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Prescribing, Recording, and Reporting Photon Beam Therapy

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(For detailed information on the availability of this and other ICRU Reports, see page 67.)

Preface

Scope of ICRU Activities

The International Commission on Radiation Units and Measurements (ICRU), since its inception in 1925, has had as its principal objective the development of internationally acceptable recommendations regarding:

(1) Quantities and units of radiation and radioactivity,

(2) Procedures suitable for the measurement and application of these quantities in clinical radiology and radiobiology,

(3) Physical data needed in the application of these procedures, the use of which tends to assure uniformity in reporting.

The Commission also considers and makes similar types of recommendations for the radiation protection field. In this connection, its work is carried out in close cooperation with the International Commission on Radiological Protection (ICRP).

Policy

The ICRU endeavors to collect and evaluate the latest data and information pertinent to the problems of radiation measurement and dosimetry and to recommend the most acceptable values and techniques for current use.

The Commission's recommendations are kept under continual review in order to keep abreast of the rapidly expanding uses of radiation.

The ICRU feels that it is the responsibility of national organizations to introduce their own detailed technical procedures for the development and maintenance of standards. However, it urges that all countries adhere as closely as possible to the internationally recommended basic concepts of radiation quantities and units.

The Commission feels that its responsibility lies in developing a system of quantities and units having the widest possible range of applicability. Situations may arise from time to time when an expedient solution of a current problem may seem advisable. Generally speaking, however, the Commission feels that action based on expediency is inadvisable from a long-term viewpoint; it endeavors to base its decisions on the long-range advantages to be expected.

The ICRU invites and welcomes constructive comments and suggestions regarding its recommendations and reports. These may be transmitted to the Chairman.

Current Program

The Commission has divided its field of interest into twelve technical areas and has assigned one or more members of the Commission the responsibility for identification of potential topics for new ICRU activities in each area. Each area is reviewed periodically by its sponsors. Recommendations for new reports are then reviewed by the Commission and a priority assigned. The technical areas are:

Radiation Therapy
Diagnostic Radiology
Nuclear Medicine
Radiobiology
Radioactivity
Radiation Physics—X Rays, Gamma Rays and Electrons
Radiation Physics—Neutrons and Heavy Particles
Radiation Protection
Radiation Chemistry
Critical Data
Theoretical Aspects
Quantities and Units

The actual preparation of ICRU reports is carried out by ICRU report committees. One or more Commission member serves as sponsor to each committee and provides close liaison with the Commission. The currently active report committees are:

Absorbed Dose Standards for Photon Irradiation and Their Dissemination
Beta-ray Dosimetry for Radiation Protection
Clinical Dosimetry for Neutrons (Specification of Beam Quality)
Determination of Body Burdens for Radionuclides
Dose Specification for Reporting Interstitial Therapy
Fundamental Quantities and Units
Fundamentals of Particle Counting Applied to Radioactivity
Hyperthermia
In situ Gamma Spectrometry in the Environment
Medical Application of Beta Rays
Performance Assessment in the Digital Representation of Images
Prescribing, Recording and Reporting Electron Beam Therapy
Proton Therapy
Relationships Between Quantities for Radiological Protection Against External Radiation (Joint with ICRP)
ROC Analysis
Secondary Electron Spectra Resulting from Charged Particle Interactions
Statistical Aspects of Environmental Sampling
Stopping Power for Heavy Ions
Tissue Substitutes, Characteristics of Biological Tissue and Phantoms for Ultrasound

ICRU's Relationships With Other Organizations

In addition to its close relationship with the International Commission on Radiological Protection, the ICRU has developed relationships with other organizations interested in the problems of radiation quantities, units and measurements. Since 1955, the ICRU has had an official relationship with the World Health Organization (WHO) whereby the ICRU is looked to for primary guidance in matters of radiation units and measurements and, in turn, the WHO assists in the world-wide dissemination of the Commission's recommendations. In 1960, the ICRU entered into consultative status with the International Atomic Energy Agency. The Commission has a formal relationship with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), whereby ICRU observers are invited to attend UNSCEAR meetings. The Commission and the International Organization for Standardization (ISO) informally exchange notifications of meetings, and the ICRU is formally designated for liaison with two of the ISO Technical Committees. The ICRU also corresponds and exchanges final reports with the following organizations:

Bureau International de Metrologie Legale
Bureau International des Poits et Mesures
Commission of the European Communities
Council for International Organizations of Medical Sciences
Food and Agriculture Organization of the United Nations
International Council of Scientific Unions
International Electrotechnical Commission
International Labor Office
International Organization for Medical Physics
International Radiation Protection Association
International Union of Pure and Applied Physics
United Nations Educational, Scientific and Cultural Organization

The Commission has found its relationship with all of these organizations fruitful and of substantial benefit to the ICRU program. Relations with these other international bodies do not affect the basic affiliation of the ICRU with the International Society of Radiology.

Operating Funds

In the early days of its existence, the ICRU operated essentially on a voluntary basis, with the travel and operating costs being borne by the parent organization of the participants. (Only token assistance was originally available from the International Society of Radiology.) Recognizing the impracticability of continuing this mode of operation on an indefinite basis, operating funds were sought from various sources.

During the last ten years, financial support has been received from the following organizations:

ADAC Laboratories
Agfa-Gavaert, N.V.
American Society for Therapeutic Radiology and Oncology
Atomic Energy Control Board
Bayer AG
Central Electricity Generating Board
CGR Medical Corporation
Commissariat à L'Énergie Atomique
Commission of the European Communities
Dutch Society for Radiodiagnostics
Eastman Kodak Company
Ebara Corporation
E.I. duPont de Nemours and Company
Électricité de France
Elscint
Fuji Medical Systems
Fuji Photo
General Electric Company
Gilbert X-Ray Company
Hitachi, Ltd.
International Atomic Energy Agency
International Radiation Protection Association
International Society of Radiology
Italian Radiological Association
Japan Industries Association of Radiation Apparatus
Konica Corporation
National Cancer Institute of the U.S. Department of Health and Human Services
National Electrical Manufacturers Association
National Institute of Radiological Sciences of Japan
N.V. Phillips Gloielampenfabrieken
Philips Medical Systems, Incorporated
Pyne Corporation
Radiation Research Society
Scanditronix AB
Shimadzu Corporation
Siemens Aktiengesellschaft
Society of Nuclear Medicine
Sumitomo Heavy Industries, Ltd.
Theratronics
Toshiba Corporation
University Hospital, Lund, Sweden
World Health Organization
Xerox Corporation

In addition to the direct monetary support provided by these organizations, many organizations provide indirect support for the Commission's program. This support is provided in many forms, including, among others, subsidies for (1) the time of individuals participating in ICRU activities, (2) travel costs involved in ICRU meetings, and (3) meeting facilities and services.

In recognition of the fact that its work is made possible by the generous support provided by all of the organizations supporting its program, the Commission expresses its deep appreciation.

ANDRE ALLISY
Chairman, ICRU

Sèvres, France
1 September 1993

Executive Summary

When delivering a radiotherapy treatment, parameters such as the volume and dose have to be specified for different purposes: prescription, recording, and reporting. It is important that clear, well defined and unambiguous concepts and parameters are used for *reporting* purposes to ensure a common language between different centers. Furthermore, it is an advantage if the same terminology is used also for prescribing and recording.

Aim of Therapy

It is important to define the aim of therapy (radical, or palliative), since this influences the choice of the volume to be treated, the radiation dose, and the treatment technique.

Volumes

It is imperative to define in a clear and concise way the volume(s) to be treated to the prescribed dose(s), irrespective of the technique that will be used. This leads to the concepts of: *GTV (Gross Tumor Volume),* and *CTV (Clinical Target Volume).*

Gross Tumor Volume

The Gross Tumor Volume (GTV) is the gross palpable or visible/demonstrable extent and location of the malignant growth.

Clinical Target Volume

The Clinical Target Volume (CTV) is a tissue volume that contains a GTV and/or subclinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy: cure or palliation.

The CTV is thus an anatomical-clinical concept, that has to be defined *before* a choice of treatment modality and technique is made.

For external beam therapy, margins will have to be added around the CTV to compensate for the effects of organ and patient movements and inaccuracies in beam and patient set up. This leads to the concept of Planning Target Volume (PTV).

Planning Target Volume

The Planning Target Volume (PTV) is a geometrical concept, and it is defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations and inaccuracies in order to ensure that the prescribed dose is actually absorbed in the CTV.

The Planning Target Volume is thus a static, geometrical concept, used for treatment planning and for specification of dose. Its size and shape depend primarily on the CTV, but also on the treatment technique used.

Depending on treatment technique, two further volumes can be identified: *Treated Volume* and *Irradiated Volume.*

Treated Volume

The Treated Volume is the volume enclosed by an isodose surface, selected and specified by the radiation oncologist as being appropriate to achieve the purpose of treatment (e.g., tumor eradication, palliation).

Irradiated Volume

The Irradiated Volume is that tissue volume which receives a dose that is considered significant in relation to normal tissue tolerance.

Organs at Risk

Furthermore, consideration has to be given to normal tissues.

Organs at risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or prescribed dose.

General Recommendations for Reporting Dose

The dose at or near the center of the Planning Target Volume, as well as the maximum and the minimum dose to the PTV, shall always be reported. Additional information (such as average dose and its standard deviation, dose/volume histograms), when available, may be useful.

The ICRU Reference Point

The present system of recommendations for reporting is based on the selection of a point within the PTV, which is referred to as the *ICRU Reference Point.*

The *ICRU Reference Point* shall be selected according to the following general criteria:

—the dose at the point should be clinically relevant and representative of the dose throughout the Planning Target Volume (PTV),

—the point should be easy to define in a clear and unambiguous way,

—the point should be selected where the dose can be accurately determined (physical accuracy),

—the point should be selected in a region where there is no steep dose gradient.

These recommendations will be fulfilled if the ICRU Reference Point is located firstly, at the center, or in the central parts, of the Planning Target Volume, and secondly, on or near the central axis of the beam(s).

In some situations, it is not possible to define the ICRU Reference Point at the center of the Planning Target Volume. In these conditions, one has to select the ICRU Reference Point inside the tissues represented by the PTV, and in a place where dose specification is considered to be meaningful. Such a place could be the region where the tumor cell density is considered to be at its maximum.

The dose at the ICRU Reference Point is the *ICRU Reference Dose.*

The Dose Variation Throughout the Planning Target Volume

As a minimum requirement, the maximum and the minimum dose to the PTV shall be reported together with the dose at the ICRU Reference Point. The three dose values then represent the dose to the Clinical Target Volume and the dose variation.

Other dose values considered to be relevant (e.g., average dose and its standard deviation, dose/volume histograms, biologically weighted doses), when available, should also be reported.

Three Levels of Dose Evaluation for Reporting

The level of completeness and accuracy of reporting therapeutic irradiation depends to a large extent on the situation in the department and on the aim of the treatment. For different clinical and practical considerations, different levels of ambition for dose evaluation can be identified:

Level 1: Basic Techniques

The minimum requirements for reporting can be followed in all centers including those with restricted therapy equipment, dosimetric, computer, and staff facilities. This basic level may sometimes be sufficient in any center when simple treatments are performed (e.g., some palliative treatments).

At this level, it is assumed that the dose at the ICRU Reference Point and an estimation of the maximum and the minimum doses to the PTV can be determined.

Level 2: Advanced Techniques

The standards of dose planning at this level allow the exchange between different centers of more complete and relevant information. At this level, it is assumed that the GTV, CTV, and PTV can be defined in one or more planes (sections) using reliable patient data acquisition tools, and/or modern imaging techniques under reliable conditions (e.g., a series of CT and/or MRI scans). It is also assumed that complete dose distributions are computed in the central plane and in other planes (sections) using only central axis dose data, and with inhomogeneity corrections, when appropriate.

Level 3: Developmental Techniques

The performance of dose planning at level 3 provides for the development of new techniques and clinical research in radiotherapy. At this level, 3-D dose computation of any beam arrangement (such as non-coplanar beams) and dose/volume histograms are available.

NB: In summary, the 3 levels could be described as follows:

Level 1: Only the dose at the Reference Point and its variation along a central beam axis is available.

Level 2: The dose distribution can be computed for plane(s).

Level 3: The dose distribution can be computed for volumes.

At any level, the dose at the ICRU Reference Point and the best estimation of the maximum and the minimum dose to the PTV should be reported.

Contents

Prescribing, Recording, and Reporting Photon Beam Therapy

1. Introduction

When treating a patient with radiotherapy, the radiation oncologist normally prescribes doses[1] to both the malignant disease and to relevant normal tissues. The therapist also records doses delivered during treatment within various volumes or at various points in the tissues for the purpose of documentation. Doses will also have to be specified for the purpose of reporting. The recommendations in this report are intended to be applicable to most clinical situations, past or present, and to most radiotherapy centers.

Specification of volume(s) and dose(s) has to be done for different purposes:

(a) for prescription,
(b) for recording (to be included in the treatment chart),
(c) for reporting.

In principle, prescriptions, records and reports of radiotherapeutic procedures should be as complete and accurate as possible and should contain adequate and explicit information on the patient's disease, the volumes irradiated, the physical parameters and technique of irradiation, the overall treatment time and the fractionation scheme. In some situations, factors additional to those listed may be considered to have clinical implications and should, therefore, be recorded and possibly reported as well.

Such specifications serve a number of purposes:

a. to enable the radiation oncologist to maintain a consistent treatment policy and improve it in the light of experience;
b. to enable the radiation oncologist to compare the results of treatment with those of departmental colleagues;
c. to enable other radiation oncologists to benefit from the department's experience;
d. to enable the results of the department's treatments to be meaningfully compared with those of other centers without having access to the complete, original data. This is particularly important in multi-center studies, in order to keep treatment parameters well-defined, constant, and reproducible.

It will be noted that all of these functions, except the first are intended to facilitate communication. In fact, there is little purpose in reporting the treatment if the data cannot be interpreted by other workers in the field. It is, therefore, considered essential to adopt a common method for recording and reporting. The recommendations given here, however, will give some freedom to the radiation oncologist to use different methods to prescribe the dose, but the prescription, recording, and reporting should be unambiguous.

The outcome of treatment can only be interpreted meaningfully if the parameters of the irradiation, in particular the distribution of dose in space and time, can be accurately correlated with the clinical and pathological extent of the disease.

However, this obvious statement is still far from being realized in practice. Many radiation oncologists and physicists are so used to the style and conventions in their own departments that they would be shocked to learn that their treatment reports were ambiguous, uncertain, or even incomprehensible, to others. Unfortunately, there is substantial evidence that this is often the case. It is not uncommon for the reporting of a treatment to be insufficiently explicit and without adequate details to enable the treatment to be repeated or evaluated without having recourse to the center of origin for further information.

While a complete description of the data relating to each patient is clearly desirable, in practice, the amount of information that can be reported in many situations, e.g., in a published paper, is limited. Furthermore, complete information for each patient,

[1] If not otherwise stated, in this report dose is taken to imply absorbed dose.

including extent of the disease and a full individual dose distribution, is not always available. One is, therefore, faced with the problem of selecting a minimum set of data for recording and for reporting, that will be the most relevant for assessing the results of treatment.

It is expected that the rapid development of new techniques for the acquisition of patient data (e.g., computed tomography, magnetic resonance imaging, nuclear medicine imaging, and ultrasonography), and the use of image handling systems will increase the complexity of radiotherapy, and this will emphasize the need for general, strict guidelines. It is equally important that recommended criteria are maintained whether the treatment is a basic or complex one. So the methods of reporting dose should be almost independent of the aim of therapy, of the treatment technique, of the anatomical information, and of the computation facilities and methods employed.

The need for selecting a subset of data is highlighted by the growing use of computerized systems for acquisition and recording of patient data and planning of treatment procedures. The information recorded in these systems is becoming more extensive. We are thus getting more and more information about the treatments, and this should improve our understanding of the results of treatment, providing the input and output data are valid and unambiguous.

The ICRU has found it important to issue a series of reports on delivery and specification of doses. Thus, an earlier ICRU Report (Report 23 [ICRU, 1973]) described the measurement of dose in a phantom irradiated by a single beam of x or gamma rays. A second ICRU report (Report 24 [ICRU, 1976]) described the determination of dose in a patient irradiated by beams of x or gamma rays in radiotherapy procedures, and defined a number of terms of importance in these procedures. Definitions of certain terms and concepts used in radiotherapy as well as recommendations for dose specification in reporting external beam therapy with photons and electrons were given in a third ICRU report (Report 29 [ICRU, 1978]), and in a fourth report (Report 38 [ICRU, 1985]), recommendations were given on dose and volume specifications for reporting intracavitary therapy in gynecology. The radiation dosimetry of electron beams with energies between 1 and 50 MeV was described in Report 35 [ICRU, 1984]. The use of computers in external beam radiotherapy with high-energy photons and electrons was analyzed in Report 42 [ICRU, 1987].

It is now over a decade since Report 29 [ICRU, 1978] was published and it has become clear that further interpretation of the concepts and more guidelines for the application of the recommendations have become necessary in order for it to be used more widely. Furthermore, the expanding use of computers in radiotherapy, allowing for inter alia a more proper evaluation of three-dimensional dose distributions, has changed the clinical practice. Therefore, it was felt appropriate to update the recommendations given in 1978, and this is the purpose of the present report. It largely repeats the previous recommendations, but some definitions and recommendations have been clarified or modified (e.g., definitions on volumes, Section 2.3., and general principles for target dose specification, Section 3). The recommendations apply to reporting but they are useful in all steps of the radiotherapy procedure. It is hoped that they will be adopted in day-to-day practice.

2. Definitions of Terms and Concepts

2.1 The Different Steps in the Radiotherapy Procedure

The decision to use radiotherapy as a treatment modality must be based on adequate clinical work-up including confirmation of the histological diagnosis, staging, etc. In the radiotherapy process, different steps then have to be taken successively, as illustrated in Fig. 2.1.

The specification of volumes and doses serves three different purposes, namely:

— for prescribing therapy,
— for recording therapy (documentation),
— for reporting therapy.

Prescription of the radiation treatment includes a statement of the aim of therapy (Section 2.2), the definition of volumes (Section 2.3) and the specification of doses (Section 2.4) that are prescribed as well as other treatment parameters, e.g., fractionation. Prescription of the treatment is a clinical decision, based on the judgement and experience of the radiation oncologist for the given type of disease and clinical situation. The prescribed dose depends on the aim of therapy (tumor eradication or palliation). However, the tolerance of surrounding normal tissues will also have to be taken into account and this could modify the prescribed dose. The prescribed dose, with acceptable dose variation, should be delivered to each defined tissue volume of interest. A provisional prescription of treatment should be performed at the time of the decision to use radiotherapy. When a standardized treatment technique is to be used (e.g., according to the department's policy, or according to a protocol), it is often possible to have a sufficient knowledge of the probable final dose distribution for this provisional prescription to remain unchanged during the planning process. However, this is not always the case, and then the prescription has to be modified during treatment planning (feedback procedure).

If the intent of therapy is changed, e.g., from radical to palliative (Section 2.2), then it may well turn out that it is not meaningful to stay with the provisional prescription, and the final prescription may well have to be modified from the provisional one.

The radiation oncologist should have the freedom to prescribe the parameters in his/her own way, mainly using what is current practice to produce an expected clinical outcome of the treatment. The prescription should, however, always be unambiguous and comprehensible to all of the staff in the department, and it should allow for a later specification for recording and for reporting.

Recording of parameters related to the treatment (see Appendix I, Table I.1.) should be possible during the whole treatment procedure, as indicated in Fig. 2.1., and a summary should be made in an unambiguous way.

Reporting of the treatment should be unambiguous and sufficiently detailed to fulfil the statements already given in the introduction (Section 1). The radiation oncologist and physicist have, in contrast to when prescribing, no freedom when reporting basal data on volumes and doses. Recommendations for reporting the different parameters are given in Section 3, and different aspects of these are dealt with in Appendix I.

2.2 Aim of Therapy

A. *Radical Treatment of Malignant Disease.* The aim of radical radiotherapy ("curative radiotherapy") is to decrease the number of tumor cells to a level that achieves permanent local tumor control. The volumes to be irradiated have to include any demonstrated tumor, and also volumes in which subclinical spread is expected at a given level of probability. These different volumes will often have to be irradiated to different dose levels. In the radical treatment of malignant disease, anatomical tumor limits thus may or may not be demonstrable. When the tumor has been previously removed (e.g., by mastectomy or hysterectomy), the remaining tissue may contain subclinical disease, the limits of which cannot be demonstrated clinically.

B. *Palliative Treatment of Malignant Disease.* The aim of palliative radiotherapy is to decrease symptoms (e.g., pain) of the malignant disease. The palliative treatment of malignant disease may include all or only part of the demonstrated tumor (e.g., irradiation of the spine for a painful deposit in a case of wide-spread metastases).

C. *Non-malignant Diseases.* The radiotherapy of non-malignant conditions may or may not include all of the affected tissues (e.g., irradiation of dermatoses).

The recommendations in this report are based on situation A, but are, in principle, also applicable to situations B and C.

2.3 Volumes

The process of determining the volumes for the treatment of a malignant disease consists of several

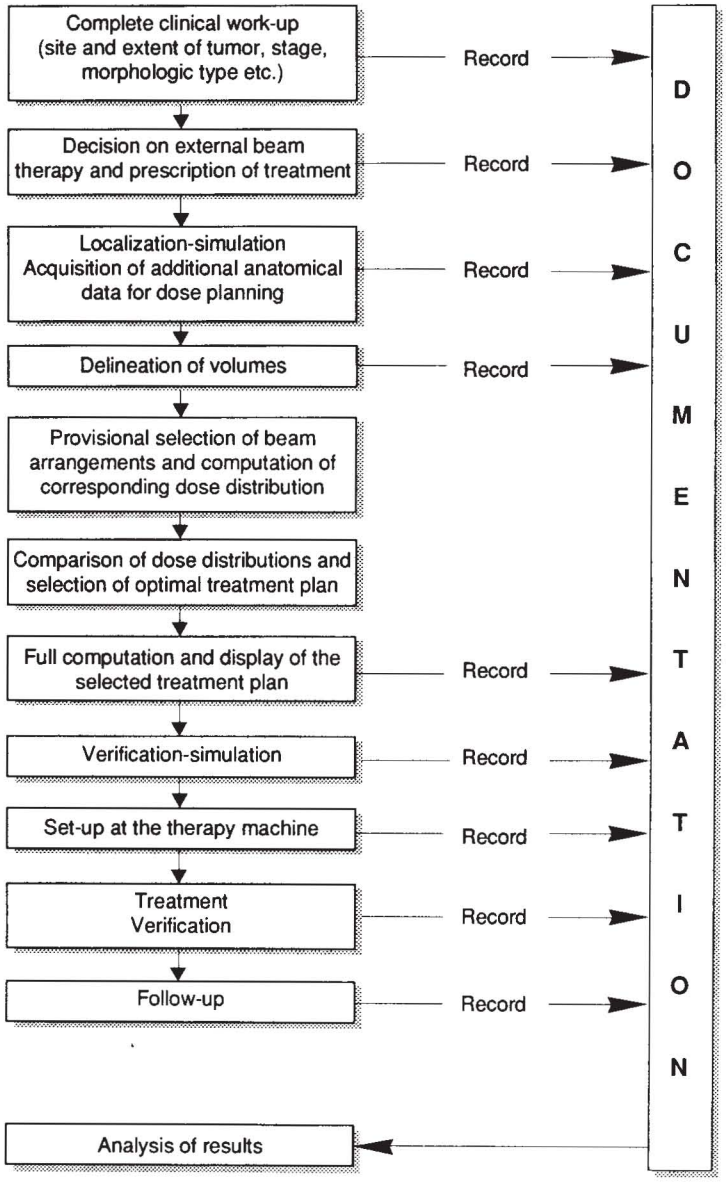


Fig. 2.1. Steps in the radiotherapy procedure. *NB:* There should be a continuous feed-back between all the different steps. A difficulty at a given point may question all the decisions made at previous steps.

distinct steps. Different volumes may be defined, often with varying concentrations of demonstrated or suspected malignant cells. Furthermore, considerations have to be given to probable changes in the spatial relationship between the volume(s) and therapy beam(s) during treatment, viz., movements of the tissues/patient, and to possible inaccuracies in the treatment set-up.

Two volumes should be defined prior to treatment planning. These volumes are:

— Gross Tumor Volume (GTV).
— Clinical Target Volume (CTV).

During the treatment planning process, other volumes have to be defined:

— Planning Target Volume (PTV).
— Organs at Risk.

As a result of treatment planning, further volumes can be described. These volumes are:

— Treated Volume.
— Irradiated Volume.

Further details are given below.[2] A schematic pre-

[2] Throughout, in the following, the singular (e.g., CTV) will also include the plural (e.g., CTVs).

sentation of the different volumes is shown in Fig. 2.2.

Acquisition of additional anatomical data besides the diagnostic information may be needed, and should be obtained with the patient under treatment conditions. Such further information could be CT-scans or orthogonal x-ray films in the treatment position.

The palpable or visible extent of the malignant tumor (evaluated also by different imaging techniques) constitutes the Gross Tumor Volume (GTV). Usually, depending on tumor site and diagnostic methods, this volume corresponds to the part of the disease where the malignant tumor cell concentration is at its maximum.

Next, a margin has to be added around the Gross Tumor Volume to include direct, local subclinical spread. This volume surrounding the GTV often has a high tumor cell density close to the demonstrated tumor with decreasing density towards the periphery. The GTV and its local margin for subclinical disease constitute a Clinical Target Volume (CTV) (e.g., CTV I).

If the tumor has been removed prior to radiotherapy, no Gross Tumor Volume can be defined.

Additional volumes which do not contain demonstrable tumor but with suspected malignant cells, may also be considered for therapy (e.g., regional lymph nodes and their volumes for subclinical spread). These volumes with only subclinical disease also constitute Clinical Target Volumes (e.g., CTV II, etc.).

The delineation of the Gross Tumor Volume and the Clinical Target Volume are based on purely anatomic-topographic and biological considerations without regard to technical factors of treatment.

For radiation treatment planning and for adequate

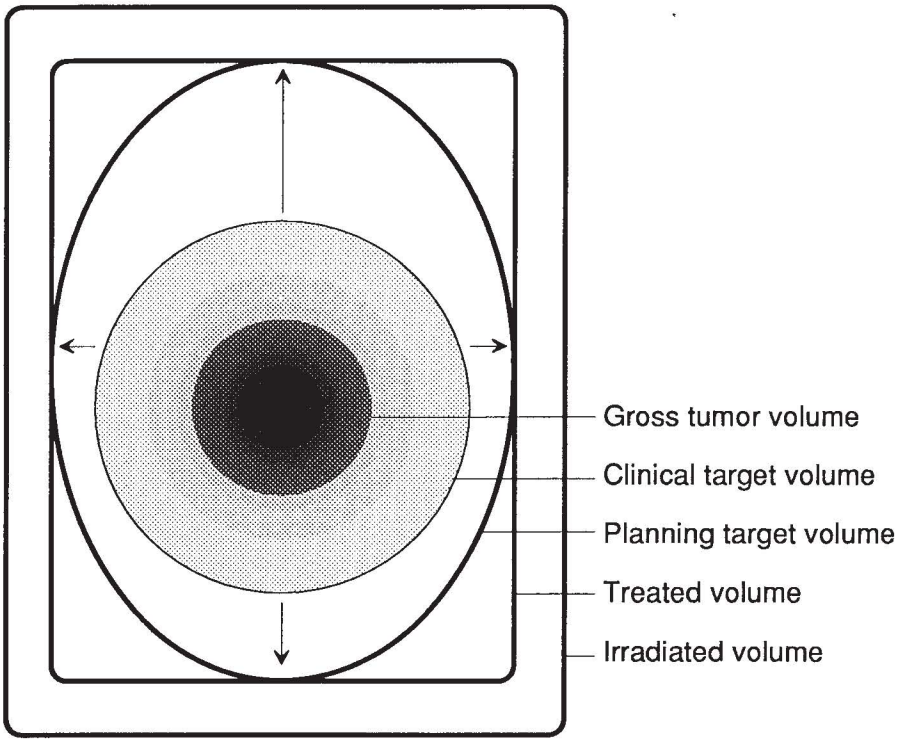


Fig. 2.2. Schematic illustration of the different volumes.

Gross Tumor Volume (GTV) denotes the demonstrated tumor.

Clinical Target Volume (CTV) denotes the demonstrated tumor (when present) and also volumes with suspected (subclinical) tumor (e.g., margin around the GTV, and e.g., regional lymph nodes, NO (according to the TNM-classification [UICC, 1987]), considered to need treatment). The CTV is thus a pure anatomic-clinical concept.

Planning Target Volume (PTV) consists of the CTV(s) and a margin to account for variations in size, shape, and position relative to the treatment beam(s). The PTV is thus a geometrical concept, used to ensure that the CTV receives the prescribed dose, and it is (like the patient/tissues concerned) defined in relation to a fixed coordinate system. Note that in the example shown the magnitude of foreseen movements of the CTV is different in different directions.

Treated Volume is the volume that receives a dose that is considered important for local cure or palliation.

Irradiated Volume is the volume that receives a dose that is considered important for normal tissue tolerance (other than those specifically defined for organs at risk).

treatment set-up, margins have to be added around the Clinical Target Volume to account for variation in size and position of tissues relative to the treatment beams, due to, e.g., patient movement, respiration, changes in size and internal position of the Clinical Target Volume and to variation in the daily set up due to technical and other factors. This volume, which takes into account both anatomical/biological factors and treatment reproducibility factors, is the Planning Target Volume (PTV).

2.3.1 Gross Tumor Volume (GTV)

From the origin of medical terminology the word tumor (latin tumor) was used to designate a swelling, which could be of different natures.

The Gross Tumor Volume (GTV) is the gross palpable or visible/demonstrable extent and location of malignant growth.

The GTV may consist of primary tumor, metastatic lymphadenopathy, or other metastases. The GTV corresponds usually to those parts of the malignant growth where the tumor cell density is largest. No GTV can be defined if the tumor has been removed, e.g., by previous surgery.

The shape, size, and location of the GTV may be determined by means of different diagnostic methods such as clinical examination (e.g., inspection, palpation, endoscopy), and various imaging techniques (e.g., x-ray, CT, DI, US, MRI, and radioisotope methods). The methods used to determine the GTV should meet the requirements for staging the tumor according to the clinical TNM (UICC, 1987), and (AJCCS, 1988), and the definition of the GTV is then in full agreement with the criteria used for the TNM-classification.

The GTV (primary tumor, metastatic lymphadenopathy, other metastases) may seemingly be different in size and shape, sometimes significantly, depending on what examination technique is used for evaluation (e.g., palpation versus mammography). The therapist should, in each case, therefore, indicate which methods have been used for evaluation and for definition of the GTV.

There are at least two reasons to identify the GTV. Firstly, an adequate dose must be delivered to the whole GTV in order to obtain local tumor control in radical treatments. Secondly, identification is necessary to allow for recording of tumor response in relation to the dose and its variation, and to other relevant factors.

2.3.2 Clinical Target Volume (CTV)

In the previous recommendations (Report 29, [ICRU 1978]), the "Target Volume" was defined to include not only the GTV but also volumes with suspected, subclinical disease, and, furthermore, it was previously also defined to include margins for expected variations in shape, size, and position of the demonstrated tumor and/or subclinical disease, as well as variations in patient set-up and beam sizes and orientation. There are reasons to differentiate between, on the one hand, considerations taking into account purely oncologic/biological factors (Clinical Target Volume [CTV]), and, on the other hand, margins taking into account the reproducibility of different anatomical/technical factors in treatment set up (Planning Target Volume [PTV]) (see 2.3.3). A detailed analysis of the problem was given by Goitein (1985).

Clinical experience indicates that around the GTV there is generally subclinical involvement, i.e., individual malignant cells, small cell clusters, or microextensions, which cannot be detected by the staging procedures. The volume surrounding the macroscopic tumor has usually a high tumor cell density close to the edge of the GTV with decreasing density towards the periphery of this volume (often a margin of about 1 cm). The GTV together with this surrounding volume of local subclinical involvement is now defined as a Clinical Target Volume (CTV). This CTV will usually be denoted CTV I.

The delineation of a CTV is thus based on purely anatomic-topographic and biological considerations without regard to movement of the tissues/patient or technical factors, and it should be described in anatomic-topographic terms.

Additional volumes with presumed subclinical spread (e.g., regional lymphnodes) may also be considered for therapy. They are also defined as Clinical Target Volumes, and may be designated CTV II, CTV III, etc.

The Clinical Target Volume (CTV) is a tissue volume that contains a demonstrable GTV and/or subclinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation.

In external beam radiotherapy, the Clinical Target Volume (CTV) is a tissue volume that has to be irradiated to a specified dose according to a specified dose-time pattern.

If different doses are prescribed, this implies the definition of different CTVs for different dose levels. Thus, for any given situation, there is often more than one CTV. One situation can be illustrated by considering a primary tumor and its regional lymphatics separately (e.g., in breast saving procedures where the breast and regional lymphatics are separated anatomically). In other situations, the aim is to treat two CTVs to different dose levels ("boost" therapy),

where the "high-dose" volume (often containing the GTV) is located inside the "low-dose" volume.

In some cases, a dose gradient over a volume may be wanted and this gradient may be either continuous or step-wise. The decision to prescribe different dose-levels or dose-gradients is based on an estimate of variations in tumor cell densities in different volumes or along different lines.

In practice, the delineation of a CTV will require consideration of factors such as the local invasive capacity of the tumor and its potential to spread to, e.g., regional lymph nodes. Consideration may also need to be given to the presence of any specially radiosensitive normal tissue (Organs at Risk, Section 2.3.6) as well as to other factors such as the general condition of the patient.

If there is a change in the size, shape, and location of a CTV during treatment (e.g., shrinkage of a tumor during therapy, or the addition of further diagnostic data), there may be a need for re-planning.

It must be clearly recognized that *volumes* are treated, even if representations of volumes usually are given only in two dimensions, or linearly. For documentation and retrieval, it is an advantage if the different parts of the CTVs are codified according to an internationally recognized system (e.g., ICD, or SNOMED, see Section 3.2.2 and Appendix I).

The definitions of the GTV and CTV are thus entirely based on general oncologic principles, and are not limited to external beam therapy. Thus, in surgery, a safety margin is taken around the gross tumor according to clinical judgement, and this implies the same use of the Clinical Target Volume concept as in external beam therapy. Also, in brachytherapy, volumes to be irradiated are defined, and thus the concept of CTV is valid. Furthermore, the concept can be applied to other modalities, e.g., regional chemotherapy, hyperthermia, and photocoagulation.

For external beam radiotherapy, additional volumes have to be defined, as given below.

2.3.3 Planning Target Volume (PTV)

To ensure that all tissues included in the Clinical Target Volume receive the prescribed dose, one has, in principle, to plan to irradiate a geometrically larger volume than the CTV. Ideally, the position, shape, and size of the CTV and of the treatment beams should be related to a common fixed coordinate system in a reproducible way. However, in practice, this will not be possible to achieve, and intrafractional as well as interfractional variations in this respect may be foreseen due to a number of factors, such as:

— movements of the tissues which contain the CTV (e.g., with respiration), as well as movements of the patient,
— variations in size and shape of the tissues that contain the CTV (e.g., different fillings of the bladder),
— variations in beam geometry characteristics (e.g., beam sizes, beam directions).

This leads to the concept of the Planning Target Volume (PTV).

The Planning Target Volume is a geometrical concept, and it is defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV.

The PTV is related to the beam(s) through a fixed coordinate system (e.g., couch top or laser planes through a tatoo or a bony landmark).

The PTV is used for dose planning and for specification of dose. Therefore, the PTV has to be clearly indicated on the sections used for dose planning. The dose distribution to the PTV has to be considered to be representative of the dose to the CTV.[3]

Note that the definition of Planning Target Volume is identical to the previous (Report 29, [ICRU 1978]) definition of "Target Volume." The two concepts are thus synonymous.

Depending on the clinical situation (e.g., patient condition and site of the CTV) and the chosen technique, the PTV could be very similar to the CTV (e.g., in the case small skin tumors, pituitary tumor), or by contrast, much larger (e.g., lung tumors). The PTV may surpass normal anatomical borders (e.g., it may include parts of clinically unaffected bony structures), or even extend into the air (e.g., in a case of tangential irradiation of a breast).

The Planning Target Volume is thus a static, geometrical concept, used for treatment planning. The PTV does not, in fact, exactly represent defined tissues or tissue borders. Actually, the tissues contained geometrically within the PTV may not truly receive the planned dose distribution, at least not in some parts close to its border. This is due to the variation in position of the CTV within the boundaries of the PTV during a course of treatment. However, the PTV is the volume that is used for dose calculation and for specification of target dose (see Section 3).

An example of Gross Tumor Volume, Clinical Target Volume and Planning Target Volume for a patient with a carcinoma of the bronchus is shown in Fig. 2.3.

When defining the PTV for a given CTV, one has to

[3] Note that the penumbra is not included in the PTV. The penumbra has to be taken into account separately when selecting beam sizes.

Fig. 2.3. Example of Gross Tumor Volume (GTV), Clinical Target Volumes (CTVs), and Planning Target Volume (PTV) for a patient with a bronchial carcinoma, T3 N0 M0 (according to the TNM—classification [UICC, 1987]) of the right lung.

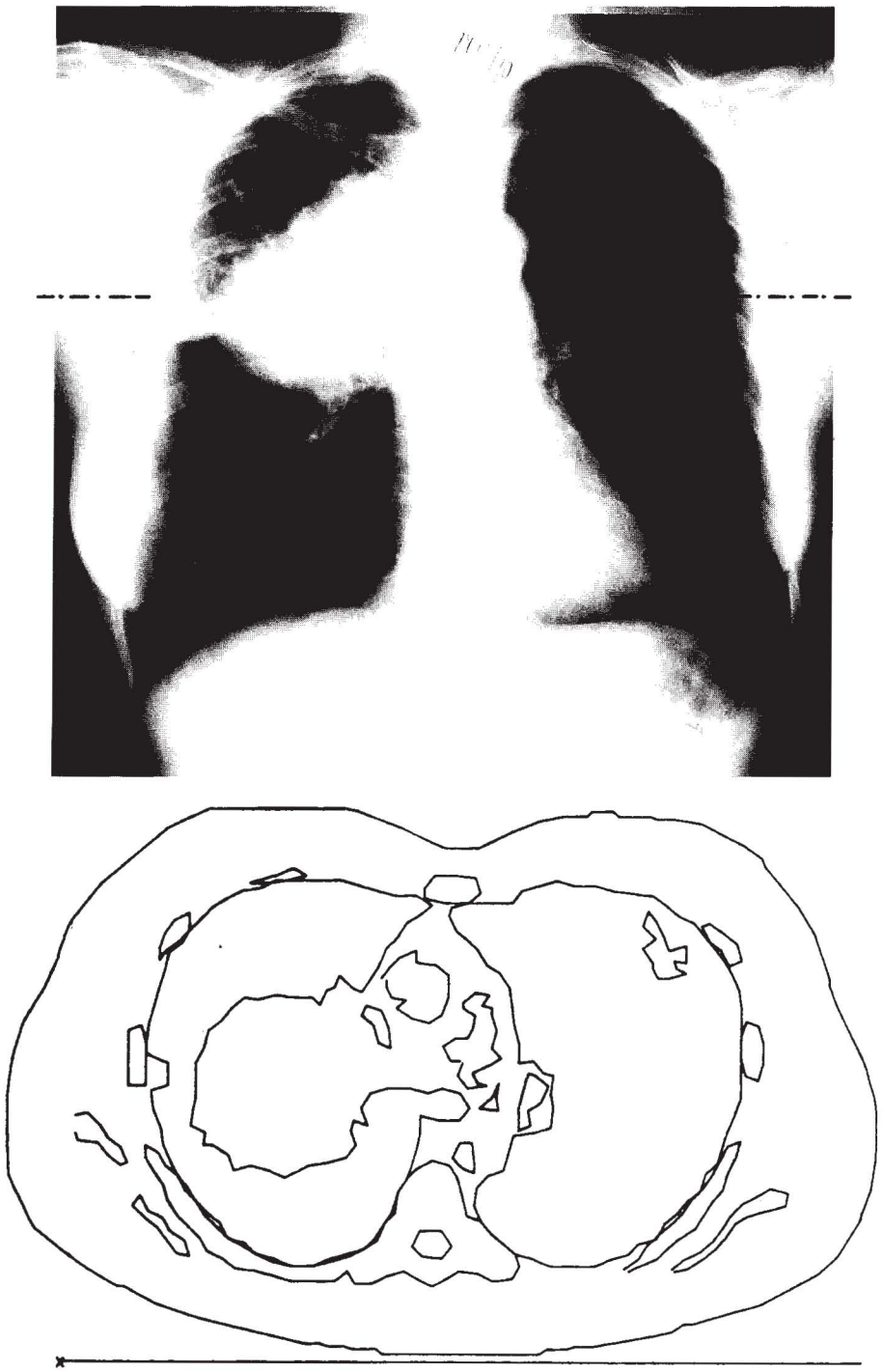


Fig. 2.3.a. One frontal chest radiograph and one transverse CT-section at the level of the centre of the demonstrated tumor are shown, and considered here to represent the true three-dimensional situation. Structures above and below the transverse section are projected into the section.

make an estimation of the overall importance of the possible variations in relation to the selected beam arrangement, considering, furthermore, anatomical location, the use of patient immobilization devices, etc. Also, consideration has to be given to the fact that most imaging techniques used for dose-planning (mainly x-ray diagnostic procedures) actually show the situation in seconds or fractions of a second, and

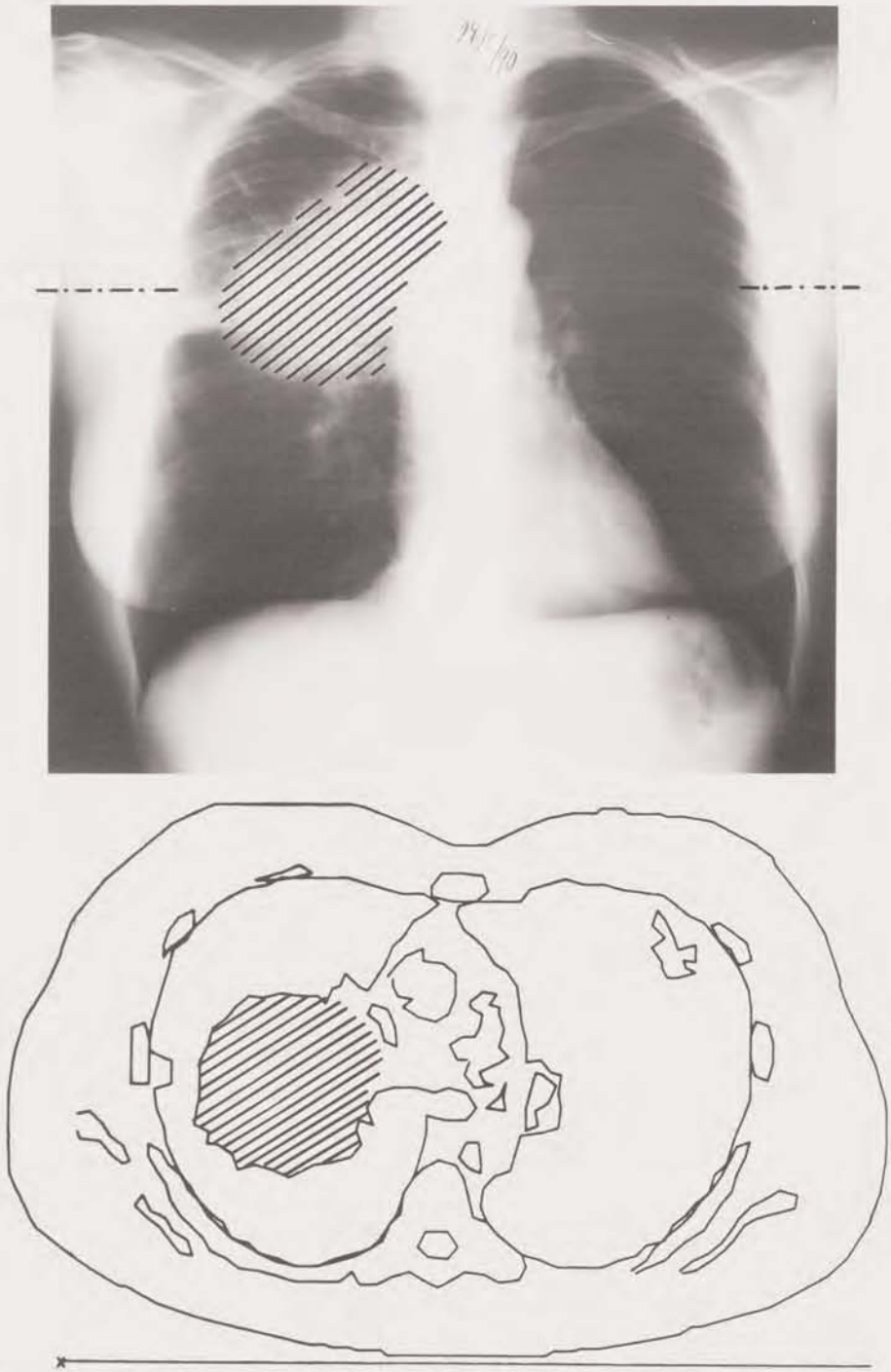


Fig. 2.3.b. The demonstrated tumor in the right hilar region extending into the lung tissue, but not involving the chest wall is the GTV, and is shown by the striated area.

not the whole integrated situation during the actual treatment (= exposure time for a single treatment fraction).

It is not recommended that all uncertainties due to the movements and spatial variations be added linearly because this would probably lead to too large margins, resulting in unnecessary side-effects. Some of the movements and variations previously listed could systematically deviate at the time of the irradiation compared to the planning process. Other uncertainties may vary at random. It is desirable to have detailed estimation of all these spatial uncertainties.

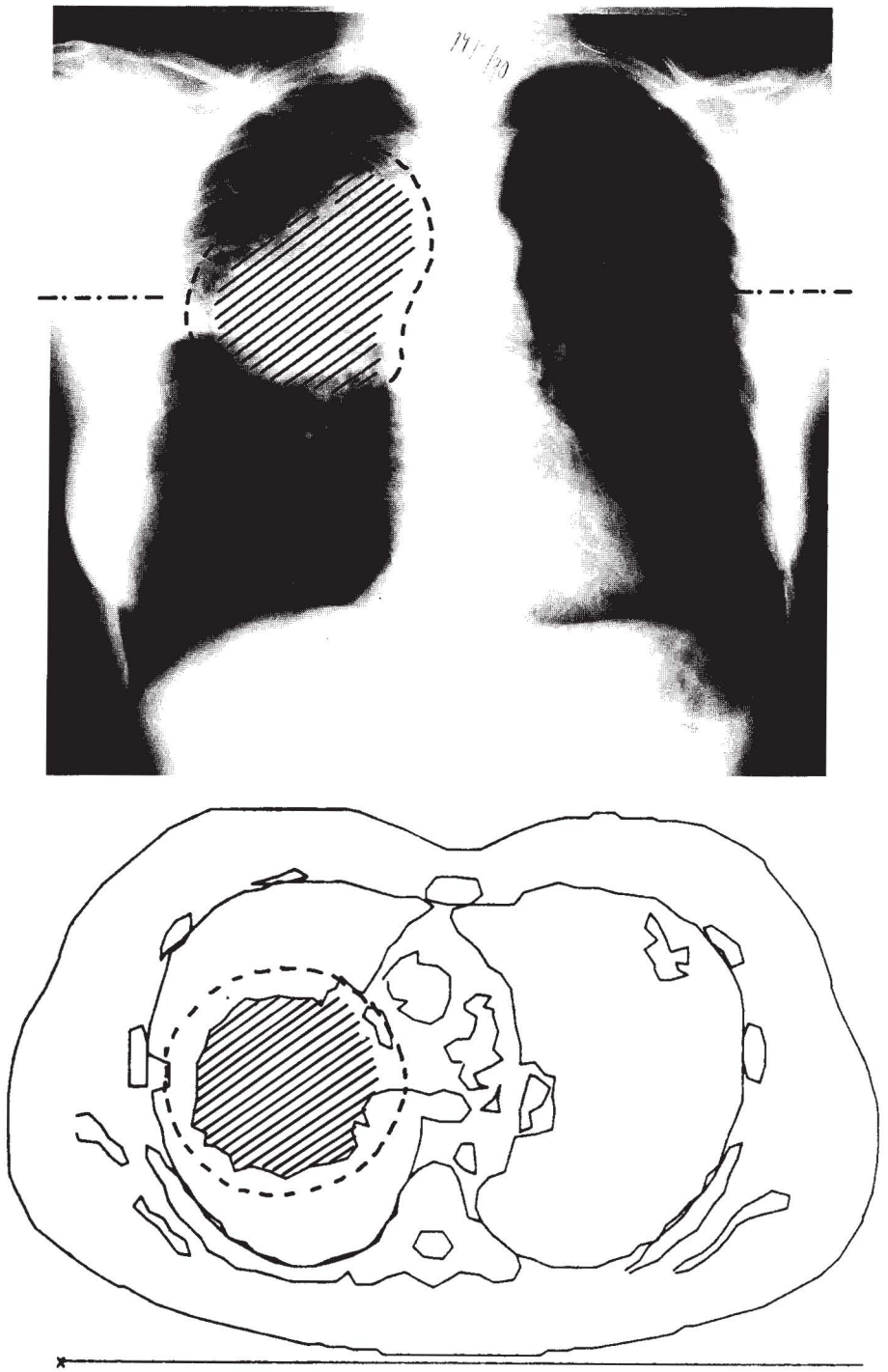


Fig. 2.3.c. A margin is added around the GTV to include presumed local subclinical involvement around the demonstrable tumor, due to individual malignant cells, small cell clusters, or microextensions, which can not be detected clinically. This constitutes the CTV I, and is shown by the broken line.

However, the information that can be obtained is usually limited, and they can only be estimated. If the random uncertainties are normally distributed and the systematic uncertainties are estimated by their standard deviations, the combined effect can be estimated. The total standard deviation is then the root of the square sum of random and systematic uncertainties.

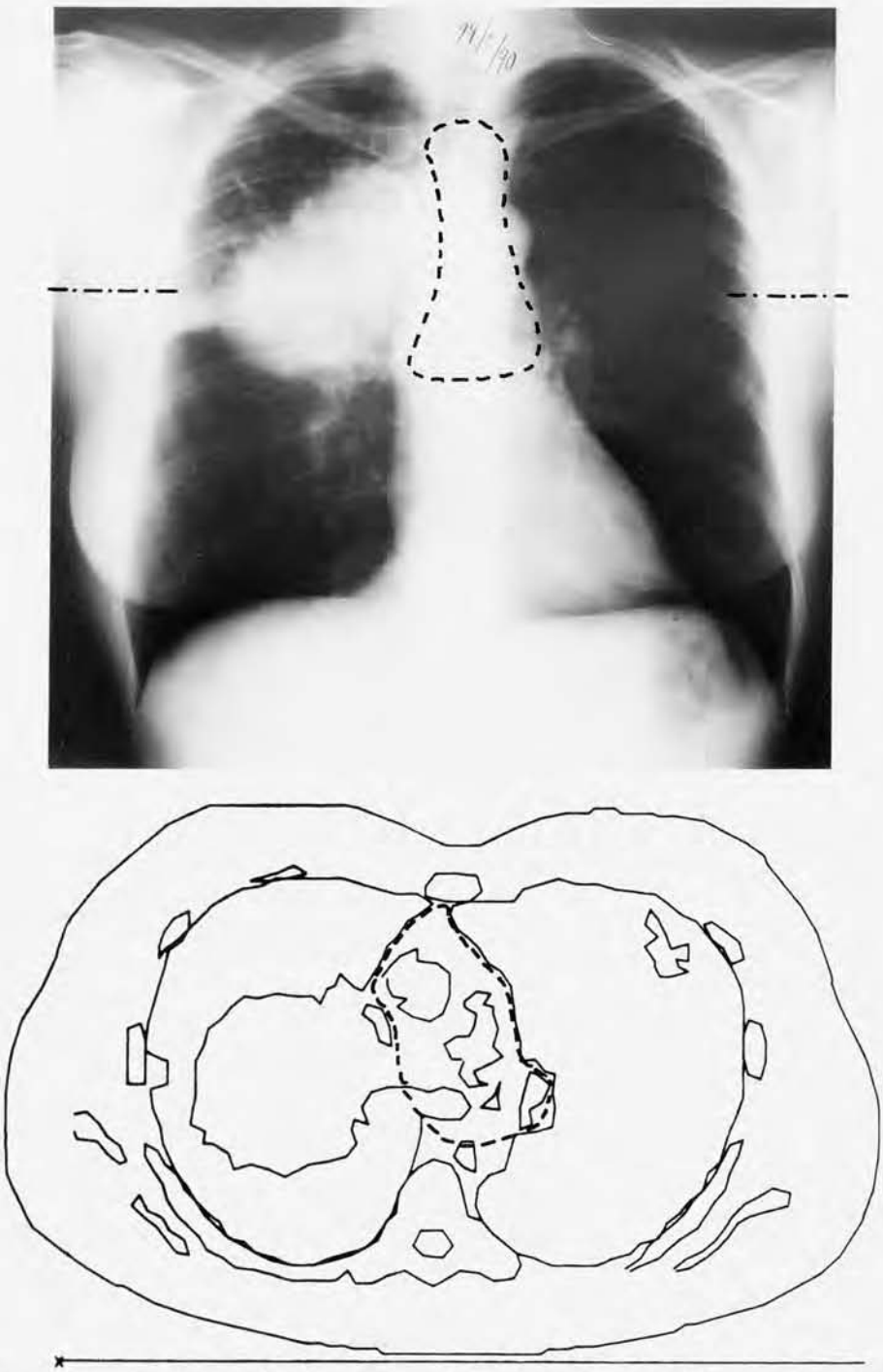


Fig. 2.3.d. There were no mediastinal lymph node metastases that could be demonstrated by clinical investigations. However, the mediastinal lymph nodes as well as the medial parts of the contralateral hilar region are considered to be at high risk, and to be treated for subclinical disease as CTV II, shown by the broken line.

Treatment planning consists of the delineation of the Clinical Target Volume and the prescription of the Target Dose. This constitutes the pure medical prescription, which must precede the integrated process of defining a proper Planning Target Volume with respect to the technical factors of the irradiation, including selection of beam arrangements, etc. Note that for a given CTV, the PTV may vary significantly with different beam arrangements.

A Clinical Target Volume may occasionally have to

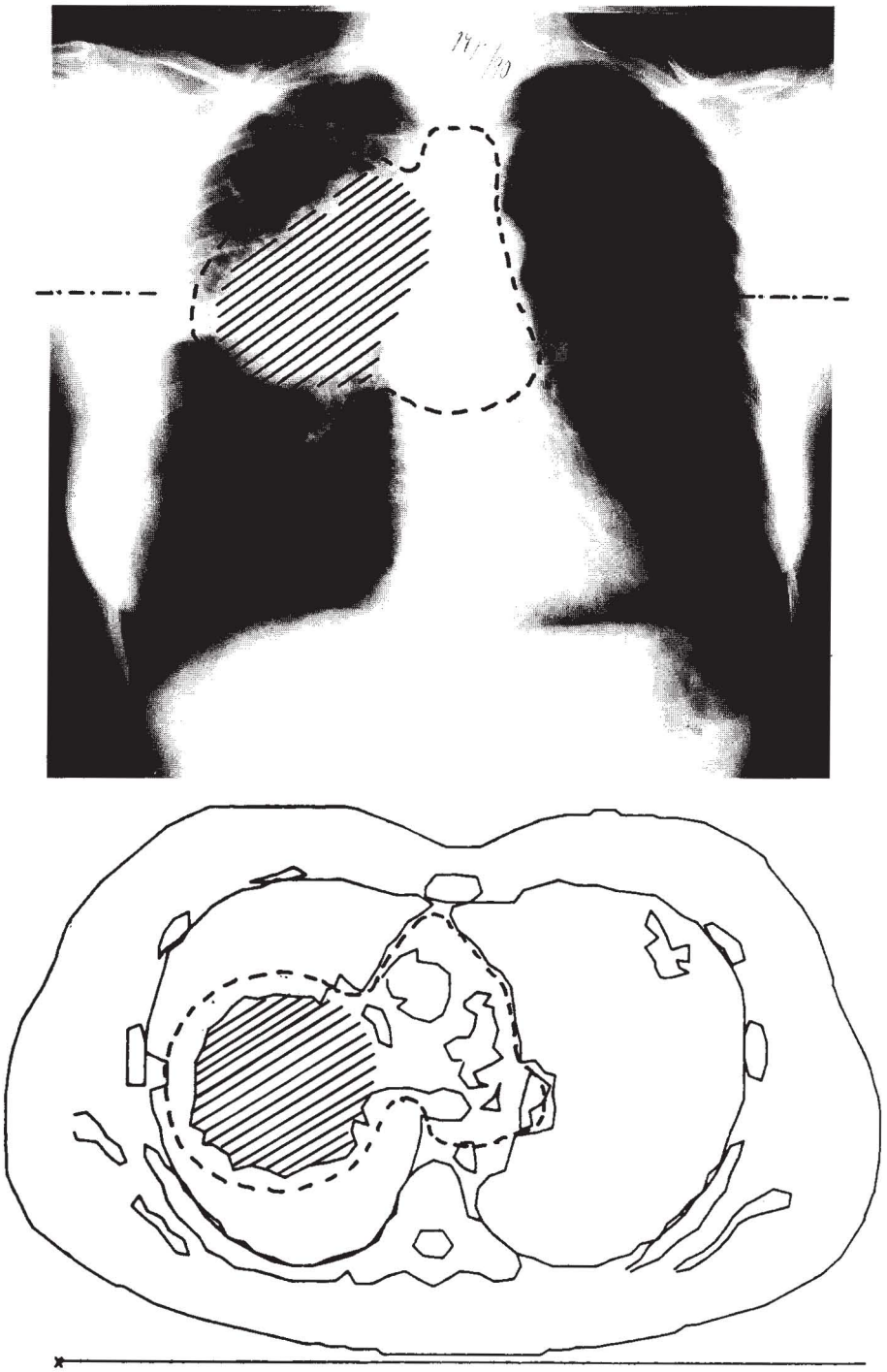


Fig. 2.3.e. The patient's condition did not allow for radical therapy, and the prescribed dose is the same (and relatively low) for both CTV I and CTV II. The two CTVs will be treated with the same beams, and are here shown joined.

be represented by 2 or more Planning Target Volumes. Such special situations are illustrated in Figs. 2.4. and 3.4.

When a dose distribution in one or more anatomical sections is presented, the PTV should be clearly indicated on the diagram (represented by an area in a particular section). It is an advantage if the CTV is also shown (Figs. 2.3.f. and II.4.).

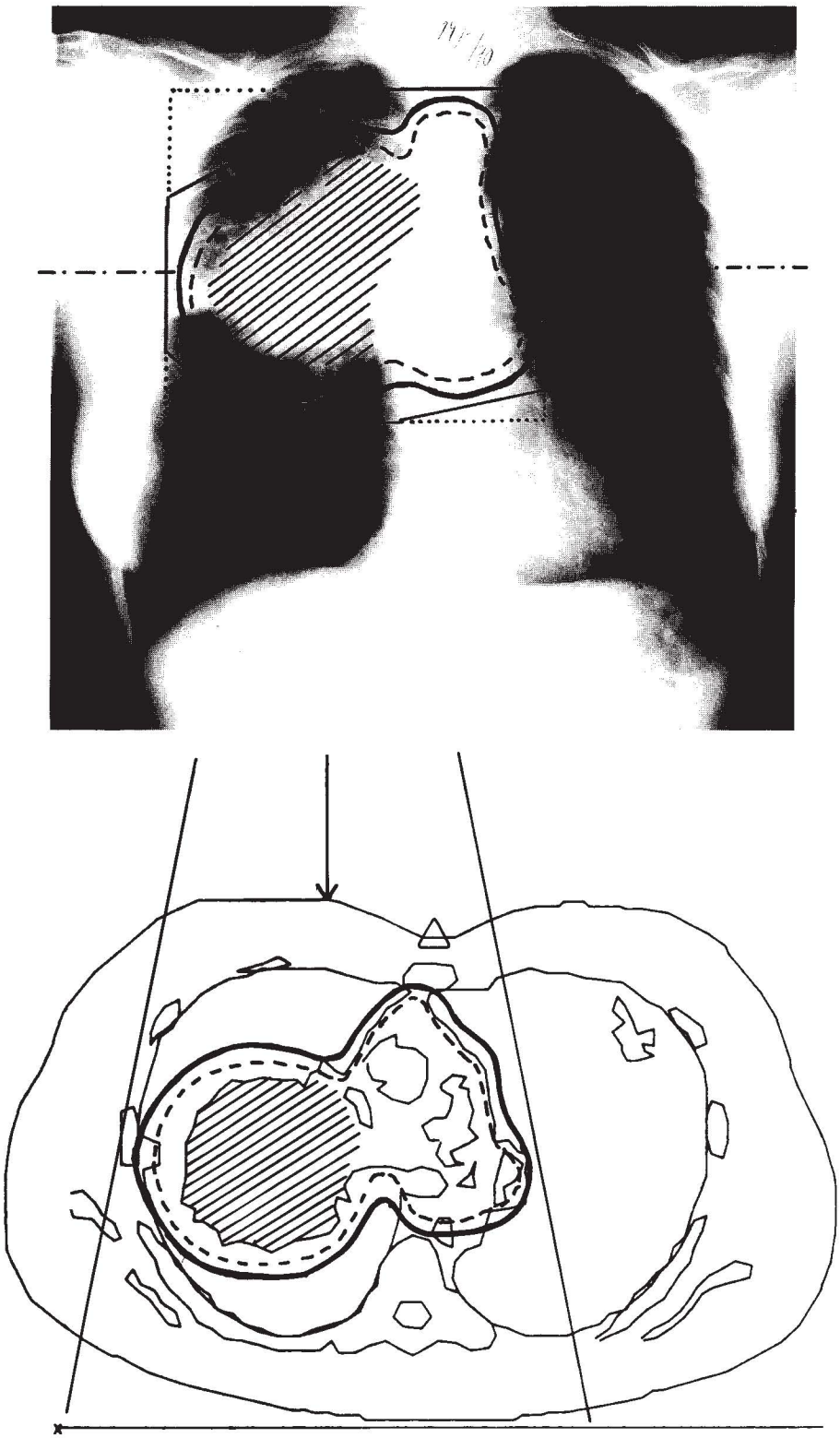


Fig. 2.3.f. The geometrical relationship between the CTV and other relevant parts of the patient on one hand and the treatment beam(s) on the other hand should be stable and not change during or between fractions. This relation should be correlated to a fixed coordinate system related to a point in/at the patient (e.g., the sternal notch). However, in relation to the fixed coordinate system, the CTV will move, e.g., with respiration, and the patient as a whole will not be perfectly immobilized during each fraction. Furthermore, there may be minor random variations in the set up (positioning of the beams in relation to the fixed coordinate system, small variations in beam size and blockings, etc.). Therefore, treatment has to be planned for a larger volume than the CTV, and a suitable PTV (indicated by the thick solid line) is defined for treatment planning purpose and for dose recording and reporting. Note that in this example the PTV extends into healthy tissues (the chest wall).

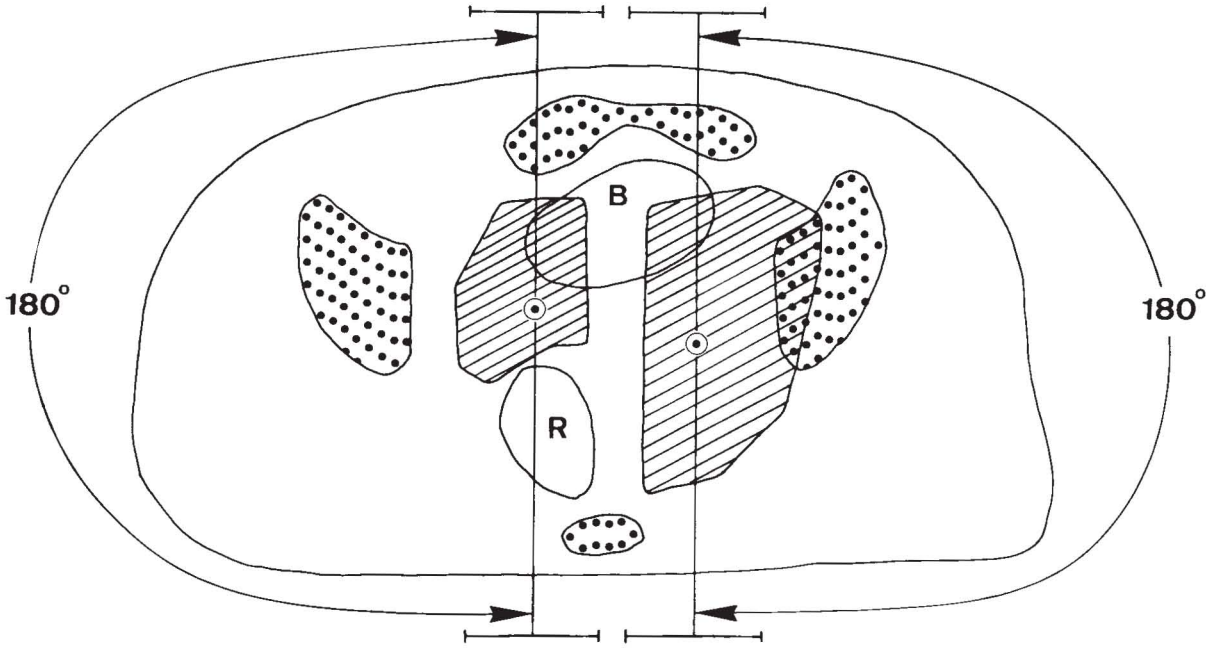


Fig. 2.4.a. A case of recurrent carcinoma of the uterine cervix. The local tumor and the iliac nodes have to be irradiated and the rectum to be spared. Two Planning Target Volumes are identified (hatched areas). The bony structures of the pelvis (dotted areas), the bladder (B) and the rectum (R) are represented. The treatment consists of a double arc therapy (180°) with a 10 MV linear accelerator (⊙ = the 2 axes of rotation).

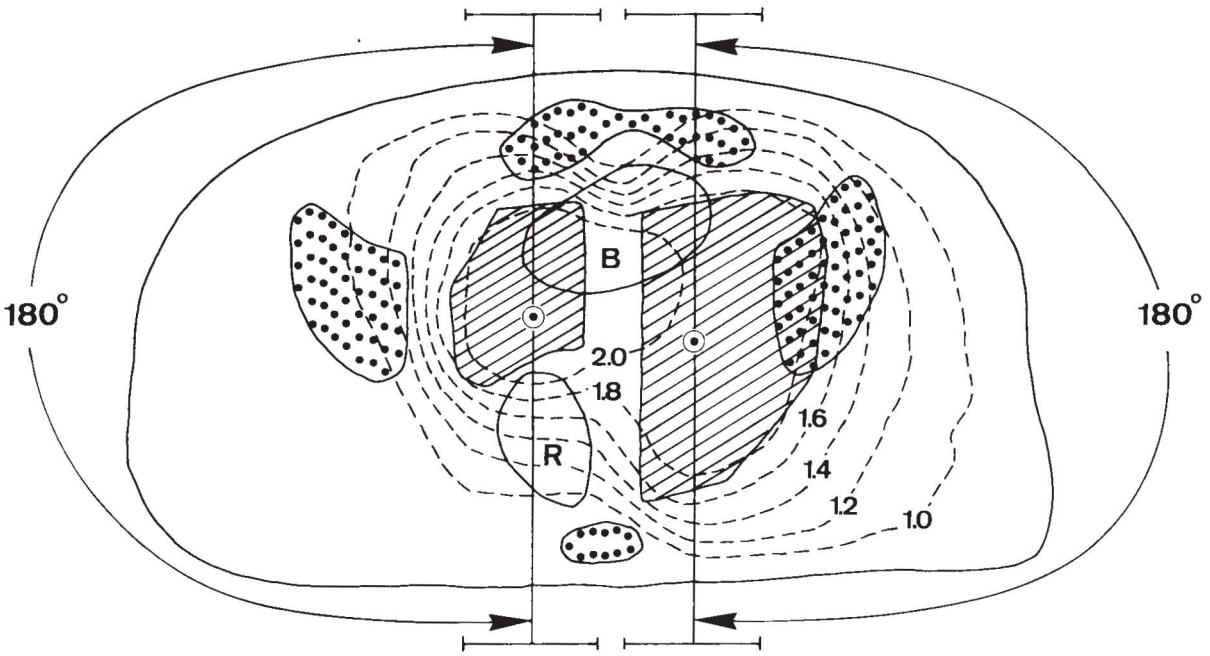


Fig. 2.4.b. The dose distribution corresponding to the treatment described in Fig. 2.4.a. is shown. The following isodose curves are drawn: 2.0, 1.8, 1.6, 1.4, 1.2, and 1.0 Gy.

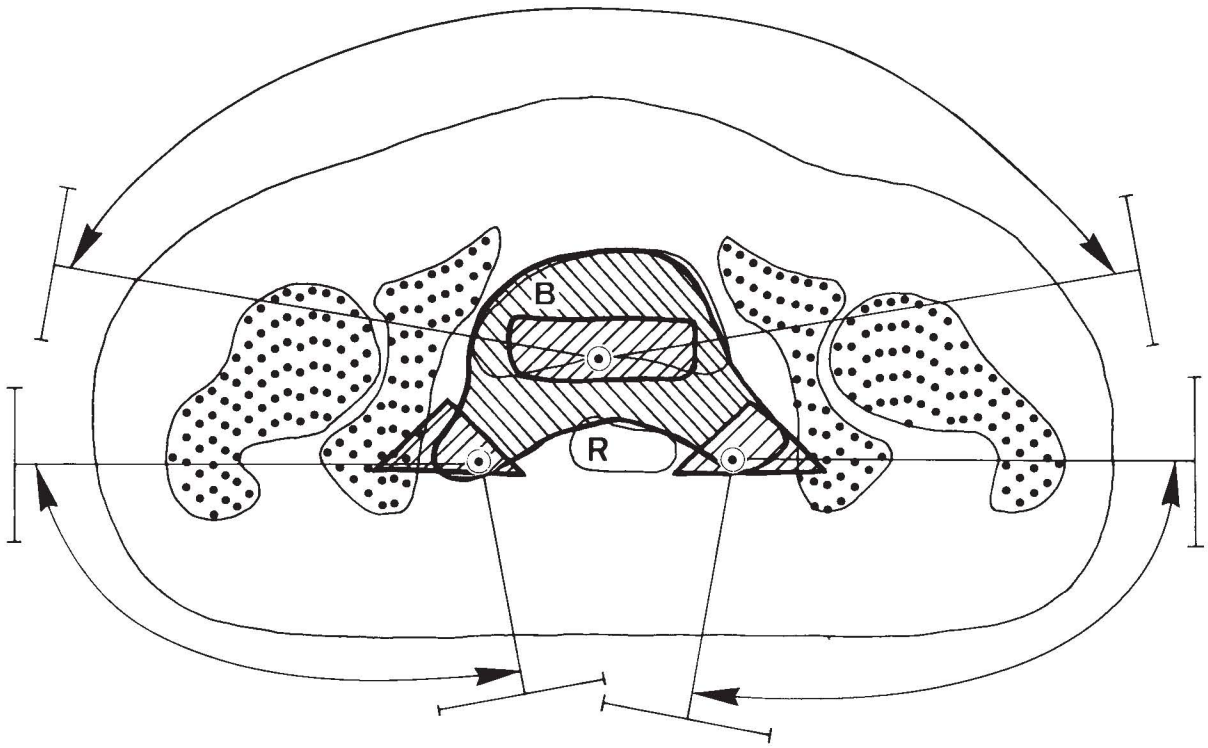


Fig. 2.4.c. A case of advanced carcinoma of the prostate. The local tumour and the iliac nodes have to be irradiated and the rectum to be spared. Four Planning Target Volumes are identified (thick full lines and hatched areas). The bony structures of the pelvis and femora (dotted areas), the bladder (B), and the rectum (R) are represented (thin full lines). The treatment consists of a triple arc therapy with a 10 MV linear accelerator (⊙ = the 3 axes of rotation).

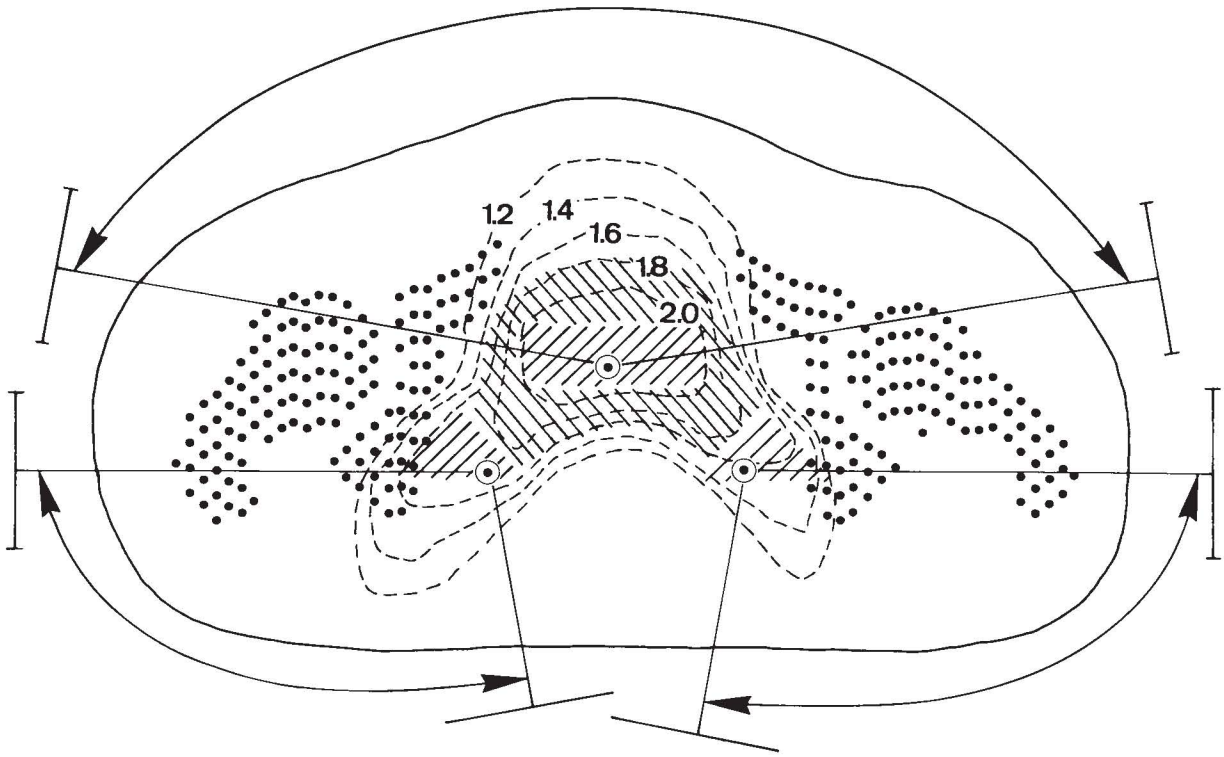


Fig. 2.4.d. The dose distribution corresponding to the treatment described in Fig. 2.4.c. The following isodose curves are drawn: 2.0, 1.8, 1.6, 1.4, 1.2, and 1.0 Gy.

2.3.4 Treated Volume

Ideally, the dose should be delivered only to the PTV. However, due to limitations in radiation treatment technique, this goal cannot be achieved, and this leads to the definition of the Treated Volume.

The Treated Volume is the volume enclosed by an isodose surface, selected and specified by the radiation oncologist as being appropriate to achieve the purpose of treatment (e.g., tumor eradication, palliation).

When the minimum target dose envelope is selected as appropriate, the Treated Volume may, in some cases, closely match the Planning Target Volume, but in other cases, the Treated Volume may be considerably larger than the Planning Target Volume. Examples of different Treated Volumes with different techniques for the same Planning Target Volume are given in Fig. 2.5.

If, however, the Treated Volume turns out to be smaller, or not wholly enclosing the Planning Target Volume, then the probability of tumor control is reduced, and the treatment plan has to be reevaluated and, if necessary, even the aim of therapy may have to be reconsidered.

There are several reasons for identifying the Treated Volume. One reason is that the shape and size of the Treated Volume relative to the Planning Target Volume is an important optimization parameter. Another reason is that a recurrence within the Treated Volume but outside the Planning Target Volume may be considered to be a "true," "in-field" recurrence due to inadequate dose and not a "marginal" recurrence due to inadequate volume.

2.3.5 Irradiated Volume

The Irradiated Volume is that tissue volume which receives a dose that is considered significant in relation to normal tissue tolerance.

The Irradiated Volume depends on the treatment technique used.

Fig. 2.5. Examples of four different Treated Volumes resulting from irradiating the same Planning Target Volume (indicated by the dotted area) with four different treatment techniques. In all cases, the Treated Volume is defined by the 95% isodose curve (-----), and, in addition, the 20% isodose (———) is given as representing the Irradiated Volume. The geometrical limits of the beams are indicated by (–·–·–).

The following ratios can be observed between the respective areas of the Planning Target Volume (1.0), the Treated Volume, and the Irradiated Volume:

a. 1.0 : 2.4 : 4.6
b. 1.0 : 1.9 : 9.0
c. 1.0 : 1.4 : 9.0
d. 1.0 : 1.1 : 11.0

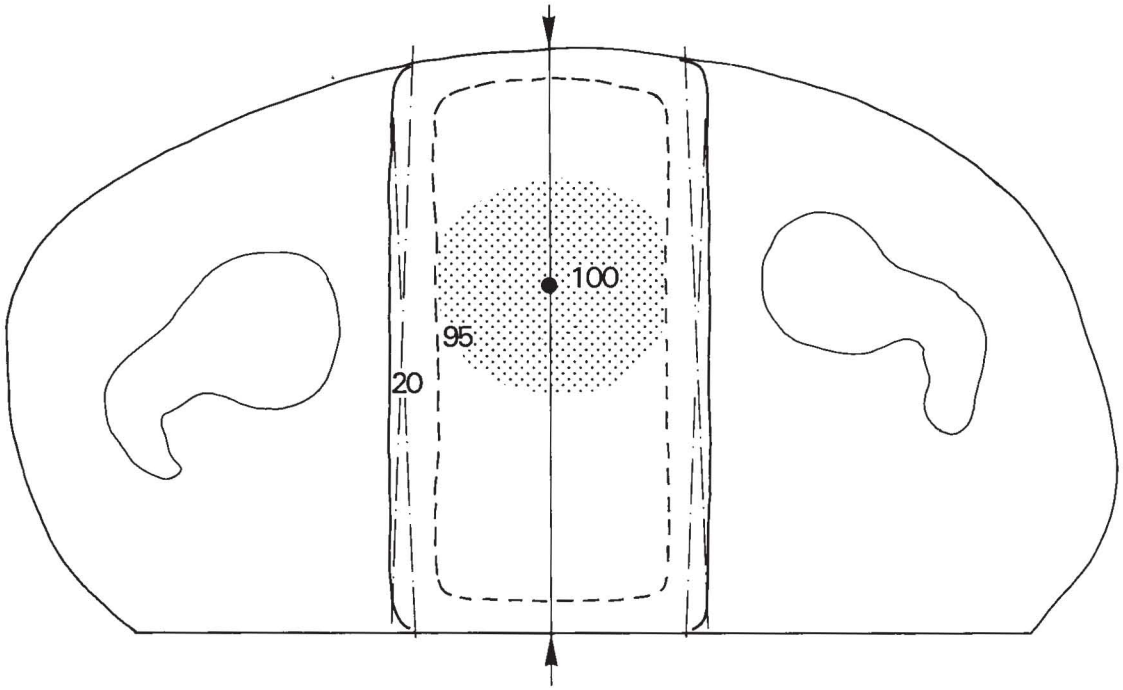


Fig. 2.5.a. Two opposed equally weighted beams.

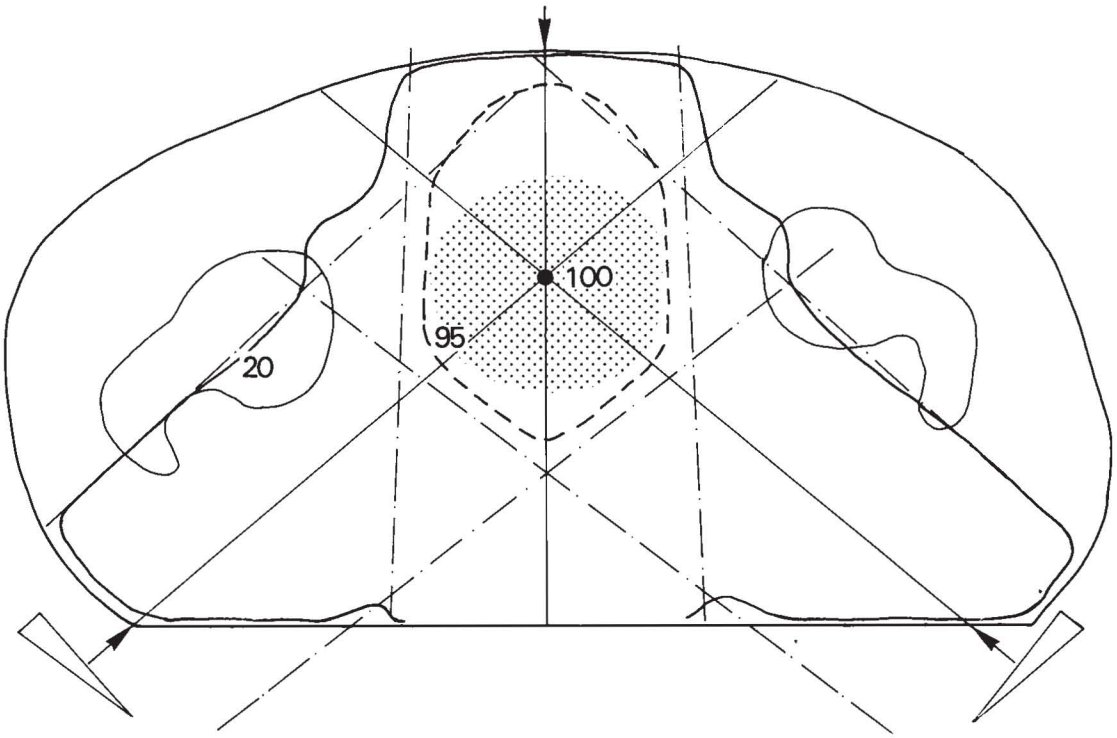


Fig. 2.5.b. Three beams.

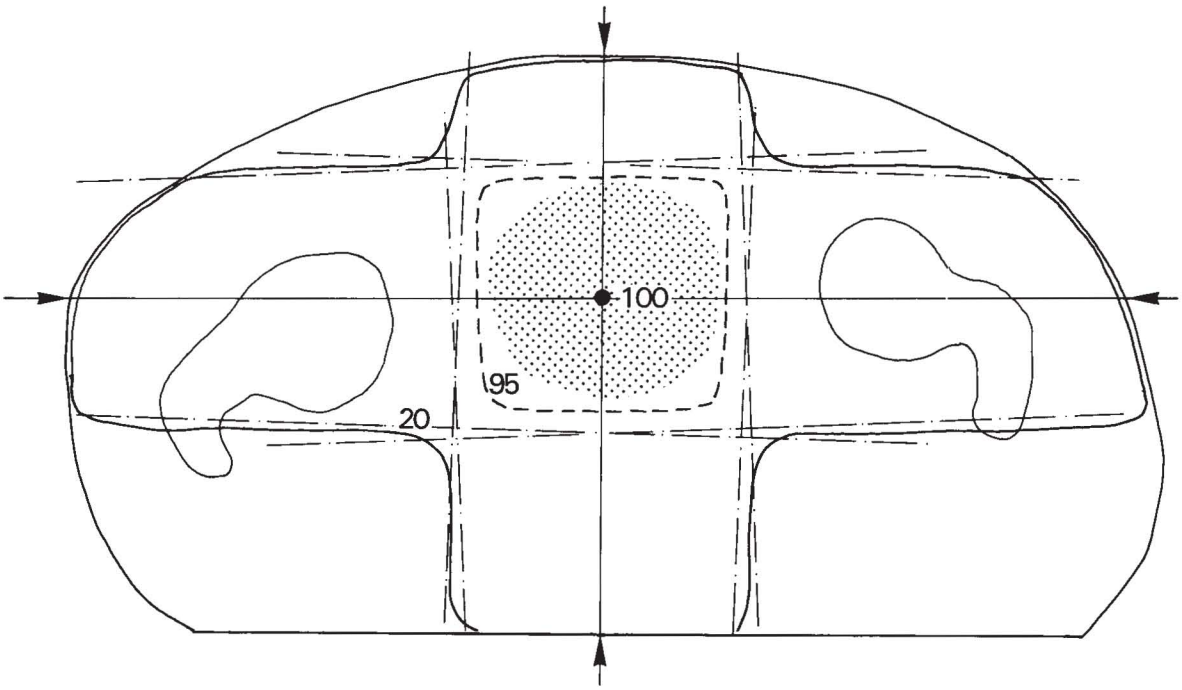


Fig. 2.5.c. Four beam box technique.

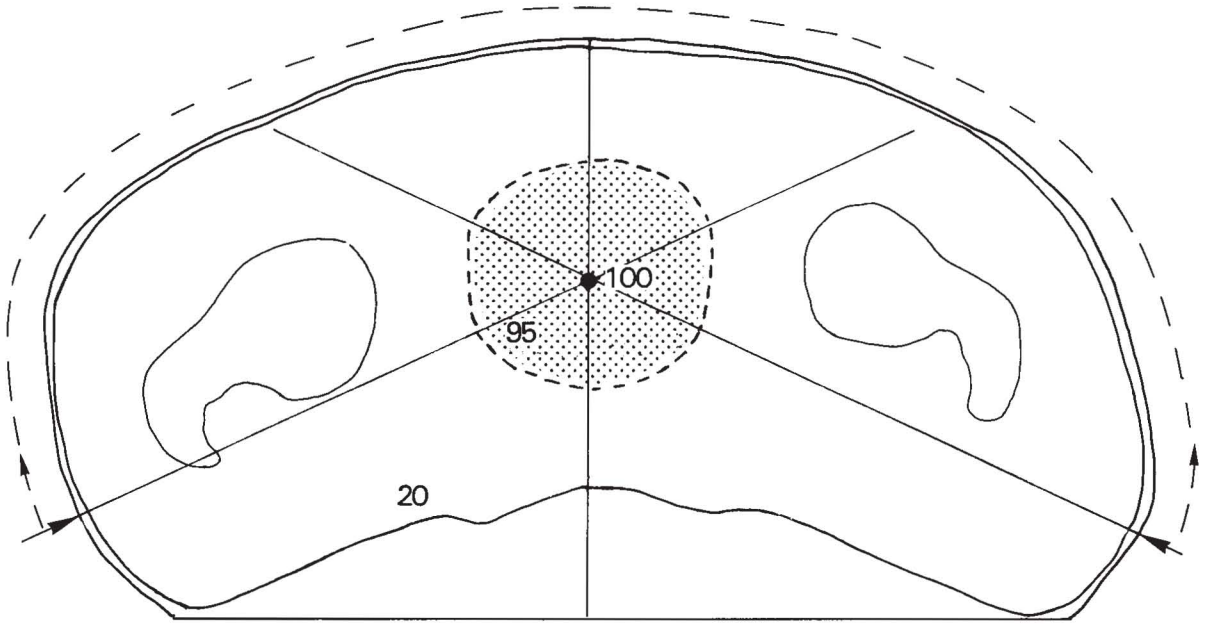


Fig. 2.5.d. Moving beam therapy; large arc.

The comparison of the Treated Volume and the Irradiated Volume for different beam arrangements can be used as part of the optimization procedure as illustrated in Fig. 2.5.

If the Irradiated Volume is reported, the significant dose level must be expressed either in absolute values or relative to the specified dose to the PTV.

2.3.6 Organs At Risk

Organs at risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or prescribed dose.

As is the case when defining the Planning Target Volume, any possible movement of the organ at risk during treatment, as well as uncertainties in the set up during the whole treatment course, must be considered.

Estimations of dose limits for normal tissues under different conditions have been tabulated by, e.g., Rubin (1975), and further elaborated by Brahme *et al.* (1988). Organs at risk may be divided into three different classes:

Class I organs: Radiation lesions are fatal or result in severe morbidity.

Class II organs: Radiation lesions result in moderate to mild morbidity.

Class III organs: Radiation lesions are mild, transient, and reversible, or result in no significant morbidity.

2.4 Absorbed Dose Distribution

The prescription of radiation treatment includes a definition of the aim of therapy and volumes to be considered, as described in Sections 2.2. and 2.3., and also a prescription of dose and fractionation.

A provisional dose prescription is usually made at the same time as the decision to use radiotherapy is made and the volumes to be considered are specified. When a standardized treatment technique is used (e.g., in a protocol), it is often possible, at the time of prescription, to have sufficient knowledge of the final dose distribution that there is no need to change the prescription due to factors that may emerge during dose planning. However, in non-standard individualized treatments, it may not be possible to achieve the prescribed doses in the selected volumes. This may be due, for instance, to high dose to organs at risk. The final dose prescription will then have to be modified from the provisional one.

Different concepts needed for reporting are defined below. Recommendations for reporting are given in Section 3.

2.4.1 Dose Variation in the Planning Target Volume

When the dose to a given volume has been prescribed, then the corresponding delivered dose should be as homogeneous as possible. Indeed, due to the steep slopes of the dose-effect-relationships for tumor

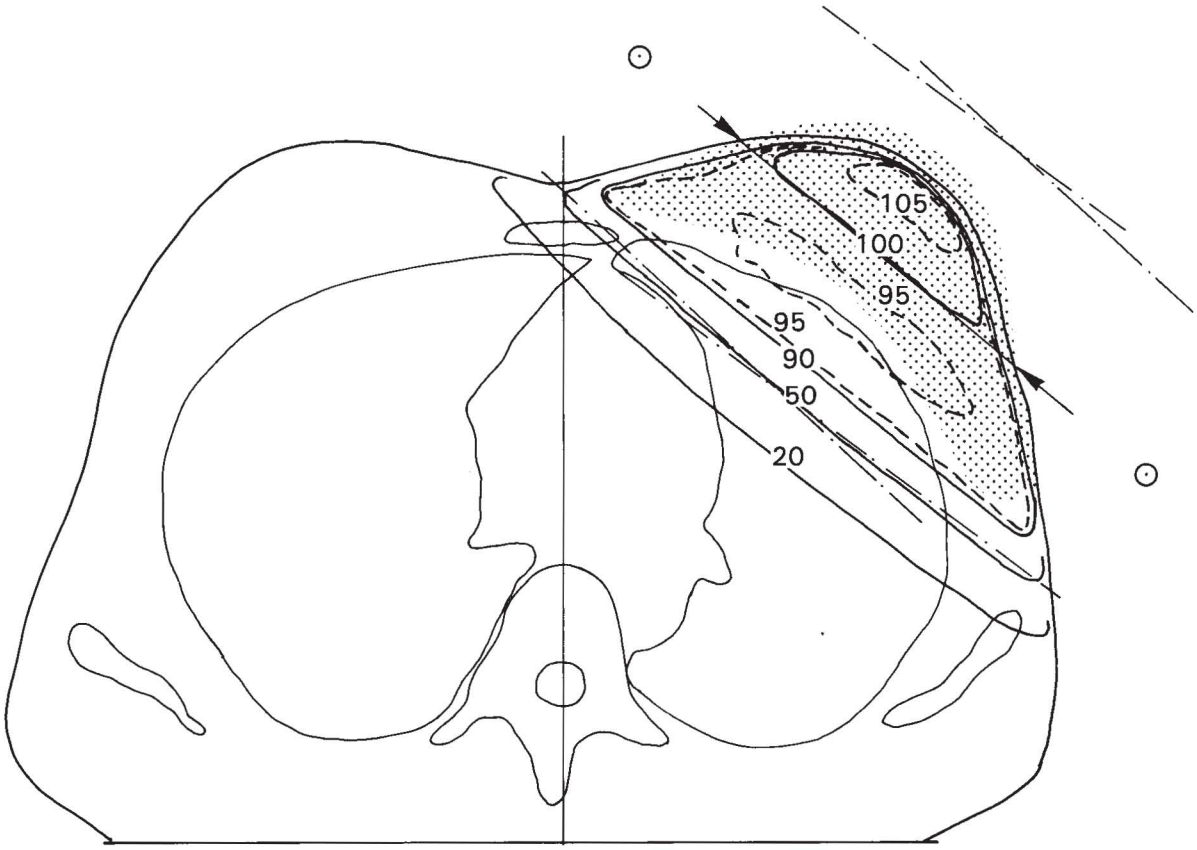


Fig. 2.6.a. Section at the level of Th V in a case of mammary carcinoma. The Planning Target Volume is indicated by the dotted area. Note that it extends slightly outside the surface of the skin over the breast in order to safeguard against variations in the position of the breast due to breathing and beam positioning variations.

Tangential irradiation using two opposed equally weighted 6 MV photon beams. The isodose distribution has been normalized to the dose midway between the beam entrances and on the central axes of the beams.

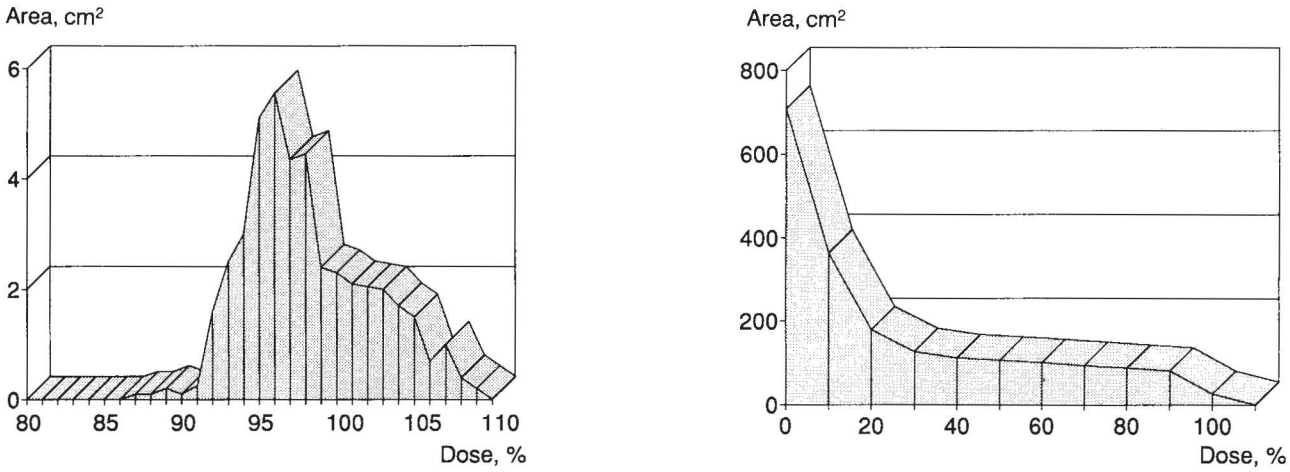


Fig. 2.6.b. Dose-area histograms for the same patient as in Fig. 2.6.a.
i. frequency dose-area histogram (left) for the PTV.
ii. cumulative dose-area histogram (right) for the whole section.
(Modified from Report 42 [ICRU, 1987]).

control, the outcome of treatment cannot be related to dose if there is too large a dose heterogeneity. Furthermore, any comparison between different patient series becomes difficult, or even impossible. However, even if a perfectly homogeneous dose distribution is, in principle, desirable, some heterogeneity has to be accepted due to obvious technical reasons. Thus, when prescribing the treatment, one has to forsee a certain degree of heterogeneity, which today in the best technical and clinical conditions should be kept within +7% and −5% of prescribed dose (Wittkämper et al., 1987, Brahme et al., 1988, Mijnheer et al., 1987).

If such a degree of homogeneity cannot be achieved, it is the responsibility of the radiation oncologist to decide whether this can be accepted or not. In fact, in some cases, a higher dose may be found in a part of the PTV where the highest malignant cell concentration may be expected, especially within the GTV, and such a situation may even be of advantage. In such cases, the different dose levels in different volumes should also be reported.

For palliative treatments, and for subclinical disease, a more heterogeneous dose distribution can more often be accepted than for radical treatments.

2.4.2 Representation of a Spatial Dose Distribution

It must always be borne in mind that radiotherapy is concerned with volumes. Patients have a three-dimensional shape, and so do Gross Tumor Volumes, Clinical Target Volumes, Planning Target Volumes, Organs at Risk, and tissue heterogeneities.

Thus, when evaluating a dose distribution, the variation within a defined volume must be taken into account. Modern dose-planning systems are based on CT cross-sectional images of the patient and should have the capacity of handling fully three-dimensional topographic patient data as well as performing a fully three-dimensional dose calculation. Methods of presenting results of calculation have been reviewed in Report 42 (ICRU 1987), and further developments in the field are expected.

A full three-dimensional dose distribution can only be inspected and visually evaluated on the screen of the graphic's display unit. For the hard-copy documentation of an isodose distribution, only two-dimensional sections are meaningful in daily routine. For practical reasons, only a limited number of sections are used. These sections should be chosen in such a way that they illustrate as closely as possible the GTV, CTV, PTV, and organs at risk, and other structures of importance (e.g., bony landmarks). For this purpose, a series of parallel transverse planes or orthogonal planes or other presentations may be used. Usually, at least a plane through the centre of the Clinical Target Volume or Planning Target Volume is used, but often, several sections are necessary in order to display the full topography and dose distribution.

In some situations, only one section may be used for dose planning (Fig. 2.6.a.). In doing so, one is forced to assume that all structures through which the section passes have a cylindrical shape. This assumption is, in most cases, an over-simplification and should be used with great care (Fig. 2.7.).

Regardless of what type of section is used, the extreme outlines of the CTV, organs at risk, the tissue heterogeneities and anatomical reference points in the corresponding three-dimensional slice should be projected onto the section. The section then contains all the relevant information for the whole slice.

The isodose lines should be drawn according to given recommendations (Report 42 [ICRU, 1987]).

In many situations, the practice is to evaluate the dose-distribution only unidimensionally, e.g., along the coinciding central axes of two opposing beams (Fig. 2.8.), or at points on a single central axis at given depths (Fig. 2.9.). Such procedures require, however, that a full treatment plan be worked out for reference purposes, and that the actual estimations only aim at verifying if any substantial deviations from the reference plan exist in the actual patient.

The proliferation of computers for treatment planning purposes also allows for alternative ways of presenting dose variations as histograms. This usually means displaying the dose as a distribution-function or frequency-function over a specified volume (area) (dose-volume/area histogram) (Fig. 2.6.b.). In addition, different single values of dose are easily obtained.

The following definitions of dose (Sections 2.4.3.–2.4.8) apply to dose calculations in a volume. When calculated in a section, they are clinically relevant only if they can be assumed to represent the entire three-dimensional situation.

2.4.3 Maximum Dose (D_{max})

One can identify the maximum dose within the PTV, and the maximum dose at tissues outside the PTV (e.g., at Organs at Risk [2.3.6]), or Hot Spots (2.4.8).

The maximum dose to normal tissues is of importance for limiting and for evaluating side-effects of treatment. However, a significant tissue volume must be irradiated for the dose level to be reported as

Fig. 2.7. Figures to illustrate the effect of treatment planning based on one section only (left figure in each set) and a complete set of sections (n = 24, right row) in a patient with a central bronchogenic carcinoma. The Clinical Target Volume includes the mediastinal and supraclavicular nodes. (By courtesy, I.-L. Lamm, Ph.D., Dept. of Radiation Physics, Lund).

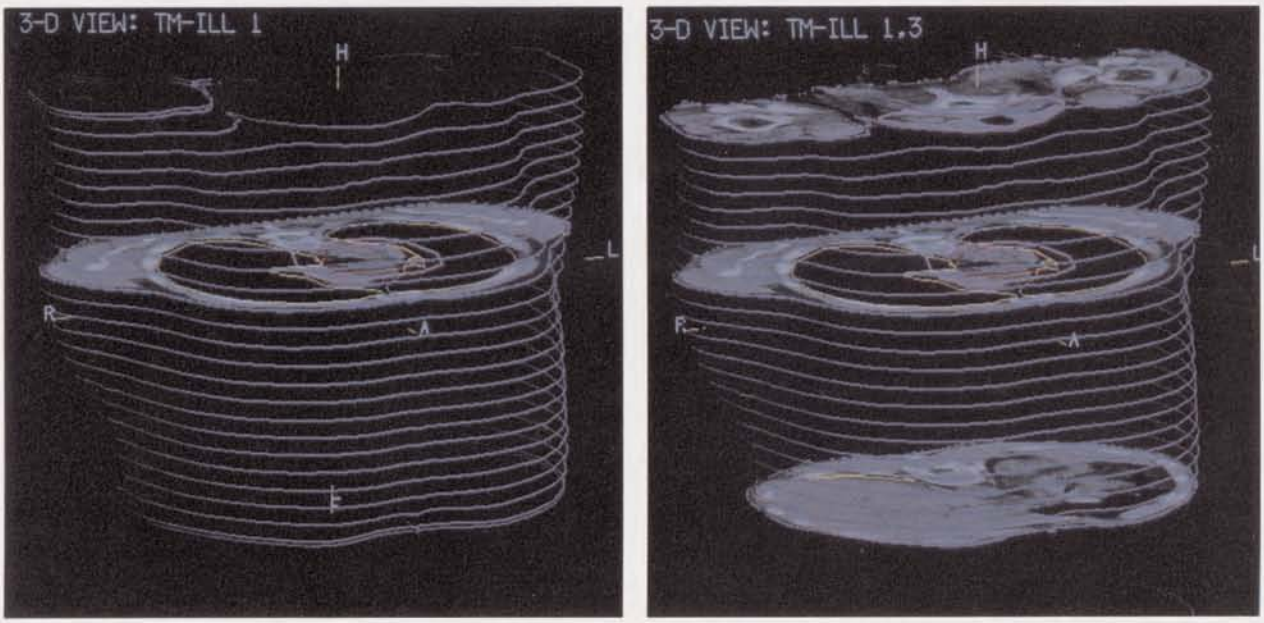


Fig. 2.7.a. & b. Sections used for defining volumes; in the 2 D case a section through the central part of the GTV, and in the 3 D case all 24 sections, but here only the central, the most cranial and the most caudal sections are fully displayed in a gray-scale.

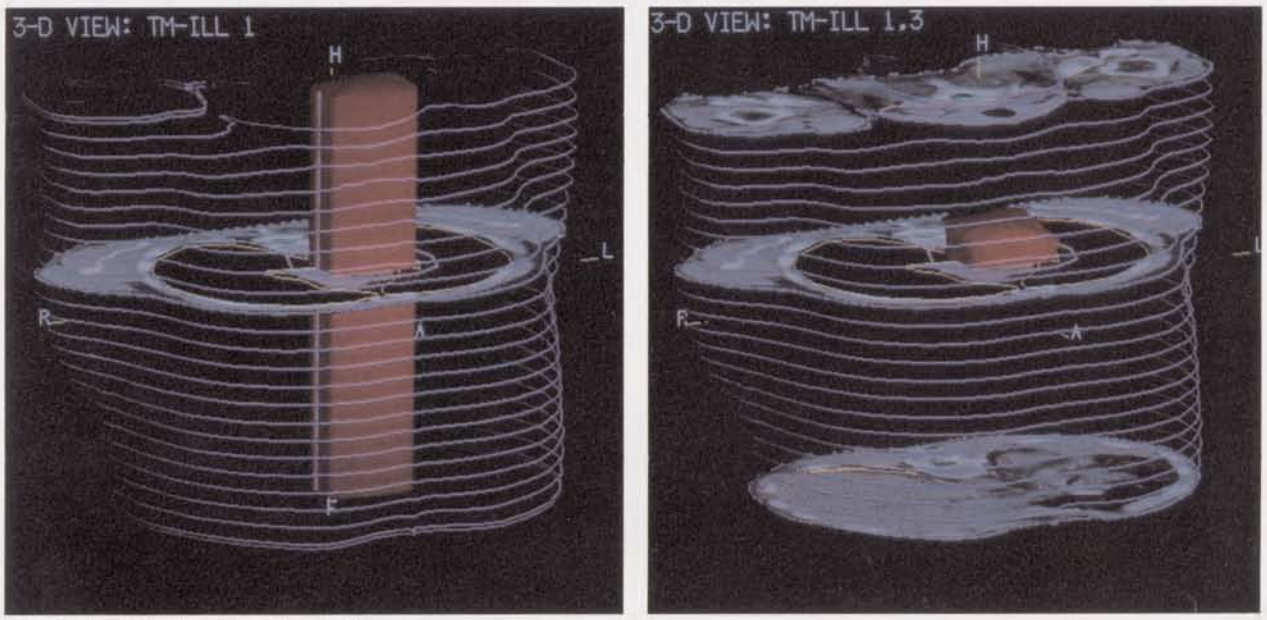


Fig. 2.7.c. & d. The Gross Tumor Volume

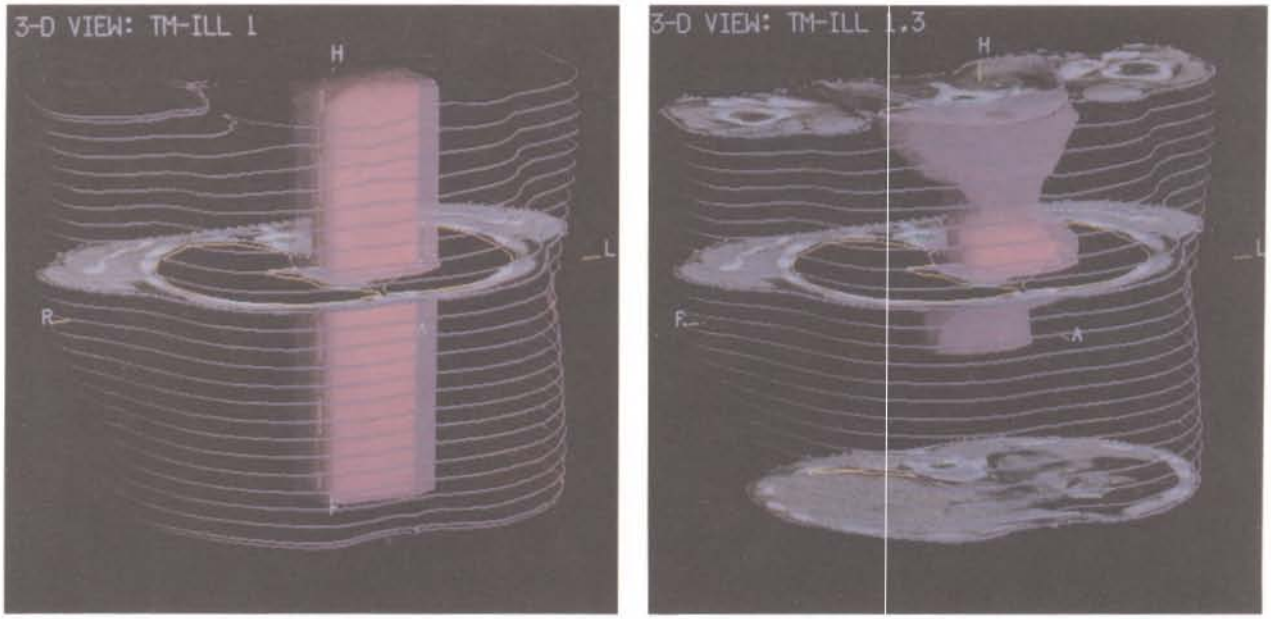


Fig. 2.7.e. & f. Clinical Target Volume, defined to include the nodes in both hilar regions, in the upper mediastinum and in both supraclavicular regions.

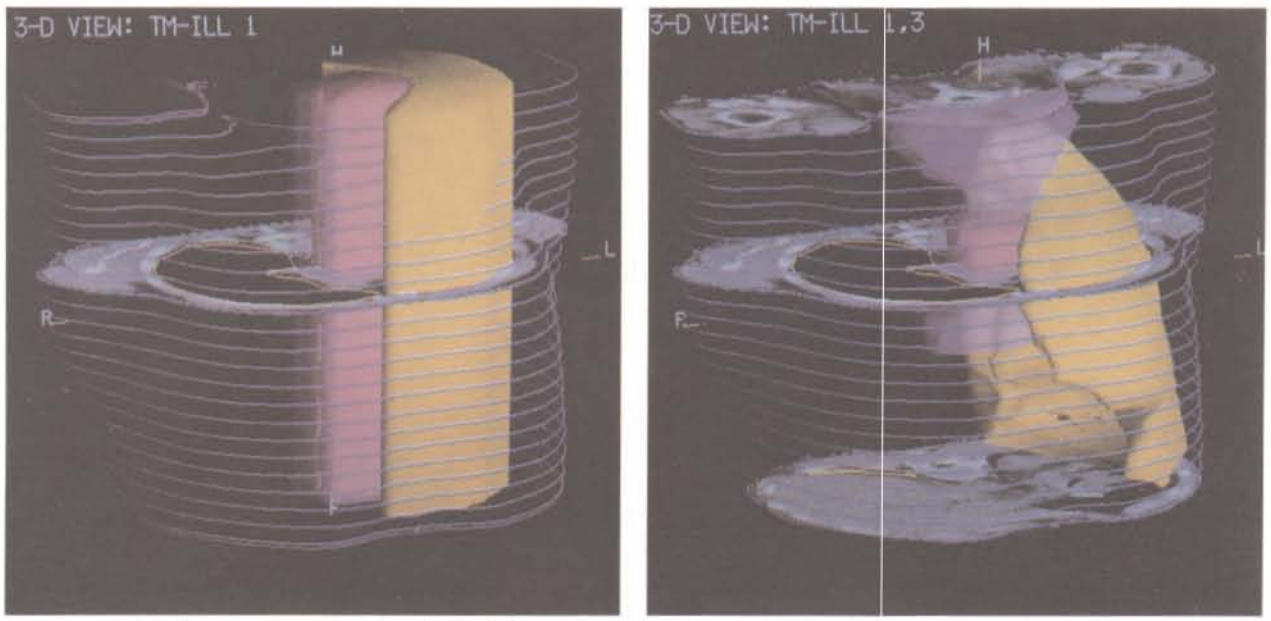


Fig. 2.7.g. & h. Clinical Target Volume and the left lung.

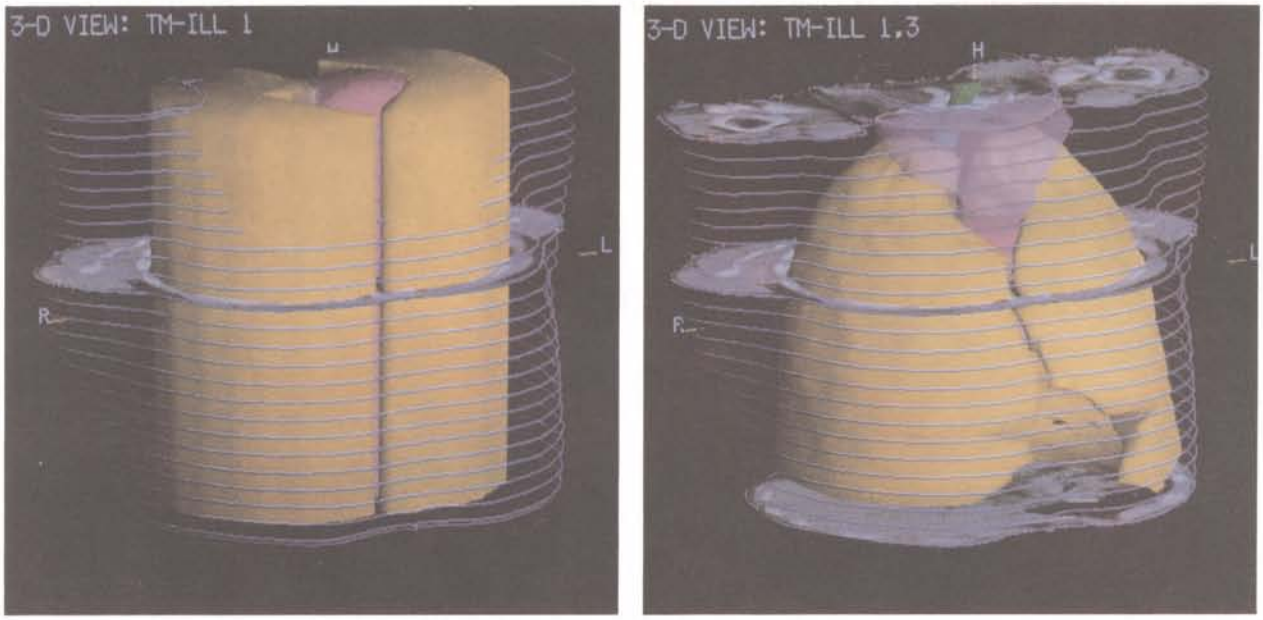


Fig. 2.7.i. & j. Clinical Target Volume and both lungs.

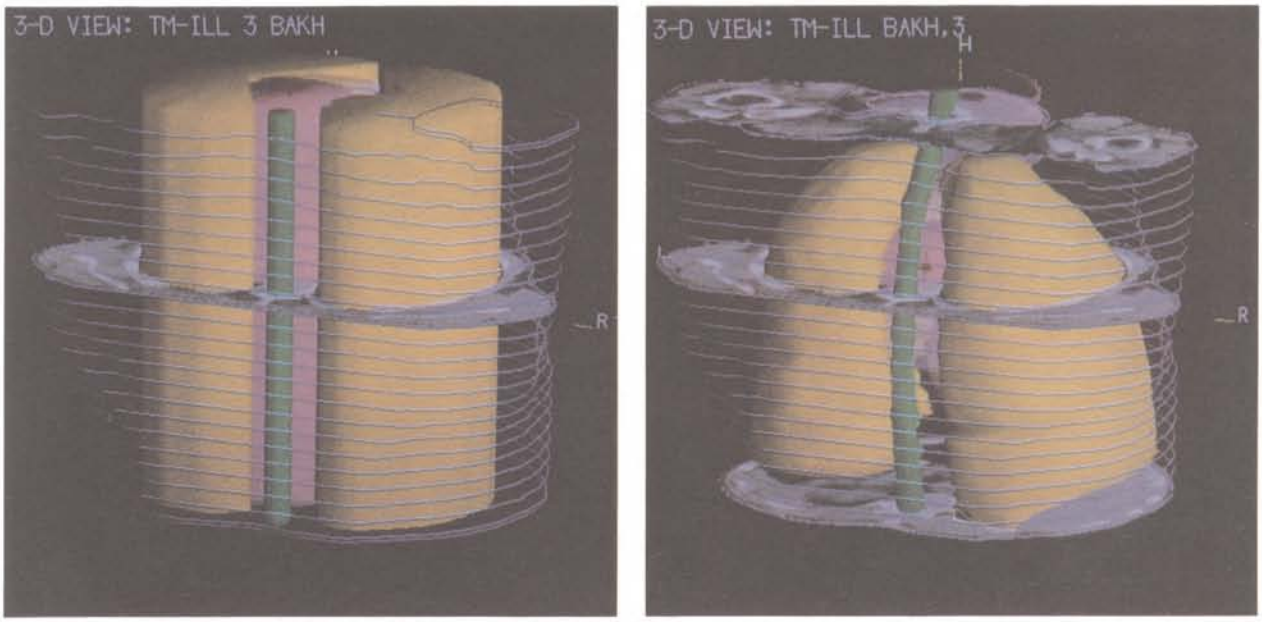


Fig. 2.7.k. & l. Clinical Target Volume, both lungs, and spinal cord, as seen from behind.

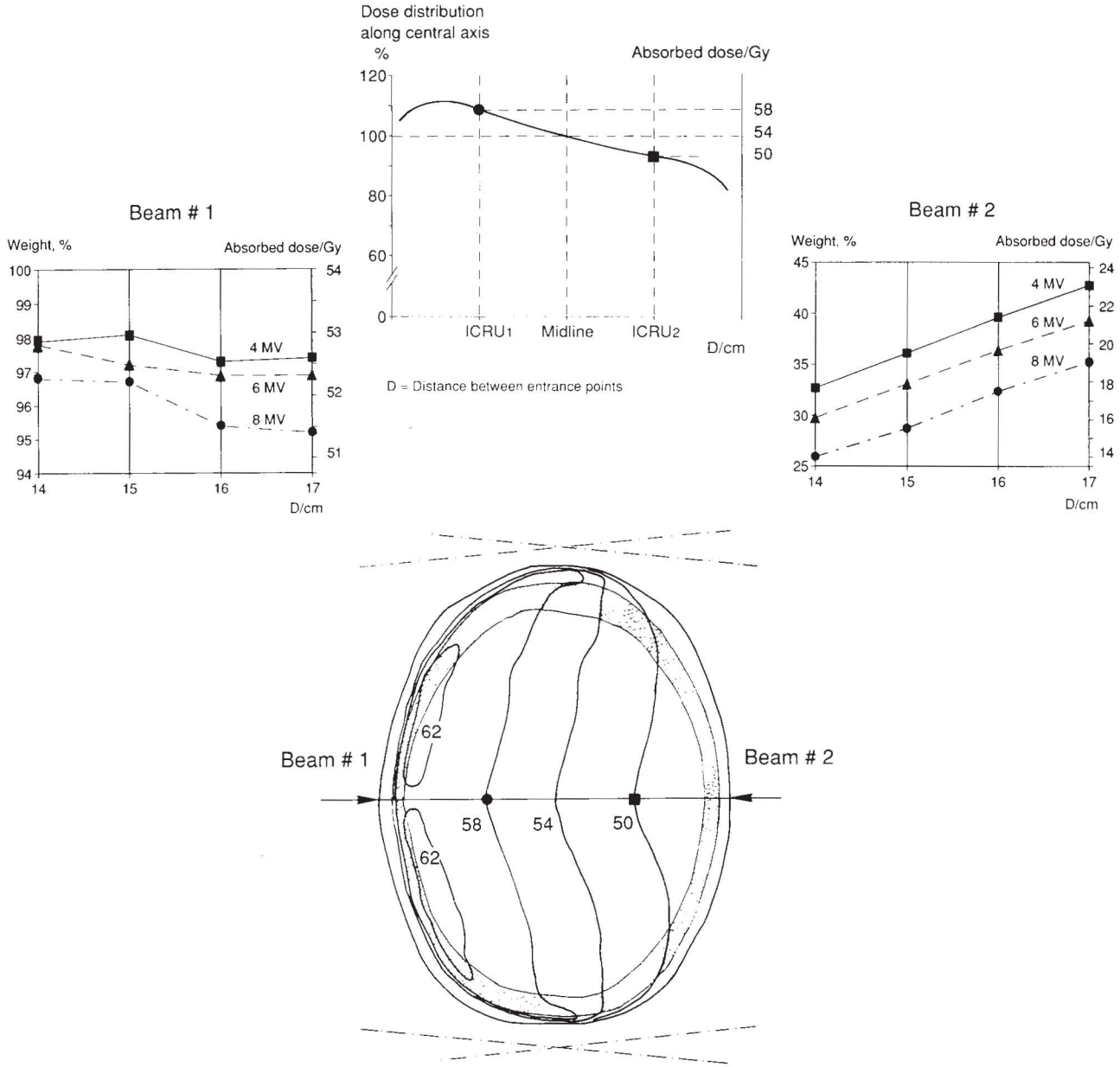


Fig. 2.8. Example of a standard treatment technique with two opposed unequally weighted beams for irradiation of malignant glioma. The prescribed dose in the center of the tumor-bearing hemisphere (ICRU Point 1) is 58 Gy, and in the center of the other hemisphere (ICRU Point 2) 50 Gy, in order to irradiate presumed malignant growth across the midline.

The beam weight and corresponding total peak absorbed dose for each beam can be read from the two nomograms for different distances between the beam entrances (D) and for different beam energies.

The resulting dose distribution along the central axis is also shown.

The case illustrates a quite complex situation (more than one prescribed dose, and unequally weighted beams), where, with a detailed analysis of the procedure as a basis, the routine work can be done in a greatly simplified but nevertheless standardized way.

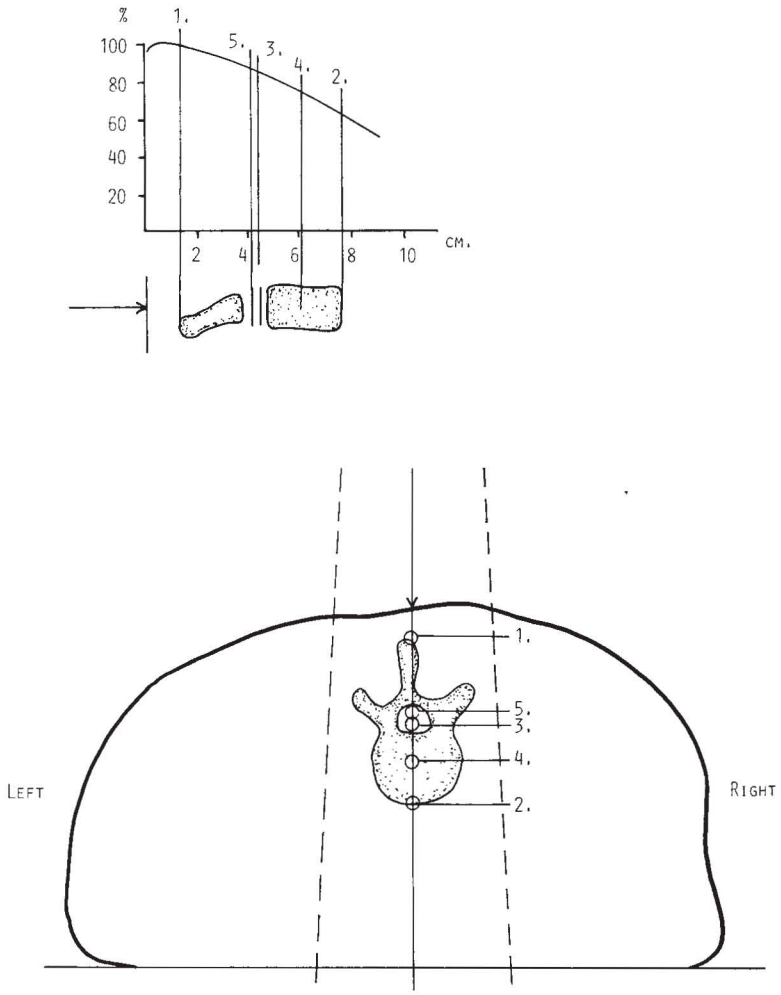


Fig. 2.9. Example of dose evaluation only along the central beam axis ("one-dimensional" dose evaluation). Treatment with a single ^{60}Co gamma beam at SSD 80 cm of a patient with painful vertebral metastases (patient prone, level L III). The beam size was selected to allow for patient movement during treatment due to pain. Normalization at peak absorbed dose in the central beam (= 100%).

For specification, the doses at the following points along the central beam axis were considered:

1. The dose at the most dorsal part of the spinal process of the vertebral body (= 98%).
2. The dose at the ventral surface of the vertebral body (= 65%).
3. The dose in the geometrical center of the whole vertebra (= midway between points 1 and 2) (= 81%).
4. The dose centrally in the vertebral body proper (= 73%).
5. The dose at the dorsal surface of the spinal cord (= 85%).

For reporting purposes, the dose at point 3 was not considered adequate, since this point is not within the proper bony structures. Instead, the dose at point 4 was selected as ICRU Reference Dose. This dose was in a position where the bone destruction was most obvious. This dose, together with the dose at point 1 and point 2, represent the Target Dose specified for reporting (= 73%, variation 98%–65% of peak absorbed dose). The dose to the organ at risk (spinal cord) is 85%.

The figure illustrates a common clinical situation. Even when no isodose distribution is available, it is possible to state within certain restrictions the PTV dose at an ICRU Reference Point and the dose variation as well as the dose to organs at risk.

maximum. For three-dimensional computation, a volume is considered clinically meaningful if its minimum diameter exceeds 15 mm. A smaller volume is, in most cases, not relevant to normal tissue tolerance for large organs such as lung, liver, kidney, skin, etc. However, when other smaller organs are at risk, a dimension smaller than 15 mm has to be considered (e.g., eye, optical nerve, larynx, etc.).

The Maximum Dose to the PTV, with the area/volume restriction described above, has to be taken into account for evaluating the homogeneity of the dose distribution (part of the optimization criteria).

When the maximum dose outside the PTV exceeds the prescribed dose, then a "hot spot" can be identified (see 2.4.8).

2.4.4 Minimum Dose (D_{min})

The minimum dose is the smallest dose in a defined volume.

In contrast to the situation with the maximum absorbed dose (see 2.4.3), no volume limit is recommended when reporting minimum dose.

The Minimum Planning Target Dose is the lowest dose in the Planning Target Volume.

2.4.5 Average Dose ($D_{average}$)[4]

The determination of the average, the median and modal doses is based on the calculation of the dose at each one of a large number of discrete points (lattice points), uniformly distributed in the volume in question.

The Average Dose is the average of the dose values in these lattice points and can be expressed by the equation:

$$D_{average} = \frac{1}{N} \sum_{V} D_{i,j,k}$$

where N is the number of lattice points, i is the column index in this lattice, j is the row index, k is the level index, and $D_{i,j,k}$ is the dose at the lattice point i,j,k located inside the volume V.

2.4.6 Median Dose (D_{median})

The Median Dose is the central value of the doses at all lattice points, when arranged according to magnitude.

2.4.7 Modal Dose (D_{modal})

The Modal Dose is the dose that occurs most frequently at lattice points in the volume concerned. There may be more than one modal dose value, which then makes this concept useless for reporting purpose.

NB: In order to determine the values of $D_{average}$, D_{median}, and D_{modal}, a complete computer-based dose distribution is required. This limits the universal use of these concepts.

2.4.8 Hot Spots

In many situations, tissues outside the Planning Target Volume will receive a relatively large absorbed dose.

A Hot Spot represents a volume outside the PTV which receives a dose larger than 100% of the specified PTV Dose.

As for the general rule about maximum dose (2.4.3.), a hot spot is, in general, considered significant only if the minimum diameter exceeds 15 mm. If it occurs in a small organ (e.g., the eye, optic nerve, larynx), a dimension smaller than 15 mm has to be considered.

[4] In this report, the term average refers to the mathematical mean. The reason for using the term average instead of mean is to avoid confusion with "min." used as an abbreviation for minimum.

3. Recommendations for Reporting

3.1 Introduction

The aim of these recommendations is to promote uniformity between radiotherapy centres, when reporting their treatments. It is, indeed, essential, when exchanging information, that the same type of treatment be reported in the same way from different centers, using the same terminology and definitions.

These recommendations deal with volumes and doses. They are valid for photon beams.

3.2 General Recommendations for Reporting Volumes

3.2.1 Gross Tumor Volume

The primary aim of the clinical work-up of a patient with a malignant disease is to define the site of the primary tumor, its size and possible invasion of adjacent structures, and to detect regional lymph node involvement and distant metastases. This staging procedure should result in an accurate assessment of the extent of disease. As this is a purely anatomical concept, it can be accurately described in standard topographic terms, e.g., "tumor in the roof of nasopharynx with metastatic nodes in the sternomastoid chain bilaterally in the neck." This constitutes the description of the Gross Tumor Volume.

In many situations, a verbal description might be too cumbersome, and, also, for the purpose of data recording and analysis, a classification is needed. For the purpose of recording and documentation, it might thus be necessary to codify this anatomical description.

There are several systems for coding anatomy. The system probably most widely used at present for describing the site of the primary tumor is Chapter 2 (Neoplasia) of the 9th edition of the ICD (International Classification of Diseases) (WHO, 1977). This code can be supplemented by a TNM- or pTNM-classification, indicating the extent of the malignant disease (UICC, 1987, 1990). However, since the ICD code was designed for the purpose of epidemiology and health care statistics, it is not a pure topographic descriptor, and has been modified for oncological purposes in the ICD-O (WHO, 1976a, 1990) code. By means of this code, it might be possible to describe the Gross Tumor Volume and Clinical Target Volume in most situations, but it does not allow for a sufficiently detailed description of a number of different structures (e.g., lymph nodes). Furthermore, laterality for paired organs and structures must be indicated by a supplementary code.

Another coding system is the SNOMED (Systematized Nomenclature of Medicine) (CAP, 1979) in which the section on topography (T-SNOMED) contains a suitable but rather complex code.

A comprehensive code for anatomical sites based on ICD-O(10) (WHO, 1990) is suggested in Appendix I, Table I.2. A simple code for description of sections is suggested in Appendix I, Table I.3.

Schematic examples of how to utilize these coding systems to describe volumes, viz., the Gross Tumor Volume and Clinical Target Volume, for recording and documentation purposes are given for four typical clinical situations in Appendix I, Fig. I.1.

For reporting purposes, however, a description in plain language is recommended.

3.2.2 Clinical Target Volume

The Clinical Target Volume is also a purely anatomical concept and can, in addition to any existing tumor, be described as including structures with clinically suspected but not proven involvement. Thus, the Clinical Target Volume cannot be defined a priori in terms of a TNM or pTNM classification, but must be defined in plain topographic terms or according to a corresponding code in conformity with the recommendations for GTV. Examples are to be found in Appendix I.

3.2.3 Planning Target Volume

Since the Planning Target Volume is defined to take variations in size and position of the Clinical Target Volume into account, it is a purely geometric concept, and thus cannot be described in anatomic terms. The recommendations are that the PTV is described by giving the size of the margins around the CTV in all relevant directions. A desirable development could be the possibility of defining the PTV in terms of coordinates in a patient related coordinate system (Report 42 [ICRU, 1987]).

3.2.4 Treated Volume

The definition of the Treated Volume is that volume enclosed within a specified isodose envelope, and thus the description of this volume for reporting must indicate which isodose level was selected or, preferably, the corresponding absorbed dose value (Gy) and, if possible, an estimation of the size of that volume (cm^3).

TABLE 3.1—*Summary of the recommendations for choosing ICRU Reference Point for dose specification for reporting treatments with emphasis on simple beam arrangements.* Note that for each situation the variation of dose (maximum and minimum dose) to the Planning Target Volume will also have to be specified for reporting.

Type of Photon Beam Arrangement	Location of ICRU Reference Point			Illustrated by Figures
	Centrally in Planning Target Volume	On beam axis	At specially selected points	
A single beam	Recommended	Recommended	May be necessary[a]	3.1.a, 2.9
Two opposed equally weighted beams		Recommended		3.1.b, 2.5.a, 2.6.a, II.1
Two opposed unequally weighted beams	Recommended	Recommended		3.1.c, 2.8
Two or more noncoaxial beams which all intersect at a point		Recommended		3.1.d, 3.1.e, 3.1.f, 2.5.b, 2.5.c
Moving beam therapy, large arc	Recommended	Recommended		3.1.g
Moving beam therapy, small arc	Recommended			3.1.h
Several beams whose central axes do not intersect at a point within the PTV, or no central axis exists in the PTV	Recommended		Recommended	3.2, 3.3, 3.4

[a] For example, see Fig. 2.9 and Section 3.3.1.

3.2.5 Irradiated Volume

In conformity with the Treated Volume, the Irradiated Volume is also defined by a specified isodose envelope and, for reporting purposes, the value of the isodose chosen, or, preferably, the corresponding absorbed dose value (Gy) should be given. Also, an estimation of the size of the volume (cm^3) should be reported.

An illustration of the variation in size of the Treated Volume and Irradiated Volume with differ-

Fig. 3.1. Examples of ICRU Reference Points (●) for dose specification, and the dose variation in the PTV from maximum (*) to minimum in typical simple beam arrangements. The Planning Target Volume is represented by the striated areas.

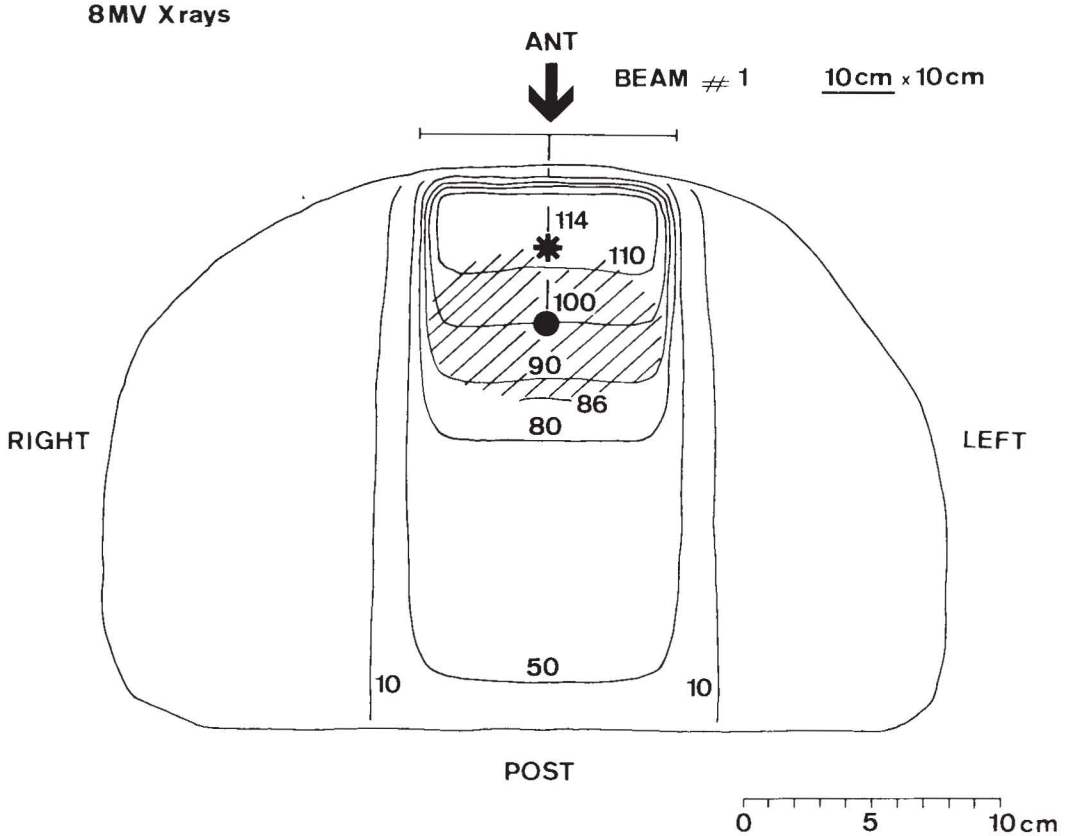


Fig. 3.1.a. One 8 MV photon beam. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axis. The dose variation in the PTV is from 114% to 86%.

ent techniques for the same PTV is to be found in Fig. 2.5.a to d.

3.3 General Recommendations for Reporting Doses

The dose at or near the center of the Planning Target Volume as well as the maximum and the minimum dose to the PTV shall be reported. Additional information (such as average dose, dose/volume histograms), when available, may be useful.

3.3.1 The ICRU Reference Point

The present system of recommendations for reporting is based on the selection of a point within the PTV, which is referred to as the ICRU Reference Point.

The ICRU Reference Point shall be selected according to the following general criteria:

— the dose at the point should be clinically relevant and representative of the dose throughout the Planning Target Volume (PTV);
— the point should be easy to define in a clear and unambiguous way;
— the point should be selected where the dose can be accurately determined (physical accuracy);
— the point should be selected in a region where there is no steep dose gradient.

These recommendations will be fulfilled if the ICRU Reference Point is located firstly at the center, or in the central part, of the Planning Target Volume, and secondly on or near the central axis of the beam(s).

The method of selection of the ICRU Reference Point is best illustrated by practical examples. Some recommended ICRU Reference Points for simple beam arrangements are listed in Table 3.1. and demonstrated in Fig. 3.1. They are located on the beam axes, or at the intersection of the beam axes (if such an intersection point exists inside the Planning Target Volume, and provided it is located in the central part of the Planning Target Volume, i.e., at least about 2 cm inside the border of the PTV), or only in the central part of the PTV.

In some situations, the conditions do not allow for the ICRU Reference Point to be localized both at or near the center of the PTV, and also on the beam axis in an area where the dose distribution is homogeneous. In these cases, the first criterion, i.e., localiza-

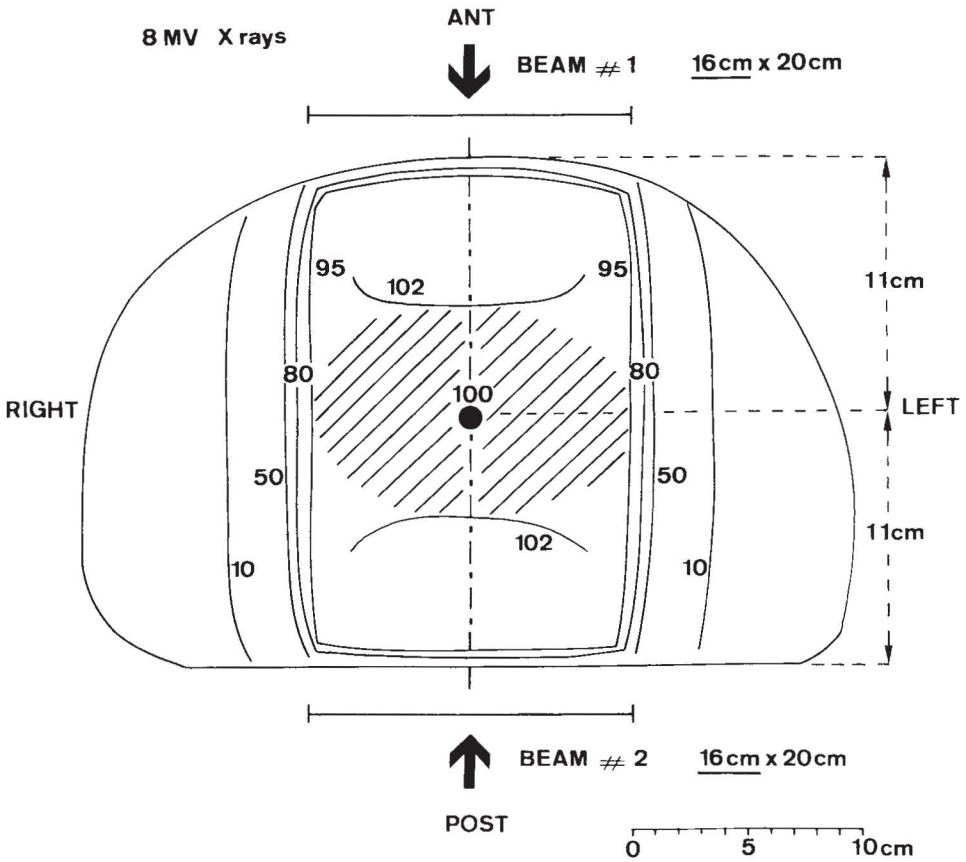


Fig. 3.1.b. Two opposed equally weighted 8 MV photon beams. The ICRU Reference Point (100%) is midway between the beam entrances and is also in the center of the PTV. The dose variation in the PTV is from 102% to 95%.

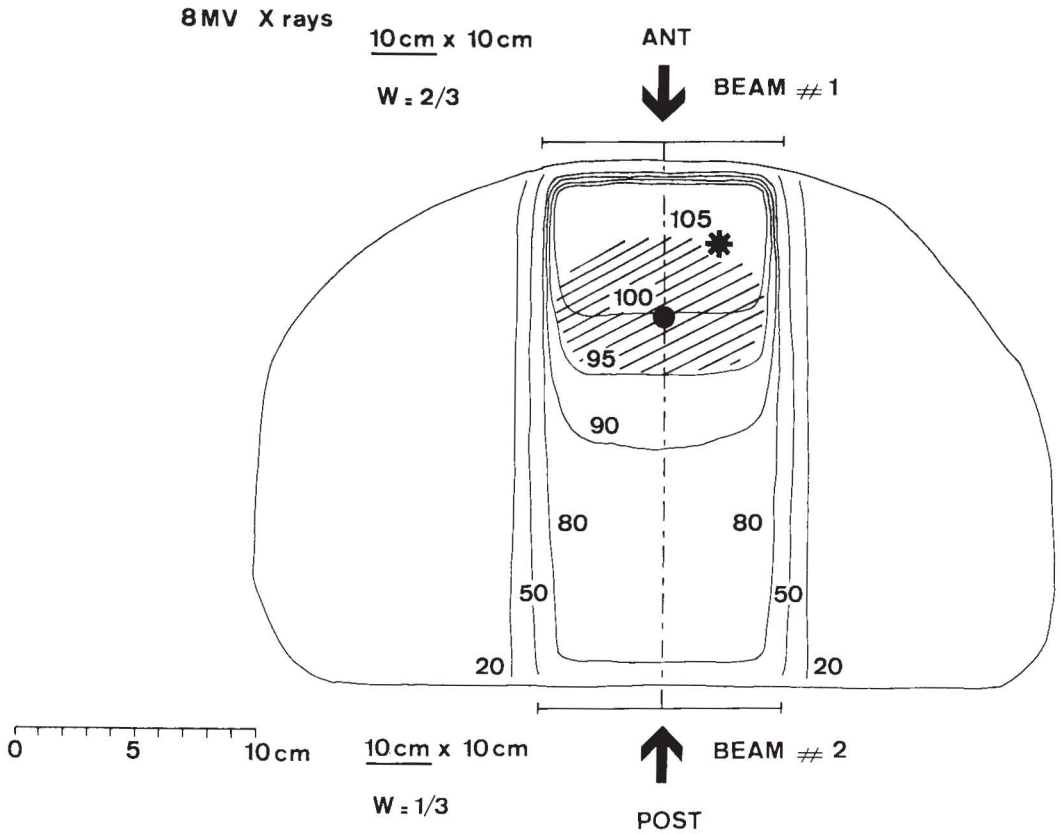


Fig. 3.1.c. Two opposed unequally weighted (1:3 at peak absorbed dose) 8 MV photon beams. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axes (but not midways between the beam entrances). The dose variation in the PTV is from 105% to 95%.

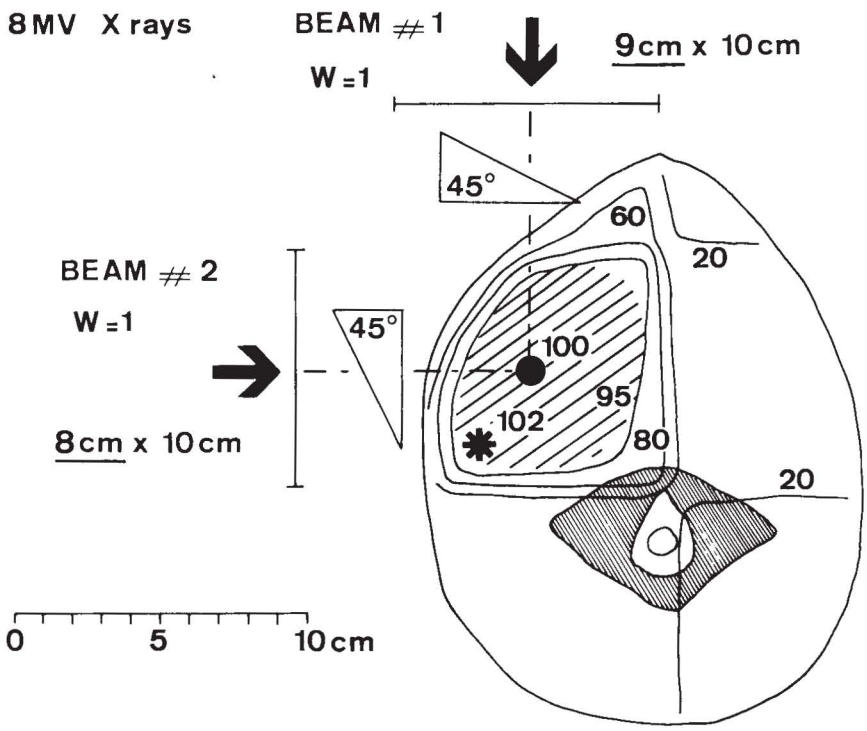


Fig. 3.1.d. Two orthogonal 8 MV photon beams. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axes. The dose variation in the PTV is from 102% to 95%.

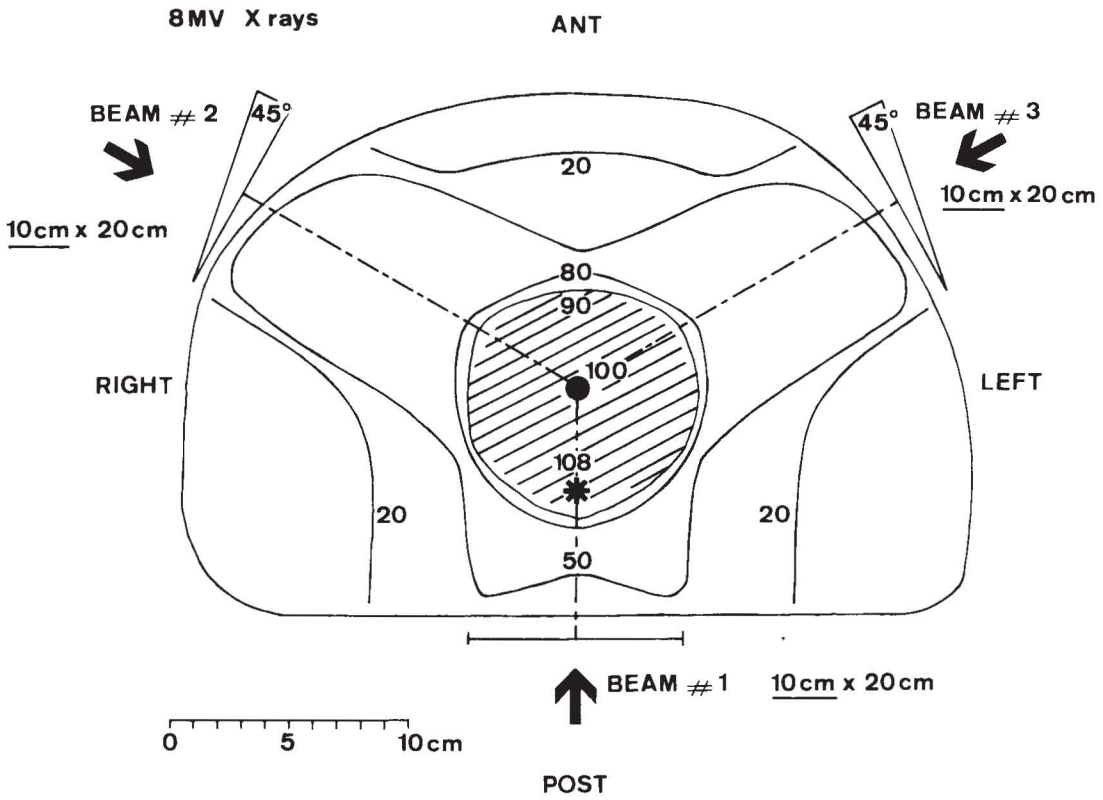


Fig. 3.1.e. Three equally weighted 8 MV photon beams that converge towards one point. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axes. The dose variation in the PTV is from 108% to 90%.

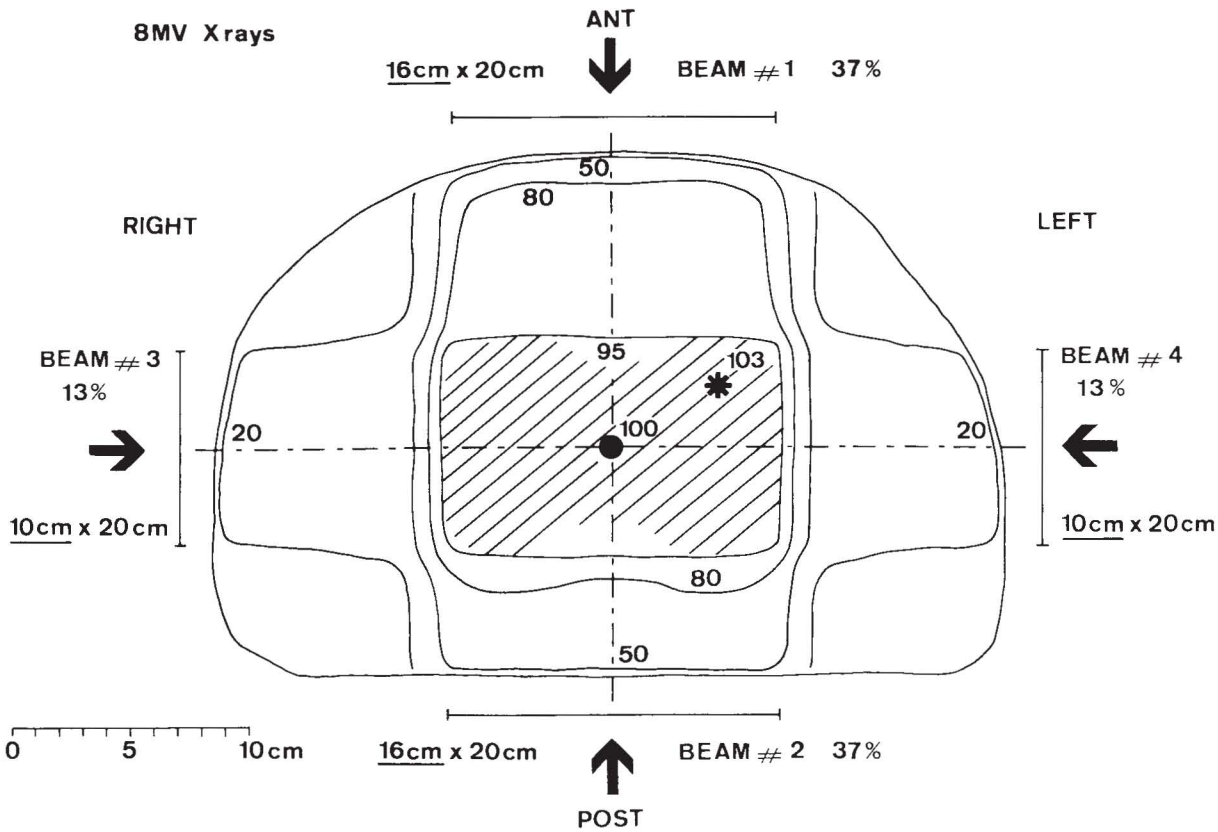


Fig. 3.1.f. Box technique with four 8 MV photon beams that converge towards one point. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axes. The dose variation in the PTV ranges from 103% to 95%.

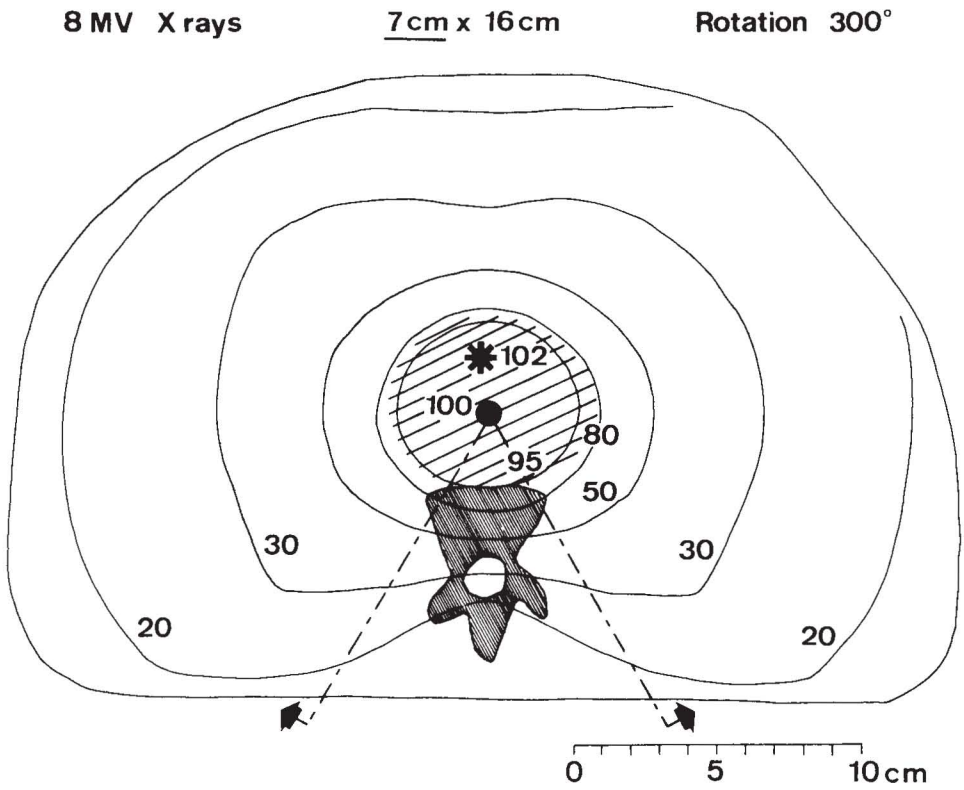


Fig. 3.1.g. Moving beam therapy with 8 MV photons; large arc. The ICRU Reference Point (100%) is in the center of the PTV and also on the central axis of the moving beam. The dose variation in the PTV is from 102% to 80%.

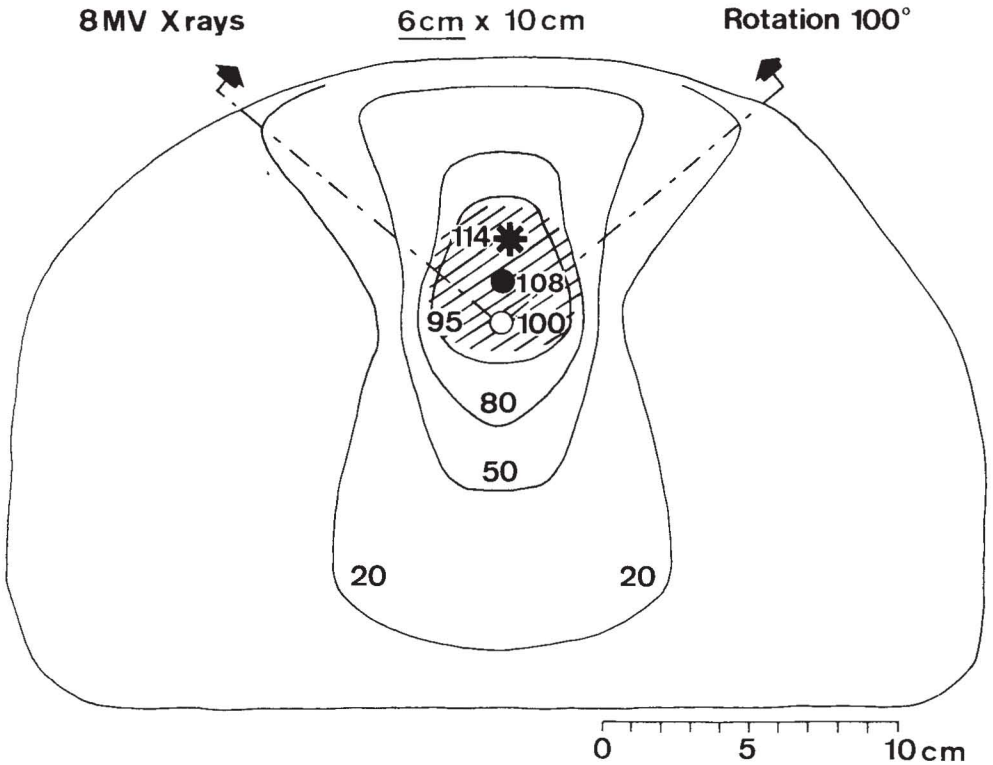


Fig. 3.1.h. Moving beam therapy with 8 MV photons; small arc (100°). The dose distribution has been normalized to the dose at the intersection of the central axis of the moving beam (open circle, = 100%). The ICRU Reference Point (solid circle = 108%) is in the center of the PTV. The dose variation in the PTV is from 114% to 85% (relative to the normalized dose), or from 106% to 79% (relative to the ICRU Reference dose).

tion at or close to the center of the PTV should be given preference. Some examples are given in Figs. 3.2, 3.3, and 3.4, and Appendix II, Fig. II.5.e.

In other situations, it will be found that the "center of the PTV" will not be a meaningful concept, if it is taken to imply the purely geometrical center or the center of gravity. Such a definition could result in the "center" being outside the tissues represented by the PTV (e.g., when treating the chest wall, where the center of gravity of the PTV may be in healthy lung tissue, or, in the case of treatment of the regional lymph nodes of a pelvic tumor, where the PTV may be ring-shaped, and its center of gravity is not in the tissue concerned). In these cases, one has to select the ICRU Reference Point inside the tissues represented by the PTV, and in a place where dose specification is considered to be meaningful. Such a place could be the region where the tumor cell density is considered to be at its maximum. An example is given in Appendix II, Fig. II.3.c. Wherever the ICRU Reference Point is localized, it must be clearly specified.

3.3.2 The ICRU Reference Dose

The dose at the ICRU Reference Point is the ICRU Reference Dose, and should always be reported.

3.3.3 The Dose Variation Throughout the Planning Target Volume

As previously indicated (Section 2.4.1.), a certain degree of inhomogeneity of the absorbed dose throughout the Planning Target Volume (PTV) cannot be avoided (i.e., the dose varies from the maximum dose value to the minimum dose level).

As a minimum requirement, the maximum dose and the minimum dose to the PTV shall be reported, together with the dose at the ICRU Reference Point. The three dose values then indicate the dose to the Clinical Target Volume and the dose variation.

The maximum dose is also relevant in relation to possible side effects.

The minimum dose is considered to be relevant in relation to tumor control. The isodose corresponding to the same value is sometimes called the "minimum isodose envelope." However, it cannot be used as the sole predictor of tumor control due to possible ambiguity in the definition of the border of the Clinical Target Volume (where, by definition, the tumor cell concentration should be zero). Tumor control may be more likely determined by the dose level in the GTV where tumor cell density is large. Furthermore, there are large dose compilation uncertainties near or in the penumbra region, where the dose gradient is steep.

Other dose values considered to be relevant (e.g., average dose and its standard deviation, dose area/volume histograms, biologically weighted doses), when available, should also be reported.

An analysis of the relative merits of using different types of doses for reporting is given in Appendix III.

3.3.4 The Three Levels of Dose Evaluation for Reporting

The level of completeness and accuracy of reporting therapeutic irradiation depends to a large extent on the situation in the department and on the aim of the treatment. For different clinical and practical considerations, different levels of ambition for dose evaluation can be identified. Three levels have been selected for reasons given below, but it is recognized that intermediate levels could also be identified.

3.3.4.1 Level 1: Basic Techniques. The minimum requirements for reporting can be followed in all centers, including those with restricted therapy equipment, dosimetric, computer, and staff facilities. This minimum level may sometimes be sufficient, in any center, when simple treatments are performed (e.g., some palliative treatments). At this level, it is assumed that the dose at the ICRU Reference Point and an estimate of the maximum and minimum doses to the PTV can be determined using, e.g., central axis depth dose tables. Some information about the dose outside the beam axis could also be obtained by means of standard isodose charts.

3.3.4.2 Level 2: Advanced Techniques. The standards of dose planning at this level allow the exchange between different centers of more complete and relevant information. At this level, it is assumed that the GTV, CTV, and PTV can be defined in one or more planes (sections), using reliable patient data acquisition tools, and/or modern imaging techniques under reliable conditions (e.g., a series of CT and/or MRI sections). It is also assumed that complete dose distributions are computed in the central plane and in other planes (sections) using only central plane dose data, and with inhomogeneity corrections, when appropriate.

3.3.4.3 Level 3: Developmental Techniques. The performance of dose planning at level 3 provides for the development of new techniques and clinical research in radiotherapy. At this level, 3-D dose computation of any beam arrangement (such as non-coplanar beams) and dose-volume histograms are available.

NB: In summary, the 3 levels could be described as follows:

Level 1: only the dose at the ICRU Reference Point and its variation along a central beam axis is available.

Level 2: the dose distribution can be computed for plane(s).

Fig. 3.2. Example of a technique for radiotherapy after breast conserving surgery in node positive patients. There are two topographically separate PTVs, namely, the breast (dotted line in section II, Fig. 3.2.c) and regional lymph nodes in axilla and supraclavicular fossa (dotted line in section I, Fig. 3.2.b). An overview of the beam arrangements is given in Fig. 3.2.a. The treatment machine is equipped with asymmetric jaws, which are used to shield to the midline in each beam, producing the four 5-MV-photon beams (two tangential [Nos. 1 and 2] to the breast, and two AP-PA [Nos. 3 and 4] towards the lymph nodes in the axilla and supraclavicular fossa). All four beams have the same isocenter (circle with cross), and all beams thus have a common border through the isocenter. Thus, there is no central axis within any of the beams. Additional parts of the beams are shielded and shown as hatched areas. The 100%, 95%, and 105% isodose lines are given, normalized to the ICRU Reference Points for the two PTVs (as indicated by the triangle [breast] and the square [regional lymph nodes]). A dose of 50 Gy is given to each of these PTVs according to the ICRU Reference Points (100% isodose lines).

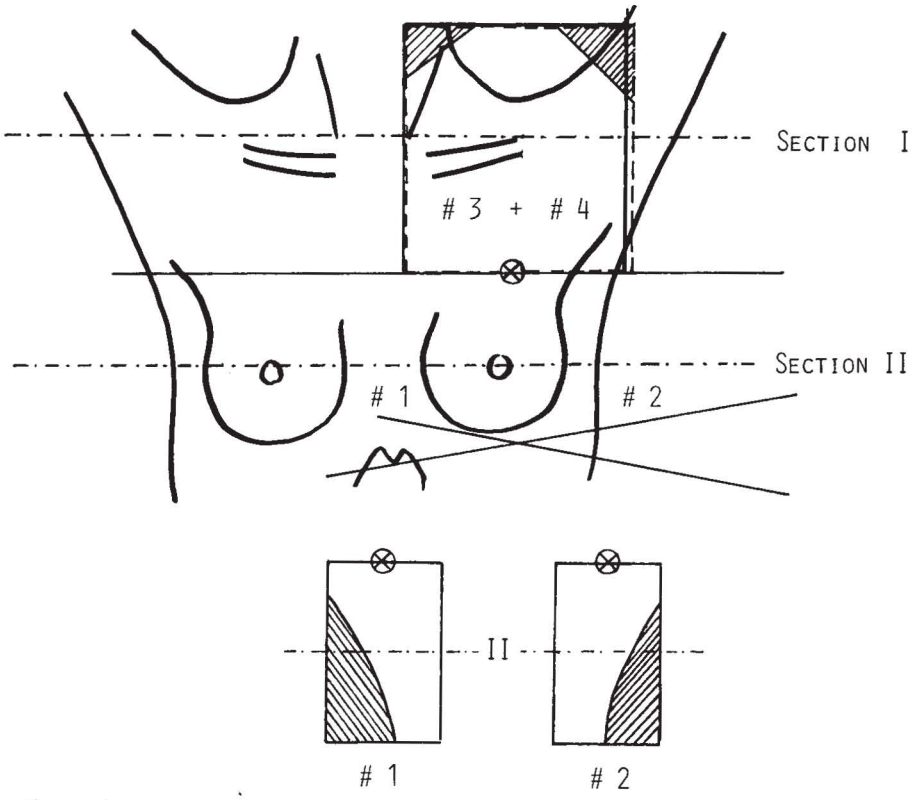


Fig. 3.2.a. Schematic overview.

Level 3: the dose distribution can be computed for volumes.

At any level, the dose at the ICRU Reference Point and the best estimation of the maximum and the minimum dose to the PTV should be reported. In addition, this information could be supplemented by, e.g., isodose plans, dose-area/volume histograms, and other information, when available, at levels 2 or 3.

3.4. A Single Planning Target Volume

3.4.1 Simple Beam Arrangements

The way to select the ICRU Reference Point is illustrated in Fig. 3.1 for a series of typical simple beam arrangements. The ICRU Reference Point is located centrally in the PTV on the beam axes at their intersection (provided that such an intersection point exists and that it is located in the central part of the PTV, or at least well inside the border of the PTV).

The dose to the ICRU Reference Point as well as the maximum and the minimum dose to the PTV should be reported.

Several of the simple beam arrangements, considered in Fig. 3.1., are used in a large proportion of treatments, especially for palliation.

3.4.2 Complex Beam Arrangements

In some situations, the ICRU Reference Point cannot be selected according to the basic criteria given in section 3.3.1, for instance:

— non-coaxial parallel opposing or non-opposing beams (e.g., different beam sizes or parallel beams),
— non-coplanar beams,
— beam intersection outside (or at the outer part of) the PTV.

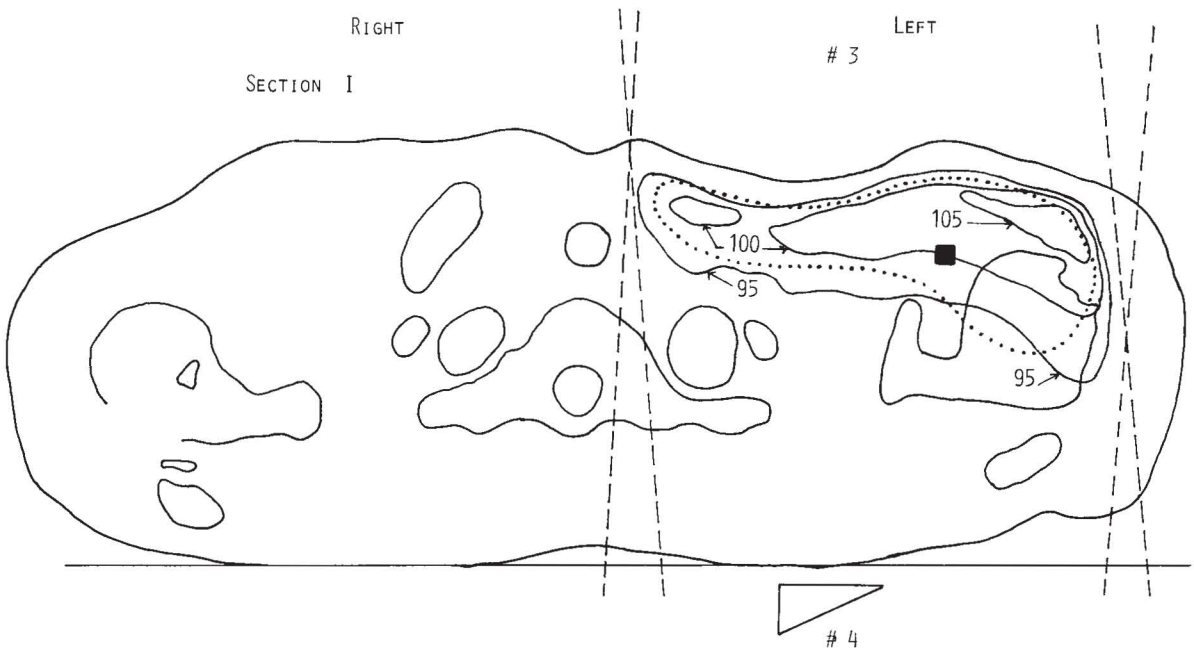


Fig. 3.2.b. Transverse section at the level of the regional lymph nodes.

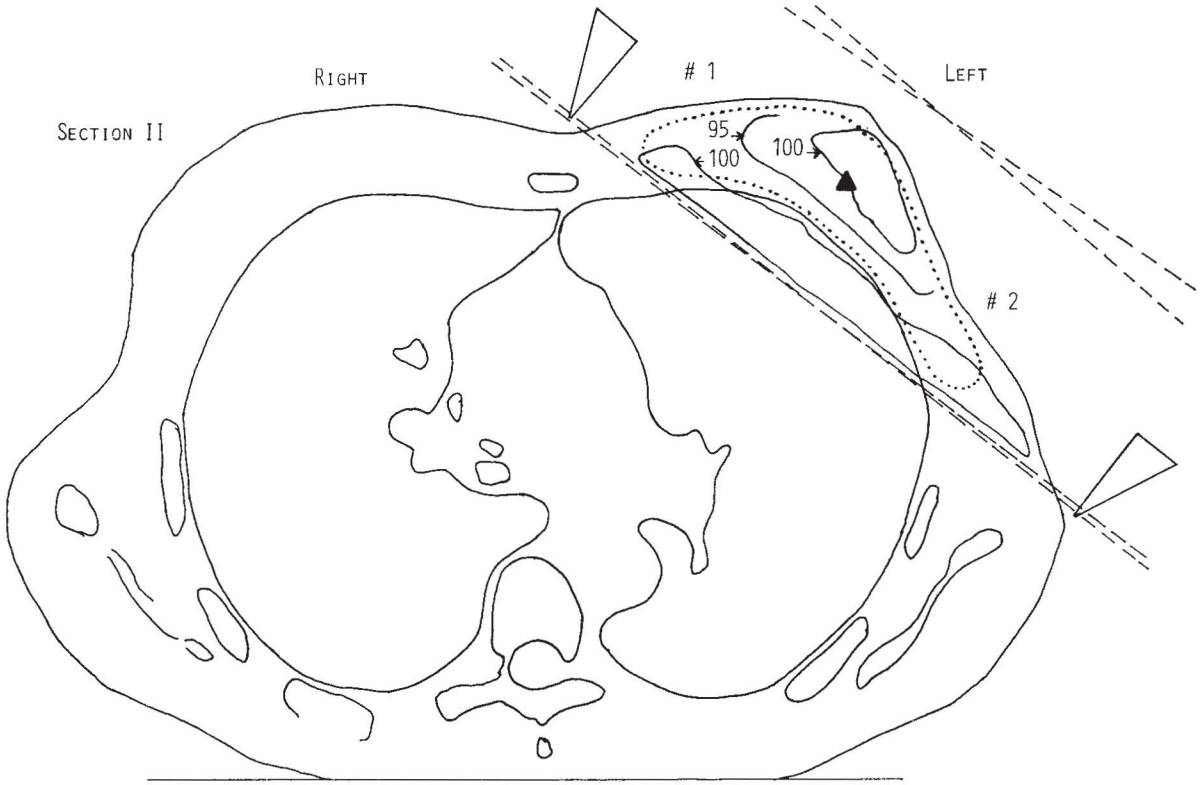


Fig. 3.2.c. Transverse section at the level of the breast.

In such situations, the ICRU Reference Point will have to be selected according to the additional criteria given in section 3.3.1.

The dose to the ICRU Reference Point, as well as the maximum and the minimum dose to the PTV, should be reported.

Examples are given in Figs. 3.2., 3.3., and 3.4., and in Appendix II, Figs. II.4. b to d.

Field	Radiation	SSD cm	Field size cm x cm	Weight (ICRU Reference Point)
1	25 MV X-rays	100	18 x 14	0.22
2	^{60}Co gamma rays	80	27 x 14	1.20
3	9 MeV electrons	100	8 x 14	0.12

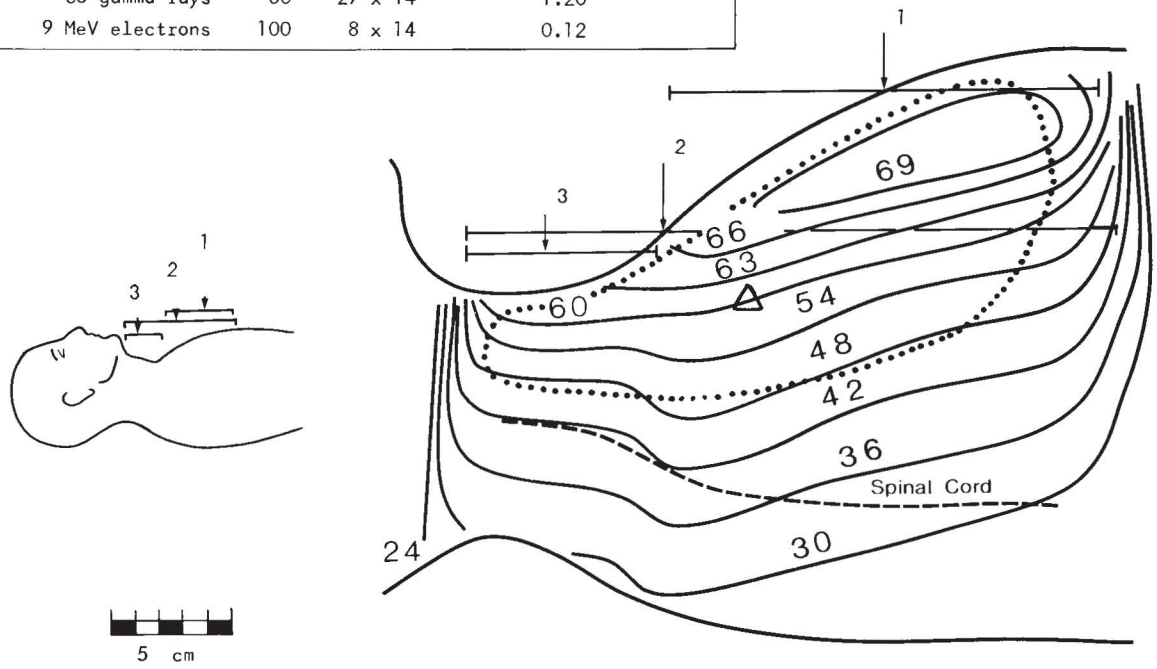


Fig. 3.3. Treatment of a thyroid carcinoma with mediastinal involvement using coplanar beams whose central rays do not intersect at one point. The purpose of treatment was to deliver 60 Gy to the thyroid and anterior mediastinum and to keep the dose to the cord below 42 Gy. Only anterior beams were used: their weight is expressed by their dose contribution to the ICRU Reference Point (triangle) and, for the electron beam, to the 60 Gy isodose in the sagital median plane. The PTV is indicated by the dotted line. The isodose lines indicate absolute values (Gy). The ICRU Reference Point is indicated by the triangle. The dose specified for reporting is 60 Gy, with the variation from 69 Gy to 47 Gy. Modified from Report 29 [ICRU, 1978].

3.5. Complex Treatments with More Than One Planning Target Volume

3.5.1 Introduction

With the increasing complexity of radiotherapy treatments, more than one Planning Target Volume is frequently identified. In practice, the two most common situations are adjacent PTVs and overlapping PTVs (Fig. 3.5.).

3.5.2 Adjacent Planning Target Volumes

In this situation, the PTVs are adjacent to each other; they do not overlap. A typical example may be the postoperative treatment of breast cancer including the breast and chest wall, and the regional lymphatics (see Fig. 3.2., and Appendix I, Fig. I.1.b.).

When the PTVs are adjacent to each other, as a minimum requirement, the dose to each PTV (at its ICRU Reference Point, as well as the maximum and the minimum dose to each PTV) should be reported as indicated in section 3.4.1. Note that since treatment of one PTV may give a dose contribution to the other PTV, reporting at level 1 may give information that does not take this into consideration. Information obtained at levels 2 and 3 (e.g., isodoses, dose-area/volume histograms) will increase the usefulness of the information.

3.5.3 Overlapping Planning Target Volumes

In this situation, one PTV is totally contained within the confines of the other. A typical example is the "boost" technique. In this case, again, two situations may occur:

— the beam axes of the two PTVs are identical and the centers coincide (see Appendix II, Figs. II.3.a. and b.).
— the centers of the two PTVs and the beam axes differ (see Appendix II, Fig. II.2.).

NB: The "shrinking field technique" can be considered as consisting of a series of smaller PTVs inserted into each other.

When the PTVs are overlapping the following procedures are recommended:

3.5.3.1 At Level 1. The dose to the ICRU Refer-

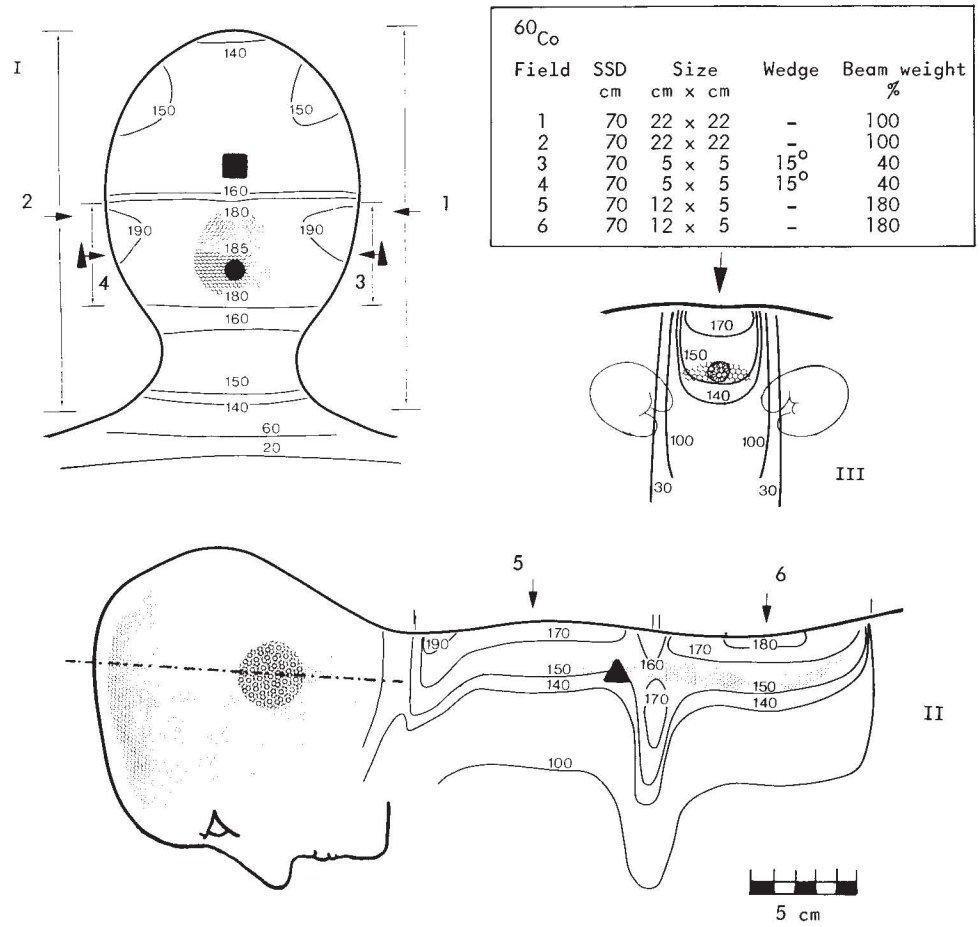


Fig. 3.4. Dose plan in 3 sections for the treatment of medulloblastoma with two PTVs (a. the demonstrated cerebellar tumor [GTV] and its local subclinical extensions [CTV I/PTV I], and b. the whole subdural space and the ventricular system [CTV II/PTV II]) with coplanar beams whose central rays do not intersect at one point, non-coplanar beams, and opposed noncoaxial beams. The weighting of the beams was chosen to give the prescribed total absorbed dose in the two PTVs with the same number of fractions. The distribution of the absorbed dose is calculated firstly for PTV I and the cranial part of the PTV II in a frontal section (I) and then a dose plan is produced for the spinal part of the PTV II in a median sagittal section (II). Furthermore, in order to evaluate the kidney dose, a transverse section (III) was also used. For reporting, three different ICRU Reference Points are defined, namely, one for the PTV I (● = ICRU 1), two (■ = ICRU 2, and ▲ = ICRU 3, respectively) for the cranial and spinal parts of the PTV II, respectively. From Report 29 [ICRU, 1978].

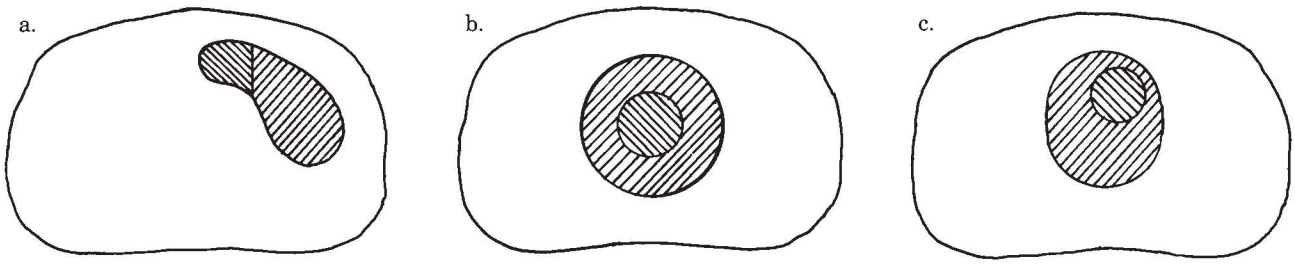


Fig. 3.5. Two different Planning Target Volumes which may be:
a. Adjacent to each other.
b. One totally contained within the confines of the other with coinciding centers and identical beam axes.
c. One totally contained within the confines of the other but different centers of the PTVs and the beam axes.
▨ = PTV I ▨ = PTV II

ence Point and the maximum and minimum dose to each PTV for each part of the treatment are calculated along the central beam axes and should be reported accordingly. At level 1, the report is confined to a simple description of technique.

3.5.3.2 At Levels 2 and 3. The dose distributions for each PTV are calculated and added and the dose to each ICRU Reference Point, as well as the maximum and minimum dose for each PTV, are reported, taking into account the cumulative contribution to each PTV. For the smaller PTV, the criteria of central position of the ICRU Reference Point in the PTV can usually be met. For the larger PTV (see Appendix II, Fig. II.3.), an ICRU Reference Point has to be selected according to criteria given in section 3.3.1. (i.e., at a specially selected position considered to be significant for tumor control in this PTV).

3.6 Organs at Risk

For each organ at risk, the maximum dose, together with the volume of the organ receiving that dose, should, when possible, be reported, (e.g., maximum spinal cord dose 42 Gy, 10 cm C1–C4, or left kidney dose 21 Gy, whole kidney).

In some situations, part of the organ or even the whole organ is irradiated to doses above the accepted tolerance level. In that case, the volume that receives at least the tolerance dose should be estimated.

When reporting at Level 3 is possible, dose-volume histograms for organs at risk, average doses, biologically weighted quantities, etc. could also be reported.

3.7 Hot Spots

If a hot spot (see section 2.4.8.) occurs, its size and position should be reported.

Appendix I

Minimum Requirements for Documentation and Recommendations for Description of Technique for Reporting

I.1 Minimum Requirements for Documentation

In section 2.1 and Fig. 2.1, the different steps in the radiotherapy procedure are indicated as well as the need for recording at all different stages of the whole radiotherapy procedure.

The recording of certain parameters at each step constitutes the necessary documentation of the treatment. Currently, this documentation is usually carried out in the form of notations on a specially designed treatment record form. In the future, this process may be replaced by various computer based systems, such as clinical registers, but the basic rationale and requirements for documentation should still apply. This topic has also been addressed in Report 42 [ICRU, 1987].

The requirements placed specifically upon a record form (and any equivalent computerized record form) for external beam therapy may be summarized as follows (modified from Möller et al. 1976):

— The radiation oncologist should be able to use the form as a prescription sheet, which states the diagnosis, aim of therapy, the GTV(s), the CTV(s), prescribed dose, and fractionation.
— It must be easy to include information necessary for treatment planning as well as relevant treatment parameters resulting from planning.
— The form must provide the technician with all details concerning the actual patient setup, and it must also be possible to use it as a log-book to enter notes on every given fraction.
— For control purposes, it must be possible to prescribe and record all dose measurements and other types of patient supervision and control of treatment together with the corresponding measures taken.
— The form must provide the supervising physician with adequate information to correctly evaluate the reactions of the patient during the entire course of treatment.
— After conclusion of treatment, all values of doses and time must be summarized to give the final dose/time values for the different volumes (PTVs and organs at risk).

TABLE I.1—*List of parameters that should be recorded at different steps in the radiotherapy procedure (compare Section 2.1 and Fig. 2.1)*
Note: * indicates recommended, (*) indicates optional

Information	Radiation Oncologist's Prescription	Dose Plan	Check and Confirm	Treatment Record Form/ Clinical Register	Reporting
PATIENT DATA					
Patient ID #	*	*	*	*	
Diagnosis					
site	*	*	*	*	*
histologic type	*	*	(*)	*	*
extent/stage	*	*	(*)	*	*
Intention of treatment	*			*	*
DOSE PLAN					
Plan ID #		*	*	*	
Date of planning		*	*	*	
Patient position	*	*	*	*	*
Anatomical description of:					
GTV(s)	*			*	*
CTV(s)	*			*	*
organs at risk	*			*	*

TABLE I.1—*continued*

Information	Radiation Oncologist's Prescription	Dose Plan	Check and Confirm	Treatment Record Form/ Clinical Register	Reporting
Image information on:					
GTV(s)	*	*			
CTV(s)	*	*			
PTV(s)	*	*			
tissue heterogeneities	*	*			
anatomical landmarks	*	*			
Orientation and position of					
reference plane		*		*	
other planes		*		*	
Normalization method		*		*	
ICRU Reference Point	*	*	*	*	*
Target absorbed dose per fraction	*	*	*	*	*
Total target absorbed dose					
at ICRU Reference Point	*	*	*	*	*
maximum		*		*	*
minimum	*	*		*	*
average		(*)		(*)	(*)
median		(*)		(*)	(*)
modal		(*)		(*)	(*)
others		(*)		(*)	(*)
Dose to organs at risk	*	*	*	*	*
Dose calculation method		*		*	*
Full dose distribution		*		*	(*)
BEAM PARAMETERS					
Beam #		*	*	*	
Radiation quality	*	*	*	*	*
SSD/SAD	*	*	*	*	*
Field sizes		*	*	*	*
Beam position	(*)	*	*	*	*
Beam direction	(*)	*	*	*	*
Gantry angle		*	*	*	
Collimator angle		*	*	*	
Other machine settings			*	*	
Wedges, compensators, etc.		*	*	*	*
Beam weight		*	*	*	(*)
Monitor units		*	*	*	
Peak absorbed dose		*	*	*	
Dose contribution to target dose		*		*	
Exit dose		*	(*)	*	
Technician's signature		*	*	*	
CONTROL MEASURES					
Port films	*	(*)	*	*	
Verification imaging	*		*	*	
In-vivo dosimetry	*		(*)	*	
Overall accuracy of treatment set-up			*	*	
TIME SCHEDULE					
Date of start	(*)		*	*	
Date of conclusion	(*)		*	*	
Number of fractions per day	*		*	*	*
Time interval between fractions	*		*	*	*
Time relation of other treatments	*		(*)	*	*
Total number of fractions	*	(*)	*	*	*
Total number of days	(*)		*	*	*

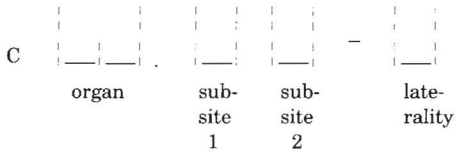
TABLE I.2—*Anatomical code*

The code given here is a suggestion of how an internationally accepted classification can be used to describe the Gross Tumor Volume and Clinical Target Volume. It is an adaptation from the International Classification of Diseases for Oncology, ICD-O, 2nd Edition (WHO, 1990), which, in turn, is based on the proposed 10th Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).

Since the ICD-O is not specific enough to describe anatomical structures in sufficient detail, a letter has been added to accomodate the necessary subsites for skin, soft tissue, bone, and lymph nodes. Laterality is also added by using the code for laterality from WHO Handbook for Standardized Cancer Registries (WHO, 1976b) as follows:

1 = right,
2 = left,
3 = central
4 = bilateral,
9 = unknown.

The full code thus has this format:



Examples are given in Fig. I.1., and in Appendix II.

C00–C14	ORAL CAVITY AND PHARYNX
C00.0	External upper lip
C00.1	External lower lip
C01.9	Base of tongue
C02.9	Mobile tongue
C03.0	Maxillary gingiva
C03.1	Mandibular gingiva
C04.9	Floor of mouth
C05.0	Hard palate
C05.1	Soft palate
C06.0	Cheek mucosa
C06.2	Retromolar area
C06.9	Oral cavity
C07.9	Parotid gland
C08.0	Submandibular gland
C08.1	Sublingual gland
C09.9	Tonsil
C10.1	Anterior surface of epiglottis
C10.2	Lateral wall of oropharynx
C10.3	Posterior wall of oropharynx
C10.9	Oropharynx
C11.9	Nasopharynx
C12.9	Pyriform sinus
C13.0	Postcricoid region
C13.2	Posterior wall of hypopharynx
C13.9	Hypopharynx
C14.0	Pharynx
C14.2	Waldeyer's ring
C15–C26	DIGESTIVE ORGANS
C15.3	Upper third of esophagus
C15.4	Middle third of esophagus
C15.5	Lower third of esophagus
C15.9	Esophagus
C16.0	Cardia
C16.1	Fundus of stomach
C16.2	Body of stomach
C16.9	Stomach
C17.0	Duodenum
C17.1	Jejunum
C17.2	Ileum
C17.3	Meckel's diverticulum
C17.9	Small intestine
C18.0	Cecum
C18.1	Appendix
C18.2	Ascending colon
C18.3	Hepatic flexure of colon
C18.4	Transverse colon
C18.5	Splenic flexure of colon
C18.6	Descending colon
C18.7	Sigmoid colon
C18.9	Colon
C19.9	Rectosigmoid junction
C20.9	Rectum
C21.0	Anus
C22.0	Liver
C22.0A	Right lobe of liver
C22.0B	Left lobe of liver
C22.1	Intrahepatic bile ducts
C23.9	Gallbladder
C24.0	Extrahepatic bile ducts
C24.1	Ampulla of Vateri
C25.0	Head of pancreas
C25.1	Body of pancreas
C25.2	Tail of pancreas
C25.4	Islets of Langerhans
C25.9	Pancreas
C30–C39	RESPIRATORY SYSTEM AND INTRATHORACIC ORGANS
C30.0	Nasal cavity
C30.1	Middle ear
C31.0	Maxillary sinus
C31.1	Ethmoid sinus
C31.2	Frontal sinus
C31.3	Sphenoid sinus
C32.0	Vocal cord
C32.1	Supraglottis
C32.2	Subglottis
C32.4	Sinus Morgagni
C32.9	Larynx
C33.9	Trachea
C34.0	Main bronchus
C34.1	Upper lobe, lung
C34.2	Middle lobe, lung
C34.3	Lober lobe, lung
C34.9	Lung
C37.9	Thymus
C38.0	Heart
C38.0A	Pericardium
C38.3	Mediastinum
C38.4	Pleura
C38.4A	Visceral pleura
C38.4B	Parietal pleura
C40–C41	BONES, JOINTS AND ARTICULAR CARTILAGE
C40.0	Long bones of upper limb, scapula and associated joints
C40.0A	Scapula
C40.0B	Acromioclavicular joint
C40.0C	Shoulder joint
C40.0D	Humerus
C40.0E	Elbow joint

TABLE I.2—*Continued*

C40.0F	Radius
C40.0G	Ulna
C40.1	Short bones of upper limb and associated joints
C40.1A	Wrist joint
C40.1B	Hand
C40.2	Long bones of lower limb and associated joints
C40.2A	Hip joint
C40.2B	Femur
C40.2C	Knee joint
C40.2D	Tibia
C40.2E	Fibula
C40.3	Short bones of lower limb and associated joints
C40.3A	Ankle joint
C40.3B	Foot
C41.0	Bones of skull and associated joints
C41.0A	Skull
C41.0B	Maxilla
C41.1	Mandible
C41.1A	Temporomandibular joint
C41.2	Vertebral column
C41.2A	Atlas
C41.2B	Vertebra C II
C41.2C	Vertebra C III
C41.2D	Vertebra C IV
C41.2E	Vertebra C V
C41.2F	Vertebra C VI
C41.2G	Vertebra C VII
C41.2H	Vertebra Th I
C41.2I	Vertebra Th II
C41.2J	Vertebra Th III
C41.2K	Vertebra Th IV
C41.2L	Vertebra Th V
C41.2M	Vertebra Th VI
C41.2N	Vertebra Th VII
C41.2O	Vertebra Th VIII
C41.2P	Vertebra Th IX
C41.2Q	Vertebra Th X
C41.2R	Vertebra Th XI
C41.2S	Vertebra Th XII
C41.2T	Vertebra L I
C41.2U	Vertebra L II
C41.2V	Vertebra L III
C41.2X	Vertebra L IV
C41.2Y	Vertebra L V
C41.3	Rib, Sternum, Clavicle and associated joints
C41.3A	Clavicle
C41.3B	Sternum
C41.3C	Costa I
C41.3D	Costa II
C41.3E	Costa III
C41.3F	Costa IV
C41.3G	Costa V
C41.3H	Costa VI
C41.3I	Costa VII
C41.3J	Costa VIII
C41.3K	Costa IX
C41.3L	Costa X
C41.3M	Costa XI
C41.3N	Costa XII
C41.4	Pelvic bones, Sacrum, Coccyx and associated joints
C41.4A	Pelvic bones
C41.4B	Ilium
C41.4C	Ischium
C41.4D	Pubic bone
C41.4E	Sacrum
C41.4F	Coccyx
C41.4G	Hip joint
C42	HEMATOPOIETIC AND RETICULOENDOTHELIAL SYSTEMS
C42.1	Bone marrow
C42.2	Spleen
C44	SKIN
C44.0	Skin of lip
C44.1	Eyelid
C44.1A	Upper eyelid
C44.1B	Lower eyelid
C44.2	External ear
C44.2A	Auricle
C44.2B	External auditory canal
C44.3	Skin of face
C44.3A	Forehead
C44.3B	Temple
C44.3C	Cheek
C44.3D	Nose
C44.3E	Nasal wing
C44.3F	Jaw
C44.4	Skin of scalp and neck
C44.5	Skin of trunk
C44.5A	Axilla
C44.5B	Breast
C44.5C	Chest wall
C44.5D	Scapular region
C44.5E	Abdominal region
C44.5F	Flank
C44.5G	Groin
C44.5H	Perineum
C44.5I	Anus
C44.6	Skin of upper limb and shoulder
C44.6A	Shoulder
C44.6B	Arm
C44.6C	Hand
C44.6D	Palm
C44.6E	Finger
C44.7	Skin of lower limb and hip
C44.7A	Hip
C44.7B	Leg
C44.7C	Ankle
C44.7D	Foot
C44.7E	Plantar region
C44.7F	Toe
C48	RETROPERITONEUM AND PERITONEUM
C48.0	Retroperitoneal tissue
C48.2	Peritoneum
C49	CONNECTIVE, SUBCUTANEOUS AND OTHER SOFT TISSUES
C49.0	Soft tissue of head and neck
C49.0A	Head
C49.0B	Face
C49.0C	Neck
C49.0D	Supraclavicular region
C49.1	Soft tissues of upper limb and shoulder
C49.1A	Shoulder
C49.1B	Arm
C49.1C	Hand
C49.2	Soft tissues of lower limb and leg
C49.2A	Hip
C49.2B	Thigh
C49.2C	Calf
C49.2D	Ankle

TABLE I.2—*Continued*

C49.2E	Foot
C49.3	Soft tissues of thorax
C49.3A	Axilla
C49.3B	Infraclavicular region
C49.3C	Chest wall
C49.3D	Scapular region
C49.4	Soft tissues of abdomen
C49.4A	Abdominal wall
C49.4B	Umbilicus
C49.5	Soft tissues of pelvis
C49.5A	Inguinal region
C49.5B	Perineum
C49.5C	Gluteal region
C50	BREAST
C50.0	Nipple
C50.1	Central portion of breast
C50.2	Upper-inner quadrant of breast
C50.3	Lower-inner quadrant of breast
C50.4	Upper-outer quadrant of breast
C50.5	Lower-outer quadrant of breast
C50.7	Accessory mammary gland
C50.9	Breast
C51–C58	FEMALE GENITAL ORGANS
C51.0	Labium majus
C51.1	Labium minus
C51.9	Vulva
C52.9	Vagina
C53.9	Cervix uteri
C54.1	Endometrium
C54.2	Myometrium
C54.9	Corpus uteri
C55.9	Uterus
C56.9	Ovary
C57.0	Fallopian tube
C57.3	Parametrium
C57.4	Uterine adnexa
C60–C63	MALE GENITAL ORGANS
C60.0	Prepuce
C60.1	Glans penis
C60.2	Body of penis
C60.9	Penis
C61.9	Prostate
C62.0	Undescended testis
C62.1	Descended testis
C62.9	Testis
C63.0	Epididymis
C63.1	Spermatic cord
C63.2	Scrotum
C64–C68	URINARY TRACT
C64.9	Kidney
C65.9	Renal pelvis
C66.9	Ureter
C67.7	Urachus
C67.9	Bladder
C68.0	Urethra
C69–C72	EYE, BRAIN AND OTHER PARTS OF CENTRAL NERVOUS SYSTEM
C69.0	Conjunctiva
C69.1	Cornea
C69.2	Retina
C69.3	Choroid
C69.4	Ciliary body
C69.5	Lacrimal gland
C69.6	Orbit (excl. eyeball)
C69.9	Eye
C70.0	Cerebral meninges
C70.1	Spinal meninges
C71.0	Cerebrum
C71.1	Frontal lobe
C71.2	Temporal lobe
C71.3	Parietal lobe
C71.4	Occipital lobe
C71.5	Ventricle
C71.6	Cerebellum
C71.7	Brain stem
C72.0	Spinal cord
C72.0A	Cervical cord
C72.0B	Thoracic cord
C72.0C	Lumbar cord
C72.0D	Sacral cord
C72.1	Cauda equina
C72.2	Olfactory nerve
C72.3	Optic nerve
C72.4	Acoustic nerve
C72.5	Cranial nerve
C73–C75	THYROID AND OTHER ENDOCRINE GLANDS
C73.9	Thyroid gland
C74.0	Cortex of adrenal gland
C74.1	Medulla of adrenal gland
C74.9	Adrenal gland
C75.0	Parathyroid gland
C75.1	Pituitary gland
C75.2	Craniopharyngeal duct
C75.3	Pineal body
C75.4	Carotid body
C75.5	Aortic body and other paraganglia
C77	LYMPH NODES
C77.0	Lymph nodes of head and neck
C77.0A	Occipital lymph nodes
C77.0B	Preauricular lymph nodes
C77.0C	Submandibular lymph nodes
C77.0D	Retropharyngeal lymph nodes
C77.0E	Cervical lymph nodes
C77.0F	Supraclavicular lymph nodes
C77.1	Intrathoracic lymph nodes
C77.1A	Lymph nodes of upper mediastinum
C77.1B	Lymph nodes of lower mediastinum
C77.1C	Hilar lymph nodes
C77.1D	Parasternal lymph nodes
C77.1E	Intercostal lymph nodes
C77.2	Intraabdominal lymph nodes
C77.2A	Celiac lymph nodes
C77.2B	Hepatic lymph nodes
C77.2C	Splenic hilar lymph nodes
C77.2D	Mesenteric lymph nodes
C77.2E	Para-aortic lymph nodes
C77.3	Lymph nodes of axilla or arm
C77.3A	Infraclavicular lymph nodes
C77.3B	Axillary lymph nodes
C77.3C	Cubital lymph node
C77.4	Lymph nodes of inguinal region or leg
C77.4A	Inguinal lymph nodes
C77.4B	Popliteal lymph nodes
C77.5	Pelvic lymph nodes
C77.5A	Iliac lymph nodes
C77.5B	Obturator lymph nodes
C77.5C	Sacral lymph nodes

TABLE I.3—*Code for sections*

The transverse planes are parallel planes perpendicular to the longitudinal axis of the body and (for the head and trunk) at 3–4 cm intervals.

TRANSVERSAL PLANES	
05	vertex of skull
06	9 cm above external auditory canal
07	6 cm above external auditory canal
08	glabella—external occipital protuberance
09	external auditory canal
10	CI—hard palate
11	CII
12	CIII
13	CIV—larynx
14	CV
15	CVI
16	CVII
20	ThI—acromio-clavicular joint
21	ThII
22	ThIII—sternal notch
23	ThIV
24	ThV
25	ThVI
26	ThVII
27	ThVIII—xiphoid process
28	ThIX
29	ThX
30	ThXI
31	ThXII
40	LI
41	LII—umbilicus
42	LIII—crista iliaca
43	LIV
44	LV
50	promontorium—anterior iliac spine
51	upper border of acetabulum
52	symphysis
53	tuber ischii
60	femur, upper half
61	femur, lower half
62	knee joint
63	tibia, upper half
64	tibia, lower half
65	ankle joint
66	foot
70	humerus, upper half
71	humerus, lower half
72	elbow joint
73	radius-ulna, upper half
74	radius-ulna, lower half
75	wrist
76	hand
PLANES PARALLEL TO THE LONGITUDINAL AXIS	
80	cranium, frontal section
81	pelvis, frontal section
85	cranium, sagittal section
86	spine and trunk, sagittal section
87	pelvis, sagittal section
SPECIAL PLANES	
90	

— The data should be unambiguous, and should also follow accepted concepts and definitions, in order to allow for pooling of information from a group of patients for evaluation.
— The record form must contain sufficient information for legal purposes, should such need arise.

In order to meet these requirements, certain mandatory data will have to be recorded. Furthermore, for the interpretation of treatment results, it may be useful also to record other data, which, from the point of view of the individual patient, may be considered to be optional.

A list of the different parameters that may be considered useful to be recorded is given in Table I.1. It conforms with the recommendations given in Report 42 [ICRU, 1987].

It may, for retrieval purposes, be useful to digitize the anatomical locations of the GTV and CTV as well as the location of sections for dose planning. Codes for these purposes are presented in Tables I.2. and I.3.

I.2 Description of Treatment Technique, Including Methods for Planning, Dose Calculation and Control, for the Purpose of Reporting

For reporting, it is recommended that the planning, technique, calculation, and control methods are described on the basis of the guidelines given below.

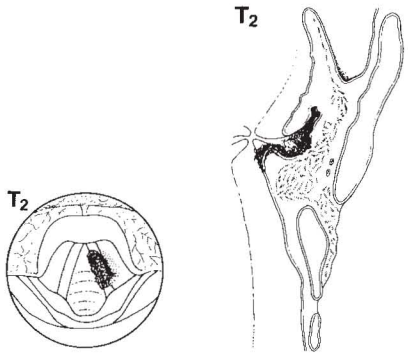
I.2.1 Treatment Planning

(i) Patient positioning (e.g., prone/supine, head/feet towards stand, sitting, etc.).
(ii) Immobilization devices (e.g., plaster of Paris cast, vacuum cast, bite blocks, etc.).
(iii) Localization and simulation performed at simulator or at treatment machine.
(iv) Treatment planning based on computed tomography or other relevant information.
(v) Optimization of dose distribution at the computer or at the simulator.

I.2.2 Technique

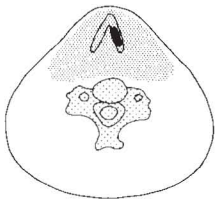
(i) Number and arrangement, location, and direction of the beams in relation to the patient.
(ii) Stationary beams with SAD or SSD technique and distance, or moving beam technique and arc.
(iii) Field sizes: geometrical field size usually corresponds to the 50 per cent isodose curve. For fixed SSD, the field size is usually given at the skin, for fixed SAD the field size is usually given at the isocenter. When field borders are parallel to the planning section, the field size in the section should be given first.

Fig. I.1. Gross Tumor Volume and corresponding Clinical Target Volume for four different clinical situations described in anatomical terms and codified according to some current coding systems (the ICD-O[9], ICD-O[10], WHO Handbook for Standardized Cancer Registries [for laterality], and T-SNOMED). See Section 3.2. Gross Tumor Volume = black area; Clinical Target Volume = dotted area.



T2 larynx

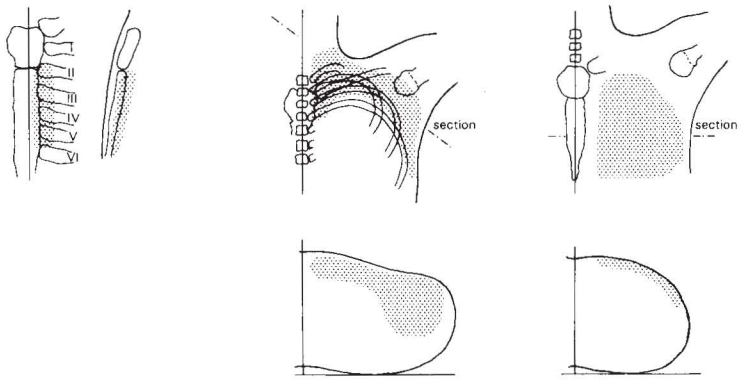
Anatomical structure	ICD-O(9)	ICD-O(10)	Laterality	T-SNOMED
Gross tumor volume				
Left vocal cord	161.0 (i)	C32.0	2	T-24410
Left ventricular cavity	161.1 (vi)	C32.1	2	T-24340
Left ventricular band	161.1 (v)	C32.1	2	T-24322
Clinical target volume				
Larynx	161.1	C32.9	3	T-24700
Cervical lymph nodes, bilat.	196.0	C77.0	4	T-08200



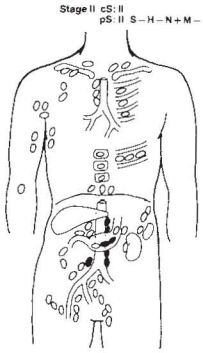
a. Glottic carcinoma (the figures illustrating GTV are taken from the TNM Atlas ([UICC, 1982]).

Postoperative breast after left MRM

Anatomical structure	ICD-O(9)	ICD-O(10)	Laterality	T-SNOMED
Gross tumor volume				
—	—	—	—	—
Clinical target volume				
Axillary lymph nodes, left	196.3	C77.3	2	T-08710
Supraclav. " "	196.0	C77.0	2	T-08220
Parasternal " "	196.1	C77.1	2	T-08350
Thoracic wall "	171.4	C49.3	2	T-Y2150

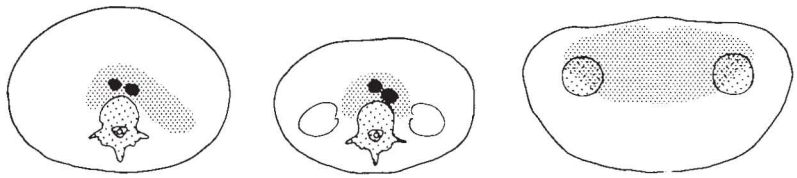


b. Breast cancer after modified radical mastectomy.

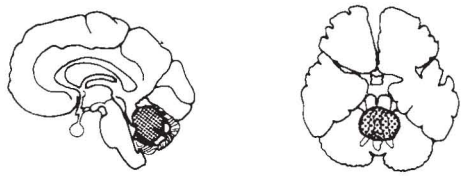


Hodgkins disease stage II

Anatomical structure	ICD-O(9)	ICD-O(10)	Laterality	T-SNOMED
Gross tumor volume				
Paraaortic lymph nodes	196.2	C77.2	3	T-08480
Celiac lymph nodes	196.2	C77.2	3	T-08410
Clinical target volume				
Splenic pedicle	196.2	C77.2	–	T-08472
Celiac lymph nodes	196.2	C77.2	3	T-08410
Paraaortic lymph nodes	196.2	C77.2	3	T-08480
Iliac lymph nodes	196.6	C77.5	4	T-08610
Inguinal lymph nodes	196.5	C77.4	4	T-08810

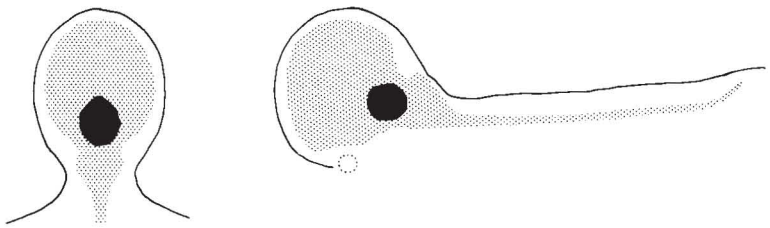


c. Abdominal Hodgkin's disease, stage II (the figure illustrating GTV is taken and modified from TNM Atlas [UICC, 1982]).



Medulloblastoma of 4th ventricle

Anatomical structure	ICD-O(9)	ICD-O(10)	Laterality	T-SNOMED
Gross tumor volume				
Roof of the 4th ventricle	191.5	C71.7	3	T-X1820
Clinical target volume				
Cerebellum	191.6	C71.6	3	T-X6000
Intracranial meninges	192.1	C70.0	–	T-X1410
Spinal meninges	192.3	C70.1	–	T-X1115



d. Medulloblastoma (the figure illustrating GTV is taken from Clinical Oncology, A Multidisciplinary Approach [ACS, 1983].

(iv) Radiation quality for each beam.
  * Orthovoltage or low-energy x-ray beams (< 300 kV): the generating potential (kV) and HVL (mm Al or Cu).
  * Gamma ray beams: the radionuclide (element and mass number).
  * X-ray beams > 2 MV: the nominal accelerating potential, and the type of accelerator.

(v) Beam modification devices (wedge filters, compensators, shielding blocks, individually cut blocks, etc.) should be indicated.

I.2.3 Absorbed Dose Calculation

(i) Dose calculation method (computerized, or manual), 1-D, or 2-D, or 3-D. The reporting should be in agreement with definitions of the different levels for reporting (Section 3.3.4).

(ii) Correction for tissue inhomogeneity (state whether performed or not). The type of correction used should be indicated, e.g., 3-D or 2-D correction for air cavities, lung, bone, etc., or full correction for the electron density.

(iii) Beam weighting (at peak dose point, specification point, isocenter, or other point).

I.2.4 Quality Control

(i) Check and confirm systems.

(ii) Verification imaging (when during treatment, frequency, and acceptability).

(iii) In-vivo dosimetry (type of measurements, frequency, and acceptability).

I.2.5 Special Comments

— The reporting of absorbed dose for external beam therapy should be accompanied by information on the time dose pattern including, at least, the number of fractions and the overall time (in days). The first and the last day of treatment are then included. Unless otherwise stated, it is understood that the fractionation is regular (5 times per week) with equal fractions, all fields being irradiated at each fraction. The position and length of any gap or interruption must be given as well as any change in dose per fraction.

— All transverse sections of the patient should be as viewed from the foot end of the patient irrespective of the patient position. The right and the left side of the section should be indicated (e.g., Dxt/Sin, or Right/Left). For other sections, the orientation should also be clearly indicated in the figure.

— For comparison purposes, ^{60}Co gamma rays should be taken as the reference radiation. The same RBE applies for photon radiations with a nominal energy of at least 2 MV, and for electron radiation in the range 1–50 MeV. For orthovoltage x-ray therapy, the RBE is larger than unity value, and a conversion factor of 1.18 may be considered adequate for the normal radiotherapy procedures. If RBE-corrected values are reported, this should be stated.

— When isodose curves are shown (relative or absolute values), care should be taken so that the correct number is unambiguously related to the correct isodose line. It is an advantage if, e.g., the "hotter" side of an isodose can be indicated, since this will, in some instances, indicate if a small volume/area is a hotter area or cooler area than the surroundings.

— When isodose plots are shown with relative dose values, it is an advantage if the isodose through the ICRU Reference Point is given the relative value 100%.

— A report on radiation therapy must always give the absorbed dose(s) in Gy or cGy. Furthermore, biologically weighted doses, calculated according to specified biological models may be of interest.

— Recording of target absorbed dose rate may be useful, and is recommended for values below 0.1 Gy per minute for any part of the Planning Target Volume.

— It should always be clearly stated if correction for tissue inhomogeneity has been carried out or not when calculating the absorbed doses. The method used for calculation should also be reported. If corrected values are reported, then, for intercomparison purposes, the uncorrected values should also be given (see section 3.3.3).

Appendix II

Examples of the Use of the Recommendations in Some Different Beam Arrangements

The patients #1 through #5 show situations of more and more complex character through levels 2 and 3 (see sections 3.4 and 3.5).

Note: The designations in [ ] denote anatomical site of GTV, CTV, and organs at risk, and anatomical level of section(s) for dose planning, according to the code list in Appendix I, Tables I.2 and I.3.

GTV = Gross Tumor Volume
CTV = Clinical Target Volume
PTV = Planning Target Volume

Case number 1. Lung Cancer.

CLINICAL SITUATION	65-year-old male, smoker, presented with a persistent cough. Clinical examination normal. Chest radiography showed a right hilar mass. Bronchoscopy showed endobronchial tumor in the right main bronchus. Biopsy revealed squamous cell carcinoma. CT scan confirmed lesion in the right bronchus with a 3 cm × 3 cm mass of lymphadenopathy at the right hilum, no evidence of mediastinal lymphadenopathy. Clinical stage T2 N1 MO.
AIM OF THERAPY	Patient inoperable. Palliative radiotherapy for the purpose of relieving cough is planned.
GTV	Primary endobronchial tumor and hilar lymphadenopathy [C34.0-1, C77.1C-1].
CTV	CTV I: GTV + local subclinical extensions [C34.0-1, C77.1C-1]. CTV II: Mediastinal regional lymph nodes [C77.1A].
PTV	A joint PTV is defined for the two CTVs.
ORGANS AT RISK	A: Spinal cord [C72.0B]. B: Left lung [C34.9-2].
PRESCRIBED DOSES	PTV: 30 Gy in 10 fractions over 2 weeks.
ACCEPTED DOSES TO ORGANS AT RISK	A: Less than 35 Gy in 10 fractions. B: As low as possible.
TENTATIVE TECHNIQUE	AP-PA beams.
PATIENT POSITIONING AND IMMOBILIZATION	Supine with head on standard head rest and arms by side. No special patient fixation.

SECTION FOR DOSE PLANNING	One CT-scan through the centre of the GTV [26].
DOSE CALCULATION	Central beam isodose data without inhomogeneity correction.
TECHNIQUE	^{60}Co. Two opposed equally weighted beams with direction 0° and 180°, respectively. Isocentric technique. Field width 10 cm (both). Field length 12 cm (both). Two corners blocked in each beam. No wedges.
CONTROL MEASURES	Simulator port films. Treatment verification films × 2. Measurement of entrance dose × 2.

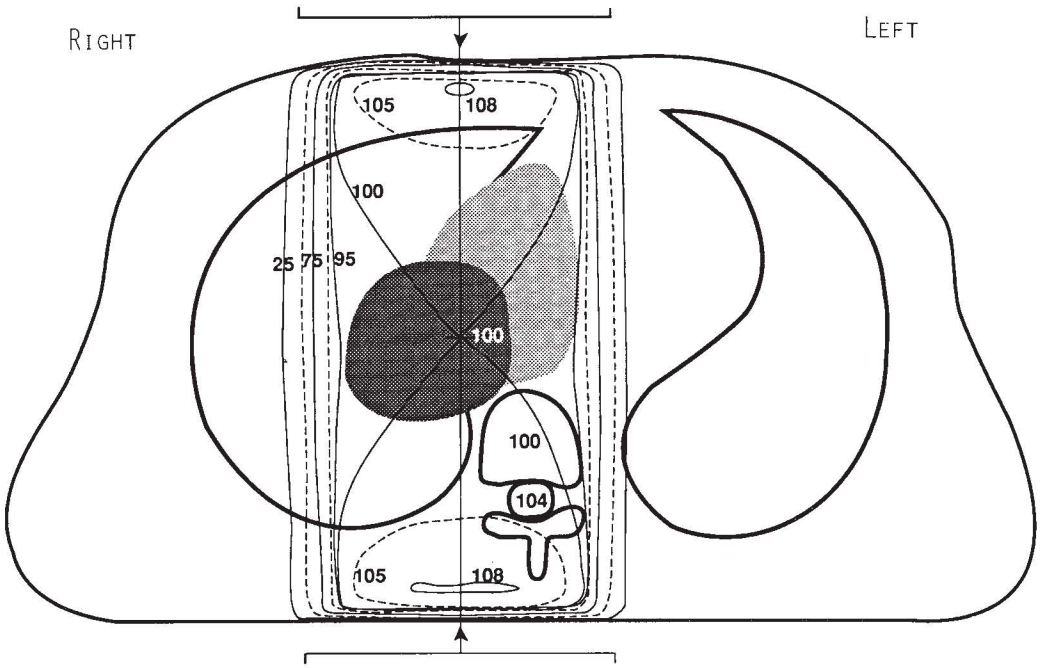


Fig. II.1. The PTV I for the primary tumor is indicated by the densely dotted area. The PTV II for mediastinal lymph nodes is indicated by the sparsely dotted area.

DOSE SPECIFICATION FOR REPORTING	Dose distribution, see Fig. II.1. 1. ICRU. Reference Point = midway between beam entrances, in the center of the PTV (100%). 2. Maximum and minimum dose to the PTV according to the dose plan (102%–95%). 3. Hot Spot (outside the PTV) = 108%.

Case number 2. Breast Cancer.

CLINICAL SITUATION	56-year old female presented with a 2 cm × 1.5 cm hard, mobile lump in the upper outer quadrant of the left breast. There was no fixation to skin or underlying muscle, and no regional lymphadenopathy palpable. Mammography showed a mass suspicious of malignancy. Clinical diagnosis T1a N0 M0 carcinoma. Excision biopsy showed infiltrating ductal carcinoma. Wide local excision and axillary dissection was then performed. Histology showed complete excision of primary tumour and 12 axillary lymph nodes excised, all 12 free of metastases. Surgical clips were placed in the tumour bed at time of re-excision.
AIM OF THERAPY	Radical radiotherapy after radical surgery. No systemic therapy.
GTV	No GTV to be defined.
CTV	CTV I : The local tumour bed with or without the use of surgical clips [C50.4-2]. CTV II : The entire breast (outside CTV I, see above), the extent to be defined anatomically by palpation and CT scan [C50.9-2].
PTV	For CTV I: A 1 cm margin is added to allow for movements of the chest wall due to respiration, and variation in repositioning of the beams. For CTV II: A 1 cm margin is added to allow for movements of the chest wall due to respiration, and variation in repositioning of the beams. (See Fig. II.2.)
ORGANS AT RISK	A: Lung tissue [C34.9-2]. B: Myocardium [C38.0]. C: Remaining breast [C50.9-1].
PRESCRIBED DOSES	PTV I: 64 Gy in 32 fractions over 6.5 weeks. PTV II: 50 Gy in 25 fractions over 5 weeks.
ACCEPTED DOSES TO ORGANS AT RISK	A: 30 Gy in at most 200 cm^3. B: 30 Gy in at most 30 cm^3. C: Less than 5 Gy.
TENTATIVE TECHNIQUE	PTV I: Two opposed tangential photon beams plus electron beam. PTV II: Two opposed tangential photon beams.
PATIENT POSITIONING	PTV I and II: Supine with arms raised above and immobilization of the head and on a wedge to make the sternum horizontal. Immobilized using plastic cast or arm poles and foot board.
SECTION FOR DOSE PLANNING	PTV I AND II: Transverse section through the site of the excised tumor [24].
DOSE CALCULATION	Single plane dose calculation using photon beam generating functions with correction for oblique incidence and tissue inhomogeneity, but no correction for loss of sidescatter in 3-D. Electron beam calculation based on uncorrected isodose data.
TECHNIQUE	PTV I: (a) Tangential photon beams as described for PTV II. (b) 9 MeV electrons. Beam perpendicular to skin. Beam direction 60°. SSD 100 cm. Field width 5 cm. Field length 4 cm. 100% in dose maximum.

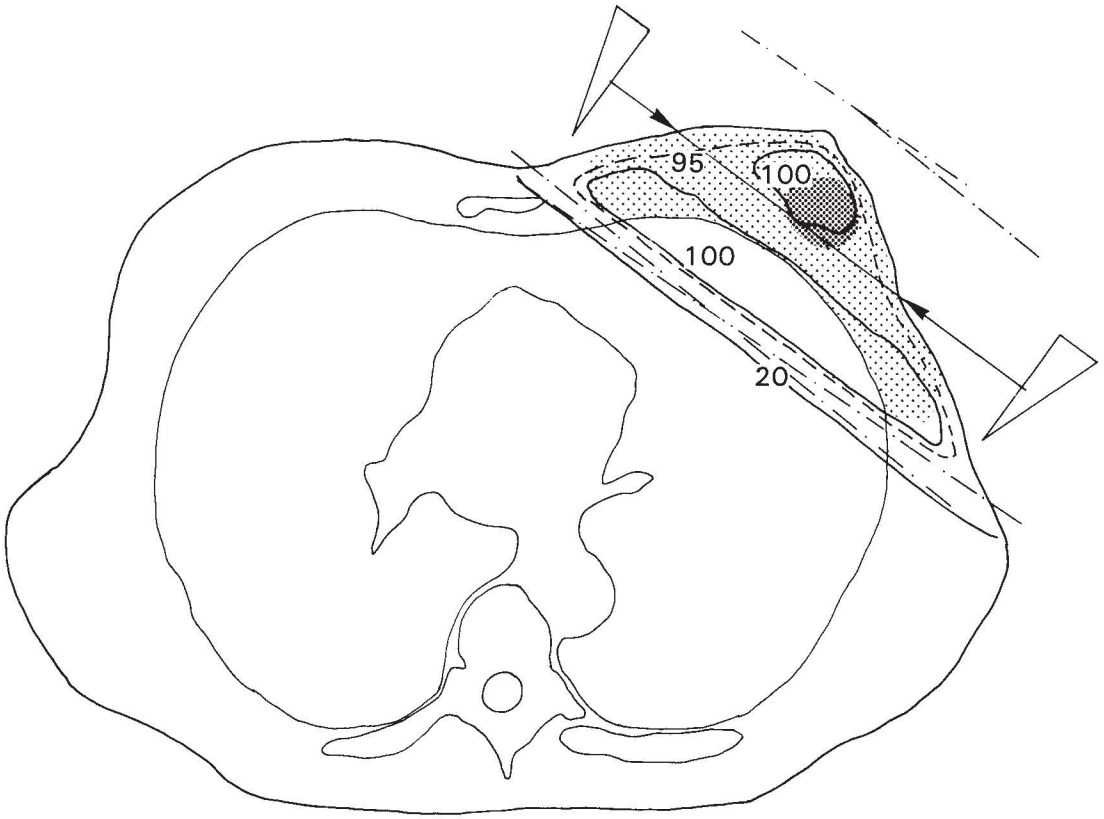


Fig. II.2.a. Isodose values (relative values) for the dose distribution with two tangential 6 MV photons beams. The PTV I is indicated by the densely dotted area and PTV II by the sparsely dotted area. The dose specified for prescription and for recording of this part of the whole treatment is 50 Gy on the beam axes midway between the beam entrances, which also corresponds to the center of the PTV II.

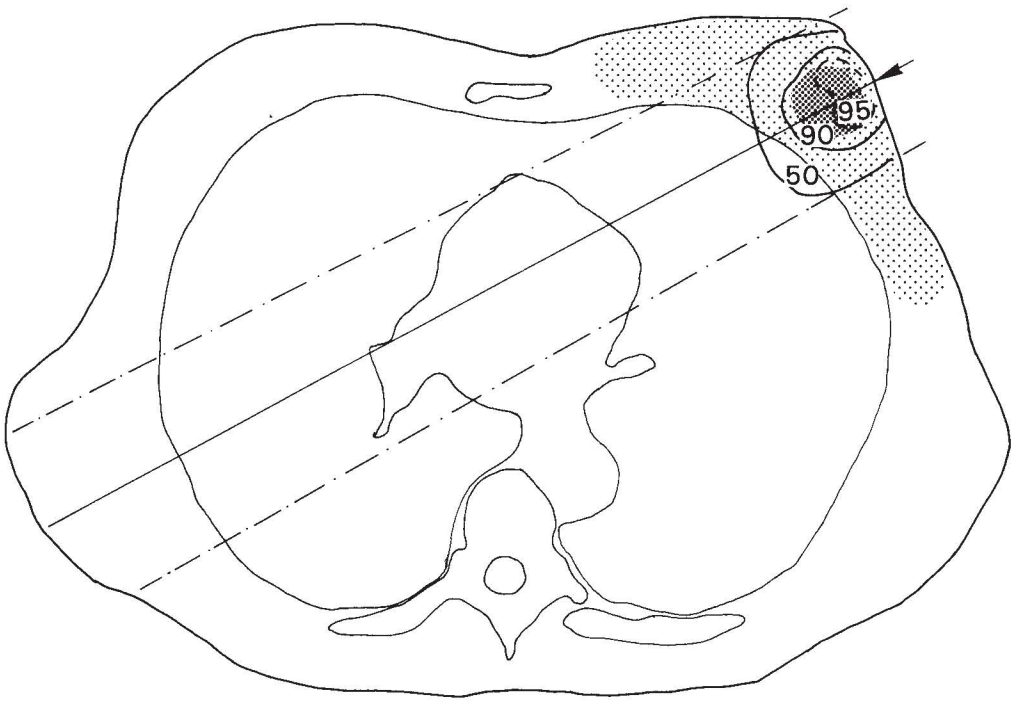


Fig. II.2.b. Isodose values (relative values) for the dose distribution with one 9 MeV electron beam for PTV I (indicated by densely dotted area). The dose specified for prescription and for recording of this part of the whole treatment is 100% (the beam energy chosen so that this value is found near the center of the PTV). The absolute dose value is 14 Gy.

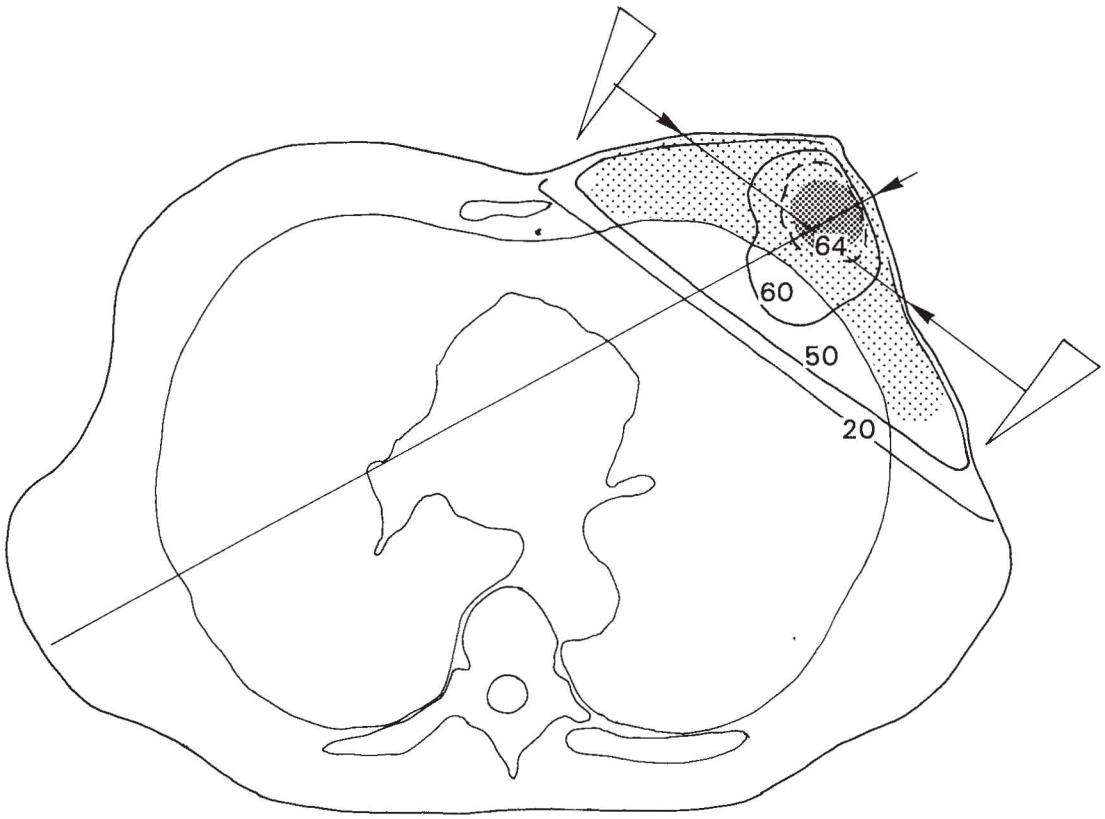


Fig. II.2.c. Isodose values (absolute values in Gy) for the total dose distribution. For reporting purposes, the following specification of dose and fractionation was adopted:

For PTV I the dose for reporting was specified at the center of PTV I = 64 Gy, with the variation 66–60 Gy, given in 32 fractions over 6.5 weeks.

For PTV II the dose only from the two photon beams, midway between the beam entrances was taken to be representative of the dose to the breast tissue outside the "boosted" volume (thus disregarding the electron treatment of PTV I). Total dose to PTV II is 50 Gy, with the variation 64–50 Gy, given in 25–32 fractions over 5–6.5 weeks.

	PTV II: 6 MV photons. Two opposed beams. Beam direction 305° and 125°. Isocentric technique. Field width 8 cm. Field length 19 cm. Wedge 15° and 15°. Beams equally weighted at isocenter. Start treatment of both PTVs with the tangential photon beams, then add with electrons to PTV I.
CONTROL MEASURES	Simulator port films. Verification films of photon beams once a week. Diode measurements of entrance dose × 2.
DOSE SPECIFICATION FOR REPORTING	PTV I: 1. Centrally in PTV I. (= at the ICRU Reference Point 1). 2. Maximum and minimum. PTV II: 1. At isocenter of photon beam treatment (ICRU Reference Point 2) only, supposing this to be representative of the central dose in the whole breast (PTV II) outside the volume corresponding to the tumor bed (PTV I). 2. Maximum and minimum.

Case number 3. Cancer of the Prostate.

CLINICAL SITUATION	57-year-old male developed acute urinary retention. Rectal examination revealed a hard prostate gland with an enlarged left lateral lobe. No palpable extensions outside the prostate. Clinical diagnosis T2 carcinoma of the prostate. No other abnormality on physical examination. Cystoscopy revealed prominent left lateral lobe of prostate gland. Biopsy showed adenocarcinoma of the prostate gland, poorly differentiated tumour (G 3). I.V. pyelography, isotopic bone scan, chest radiograph and acid phosphatases were all normal. CT scan of the pelvis confirmed T2 staging. No involvement of seminal vesicles or lymph nodes.
AIM OF THERAPY	Radical radiotherapy to prostate gland and pelvic lymph nodes.
GTV	Tumour within the prostate gland.
CTV	CTV I: The entire prostate gland with good left lateral margin. Define by CT scan and palpation [C61.9]. CTV II: The regional lymph nodes in the obturator, internal and external iliac and pre-sacral lymph nodes and also common iliac lymph nodes [C77.5B-4, C77.5A-4, C77.5C].
PTV	For CTV I and II to allow for variation in repositioning in the beams. There is little organ movement. (See Fig. II.3.)

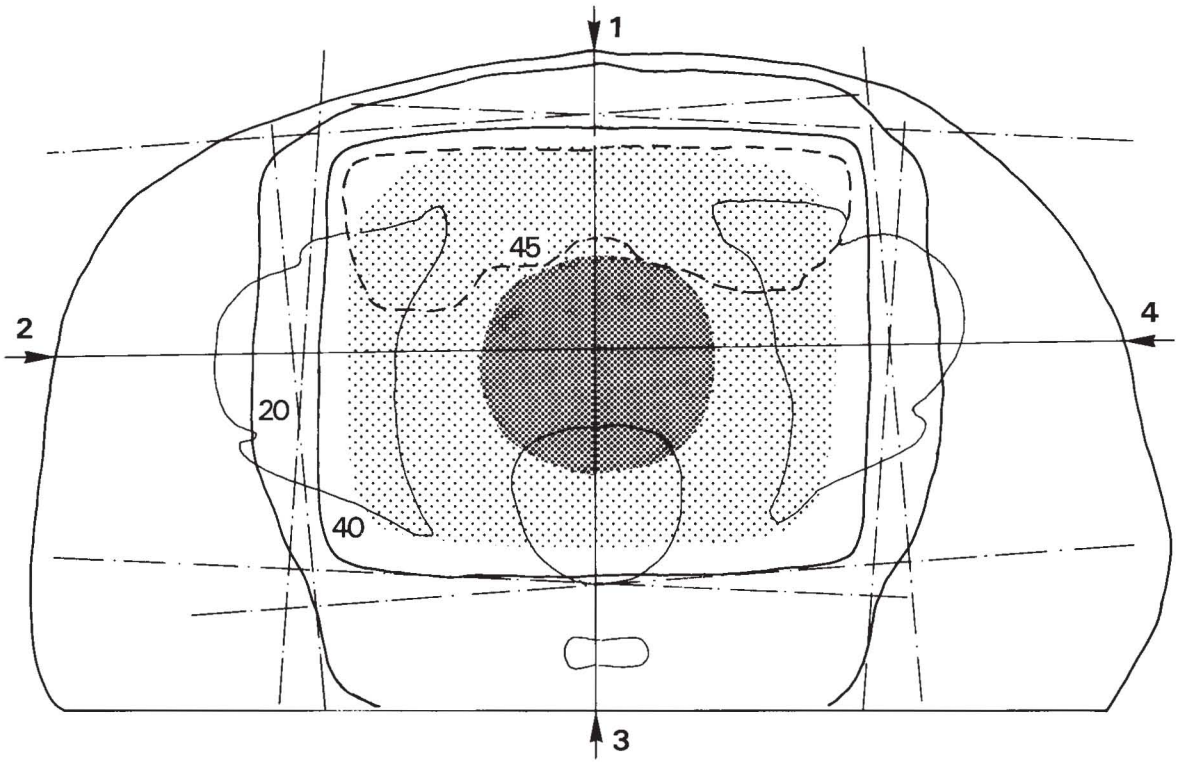


Fig. II.3.a. Isodose (absolute values) distribution for the first treatment of both PTV I and II (the latter indicated by the sparsely dotted area, and the former indicated by the densely dotted area). The dose specified for prescription and for recording (44 Gy) is at the intersection of the beams.

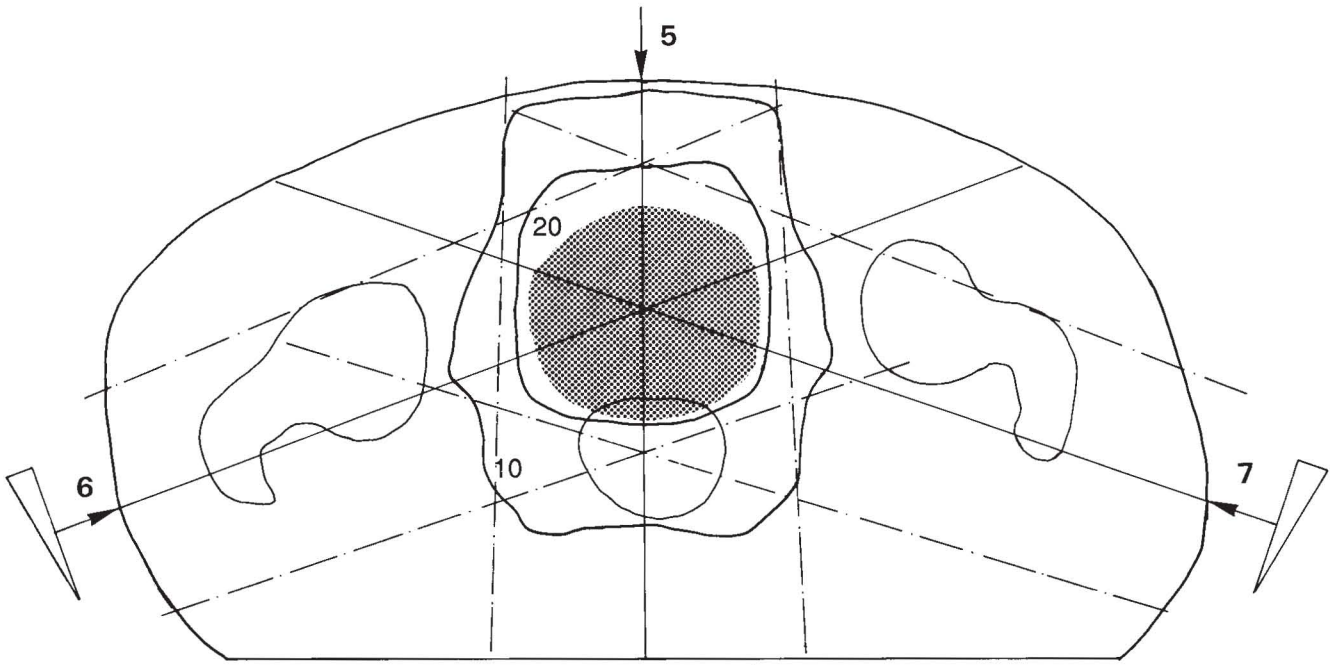


Fig. II.3.b. Isodose (absolute values) distribution for the second treatment intended to be only of PTV I (indicated by the densely dotted area). The dose specified for prescription and for recording (22 Gy) is at the intersection of the beams.

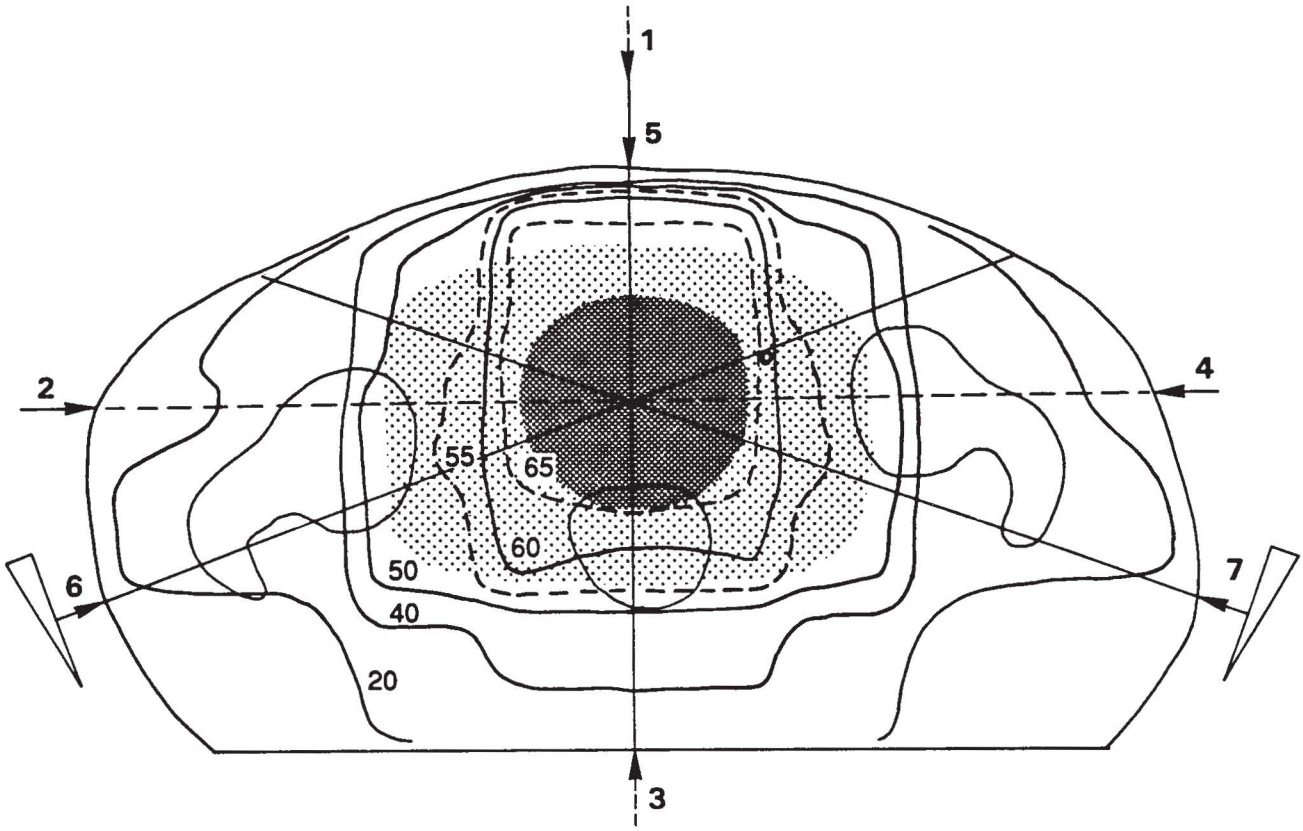


Fig. II.3.c. Isodose (absolute values) distribution of the total treatment. For reporting purposes, the following specification of dose and fractionation was adopted:

For PTV I (the primary tumor and prostate) the dose at the intersection (see below) of the 7 beams and the variation of dose in PTV I = 66 Gy (69–66) given in 32 fractions over 45 days.

For PTV II (the regional lymph nodes) the dose at a point considered significant for the regional lymph nodes (indicated by the circle) = 65 Gy), and the variation in dose in PTV II = 68 − 52 Gy, given in 22–32 fractions over 31–45 days.

Note: The example illustrates the problems encountered in "boost" therapy. It is usually only possible to achieve a homogeneous dose to PTV I. It is recommended that a display of the total dose distribution from the combined treatments to both PTVs is made at the outset. Also, for this case, note that for the dose planning of the two different parts of the whole treatment, different sections were used, but for reporting purposes in this case, only one section was considered, disregarding the possible importance of 3-D evaluation. The true minimum dose of PTV II will then be lower than the one stated above, and of the order 42 Gy at the most cranial section.

ORGANS AT RISK	A: Small bowel [C17.9]. B: Rectum—posterior wall [C20.9]. C: Femoral heads [C41.4G-4].
PRESCRIBED DOSES	PTV I: 66 Gy in 32 fractions. PTV II: 44 Gy in 22 fractions.
ACCEPTED DOSES TO ORGANS AT RISK	A: Small bowel below 44 Gy. B: As low as possible. C: Below 35 Gy.
TENTATIVE TECHNIQUE	PTV I and II: Four beams (anterior, posterior, right and left lateral). PTV I: Anterior and two posterior oblique beams.
PATIENT POSITIONING AND IMMOBILIZATION	PTV I and II: Supine with head on standard head rest and arms on chest. No cast immobilization. Laser alignment and skin tattos.
SECTIONS FOR DOSE PLANNING	PTV II: Principal section through center of PTV II. Other sections used for localization of target volume [51]. PTV I: Principal section through center of PTV I [52].
DOSE CALCULATION	Dual plane but not off-axis dose calculation based on generating function, corrected for oblique incidence and tissue inhomogeneity.
TECHNIQUE	PTV I and II: 8 MV photons. Anterior, posterior, right and left lateral beams. Beam directions 0° and 180° (ant & post) and 90° and 270° (laterals). Isocentric technique. Field width 16 cm (ant & post). Field width 12 cm (laterals). Field length 16 cm (all beams). Weight at specification point 28%, 28%, 22%, and 22%. PTV I: 8MV photons. Anterior and right and left posterior oblique beams. Beam directions 0°, 250°, 110°. Isocentric technique. Field width 8 cm (anterior) and 7 cm (posterior oblique beams). Field length 9 cm. Wedge 15° for posterior oblique beams. Weight 46%, 27%, and 27%. Start treating both PTVs together, then treat only PTV I.
CONTROL MEASURES	Simulator port films. Verifications films of photon beams once a week.
DOSE SPECIFICATION FOR REPORTING	PTV I: 1. At isocenter (ICRU Reference Point 1). 2. Maximum and minimum. PTV II: 1. A point is selected that is considered to be representative for the regional lymph nodes (ICRU Reference Point 2) 2. Maximum and minimum.

Case number 4. Cancer of the Floor of the Mouth.

CLINICAL SITUATION	58-year old male presented with a 4.5 cm x 3.5 cm × 4.0 cm ulcerated tumor in the left floor of the mouth. The tumour extended into the tongue but did not reach the midline. It did not involve the submandibular salivary gland. There was no fixation to the mandible. There were no palpable regional lymph nodes. Physical examination otherwise unremarkable. Clinical stage = T4 N0 M0. Biopsy showed moderately differentiated squamous cell carcinoma. The patient was considered unfit for radical surgery.
AIM OF THERAPY	Radical radiotherapy. No surgery, no systemic therapy.
GTV	Demonstrated tumor in the floor of the mouth.
CTV	CTV I: GTV + local subclinical extension [C04.9-2]. CTV II: The ipsilateral regional lymph nodes in the submandibular region, the neck, and the supraclavicular fossa [C77.0C-2, C77.0E-2, C77.0F-2].
PTV	1 cm margin is added to allow for movements and variation in beam set up. Note I: CTV I is well located inside CTV II and thus needs no special margin for planning purpose, since no external beam boost therapy was intended. Note II: Since the dose to the cord would have been unacceptable with the same margin around the CTVs in all direction, the compromise was made to retain the prescribed dose (see below) but accept a smaller positional margin close to the cord. Extra careful checking of the beam positioning close to the cord then becomes necessary. (See Fig. II.4.)
ORGANS AT RISK	A: Right parotid gland [C07.9-1] B: Spinal cord [C72.0A]
PRESCRIBED DOSES	66 Gy in 33 fractions over 6.5 weeks.
ACCEPTED DOSES TO ORGANS AT RISK	A: At most 20 Gy. B: At most 46 Gy.
TENTATIVE TECHNIQUE	Two photon beams.
PATIENT POSITIONING AND IMMOBILIZATION	Supine in individualized plastic casts. Arms along side. Use mouth bites to spare upper oral cavity.
SECTION FOR DOSE PLANNING	See Fig. II.4.a. 1. One section (#I) at the level of the GTV (principal plane) [11]. 2. One section (#II) at the level of the larynx [13]. 3. One section (#III) at the level of the supraclavicular fossae [20].
DOSE CALCULATION	True 3-D dose planning based on the 3 sections and interpolated volume, using pencil beam photon algorithms.

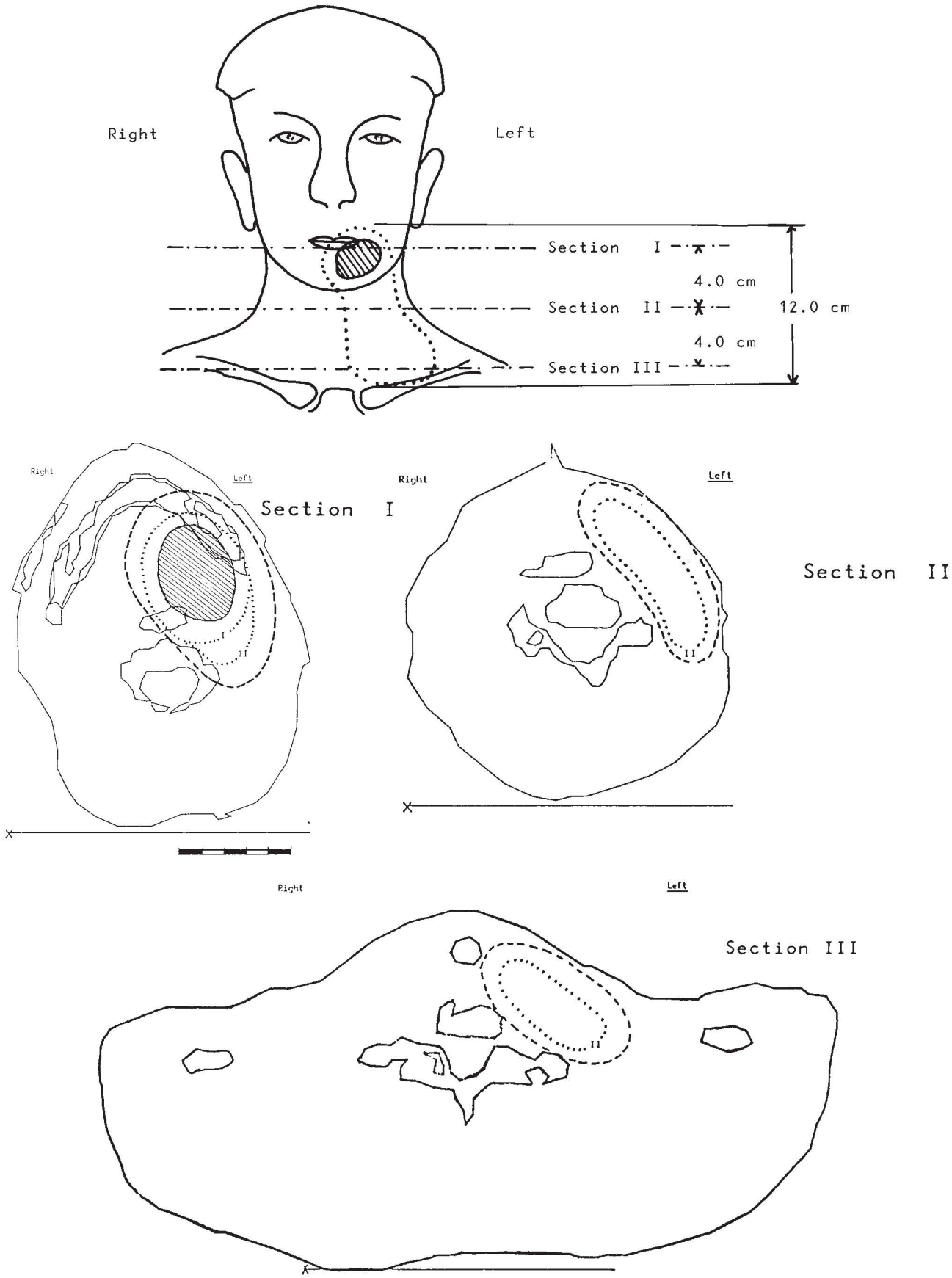


Fig. II.4.a. Schematic presentation of the GTV and CTVs and the 3 different sections used for dose planning. The height of the PTV = 12 cm. GTV = Striated area. CTV I = Dotted line (I). CTV II = Dotted line (II). PTV = Dashed line.

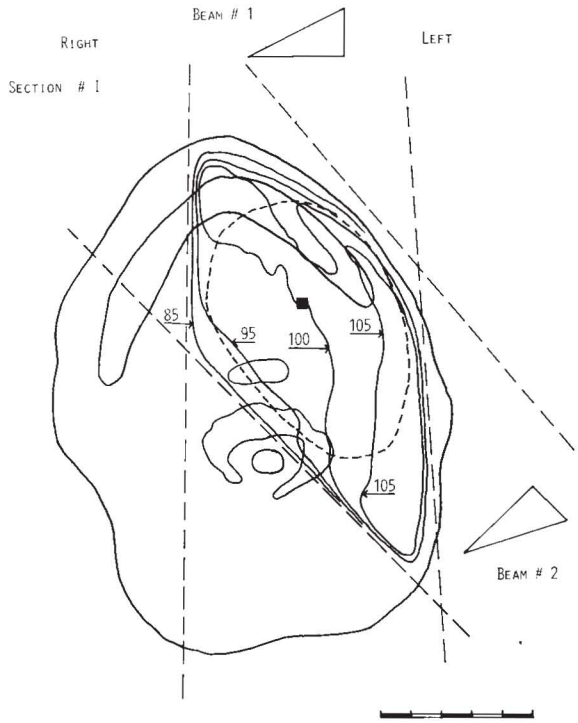


Fig. II.4.b. Dose distribution (relative values normalized to the specification dose, the 85%, 95%, 100%, and 105% being shown in the graphs) in section #I, at the level of the GTV. This level was considered to be the most relevant for dose specification rather than level #II (which is the level of the intersection of the central rays, but where there is no GTV). Thus, an ICRU Specification Point 2 was defined in section #I centrally in the GTV (indicated by the filled square). The dose prescribed at this Reference Point 2 is 100% = 66 Gy.

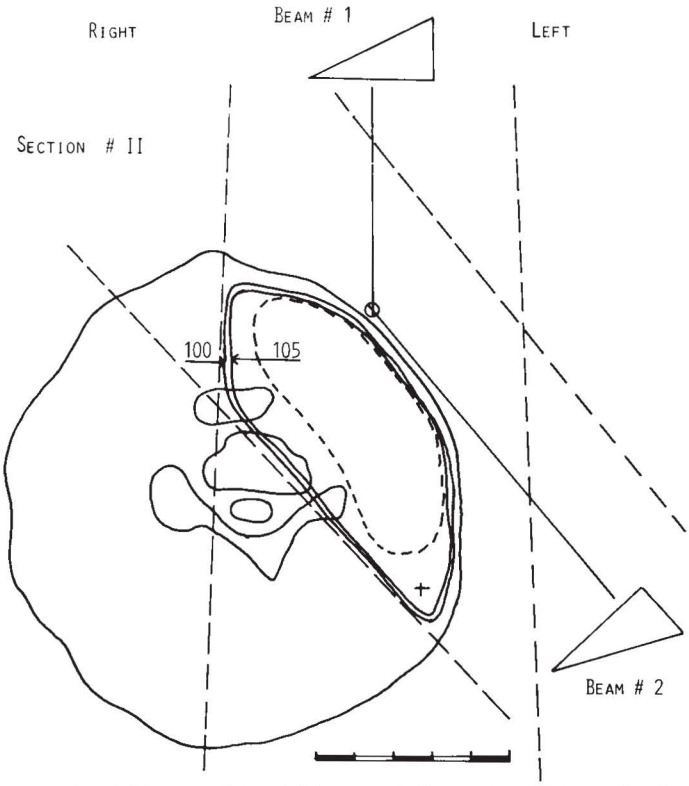


Fig. II.4.c. Dose distribution in section #II (=central plane). The cross indicates the position of the single largest dose value in the whole volume.

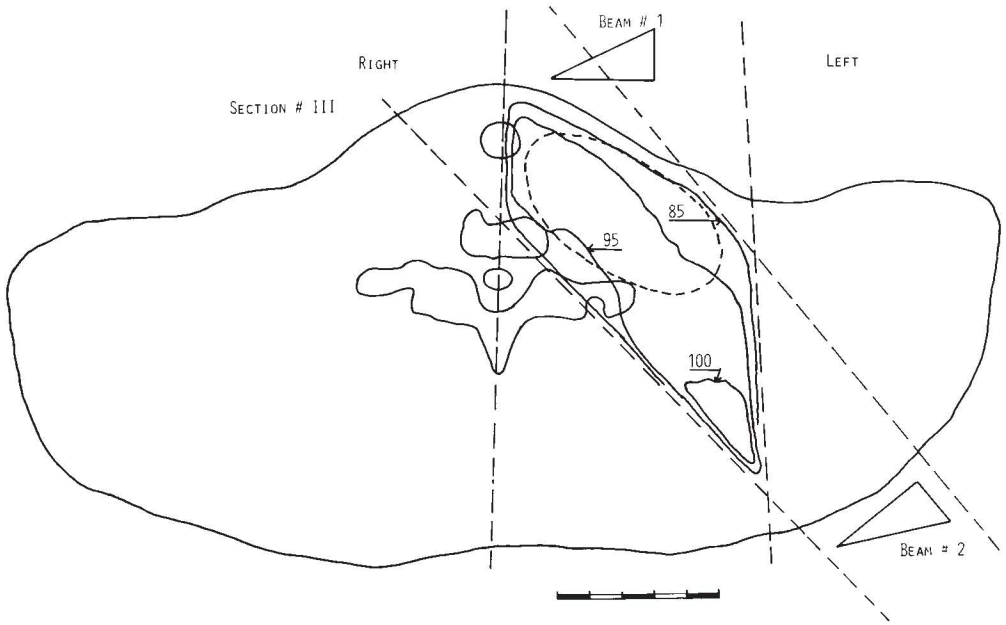


Fig. II.4.d. Dose distribution in section #III.

TECHNIQUE

6 MV photons.
Two beams.
Beam angles 0° and 140°.
Isocentric technique. The central beams intersect at the body surface (at the level of section #II).
Field width 7.4 cm.
Field length 14 cm.
Beams blocked using "beam's eye view."
Wedge +30° and −30°.
Beams equally weighted.
Collimator rotation: beam #1 = 17°, beam #2 = 0°.

CONTROL MEASURES

Simulator port films. Verification films of photon beams three times a week (with special attention to the medial borders, see above).
Diode measurements of entrance dose × 2.

DOSE SPECIFICATION FOR REPORTING

1. Centrally in PTV in section # I (ICRU Reference Point 2) (since the beams intersect at the level of section # II where there is only subclinical disease, and furthermore, they do not intersect well within the tissues of the patient) = 66 Gy.
2. Maximum and minimum doses in PTV (to be found in sections #II and III, respectively) = 108% (71 Gy) and 84% (=55 Gy), respectively. Note that the minimum dose can be raised by using beam compensating filters, bolus to diminish the effect of build-up, or additional treatment to section #III.
3. Furthermore, the following dose parameters to the PTV are available:
   — average value = 102% (standard deviation = 6.6).
   — median value = 101%,
4. Organs at risk:
   Spinal cord dose = maximum 50% = 33 Gy.
   Dose to the right parotid gland = $<15\%$ = <10 Gy.

Case number 5. Liposarcoma of the Thigh.

CLINICAL SITUATION	A 38-year old male presented with a painless mass in the right posterior thigh. Clinical and radiological examination indicated a liposarcoma in the long head of the biceps femoris muscle, which was verified by means of fine needle aspiration biopsy. At subsequent operation, the lateral part of the tumor was found to protrude out of the muscle. Microscopically, a grade IV liposarcoma was diagnosed, and the surgical margin was classified as probably not radical. Thus postoperative radiotherapy was indicated.
AIM OF THERAPY	Radical radiotherapy to avoid local recurrence.
GTV	Not to be defined, since there was no demonstrable tumor left after surgery.
CTV	Posterior compartment of the right thigh [C49.2B-1].
PTV	To allow for variations in set-up; organ movement is negligible. (See Fig. II.5)
ORGANS AT RISK	The testes were carefully pushed well outside the beams [C62.9-4].
PRESCRIBED DOSE	51 Gy in 17 fractions over 24 days.
ACCEPTED DOSE TO ORGANS AT RISK	Testes: as low as possible.
TENTATIVE TECHNIQUE	Two lateral opposing beams. Care should be taken to avoid irradiation of the entire cross-section of the leg.
PATIENT POSITIONING	Recumbent position on right side and immobilization individual cast, with right leg straight and left leg flexed 90 degrees.
SECTIONS FOR DOSE PLANNING	55 transversal CT-slices from pelvis cranially to the knee joint caudally. Reconstructed sagittal section through entire length of femoral bone [50 > > > 62].
DOSE CALCULATION	True 3-D dose planning.
TECHNIQUE	PTV: 6 MV photons. Two opposed beams with directions 90° and 270°, respectively. Beam sizes 14 cm × 35 cm (both).
CONTROL MEASURES	Port films on simulator. Verification films weekly. In vivo dose measurements of entrance dose and dose to testes at each fraction.
DOSE SPECIFICATION FOR REPORTING	PTV: 1. Centrally in PTV (= the ICRU Reference Point). 2. Maximum and minimum.

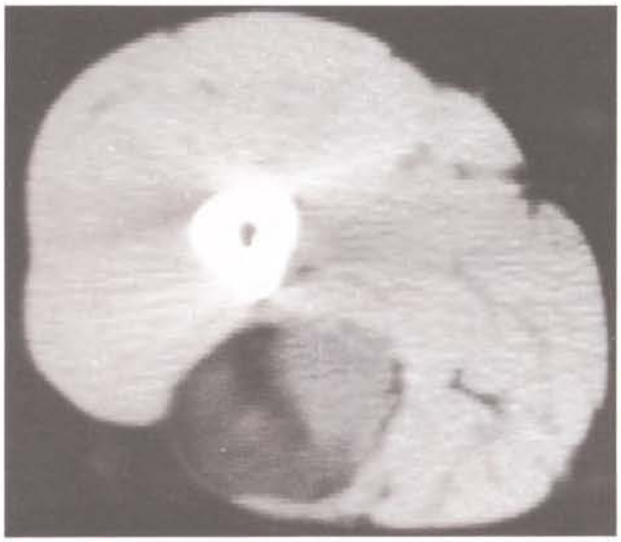


Fig. II.5.a. Based on clinical, radiologic, and cytologic findings, a high-grade liposarcoma in the long head of the biceps femoris was diagnosed.

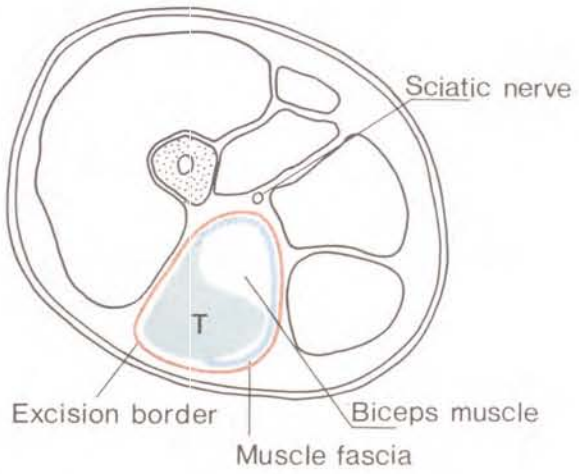


Fig. II.5.b. At operation, the medial part of the tumor was found embedded in the long head of the biceps muscle. The lateral part of the tumor protruded out of the muscle and was covered by a thin membrane. Whether this was muscle fascia or a tumor pseudocapsule was uncertain. The tumor and the long muscle head were removed en bloc. Microscopic examination showed a grade IV liposarcoma. There was no fascial containment of the tumor in the lateral part. The margin was thus classified as marginal, and radiotherapy was indicated.

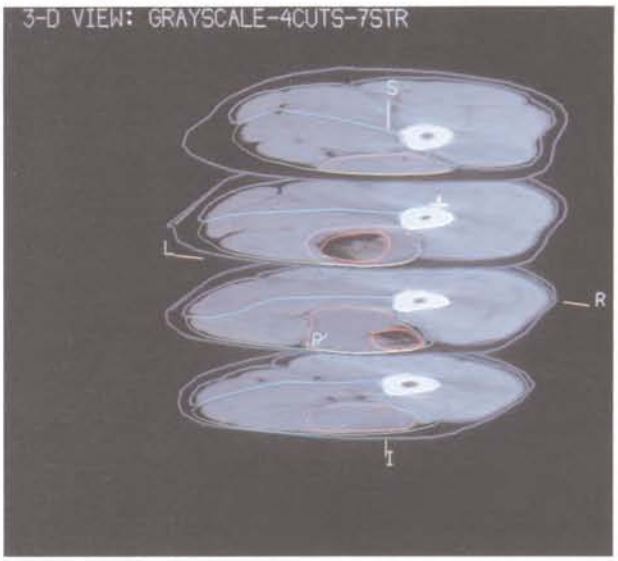


Fig. II.5.c. Multiple-plane display of 4 of the 8 CT sections taken before surgery. In each section, the external contour and outlines of bone, muscle compartments, and gross tumor are visualised.

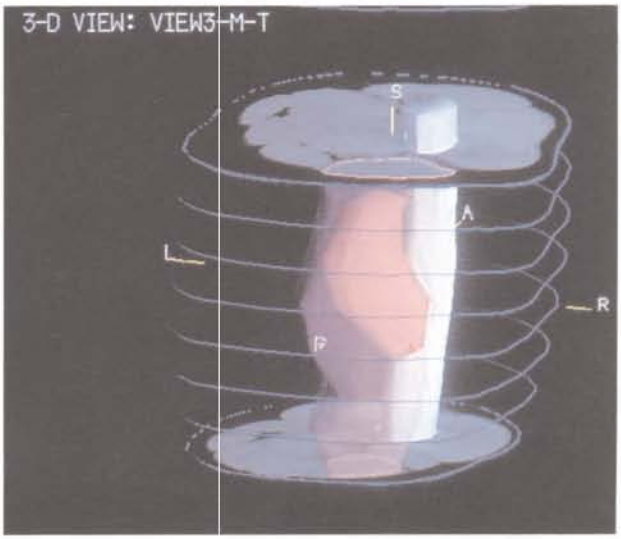


Fig. II.5.d. Volumetric image constructed from the outlines in the 8 CT sections described in Fig. II.5.c. The most proximal and distal sections are shown with a gray scale. The femur is displayed as a solid structure (white) as well as the gross tumor (pink), while the biceps muscle is displayed as a semitransparent structure (magenta). The spatial relationship of these structures can easily be conceived. The orientation of the image is given by the patient related coordinate system (L = Left, R = Right, S = Superior, I = Inferior, A = Anterior, P = Posterior).

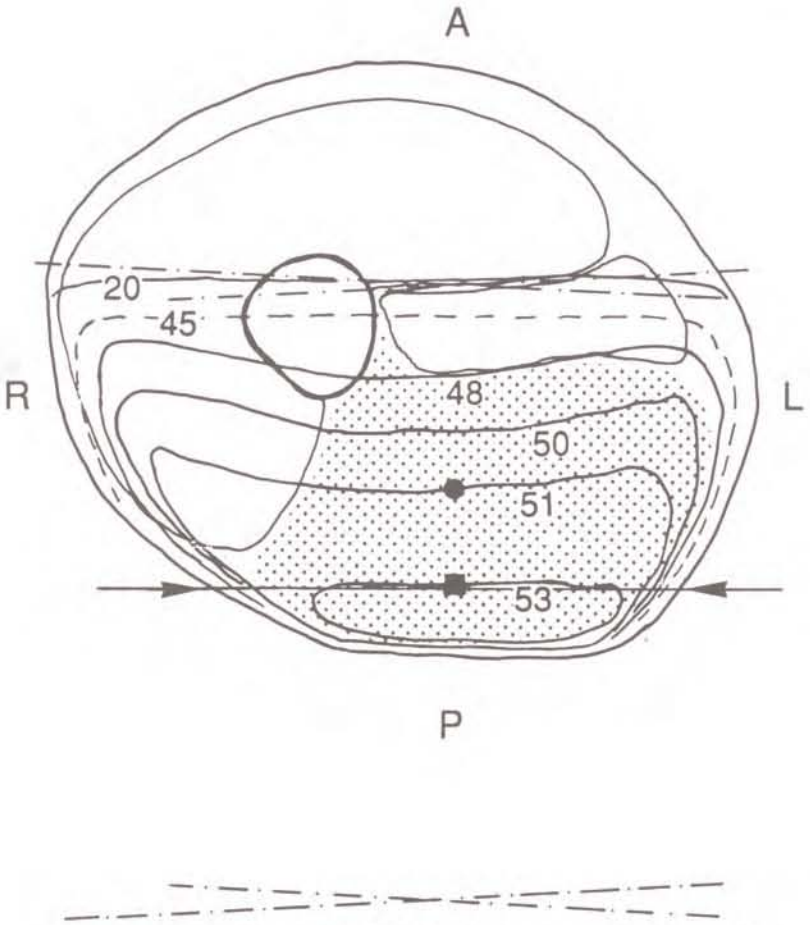


Fig. II.5.e. Transverse section through the central part of the PTV. The entire cross-section of the posterior compartment was defined as the CTV. Radiation is given by two opposing beams, beam directions 90° and 270°, respectively. Irradiation of the entire cross-section of the thigh is avoided. The numbers indicate absolute dose levels (Gy) for the individual isodose curves. The specified target dose (PTV-dose) is 51 Gy at a point centrally in the PTV (●). This point was chosen as being more representative than the point midway on the beam axes (■). The maximum dose to the PTV is 53 Gy, and the minimum dose is 45 Gy.

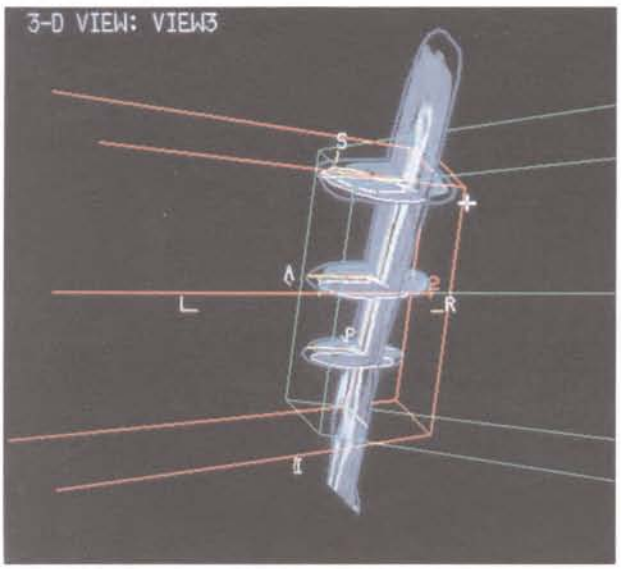


Fig. II.5.f. The geometric limits of the two beams are displayed in green (beam #1) and red (beam #2). Sagittal section through the femur constructed from 55 transverse CT-sections, of which three are shown here.

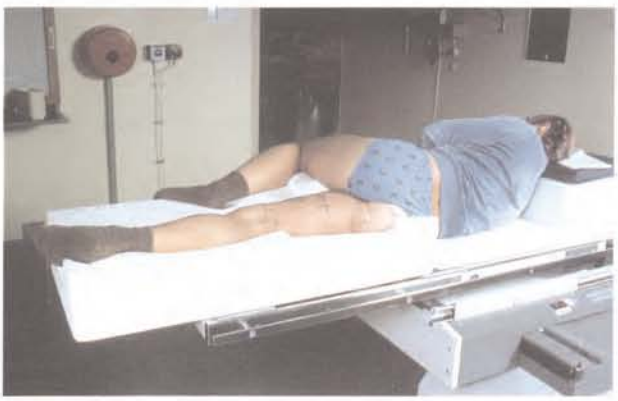


Fig. II.5.g. Position of patient during radiotherapy.

Appendix III

Relative Merits of Central Dose, Minimum Dose, and Average Dose for Reporting

It is recommended (Section 3) that a point in the center or in the central part of the Planning Target Volume (PTV) be selected as the ICRU Reference Point (Section 3.3.1), and that the dose at that point be defined as the ICRU Reference Dose (Section 3.3.2). It is mandatory to report the ICRU Reference Dose and to describe the dose variation by reporting also the maximum dose and the minimum dose in the PTV. In Section 3.3.1, general criteria are given for the selection of the ICRU Reference Point.

Among radiation oncologists and radiophysicists around the world, there is unanimous agreement regarding the need for uniformity in prescribing and reporting treatments. However, currently, many different methods are used (Hendricson, 1988). Only one dose value is usually reported in the scientific literature, and such a single value is often used without further explanation as to its meaning. Dose variations are seldom reported, and reports based on, e.g., dose-volume histograms, can not be easily interpreted.

For prescribing and reporting external beam therapy, many types of dose values are available (see Sections 2.4.3–2.4.7). Three commonly used methods for prescribing and reporting dose in external beam therapy will be analyzed. These three methods of reporting by stating one single dose value are:

* dose in or at the central parts of the Planning Target Volume (PTV) and on or close to the central axis of the beam(s),
* dose at the periphery of the PTV, e.g., isodose line or isodose surface (envelope) encompassing the PTV,
* average dose in the PTV.

The relative merits of the three different methods are given in Table III.1. Other methods for reporting, e.g., median dose, maximum dose, and modal dose are not dealt with here.

One of the first requirements for specification of doses for reporting is that the specification should be applicable to all clinical situations and all different levels of ambition for dose computation. The only dose parameter that meets this criterion is the dose in the central part of the PTV. This contrasts with the situation with minimum and average dose to the PTV, where, if the dose calculation is to be significantly meaningful, it can only be done at level 3 and, to some extent, at level 2 (Section 3.3.4).

A second requirement for reporting the dose is that the dose value should be physically accurate. In an irradiated medium without any heterogeneity, it is obvious that the dose along the central axis can be calculated with good accuracy, since the beams are calibrated and also regularly checked at points along this axis. In points located off-axis or at the periphery, the uncertainty in the dose value will be much larger. This is caused by instability and heterogeneity of the dose distribution as well as the steep dose gradient close to the border of the beam. The dose at the periphery of the PTV thus cannot be determined in an accurate way and hence is unsatisfactory for comparison between different centers. The average dose can, however, be computed with good accuracy, since the off-axis variation is often averaged out inside the beam.

From a radiobiological point of view, the average dose to the cancer cell population is the parameter which is best correlated with tumor response, provided that the dose heterogeneity is not too large. However, in the CTV, the tumor cell density varies to a large extent and reaches, in principle, zero at its border. Therefore, the average dose to the corresponding PTV does not necessarily correspond to the average dose in the cancer cell population, and may thus lose part of its biological significance.

Isodose lines or isodose surfaces at the periphery of the PTV are used in some centres for dose specification (for prescription and for reporting). The objective with this approach is to ensure that all tissues containing tumor cells will receive at least the prescribed dose. In this situation, the dose value of the isodose line or isodose surface is identical to the minimum dose to the PTV. The dose at the periphery of the PTV thus can not be considered to be the most relevant single value to describe a treatment (even though it has to be estimated and reported in addition to the dose to the ICRU Reference Point). The

TABLE III.1—*Advantages and disadvantages of using central dose in the PTV, minimum dose to the PTV, average dose to the PTV*

Parameter	Comments
COMPUTATION OF DOSE	
Central dose in the PTV	Easy to determine.
(=ICRU Reference Dose)	Good physical accuracy.
	Almost independent of type of dose computation (1-, 2-, or 3-D).
Minimum dose to the PTV	Computer is needed.
	Limited physical accuracy.
	Dependent on dose computation method (1-, 2-, or 3-D).
Average dose to the PTV	Computer is needed.
	Good physical accuracy.
	Dependent on dose computation method (1-, 2-, or 3-D).
SELECTION OF SPECIFICATION POINT	
Central dose in the PTV	No freedom for selection.
(=ICRU Reference Dose)	
Minimum dose to the PTV	Some freedom for selection.
	Furthermore, the selection can be influenced by the presentation of the values of the isodoses.
Average dose to the PTV	No freedom for selection.
SPATIAL UNCERTAINTIES AND MOVEMENTS	
Central dose in the PTV (=ICRU Reference Dose)	Almost independent.
Minimum dose to the PTV	Dependent.
Average dose to the PTV	Somewhat dependent.
PLANNING TARGET VOLUME DEFINITION	
Central dose in the PTV	Independent of the delineation of the PTV.
(=ICRU Reference Dose)	Independent of method of patient data acquisition (1-, 2-, or 3-D).
	Can be used for all types of volumes.
Minimum dose to the PTV	Delineation of the PTV may vary with different therapists, and the minimum dose then depends on the PTV.
	Dependent on type of patient data acquisition (1-, 2-, 3-D).
	Can be used for all types of volumes.
Average dose to the PTV	Dependent on the delineation of the PTV.
	Dependent on method of patient data acquisition (1-, 2-, 3-D).
	Little significance if large dose variation in PTV.
CLINICAL AND BIOLOGICAL RELEVANCE	
Central dose in the PTV	Defined in a region where the tumor cell density usually is high.
(=ICRU Reference Dose)	
Minimum dose to the PTV	Defined in a region with low or variable tumor cell density.
Average dose to the PTV	Variation of tumor cell density from its maximum value down to zero.

decision of the clinical safety margin is one of the most critical steps in radiotherapy. Consequently, the size and border of the CTV may vary considerably from one radiation oncologist to another for the same clinical situation, due to different opinions. Also, the selection of proper margins when defining the PTV may vary from therapist to therapist.

The dose at the central part of the PTV, along the central axes of the beams, must then be reported in all cases. It is the most representative single dose value for the PTV. However, in order to evaluate the total dose distribution in the PTV, the dose variation (maximum and minimum dose to the PTV) (Section 3.3.3) also have to be reported.

References

ACS (1983). American Cancer Society, *Clinical Oncology for Medical Students and Physicians. A Multidisciplinary Approach,* 6th Edition, Rubin, P., Ed., page 269. (American Cancer Society, Atlanta).

AJCC (1988). American Joint Committee on Cancer, *Manual for Staging of Cancer,* 3rd edition, Beahrs, O. H., Henson, D., Hutter, R. V. P. and Myers, M. H., Eds. (J. P. Lippincott, Philadelphia).

BRAHME, A., CHAVAUDRA, J., MCCULLOUGH, E., NÜSSLIN, F., RAWLINSON, A., SVENSSON, G., LANDBERG, T., ROSSI, H. and WAMBERSIE, A. (1988). "Accuracy Requirements and Quality Assurance of External Beam Therapy with Photons and Electrons," *Acta Oncologica,* Suppl. #1.

GOITEIN, M. (1985). "Calculation of the uncertainty in the dose delivered during radiation therapy." *Med. Phys.* **12,** 608–612.

HENDRICKSON, F. R. (1988). "Dose Prescription Dilemma." *International Journal of Radiation Oncology, Biology, Physics,* **14,** 595–596.

ICRU (1973). International Commission on Radiation Units and Measurements, *Measurement of Absorbed Dose in a Phantom Irradiated by a Single Beam of X or Gamma Rays,* ICRU Report 23 (International Commission on Radiation Units and Measurements, Washington).

ICRU (1976). International Commission on Radiation Units and Measurements, *Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays,* ICRU Report 24 (International Commission on Radiation Units and Measurements, Washington).

ICRU (1978). International Commission on Radiation Units and Measurements, *Dose Specification for Reporting External Beam Therapy with Photons and Electrons,* ICRU Report 29 (International Commission on Radiation Units and Measurements, Washington).

ICRU (1984). International Commission on Radiation Units and Measurements, *Radiation Dosimetry of Electron Beams with Energies between 1 and 50 MeV,* ICRU Report 35. (International Commission on Radiation Units and Measurements, Washington).

ICRU (1985). International Commission on Radiation Units and Measurements, *Dose and Volume Specification for Reporting Intracavitary Therapy in Gynecology,* ICRU Report 38 (International Commission on Radiation Units and Measurements, Washington).

ICRU (1987). International Commission on Radiation Units and Measurements, *Use of Computers in External Beam Radiotherapy Procedures with High-Energy Photons and Electrons,* ICRU Report 42. (International Commission on Radiation Units and Measurements, Washington).

MIJNHEER, B. J., BATTERMANN, J. J., and WAMBERSIE, A. (1987). "What degree of accuracy is required and can be achieved in photon and neutron therapy?," *Radiotherapy and Oncology,* **8,** 237–252.

MÖLLER, T. R., NORDBERG, U. B., GUSTAFSSON, T., JOHNSSON, J.-E., LANDBERG, T. G., and SVAHN-TAPPER, G. (1976). "Planning, control, and documentation of external beam therapy," *Acta Radiol.* Suppl. 353.

RUBIN, P. (Ed.), (1975). *Committee on Self-evaluation and Testing: SET R.T.1: Radiation Oncology* (American College of Radiology, Reston, VA).

CAP (1979). College of American Pathologists, *Systematized Nomenclature of Medicine,* (SNOMED), 2nd edition (College of American Pathologists, Northfield, IL).

UICC (1982). International Union against Cancer, *TNM Classification of Malignant Tumours,* Spiessl, B., Scheibe, O. and Wagner, G., Eds. (Springer Verlag, Berlin).

UICC (1987). International Union against Cancer, *TNM Classification of Malignant Tumours.* 4th edition, Hermanek, P. and Sobin, L. H., Eds. (Springer Verlag, Berlin).

UICC (1990). International Union against Cancer, *TNM Atlas, Illustrated Guide to the TNM/pTNM Classification of Malignant Tumours,* 3rd edition. Spiessl *et al.,* Eds. (Springer Verlag, Berlin).

WHO (1976a). World Health Organization, *International Classification of Diseases for Oncology,* (ICD-O [9]) (1st edition, based on 9th revision) (World Health Organization, Geneva).

WHO (1976b). World Health Organization, *Handbook for Standardized Cancer Registries.* WHO Offset Publ. No. 25 (World Health Organization, Geneva).

WHO (1977). World Health Organization, *International Classification of Diseases, Injuries and Causes of Death,* 9th revision. (World Health Organization, Geneva).

WHO (1990). World Health Organization, *International Classification of Diseases for Oncology,* (ICD-O [10]) (2nd edition, based on 10th revision) (World Health Organization, Geneva).

WITTKÄMPER, F. W., MIJNHEER, B. J. and VAN KLEFFENS, H. J. (1987). "Dose intercomparison at the radiotherapy centres in The Netherlands. 1. Photon beams under reference conditions and for prostatic cancer treatment." *Radiotherapy and Oncology,* **9,** 30.

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The following ICRU Reports were superseded by subsequent Reports and are now out of print:

ICRU Report No.	*Title and Reference**
1	*Discussion on International Units and Standards for X-ray work, Br. J. Radiol.* **23,** 64 (1927).
2	*International X-Ray Unit of Intensity,* Br. J. Radiol. (new series) **1,** 363 (1928).
3	*Report of Committee on Standardization of X-ray Measurements,* Radiology **22,** 289 (1934).
4	*Recommendations of the International Committee for Radiological Units,* Radiology **23,** 580 (1934).
5	*Recommendations of the International Committee for Radiological Units,* Radiology **29,** 634 (1937).
6	*Recommendations of the International Commission on Radiological Protection and of the International Commission on Radiological Units,* National Bureau of Standards Handbook 47 (U.S. Government Printing Office, Washington, D.C., 1951).
7	*Recommendations of the International Commission on Radiological Units,* Radiology **62,** 106 (1954).
8	*Report of the International Commission on Radiological Units and Measurements (ICRU) 1956,* National Bureau of Standards Handbook 62 (U.S. Government Printing Office, Washington, D.C., 1957).
9	*Report of the International Commission on Radiological Units and Measurements (ICRU) 1959,* National Bureau of Standards Handbook 78 (U.S. Government Printing Office, Washington D.C., 1961).
10a	*Radiation Quantities and Units,* National Bureau of Standards Handbook 84 (U.S. Government Printing Office, Washington, D.C., 1962).
10d	*Clinical Dosimetry,* National Bureau of Standards Handbook 87 (U.S. Government Printing Office, Washington, D.C., 1968).

10e *Radiobiological Dosimetry,* National Bureau of Standards Handbook 88 (U.S. Government Printing Office, Washington, D.C., 1963).

11 *Radiation Quantities and Units* (International Commission on Radiation Units and Measurements, Washington, D.C., 1968).

19 *Radiation Quantities and Units* (International Commission on Radiation Units and Measurements, Washington, D.C., 1971).

19S *Dose Equivalent* [Supplement to ICRU Report 19] (International Commission on Radiation Units and Measurements, Washington, D.C. 1973).

21 *Radiation Dosimetry: Electrons with Initial Energies Between 1 and 50 MeV* (International Commission on Radiation Units and Measurements, Washington, D.C., 1972).

29 *Dose Specification for Reporting External Beam Therapy with Photons and Electrons* (International Commission on Radiation Units and Measurements, Washington, D.C., 1978)

*References given are in English. Some of the Reports were also published in other languages.

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