Basic radiation protection for cardiac angiographers

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We have monitored radiation exposure to the operators during the performance of nearly 1000 adult coronary angiograms. The purpose of this study was to measure the absolute and relative radiation exposures received by the operators as a function of several key variables. These variables include the kind of radiological equipment used for the procedure, the efficiency of protective shielding, the experience of the operator (fellow or staff), and the experience of the operator with a particular kind of equipment. The results of our studies are given in the *Table.* In general terms, the radiation doses received by busy, skilled operators using any apparatus over the course of the year represents a modest fraction of the maximum permissible doses.

In studying the *Table* more closely, it is seen that the thyroid gland and perhaps the lens of the eye are the critical organs in terms of radiation dosage. The permissible workload for a single operator using the Cardio Diagnost system with the protective shield in place is essentially unlimited. This is true even for a pool of operators consisting of both fellows and staff. The Poly Diagnost C, in the hands of staff operators, yields exposure levels higher than those received by operators using the Cardio Diagnost. It is easily inferred from phantom measurements that the addition of either a table-mounted

Table. Average exposures mR/examination

	Cardio Diagnost			Poly Diagnost C		Cradle with LAD			
	Pool, no shield	Pool, shield	Staff, shield	Staff A (No shield)	Staff B (No shield)	Fellow, operator	Fellow, asst.	Staff 1	Staff 2
Eyes	6.2	1.9	0.4	10.0	5.2	11.0	6.4	2.0	1.8
Thyroid	8.2	1.4	0.1	9.5	5.7	7.8	6.6	2.4	2.8
Torso	0.6	M	M	1.0	0.8	M	M	0.2	0.3
Hands	6.1	2.1	0.3	7.2	6.3	6.5	6.6	2.7	4.1
Lower legs	29.0	1.5	1.2	11.0	8.5	7.6	4.0	3.7	5.1

LAD = lateral angulation device. Staff A = 1st experimental run, Staff B = 2nd experimental run.

or ceiling-mounted protective shield will substantially reduce the exposure of Poly Diagnost C operators. With this shielding in place, the workload for an operator using the Poly Diagnost C will also be essentially unlimited. Experiments are under way to confirm the phantom studies.

The cradle system with the lateral angulation device poses a somewhat different problem. Although it is not uncommon to find clusters of personnel immediately around the catheterization table with any kind of apparatus, both the Cardio Diagnost and Poly Diagnost C systems are designed to function with only one operator in the high radiation exposure region. Cradle with lateral angulation device systems in most instances require at least two operators—one manipulating the catheter and the second operating the controls. If we imagine that a catheterization table laboratory has two angiographers available for duty, the number of cases permitted per individual is a function of the apparatus. Systems such as the Cardio Diagnost and Poly Diagnost C require that each of the two operators be in the high dose radiation region during only half of the cases performed through a year. In the case of the lateral angulation device system both operators are required for the performance of each study and, therefore, both operators will be in the laboratory for all the cases. The collective dose (the sum of the doses received by both operators) will place a different limitation on the workload than the limitation inferred from the per case data shown on the *Table.*

Technical appendix

Steps to reduce occupational radiation exposure to the staff in the cardiac catheterization laboratories:

1. X-ray beam field size. Reduce the volume of patient tissue irradiated by the x-ray field as much as possible. Since the scattered radiation that exposes the operator is proportional to the volume of tissue irradiated, smaller irradiated volumes in the patient yield less scattered irradiation of the staff. Additional benefits of a small x-ray field include lower patient dosage. Better image quality also results when less scatter reaches the image intensifier.

2. Distance. The intensity of the radiation field is reduced by a factor of four when the distance between the source and monitoring location is doubled. In the case of the cardiac catheterization laboratory, the main source of radiation exposing the operator is scatter from the patient. A step or two backwards from the tableside while the x-ray beam is running will often cut the radiation exposure to the staff member by at least a factor of two. Only essential staff should be within 6 feet of the patient's chest when the x-ray beam is on.

3. Time. The dose received both by the patient and the staff is proportional to the time the x-ray beam is on. As a rule of thumb the same amount of radiation is required for either one of cine frame or one second of fluoroscopy.

4. Shielding. The radiation dose received by the operator can be reduced by the judicious employment of shielding devices. Such protective devices will include lead aprons, leaded thyroid collars, eye glasses containing high atomic number of materials (with side shields) worn by the operator as well as protective shields attached either to the ceiling suspension or to the patient cart. Although shielding should keep the radiation dose to the operator as low as is readily achievable, the weight and complexity of the shielding should not be increased to the point that it interferes with the examination or jeopardizes the welfare of the patient.