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# RADIOLOGY

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## Clinical Dosimetry During the Angiographic Examination

### Comments on Coronary Arteriography

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#### SUMMARY

Data are given on the radiation exposure occurring in high volume angiographic suites to physicians and technical personnel. Emphasis is directed to coronary artery examinations since multiple recording modalities are utilized in these examinations and consequently personnel exposures are greater than in other angiographic studies. A comparison of dose exposures when these examinations are done via the brachial versus the femoral method and an explanation of the higher doses recorded by the brachial method are discussed. A clear health hazard is identified. In those departments with a large volume of angiographic examinations, a periodic rotation of personnel should be instituted. With the availability of inexpensive dose-rate meters, the directors of cardiovascular laboratories should individually monitor and evaluate exposure to their physicians and the technical personnel involved in their examinations.

THE SPECIFICATIONS for safe radiological equipment have been the subject of considerable discussion and more recently these data have been widely published. General acceptance is assured since many of the requirements now carry the force of law following passage of Public Law 90-602 entitled Radiation Control for Health and Safety Act of 1968.<sup>1,2</sup> For the most part, these federal standards are direct adoptions of the National Committee on Radiation Protection recommendations. With the establishment of these regulations, the routine radiological survey of diagnostic angiographic facilities becomes a critical necessity.

One of the major problems in the protection of angiographic personnel arises because familiarity with the surroundings and the equipment tends to diminish one's respect for the radiation hazard. Many diagnostic departments are without area radiation monitors; since the personnel cannot sense the radiation, they tend to forget that a radiation field may exist in their working environment. Therefore, the shortcuts they take may lead to unnecessary increased radiation exposure.<sup>3,4</sup>

For example, for at least several years and several thousand examinations we hand injected contrast media for most selective vascular examinations, in spite of our knowledge that the sophisticated flow rate injectors were more uniform and reproducible than the varying pounds per square inch delivered by hand held syringes and multiple staff physicians. Presently we hand inject only two arterial vessels: the vertebral and the coronaries and/or their respective bypass or anastomotic grafts. In these critical examinations we feel that the hand control and television monitoring of the injection are more critical than flow rate specificity.

Coronary artery examinations are increasing annually at the rate of approximately 20%. It has been estimated that approximately 400,000 coronary artery examinations are being performed in the world yearly. An estimated 80% of these examinations are being done by cardiologists and the remaining 20% by radiologists. To correlate this industry source information, we are in the process of surveying the 7,000 hospitals in the U.S. concerning the number performing coronary arteriography, the approach method, number of exams, estimated fluoroscopic time, etc. The significant increase in the number of angiographic examinations in general and coronary artery studies specifically has prompted us to conduct an evaluation of the radiation dose received by the personnel involved in these procedures. Certainly the radiation dose to angiographic personnel has always

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been considered greater than the average exposure received by other diagnostic personnel.<sup>4,6</sup>

### Methods and Materials

We have recently had occasion to monitor our personnel and radiation output in three relatively new and varied angiographic suites. Two include under the table tube-over the table intensifier systems while the other represents an over the table tube arrangement. The information we needed could not be obtained by badge monitoring with periodic reports because we were interested in dose rate per examination utilizing different recording modalities, and because technologists frequently lost badges or were unaware of where they should be worn. We used a digital dose-rate meter,\* to allow us to make a systematic survey of area and personnel exposures. This digital exposure-rate meter provides a fully compensated direct readout of either total exposure or exposure rate. When exposures are in a range of .5-20 mR/min as frequently occurs during angiographic examinations, response time can be as short as two seconds, and correspondingly shorter at higher dose rates. In the total exposure mode one can record a pulsed beam, i.e., angiographic exposures at 1-6 sec for 10 sec, and a total readout can be obtained. This then allows simple calculation of exposure per film, to either personnel, patient or surrounding area. The speed of this digital meter display is an advantage over ordinary analogue display response to short pulsed exposures. During continuous exposures as in fluoroscopy or cine at 60 frames/sec, the rate meter recording is used. The unit was calibrated against a Victoreen Radacon II model for comparison.

Since personnel exposures during coronary arteriography are higher than during other angiographic examinations, we began with a survey of coronary arteriography equipment in room 1, equipped with under the table tube-over the table intensifier system. We were interested primarily in the hands, lens and gonadal exposure for technical personnel and examining physicians during coronary artery, anastomotic graft and ventriculography examinations.

First, we evaluated these exposures during fluoroscopy by both femoral and brachial methods. Average fluoroscopic time for a complete examination via the femoral was 10-15 min, while average fluoroscopic time for the Sones technique was 6-10 min. In an uncomplicated exam the femoral approach could be as short as 4-5 min, with similar times noted by the Sones technique. We also averaged in the times of those patients who had combined coronary arteriography and postoperative evaluation of aorta to coronary artery bypass grafts. Many of these grafts are now being evaluated using a femoral approach, which prolongs the average fluoroscopic examination time and accounts for the 15 minute average. In our experience, with examinations being performed by equally experienced examiners, the Sones technique has more rapid fluoroscopic times. It should be noted, however, that the Sones approach can take considerably longer when being performed by a beginner. The difference in fluoroscopic times for the different methods by the experienced examiner arises from the use of three catheters in the femoral method and the fluoroscopic positioning of each in comparison to a single catheter for all phases of the exam by the brachial method.

During fluoroscopy, we noted hand exposure via the Sones approach at 1.1 mR/min vs .7 mR/min by the femoral technique. This is directly related to the proximity of the tube source to the operator's hands. Initially the fluoroscopic output of the unit was calculated by placing the probe at table top and at 4 mA-115 kVp and 3 mm Al filtration, output was 4.05 R/min. At 1.5 mA output was 1.81 R/min with an 8 cm<sup>2</sup> field size. The tube to intensifier distance was 35 inches with a tube to table top distance of 20 inches.

Lens exposure from the femoral approach was .3 R/min during fluoroscopy. The technician adjacent to but behind the radiologist and assisting him receives insignificant dosage; essentially non-recordable amounts beyond the noise level are present behind the .5 mm Pb equivalent aprons. A technician positioned adjacent to the patient's head receives 2 mR/min or approximately 30 mR during 15 min of fluoroscopy. This again relates to isodose distribution curves which are entirely dependent on proximity to the radiation field and on over-all fluoroscopic field size. Prior to this study there was a tendency in our institution for a technician to stand close to the intensifier tube in order to control monitoring, table and cine controls.

During 35 mm cine the dose to the operator's hands via the brachial approach is 11 mR/min vs 4-5 mR/min at the femoral site. Assuming 6-10 sec runs for a total of 6-8 runs or about 60 seconds, we find approximately 5 mR total exposure during cine by the femoral technique and 11 mR by the Sones technique. Lens dose during 35 mm cine examination by the femoral technique is 3 mR and approximately double by the brachial method. Technician lens exposure during 35 mm cine can be as high as 13 mR when positioned directly adjacent to the intensifier tube.

We also included exposures during use of the 105 mm spot film camera for indirect radiography. This camera is an ideal supplement to 35 mm cine. The films are processed and available for viewing in 90 seconds, and can be immediately copied and placed on the patient's chart or taken directly to the operating room. However, the camera is entirely supplemental and is not intended as a replacement. Exposure to the operator's hands in the femoral area during 105 mm filming of the coronary arteries amounts to approximately 2 mR, assuming 30 to 50 frames at .02-.05 mR/frame. Retinal dose is 10% of that or .005 mR/frame for a total of 2 mR. Filming was done using a 6 focal spot magnified 6" mode at 300 mA and approximately 10-15 msec and 85 kVp. Patient skin dose adjacent to the field during 105 mm filming was 43 mR/frame.

Total dosage accumulated during coronary arteriography including fluoroscopy time, 35 mm cine recordings and 105 mm supplements can be as high as 43 mR/exam to the technician, 17 mR/exam to the radiologist's hands and 10 mR to the lens. The technician positioned at the head of the unit for cine controls and panning is receiving a dose greater than maximum weekly permissible doses, i.e., at 43 mR/exam and approximately 5 exams/day the technician's exposure equals 200 mR/day or 1,000 mR/week. Although this would still be within permissible limits for extremity dose including the hands (1500 mR/week), our measurements were made at the chest and lens level for which the permissible level is 100 mR/week. To stay below this level, the technician would have to be limited to 3-4 exams per week. Although it is doubtful that a technician would remain stationary in this relatively high dose area, such dosage levels could be reached under the above cir-

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stances. Similarly, because of the closer proximity to the source, exposure to the operator is approximately two times greater from the brachial approach than the femoral. This may not be significant in those departments performing only 2-3 exams/week, but for those approaching 4-5 exams weekly, periodic rotation of both physicians and technical personnel is strongly recommended (fig. 1).

Room II was essentially the same as room I, incorporating under the table tube-over the table intensifier, coupled to a 35 mm and 105 mm camera. Fluoroscopic output, hand and lens dose for fluoroscopy, 35 and 105 mm exposures are almost identical to those produced by the equipment in room I.

Proceeding then to a discussion of the over the table tube-under the table intensifier unit in room III coupled to a 70 mm camera, we recorded for 100 kVp, 3.5 mA an output at the table top of 3.67 R/min. Tube to the table top distance was 35 inches with a tube to intensifier distance of 37 inches. During the conventional renal arteriogram in an unshielded system one can receive at the hand level near the procedure site exposure variations from 2-10 mR/min or for a 15 minute examination 20-100 mR total (fig. 2). If one uses a 15 cm field size without cylinder extension cone, hand dose can approximate 9-10 mR/min. By reducing the field size to 10 x 10, a 30% reduction in dose to the hands occurs. When adding a cylinder extension cone and reducing field

size to 5 x 5 cm a 50% reduction or 4 to 5 mR/min hand dose occurs. This is still considerably greater hand dose than conventional under the table tube dosage of .7 to 1. mR/min. However when one extends the hand distance to 50 or 60 cm away from the primary beam, for example, when one is doing a carotid arteriogram from a femoral puncture site, then the dose can be as low as 2 mR/min. Obviously a reduction in field size to smaller dimensions during fluoroscopy would flatten out to even greater degrees the isodose curves.<sup>7</sup> Field reduction with the extension cylinder cone, a retinal eye shield as suggested by Amplatz, and protective side paneling for both tube and table, are all essential features to reduce personnel exposures with these relatively high dose units.

The over the table tube-under the table intensifier unit is also coupled to a 70 mm camera and exposures are calculated to be .08 mR/frame at the hand level; at 50 frames this amounts to 4 mR. Radiation leakage from the top of the cone can also occur. In our own experience proximal cone leakage amounted to 4.3 mR/min when a large (15 x 15 cm) field was tested. At the edge of the field 44 mR/min was noted. This room is used for many neurovascular examinations and we calculated patient lens dose during conventional arch angiography to be 1.4 mR/frame or for 20 frames of 11 x 14 inch films a total lens dose of 28 mR. When a technician remains in the room for

### Coronary Arteriography

#### Total Dose

Hands 16 mr

Lens 10.2 mr

Technician 43 mr

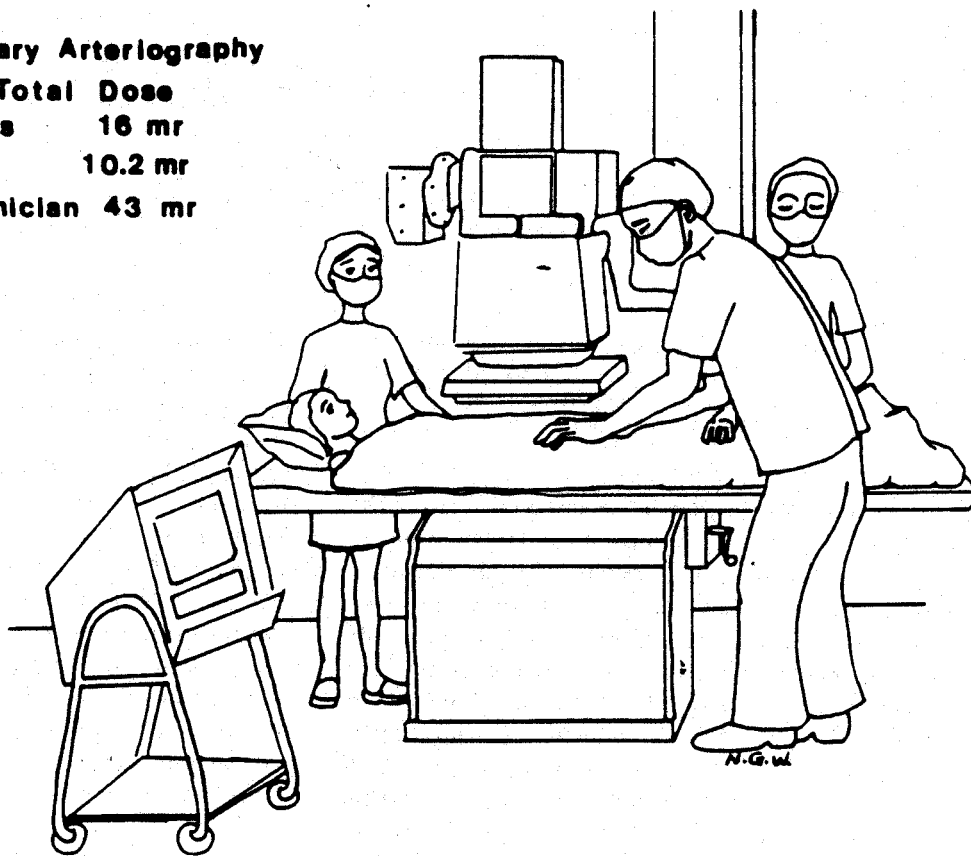


Figure 1

Diagrammatic illustration of under the table tube-over the table intensifier system with vascular personnel in positions where total exposure during coronary arteriography was recorded. During fluoroscopy exposures are as follows: hands, .75 mR/min; lens, 48 mR/min; technician, 2 mR/min at 110 kV, 1-2 mA, and 11 cm<sup>2</sup>-20 cm<sup>2</sup> field size. During 35 mm cine exposures are as follows: hands, 5 mR/min; lens, 3 mR/min; technician 13 mR/min at 60-70 kV, 300 mA, 60 frames/sec, and 6 focal spot. Exposures during 105 mm camera use are as follows: hands, .04 mR/frame and lens, .005 mR/frame

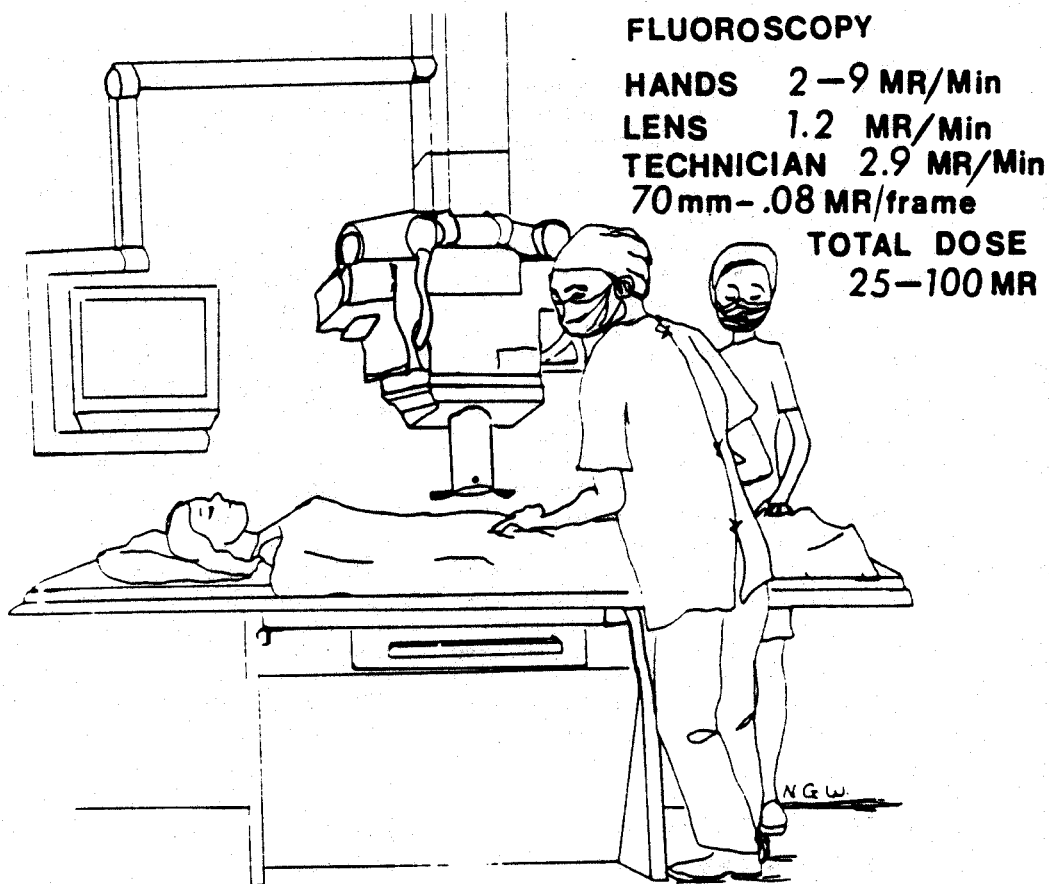


Figure 2

*Diagrammatic illustration of over the table tube and under the table intensifier system without modifications. There are potentially high exposures to personnel as positioned during arteriographic examinations*

patient assistance during the changer work, body exposure dose is approximately 1 mR/frame. This would refer to a technician standing adjacent to the patient during serial exposures (1000 mA, 70-80 kV, .05 sec).

#### Discussion

Our survey shows that in an unmodified over the table tube system a significantly larger dose of scattered radiation exists. A potentially high total dose of 25 to 100 mR/exam was recorded with lens doses approaching 1.2 mR/min. Consequently a 10 minute procedure could yield 10 mR/exam lens dose and four examinations per day or 40 mR/day or 200 mR/week would be two times the recommended maximum permissible dose. As shown, however, this can be reduced to acceptable values by reducing the field size during fluoroscopy to  $5 \times 5$  cm, by using an extension cylinder cone, protective panels and lens protective shield, and most significantly by reducing the total fluoroscopic time. Studies by Hoffmann et al. have shown that the addition of a lens shield can reduce the lens dose to .05 mR/min with a similar type in-

stallation.<sup>8</sup> Ordinary glasses are of additional value.

As originally predicted, fluoroscopy remains the single largest contributor to personnel exposure<sup>7, 8</sup> and there is, in fact, an almost arithmetic proportion between the experience of the angiographer and the duration of fluoroscopy. Also, in many institutions most of the staff are trained to perform routine angiographic examinations, so that no one physician exceeds permissible radiation dose levels. If this were not the case, over-exposure would occur. We presently recommend rotation of both the angiographers and the vascular technicians, especially for those performing coronary arteriography since personnel are present in the room during the entire examination and since multiple radiation recording modalities are utilized.

Although our primary interest was in the coronary artery studies, we also calculated average fluoroscopic times for varying angiographic examinations. Aortofemoral arteriography and routine femoral arteriography can be as short as 37 seconds or as

prolonged as 5-6 minutes. In general, most lower abdominal nonselective aortic procedures involved approximately one minute fluoroscopic time. Bilateral selective renal angiography averaged 5 minutes. Pulmonary arteriography varied from 1 minute to 7 minutes fluoroscopic time. Bilateral selective carotid arteriography and aortic arch angiography could approach fluoroscopic durations as long as 20 minutes. It is alarming how prolonged the fluoroscopic times can be during a difficult selective examination.

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