hyper- and hypopigmentation with reticulate telangiectasia. Histologically, the eruption demonstrates epidermal atrophy, hyalinized and irregularly stained collagen, and telangiectasia of superficial vessels in the dermis

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[2]. Other critical injuries due to excessive radiation are listed in Table 2.

Table 2. Possible damage caused by radiation.

1.	Skin injuries: Erythema, temporary or permanent depilation, burns, dermal necrosis, and/ or ulceration.
2.	Cataracts.
3.	Bone marrow dysfunction.
4.	Tissue atrophy.
5.	Infertility.
6.	Cancer or benign tumor e.g. left side brain tumor.

PRACTICAL APPLICATIONS

All cardiac catheterization laboratories should have a radiation safety program along with a goal to reduce radiation exposure as low as is reasonably achievable (ALARA). The universal precautions to protect patients alongside operators include effective shielding and appropriate position of XR equipment [3]. They are listed in Table 3.

Table 3. Universal measures to decrease radiation exposure.

1.	Use the ceiling mount lead shield to protect the upper body, head, and the eyes.
2.	The lead skirt attached to the table should be positioned correctly to protect the lower body.
3.	Have an additional extra-shielding of X-Ray equipment if there are frequent cases of chronic total occlusion are performed in the cardiac catheterization laboratories.
4.	Keep the table as high as necessary.
5.	Keep the image intensifier as close to the chest of the patient as possible, especially in the cranial position.
6.	Good collimation and prevention of excessive radiation is very important for quality of the image because radiation scatter causes image degradation.

The other changes include: the high or low setting of radiation during fluoroscopy or cine angiography, the magnification of image, and/ or the position of the image intensifier. All of these changes can be manipulated at the operator's disposal.

In general, pulsed fluoroscopy reduces radiation exposure when compared to continuous fluoroscopy. Low dose fluoroscope gives 27nGy per pulse and standard dose fluoroscope gives 38nGy per pulse, while normal cine fluoroscope gives 200 nGy per pulse. The low dose setting (115kv) gives an adequate image for PCI in the left anterior descending coronary artery, the proximal right coronary artery (RCA), or the left circumflex (LCX); because these arteries do not move a

lot (compared with obtuse marginal (OM) or the distal RCA). The standard (120kv) setting is reserved for wire crossing when a sharp image is needed. Therefore, cine angiography could be potentially avoided if the quality of image on fluoroscope is good enough [1].

The speed of image capturing (frame rate per second) should be set as low as possible, preferably at 7.5 frames per second instead of 15 frames per second (based on X-ray equipment in the US) [3].

At the beginning of the PCI, frozen frame images could be saved as maps or guides so repeated fluoroscopes could be minimized. The use of magnified imaging should also be restricted unless necessary (as when positioning a coronary stent). Extreme cranial positions of the image intensifier causes the most radiation to the operator, this position should only be used when crossing the occlusion stump or distal re-entry in distal RCA or OM branch. Critical measures practiced by operators in order to decrease the radiation risk are listed in Table 4 [1-3].

Table 4. Measures practiced by operators to decrease radiation exposure.

1.	Press the pedal only when looking at the screen monitor.
2.	Stand as far away as possible from the radiation source because the radiation danger decreases rapidly with distance by the inverse square law.
3.	Monitor radiation dose to both patients and operators. Monitor fluoroscope time if measurement of radiation dose is not available.
4.	Document your actual dose of radiation by wearing two radiation detectors: one under the lead apron, and one outside the lead apron on the left shoulder.
5.	Wear the thyroid collar

OPTIMAL PROJECTION ANGLE

During critical moments, such as crossing the proximal or distal cap, or distal re-entry, the operator needs the best images of the areas in focus which differ according to the region of interest (ROI). The operator should explore the angles in which the stump can be seen most clearly, especially at the entry point. The best outcomes occur when the two projection angles are perpendicular to the vessel axis of the ROI and also to each other (orthogonal projection), as the summation of the blind area is the smallest in these orthogonal projections [1].

MULTI-SLICE COMPUTED TOPOGRAPHY

Further measures to decrease the use of radiation during PCI for CTO lesions include the use of pre-PCI multi-slice computed tomography (MSCT). MSCT is an imaging modality that could outline the shadow of an angiographically invisible and totally occluded artery. The information provided by MSCT includes: visualization of an occluded artery and collateral vessels, length and diameter of the vessel in the CTO lesion, and the morphology of a CTO lesion [1].

A volume-rendered (VR) image is useful to characterize an overall picture of the coronary arteries around the heart. The VR function is used to identify the location, tortuosity, calcification, bifurcation of a CTO lesion, lesion morphology, and the wire direction. A slab maximum intensity projection (MIP) image can be one of the most crucial adjunctive diagnostic images for CTO PCIs. The location of plaque, the degree of calcification, and the length of the lesion on the slab MIP image are closely related to the information provided by a coronary angiography. The lesion morphology can also be ascertained using this function. In addition, a multiplanar reconstruction image qualitatively identifies a route for vessels and location of calcification and remodeling. It is also helpful to gauge the degree of calcification [1].

In a typical example that favors the use of MSCT for a CTO PCI, the collateral vessel could not clearly be seen on baseline angiography. However, MSCT identified a short and soft occlusion, without severe calcification, that was located only in the distal artery. As a result, an intermediate wire was easily advanced into the distal artery within a few minutes of reviewing the MSCT images. As with any technique, pre-procedural MSCT is not mandatory for every CTO case. Yet, it can be useful in identifying the actual occlusion length and visualizing the collateral vessels. Therefore, MSCT should be performed when the occlusion length and/or the vessel course is unclear by conventional angiography. Obtaining an MSCT prior to such CTO cases

would also minimize radiation exposure during the actual PCI [1].

CONCLUSION

PCI of chronically occluded coronary arteries is a challenging field which can yield significant improvement in quality of life. We have described various techniques which can be utilized to ensure that radiation exposure is kept as low as reasonably achievable, both for the benefit of the patients as well as operators.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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