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DOSE DISTRIBUTION STUDIES IN EXTERNAL IRRADIATION OF CARCINOMA COLLI UTERI

by

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Comparisons between different treatment techniques and precalculation of the radiation effects should preferably be based on the energy absorbed in the tissue in question. This can be visualized conveniently with dose distribution diagrams giving the absorbed dose in rads. As a basis for comparison of various irradiation techniques, a description of the techniques used at Radiumhemmet in the external treatment of carcinoma of the cervix will be given in this paper.

Terminology and definitions are those proposed by the International Commission on Radiological Units and Measurements (ICRU 1963).

Extension of the tumour. According to KOTTMEIER & VARA (1963), carcinoma of the uterine cervix may start in any part of the cervix or portio. From their origin in the epithelium the changes extend either exofytically towards the vagina, or infiltrate the underlying tissue. The growth is relatively fast in other parts of portio, fornices, vaginal wall and the parametrium; parametrial

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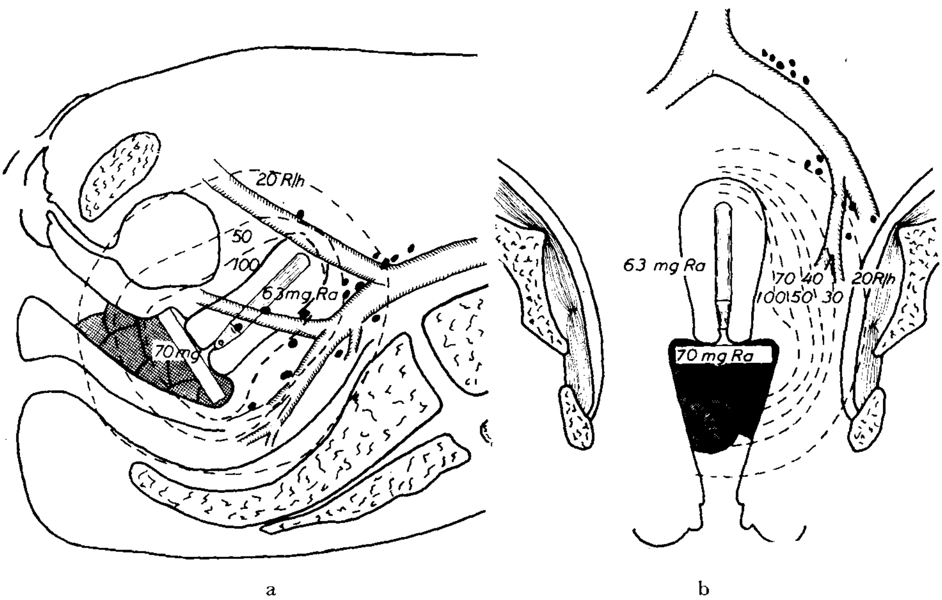


Fig. 1. Dose distribution from a radium application: in a medial cross-section of the patient (a), and in a plane through the uterus and perpendicular to the sagittal plane (b). Vena iliaca interna, externa and obturatoriae are projected in these planes.

extension occurs often very early. In about 60 % of all cases, where the growth is clinically limited to the cervix, histologic investigation reveals neoplastic tissue in the parametrium. An early spread along the lymph vessels (18 % in stage I) to the regional lymph nodes usually occurs. In spite of the rapid spread in the parametrium and the regional lymph nodes the changes are limited for a comparatively long time to the lesser pelvis (KOTTMEIER & VARA 1963).

The region that may in all probability contain malignant growth is outlined in Fig. 1 where the vena iliaca externa and interna and vena obturatoriae are projected in a medial plane as well as one through the uterus.

Intracavitary irradiation

Studies of the dose distribution in the pelvis in intracavitary radium treatment of cancer of the cervix according to the Stockholm technique have been published elsewhere (SIEVERT 1932, KOTTMEIER 1951 and 1964, WALSTAM 1954, KJELLGREN & RAGNHULT 1963).

The dose distribution from a typical intracavitary radium application is

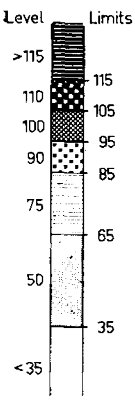


Fig. 2. Shading code for the dose levels.

illustrated in Fig. 1. The dose decreases rapidly with the distance from the source. In this example the dose in nodi lymphatici obturatoriae and nodi iliaci externi is only about 25 % of the dose 2 cm from the cervical channel, about 30 % of the dose in the posterior bladder wall or about 50 % of the dose in the anterior wall of the rectum. This implies that the regional lymph nodes cannot be given an adequate dose with the intracavitary irradiation alone without causing overdosage in tissues nearer the source, e.g. the bladder and rectum (KOTTMEIER 1964). At Radiumhemmet, the intracavitary irradiation is therefore combined with external irradiation in all cases of carcinoma of the uterine cervix, preclinical carcinoma stage I-A excepted.

External irradiation

Radiation quality. At Radiumhemmet, almost all external irradiation until 1957 was performed with orthovoltage roentgen techniques. The radiation qualities used had a HVL in the range 0.5 to 2.0 mm Cu and the SSD was 50 to 60 cm. Since 1957, when the first kilocurie cobalt 60 unit, Gammatron-1, was installed (HULTBERG et coll. 1959), an increasing number of patients have been treated with cobalt 60 radiation. The experience from treatment with orthovoltage roentgen rays is not directly applicable to telecobalt therapy in so far as calculation of exposure is concerned. Among the advantages of cobalt 60 gamma radiation over orthovoltage are the build-up of the absorbed dose causing a skinsparing effect, the higher percentage depth dose and the lower absorption in bone tissue. The last two effects are evident from the illustrations. There are possibly also differences in the relative biologic effect (RBE), which may be 10 to 30 % higher for the roentgen qualities considered here than for cobalt 60 gamma radiation (PATERSON 1960).

Calculation procedure. In order to facilitate comparison between the various dose distribution diagrams the doses are expressed as percentages of the absorbed dose at a point 5 cm from the pelvic midline. This point corresponds to the so-called point B (TOD & MEREDITH 1953). The dose at this point is named the target dose. Fig. 2 shows the shading code used to illustrate the dose distribution in subsequent figures. This code is adjusted to irradiation with cobalt 60 radiation, where it is considered desirable to plan the treatment so that the dose is within $\pm$ 5 % in the target volume.

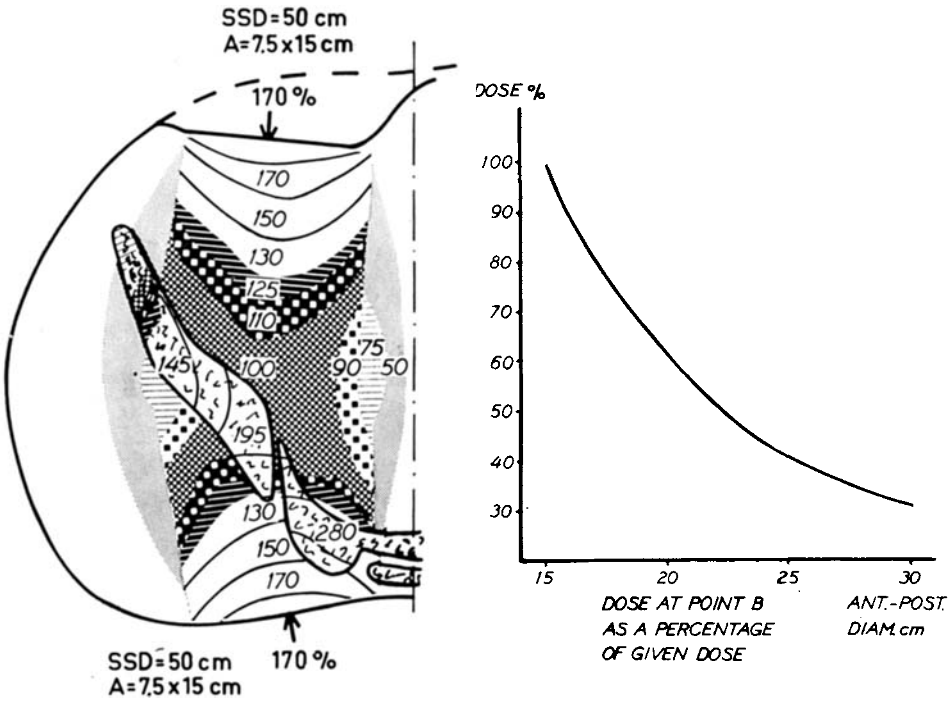


Fig. 3. The left hand side of the figure illustrates the dose distribution in a horizontal cross-section 10 cm above the symphysis when using a technique with compressing tubes. The dependence of the target dose on the patient thickness is shown to the right.

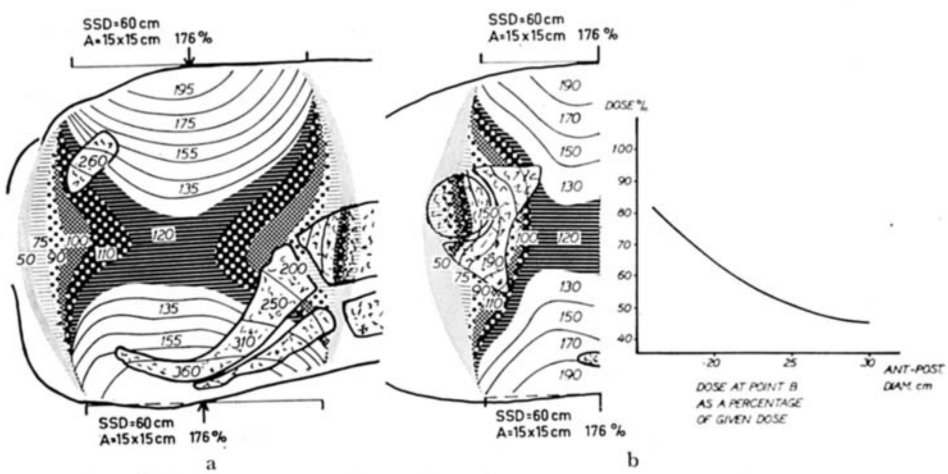


Fig. 4. Dose distribution in a medial cross-section (a), and in a horizontal cross-section 5 cm above the symphysis (b) by using two opposed beams (HVL = 1.0 mm Cu). On the right hand side of 4b, the dependence of the target dose on the antero-posterior diameter of the patient is plotted.

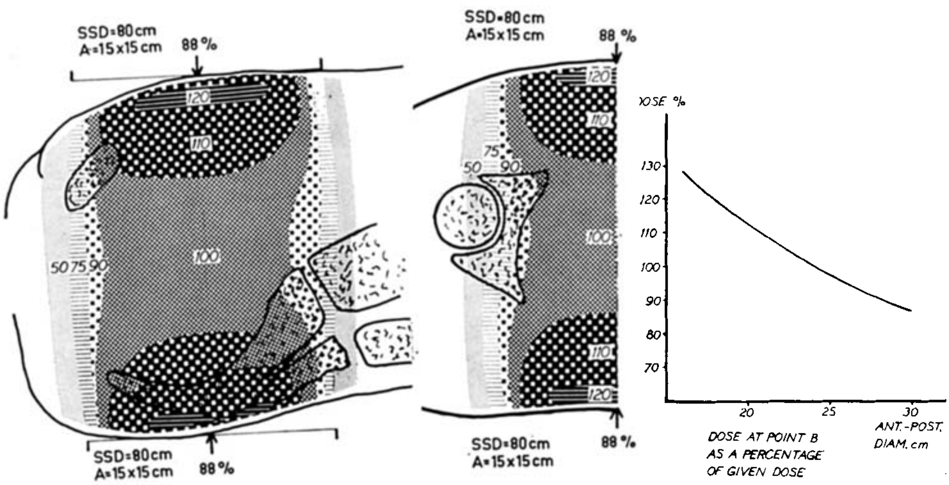
The various dose distributions are obtained by graphical summation of the standard isodose charts. Calculated charts (IAEA 1962) were used for orthovoltage. The isodose charts for cobalt 60 were measured with an automatic isodose recorder (LARSSON et coll. 1963) fitted with an ionization chamber, with an outer diameter of 4.5 mm and a length of 15 mm (BENNER et coll. 1959). The ionization current was amplified with a vibrating reed electrometer.

In the calculations, corrections were made for the oblique incidence of the cobalt 60 beam according to the isodose curve shift method (DUTREIX and DUTREIX 1962). Consideration was paid to the different absorptions in bone and soft tissue. The average density of bone tissue is assumed to be 1.3 g/cm^3 (ELLIS & JONES 1957, GEST 1961). In virtue of the statements in NBS Handbooks (ICRU 1959 and 1962) the relative dose reduction per cm bone tissue is estimated to about 1.1 % for cobalt 60 radiation and about 7 % for the roentgen quality of HVL = 1.0 mm Cu. The conversion factors f, from R to rad, used in these calculations, are

	Muscle	Bone
Co 60	0.96 rad/R	0.93 rad/R
HVL 1.0 mm Cu	0.95 rad/R	1.93 rad/R

The antero-posterior and the lateral diameters of the patient, in a horizontal cross-section 5 cm above the symphysis, are chosen as 20 cm and 35 cm, respectively.

Various irradiation techniques. The most common and simplest techniques earlier used at Radiumhemmet are illustrated in Figs 3 to 5. From these figures it is obvious that the techniques result in a very inhomogeneous dose distribution. The minimum dose in the irradiated volume is generally received by the region where the target volume is situated. The maximum dose is received by regions containing the rectum, the small bowels and the urinary bladder. In those cases where the irradiation techniques as illustrated in Figs 4 and 5 are combined with intracavitary applicators, the urinary bladder and the rectum are protected by lead absorbers placed in the beam in front of the position of the applicator. In this way it is possible to diminish the dose from the external irradiation in the most critical parts of the bladder and rectum by about 50 %. For radiation qualities with HVL 1.0 mm Cu the energy absorption per gram bone tissue (absorbed dose) is about twice as high as that of soft tissue. The energy absorption per gram tissue from ^{60}Co radiation is on the other hand somewhat lower in bone than in wet tissue. In the irradiation of the pelvic walls with this technique and conventional



a b

Fig. 5. Dose distribution from two opposed cobalt 60 beams in a medial cross-section (a), and in a horizontal cross-section 5 cm above the symphysis (b). On the right hand side of 5b, the dependence of the target dose on the antero-posterior diameter of the patient is plotted.

roentgen rays, those parts of the head and neck of the femur that are in the beam will receive appreciable doses, 70 to 150 % in the case illustrated in Fig. 4 and 150 to 200 % in Fig. 3. When opposed beams are used, the resulting dose distribution depends very much on the patient diameter along the central ray. In order to illustrate this, the target dose as a percentage of the given dose is plotted as a function of the patient's a.p. diameter in Figs 3, 4b and 5b. From these diagrams it is clear that it is not sufficient to state the given dose only, especially when orthovoltage radiation qualities are used.

With moving beam techniques (Dahl & Vikterlöf 1960) or suitable combination of several fixed beams it is however possible to obtain a better dose distribution with the maximum dose in the target volume and a rapid decrease of dose towards critical organs such as the bladder and rectum.

In cases where the growth has spread into the vagina and the paravaginal tissue it is more difficult to obtain a sufficiently large and homogeneous dose in the total target volume. With the techniques described the lower boundary of the beams must be kept sufficiently high in the body in order to avoid tangential irradiation of the perineum. This implies that there is a risk that the lower part of the vagina will receive an inadequate dose. For this reason beams are sometimes directed towards the vulvae, thus irradiating the lower

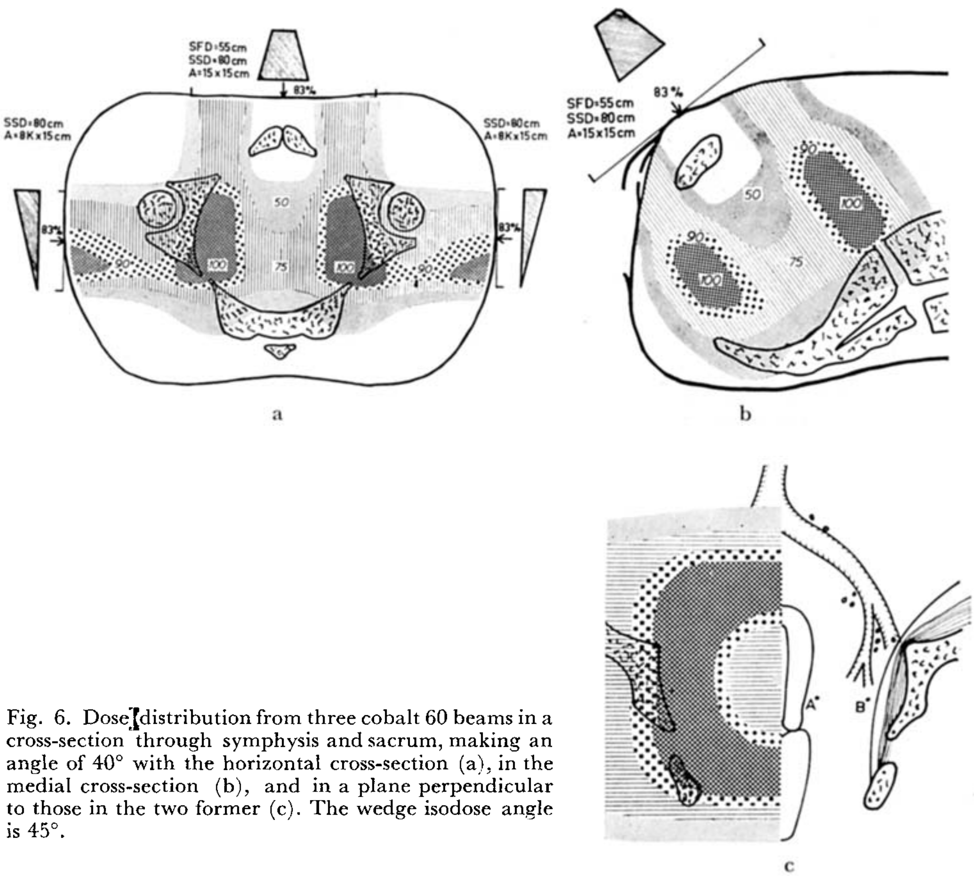


Fig. 6. Dose distribution from three cobalt 60 beams in a cross-section through symphysis and sacrum, making an angle of 40° with the horizontal cross-section (a), in the medial cross-section (b), and in a plane perpendicular to those in the two former (c). The wedge isodose angle is 45°.

part of the vagina. It is, however, almost impossible to avoid local over- or underdosage if too simple techniques are used.

Wedge filter beams at a suitable angle in the perineal and anterior areas makes it possible to give a high and homogeneous dose to the vagina and the paravaginal tissue, at least when the patient is thin. The bladder and the rectum are protected by applying the beam parallel to the vagina. With this technique, however, it is difficult to include the pelvic walls in the homogeneously irradiated region.

With three beams applied equally loaded, as illustrated in Fig. 6, however, it is possible to irradiate the paracervical and paravaginal tissues and the pelvic walls at the same time. A high relative dose is obtained in the target volume with a rapid decrease of dose towards the bladder, the rectum and the small bowel. Tangential irradiation of the perineum and local overdosages are avoided. The beams can easily be modified to suit the shape of the target volume. All the three beams may be applied with the patient in the supine position. By using a lead absorber in the anterior beam it it also easy to protect regions already heavily irradiated with intracavitary radiation sources. The effect of a 4 cm high circular truncated lead cone in the anterior beam is illustrated in Fig. 6.

Checking the precalculation. The precalculated dose distribution may easily be checked during the treatment by measurements in the vagina, the rectum and at the exit surface. The measurements are at Radiumhemmet made with Bg chambers (SIEVERT 1934). The small size and the favourable physical properties of these chambers make them particularly suitable for these measurements (SIEVERT 1934, DAHL & VIKTERLÖF, HULTBERG et coll. 1959, SKÖLDBORN 1959). When measuring in the rectum, the chambers are inserted in a flexible plastic tube and when measuring in the vagina a rigid one is used. Exit dose measurements can be made to correct for inhomogeneities (SUNDBOM 1965). The positions of the beam and detectors in relation to the pelvic bones are checked with exit films in a similar way as was done by LINDELL & WALSTAM 1956. The film used is Gevaert Dipos N 51, which is so insensitive that it can be left on the exit side of the patient throughout an ordinary treatment session.

The irradiation techniques described above are the principal ones used. Every patient irradiation with the multifield technique worked out during the last few years is individually planned, however, and the technique is matched to the shape and position of the tumour and the geometry of the patient.

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SUMMARY

Various techniques for the external irradiation of carcinoma colli uteri are discussed and illustrated by dose distribution in two or three planes. For external irradiation of patients who have received intracavity radium application a technique with three beams is proposed and its advantages are discussed.

ZUSAMMENFASSUNG

Verschiedenartige Methode für externe Bestrahlung des Cervixkarzinomes und deren Dosisverteilung in zwei oder drei Ebenen werden besprochen. Für Patienten, die bereits intrakavitäre Bestrahlung erhalten haben, wird ein externer Bestrahlungsplan mit drei Feldern angegeben und die Vorteile dieses Plans erläutert.

RÉSUMÉ

L'auteur examine diverses techniques d'irradiation externe du cancer du col de l'utérus et donne des exemples de distributions de doses dans deux ou trois plans. Pour l'irradiation externe des malades qui ont eu une application intracavitaire de radium, il propose une technique à trois champs et en examine les avantages.

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