FROM THE RADIOTHERAPY CLINIC OF THE CENTRAL HOSPITAL OF THE UNIVERSITY OF TURKU, FINLAND.

LARGE DIMENSIONAL MULTIFOCUS RADIATION SOURCE IN SUBCUTANEOUS SIEVE THERAPY

by

P. KLAMI and P. RUOTSALAINEN

A tumour surrounded by healthy tissue can be destroyed if the difference between the biologic effect of irradiation of healthy and pathologic tissue is sufficiently great. With little or no difference the matter becomes a physical one of arresting the growth with as large a dose as possible without causing irreversible damage to the surrounding healthy tissues.

A typical example is radiotherapy of subcutaneous tumours. Healthy tissue is so close to the pathologic tissue that a sufficiently large dose difference cannot be obtained by physical means. One way is to remove the skin surgically from the therapy field for a single irradiation. If operation is to be avoided, or fractionated therapy is preferred to one large single dose, a high skin dose has to be given with disregard to tolerance. As early as in the first half of this century, KÖHLER (1912), to avoid defects of this kind, proposed the method known as 'Siebbestrahlung' or sieve therapy, which has been generally adopted for the treatment of deep-lying tumours.

It is possible to give much higher doses to very small skin fields than to large skin fields because the former will recover. A single field, 1 cm^2 in size, can be

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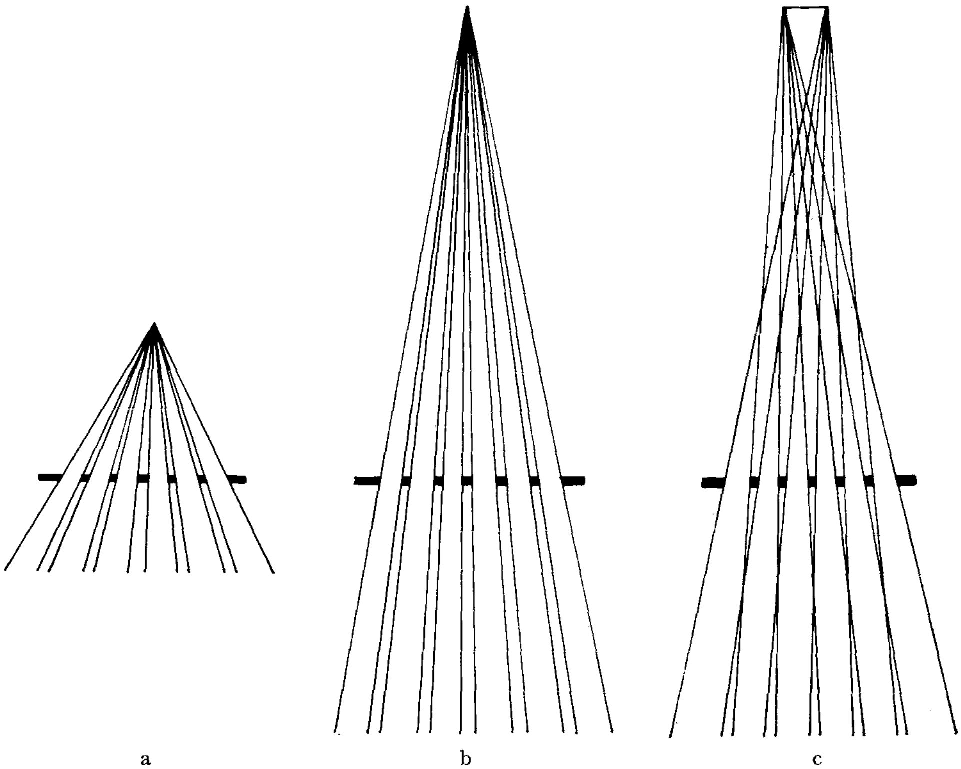

Fig. 1. Irradiation of an object through a sieve plate. The beams from a point source diverge more and more the deeper they penetrate the object (a), a fault somewhat reduced by a larger SSD (b). With a large radiation focus the edges of the penumbras begin to intersect (c).

irradiated to 35 000 rad or even to 50 000 rad without irreversible damage. The surrounding skin will remain unirradiated and regeneration can take place. This fundamental advantage is utilized in sieve therapy, larger areas being irradiated through the holes of the lead grid while the skin between the holes is protected from radiation (BARTH 1959).

Therapy of this kind is nowadays in use in many radiotherapy centers, although in principle the method embodies a considerable error. The primary beams, from a point source through the holes of the sieve to an object, diverge further and further from each other the deeper they penetrate (Fig. 1a) and the dose distribution in the object becomes unhomogenous. Excepting secondary radiation, this disadvantage may be somewhat reduced by removing the source farther from the object (Fig. 1b). When the radiation focus is large the faint edges of the penumbra begin to intersect beneath the surface of the object.

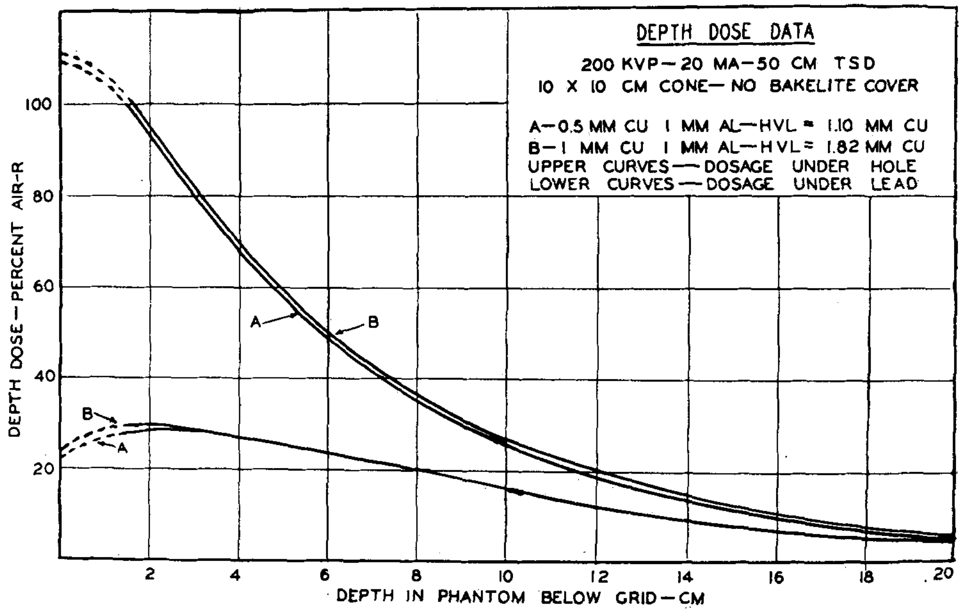

Fig. 2. Depth dose in R per 100 R in air using a 10 cm × 10 cm cone without cover. (From SOPP & STANTON, Amer. J. Roentgenol. 71 (1954), p. 842).

The result produced by effectively penetrating roentgen rays (HVL 1.10 to 1.82 mm Cu, SSD 50 cm) is presented in Fig. 2 (SOPP & STANTON 1954). The dose distribution close to the skin is unhomogenous, less so beneath the lead than beneath the holes (Fig. 3, SOPP & STANTON). The dose differences are not satisfactorily equalized under less than a depth of about 14 cm in the tissue (difference $< 30\%$). The depth dose is thus only a little more than 10 % of the skin dose and the therapy is almost meaningless even with a skin dose as high as 20 000 rad.

The sieve method used today could be much improved with a radiation source so arranged that one focus is provided for each hole of the grid (Fig. 4a). The separated radiation beams would intersect still closer to the surface of the object if in addition the source of radiation could be brought close to the grid (Fig. 4b). The use of a radiation source with large foci would offer still greater advantages (Fig. 4c).

Radiologists working with the usual sources of radiation argue that in accordance with the inverse square law, the intensity of radiation will rapidly fall off when the source of radiation lies so close to the object. One of the authors of

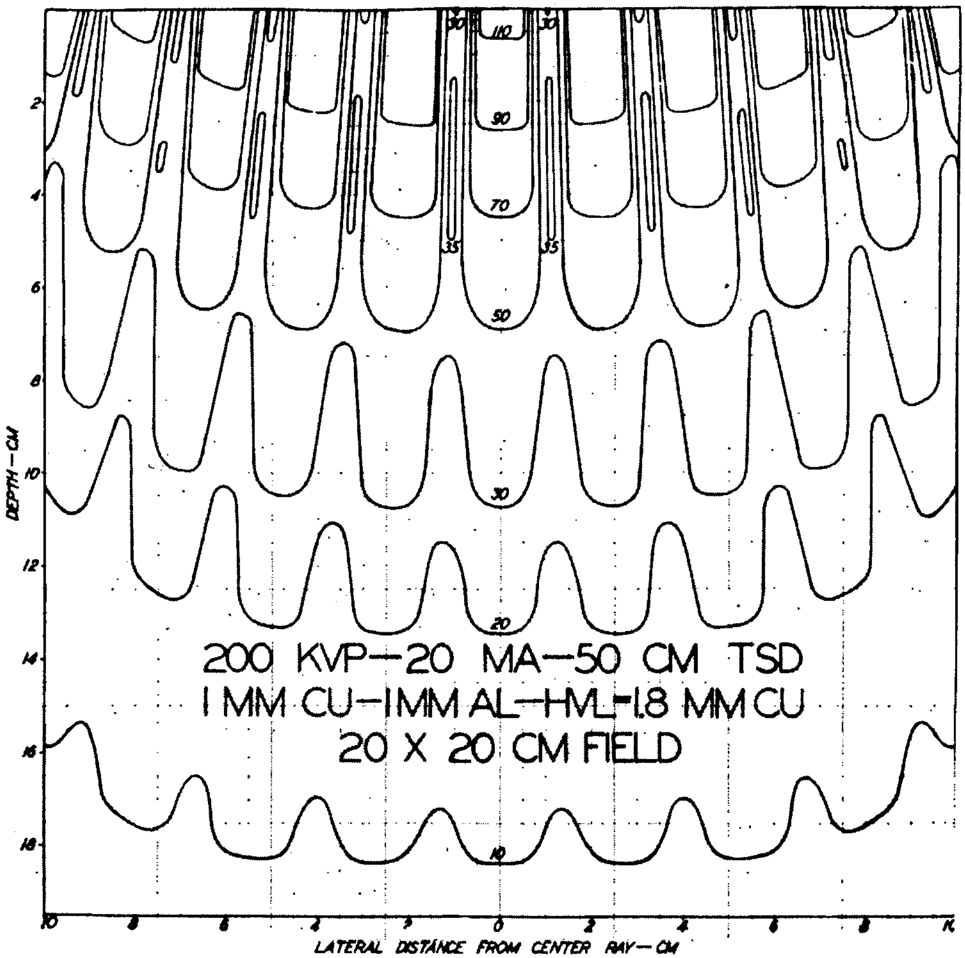

Fig. 3. Isodose curve for a 20 cm × 20 cm cone with bakelite cover. (From Sopp & Stanton, Amer. J. Roentgenol. 71 (1954), p. 844).

this paper (Klami 1968) has earlier dealt with the theory of radiation sources of large area dimensions with every focus of the source delivering a collimated radiation beam. It seems that this kind of source differs from other known sources in that the relative depth dose is practically independent of the focus-skin distance. This is explained by the fact that the sum effect of separated radiation beams increase in proportion to the square of the distance, which thus is an effect opposite to the inverse square law. Accordingly, a source of radiation of

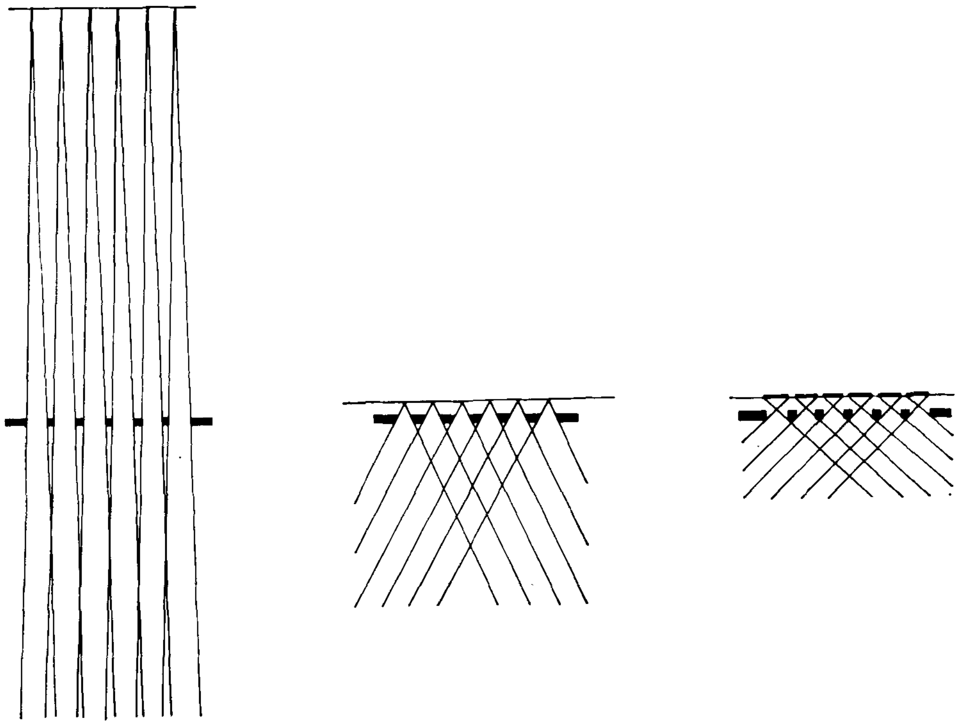

Fig. 4. Irradiation of an object through a sieve plate from a multifocus radiation source (a). The beams intersect nearer the object surface when the source-skin distance is short (b), an advantage which is increased by a large focus (c).

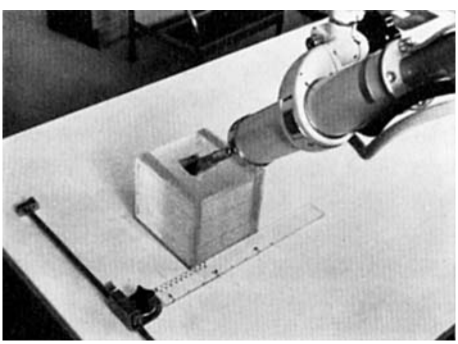

Fig. 5. Arrangement for experiment. A multifocus radiation source is simulated by gradually moving the acrylic phantom relative to the stationary radiation focus.

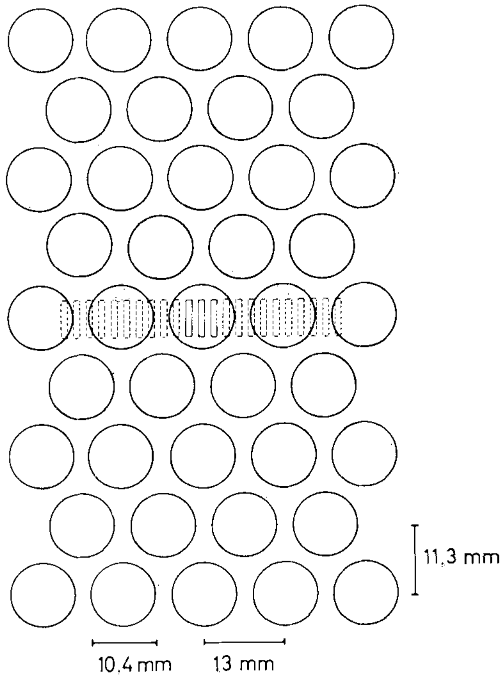

Fig. 6. The positions of the radiation focus during the experiment. A row of LiF-teflon microrods, for measuring the homogeneity of the field at 1 cm, lie in the middle.

this kind when used for sieve therapy may be brought extremely close to the object and sieve by taking into account the nature of the source, without debasing the relative depth dose. The dose will decrease only due to absorption and scattering in the object. Thus, when the focus-skin distance becomes less, the relative depth dose will also decrease because the area of the skin field in every separated radiation beam will grow smaller. Some other insignificant sources of error will also be present in the calculations and demand that the applicability of this sieve therapy method be checked empirically.

A multifocus tube has not yet been built because its advantages have not been recognized. It is possible, however, to examine the applicability by simulating such a tube (Fig. 5). A conventional slope target tube has been used as the source of radiation so that the target could be brought quite close to the object. A sheet of lead with a hole equal in size to that of the grid was set in front of the source of radiation. A lucite phantom was moved step by step in relation to the stationary hole of the grid so that the irradiation beam was brought in turn to the positions in Fig. 6 and the irradiation time through every 'hole' was of the same length.

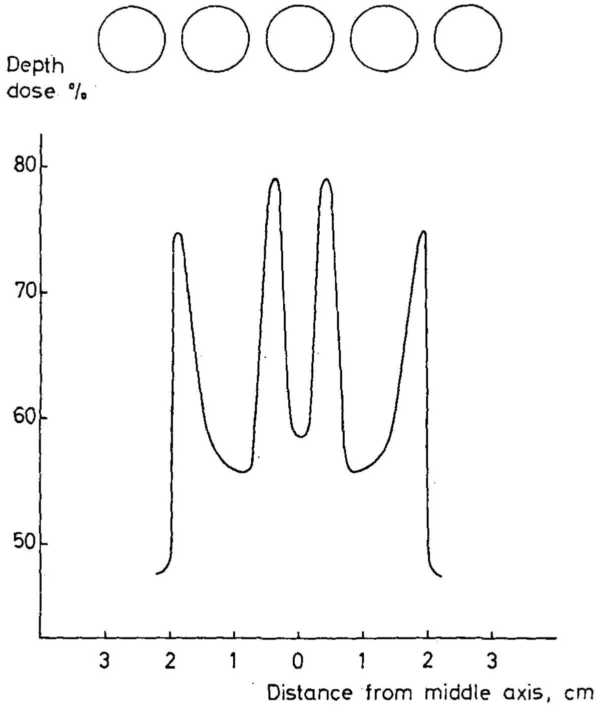

Fig. 7. The appearance of the depth dose curve at the depth of 1 cm, measured as shown in fig. 6.

Measurements were carried out on the lucite phantom, which was composed of 1 cm plates, 15 cm $\times$ 15 cm in size. Lucite was selected because its absorption properties correspond to water. Slots were cut for three LiF-teflon microrods (diameter 1 mm and 6 mm long) side by side at 1 mm distances for measuring the depth dose on each plate. The empty space was filled with water. A whole row of slots were also cut for the microrods beneath the middle row of the holes of the grid for measuring the homogeneity of the radiation field at a depth of 1 cm in that particular plate. The distance between these slots was 2 mm (Fig. 6). The depth dose curve was measured only beneath the middle hole; the doses were recorded with the Con-Rad TLD Reading Instrument (RUOTSALAINEN).

The dose at 1 cm was well levelled and the doses beneath the lead strips were even higher than those beneath the holes (Fig. 7). This was due to the edges of the beams from the various holes beginning to intersect at a depth of about 5 mm. The measured percentage depth doses and technical data are presented in Fig. 8. The half-value layer in tissue (HVLT) is about 3 cm, which is more than three times the HVLT of usual contact therapy with the same HVL and SSD.

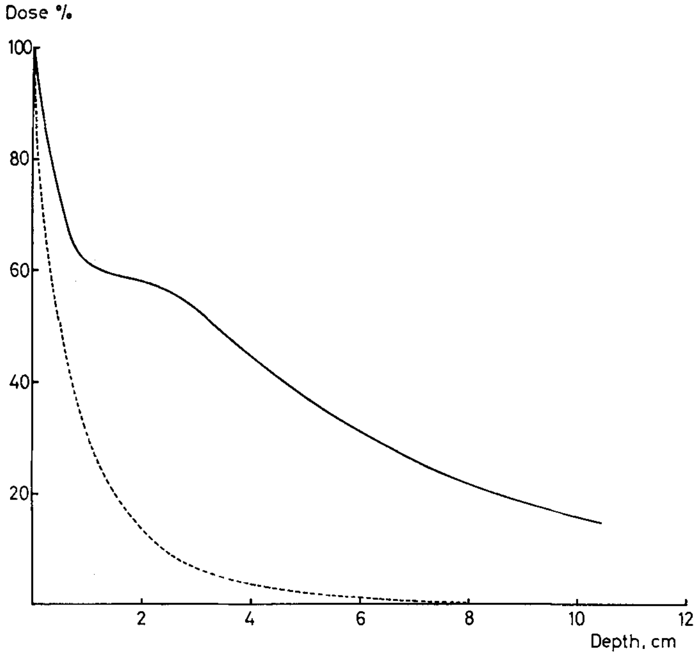

Fig. 8. The relative depth dose achieved in the experiment in fig. 6 (unbroken line) compared with that in conventional irradiation through one hole (dashed line). Technical data in both cases: 100 kV, 0.3 mm Cu, SSD 15 mm.

Discussion

The purpose of this preliminary investigation has been to examine the possibilities presented by this new kind of sieve therapy. The experiment reported is one of many others along the same lines. Many details, such as the best ratio of the grid and the shape of the holes, have yet to be investigated. It has also not been decided whether the skin recovers as well as it does after conventional sieve therapy.

If the aim were to give 6 000 rad to a tumour, and 20 000 rad could be applied to the skin, the tumour dose mentioned above would be reached at a depth of about 6.3 cm with a tube voltage of 100 kV. The HVLT could be increased by raising the energy of radiation although this would demand roentgen rays produced by low-energy accelerators and consequently more expensive apparatus. But with higher energies of 0.2 MeV or more the differences between the absorption in various tissues would be equalized, e.g. it would be possible to irradiate the chest wall radically.

SUMMARY

Phantom experiments have suggested that the best object for sieve therapy is the subcutaneous tumour that can be radically irradiated by using a large dimensional radiation source and a short source-skin distance. The theory is discussed in detail.

ZUSAMMENFASSUNG

Phantomexperimente zeigten, dass das am besten geeignete Objekt für die Siebbestrahlung ein subkutan gelegener Tumor ist, der radikal von einer Strahlenquelle grossen Durchmessers und mit kurzem Hautabstand bestrahlt werden kann. Die theoretischen Bedingungen werden erörtert.

RÉSUMÉ

Des expériences sur fantômes ont montré que le meilleur objet pour thérapie suivant la méthode du crible est une tumeur sous-cutanée qui peut être irradiée radicalement par une source de radiation de grande dimension avec une courte distance source-peau. Les auteurs discutent en détail la théorie de cette méthode.

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