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In Vivo Thyroid Autoradiography[1,2,3]

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Previous efforts to obtain images on photographic film localizing radioactive materials within organs *in vivo* have required thick lead plates with multiple holes as collimators and a thick scintillation crystal to absorb the medium energy gamma-rays (1, 2). The problems of collimation, whether for autoradiographic images or for scanning purposes, are greatly simplified with low-energy gamma rays, which are absorbed by thin sheets of lead. Autoradiographic visualization of the thyroid *in vivo* with the use of ordinary x-ray grids for collimation of the low-energy gamma radiation from ^{125}I is described in this paper. The techniques described are applicable to visualization of other low-energy gamma emitting isotopes by autoradiography and by other methods.

MATERIALS AND METHODS

Iodine-125 decays by electron capture (3) with emission of K x-rays (27.3 and 31.2 keV) and gamma rays (35.4 keV) which are equivalent to diagnostic x-rays with respect to penetration of lead. Diagnostic x-ray grids, constructed of alternate strips of lead and cardboard, allow low energy x-rays or gamma rays to pass through the planes between the lead strips. Unfocussed, commercially avail-

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Fig. 1

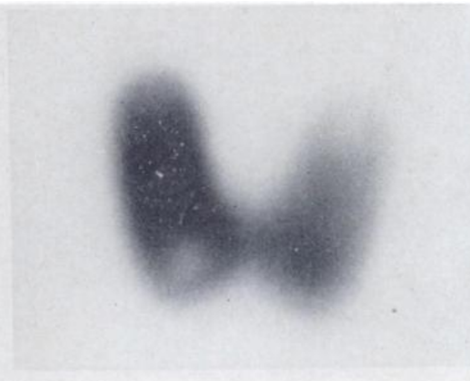

Fig. 2

Fig. 1. Autoradiograph of thyroid phanton made with cross grids, 6:1 and 8:1 grid ratios.
Fig. 2. Autoradiograph of thyroid phantom made with single grid, 6:1 grid ratio, rotated during exposure.

able[1] diagnostic x-ray grids with grid ratios of 6:1, 60 lines per inch, or 8:1, 80 lines per inch, were used for collimation of the radiation from iodine-125. A grid with ratio 6:1 was milled to half its original thickness to produce a grid with ratio 3:1, 60 lines per inch. In place of crosshatch grids, which are available only in a very limited variety, two grids were placed adjacent to each other with the lead strips crossed at right angles.

A commercially available[2] thyroid phantom was filled with a solution containing 20 microcuries per ml of iodine-125. One-half of the phantom is twice as deep as the other half. The phantom has three *cold nodules* and one *hot nodule*. The *cold nodules* are 5.5 mm, 9 mm and 12 mm in diameter. The *hot nodule,* which is twice as deep as its surrounding area, is 12 mm in diameter.

Except where it is noted, Radelin TF intensifying screens were used with Kodak Royal Blue film, in bakelite-front cassettes. Autoradiographic exposures were made with the grid or grids placed adjacent to the front of a cassette at a distance of 0.5 cm from the film. The grids were used in three different ways, as follows: (1) a single stationary grid, (2) two stationary crossed grids, or (3) a single grid rotated during exposure. The grid-cassette combination was placed adjacent to the thyroid phantom or above the neck of a patient for the autoradiographic exposure. The distance between the grids and the radioactive source varied between 1 cm (minimum with phantom) and approximately 7 cm (*in vivo* exposure). Exposure times for the phantom sources were a minimum of ten minutes and a maximum of five hours. Thyroid exposures *in vivo* were one hour in the examples presented.

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[1]Liebel-Forsheim Co.
[2]Picker X Ray Corporation.

Fig. 3

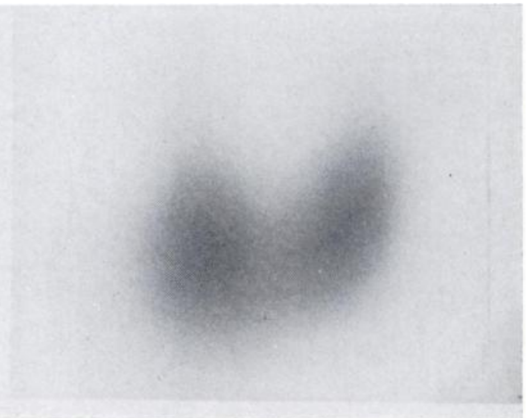

Fig. 4

Fig. 3. Autoradiograph of thyroid phantom made with crossed grids, both 3:1 grid ratio.
Fig. 4. Autoradiograph of thyroid *in vivo* made with single grid, 6:1 grid ratio, rotated during exposure.

RESULTS AND DISCUSSION

An autoradiographic image of the thyroid phantom is illustrated in Figure 1. The small *cold nodule,* 5.5 mm in diameter, and the *hot nodule* are both easily discernible. An exposure of five hours was used in producing this image. Collimation was attained with two crossed x-ray grids, one with a grid ratio of 6:1, 60 lines per inch, the other with a grid ratio of 8:1, 80 lines per inch. The distance between the film and the mid-plane of the radioactive solution was 2.5 centimeters. This arrangement of two crossed x-ray grids, with 60 and 80 lines per inch, is equivalent to a parallel-channel collimator with 4800 channels per square inch. The depth of each channel is equivalent to the thickness of each grid (2 mm). The thin lead strips of the grid, standing on edge, are effective collimators for soft gamma radiation. The resolution obtained with a parallel channel collimator depends not only on the width and depth of the channel, but also on the distance between the collimator and the source on one side and the distance between the collimator and film on the other side (4). In this instance the film was 0.5 cm from one side of the grids, and the center of the radioactive phantom was 1.4 cm from the other side of the grids. It is difficult to get a human thyroid closer than about 3 cm from the grids when a flat cassette is used.

Clayton and others (5) have reported some of the factors which affect the speed of image formation, including the use of very fast films and intensifying screens. With respect to collimator design, resolution and speed vary inversely, *i.e.* A collimator which gives high resolution will require a long exposure. In this study the exposure time was decreased by using crossed grids with low grid ratios and by using a single grid which was rotated during exposure. The exposure time when a single grid is used is reduced several-fold compared to the exposure time with crossed grids, but with a single grid the radiation is uncollimated in the direction parallel to the grid lines, and the image is enlarged

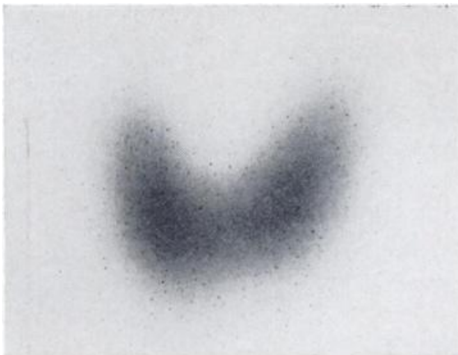

Fig. 5

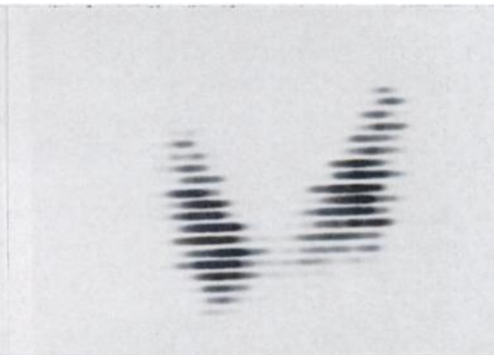

Fig. 6

Fig. 5. Autoradiograph of thyroid *in vivo* made with crossed grids, both 3:1 grid ratio, stationary during exposure. Black dots are artifacts of this particular film.

Fig. 6. Photoscan of same thyroid as shown in Figure 5.

and blurred in this direction. When a single grid is rotated during exposure, the entire periphery of the image is blurred. But the blurred part of the image is relatively light, since any one part of the periphery is exposed to uncollimated radiation during only a portion of the exposure.

Figure 2 illustrates an autoradiograph of the thyroid phantom which was made with the use of a single rotating grid, 6:1 ratio, 60 lines per inch, with an exposure of ten minutes. The distance between the radioactive solution and the film was 3.2 centimeters. The larger *cold nodules*, the *hot nodule*, and the difference in density between the two halves are apparent in the image. The small *cold nodule* (5.5 mm diameter) is discernible in the upper left pole.

Rotation of the grid in clinical usage presents some problems, although the method is feasible. An alternative solution to the exposure problem is to use crossed grids, or a crosshatch grid, with a low grid ratio. An autoradiograph of the thyroid phantom made with the use of crossed grids is illustrated in Figure 3. In this case the grid ratio was 3:1, 60 lines per inch, and an exposure of 30 minutes was used. Other exposure factors were the same as for Figure 2. The resolution of this image is better than that of the image in Figure 2, but a longer exposure was required.

With either of these two methods, a single rotating grid, or crossed low-ratio grids, exposure *in vivo* has been feasible. Two examples of *in vivo* autoradiography of the thyroid are presented in Figures 4 and 5. These were both done with patients who were being treated with radioactive iodine for hyperthyroidism. The approximate content of ^{125}I in the gland was 15 microcuries per gram.

Figure 4 illustrates an image obtained with a single grid, 6:1 ratio, 60 lines per inch, rotated during exposure. The distance between the gland and the film was about 8 cm in this case. An exposure of one hour was used for this image, which has the shape of the thyroid gland and shows the approximate size of the gland.

An image which was obtained with the use of two crossed grids, 3:1 ratio, 60 lines per inch, stationary during exposure is illustrated in Figure 5. In this instance, Du Pont Lightning Screens were used with an exposure time of one hour. In this case, the film was 2 cm above the neck, or about 3 cm from the gland. The grids were 0.5 cm from the film. This image defines the gland well. The dark dots are an unfortunate artifact on this particular film. Figure 6 illustrates a photoscan, made with a 31-hole collimator, of the same thyroid for comparison.

SUMMARY

It has been shown that diagnostic x-ray grids are a practical means of collimation for soft gamma rays. In autoradiography of a thyroid phantom, excellent resolution was achieved with a long exposure time, but even with reasonable exposure items, good resolution was possible. The feasibility of the method for *in vivo* autoradiography of the thyroid has been demonstrated. Improvements in speed, either with faster film, faster intensifying screens, or both, would reduce the exposure time sufficiently to make this type of autoradiography a practical, inexpensive method for visualization of radioactive organs.

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