Improved Radiation Protection for Physicians Performing Cardiac Catheterization

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Physicians and their assistants performing diagnostic angiography must be concerned with the radiation exposure they receive. The introduction of hemiaxial projections for imaging has increased diagnostic accuracy but has also greatly increased the physicians' exposure to scattered radiation. This increase is especially critical for the eyes and thyroid of the physician who routinely performs these procedures. To reduce such exposure a ceiling-suspended shield (60 × 45 cm), made of 6.4 mm glass with a 19.5 kg/m² (4 lb/ft²) lead equivalency, was developed. During procedures the shield is interposed between the physician and the region of the patient acting as the source of scattered radiation. The degree of radiation protection to the operator was assessed by measuring the distribution of scattered radiation in the vicinity of the operator with and without the shield. The effectiveness of the shield was determined in the 30° right anterior oblique (RAO), 5° left anterior oblique (LAO), 35° LAO, and 50° LAO-15° cranial angulations. At critical heights such as the level of the eyes and thyroid, scattered radiation levels were reduced by 85% or greater in all angulations. Without interfering with the physician's ability to observe the patient or manipulate the catheter, this shield can significantly reduce the physician's exposure to radiation.

Several investigations have measured radiation exposure to the physician during cardiac catheterization and coronary angiography.[1-7] Most of these investigations were performed using a fixed undertable x-ray tube or a U-arm system. The exposure levels reported in these studies are excessive for physicians who perform angiography routinely. Guidelines have been established for occupational radiation exposure.[8] Because of exposure to critical organs such as the eyes and thyroid, compliance with these guidelines may require that the physician perform only several procedures a week.[1,2]

Radiographic systems with high output capacity generators and x-ray tubes have recently been introduced, thus providing the potential for better definition of vessels and lesions on cineangiography. In addition, C-arm and parallelogram support structures are being used which allow the physician to easily obtain hemiaxial views. These developments enhance the diagnostic accuracy of coronary angiography[9-11]; however, the radiation exposure to the operator is potentially greater with these systems than with older undertable-mounted x-ray tube systems.

To reduce the physician's radiation exposure, a protective shield was developed in the cardiac catheterization laboratory at the San Francisco Veterans Administration Medical Center. The purpose of this study was to assess the effectiveness of this shield in reducing the radiation exposure to the physician performing cardiac catheterization with a poly C-arm system.

Methods

The radiographic equipment consists of a Poly Diagnost C System and a Maximus M-100 Generator (Philips Medical Systems). The Poly Diagnost C has a U-arm type imaging system with a parallelogram support. In addition to the left-right rotation of the x-ray tube and intensifier, the parallelogram support allows isocentric cranial and caudal angulation.

The radiation protection shield (Fig. 1) is made of transparent 6.4 mm glass (60 × 45 cm) with a 19.5 kg/m² (4 lb/ft²) lead equivalency. Attached to the bottom of the glass is a piece of flexible leaded rubber 22 cm long with 19.5 kg/m² lead equivalency.

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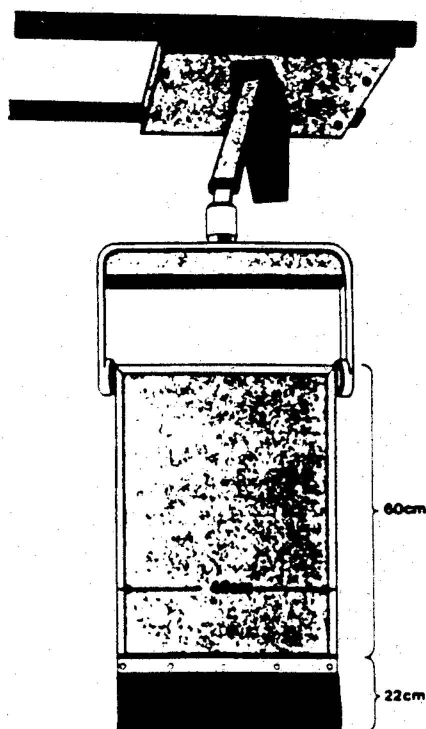

FIGURE 1. Diagram of the radiation protection shield with ceiling mount.

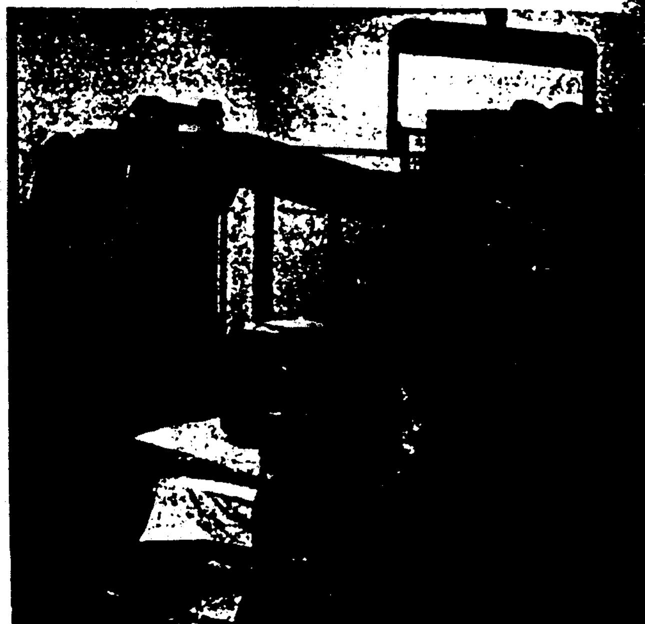

FIGURE 2. Photograph illustrating the use of the shield during cardiac catheterizations performed through the femoral approach.

The shield is mounted on ceiling rails with a swivel arm allowing for easy mobility in the longitudinal and vertical planes. In addition, it is counterbalanced to allow for easy vertical movement. During procedures the shield is draped with a sterile, transparent cover. Therefore, the physician performing the procedure can position the shield between himself and the x-ray scattering source (patient and x-ray tube) (Fig. 2). The flexible leaded rubber attached to the bottom of the glass is designed to lie on the patient, thus providing additional protection by eliminating the scattered radiation which would reach the operator beneath the leaded glass.

The radiation protection afforded by the shield was determined by measurements of radiation levels in the vicinity of the operator with and without the shield in place. A Rando anthropomorphic phantom was used in this study. This whole body phantom contains human bones and is comprised of materials which simulate human soft tissue. Its shape is that of an adult male weighing 70 kg with a 22 cm chest diameter. The radiation levels were measured with a Victoreen Panoramic survey meter during fluoroscopy at 95 kVp and 1 mA. The effectiveness of the shield was determined with the x-ray tube aligned in the following projections: 30° RAO, 5° LAO, 35° LAO, and 50° LAO-15° cranial angulation.

Results

Table I gives a comparison of radiation exposure levels for the various anatomic locations of the operator without and with the shield. The values listed are for an operator who is 5 feet, 10 inches tall and standing in the position shown in Figure 2 with the height of the catheterization table at 90 cm. These radiation levels were obtained with the phantom simulating the patient. As shown in Table I, there is a significant reduction in radiation exposure afforded by the shield to all anatomic areas above and including the pelvis. For the eyes and thyroid, which are of critical concern, there was an 85% or greater reduction in exposure levels for all angulations.

To further illustrate the effectiveness of this shield, the isoexposure curves for the 50° LAO-15° cranial angulation are shown in Figure 3. This angulation is commonly used during cardiac cineangiography to better visualize the left main coronary artery, the proximal left anterior descending artery, and the distal right coronary artery. Using this cranial angulation, the eyes and thyroid of the operator are exposed to 41 mR/h during fluoroscopy at 95 kVp and 1 mA. For a 10 second cineangiogram at 30 frames/s and 2.8 mAs/frame, the exposure to the eyes and thyroid of the operator would be 9.6 mR. For an identical angiogram with the x-ray tube in the same projection, use of the protective shield would reduce the exposure to these organs to 0.2 mR.

It should be noted that the effectiveness of the shield does not significantly depend on the x-ray tube potential. The equivalent lead thickness of this shield is 1.58 mm. Thus, even for x-rays of 150 kV, less than 3% will penetrate the glass.

Discussion

Concern has been expressed over the radiation exposure to physicians performing cardiac catheterizations. Previous studies have documented that the physician performing catheterization and his assistant can receive significant radiation exposure.[1–7] The irradiation of the physician primarily results from scattered radiation arising within the patient from the tissues penetrated by the primary beam. The exposure received during 1 second of fluoroscopy is approximately equal to that received during 1 cineangiographic frame. The

TABLE I Radiation Exposure Levels (milliroentgen/hour)

Anatomic Location	X-Ray Tube Angulation: 30° RAO: Without/With Shield	5° LAO: Without/With Shield	35° LAO: Without/With Shield	50° LAO-15° Cranial: Without/With Shield
Eyes, thyroid	3.8/0.5	12/0.6	25.5/0.5	41/0.7
Chest	6.5/0.7	18.5/0.8	33/0.7	58/0.7
Pelvis	10/1.4	18.5/5.9	27/5.7	57/3.2
Lower legs	38/36	31/31	45/45	2.5/1.8

during a cardiac catheterization, 50 to 80% of the physician's exposure occurs during cineangiography.[1,2] The actual exposure level will vary depending on the radiographic equipment and the type of procedure involved. With the advent of C-arm and parallelogram-supported imaging systems to obtain the hemiaxial views, exposure levels to the physician can be increased; greater emphasis should be placed on the radiation protection of physicians routinely performing cardiac catheterizations.

This study measured the radiation exposure levels for physicians using a Philips Poly Diagnost C System in 4 different angulations. As shown in Table I, the LAO-cranial angulation has the greatest potential for exposure to the physician's chest, eyes, and thyroid. The thyroid and the lens of the eye, which are not shielded by the routine lead apron, remain the most critical organs for radiation exposure for individuals routinely performing catheterization. Radiation-induced cataracts are well described in animals and humans who are chronically exposed to ionizing radiation; the dose-response curve appears to have a threshold.[12] There is a higher incidence of thyroid carcinoma in persons exposed to both therapeutic and occupational radiation; this probably follows a linear dose-response curve.[12] The maximal exposure recommended is 5 R/year (100 mR/wk) for the lens of the eye and 15 R/year (300 mR/week) for the thyroid.[8]

Protection devices are available for individual organs: thyroid shields and leaded eyeglasses. However, eyeglasses are only effective in protecting the lens of the eye from scattered radiation when the operator is looking in the direction of the source of radiation, that is, looking directly at the part of the patient that is being irradiated. Generally the physician is watching the television monitor during fluoroscopy or cineangiography. Thus, the eyeglasses may not be effective in reducing exposure to this organ. The shield described in this report protects these individual organs while decreasing the general exposure to the pelvis, chest, and face.

In addition to the protective devices for the individual organs, other shields or screens have been designed to decrease the operator's exposure.[2,3,13] In order to be of value, the device or shield must exhibit the following features: (1) it must be effective in reducing the scattered radiation to the operator in the various projections; (2) it must not interfere with patient care and catheter manipulation; and (3) it must be easy and comfortable for the operator to use. The protective

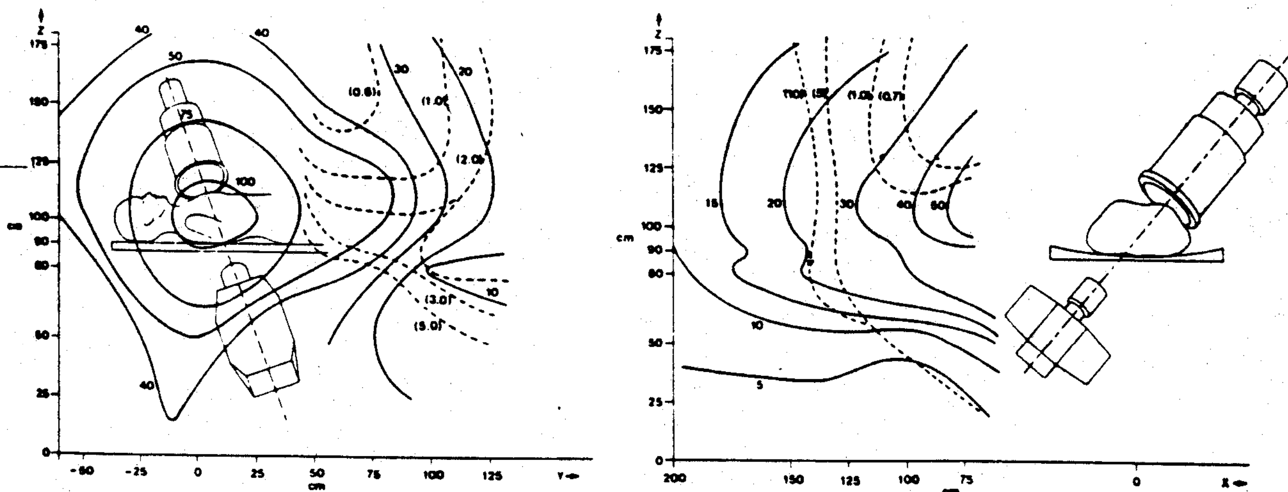

FIGURE 3. Isoexposure curves expressed in milliroentgen/hour for the 50° LAO-15° cranial angulation in (left) the longitudinal plane with the operator at 75 cm on the Y axis, and (right) the horizontal plane with the operator at 75 cm on the X axis. The **solid lines** give the radiation exposure levels *without* the protection of the shield; the **dashed lines** show the values *with* the shield. The vertical center of shield is at 75 cm in both the X and Y planes with the operator behind the shield as shown in Figure 2. Z represents the vertical plane, Y the longitudinal plane, and X the horizontal plane.

shield described in this report meets these criteria. This shield reduces the physician's exposure to the eyes and thyroid by at least 85% in all views (Table I). For example, during fluoroscopy at 95 kVp and 1 mA in the LAO-cranial angulation, it reduces the exposure level from 41 to 0.7 mR/hour. This shield is thus effective in reducing the scattered radiation to the thyroid and the eyes of physicians performing cardiac catheterization.

Our shield also has the second and third features described above. It is made of transparent glass and covered with a transparent, sterile cover during the procedure; thus, the physician is able to observe the patient. With the mobility afforded by the ceiling rails, swivel arm, and counterbalance, the physician can easily position the shield before fluoroscopy and cineangiography. The shield is positioned with the flexible leaded rubber on the patient's lower abdomen, so it does not interfere with catheter manipulation at the groin site. This shield has been in daily use for over 2.5 years in the cardiac catheterization laboratory at the San Francisco Veterans Administration Medical Center.

This study assesses the potential radiation exposure to physicians performing cardiac catheterization using a Poly C Diagnost System. The radiation exposure to the eyes and thyroid is considerably increased using the LAO-cranial view compared with the traditional RAO and LAO views. A leaded glass shield is described which was found to be effective in significantly reducing (>85%) the physician's radiation exposure in all angulations. In addition, this shield does not interfere [illegible] patient observation or catheter manipulation.

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