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A SIEVE FOR TELECOBALT THERAPY

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コバルト遠隔照射用の篩について

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テレコバルト篩照射法はレ線篩照射法のように皮膚糜爛を生じることもなく，又レ線篩照射法よりも深部における不均等度が高いという利点がある．本論文はガラス線量計を用いてテレコバルト篩照射法による深部線量分布を測定し，かつ不均等度を算出し，レ線篩照射法のそれと比較した．また同じくガラス線量計を直線に並べこれを回転することによつて，各深部の平均線量を近似的に測定した．更にテレコバルト篩照射法の深部線量分布を幾何学的作図とプラニメーターによる計測によつて求める方法を考案し，この計算値が実測とよく近似することを知り得た．この結果はテレコバルト用篩の設計に役立つものと信じる．

Sieve irradiation was first deviced by Köhler[1)] in 1909. Using the sieve, which was a net constructed with wires 1 mm. in diameter crossed at intervals of 2 mm., he could irradiate with 10-15 times the dose of conventional irradiation at that time.

The purpose of sieve irradiation, of course, is to reduce radiation damage to the skin. The skin tolerance dose is increased by the use of a sieve in radiation therapy. Marks[2)] (1950) reported that he could irradiate 24,000 r in 28 days. Tanzel[3)] (1952) exposed patients to 280 r in air daily and a total of 23,000 r in 30 days, and Freid, Lipman and Jacobson[4)] (1953) and Gros, Wolf and Burg[5)] (1953) have given the same large doses by means of sieve irradiation. Kaneda and Kondo[6)] (1956) stated that the maximal skin tolerance dose was 24,000 r in sieve therapy.

By dividing the radiation the sieve makes it possible to give generally 4 times and up to 6 times the conventional irradiation dose. Elevation of the skin tolerance dose results in an increase of the depth dose. With skin doses over 10,000 r, however, a moist dermatitis is inevitable, and doses of 16,000 r, cause severe erosion which results later in a sieve-patterned leucoderma.

Many telecobalt therapy apparatusses are in use throughout the world. There are over 200 units in Japan, and the U.S.A. is the only country to have more.

The first advantage of telecobalt therapy is, of course, the elevation of skin tolerance dose to about 12,000 r. The second is a greater depth dose than X-ray therapy.

Since telecobalt has these advantages, can it be said that a sieve would not be useful in telecobalt therapy?

The reasons we use the sieve in telecobalt therapy are :

a) Normal tissue damage may be minimized by dividing the radiation in space, so that the therapeutic ratio for malignant tumours may be increased.

b) Systemic radiation reactions such as radiation sickness and leucopenia are minimized, and patients are able to tolerate a large dose with a larege field of irradiation.

c) With talecobalt sieve therapy, skin damage may be decreased more than with conventional telecobalt therapy.

The sieve for telecobalt therapy has already been reported by Becker, Gudden and Kuttig[7] (1958), Caffaarelli and Laconi[8] (1960), and Mauderli, Gould and Lane[9] (1060). In our clinic, a telecobalt sieve was constructed in 1960 and has been used in many cases of lung cancer[10].

In this paper, the results of our experiments on dose distribution and some considerations in regard to telecobalt sieve are reported.

Telecobalt sieve constructed in our clinic

The cobalt-60 source in our clinic is of a wafer type 2 cm. in diameter. Our sieve, shown in Figs. 1 and 2, is made of lead 4.6 cm. in thickness perforated with cylindrical holes 1.0 cm. in diameter in the direction of the radiation from the source.

Fig. 1 Geometric arrangment of the sieve

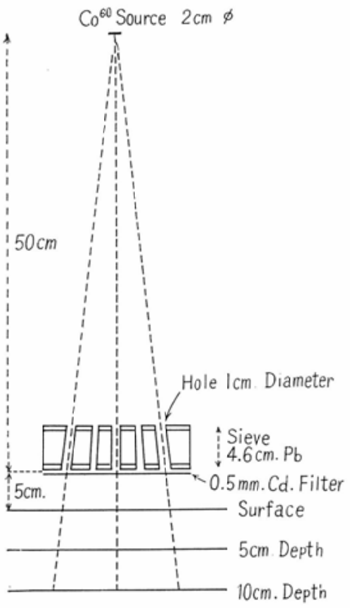
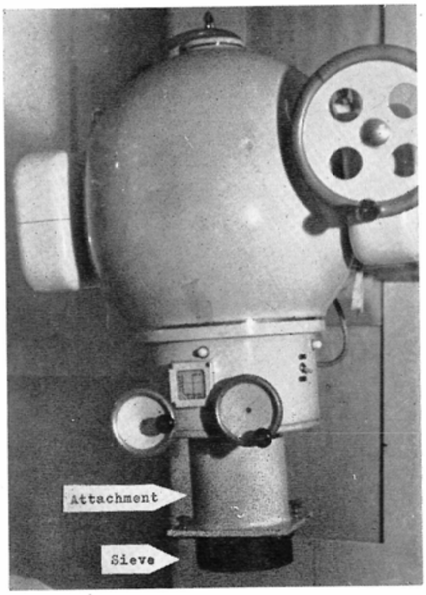


Fig. 2



Three adjacent holes make an equilateral triangle. The open area is 55% of the sieve on the source side, 45% on the patient side, and 50% in the center. Although the sieve weighs 8 kg., it can easily be fixed to the telecobalt therapy unit by means of the attachment shown in Fig. 2. A Cd-filter 0.5 mm. thick is placed under the sieve to remove the soft radiation scattered from the lead of the sieve. Moreover, in practical use, the sieve is placed 5 cm. away from the skin, so the source-skin distance is 55 cm.

Dose distribution and "Inhomogeneity Quotient"

The dose distribution in a water phantom was measured with a fluoroglass dosimeter (Toshiba Co.) which is a rod 1mm. in diameter and 6mm. in length. For each depth, measuring points were chosen, at the center of the openings (Point A) and at the center of the shielded (Point B), which is the center of a triangle. At each point figured by radiography, a rod was fixed perpendicularly on the film and exposed in a water phantom. The results are shown in Fig. 4 and Table 1.

The depth dose at the opening (Point A) decreases exponentially as the depth increases, but at the shielded (Point B) the dose decreases very slowly.

The ratio of the dose at the opening to that at the shielded, the so-called "Inhomogeneity Quotient", is one of the important factors in biological sieve effects.

Fig. 3 Point A represents the center of the opening. Point B represents the center of the shielded.

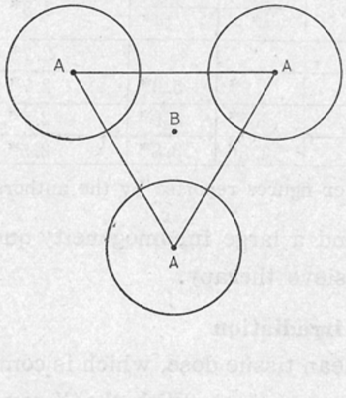


Fig. 4 Depth dose curves of telecobalt sieve irradiation in comparison with X-ray sieve irradiation.

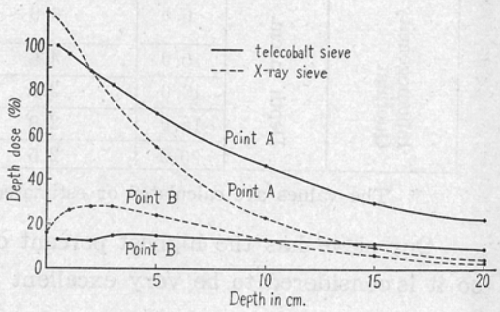


Table 1 Depth doses of telecobalt sieve irradiation and "Inhomogeneity Quotient"

Depth in cm.	Point A	Point B	Inhomogeneity Quotient
0.5	100	13.7	7.3
5.0	70	15.3	4.6
10.0	47	13.4	3.5
15.0	31	11.2	2.8
20.0	23	9.2	2.5

This problem has already been pointed out by Kaneda, Hishida and Maeda (1962), in the experiment of survival of mice, in which no sieve effect could be seen in those irradiated with an inhomogeneity quotient below 2.

The inhomogeneity quotient decreases to a value below 2 at 10 cm. depth in X-ray sieve irradiation of 1.0 mm. Cu h.v.l. (Fig. 4), however with telecobalt sieve therapy it holds a value of 3.5 at 10 cm. depth and 2.5 even at 20 cm. depth, where we can, therefore, expect the biological sieve effect.

As mentioned above, sieves for telecobalt therapy have been constructed by several workers. The size and structure of sieves differ, so the inhomogeneity quotient varies, but these telecobalt sieves generally have a larger quotient value than X-ray sieves (Table 2).

Table 2 Comparison of different telecobalt sieves.

			Kyoto Pref. Univ. Med. Japan	Becker Germany	Mauderli U.S.A.		Caffarelli Italy
Hole diameter, in mm.			10	11	6.35, 11.1, 9.53		15
Ratio of opening, %			55	50	40, 33, 29, 25*		50
Thickness. in mm.			46	30	56		60
Source diameter, in mm.			20	20	20		28
Distance: Source-distalend of sieve, in cm.			50	50	35.6		80
Distance: Distalend of sieve-skin. in cm.			5	0	14.4		
Dosimetry			Fluoroglass	Ion chamber 0.05cm³	Film		Film
Inhomogeneity Quotient	Depth in cm.				No. 1	No. 12	
		0.5	6.9	4.0*	4*	14*	3.3*
		5.0	4.6				2.7*
		10.0	3.5		1.9*	5.9*	2.7*
		15.0	2.8	2.3*	1.5*	5.0*	2.7*
		20.0	2.5		1.3*	3.8*	2.5*

* The values are calculated or estimated from the data or figures reported by the authors.

Our sieve has the highest percent of open area and a large inhomogeneity quotient, so it is considered to be very excellent for telecobalt sieve therapy.

Mean dose in telecobalt sieve irradiation

In sieve therapy, it is necessary to calculate a mean tissue dose, which is commonly defined as the average dose of the shielded and the opening. With the X-ray sieve, it is relatively easy to calculate the mean dose by such methods as Schröck-Vietor's[11]. but not with telecobalt sieve. Mauderli et al. reported film dosimetry to obtain the volume dose.

In our laboratory the mean dose was measured by fluoroglass in the following way. As is shown in Fig. 5, the equilateral triangle, formed by the centers of three openings, is a unit with a definite ratio of open and shielded areas. The average dose in this area is the mean dose in sieve therapy. As is shown in Fig.

Fig. 5

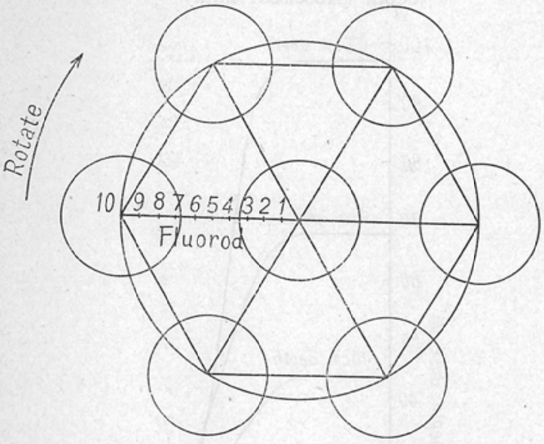
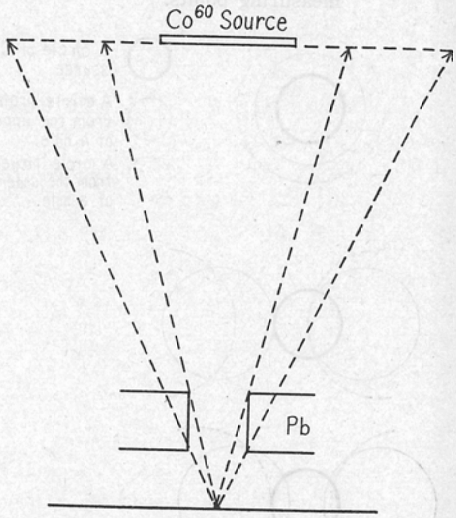


Fig. 6



5, a circle can be drawn surrounding a hexagon, which consists of 6 equilateral triangles. The percent of the open area in the circle is very close to that in the hexagon. When a mean dose in that circle is measured, it can be clinically used as a mean dose of the sieve.

Fluorods were fixed in the phantom at 10 equidistant points along the radius of this circle, and were exposed to γ-rays when the phantom was rotating around an axis through the center of the circle. The dose to each rod (D_n) was multiplied by its distance (R_n) from the center of the circle, and the mean dose (D_M) was calculated from the sum of each product:

$$D_M = \frac{\Sigma D_n R_n}{\Sigma R_n}$$

The mean dose at 0.5, 5, and 10 cm. depth was 53.2, 39.0 and 25.2% of the air dose, respectively. The mean value obtained at each depth was lower than one half of the sum of the percent depth doses of points A and B.

Calculation of depth dose

A new method of calculation was devised to estimate the approximate dose distribution in telecobalt sieve irradiation, and the results were compared with data obtained with fluorods in our clinic and with the data reported by Mauderli et al.

As is shown in Fig. 6, when the upper and lower edges of a hole in the sieve are projected from a measuring point to the level of the source, two circles can be drawn around the 2 cm. circular source. When the measuring point is at the center of the opening, the three circles are concentric, (Fig. 7) and radiation from the source reaches the measuring point without any shielding. When the measuring point moves away from the center of the opening, the three circles are no longer concentric. Thus, in respect to the path way of radiation, the source can be divided into three parts; inside both circles, between the two circles and outside both circles.

Fig. 7 Displacement of circles in relation to measuring points.

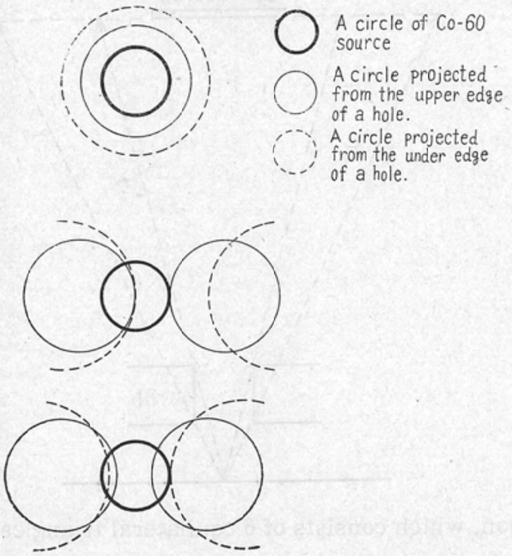


Fig. 8 Dose distribution calculated at each depth (Abscissa: mm.)

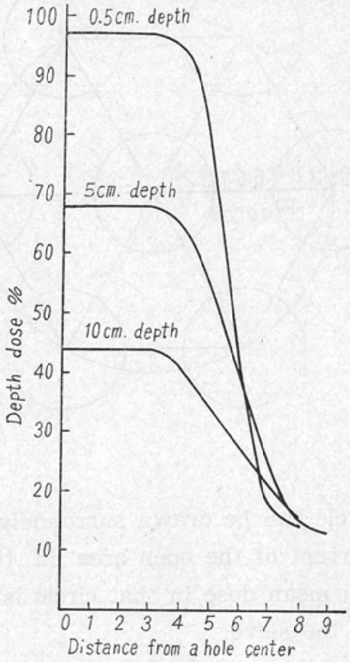
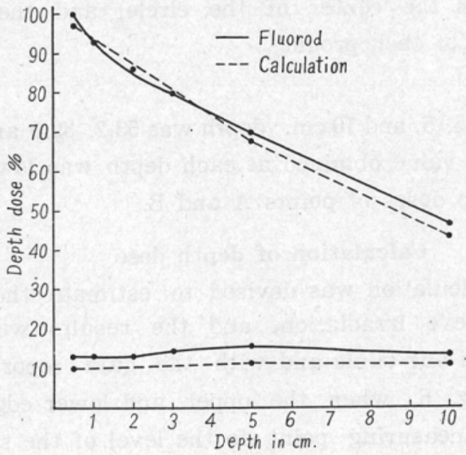


Fig. 9 Comparison of calculated doses with the data measured by fluorods.



From the first (S_α) radiation passes through the sieve without any shielding, from the second (S_β) radiation penetrates obliquely through the side wall of a hole and from the third (S_γ) radiation must penetrate the entire 4.6 cm. of lead. These three parts of the source can be drawn geometrically and measured by a planimeter. When the penetrating percent doses from, S_α, S_β, and S_γ are assumed to be 100, 40 and

10%, respectively, the primary radiation coming to the measuring point, in another word, the Utilization (U%) of the source is calculated as follows:

$$U=\frac{S_\alpha \times 100+S_\beta \times 40+S_\gamma \times 10}{S} \qquad S=S_\alpha+S_\beta+S_\gamma$$

Finaly, the depth dose (D_g) can be calculated when U is multiplied by percent depth dose (D_P) of primary radiation at each depth and an appropriate dose of scattered radiation is added. The value of percent depth dose of primary radiation was quoted from the Wacksmann's data, and the dose of scatter was defined as one half of the dose (D_S) which is the difference between the percent depth dose of 0 cm^2 and 100 cm^2. quoted from the same table, because the sieve has an open area of about 50% and the dose of scatter may be one half of that with a homogeneous irradiation.

$$D_g=U \times D_P+D_S/2$$

The depth doses calculated at 0.5, 5 and 10 cm. depth are shown in Fig. 8. In Fig. 9, these calculated values are compared with those measured by fluorods, and the results are found to be very similar, although at point B the former is slightly lower than the latter When this method of calculation was applied to Mauderli's sieve, it showed a very satisfactory coincidence.

From these findings, it could be said that this calculation method is able to distinguish different properties of different sieves and give good information for the construction of telecobalt sieves.

Summary

It is believed that sieve irradiation has of great value not only in X-ray therapy but also in telecobalt. A Telecobalt sieve was constructed in our clinic and has been used clinically.

In this paper, dose distribution and mean dose at each depth measured by fluorods are reported, and a new method of calculation is described.

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附記

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