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INVESTIGATION INTO THE PHYSICAL BASES OF GRID PROJECTION WITH LARGE GAMMA SOURCES*

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The paper examines the possible extension to gamma rays of the projected grid irradiation method developed by the authors for X-ray therapy. On the basis of dose distribution measurements performed in a MIX-D phantom the characteristics of a projected grid are defined. relationships between the size of grid openings, their spacing, the size of the radiation source and the hardness of radiation, as well as a criterion to assess the quality of the grid are developed. A projection grid designed on the basis of the investigations, suitable for total irradiations, is described.

In an earlier work we developed a method for special inhomogeneous irradiation of larger areas through a projected grid for X-ray treatment [1, 2]. In this method, provided certain physical conditions are fulfilled, a lead grid covering the whole surface of the body is substituted by a small size lead grid placed in the proximity of the X-ray tube, the grid being projected to the body at a distance of 1—2 m by the X-rays starting from the focus.

Considering the favourable therapeutical results gained with subtotal and total grid irradiations it seemed to be desirable to examine the possible application of the principle of grid projection to gamma radiation, primarily to ^{60}Co therapeutic radiation sources.

With respect to projected grids, X-ray and gamma radiations show two significant differences.

1. The size of gamma radiation sources of an order of magnitude of kilocuries are multiples of the sizes of the focus spots of X-ray tubes and are unfit for the application of the simple methods of central projection.

2. The penetration of gamma rays in common use in Curie therapy is much stronger than that of X-rays generated with conventional 180 kV peak voltage owing to which, instead of the projection of a plane grid (of 1.5 mm thickness) the problem of projecting a spatial grid (of 50—100 mm thickness) is raised.

The effect of both differences in projection is that sharp grid contours formed in projecting a plane grid with a punctiform radiation source are eliminated and are replaced by a penumbra of considerable width. In addition

* Dedicated to Prof. A. Szalay on his 60th birthday.

the size and shape of radiation sources affect the size and spacing of the grid openings in a decisive manner. It is apparent that the grid openings to be projected cannot be smaller than the projection of the radiation source perpendicular to the direction of projection and that the spacing of grid openings cannot be closer than the respective dimension of the radiation source. Otherwise the radiation cones that pass through the openings would converge and at a particular distance would intersect so that the irradiation would no longer have grid characteristics.

Besides the dimensions of the radiation source, the size of the grid openings is affected by the ratio of the distance of grid-to-radiation-source to the distance of body-to-radiation-source, and the spacing of the grid openings by the required ratio of the area of the holes to the total area of the field areas, that is to say, by the grid percentage.

The quantitative relationship between the factors pointed out above have been examined by experimental irradiations in a MIX-D phantom, with our ROTACERT cobalt unit of 3000 Ci activity. With the strongly inhomogeneous dose areas the calculation of the build-up factor and the determination of dose distributions belonging to various depths on this basis have seemed hopeless from the beginning.

To measure dose distributions to high precision, small Sievert type condenser ionization chambers of an air volume of 6 mm^3 were made of air-equivalent material. Ionization chambers were placed in the tissue-equivalent phantom sheets prepared with extreme care, along the straight lines connecting the centres of the grid openings, at a spacing of 1 cm. Measurements were taken on the surface and at depths of 5, 10, 15 cm. The grid openings were located at the respective depths by exposures on X-ray films placed between the phantom sheets.

From the dose distribution curves it was apparent that with gamma radiation the width of the penumbra can by no means be neglected, and consequently, the two most important characteristics of the grid: grid percentage and the dose belonging to grid openings must be defined.

The determination of grid percentage can be reduced to the determination of the grid openings. We suggest defining the area of a grid opening as the area bordered by the 50% isodose curve.

Doses and dose intensities belonging to grid openings are given in the literature by a single figure which, in the case of uniform dose distribution, is quite definite and unambiguous. In gamma radiation, dose distribution in grid openings is inhomogeneous, from 100 per cent corresponding to the centre, it drops to 50 per cent at the edge of the grid opening, as discussed above. The analysis of dose distributions found in measurements has led to the conclusion that the integral dose calculated for a layer of 1 cm thickness of the grid opening may be approximated as an integral dose of a homogeneous irradiation with a 90 per cent dose. Accordingly, the dose belonging to a grid opening seems to be logically defined as 90 per cent of the dose maximum measured in the grid opening.

On the basis of dose distributions obtained at various depths, integral dose figures belonging to a layer of 1 cm thickness at the respective depth

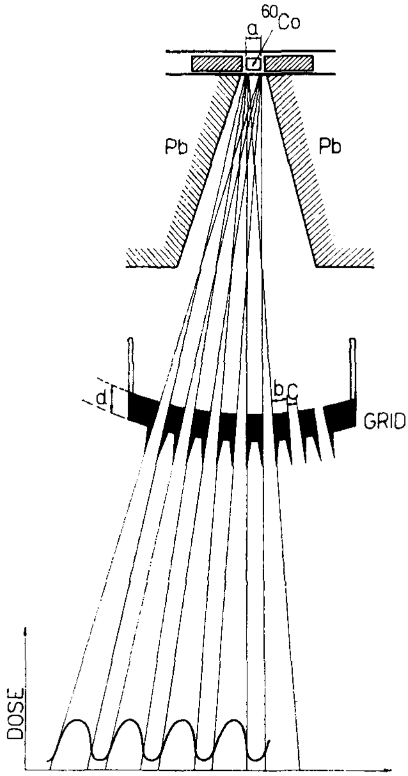

Fig. 1. Projected lead grid developed for total grid irradiation by hard gamma rays with dose distribution. Diagram of cross section. $a = b = c$, $d = 5$ cm

have been calculated. As a criterion of the quality of the grid we considered the identity of the ratio of integral doses belonging to the 1 cm layer in irradiations performed with and without the use of the grid.

Compliance with, or even approximation to this requirement gives a physical basis of much better exactitude to the study of grid effects, still unclarified in many respects, than either the requirement of the preservation of grid percentages in air at various distances behind the grid, or the simple demand put forward in the literature: to realize grid effect on the body surface, without heeding the course of dose distribution at various depths of the body, or whether a complete homogenization might or might not occur.

Having subjected the model grid constructed along the lines outlined above to several subsequent modifications on the basis of dose distribution measurements, finally we succeeded in developing a projection grid for cobalt units which complies with the above demand to an accuracy of ±10 per cent, suitable to give a satisfactory solution to the problem of both subtotal and total grid irradiations with a grid of minimum weight.

The cross section of the total grid is represented in Fig. 1.

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ИССЛЕДОВАНИЕ ФИЗИЧЕСКИХ ОСНОВ ПРОЕКЦИОННОГО ОБЛУЧЕНИЯ ЧЕРЕЗ РЕШЕТКИ В СЛУЧАЕ БОЛЬШИХ ИСТОЧНИКОВ ГАММА ИЗЛУЧЕНИЯ

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Резюме

В статье исследуется распроствание на гамма излучение метода проекционного облучения через решетки, введенного авторами для рентгеновского излучения. На основе измерений, проведенных в фантоме MIX—D, определяются характеристики проекционной решетки, величина отверстий решетки, расстояние между отверстиями, соотношение между величиной источника и жесткостью излучения, и также условия пригодности решетки. Наконец дается описание проекционной решетки, проектированной на основе исследований для полного облучения.