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TUMOUR DOSE CONCEPT

by

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It is recognized that with therapeutic irradiation the dose within the tumour volume is often not quite homogeneous even after careful dose planning. It is desirable, for facilitating comparisons to be made between different irradiation alternatives, as regards dose levels and radiation techniques for the individual patient and for different patients and patient groups, that the dose within the tumour volume can be represented by one figure. A generally accepted definition of the term 'tumour dose' is therefore desirable.

ELLIS & OLIVER (1961) have discussed some alternative definitions of the tumour dose:

1. *Median dose:* the average of the maximum and minimum values in the tumour volume.
2. *Average dose:* the average value of the dose in the tumour volume.
3. *Modal dose:* the dose most frequently occurring in the tumour volume.

At a meeting held at the Royal College of Surgeons in England, the Faculty of Radiologists recommended the use of the modal dose as the definition of tumour dose for 4 to 8 MV-linear accelerators. Its application to cobalt 60

Submitted for publication 20 February 1964.

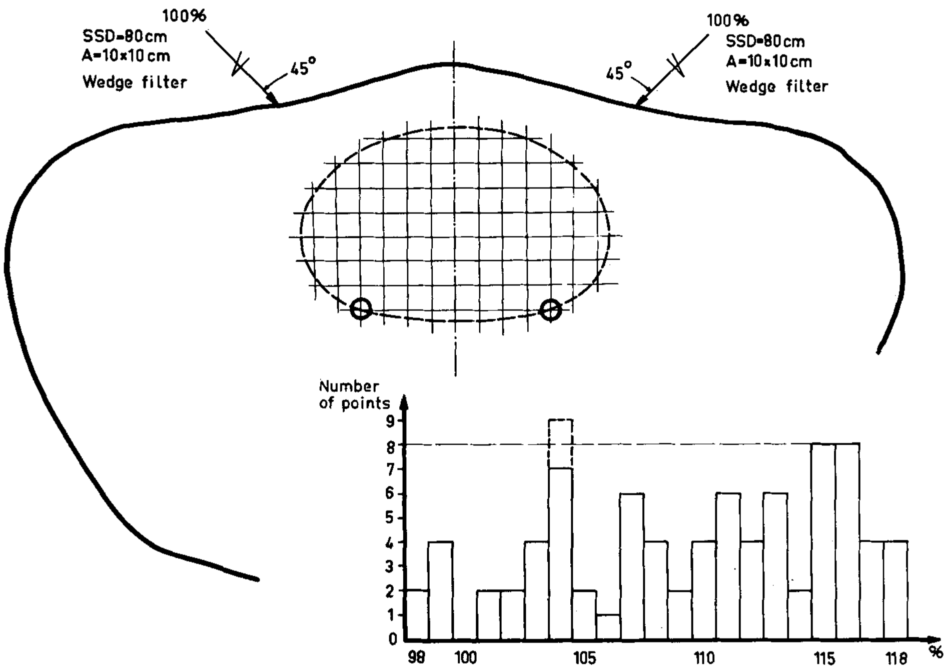

Fig. 1. Illustration of calculation of modal dose. Broken line indicates tumour area. (The complete dose distribution is shown in fig. 4.)

units was not explored in any detail but it was felt that it would be desirable and probably equally practicable to use it in fixed beam cobolt 60 therapy (Spiers & Meredith 1962).

The suitability of these alternatives will now be discussed from the physical viewpoint.

The definition of the tumour dose must in every particular case enable calculations to be made with sufficiently small margins of error. The tumour dose should also be calculable in practice without an unreasonable amount of work. Furthermore, the definition should be the same for all irradiation techniques and radiation qualities.

Which of the above definitions, if any, is most suitable from medical and biologic viewpoints can in the strictest sense be decided only if the tumour dose value obtained is related to the biologic effect. The median dose seems to be the least advisable, however, as it is independent of how the energy absorbed per gram is distributed in the tumour volume. The values of the median dose may, for instance, be identical whether the larger part of the tumour receives a dose close to the maximum or near the minimum value.

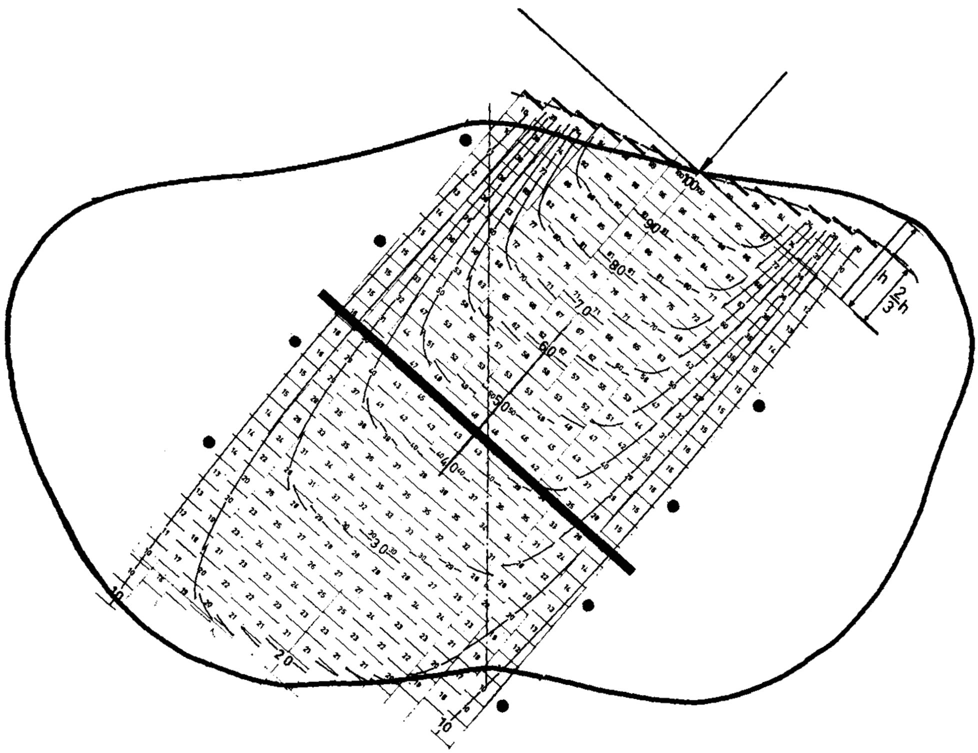

Fig. 2. Calculation of average dose. Correction for oblique incidence with a special isodose diagram.

The study now presented of two-dimensional dose distributions is therefore limited to a comparison between modal dose and average dose as regards both the practical methods of calculation and the reproducibility. The examples with cobalt 60 radiation refer to both fixed beam and moving beam therapy.

Calculation of modal dose and average dose

A grid is mounted over the tumour area in the determination of the modal dose by the Spiers & Meredith's method, as seen in Fig. 1. The doses from the different beams are summed up at the points of intersection between the lines of the grid. A histogram is drawn with the number of points on the vertical axis and the percentage dose on the horizontal axis. The dose value found at the largest number of points is called the modal dose. The average dose may also be obtained with the use of this grid by adding the doses at all the points and dividing the sum by the number of points.

Another possibility of calculating the average dose, which may imply practical advantages, is illustrated in Fig. 2. The grid is fixed to the isodose diagram instead of to the patient. The standard isodose diagram, copied on thin perspex, is divided into strips, 1 cm in width. This enables a correction for an oblique incidence to be made by displacing each of these strips at a fixed distance between the entrance surface of the diagram (which is perpendicular to the beam axis) and the body contour. This displacement is two-thirds of the last-mentioned distance as suggested by DUTREIX & DUTREIX (1962). The figures of the standard isodose diagram represent the average dose within an area of 1 cm^2 and are determined graphically. The contribution to the average tumour dose from each beam is obtained by adding the dose values within the tumour area and then dividing the sum by the number of elements within the area. The average dose for the entire planning is then obtained by adding up the average doses of all the beams. The determination of the modal dose is more laborious in that the particular dose value from each beam must, as mentioned above, be noted and summed up at each point of the grid fixed to the tumour area.

A third method of calculating the average dose is by means of a planimeter. The area between two isodoses is measured and multiplied by the mean value of the two doses; this is done for the whole tumour area. All the products are then added and the sum is divided by the tumour area. The dose intervals in this case are thus constant; in the other two methods the areas are constant.

Examples. Certain difficulties may arise in the determination of the modal dose, as will be seen from the example in Fig. 1. The modal dose is calculated to be 115 % or 116 % for these two beams with wedge filters if the two points of intersection marked with circles in the figure are ignored. If, on the other hand, these points are assumed to be situated within the tumour area, the modal dose will be 104 %. This shows that the modal dose may depend on the positioning of the grid. The average dose is in both cases 110 % (109.7 % and 109.5%, respectively). This is not surprising as the two points, each representing an area of 1 cm^2, cannot of course have any notable effect if the definition of the average dose is taken into account.

The modal and average doses have for this example also been calculated with a more open grid, one with a linear distance of 2 cm. Every other line in the grid is left out with the same mounting as in Fig. 1. This produces four different series of points of intersection. The encircled points have not been taken into account, i. e. the modal dose for the original grid is 115 % or 116 %. The modal dose is in the different cases 115 %, 116 %, 104 % and 113 %, the average dose being 108.9 %, 109.5 %, 109.5 % and 110.5 %, respectively.

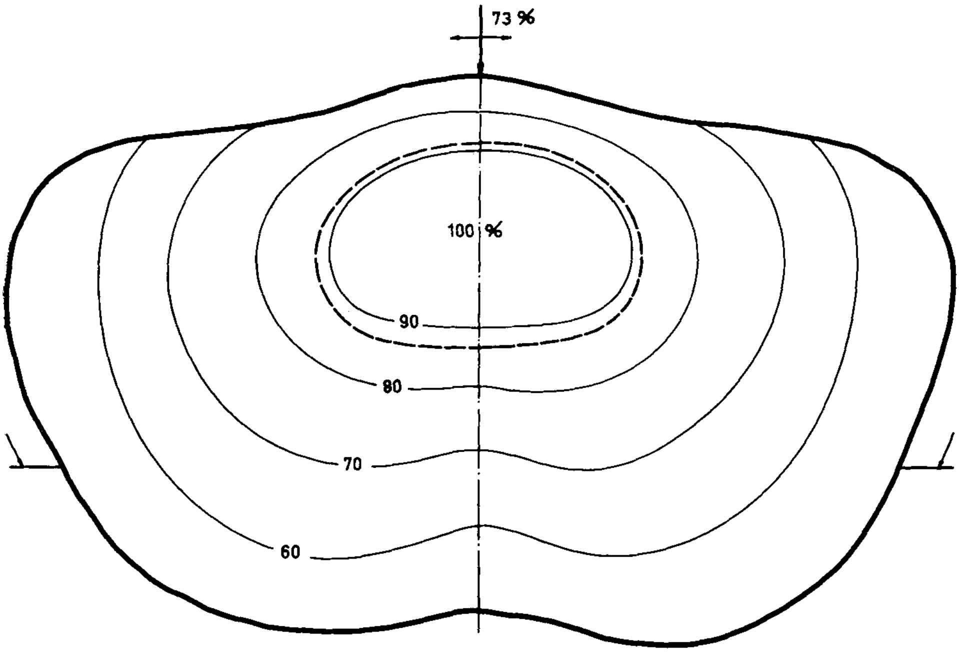

Fig. 3. Dose distribution obtained with moving beam technique (isodose chart 082 in HULTBERG et coll. 1959). Broken line indicates tumour area.

Median dose	94 ± 6 %	
Modal dose	$88\ {}^{+\,12}_{-\ \ 0}$ %	or 94 ± 6 %
Average dose	94 ± 6 %	

It appears from this that the average dose can be calculated with fewer points than the modal dose.

The average dose has also been calculated by the planimeter method. The value is 109.7 % with only three areas, the area between 110 % and 100 %, and the areas with larger and smaller doses, respectively, than these.

Another way of proceeding is to project the tumour area into the standard isodose diagrams and calculate the average dose for each beam separately. The number of areas between two isodoses, separated by 10 % of the peak dose, will then be larger, in this case 8 in each beam. The peak dose is the maximum value of the absorbed dose which occurs along the beam axis. The average dose was calculated as 109.8 %. This method consequently gave values that were practically the same as those obtained with the grid method.

Another example, showing that the modal dose is dependent on the number of points, is seen in Fig. 3. The irradiation is performed with the beam

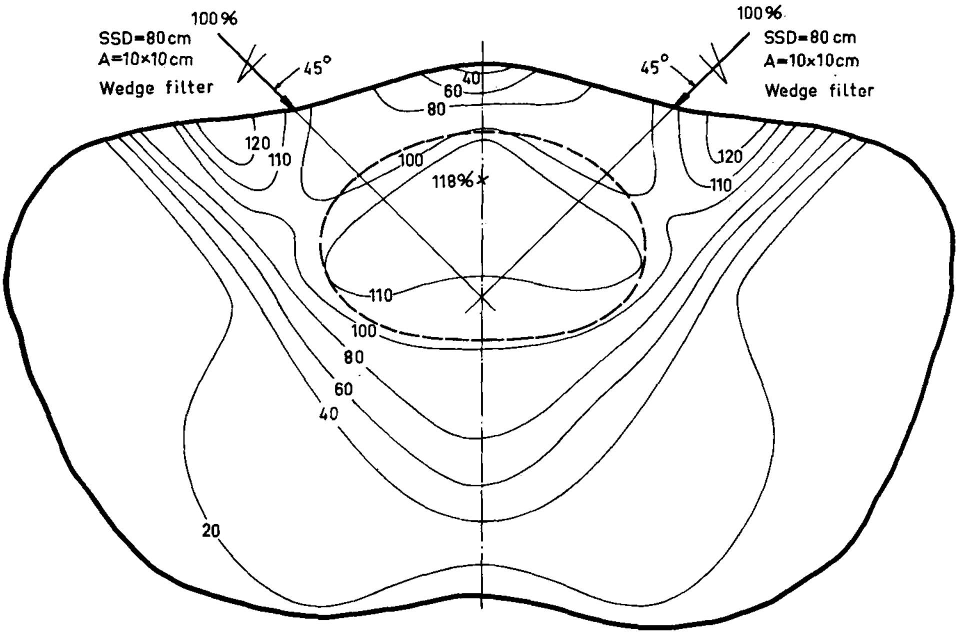

Fig. 4. Dose distribution resulting from two beams with wedge filter. Broken line indicates tumour area.

Median dose	108 ± 10 %	
Modal dose	104 $^{+14\ \%}_{-\ 6\ \%}$	or 116 $^{+\ 2\ \%}_{-18\ \%}$
Average dose	110 $^{+\ 8\ \%}_{-12\ \%}$	

oscillating 180°. The modal dose is determined at 94 % using a grid with a linear distance of 1 cm; if a sufficiently dense grid is used, the modal dose will be equal to the minimum dose (88 %). This obtains at all dose distributions where the dose falls approximately linearly from the centre towards the periphery as at the same time the area, and consequently the number of points, increases with the square of the distance from the centre. If the dose decreases with the square of this distance, all values from the maximum to the minimum have the same frequency. This means that the modal dose cannot be determined at a definite value.

The average dose has also been calculated for this example. The value of 93.5 % was obtained when a grid with a linear distance of 1 cm was used, and the values were 93.7 %, 93.6 %, and 93.6 %, respectively, when the average dose was calculated by means of the planimeter method, with dose intervals of 2 %, 5 % and 10 %.

Comparison of treatment plannings. Two dose plannings for the same patient were used in the above to exemplify calculations in accordance with two different definitions of tumour dose. The dose distribution for the moving beam alternative is shown in Fig. 3, and the one with two wedge-filter beams in Fig. 4. A suitable standardization has to be made for a comparison of these two treatment alternatives as regards the dose distribution within and outside the tumour area. The isodoses as represented in the figures are functions of the peak doses of the standard isodose diagrams. The most suitable principle should then be to standardize the treatment plannings to the tumour dose. If these were standardized to the average dose, the maximum doses (in %) in the two treatment alternatives would be approximately identical, whereas the minimum doses would be lower in the wedge-filter beam alternative. This comparison shows that the latter alternative gives a lower minimum dose at the same total dose absorbed within the tumour.

Discussion

It would be most valuable if one definition of the term tumour dose could be accepted and used at all radiotherapy clinics. The definition must be such that the calculations in every particular case are reproducible within desired limits, and may be performed without an unreasonable amount of work. The average dose would appear to be preferable to the modal dose. The examples of irradiations chosen to illustrate this may seem unfavourable, as the maximum dose variation is $\pm$ 10 %. The definition must, however, also be valid for such types of irradiation, since they are used in practice, for instance when a certain dose value must not be exceeded in a radiosensitive organ. When the dose variation within the tumour area is small, the difference between the modal and average dose is of course very small, but the practical advantages in the calculation of the average dose still remain. If the calculation of the tumour dose is to be extended to the whole tumour volume, it is of particular advantage if the number of points of calculation are not too high. Apart from the average dose, it would appear to be most important that the maximum and minimum dose values within the tumour area are stated at the dose planning.

SUMMARY

It would be an advantage if the term 'tumour dose' could be uniformly defined in order that comparisons of different patients and patient groups as regards dose levels and radiation techniques could be facilitated. It is suggested that the 'average dose' may be the best one to use.

ZUSAMMENFASSUNG

Es erscheint wünschenswert, dass der Ausdruck „Tumordosis" einheitlich definiert wird, damit Vergleiche zwischen verschiedenen Patienten und Patientengruppen bezüglich Dosenabgabe und Bestrahlungstechnik leichter vorgenommen werden können. Es wird angeregt, dass der Ausdruck „Durchschnittsdosis" am brauchbarsten ist.

RÉSUMÉ

Il est souhaitable que le terme « tumour dose » reçoive une définition uniforme pour faciliter la comparaison entre divers malades et groupes de malades en ce qui concerne les doses et les techniques d'irradiation. Les auteurs pensent que le terme « average dose » (dose moyenne) est le meilleur.

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