Conference of Radiological Health Specialists

Selecting Surveyors of X-ray Equipment

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NATURAL RADIOACTIVITY originating from cosmic showers and naturally occurring radionuclides in the earth's crust was man's most important source of radiation 100 years ago. Since that time man has made radiation sources, such as X-rays, radionuclides, nuclear reactors, and nuclear detonations, and sources inherent in the processing of naturally occurring radioactive materials. As man is subjected to exposure from a combination of many or all of these sources, his total exposure increases as more uses are devised for these sources. This does not mean that he has to live on a remote island and carry a lead umbrella; however, it has prompted public health officials and other interested persons to take a hard look at these multiple sources and attempt to reduce unnecessary exposure where possible.

X-ray Equipment

The Public Health Service estimates that more than 200,000 X-ray units are in use today. Approximately half of these units are used by dentists and the remainder are owned and operated by or under the direction of physicians, including general practitioners, osteopaths, chiropodists, and chiropractors.

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From July 1960 to June 1961, according to data of the U.S. National Health Survey (*1*), an estimated 85 million visits were made to medical facilities for medical X-rays.

Precise data on the amount of radiation received by the U.S. population from the use of medical and dental X-rays are not available, but there are indications that this is one of the major sources of radiation exposure today. Unlike exposure from natural background and certain other sources, something can be done about unnecessary exposure from medical and dental X-rays.

With the rapid rise in the number of X-ray machines in use and the great number of persons using and receiving X-rays yearly, it is imperative to keep public and occupational exposure to unnecessary radiation at a minimum while encouraging the continued development of the beneficial uses of this valuable diagnostic and research medium.

Reports of X-ray surveys from Los Angeles (*2*), New York City (*3*), and other cities indicate that from 40 to 90 percent of X-ray machines are either defective at the time of the survey or they do not meet the recommended standards (*4*).

After initial inspection of approximately 2,700 radiation facilities in Los Angeles in July 1962, the city health department reported that excessively large beam diameters (more than 24 inches for 14-inch by 17-inch chest film) were found in 41 percent of all chest radiography units, and that excessively large beam diameters (exceeding the size of the film used in a particular X-ray examination) were found in 20 percent of the trunk radiography units and 19 percent of the units used for extremities (*2*). An example of excessive beam diameter is shown in figure 1. Approximately 45 percent of the medical radiographic facilities had inadequate filtration, and 11 percent of all installations had inadequate protection for the X-ray operator.

The Florida State Board of Health, after a study in Polk County in 1963, reported that of 139 radiographic units 42 percent had excessively large beam diameters and 37 percent had inadequate filtration (final report of E. F. Seagle, field project engineer, to Division of Radiological Health, Public Health Service, August 1963). The study included equipment of all medical practitioners in the county except veterinarians.

The New York City report (*3*) stated that, as of May 1961, of 3,623 medical diagnostic X-ray and fluoroscopic units surveyed, 92 percent were deficient. Of these, 1,648 units were used for chest X-rays, but 66 percent did not limit the beam to the chest. Filtration was inadequate in 25 percent of the radiographic units and in 19.4 percent of the fluoroscopic units. Of 1,687 physicians operating fluoroscopes, 59.5 percent received primary radiation around the head and shoulders because the shutters of their machines did not limit the X-ray beam to the protective leaded glass screen.

Of 2,716 dental X-ray units surveyed in New York City, 53 percent were deficient, 27.5 percent had excessive beam diameters, 33.7 percent had inadequate filtration, and 5 percent had inadequate protection for the operator. Other studies continue to document that this inadequacy is general throughout the United States. Despite standards existing for about 25 years, these defects have remained uncorrected. This poses a public health problem as well as an occupational health hazard.

Radiation Safety

The answer to substandard X-ray equipment lies in a challenge to its manufacturers to design greater safety features, to its owners and users to impose upon themselves stricter adherence to radiation safety practices, to colleges and professional organizations to strengthen training in the radiation safety phase of X-ray

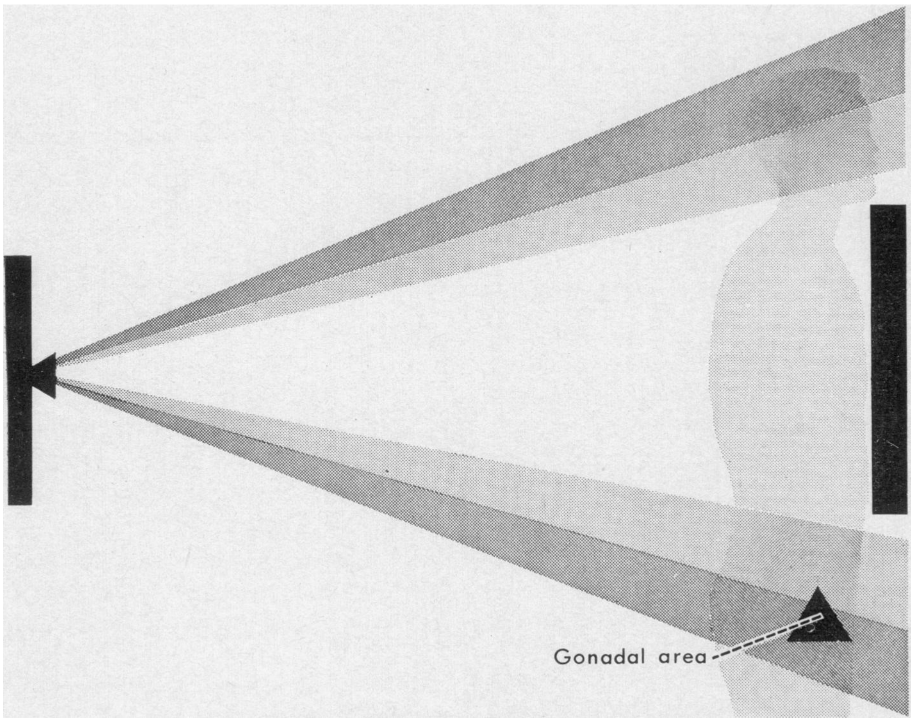


FIGURE 1. Excessive X-ray beam diameter.

Table 1. Weights assigned to measurements of X-ray equipment for safety features

Item	Assigned weight (points)
Radiograph	
Beam size	60
Beam alignment	10
Filtration	10
Protective barrier (operator and others)	5
Timer	2
Scatter radiation	2
Film processing	2
Darkroom	2
Other contributions (workload, brand of film, other radioactive materials present, caseload, tube rating, screens)	1–7
Total points	100
Fluoroscope	
Tube target to panel distance	30
Dark adaptation	20
Filtration	10
Milliamperes used	10
Speed of screen	10
Roentgen output at panel	5
Shutters adequate	5
Apron and gloves	5
Other contributions (transmission through screen and lead glass, light leaks in fluoroscopy room, scatter radiation, other radioactive materials present, reset cumulative timer)	1–5
Total points	100

usage, and to public health officials to consider these problems and take appropriate action on the aspects that fall within their area of concern.

The first emphasis given to radiation safety by health departments was on the occupational exposure of the X-ray user, and this was carried out mainly by occupational or industrial hygiene personnel. This area of concern now includes the general population's unnecessary exposure from X-ray machines that fall below health department standards.

The Public Health Service's Division of Radiological Health is assisting the States in radiological health matters. At present approximately 43 States have taken steps toward enacting radiation control regulations (*5*). In most States, however, these steps have not progressed to the performance of X-ray surveys of the kind discussed here. Health officials have one primary course of action, and that is to locate and survey for safety features, according to recommended standards, every X-ray unit in the United States (*4*). This kind of survey program has been undertaken in about 25 States, by the State, county, or municipal health department.

Surveyors

The question arises as to who is qualified to survey X-ray equipment and make recommendations for correction of defects. At present, persons conducting these surveys have varying levels of training and background. The opinion that only those highly trained in radiation physics or health physics are qualified is not well founded. Dr. Russell H. Morgan, chairman of the Commission on Public Health of the American College of Radiology, stated that ". . . health physicists are not necessary for inspection tasks. . . ."

Of course, a surveyor would not be able to begin at the lowest level of the educational and experience scale, nor would he have to be so highly trained as to be certified by the College of Radiology (although ideal—not practical) for the kind of survey discussed here; namely, inspection of X-ray machines. Rather, a person with a college degree and adequate training in this particular segment of radiological health could satisfactorily complete X-ray surveys as part of a program directed by a qualified physicist.

St. Louis Study

To determine the qualifications necessary for a surveyor we conducted a study in St. Louis, Mo., with the aid of the State Assistance Branch of the Division of Radiological Health, designed to demonstrate the public health effectiveness achieved by the use of different categories of surveyors of X-ray installations. For the study we selected a hospital, two offices of radiologists, two offices or clinics of group practitioners, and three offices of private general practitioners.

These installations were independently surveyed for safety factors by:

1. The physician. (How well is your equipment protected against unnecessary radiation? What about your techniques and processing?)
2. A certified radiation physicist.

3. A certified health physicist.

4. A Public Health Service demonstration team trained especially for this purpose.

5. Health department sanitarians with no radiation control background or formal training other than 2 weeks' experience with the PHS team.

The staff of the various installations were cautioned not to discuss their inspections with persons who subsequently performed the surveys and to carry out normal X-ray procedures. Reports of each surveyor's findings were tabulated by Dr. Brodeur's office.

Some of the items a surveyor should check while examining an X-ray installation for safety features are shown in figures 2–5. The weights assigned to these measurements are shown in table 1. The few examples shown here will give those not familiar with X-ray surveys a better idea of what actually takes place in a practitioner's office during a safety survey.

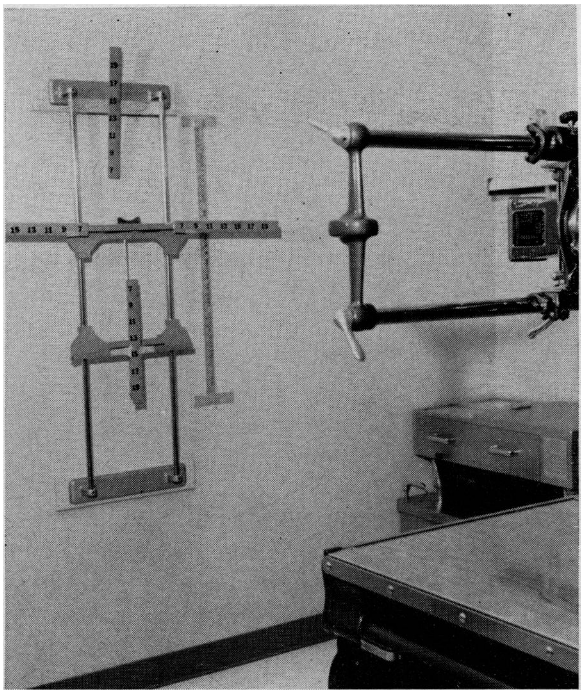
Surveyors' scores. The surveyors' scores were computed on the basis of items considered significant in the reduction of X-ray exposure according to the following criteria, listed in order of decreasing importance: (*a*) gonadal exposure, patient and personnel; (*b*) nongonadal exposure to permanent personnel; (*c*) nongonadal exposure to patient; and (*d*) transient exposure, that is, exposure to persons who are present in the X-ray department occasionally or possibly just once.

Items that would contribute unnecessary exposure within these categories were prepared by J. Miller, chief, and E. F. Seagle, assistant chief, medical X-ray program, Public Health Service. These items and their relative importance are shown in table 1, which reveals that the selection of criteria and the assignment of weight to each is far from arbitrary. If attention were given only to the first three items in table 1 (80 percent of the points assigned), the improvement in unnecessary exposure would be much greater than if attention were given exclusively to the remaining items. While we do not recommend such an impractical procedure, the facts serve to point to areas predominantly responsible for potential health hazards.

If a surveyor incorrectly measured an item, no score was given for this item. If he failed to include a certain item on the list, no score was given for this item. If a surveyor measured or checked all of the items listed plus some other lesser contributory factors perhaps peculiar only to a specific installation, his total

Table 2. Scores achieved by various surveyors of X-ray installations, St. Louis, Mo.

Number of X-ray units	Practitioner	Certified radiation physicist	Certified health physicist	PHS demonstration team	Sanitarian
1	0	20	90	95+	90+
2	0	32	90	95+	90+
3	0	20	95	95+	90+
4	80	32	90	95+	90+
5	80	20	95	95+	90+
6	80	20	60	95+	90+
7	75	20	95	95+	90+
8	75	32	60	95+	90+
9	75	20	95	95+	90+
10	75	32	60	95+	90+
11	75	20	95	95+	90+
12	75	32	60	95+	90+
13	85	20	90	95+	90+
14	85	32	95	95+	90+
15	85	20	60	95+	90+
16	80	20	95	95+	90+
17	80	20	60	95+	90+
18	80	32	95	95+	90+
19	50	----	----	95+	90+
20	50	----	----	95+	90+
Total points	1, 285	444	1, 480	1, 900+	1, 800+
Average points	64	25	82	95+	90+



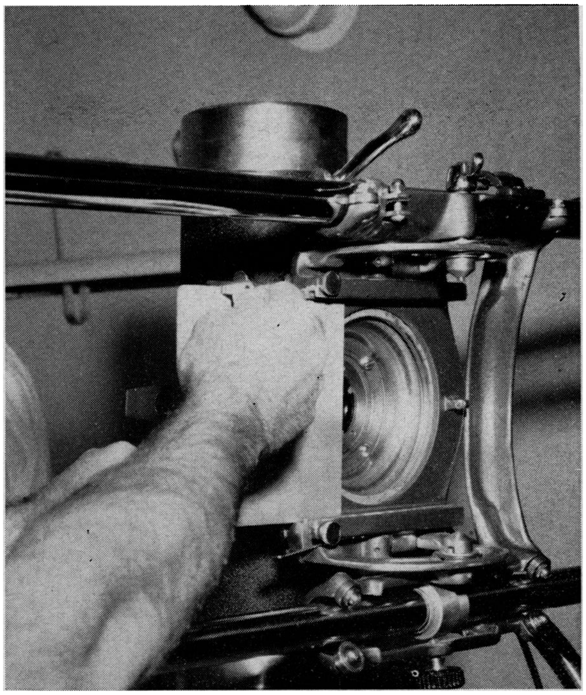


FIGURE 2 (left). Fluorescent strips determine the beam dimension of each cone at the film plane. The linear scale is used for alignment of the beams with this plane. FIGURE 3 (right). Slotted key is used in measuring added filtration.

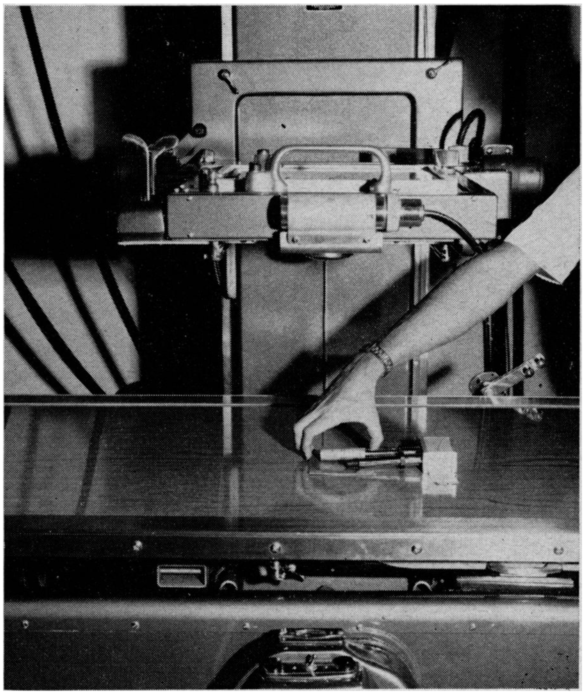


FIGURE 4 (left). Stray or scatter radiation is measured in an office adjacent to the X-ray room, where typical exposures are being made using a simulated patient. FIGURE 5 (right). Measurement of table top dose rate. This may be combined with cap on/cap off procedure for obtaining total filtration.

score would approach 100 points. Scores are shown in table 2. The scoring factors were the number and kind of items checked and the accuracy of the measurement observations made. Naturally, this prejudiced the scores in favor of the Public Health Service team, but each surveyor was asked to evaluate the same specific problem—the production of unnecessary patient exposure.

Cost analysis. The cost of each survey by each category of surveyor in the study was based on the actual cost of completing his particular survey (table 3). For example, one surveyor may charge $150 to $200 per day. The number of units he surveyed per day is divided into this amount. For a government surveyor who lived in the city or county surveyed, the number of units per day was divided into his salary per day plus his transportation and so forth.

The cost of equipment to make the measurements was the same for each survey, and it was not included in the analysis; however, a complete survey kit requires an initial investment of approximately $1,300.

A comparison of cost per unit with the percent of public health effectiveness, by category of surveyor, is shown below.

Surveyor	*Cost per unit*	*Percent effectiveness*
PHS demonstration team	$13	95+
Sanitarian	7	90+
Certified health physicist	25	82
Certified radiation physicist	76	25
Practitioner	35	64

Discussion

The following limitations should be considered regarding the variation in the comparative effectiveness scores of the different surveyors:

1. The study was confined to one geographic location.

2. Except for practitioners, only one representative was used in each category of surveyor.

3. The amount of time to be spent at each installation was limited.

4. The instructions were limited as to what factors to measure, and may have caused some misunderstanding. For example, "Go to this installation and perform your normal survey for patient and practitioner safety factors," may have been interpreted differently by persons with different backgrounds and functions. However, if a practitioner were to request a "safety" survey, he would probably request it in these terms rather than stating in detail which measurements he requires. The measurements should be included in the service, and the surveyor must be familiar with the measurements acclaimed (*4*) as those needed to determine the most important safety and technical parameters. The request for service was therefore stated in terms most often used by practitioners.

The low effectiveness score shown for the certified radiation physicist may be accounted for by the difference in his function from that of the other surveyors. His function is also the broadest and requires the highest level of training and background for certification by

Table 3. Cost computation of surveys of X-ray installations, by category of surveyor, St. Louis, Mo.

Item	Practitioner (1 man/1 hour/1 unit)	Certified radiation physicist (1 man/4 days/18 units)	Certified health physicist (1 man/3 days/18 units)	PHS demonstration team (1 man/4 days/20 units)	State sanitarian (1 man/4 days/20 units)
Salary				$83	$78
Expenses and travel		(1)	(1)	170	70
Patient fees lost (net)	35				
Consultant fees		1,364	450		
Total	35	1,364	450	253	148
Cost per unit	35	76	25	13	7

[1] Included in total amount.

NOTE: Cost of instrumentation not included. Figures rounded to the nearest dollar. Number of units includes radiographic and fluoroscopic. Cost per unit: total cost divided by number of units. Total cost: travel to offices; set fees; less professional fees (practitioner); salaries; and other.

the American College of Radiology. Although each certified physicist is knowledgeable about all phases of radiation physics, he may be more knowledgeable on certain aspects than on others.

The certified radiation physicist engaged for this survey may not have been strongly oriented toward patient safety factors at X-ray installations, whereas the PHS demonstration team and the sanitarians they trained were taught to work full time on this one facet. For calibration of therapy equipment or other facets of radiological health, the scores may well have been reversed.

In summary, the cost comparisons speak for themselves. The comparisons of effectiveness, however, are tabulations of only one facet of radiation protection. They do not compare one group's knowledge with another's, and are not intended to belittle the efforts of any group. This study was designed only to compare the results achieved when persons engaged in various facets of radiological health undertake a survey of safety factors in X-ray installations. We feel that this kind of study might well be duplicated in other locations of the country to see whether the same trend is evident in the comparisons.

Conclusions

The St. Louis study demonstrated that for a relatively low cost an effective X-ray protection survey, from a public health significance standpoint, can be obtained by training and using health department personnel. In many areas they are the only persons available to perform such a survey. Even if sufficient certified radiation physicists and certified health physicists were available for survey purposes, they would be better engaged as consultants in matters such as calibration of therapy units and detailed and broad studies of X-ray installations or to design or supervise X-ray inspection programs, which can be carried out in a practical manner by personnel with less training and experience. Their function is obviously different from that of a surveyor whose sole function is to examine in a prescribed manner primarily for factors which contribute most to reduction of exposure from unnecessary radiation.

We wish to stress again that the study was not intended to demonstrate that trained technicians are better qualified as radiation experts than radiation and health physicists. Any conclusion to that end is illogical. The effectiveness of the technician teams conversely is the result of the skills of the radiation and health physicists who directed the establishment of the criteria used in this study (*4*). Nor do we wish to imply that all X-ray programs be limited to a physical check of a few machine components. A more comprehensive physical view or the inclusion of an educational effort can be an integral part of the inspection program, provided qualified personnel for these additional duties are available.

The results of the study indicate that, from a cost and public health standpoint, the training of a health department person with a college degree by his own department or by the Public Health Service to perform effective X-ray surveys is a sound investment. This kind of X-ray surveyor has the potential for effecting the greatest mass reduction in unnecessary exposure to radiation in the United States today.

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