D IAGNOSTIC radiographic examination of infants and children is invaluable in the investigation of many diseases. It is an extension of the physical examination, for there is no better way to look into the body. Not even exploratory surgery permits the rapid, detailed examination of deep-seated structures provided by radiology. Consequently, the problem eventually reduces itself to one of “risk:benefit ratio.”

The problem of proper radiation protection in children is not new, and a number of articles are available on the subject. Some of these articles contain data regarding specific permissible dosages to various areas of the body; others are more general in their assessment. However, even with these data, it is difficult to establish definite limits of radiation tolerance because the long-term effects have not yet been defined with precision.

Radiation overexposure can be broken down into four categories: (1) radiation skin reaction and radiation sickness, (2) disturbances in normal functional processes (e.g., radiation pneumonitis), (3) carcinogenic effects, and (4) genetic effects. The possible genetic effects are those of concern in the pediatric age group. The dose required to produce deleterious effects in the other categories described are virtually precluded by modern radiographic apparatus and technics. Carcinogenic effects have not been demonstrated from radiation doses received with pediatric diagnostic radiography. However, this remote hazard must be kept in mind for children with chronic illnesses requiring repeated radiographic examinations.

Radiation skin reaction or radiation sickness is not a complication of diagnostic radiography.

Methods of reduction of radiation exposure can be considered under five broad categories: (1) careful consideration of the need for radiographic examinations, (2) properly trained personnel, (3) proper protection of the patient, (4) radiation-reducing mechanical and physical characteristics of radiographic equipment, and (5) careful consideration of repeat and follow-up examinations.

REDUCTION OF RADIATION EXPOSURE

Consideration of the Need for Radiographic Examinations

1. Is the examination necessary? Is it used to confirm a diagnosis, to add another parameter to the diagnostic investigation, or is it just a complementary study?

2. Is there another better, or perhaps safer, examination or test (i.e., isotope examination, ultrasound examination, various laboratory tests) which can provide the same answer? Radiologic care of the child is best accomplished by the referring physician consulting with the radiologist. Clinical correlation aids the radiologist in determining the necessity for radiographic studies. If radiographic studies are required, the radiologist assumes the responsibility for the examination and the adequacy and accuracy of interpretation. In this manner, the radiologist shares responsibility with the referring physician for the general medical care of patients.

3. Are repeat or extra examinations obtained when old films are not available? Many times a child is referred from another center or physician and his films are a day or two late in arriving. Repeat studies, especially if they are extensive, should not be performed unless they are deemed necessary on an emergency basis. If possible, the physician should wait a reasonable time for

The statements presented herein do not preclude alternatives which may be more appropriate, taking into account local situations and all other relevant facts.

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the original films to arrive, especially if he considers the potential hazards of radiation and the additional expense. The same principle applies to "lost films," which may be temporarily misplaced and should not be automatically repeated.

4. Is the referring physician aware of what the roentgenogram is likely to tell him? This attitude requires orientation early in the referring physicians' training. Perhaps he should spend time during his training (elective time or formal rotation) in a radiology department to learn what to expect from the various radiographic examinations. He could learn how to communicate with radiologists, both on a daily person-to-person basis, and in the more general sphere of specialty-to-specialty.

**Trained Personnel**

1. Adequate training of the radiologist. Radiology residencies at institutions where pediatric radiology is not available should provide a rotation at a hospital that does have training in this subspecialty. Fluoroscopy should be done by radiologists. Nonradiologists required to use fluoroscopy (such as a cardiologist during cardiac catheterization) should be trained by a radiologist in the physics, use, and hazards of the procedure.

2. Specially trained radiology technicians are necessary for the radiographic examination in infants. The use of experienced and well-trained technicians, with ancillary personnel, leads to more efficient radiographic examinations and a decreased number of technical failures, which result in repeated examinations.

**Protection of the Patient**

1. Collimation. It is most important that only the area to be examined be exposed to the direct x-ray beam. This can be accomplished by the use of various collimation devices. Automatic collimators are now available on some x-ray equipment.

2. Gonadal shielding. Gonadal shielding has been a point of perennial discussion; indeed, it is of utmost importance. However, on a practical basis, it is not always possible to adequately shield the gonads. Collimation, lead gonadal shields, and especially designed lead-impregnated or lead-lined clothing have all been employed. In certain examinations, one cannot completely protect the gonads (i.e., pelvis, hips, and lower abdomen). This is not to say that gonadal shielding should not be employed; but, gonadal shielding should not take precedence over the other measures utilized in reducing radiation exposure. Gonadal shielding is important, but it is only one aspect of reducing radiation in children exposed to diagnostic radiography.

3. Immobilization. The infant should be immobilized to help obtain more acceptable examinations with the first exposure. Many immobilization devices are available and most are acceptable. Care should be taken so these devices do not injure the infant nor compromise the airway.

**Mechanical and Physical Aspects of Radiographic Equipment**

1. Three-phase generator equipment should be used whenever possible because the constant potential output leads to shorter exposure time, less motion, and a significant reduction in repeat examinations and unnecessary radiation.

2. Filtration. All radiographic x-ray emitting tubes have inherent filtration, but added filtration (up to a total of 3 mm of aluminum) should be added to "purify" the x-ray beam by deletion of radiation in the undesirable low (soft) kilovolt ranges.

3. Phototimers. Phototimers regulate exposure times in an optimal range. This reduces technical error and results in fewer repeated examinations.

4. Fluoroscopy. Image intensification equipment emits five to ten times less radiation than conventional fluoroscopic equipment. Therefore, only image intensification should be used when fluoroscopy of children is required.

5. Videotape does not add to radiation exposure, but cineradiography does. Where physiologic aspects and motion studies are
preferable, either videotape or rapid spot filming (70, 90, and 110 mm) can yield the desired information.

6. Film screens and cassettes. The radiation required for each radiographic examination is dependent on the type of film screens and cassettes used. Unfortunately, the screens and cassettes which require the least amount of irradiation result in the poorest radiographic detail. Therefore, the radiologist should use screens and cassettes that produce diagnostic radiographs at the lowest radiation exposure.

7. Processing and developing. Uniform and controlled processing and developing insure acceptable films. No matter how competent the technician, nor how refined the equipment, if processing is such that the resultant film is uninterpretable, the examination will have to be repeated. Uniform processing and developing reduce the number of repeated examinations.

**Careful Consideration of Repeat Examinations**

1. Repeat examinations are often ordered without much thought of radiation hazards to the patient. As with the initial examination, certain questions should be asked: Why am I ordering a repeat examination? Will it tell me something new or does it merely confirm my clinical impression or data obtained from previous roentgenographic examinations?

2. If the examination is necessary, does it need to be performed immediately or can it be postponed? Many times follow-up chest roentgenograms for pneumonia are obtained too early; and, because roentgenographic clearing has not as yet occurred, repeat examination has to be obtained at a later date.

3. Standing orders for preoperative and postoperative, cardiac, orthopedic, urologic, and similar radiographic procedures often lead to sizable film folders and considerable radiation to the patient. There is no question that many of these examinations are unnecessary; but, they are obtained because of the so-called “routine” procedure.

All studies should be tailored to the individual needs of the patient.

4. Mobile radiographic equipment emits more irradiation than stationary equipment in a radiographic room. Hospital personnel, as well as the patients, are exposed to the additional radiation. Portable radiographs should only be obtained when they are essential for the care of the patient, and if it is not possible to bring the patient to the department.

**SUMMARY**

As is readily apparent, the problem of reducing radiation exposure to the pediatric patient encompasses many areas. In the past, more attention has been devoted to the concrete aspects such as refined radiographic equipment and gonadal shielding. Less attention has been devoted to the abstract aspects which involve the general philosophy and disposition of the referring physician and his radiologic consultant. In this regard, it cannot be overstated that close communication with the radiologist is mandatory. The (pediatric) radiologist is constantly aware of the aspects of radiation safety and utilizes this information when he obtains radiographic examinations.

There is a tendency to treat radiographic examinations in the same context as clinical and chemical laboratory investigations. Perhaps this attitude stems from the fact that radiographs are often ordered at the same time as these laboratory tests. Such an orientation is dangerous, and it behooves the referring physician and the radiologist to work in cooperation to remedy this situation. Indeed, it is simple to improve radiographic equipment and not too difficult to shield the child; but, it is difficult to formulate a proper attitude regarding radiographic examinations and their potential hazard to the pediatric population.

The Committee on Radiology plans to prepare additional recommendations on radiographic examinations to provide more detailed and technical information which should be helpful to pediatricians and other physicians providing care for children.
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REFERENCES
# Radiation Protection in Diagnostic Radiography of Children


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