AAPM REPORT NO. 58

MANAGING THE USE OF FLUOROSCOPY IN MEDICAL INSTITUTIONS

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MANAGING THE USE OF FLUOROSCOPY IN MEDICAL INSTITUTIONS

I. INTRODUCTION

The Need for Radiation Management in Fluoroscopy

The use of x-ray fluoroscopy has increased dramatically in recent years and is spreading beyond the radiology department. Although radiologists receive training in radiation safety and radiation biology, these topics are not part of most medical school or post graduate medical residency training for other medical specialists using fluoroscopy. Furthermore, improvements in radiologic technology have allowed more powerful x-ray sources to be incorporated into the standard and mobile fluoroscopy systems used by these specialists. The use of such equipment by personnel who have not received specialized training in the proper use of radiation creates the potential for excessive radiation exposure to personnel and patients. Inadequate training combined with increased radiation outputs, higher x-ray tube heat capacities, and real-time digital image acquisition and storage capability can produce patient doses that induce serious skin damage and other potentially deterministic effects. Deterministic effects are those for which the severity of the effect varies with the dose and for which a threshold usually exists.

For these reasons it is necessary to develop procedures for managing the use of radiation from fluoroscopy to ensure that patients and personnel are not exposed to excessive levels of radiation. The purpose of this document is to provide medical physicists with resources that can be used in managing the use of radiation from fluoroscopic equipment in medical institutions.

Managing fluoroscopic use is not limited only to radiation safety practices. It also involves equipment performance evaluation and quality control testing, monitoring of radiation doses to patients and personnel, and education and training of personnel. There are a number of resources to assist the practicing medical physicist with methods for evaluating performance of fluoroscopic equipment. Several such resources are listed at the end of this document (1-3). These issues will not be addressed here. It is also assumed that the reader is familiar with the basics of personnel radiation safety and personnel monitoring. A list

of several documents that deal with basic radiation safety and radiation bioeffects is also provided for completeness (4-11).

Two aspects of management of radiation use that have not been dealt with in the past are: 1) a quality management program that monitors radiation usage in general, as well as radiation doses to individual patients and 2) the development of a training and credentialing process for users of fluoroscopy equipment. This document is designed to provide practicing medical physicists with information regarding these areas and resource materials that may be used in an education program for non-radiologists who use fluoroscopy.

II. MONITORING PATIENT DOSES

Patient dose monitoring serves several purposes. 1) It allows comparison among users within and outside an institution for quality improvement (See section III). 2) It allows verification of workloads used to determine the adequacy of shielding or the extent of protective measures that have been taken to protect personnel. 3) In cases of high dose procedures it provides information that may assist the medical staff in the direct care of individual patients.

The medical physicist plays a major role in monitoring the radiation dose to patients undergoing fluoroscopic procedures.

Monitoring by Type of Procedure

The first two purposes stated above can be achieved by maintaining records of fluoroscopic time. Regulation requires that fluoroscopic equipment must have a resemble timer that indicates the passage of five-minute time periods. This can be used to keep track of fluoroscopic times for various procedures. Unfortunately, the value of recording this information is not generally understood by the medical personnel who are available to perform the duty. Hence, an accurate record of fluoroscopic time is not always maintained. A useful addition to a fluoroscopic system is a cumulative, non-resetable timer that allows the physicist to determine what fractions of procedures are actually being logged. More reliable information can be obtained using

automated systems that record either dose-area product or total exposure at the skin. Data from an automated process are more reliable.

Table 1 provides some typical fluoroscopic exposure times, techniques. workloads. and estimates of the number of recorded images for a variety of applications obtained at one training institution. These data can be useful in determining if use of fluoroscopy is comparable in your institution. It is likely that exposures will vary significantly between training institutions and the private practice setting. Typically, fluoroscopic times used in private practice are about half those used in training programs. The number of spot films used for typical gastrointestinal exams are typically one-third to one-half of the number of digital images shown in the table. No rigid limit can be placed on any given procedure without regard to the patient's condition and prognosis, or the potential benefits of the procedure to the patient. The table also can be helpful in deciding which types of procedures are likely to lead to high skin doses. Such procedures may need to be monitored on a patient-by-patient basis.

Monitoring Individual Patient Doses

For certain high dose procedures, particularly interventional procedures, it may be valuable, or even necessary to monitor the dose to the skin of individual patients (12). For this purpose, recording of fluoroscopic times is inadequate. In certain types of interventional procedures (e.g., neurological embolizations), much of the radiation dose to the skin is derived during digital subtraction angiography. Some interventional procedures involve frequently moving the x-ray source relative to the patient during the procedure. Thus, if one wants to calculate skin doses based on technique factors and machine output data, it is necessary to know the source-to-skin distance as well as the amount of time radiation has been applied at different locations on the skin. Adjustments to collimators and gantry angles of C-arm equipment also affect whether x-ray fields overlap at certain points on the skin.

Table I. Fluoroscopic Exposure Times, Techniques, and Workloads

Department/Section BP-Biplane, SP-Single Plane, PC-Port, C-Arm	Unit	Weekly Use (Pat)	kVp (avg.)	Ave. Time (Min.)	mA (Avg.)	mAmin	# of Spots	Cine fps/ sec/run	Remarks
1. Cardiology									
Ped. Cath	BP	5	65	20	1	20		60/10s	2 Runs
Adult Cath - Left Heart	SP	10	70	10	3	30		30/10s	10 Runs
- Right/Left Heart	SP	15	70	30	3	90		30/10s	10 Runs
- PTCA (angioplasty)	SP	10	70	90	3	270		30/10s	20 Runs
EP Lab	SP	5	70	40	2	80			Fluoro only!
2. Medicine									
Endoscopy - ERCP	PC	5	70	30	2	60	2		(9×9) Spot
3. Neuroradiology									
Angiography - Cerebral	BP	10	80	15	3	45	240		Digital
- Cerebral w/ Embolization	BP	1	80	135	3	405	1350		Digital
Myelography (In Rad. Department)	SP	8	70	10	2	20	12		(9×9) Spot

Table I. Fluoroscopic Exposure Times, Techniques, and Workloads (Cont.)

Department/Section BP-Biplane, SP-Single Plane, PC-Port, C-Arm	Unit	Weekly Use (Pat)	kVp (avg.)	Fl. Time (Min.)	mA (Avg.)	mAmin	# of Spots	Cine fps/ sec/run	Remarks
4. OB-GYN									
Hysterosalpingogram (Rad. Department)	SP	2	70	5	2	10	5		Digital
5. Orthopedics									
Arthrogram (In Rad. Department)	SP	1	65	15	1	15	13		Digital
6. Mobile/OR.									
C-Arm Fluoro (On the Floor)	PC	2	70	1	2	2			Fluoro Only!
Pacemaker - (In OR)	PC	8	76	8	2.5	20	2		Fluoro Only!
Orthopedic - (In OR)	PC	10	60	8	1	8	2		(9x9) Spot
Line Placement (In OR)	PC	16	70	1	2	2			Fluoro Only!
G. I. Fluoro (In OR)	PC	9	76	1.5	3	4.5	2		(9x9) Spot

Table I. Fluoroscopic Exposure Times, Techniques, and Workloads (Cont.)

Department/Section BP-Biplane, SP-Single Plane, PC-Port, C-Arm	Unit	Weekly Use (Pat)	kVp (avg.)	Fl. Time (Min.)	mA (Avg.)	mAmin	# of Spots	Cine fps/ sec/run	Remarks
7. Radiology									
G. I.	SP	27	100	10	2	20	18		Digital
B. E.	SP	9	95	13	2	26	23		Digital
Chest/Abdomen General	SP	15	95	7	2	14	10		Digital
Enteroclysis (Small Bowel)	SP	2	100	20	2	40	23		Digital
Pediatrics	SP	20	65	10	1	10	5		105-Camera
Angiography - Abdominal/Chest	SP	3	80	20	3	60	45		Digital
- Angio w/ Thrombolysis	SP	1	80	40	3	120	45		Digital
- Extremity	SP	2	65	15	1	15	47		Digital
Angioplasty/Angiography-Abdomen/Chest	SP	1	80	30	3	90	50		Digital
Extremity	SP	1	65	30	1	30	40		Digital
8. Urology									
Cysto - Retrograde	SP	10	68	5	2	10	2		(9x9) Spot

At this time, no automated system adequately provides all the necessary information to determine dose to any point on the skin accurately. Systems are available that will record and display total skin entrance exposure (13,14). However, the values reported by this system do not take into account the horizontal movement of the patient couch relative to the x-ray beam. This type of system at least will not underestimate the exposure. Dose-area product meters, as presently designed, do not provide enough information to determine dose to a point unless additional information about the x-ray field size and source-skin distance is recorded separately.

Direct measurement of skin dose during high dose fluoroscopic procedures is complicated by the fact that it is not possible, a priori, to know where the most intense radiation level will exist on the skin. Standard TLD chips cover only a small area and are likely to underestimate the maximum skin dose because they may not be placed at the location of highest dose. One manufacturer currently offers a sheet of MgB_4O_7 TLDs that covers approximately a 12" x 12" area with dosimeters placed at 3 mm intervals in a two-dimensional array (15). The TL material is held to the sheet using a polyamide binder. At this time the usefulness of this material for dosimetry during high dose fluoroscopy has not been completely analyzed.

Photographic film may be used to estimate skin dose over a large area. The advantages of film are: low cost, ready availability of processing, and ease of analysis by densitometry. The major disadvantage is that few types of film available in large sheets have the sensitivity to measure doses in the range of several gray (16). Certain fine grain films used in the graphic arts field for copying seem to have good potential in low energy, high dose dosimetry (17,18). The suitability of any film for use under these conditions needs to be investigated before it can be used. Particular problems that the physicist needs to be aware of are: the energy sensitivity of the film, changes in response from one box or emulsion batch to another, and the potential for the patient's body heat to alter sensitivity during exposure. Even if it is not useful for the direct measurement of dose, photographic film will, if it is not too sensitive, provide information about the location of the x-ray field on the skin and the field sizes used. This information may be useful in converting numbers from automated dosimetry

systems or dose-area-product meters to reasonable local skin dose estimates.

"Radiochromic" film may also be a candidate for skin dose monitoring. Its ability to turn color after direct x-ray exposure and its insensitivity to room light would make it possible for fluoroscopists to obtain immediate qualitative information regarding the skin exposure and the area exposed (17). Unfortunately, the upper limit of the sensitivity range of these films currently barely exceeds the threshold for mild erythema.

For procedures that demonstrate the potential for high skin doses, a description of this potential should be provided to patients by the physician and informed consent should be obtained before performing the procedure. Patients who are suspected of having received doses sufficient to initiate erythema should be called back to the clinic at two weeks to determine the level of their skin reaction. Automated dosimetry systems that provide instantaneous information about the maximum possible skin dose may be beneficial in eliminating patients who do not require such follow-up and in determining which types of procedures warrant informing patients of the potential for skin damage or other deterministic effects.

III. QUALITY MANAGEMENT PROGRAM FOR MONITORING FLUOROSCOPIC USAGE

Introduction

The goal of everyone involved in a fluoroscopic study is for the procedure to be accomplished with the highest quality of care and a minimum of radiation exposure to both patients and attending personnel. Sometimes concerns are raised that this may not be occurring. For example, a technologist may feel a fluoroscopist uses an unnecessary amount of radiation. Such subjective observations are very difficult to act upon. A management plan with a program for quality improvement provides a recognized method to employ scientific principles for obtaining quantitative data to effect the change needed to achieve improved quality.

All medical facilities, whether ambulatory care or hospital, must establish processes that provide a safe environment for the patient and employee. Monitoring the use of fluoroscopy is well suited for incorporation into a quality management program. It is consistent with the standards of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) concerning the management of the environment of care (19). Although management programs are not currently required by law, the JCAHO requires such programs as a part of its accreditation process. JCAHO requires that a documented management program has organizational processes that address safety, medical equipment, and hazardous materials, which includes hazardous energy sources.

A management program is a plan designed with performance standards to measure and assess the organization's status in achieving a goal. The purpose of a management program is to provide the highest quality healthcare to the patient. A fundamental principle is that this is a management plan. There must be a commitment to the program by all those in a management position, both institutional administration and medical leadership, as well as the actual providers of the product. The management program must be a dynamic process to continuously improve the quality of patient care. This idea may be described as, or more generally known by the terms, "continuous quality improvement" or "total quality management." A cornerstone of the quality improvement process is that actions are based on statistical analysis of measured data. This is attractive to physicists because the use of quantitative measurements in the application of scientific principles is a part of daily practice. The program that follows incorporates methods of quality improvement established over the last 40 years (20-23).

A Road Map for Quality Improvement

The first step in the quality improvement of a process is to state the intended goal. This statement should describe the process to be studied and its boundaries. It must include the recipients of the results of the study and why the results are important, for example: "Fluoroscopic exposure times will be recorded to provide physicians and the medical leadership with a measure of the radiation exposure to their patients from certain procedures to aid in patient exposure reduction."

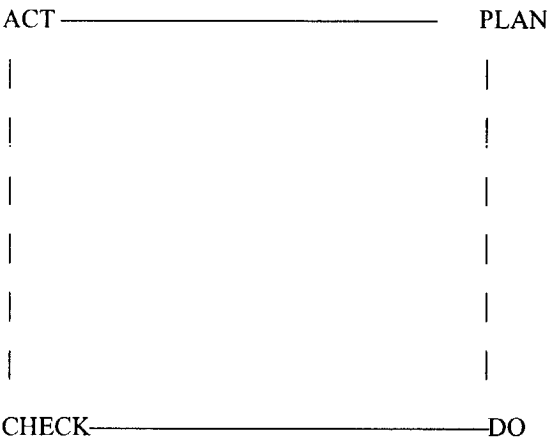
A team whose members are familiar with the process or problem should be organized. The team must include the team leader. If all fluoroscopy equipment is controlled by the radiology department, then a medical physicist or radiologist might be the team leader. In a large medical center where different departments may be responsible for and operate fluoroscopy equipment, a more appropriate team leader might be the institution's Radiation Safety Officer (RSO), or the administrator responsible for the institution/Es support services. In any case, a medical physicist should be a part of the team. The team should include individuals who work close to the process such as fluoroscopists, nurses, and technologists. The team evaluates the process using statistical tools.

The group must clarify the current knowledge of the process or problem to be studied. At this early stage, it may be desirable to refine the original goal statement, boundaries, or group membership.

A key area to understanding any process is defining the key quality characteristics of the process output that are important. For example, the time of the fluoroscopic procedure is important. Other important characteristics may be patient entrance exposure or occupational dose to tableside operators.

Ideally, while measuring the key characteristic, no other variable should affect the process, This is not generally possible. The team needs to identify the most important process variable(s) that must be controlled to minimize the variation in the measured characteristic. Examples of process variables in monitoring fluoroscopy usage are: medical procedure type (interventional versus diagnostic study), operator education (radiologist, non-radiologist, resident, fellow), operator experience, equipment type (mobile C-arm, biplane fluoroscopy, radiography-fluoroscopy) and patient condition.

Having chosen a process to improve, the team can apply the improvement concepts following what is called the "PDCA Cycle". PDCA stands for Plan-Do-Check-Act. The purpose of the cycle is to increase understanding of the process and converge on a stabilized or final method of improvement.



Typical actions that may occur during the different parts of this improvement cycle are:

PLAN

Establish data collection tool
Decide on improvements
Establish responsibility for refinements
Refine data collection procedures

DO

Collect data
Analyze data
Optimize use of graphical and statistical tools

CHECK

Look for patterns
Consider the customer and worker views
Identify measured improvements
Develop strategy for further improvements
Explore alternate measures

ACT

Standardize parts or procedures of the process to maintain gains
Revise policies and procedures
Define training needs
Monitor results of changes for further refinements
Document progress
Evaluate process for updating, completion, recommendations

Example Application

Scenario: Teaching hospital

Process needing improvement:
Reduction of radiation exposure during fluoroscopic procedures.

Team: Radiologist, cardiologist, medical physicist, technologist, administrator from department using fluoroscopy equipment.

Causes of process variation (agreed upon by team):
procedure type
complexity of procedure
fluoroscopists Æ experience
equipment used

Selected process improvement:
Provide baseline fluoroscopic times to fluoroscopist and management for different process variations.

PDCA Cycle

[Plan-Do]

1. Log maintained by technologists will record the following data:
   - Date
   - Procedure name
   - Fluoroscopist
   - Fluoroscopist's status
   - Total fluoroscopy time
   - Machine ID
   - Recorder's name or initials

2. Data from the log is regularly entered in a database and analyzed by the medical physicist; radiologist will follow-up areas not providing logs.

[Check]

3. Quarterly analysis will report average fluoroscopic times ± two standard deviations by:
   (a) procedure type for entire department;
   (b) individual physician for each procedure type.

4. Evaluate if the radiation risk to patients can be or is being reduced;
   Review with fluoroscopists and management for value of information;
   Review with technologists for improvements in data collection process;
   Review with physician for improvements in technique.

[Act]

5. Possible actions (Revising steps 1 through 4 as appropriate):
   Revise data collection (e.g., process variables in log)
   Provide further training
   Revise analysis and reporting
   Revise evaluation of risk reduction

6. Repeat "P-D-C-A" cycle until gain in improvements are maximized and sustained.

IV. CREDENTIALING OF PHYSICIANS USING FLUOROSCOPY

Introduction

Some states require a permit to operate or supervise the operation of fluoroscopic equipment. If not required by law, a facility should work with a qualified medical physicist to establish minimum requirements concerning the safe use of fluoroscopic equipment for every physician that performs fluoroscopy (24-26). In this section we describe a permit or credentialing process for use of fluoroscopy. This process can be used to establish minimal competency. A fluoroscopy permit program should involve the following elements.

Privileges

Fluoroscopy supervisor or operator privileges should be required for any physician who does one or more of the following:

a. Actuate or energize fluoroscopy equipment.
b. Directly control radiation exposure to the patient during fluoroscopy.
c. Supervise one or more radiological technologist(s) who perform (a) or (b) where allowed by law.

To obtain supervisor/operator privileges, a physician must demonstrate competency in fluoroscopic radiation protection and in the use of fluoroscopic and ancillary equipment.

Minimum Competency

Competency in the safe use of fluoroscopy may be established by means of an examination process or demonstration of appropriate continuing medical education credits. In either case the medical physicist should be involved in developing and possibly providing physician training. Information suitable for such training programs are provided in the following section of this document.

Insuring Physician Qualifications

Mandatory credentialing is a practical means to insure the qualifications of fluoroscopy operators. A requirement of minimum competency is part of the credentialing process. The medical physicist as Radiation Safety Officer or member of the Radiation Safety Committee should be instrumental in the implementation of this policy.

Establishment of a fluoroscopic permit or credentialing process should originate in the institutional RSC with support from the risk management department.

An information packet to bring to the RSC committee may include:

- FDA advisory on skin injuries
- Examples of specific cases that have resulted in radiation injury
- Information on other risks associated with radiation exposure
- Doses at which risks are significant
- Information on regulations requiring credentialing
- Dose information specific to your facility, e.g., average and exceptional fluoroscopic times for typical procedures.
- Information regarding equipment dose mode options (such as high dose or dose-saving).

Prepare a recommended policy for approval by the Radiation Safety Committee together with a plan for implementation (see example "Plan for Implementation" below). Radiation Safety Committee representatives (physician and administrative representative) must take the policy from the RSC to the physician credentialing committee within the facility. The information packet may be included with the RSC policy.

Plan for Implementation

1. Identification of physicians needing training and testing to meet competency requirements. Because institution policies and equipment capabilities change over time it is important to require that all uses of

fluoroscopic equipment demonstrate knowledge of policies, radiation effects, and competence in the use of the equipment.

Credentialing forms should include questions regarding:

a. need for privileges to use x-ray equipment, and the type of use anticipated;

b. documentation of any previous training - to be reviewed by RSO or RSC to establish exemption from training (hut not testing).

Upon review, physicians requiring training and testing to establish competency should be referred to the medical physicist for scheduling.

All physicians to be granted privileges for the use of x-ray equipment should he provided with information on institution policies together with state and federal regulations.

2. Training options

a. Possible formats

Self study - Videotape, slides, audio tape, books and articles, self-tests to demonstrate understanding. The advantage of including self-study as part of the program is that it allows physicians to complete the training at their convenience. Several articles are suggested at the end of this document for independent study (27-30).

Lectures (dialogue) - This format allows for important interaction between the medical physicist and physicians. The medical physicist can answer questions and become aware of the concerns of physicians and areas where problems exist. This time can he used to begin to establish a relationship with the physicians, so that they become aware of the medical physicist as a resource.

Hands-on equipment demonstrations - especially important for physicians who routinely use fluoroscopy (cardiologists, for example).

b. Appropriate information

Information to be included in the training should be practical and tailored to the needs of the physician. Sample outlines for lecture or self-study and demonstrations, as well as some useful references follow in section V.

c. Testing

Written exams following training should be used to verify competency. Questions on all items listed in the sample outline should be included in the exam.

d. Updates

In-services should be provided by the medical physicist whenever equipment changes warrant. Periodic refresher training and re-examination should be conducted annually.

V. TRAINING PROGRAMS IN THE SAFE USE OF FLUOROSCOPY

The following documents are intended to be an aid to the physicist in organizing and presenting safety training to fluoroscopists. These documents may not be applicable to all situations. We have tried to make them as complete as possible, recognizing that each state has its own regulations and each hospital, its own policies. For this reason it is not possible to include, in a document intended for general use, statements that specify requirements. For example, in some states only physicians may perform fluoroscopy. In others, technologists may perform fluoroscopy but only under the direction of physicians. In some states, technologists may perform fluoroscopy without supervision. In some states, or hospitals, these technologists must be registered by the ARRT or licensed by the state. These kinds of variations are found in many aspects of radiation safety. Keep this in mind in preparing your own education program and plan on modifying these documents to meet specific state, local, and institutional requirements.

Sample Lecture Outline

I. Introduction
   A. Why this course?
      1. Radiation Control and Credentialing Committee requirements
      2. Fluoroscopy can cause serious injuries, FDA Public Health Advisory (1994)
      3. JCAHO: continuous monitoring and quality management
   B. Goals of this presentation
      1. Present facts about radiation (units, biological effects).
      2. How fluoroscopy works.
      3. How much radiation is received by patients and staff.
      4. Steps to reduce radiation.
      5. Regulations.

II. Ionizing radiation
   A. Ionizing part of the electromagnetic spectrum.

III. Generating x-rays
   A. kVp determines the penetration of the x-rays (impacts image contrast and radiation dose).
   B. mA determines the number of x-rays (affecting radiation dose and image noise).
   C. Collimation limits x-ray field, shields personnel.

IV. X-rays and matter
   A. Some x-rays pass through matter undisturbed to form image.
   B. Some x-rays are absorbed in matter.
      1. More at low energies.
      2. More in high atomic number material (lead aprons).
   C. Some x-rays are scattered.
      1. Causes low contrast images.
      2. Major source of exposure to personnel.

V. Fluoroscopy
   A. Image intensification (including magnification).
   B. Automatic Brightness Control.
   C. Pulsed vs. continuous dose rates for routine and high level control operations.
   D. Record mode (higher doses).

VI. Quantifying radiation

A. Exposure - roentgen (R) or coulomb per kilogram (C/kg).

B. Dose - rad or gray (Gy).

C Effective Dose, rem or sievert (Sv)

1. Quality Factor (Q)

D. 1 R = 1 rad = 1 rem = 1000 millirem.

E. 1 Gy = 100 rad; 1 Sv = 100 rem

VII. Natural Background Radiation

A. Sources: Terrestrial, cosmic, internal.

B. Variation with altitude.

C. Radon.

VII. Medical Dose Rates

A. Fluoroscopic patient entrance dose.

1. 20 mGy/min (2,000 millirem/min).

2. High dose 300 mGy/min (30,000 millirad/min).

VIII. Typical personnel exposure

A. At table side:

1. Without a lead drape:

a. 2 mGy/hr (200 millirad/hr) during fluoroscopy.

b. 30 mGy/hr (3,000 millirad/hr) during high dose rate fluoroscopy.

c. Rule of thumb: scatter to unshielded personnel at 1 feet from patient is 1/100 of the patient skin exposure.

2. With a lead drape or shield:

a. 20-50 mGy (2-5 millirad/hr) during fluoroscopy.

b. 150-400 mGy/hr (15-40 millirad/hr) during high dose rate fluoroscopy.

B. At eye or thyroid level during fluoroscopy.

1. without a lead drape 2-5 mGy/hr (20-50 millirem/hr).

2. with a lead drape 1 mSv/hr (0.1 millirem/hr).

IX. Deterministic Effects of Radiation

A. Effects on the individual.

B. Severity of the effect depends on dose and dose rate, volume irradiated, biological variability.

C. Possible effects.

D. Latent period.

E. Threshold.

F. Fluoroscopic times to achieve effects.

X. Stochastic Effects:

A. Cancer deaths: 400 “extra” cancer deaths per 10 mSv (1 rem) total body effective dose equivalent per million from exposures over a long time.

B. 190,000 cancer deaths per million in an unirradiated population. If 1 million people are irradiated to 10 mSv (1 rem) there would be 190,400 cancer deaths (0.2% increase / 10 mGy (rad).

C. Thyroid Cancer: Natural incidence 4/100,000 (about 5% fatal) Induction rate due to radiation is 0.04 thyroid cancers per 100,000/rem thyroid effective dose equivalent.

D. The average latent period for cancer induction is 20 years; for leukemia, 7 years.

XI. Fetal Irradiation:

A. Lifetime cancer risk: 1/2500, 1/1000/rem if irradiated in utero.

B. Mental retardation - most serious effect.

1. threshold: 10-20 rad.
2. dose dependent: 0.2-0.3 IQ points per rem.
3. Most sensitive period: 8-15 weeks post conception. No radiation induced mental retardation by exposure before 8 weeks or after 26 weeks. The natural incidence of mental retardation 0.3 per 1000 live births.

XII. Genetic Effects

A. Normal incidence: 110,000 abnormalities per million live births.

B. 22-110 abnormalities per million more from a dose of 10 mSv (1 rem).

C. Doubling dose: about 2 Sv (200 rem).

XIII. Dose limits and Personnel Monitoring

A. Annual occupational effective dose:

1. 50 mSv (5000 millirem) for whole body.
2. 150 mSv (15 rem) to the lens of the eye.
3. 500 mSv (50 rem) for extremities, skin or organs.
4. Fetal exposure: 5 mSv (500 millirem) during pregnancy, 0.5 mSv (50 millirem)/mo.
5. Employees must declare pregnancy in writing to receive this consideration.

B. Total Effective Dose Equivalent must he less than age in rem or 10 MsV x age in years.

C. Exposures must be maintained as low as reasonably achievable (ALARA).

1. Badges are reviewed by radiation safety officer.
2. Investigation levels are set lower than maximum permissible levels.

D. Personnel monitors

1. At least one badge outside the protective apparel on collar.
2. Not to be worn while a patient.
3. Dose to the badge is not dose to the person.

E. Continuous non-occupational Exposures (general public) less then 1 mSv per year (100 mrem/yr).

XIV. Exposure Reduction

A. Time.

I. Do not expose the patient unless the physician is viewing the TV image.
2. Use freeze frame (last image hold) when possible.
3. Use pulsed fluoroscopy, if designed to reduce dose, when possible.
4. Use record mode only when permanent record is required.

B. Distance.

1. One step back from tableside can cut the exposure rate by a factor of 4.
2. Lateral fluoroscopy: 5 times dose reduction on intensifier side vs. x-ray source side.
3. Move Image Intensifier closer to patient:
   a. less patient skin exposure.
   b. more of the scatter is intercepted by the tower.
   c. sharper images.

C. Shielding

1. Lead Aprons (0.5 mm thick) attenuate scattered x-rays by a factor of 20.
2. Thyroid Collars.
3. Protective glasses.
   a. wrap-around provision adds protection.
   h. only needed for very high work load.
4. Always use shielded rooms when it is possible to move the patient.
5. Consider patient shielding: gonads, eyes, thyroid.

D. Other dose reduction techniques

1. Collimate to the smallest region needed with the largest field of view possible.
2. Consider removing grids for small fields.
3. Use alternate C-arm gantry angles to avoid high skin doses in long procedures.
4. Avoid HLC rate mode.
5. Never place any part of your body in the primary x-ray beam.
6. Consider increasing added beam filtration beyond minimum requirements.

XV. State Regulations and Hospital Policies

Add policies and regulations unique to your situation.

Sample Handout for Physicians - Radiation Dose Reduction in Fluoroscopy

I. X-ray Physics and Technology

Ionizing radiation:

X-rays, gamma rays, alpha and beta particles are ionizing radiations. All of these can come from the decay of a radioactive material. However. x-rays most commonly are produced in a vacuum tube by an x-ray machine. Alpha and beta particles do not penetrate very far in tissue, and are not a concern in x-ray safety. Gamma rays ate produced by radioactive materials used in nuclear medicine. X-rays and gamma rays have the same properties. Both are electromagnetic radiation that can penetrate the body more or less depending on their energies.

At high enough energies electromagnetic radiation can ionize an atom, that is, remove electrons from the atom. X-rays behave more like particles than waves. These particles are called **photons,** or quanta, which can bounce off or scatter from matter.

Generating x-rays:

X-rays used for medical imaging have energies of about 25,000 to 125,000 electron volts (25 to 125 keV). An electron volt is a unit of

energy. These are made by accelerating electrons in the x-ray tube from the negative cathode of the tube to its positive anode across voltages of 25 to 125 **kVp** (peak kilovolts).

Changing the kVp of the x-ray machine changes the energy and number of the x-rays. Changing the **mA** (milliamperes) changes the numher but does not change their energy. The total number of x-rays produced also depends on the total time (seconds) of the exposure. The total number of x-rays depends directly on the product of the mA and the seconds or mA-s.

The x-ray tube is surrounded by a lead housing that allows x-rays only to be emitted through a small opening or port. This **primary beam** of useful radiation is shaped by the **collimator,** which contains lead strips that can be adjusted to provide different beam shapes or sizes.

Interactions of x-rays with matter:

When x-rays pass through tissue, they are scattered. Scattering occurs in all directions. In the diagnostic energy range there is little change in the amount of scattering with the x-ray energy. The more dense a material is the more scattering occurs. Scattered radiation is the source of exposure while working around patients during fluoroscopy.

Fluoroscopy:

Most of the radiation that passes through the patient is absorbed by the fluorescent screen of the **image intensifier.** The screen gives off light that is converted to electrical energy and amplified (intensified) before being converted back to light in the intensifier. The light image is then viewed. The TV monitor needs a relatively constant electronic signal level for proper visualization of the image. This is controlled by the **automatic brightness system** (ABS), which adjusts the x-ray generator and the radiation striking the patient. When the fluoroscope is moved from a region that transmits little radiation to one of high transmission (e.g., the heart to the lungs) the ABS lowers the dose rate and prevents a whited out appearance of the image.

Fluoroscopic units usually have some means of image recording or **fluorography.** This may be electronic in the case of digital images or may use film for still pictures (spot films) or motion pictures (ciné). During fluoroscopy the noise due to the low level of x-rays used is averaged by the eye over several TV frames. When images are recorded, the eye looks at the same image continuously or, sometimes, in slow motion. Thus, recording images requires higher radiation doses than continuous TV imaging. Dose rates during ciné recording dose rates ate usually 10 to 20 times higher than during normal fluoroscopy.

In many cases there is an x-ray **grid** between the patient and the intensifier. The grid contains small strips of lead lined up parallel to the x-ray beam so that radiation from the primary beam passes through the grid but radiation scattered from within the patient is absorbed in the strips. Radiation improves the contrast in the picture. Using a grid means less radiation reaches the image intensifier so more kVp or mA is needed and the patient dose is higher. In many fluoroscopy applications the x-ray field is so small that there is little scatter to be removed. In systems where the grid is not permanently mounted on the intensifier, removing the grid may be advisable for studies involving small field sizes and thin patients.

Quantifying radiation:

Ionizing radiation is measured by measuring the ionization produced in a certain volume of air. This is done in an ionization chamber. The number of ions produced by x-rays in a certain amount of air is called the **exposure.** The unit of exposure is the roentgen (R) named after the discoverer of x-rays. The SI unit of exposure is coulombs per kilogram (C/kg).

We are more often interested in how much of the x-ray energy. The energy absorbed in a material is called the radiation **dose.** The unit dose is the **rad** or gray. X-rays used in fluoroscopy produce a dose in soft tissue of about one rad (a little less) if the exposure at that point in air is one roentgen.

In discussing risk of an individual of getting cancer from radiation it is sometimes necessary to average the energy absorbed over all the

organs at risk. This weighted average is called the **effective dose** or effective dose equivalent.

The SI unit called **gray (Gy)** is 100 rad and the **sievert (Sv)** is 100 rem. At diagnostic x-ray energies, one roentgen is approximately one rad, which is approximately one rem. These units are sometimes too large unit to work with, so doses, etc. will often he given in millirad (mrad), millirem (mrem) or milliroentgens (mR). Other units that are based on the international system of units (SI units) are coming into more common use.

Background radiation doses:

We are constantly exposed to ionizing radiation from natural sources. This **background radiation** comes from cosmic rays from outer space, radioactive materials that have always been in the earth (like radium, radon and uranium), and from the same radioactive materials that we have collected in our bodies through eating food grown in the earth. If the radiation to our lungs from radioactive radon gas is included, the average background effective dose is about 300 mrem.

Medical doses:

The greatest single source of radiation exposure to the average person in the United States comes from medical irradiation. Medical doses range from a few mrad for a chest x-ray to thousands of rad in the treatment of cancer. The average U.S. citizen gets an effective dose from medical radiation of about 100 mrem per year. During fluoroscopy a patient typically receives radiation to the skin at a rate of about 2 R per minute. This exposure rate can be as high as 30 R per minute under certain conditions using a high dose rate mode if the patient's skin is close to the collimator. Under these conditions the fluoroscopist will hear a special warning sound coming from the generator. During ciné recording, exposure rates at the skin may exceed 90 R/min.

Typical X-ray personnel exposures:

Typical exposure rates to personnel involved in x-ray fluoroscopy procedures are considerably lower than those to patients. As a rule of thumb the exposure rate to personnel standing three feet from a patient would be about 1/1000 of the patient's exposure if no protective measures are used. For the patient exposure rates mentioned above, this would lead to personnel exposure rates of typically 120 mR/hr. dose rates to fluoroscopists who must stand close to the patient could be as high as about 60 mrad/min if protective shielding is not employed. A lead shield between the patient and personnel will reduce personnel dose by more than a factor of ten. Often employees are able to stand farther away from the patient leading to dose reductions of 100 or more. Table 2 shows the decrease in exposure with increases in distance to the source.

II. Radiation Biology

Biological effects of radiation:

Atoms ionized by radiation may change chemically, becoming free radicals. These free radicals can damage a cell's DNA. The DNA may also be altered directly by radiation. In either case if the DNA is damaged, several things can happen. The most likely is that the damage will be repaired before the end of the cell's cycle. If not, the cell will probably die. There is some chance that the cell will survive and behave differently because of the damaged DNA. For example, it may become malignant. Large radiation doses may kill many cells causing noticeable damage such as erythema or epilation. Low doses do not cause such significant changes but may produce a malignant change.

Radiation sensitivity:

Repair enzymes and the immune system reduce the likelihood of radiation causing cancer or genetic changes, but they do take time to act. If radiation is received slowly over a long time, it has much less effect than if the same dose is received in a short time. Younger cells, particularly undifferentiated cells, and other cells that grow and reproduce rapidly are more radiosensitive than mature, slowly changing

cells. For this reason, radiation to children and pregnant mothers causes additional concern. The bone marrow is much more sensitive to radiation than nerve cells, which have an extremely long cell cycle.

Effects of high doses:

A large number of effects of ionizing radiation (occur at high doses. These all seem to appear only above a threshold dose. While the threshold may vary from one person to another, it is about 200 rad. The severity of these effects increases with increasing dose above the threshold. These so called deterministic effects are usually divided into local changes in different tissues and the effects associated with whole body exposures that lead to acute radiation syndrome.

Local effects include erythema, epilation, sterility, and cataracts. The first three of these can be temporary at doses of 200 rad or permanent at doses greater than 600 rad. Above 50 rad, a decrease in leukocyte counts can be detected. Most of these deterministic effects ate seen within days or weeks after the exposure, but cataracts may appear a few years after exposure. Table III shows some of the potential deterministic effects to patients from fluoroscopy and how long it would take to achieve them at “typical” and “high” dose rates.

Table III.

Effect	Threshold Dose (rad)	Hours of Fluoro on time @ 2 rad/min	Hours of Fluoro on time @ 30 rad/min	Time to onset of effect
Epilation	300	2.5	0.17	3 wk
Erythema	600	5.0	0.33	10 days
Pericarditis	800	6.7	0.44	>10 wk
Dermal Necrosis	1800	15.0	1.00	>10 wk

Effects of low doses:

Estimates of low level radiation exposures are based on data from higher dose exposures Studies of the survivors of Hiroshima and Nagasaki, radiation workers and some patients all provide data. The NCRP estimates that an exposure of 1 rem to 1 million persons would

result in an increase in cancer deaths from 190,000 to 190,400. This is an increase of 0.2 percent.

Genetic changes are thought to follow a linear non-threshold response. The doubling dose, is the radiation dose required to double the natural mutation rate. It is estimated to be about 200 rad.

The effects of radiation on the embryo and fetus:

Animal studies have shown the embryo and fetus are more sensitive to the effects of radiation than the adult. Exposure in utero can lead to increases in birth defects. In utero exposures during the bombings of Hiroshima and Nagasaki to doses greater than 20 rad showed an increase in mental retardation and microcephaly if the exposure occurred during the 8-26 week period when the brain is developing.

The National Council on Radiation Protection and Measurements has recommended limiting the effective dose equivalent to the fetus of a pregnant worker to 50 mrem during any month of the pregnancy. Many states have incorporated this limit in their regulations for workers exposed to x-rays.

III. Radiation Safety

Maximum radiation effective dose equivalent limits:

Generally the reading on a radiation monitor (film badge) worn outside the apron at the collar will be about three to ten times the total effective dose equivalent obtained using the formula. Personnel working in radiation areas while wearing aprons must wear a film badge outside the apron at the collar. If they are likely to receive doses near the deterministic limits for the thyroid or lens of the eye, this badge will overestimate the effective dose and it may be advisable to wear another badge behind the apron on the trunk of the body. These factors are thoroughly discussed in NCRP Report 122: “Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers for External Exposure to Low LET Radiation” (7).

The following are the maximum effective dose equivalent limits recommended by the National Council on Radiation Protection and Measurement (NCRP Report #116).

Stochastic:

Effective dose	5 rem / year
Cumulative exposure	1 rem x age in years
Fetus	500 mrem / gestation period
	50 mrem / month

Deterministic:

Lens of the eye	15 rem / year
Others: red bone marrow breasts, lungs, gonads, skin, extremities.	50 rem / year

The ALARA philosophy:

Even though regulating bodies have established upper limits on the amount of radiation that employees can receive, they apply the assumption that lower doses mean lower likelihood of long range effects. This means that doses should be kept as low as reasonably achievable (ALARA).

Sample Demonstration of Fluoroscopy

The medical physicist demonstrates important principles of fluoroscopy as well as specific system features to physician users. Small groups of four or less physicians are preferable.

Patient equivalent phantom(s) and dosimeter(s) will be needed for these demonstrations.

Topics to be covered during the demonstration:

A. Effects of geometry on patient exposure
   1. Demonstrate the inverse square law.

2. Show the effect of distance between the patient and x-ray tube as well as the distance between the patient and the image intensifier on patient and personnel dose.

B. Automatic Brightness Control (ABC)

1. Explain how the ABC system works to maintain the brightness of the image.
2. Demonstrate the equipment options available
3. Demonstrate all available ABC modes on the system and their impact on patient exposure and image quality. Be sure to demonstrate high dose and pulsed fluoroscopy modes.
4. Use varying phantom thickness to demonstrate how the skin entrance exposure rates changes with patient size and tube angulation.
5. Show how the ABC system responds when a magnification mode is selected.
6. Show the effect of grid removal (if possible) on both skin entrance exposure and image quality. Discuss situations (high contrast) where grid removal is appropriate.

C Personnel exposure - scattered radiation

1. Explain and show where the main sources of scatter are located.
2. Demonstrate the effects of geometry on scattered radiation. Show how various geometries change the pattern of scattered radiation in the room.
3. Show how the intensity of scattered radiation is reduced by proper use of shielding.

D. Questions and answers / discussion

Sample Examination Questions

1. The average latent period for induction of a solid cancer is:
   A. 7 months
   B. 7 years
   C. 20 months
   D. 20 years

2. When you pan a fluoroscope from a region that transmits little radiation in the patient to one of high transmission (e.g., the heart to the lungs) the automatic brightness system:
   A. raises the dose
   B. prevents flaring of the image
   C neither A or B
   D. both A and B

3. The threshold for cataract production following radiation exposure over a long period of time is:
   A. There is no threshold.
   B. 2 Sv (200 rem)
   C. 6 Sv (600 rem)
   D. 12 Sv (1200 rem)

4. How many extra fatal cancers will be produced if a population of one million persons were irradiated to a whole body effective dose equivalent of 10 mSv (1 rem)?
   A. 100
   B 200
   c. 400
   D. No one knows.

5. Using pulsed fluoroscopy:
   A. always decreases patient and personnel exposure
   B. always increases patient and personnel exposure
   C. may increase or decrease patient and personnel exposure depending on equipment design
   D. increases patient exposure but decreases personnel exposure

6. The major source of radiation to the staff during fluoroscopy is:
   A. the patient
   B. the x-ray tube
   C. the collimator
   D. the image intensifier

7. Standing on the _____ side of the patient during lateral fluoroscopy will reduce the scattered radiation to the staff.
   A. tube
   B. image intensifier

8. A 0.5 mm thick lead apron attenuates 90 kVp scattered x-rays by a factor of:
   A. 5-15
   B. 20-60
   C. 75-125
   D. more than 1,000

9. The annual natural background (not including radon) in the U.S. is:
   A. 1 mSv (100 mrem)
   B. 2 mSv (200 mrem)
   C. 3 mSv (300 mrem)
   D. 4 mSv (400 mrem)

10. The annual whole body occupational dose limit is?
   A. 5 mSv (500 mrem)
   B. 50 mSv (5 rem)
   C. 150 mSv (15 rem)
   D. 500 mSv (50 rem)

11. What is the annual occupational dose limit to an employee's eye?
   A. 5 mSv (500 mrem)
   B. 50 mSv (5 rem)
   C. 150 mSv (15 rem)
   D. 500 mSv (50 rem)

12. Typical effective dose equivalent rates next to the table during fluoroscopy are:

A. 0.1 mSv/hr. (10 mrem/hr)
B. 1 mSv/hr. (100 mrem/hr)
C. 10 mSv/hr. (1 rem/hr)
D. 100 mSv/hr. (10 rem/hr)

13. What is a typical skin dose rate to the patient during fluoroscopy?

A. 3 mSv/min (300 mrem/min)
B. 30 mSv/min (3 rem/min)
C. 300 mSv/min (30 rem/min)

14. What is the typical skin dose rate to a patient during high dose rate fluoroscopy?

A. 3.0 mSv/min (300 mrem/min)
B. 30 mSv/min (3 rem/min)
C. 300 mSv/min (30 rem/min)

15. Where should the personnel radiation monitor be worn if only one is available?

A. Under the protective apron at waist level
B. Outside the protective apron at waist level
C. Outside the protective apron on the collar.

16. What is the maximum effective dose equivalent permitted to a fetus of an occupationally exposed individual?

A. 0.05 mSv (5 mrem)
B. 0.5 mSv (50 mrem)
C. 5 mSv (500 mrem)
D. 50 mSv (5 rem)

17. Who is permitted to fluoroscope or take x-rays of humans?

A. Licensed physicians
B. Licensed physicians and registered x-ray technologists
C. Anyone trained to do so
D. Doctors, nurses and registered x-ray technologists

18. The acute radiation effective dose equivalent required to produce skin erythema is:

A. 0.5 Sv (50 rem)
B. 2-5 Sv (200-500 rem)
C. 6-8 Sv (600-800 rem)
D. >10 Sv (>1000 rem)

19. The acute radiation effective dose equivalent required to produce desquamation is:

A. 0.5 Sv (50 rem)
B. 2-5 Sv (200-500 rem)
C. 6-8 Sv (600-800 rem)
D. >10 Sv (>1000 rem)

20. Which of the following are occupational dose limits?

A. for the breast, 500 mSv (50 rem)
B. for the lens of the eye, 150 mSv (I5 rem)
C. for a fetus, the same as a member of the general public
D. an accumulated lifetime DE of 600 mSv (60 rem) for a 30-year-old employee

Answers. 1-D; 2-B, 3-C, 4-C, 5-C, 6-A, 7-B, 8-A, 9-A, 10-B, 11-*, 12-C, 13-B, 14-C, 15-C, 16-C, 17-*, 18-B, 19-D, 20-*.
* Answers depend on state regulations,

REFERENCES

1. AAPM. Quality Assurance in Diagnostic Radiology, Medical Physics: Monograph No. 4. Waggener RG, Wilson CR, eds. American Institute of Physics, New York, 1980.
2. National Council on Radiation Protection and Measurements. Report 99: Quality Assurance for Diagnostic Imaging. NCRP, Bethesda, MD, 1988.
3. AAPM. Specification, Acceptance Testing and Quality Control of Diagnostic X-ray Imaging Equipment. Seibert JA, Barnes GT, Gould RG, eds. AIP, Woodbury, NY, 1994.
4. Starchman DE, Hedrick WR. A Practical Guide for Protecting Personnel, Pregnant Personnel, and Patients During Diagnostic Radiography and Fluoroscopy. Radiology Management 1993; 15: 22-30.
5. National Council on Radiation Protection and Measurement. Report 105: Radiation protection for allied health personnel. NCRP, Bethesda, MD, 1989.
6. National Council on Radiation Protection and Measurement. Report 107: Implementation of the principle of "as low as reasonably achievable" (ALARA) for medical and dental personnel. NCRP, Bethesda, MD, 1990.
7. NCRP Report No. 122. Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers for External Exposure to Low LET Radiation.
8. National Research Council Committee on the Biological Effects of Ionizing Radiations. Health effects of exposure to low levels of ionizing radiations (BEIR V). Washington, DC: National Academy, 1990.
9. Wall BF, Harrison RM, Spiers FW. IPSM Report #53, Patient dosimetry techniques in diagnostic radiology. Institute of Physical Sciences in Medicine. York, England, 1988.
10. Hall EJ. Radiobiology for the Radiologist, Harper and Row, New York, NY.
11. Pizzarello D, Witcofski RL. Medical Radiation Biology, W. B. Saunders, Co., Philadelphia, PA.
12. Wagner LK, Eifel PJ, Geise RA. Potential Biological Effects Following High X-ray Dose Interventional Procedures. Journal of Vascular and Interventional Radiology 1994; 5:71-84.

13. FDA Advisory: Avoidance of serious x-ray induced skin injuries to patients during fluoroscopically-guided procedures, September 9, 1994 and Public Health Advisory, September 30, 1994.
14. Pina MV, Deye JA. Comparison of two patient exposure measuring devices in a busy cardiac catheterization laboratory. Med Phys 20(3):917, 1993.
15. Gkanatsios N, Huda W. Evaluation of an on-line patient exposure meter in neuroradiology. Radiology 197(P):359, 1995.
16. Braunlich PF. Laser Heated Thermoluminescence Dosimetry. In: Luminescence: Phenomena, Materials, and Devices. Rao RP, ed., Nova Science Publishers, Inc. Cormack, NY, 1992.
17. Fajardo LF, Geise RA, Ritenour ER. A Survey of Films for Use as Dosimeters in Interventional Radiology. Health Physics, 68(4):595-599, 1995.
18. Fajardo LC, Geise RA, Ong HS, Lien W. Dose Response of a Film for Patient Dosimetry in Interventional Radiology. Med Phys 22(6):971, June 1995.
19. Geise RA, Fajardo LC. Exposure Response of LOC4 Film for Patient Dose Estimates in Interventional Radiology. Radio1 (P):358 1995.
20. Accreditation Manual for Hospitals. Environment of Care Standard 1.2, Joint Commission on Accreditation of Healthcare Organizations, 1995.
21. Walton M. "The Deming Management Method', Putnam Publishing Group, 1986.
22. Leader Workbook "Focus on Continuous Improvement", Hospital Corp. of America, 1990.
23. Nelson MT. Continuous Quality Improvement (CQI) in Radiology: An Overview. Applied Radiology, July 1994.
24. Moen RD & Nolan TW, "Process Improvement", Quality Progress, September 1987.
25. Swayne LC, Lam SCP, Fillipone AL, Ambrose RB. Credentialing Crossover Privileges. In: Fluoroscopy for Non-Radiologists. Radiology 190:281-282, 1994.
26. Balter S. The Training and Credentials of Fluoroscopists. In: Proceedings of the FDA/ACR Workshop on Fluoroscopy: Strategies for Improvement in Performance, Radiation Safety and Control. American College of Radiology, Reston, VA, 1993.

27. Spies, JB. “Physician Credentials and Privileges” in Proceedings of the FDA/ACR Workshop on Fluoroscopy: Strategies for Improvement in Performance, Radiation Safety and Control. American College of Radiology, Reston, VA, 1993.
28. Henderson PJ. Martin MS. California Syllabus on Fluoroscopy Radiation Protection. State of California, 1987.
29. Wagner LK, Archer BR. Radiation management for fluoroscopy for Physicians. Partners in Radiation Management, Houston 1995.
30. Geise RA, Hunter DW. “Personnel Exposure During Fluoroscopy Procedures,” Postgraduate Radiology, 8:162-173, 1988.
31. Geise RA and Morin RL. Radiation Management in Interventional Radiology. In Interventional Radiology, Casteñeda-Zuniga W, 3rd ed. Williams and Wilkins, Baltimore. In press.

APPENDIX A

Radiation Safety / Quality Assurance Program

There is an institutional Radiation Safety and Quality Assurance Program under the direction of the Radiation Safety Officer composed of the following:

Policies appropriate for the safe use of x-radiation by staff have been developed. The radiation safety program includes monthly review of personnel radiation exposure and radiation safety surveys as necessary.

Employees are required to receive education regarding the radiation safety and quality assurance at the time of employment and annually thereafter.

Problems that may arise regarding radiation safety are reviewed by the Radiation Safety and Quality Assurance Committee during its regular meetings. The Radiation Safety Officer will direct problems for resolution to the appropriate persons who will report back to the committee upon resolution of the problem.

Quality control procedures have been developed that will be used to assure and continuously improve the quality of x-ray imaging. The program includes routine quality control tests, equipment preventive maintenance, and annual monitoring of equipment performance and patient doses by a Certified Radiological Physicist. The radiation safety and quality assurance policies and procedures are reviewed annually by a Certified Radiological Physicist who will report to the Radiology Radiation Safety and Quality Assurance Committee regarding the appropriateness of the program components.

Records are maintained of all aspects of personnel exposures, quality control tests, equipment calibrations and repairs, radiation safety surveys, patient dose monitoring, equipment performance monitoring, and minutes and actions of the Radiation Safety Committee.

Personnel radiation exposure monitoring:

At the time of employment, personnel must provide any past radiation exposure history in writing to the Radiation Safety Officer. Personnel who have had or are likely to have had radiation exposure during any part of the current calendar quarter that exceeds one-fourth of the annual maximum permissible levels should notify the Radiation Safety Officer.

Personnel who are likely to receive one-tenth of the annual maximum permissible levels from exposure to x-rays are provided a collar badge to be worn in front of the apron.

Depending on the circumstances of exposure to x-rays at the collar outside the apron some individuals may be provided with a second badge to be worn at waist level behind the apron.

Pregnant personnel who are likely to receive more than 20 mrem per month on the collar badge from x-ray exposure should wear a second badge behind the apron at the waist.

in case of pregnancy different effective dose limits apply. in order for these differences to be considered, the pregnant individual must contact the RSO and declare her pregnancy in writing.

Badges should not be worn outside the work place. When not in use, badges must be left in a secure location where radiation levels are not expected to be above background. Badges must not be exposed to heat or high humidity.

It is illegal in some states to falsify the exposure information provided by a film badge or tamper with badges in any way.

Upon termination of employment, personnel should supply their forwarding address so that a final report of radiation exposure may be sent. The final report will be sent within thirty days of receipt of the information by the department.

General radiation safety rules:

The three basic methods of protection from exposure to ionizing radiation are time, distance, and shielding. Whenever practical, minimize the time you are near the part of the patient being exposed, increase your distance from them, and use available means of shielding to reduce your exposure. Tripling your distance from the patient being examined has approximately the same effect as putting on a lead apron. Both methods should be used for maximum exposure reduction.

Do not allow anyone in the x-ray room during exposure unless they absolutely must be there in order for the examination to be performed (or they are in training). If patients in an adjacent bed cannot he removed to a distance at least six feet away they must be shielded with a lead apron.

No one should hold patients during fluoroscopy if other suitable means of restraint or support are available. Persons holding patients must wear lead aprons and, if hands are close to the beam, lead gloves.

Scattered radiation from the patient is greatest in the region towards the x-ray tube, and least on the side of the patient opposite the tube (near the intensifier). When possible during lateral or oblique fluoroscopy, stand on the side of the patient farthest from the x-ray source (closest to the image intensifier).

Minors (other than patients) are not allowed in the room during fluoroscopy.

Never fluoroscope anyone solely for training or demonstration.

Never place any part of your body in the primary beam of the x-ray machine.

Wear your film badge at all times when involved in any radiation producing procedure.

Mobile fluoroscopic equipment should only be used when it is not practical to bring the patient to a shielded room. If a patient can be

moved without compromising patient care they should not be examined using mobile x-ray equipment.

Report any incident involving unwarranted radiation exposure to personnel to the RSO.

Employing radiation shielding:

Protective barriers are provided in the walls of all rooms containing fixed x-ray equipment. They typically contain 1.5 mm of lead or equivalent shielding material. Stand behind the shield whenever possible while making exposures for recording purposes.

Lead aprons contain the equivalent of 0.25 to 0.5 mm of lead. They must be worn during any fluoroscopic procedure or whenever you must be in an x-ray room while x-rays are being produced. Hang aprons on the appropriate hangers when not in use to reduce the likelihood of cracking. Never store an apron folded. Lead gloves containing at least 0.5 mm of lead should be worn whenever the hands are near the x-ray field unless contraindicated by the procedure (e.g., to maintain a sterile field).

Many materials can assist in reducing exposure through shielding. Intensifier and fluorographic recording devices are designed to function as an x-ray shield. They are more efficient than a lead apron. The human body absorbs more radiation than the average lead apron. Standing behind someone who must be closer to the patient to accomplish his/her job is a very good way to reduce your exposure.

Patients and employees within 6 feet of the patient being fluoroscoped with a mobile machine must be protected with at least 0.5 mm of lead (i.e., an apron).

Doors that are part of a radiation barrier must be closed during exposures.

Technologists should not perform fluoroscopy for medical purposes unless under the direct supervision of a physician.

Radiation protection for women of child bearing age:

The fetus is limited to lower exposures in the work place than workers. Because of possible discrimination, these limits only apply to women who have declared their pregnancy in writing. If you become pregnant and wish this added protection you must contact your supervisor and declare your pregnancy in writing.

Under these conditions the radiation effective dose equivalent to the embryo or fetus of an occupationally exposed woman must not exceed 500 mrem during the gestation period or 50 mrem in any one month. Pregnancy does not automatically prohibit a worker from working with radiation. When pregnancy is declared in writing, the individual's radiation history will be reviewed to determine if the occupational dose limits are likely to be reached and if any special precautions, monitoring, or changes of duties are appropriate.