Evaluation of Physician Exposure During Cardiac Catheterization[1]

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ABSTRACT—The radiation exposure received by the examining physician during cardiac catheterization has been measured at 13 body locations. Results thus far indicate that the lens of the eye (forehead) receives the highest average exposure per procedure of those parts of the body limited to an occupational exposure of 5 rems a year, with similar levels at the forearms and hands.

INDEX TERMS: Catheters and Catheterization • Radiations, protection against

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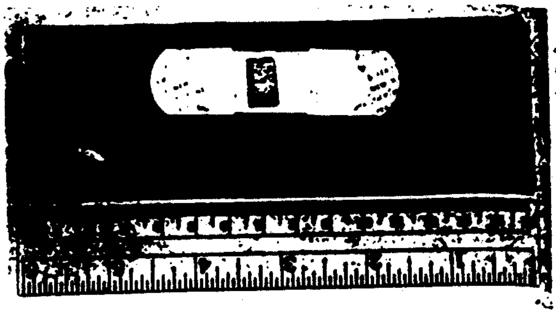

Fig. 1. Diagram of the dosimeters.

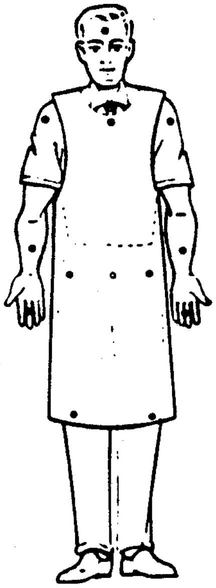

Fig. 2. Location of monitoring sites on the physician.

Cardiac catheterization procedures may result in relatively high physician exposure because of the extended periods of fluoroscopy involved and the use of supplemental cinefluorography and biplane radiography. At many hospitals (including the University of Virginia Hospital), the possibility of high physician exposure is enhanced by the fact that protective gloves are not worn and the use of lead-rubber drapes around the image amplifier assembly has been deemed impractical. Presumably, the level of exposure should be reflected by the records of the two film badges the physicians are instructed to wear on their collar and wrist, respectively. In most instances, however, film badge records do not agree with anticipated levels of exposure, indicating that (*a*) the film badge, if worn as instructed, does not give a true measure of exposure; (*b*) the film badge is being worn improperly behind the protective apron; or (*c*) the film badge is not being worn at all. The purpose of this study is to determine the levels of radiation exposure to various portions of the physician's body during a single cardiac catheterization procedure. These data will be used to evaluate technique and equipment design and stress the need for the physician to observe the principles of radiation protection.

TECHNIQUE

We are using Harshaw TLD-100 lithium fluoride dosimeters to determine the radiation exposure of the physician at 13 body locations. These dosimeters are in the form of 1/4-inch square ribbons with a mass of 95 mg, which is approximately four times greater than that of dosimeters now commonly used. This increase in mass results in a proportionate increase in sensitivity, allowing the measurement of exposure levels for single procedures. The sensitivity of the dosimeters, as determined by laboratory tests, was found to be essentially constant over the range of beam qualities that would be expected from an x-ray unit having kVp-adjusted automatic brightness control. The increase in h.v.l. of the scattered radiations over those of the primary beam was also considered in these tests.

Two dosimeters sealed in a polyethylene packet (Fig. 1) are located at each monitoring site. With the exception of those used on the fingers, the packets are then affixed to the underside of Band-aids for ease of application. The finger dosimeter packets are immersed in a benzalkonium chloride-alcohol solution prior to placement on the physician after scrubbing. They are worn under the surgical gloves and held in place with sterile tape.

Figure 2 shows the locations of the dosimeters on the physician. Those on the forehead, shoulders, forearms, and fingers are taped directly to the physician. The other six dosimeters are taped on the apron in areas approximating the neck, mid-

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personnel should be stationed during fluoroscopy and point out the need to provide a portable protective shield for such personnel.

Although the data collected to date are rather limited, we feel that specific technique, equipment design, and maximum work-load recommendations can be made at the completion of the study. The experience gained should also enable us to define the exposure conditions of a typical cardiac catheterization procedure, which in turn can be used to reconstruct the same conditions in a phantom study of patient gonadal exposure. Future plans call for extending these investigations to other types of special radiographic and fluoroscopic procedures.

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Holographic Storage of Roentgenogram Images[1]

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ABSTRACT—Storage and recording of full-size roentgenograms in the form of holographic images on photographic plates in areas ~0.1 cm² or less appears to be feasible. Deterioration of quality, if any, remains to be determined. However, by its very nature, holography should minimize such a loss of quality.

INDEX TERMS: Holography • Images, storage • Laser • Roentgen Rays, apparatus and equipment

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The storage of x-ray films is a costly process, involving large space requirements and maintenance over a period of several years. Much of the expense and inconvenience arises from the size of radiographs, which typically measure 14 × 17 in. Cost and space requirements could be substantially reduced if the same information could be microminiaturized, stored in that form, and easily recovered without loss of diagnostic quality. Conventional microfilming is expensive, and the quality of the reproduced copy has proved to be inadequate. Storage of optical information by holographic means, however, offers the distinct advantage that each point on the photographic plate records all of the information contained in the wavefront at that point (1). Thus, for planar objects such as radiographs, any point on the hologram is sufficient to record all the information contained in an illuminated radiograph and should be capable of producing high-quality reproductions. Radiographs could be reduced from standard sizes to dimensions limited only by the grain size of the emulsion being used as a medium for recording. As a conservative estimate, as many as 3,000 different radiographs could be stored on a single 4 × 5-in. photographic plate. Reconstruction is achieved by real image playback, using a direct laser beam to project the image onto a suitable surface or a vidicon camera.

METHOD

The experimental set-up is shown in Figure 1. The monochromatic light source used was a 4 mW He-Ne gas laser. The rest of the equipment, constituting the holographic camera, was mounted on an air-suspended optical bench to avoid small displacements of phase information during the recording period. All mirrors were polished and optically flat to ±1,500 Å. High-resolution Kodak 649F photographic plates were used as the recording medium. The beam splitter transmitted 96% of the light and reflected 4%, which was then used to furnish a reference beam. Due to the low power of the laser, recording times were long (~five minutes). The use of opal glass was found necessary in order to achieve uniform illumination of the radiographic section. However, a certain amount of loss of detail also occurred.

A large diffusion lens may be used; however, this introduces a washed-out area on the plate corresponding to the focal spot of the lens, which is visible through the x-ray film and is therefore recorded on the plate. Further improvement in technique should resolve this difficulty.

A spatial filter consisting of a 10× microscope objective and a pinhole 25 μ in diameter was used between the laser aperture and the beam splitter to increase the signal-to-noise ratio on the holographic plate.

Recording masks were made from thin, pressed paperboard and positioned in the plate holder as close to the emulsion as possible. One mask contained successively smaller circular apertures ranging from 2 cm to 1 mm in diameter. Long rectangular openings ranging fom 1.5 cm to 2 mm in width were cut in the second mask.

Reconstruction was accomplished by illuminating a small section of the individual patterns with the original laser beam (diameter ~1 mm) and focusing the real image on a white paper screen.

RESULTS

All holographic images gave recognizable reconstructions of the original roentgenogram. The best

EXPOSURES TO THE PHYSICIAN DURING CARDIAC CATHETERIZATION PROCEDURES

Dosimeter Location	Average Exposure (mR)	Exposure Range (mR)
Forehead	26	9.3–42
Neck	28	19–46
Left shoulder	37	18–80
Right shoulder	10	2.1–22
Left forearm	57	23–110
Right forearm	19	2.0–35
Left hand	32	9.1–69
Right hand	41	3.5–150
midsection (outside apron)	24	8.0–40
midsection (outside apron)	20	2.3–34
al inside apron)	<1	<1–2.3
bottom apron	2.2	<1–6.9
bottom apron	1.8	<1–5.1

and lower extremities. One of the three ers located at the midsection is placed under g to give an indication of gonadal exposure. r two are taped to the outside of the apron the level of exposure that can be expected if ctive apron is not worn. The following ters are recorded for each procedure moni- total fluoroscopy time; (b) fluoroscopic erage; (c) frames/sec. and footage of ciné ciné milliamperage; and (e) biplane radio- echnique factors and number of films.

RESULTS AND CONCLUSIONS

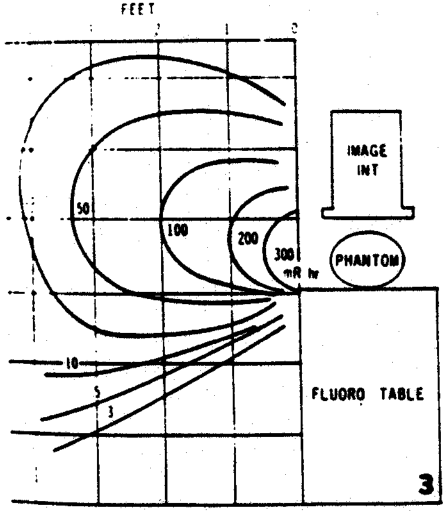
I gives the ranges of exposure and average to the areas monitored. These values are the nine sets of measurements which have mpleted to date. The lens of the eye, as by dosimeters taped to the forehead, re- the highest exposure of those parts of the body which are limited to an occupational exposure of 5 rems per year. The forearm closest to the primary beam and the hands also received exposures of the same magnitude; however, these areas are allowed up to fifteen times the maximum permissible exposure to critical areas. Film badge records did not indicate such levels of exposure for the most part.

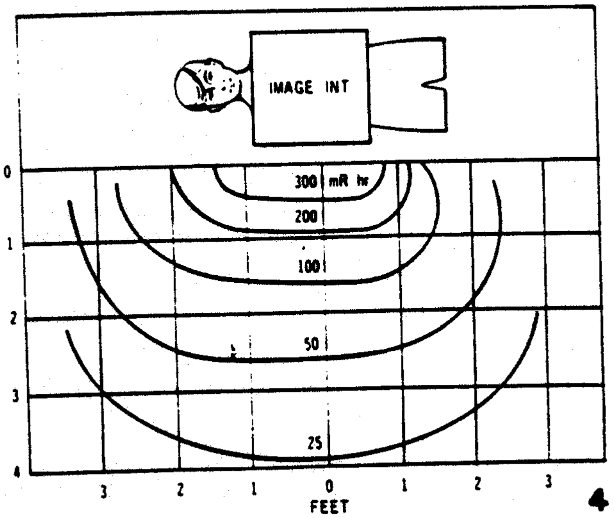
Gonadal and lower extremity exposures have always been very low in this study because of the protection afforded by the wearing of a lead-rubber apron and the construction of the fluoroscopic table. The average exposure to the lower extremities was about 2 mR, while that to the gonads was less than 1 mR. It should be noted that differences in operator technique, exposure factors, and the type of examination resulted in a wide variation in the measurements at each of the monitoring sites (TABLE I).

Isoexposure curves were determined by placing an Alderson average-man phantom on the fluoroscopy table in the position normally assumed by the patient during catheterization (Fig. 3). Exposure levels were measured with a Victoreen 555 Radocon II at an x-ray tube potential of 95 kVp, measured with a Hivex resistance bank at a tube current of 3 mA. Total filtration in the beam was 3 mm Al-equivalent; the table-top exposure rate was 6.7 R/min.

The isoexposure curves, in a vertical plane passing through the image intensifier assembly, readily explain the high exposure levels recorded on the upper unprotected portions of the body. Since these levels are probably related to the absence of lead-rubber drapes, increased protection in this area merits further investigation.

Figure 4 shows the isoexposure curves in a horizontal plane at the level of the table top. These curves permit conclusions as to where paramedical





3 Isoexposure curves in a vertical plane through the image intensifier assembly (mR/hr.).
4 Isoexposure curves in a horizontal plane at the level of the table top (mR/hr.).