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# COMPUTATION OF DOSES IN DERMATOLOGIC ROTATION THERAPY

by

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Green, Jennings & Hendtlass (1951) worked with a voltage of 50 kV at a focus-skin-distance of 50 cm to treat large areas of the human skin with a minimum of tube settings. Wagner (1955) and Schirren (1955) have given treatments at focus-skin distances of 100 and 200 cm, respectively. While at a distance of 100 cm it is necessary to use four radiation fields to cover the front as well as the back of a patient, Schirren found it sufficient to use one field for each at a FSD of 200 cm. A drawback common to the procedures used by Wagner and by Schirren is that the sides of the patient are insufficiently irradiated due to the grazing incidence of the radiation.

The possibility of applying the techniques of rotation therapy in an attempt to achieve a more uniform distribution was considered. A revolving disk was installed in the floor of a treatment room and on this the patient could stand and support himself with his hands on a coupled bar mounted under the ceiling. The roentgen tube was fixed with the central ray directed horizontally and intersecting the vertical axis of the revolving disk. A Maclett OEG 60 tube was chosen for the treatments; this is provided with a 1 mm Be window at the end of the tube housing and is said to have a more homogeneous field than other tubes for superficial therapy. The tube was energized with a Dermopan apparatus and operated at 50 kV, 25 mA and a total filtration of 1 mm Be.

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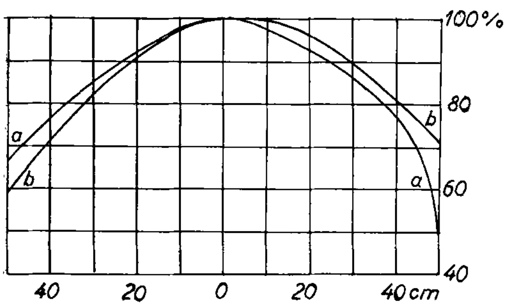


Fig. 1. Field inhomogeneity in the 100 cm plane.

The dose rate D in the central ray was first measured at a focus distance of 100 cm. The direction of the central ray was found visually as the line connecting a point source of light placed 100 cm from the focus and its image in a small mirror placed in contact with the Be window. The dose rate measurements were carried out with a Küstner 'Panzerdosimeter' supplied with a 'Kurzkammer', which was adjusted by reference to a parallel-plate standard chamber using radiation of the same quality.

The percentage variation of the dose in a plane perpendicular to the central ray at 100 cm focus distance is shown in Fig. 1. Curve *a* represents the relative dose distribution along a horizontal line while curve *b* is the dose distribution in the vertical direction. The tube was mounted with the water inlet directed downwards. It can be seen that the irradiation field was most homogeneous in the vertical direction. It is possible to draw isodose curves for the entire 100 cm plane with reasonable accuracy (Fig. 2) from the curves *a* and *b* of Fig. 1.

The absorption curves in skin-equivalent material for radiation at 100 cm and, respectively, 200 cm focus distances are shown in Fig. 3. In the former case the first HVL was found to be 1.35 mm tissue and the second HVL 1.85 mm tissue.

The following simplifications are made to facilitate a calculation of the dose for a full revolution of the patient.

1. The dose is calculated only for a horizontal section through the patient at the level of the central ray.

2. This section is approximated by an ellipse with the semi-axes: $b = 12$ cm (from the axis of rotation to the skin surface over the sternum and spine, respectively), and $a = 19$ cm (from the axis of rotation to the sides of the thorax).

3. The axis of rotation is placed 115 cm from the focus, coinciding with the centre of the ellipse. The FSD in the direction of the central ray will then vary from 103 cm (focus-sternum and focus-spine, respectively) to 96 cm (from focus to either side of thorax).

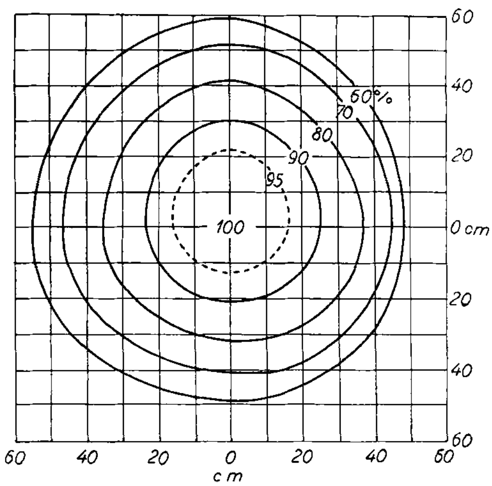


Fig. 2. Isodose curves in the 100 cm plane.

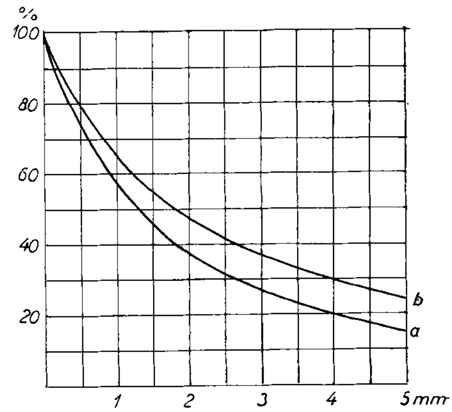


Fig. 3. Curves of absorption in tissue equivalent material: curve *a* at a focus distance of 100 cm, curve *b* at a focus distance of 200 cm.

In Fig. 4, $SS_1$ represents the track followed by the xiphi sternum in a rotation of the patient by $\alpha$ (degrees) from the central ray, FO. The dose rate received to the sternum in the position $S_1$ is given by

$$d_\alpha = k_1 \cdot k_2 \cdot k_3 \cdot D = k_\alpha \cdot D$$

where

D is the dose rate at the point of reference, C, of the central ray; FC = 100 cm;

$k_1$ is a correction taking account of the inhomogeneity of the field from C to $S_2$;

$k_2$ is a factor correcting for the decrease of the dose rate from $S_2$ to $S_1$, according to the inverse square law;

$k_3$ is a correction factor for the decrease of the dose rate due to absorption in the air between $S_2$ and $S_1$.

To find the correction factors for different values of $\alpha$ it is necessary to calculate $x, y$ and $y^1$ in Fig. 4. This may be done with the aid of the simple trigonometric formulae:

$$x = \frac{100}{115 - 12 \cdot \cos \alpha} \cdot 12 \sin \alpha$$

$$y = \sqrt{115^2 + 12^2 - 2 \cdot 115 \cdot 12 \cdot \cos \alpha}$$

$$y^1 = \sqrt{100^2 + x^2}$$

Since curve *a* (Fig. 1) is not symmetrical with respect to the central ray, an average value of $k_1$ has been used in the table; this means that the irradiation of the xiphi sternum is considered to be equal for positive and negative values of $\alpha$.

The values of $x, y$ and $y^1$ have thus been calculated for $\alpha = 0°, 10°, 20° \ldots 80°$, and by using these results one finds the values of:

$k_1$ from curve *a* (Fig. 1)

$k_2$ from $k_2 = \left(\frac{y^1}{y}\right)^2$

$k_3$ from curve *a* (Fig. 3)

considering that $(y - y^1)$ cm air correspond to $(y - y^1)/80$ mm tissue.

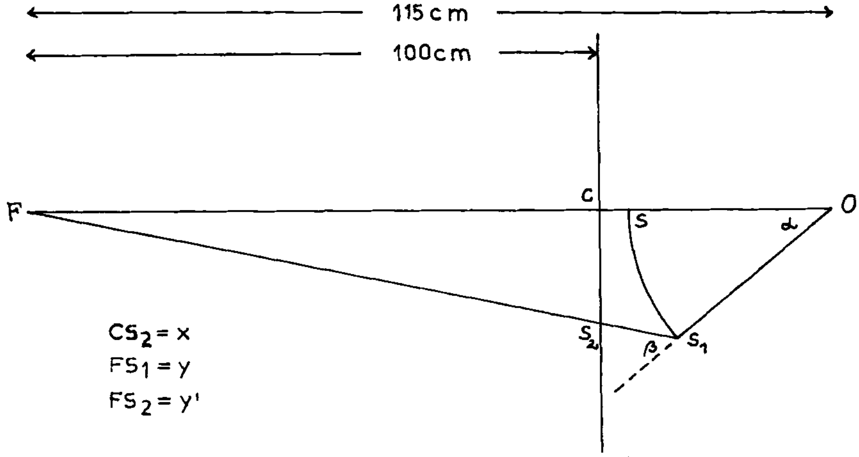


Fig. 4. Geometry of irradiation at sternum, α degrees from the central position.

The dose for one revolution may be calculated with sufficient accuracy, if the time T for one turn is divided into 36 sections of equal size, for which the dose to the sternum is given by

$$T/36 \cdot \frac{d_\alpha + d_{\alpha+10}}{2}$$

The total dose in one revolution will, therefore, be $D_0 = \frac{T}{36} \cdot 2 \cdot (0.5\, d_0 + d_{10} + d_{20} + \ldots + 0.7\, d_{80}) = \frac{T \cdot D}{18} \cdot (0.5\, k_0 + k_{10} + k_{20} + \ldots + 0.7\, k_{80})$,

where, e. g. $k_{10} = k_1 \cdot k_2 \cdot k_3$ for $\alpha = 10$ degrees. At an angle of $\alpha = 84°$ the radiation will strike the sternum tangentially. The correction factors $k_1$, $k_2$ and $k_3$ as well as their product $k_\alpha$ are given in the table for different values of α.

If a calculation of the dose at 1 mm depth is also desired, $d_\alpha$ must be corrected by a further factor $k_4$ to take care of absorption in a skin layer of thickness z, which the radiation has to penetrate. If the surface of the skin is considered to be a plane within a small area around the xiphi sternum we have $z = 1/\cos\beta$, where β is the angle of incidence (Fig. 4), which can be computed from the relation

$$\sin\beta = \frac{115}{y} \cdot \sin\alpha$$

**Table**

*Calculations of dose on sternum; focus-axis of rotation 115 cm*

| | $k_1$ | $k_2$ | $k_3$ | $k_4$ | $k_\alpha = k_1 \cdot k_2 \cdot k_3$ | $k_\alpha = k_1 \cdot k_2 \cdot k_3 \cdot k_4$ |
|---|---|---|---|---|---|---|
| 0° | 1.00 | 0.94 | 0.98· | 0.58· | 0.92· | 0.54 |
| 10° | 1.00 | 0.94 | 0.98 | 0.57· | 0.92 | 0.53 |
| 20° | 0.99· | 0.93 | 0.98 | 0.56· | 0.90· | 0.51 |
| 30° | 0.99 | 0.91· | 0.97 | 0.53· | 0.88 | 0.47 |
| 40° | 0.98· | 0.89 | 0.95 | 0.49 | 0.83 | 0.43 |
| 50° | 0.98 | 0.87 | 0.94 | 0.42 | 0.80 | 0.33· |
| 60° | 0.97 | 0.84 | 0.93 | 0.32· | 0.76 | 0.24· |
| 70° | 0.97 | 0.81 | 0.91· | 0.20 | 0.72 | 0.14· |
| 80° | 0.97 | 0.78· | 0.90· | 0.00 | 0.69 | 0.00 |

For the calculated values of z, the factor $k_4$ can be read from the absorption curve *a* in Fig. 3. The total correction factor $k'_\alpha = k_1 \cdot k_2 \cdot k_3 \cdot k_4$ is then calculated for all values of $\alpha$ and the dose $D_1$ at 1 mm depth may be evaluated by analogy with $D_0$.

Similar calculations have been carried out for the sides of thorax, the only difference being that $b$ (= 12 cm) is replaced by $a$ (= 19 cm). An attempt has here been made however to estimate the influence of the curvature of thorax on the thickness of the absorbing layer. The difference between the z values found by the two methods is considerable only for larger values of $\alpha$ and $\beta$. A value of z = 44 mm was, for example, found by the primitive method, as compared to z = 11 mm with the more exact calculation for $\alpha = 80°$. Both of these thicknesses will, however, only permit a small percentage of the radiation to penetrate to a depth of 1 mm. It was consequently found that the depth dose calculated by taking the curvature of the surface into account exceeded the former value by only 2 %.

The dose at other points of the elliptical cross-section must lie between those at the sternum and at the sides of the thorax. These differ by only 10 %. Nevertheless, a computation was also carried out for a point P of the ellipse, the radius vector of which subtends an angle of 45° with the principal axes. From the formula of ellipse expressed in polar coordinates

$$\varrho^2 = \frac{b^2}{1 - \varepsilon^2 \cdot \cos^2 v}$$

the distance $\varrho$ from P to the axis of rotation is found to be 14.4 cm, since $v = 45°$ and $\varepsilon = \sqrt{\frac{a^2 - b^2}{a}} = 0.775$. The surface dose may then be calculated with the formulae given above.

The angle of incidence is found to be 23.2 degrees when point P of the ellipse is located on the central ray. By turning the ellipse in one direction from the central ray ($\alpha$ negative) the angle of incidence will become $\gamma = \beta + 23.2$ degrees, while for a turn in the opposite direction ($\alpha$ positive) $\gamma = \beta - 23.2$ degrees. The irradiation will consequently not be symmetrical with respect to the central ray and it will be necessary to calculate the depth dose for each interval of 10 degrees ranging from $\alpha = -60°$ to $\alpha = +107°$.

We then arrive at the following results:

D = 150 r/min at 100 cm focus distance.

*Surface dose per revolution:*

| | | | |
|---|---|---|---|
| Sternum and spine | $D_0 = 0.375 \cdot D \cdot T$ | $= 56.3 \cdot T$ | roentgen |
| Sides of thorax | $D_0 = 0.415 \cdot D \cdot T$ | $= 62.2 \cdot T$ | » |
| Point of 45° | ($D_0 = 0.383 \cdot D \cdot T$ | $= 57.5 \cdot T$ | » ) |
| Mean value | $D_0 = 0.395 \cdot D \cdot T$ | $= 59.2 \cdot T$ | roentgen |

*Dose in 1 mm depth per revolution:*

| | | | |
|---|---|---|---|
| Sternum and spine | $D_1 = 0.163 \cdot D \cdot T$ | $= 24.5 \cdot T$ | roentgen |
| Sides of thorax | $D_1 = 0.182 \cdot D \cdot T$ | $= 27.3 \cdot T$ | » |
| Point of 45° | ($D_1 = 0.165 \cdot D \cdot T$ | $= 24.8 \cdot T$ | » ) |
| Mean value | $D_1 = 0.172 \cdot D \cdot T$ | $= 25.9 \cdot T$ | roentgen |

T min is the time for a full revolution.

Similar measurements and calculations have been carried out with a distance of 215 cm between the focus and the axis of rotation. The curves showing the inhomogeneity of the field in the 200 cm plane are found to have almost the same shape as curves *a* and *b* of Fig. 1, with the exception that the figures on the abscissa should be doubled. From the absorption curve *b* of Fig. 3 the first HVL is found to be 1.85 mm tissue and the second HVL 3.0 mm tissue. It will be noted that the radiation is considerably more penetrating than in the 100 cm plane:

D = 20 r/min at 200 cm focus distance.

*Surface dose per revolution:*
Sternum and spine $D_0 = 0.410 \cdot D \cdot T = 8.2 \cdot T$ roentgen
Sides of thorax $D_0 = 0.433 \cdot D \cdot T = 8.7 \cdot T$ »
Mean value $D_0 = 0.421 \cdot D \cdot T = 8.4 \cdot T$ roentgen

*Dose in 1 mm depth per revolution:*
Sternum and spine $D_1 = 0.215 \cdot D \cdot T = 4.3 \cdot T$ roentgen
Sides of thorax $D_1 = 0.229 \cdot D \cdot T = 4.6 \cdot T$ »
Mean value $D_1 = 0.222 \cdot D \cdot T = 4.4 \cdot T$ roentgen

The dose received by skin areas lying above or below the central section will be smaller than the calculated values. This is due to the inhomogeneity of the field in the vertical direction and — in the case of the depth dose — to the more oblique incidence as well. A calculation of these doses will, however, become considerably more complicated because of the three-dimensional geometry and also due to the fact that an approximation by an ellipse will be rather rough. To find an upper limit of the dose per revolution it will generally be sufficient to use those values that can be found by multiplying the previously calculated values for the central section, $D_0$ and $D_1$, with a correction factor $k_5$, which accounts for the inhomogeneity of field in a vertical direction; this factor may be read from curve *b* in Fig. 1.

## Acknowledgement

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## SUMMARY

A method of covering large areas of the skin by rotating the patient during the treatment is described. The dose per revolution of the patient is calculated for the surface of the skin and for 1 mm depth at distances of 115 cm and 215 cm, respectively, between the focus and the axis of rotation.

## ZUSAMMENFASSUNG

Eine Methode, die zur umfangreichen Bestrahlung grosser Hautflächen mit Hilfe von Rotation der Patienten führt, wird beschrieben. Die Strahlendose an der Oberfläche und in 1 mm Tiefe wird für je eine Umdrehung des Patienten für einen Abstand Fokus-Rotationsachse von 115 cm, bezweck 215 cm angegeben.

## RÉSUMÉ

L'auteur décrit une méthode d'irradiation de grandes surfaces de peau par rotation du malade au cours du traitement. La dose par révolution du malade est calculée pour la surface de la peau et pour une profondeur de 1 mm à des distances foyer-axe de rotation de 115 cm et 215 cm.

## REFERENCES

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