Rational Therapy

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X-rays: keeping the doses down

Simple and inexpensive methods are available for reducing the doses of radiation received by patients who undergo diagnostic radiology.

In most countries, diagnostic radiology accounts for the largest contribution to the irradiation of people by man-made ionizing radiation. Significant medical benefit derives from X-ray examinations but there is an accompanying risk. A summary of principles and methods for protecting patients undergoing diagnostic radiological procedures has recently been published (1).

Radiation doses a from X-ray examinations can be reduced by technological modification, which is the approach considered in the present article, or by eliminating examinations that are not really necessary. Dose reduction through technological modification can be achieved while maintaining, and sometimes even improving, the diagnostic information obtained.

The methods of reducing irradiation outlined below are simple and inexpensive to introduce. Each results in a reduction of equivalent dose received in one or more radiosensitive tissues. Reductions in irradiation are achieved by increasing the efficiency with which incident X-radiation is used. Medical personnel can also be expected to benefit (2), although their absolute dose reductions are likely to be small. Doses received by staff do not come from the primary X-ray beam but rather from scattered radiation that is already considerably attenuated by protective barriers and shielding.

When resources in a diagnostic radiology facility or programme are limited they should be applied in such a way as to achieve the largest possible reduction in the

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a "Radiation dose" refers to the dose equivalent in one or more radiosensitive tissues. For the dose reduction methods cited in the present article a reduction in the dose equivalent to the skin on which X-radiation is incident translates into the same proportional reduction in the dose equivalents in these tissues.
collective effective dose. Special attention should be given to frequently performed X-ray examinations and to X-ray equipment in frequently used X-ray rooms which produces the higher radiation doses and affects numerous patients. It should be noted, however, that a relatively large number of patients may be examined in a particular X-ray room, say 8000 a year, yet the resulting collective effective dose may be comparatively small (e.g., 0.8 man-sievert a year) if routine chest X-ray examinations constitute a significant proportion of the total (3). On the other hand, another X-ray room may be used for only 1200 fluoroscopic examinations a year at higher radiation doses, and the resulting collective effective dose may be many times larger (e.g., 10 man-sieverts a year). If the cost of achieving a 50% reduction in radiation dose in these two rooms were the same and the allocation of limited monetary resources were a factor, it would be more cost-effective to implement the changes in the room producing the larger collective effective dose. If, however, the cost of implementing change in the two rooms were negligible the desired modifications could be introduced in both.

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The actual collective effective dose reduction at a given clinical facility, in terms of total man-sieverts avoided, depends on the effective doses in tissues avoided per examination and on the total number of patients undergoing examination during the useful life of the equipment. The cost per man-sievert avoided for the methods given in the present article varies between clinical facilities but is always small and in some cases is negligible.

It is instructive to compare the costs of reducing radiation dose in diagnostic radiology as discussed in this article with those of doing so in nuclear power plants. The cost of reducing the collective effective dose by 1 man-sievert in diagnostic radiology, using the methods described below, is typically much less than a few hundred dollars, and is sometimes negligible (4). On the other hand, many governments are prepared to spend up to several million dollars on modifications in nuclear power plants to reduce the collective effective dose by 1 man-sievert (5). It is clearly more cost-effective to achieve reductions in radiation doses in diagnostic radiology than in the nuclear power industry.

Optimum temperature of photographic developer

Photographic processors used for radiographic film are frequently operated below optimum levels. The temperature of the developer is sometimes reduced in order to minimize the background “noise” (i.e., the speckled appearance seen in many radiographic images), which reduces the ability to see fine details and subtle differences in tissue density. A survey in the United Kingdom indicated that, on average, photographic processors were operated with developer temperatures 2.3°C below manufacturers’ recommended values (6).
Increasing the temperature of the developer by 2°C to meet manufacturers’ recommendations for optimum radiographic speed and contrast can reduce the radiation dose from most radiographs by 20% or more. The cost is negligible. It is extremely important to operate the photographic processor at the temperature and for the duration recommended by the film manufacturer. This avoids needless radiation exposure to the patient. The temperature should be raised to the optimum temperature to reduce the radiation dose, followed by adjustments to control the contrast.

Elimination of antiscatter grids in selected applications

Antiscatter grids are used to reduce the amount of scattered radiation that reaches the film or fluoroscopic screen, thereby increasing the contrast of the image. In addition, some of the primary radiation used to produce the image is removed from the X-ray beam. Antiscatter grids are not necessary if the X-ray field is small, if the image contains primarily high-contrast information, or if the part of the body being radiographed is thin. In these situations there is a minimal amount of scattered radiation and a high-contrast image will not be degraded significantly by the addition of a small amount of scattered radiation. The radiation dose can be reduced by about 50% in each of these circumstances (7) and the cost of implementation is negligible.

Some situations in which antiscatter grids can be eliminated are indicated below.

- During paediatric radiology the body parts being examined are relatively thin and the size of the radiation field is small. Consequently it is possible to remove the antiscatter grid without significantly reducing image contrast.

Medical personnel can also be expected to benefit, although their absolute dose reductions are likely to be small.

- During cardiac catheterization it may be possible to remove the grid for the fluoroscopic portion of the examination. It is still necessary to use the grid for cine-imaging, since the iodine-filled vessels of interest are of low contrast (7, 8).

- On the very rare occasions when pelvimetry is medically indicated, only small fields are necessary to see the maternal landmarks. Consequently the antiscatter grid can be eliminated (9).

It should be noted that ultrasound may, in many cases, eliminate the need for pelvimetry. Computed tomography is another possibility if the dose is low. If pelvimetry is needed, then very high-speed screens and films should be used, and the grid should not be used.

Reduction of tube current and exposure time for computed tomography

Computed tomography doses can exceed 100 mSv for a single series of non-overlapping scans. However, most computed tomographic scanners produce adequate images at doses of about 50 mSv for adults and 10–20 mSv for children. These
reductions in dose can be obtained by decreasing the tube current and exposure time, and no equipment changes or calibrations are required. The cost is negligible.

**Substitution of posteroanterior for anteroposterior projections**

By changing from an anteroposterior to a posteroanterior projection it is possible to obtain a reduction in the dose equivalent in radiosensitive tissues directly in the field. For example, in radiography for the diagnosis and treatment of scoliosis, this change results in a 95% reduction in effective dose to the breast of the adolescent female, for whom the risk of breast cancer is 15 times higher than in the adult. By similarly turning the patient in conventional tomography of the sphenoid (sella) the dose equivalent in the lens of the eye can be reduced, again by 95%. In computed tomography, comparable reductions in dose equivalent in the lens of the eye can be obtained if the posteroanterior projection is used with 180° scans. Again the cost is negligible.

**Elimination of image-intensified fluoroscopy for positioning**

Some facilities conduct fluoroscopy with image intensifiers in order to position the part of the body under investigation before making a radiograph. This may ensure correct positioning but it also results in needlessly irradiating the patient. A trained radiographer should be able to position the patient properly without fluoroscopy. Fifteen seconds of fluoroscopy may result in a skin dose of 10 mSv, whereas the skin dose for most radiographic films is 2–4 mSv. Even if radiography has to be repeated, the total radiation dose to the patient is less than if fluoroscopy is used. The reduction in the radiation dose amounts to 60–80% and the cost is negligible.

**Use of radiography in place of image-intensified fluoroscopy**

Fluoroscopy with image intensifiers is often used for X-ray examinations even though radiography would provide better diagnostic information (e.g., in X-ray examinations of the chest). This is sometimes done because of the high cost of radiographic film, but the economy may be false. An X-ray examination of the chest requires a skin dose of about 0.2 mSv, while fluoroscopy of the chest requires about 20 mSv for an exposure time of 30 seconds. A reduction in the radiation dose of 99% is thus obtainable, and the cost of implementation is approximately US$ 2.00 per radiographic film measuring 35 x 43 cm. WHO strongly recommends the replacement of chest fluoroscopy by screen-film imaging of the chest.

**Use of intensifying screens for mammography**

Screen-film systems designed specifically for mammography are available and should be used in place of direct-irradiation (i.e., non-screen) radiographic film. This gives a reduction of 80–90% in effective dose to the breast. In addition the radiographic contrast is increased, providing better image quality. The cost of implementing this method is $150 per cassette and screen.

**Use of high-efficiency intensifying screens**

Intensifying screens containing high-efficiency phosphorescent materials, such as rare earths, barium, and tantalum,
require a radiation dose in the patient which is half or less than that needed with conventional (i.e., calcium tungstate) intensifying screens for the production of radiographs of similar image quality (10). Since the cost of high-efficiency screens in most countries is the same as that of conventional ones, no additional cost may be involved when replacement is effected. If conventional screens are replaced before the end of their useful life there is, of course, a nominal cost (4). However, a saving may be achieved since the green-sensitive film used with high-efficiency screens may cost less than conventional film. In addition, the reduced loading of the X-ray tube may extend its life. The cost of implementation may range from zero to $285 per screen-film pair.

Use of carbon fibre and other low-attenuation materials

Any material placed between patient and image receptor absorbs radiation that would normally be used to produce an image, and consequently a higher dose is required than would otherwise be the case. Attenuating structures include the table top, grid cover sheets, cassette face, compression devices, image intensifier covers, automatic exposure control devices, and compression plates or film changers. The use of carbon fibre or other low-attenuation materials for these components reduces the absorption of radiation, thus resulting in a lower dose being given to the patient.

By replacing a conventional table top with one of carbon fibre the radiation dose received by the patient can be reduced by 10–30%; the replacement of aluminium cassette fronts by carbon fibre material reduces the radiation dose received by the patient by up to 12%; the use of carbon fibre grids and interspace material gives reductions in radiation dose of 25–40% (11). The replacement of all three items would reduce the radiation dose by as much as 60%. Carbon fibre table tops, cassette fronts and grids cost about $3600, $110 and $1100 each respectively.

References