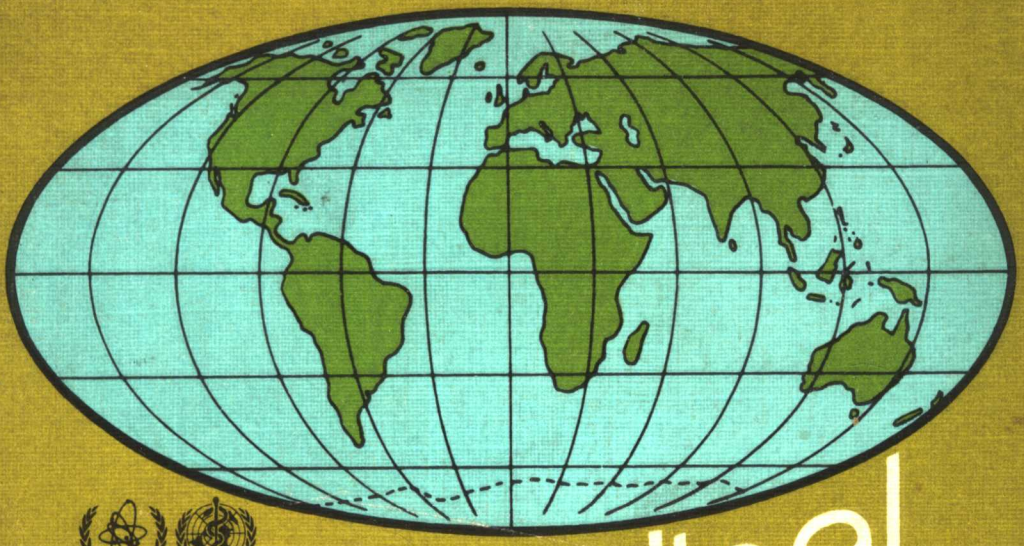

PROCEEDINGS OF A SYMPOSIUM
PARIS, 27–31 OCTOBER 1980
JOINTLY ORGANIZED BY
IAEA AND WHO

biomedical dosimetry: physical aspects, instrumentation, calibration

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1981

PROCEEDINGS SERIES

BIOMEDICAL DOSIMETRY: PHYSICAL ASPECTS, INSTRUMENTATION, CALIBRATION

PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM
ON BIOMEDICAL DOSIMETRY: PHYSICAL ASPECTS,
INSTRUMENTATION, CALIBRATION
JOINTLY ORGANIZED BY THE
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AND THE
WORLD HEALTH ORGANIZATION
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FOREWORD

Radiation dosimetry, the accurate determination of the absorbed dose within an irradiated body or a piece of material, is a prerequisite for all controlled and safe use of ionizing radiation. The importance of dosimetry has been realized since the very first applications of ionizing radiations in medicine and biology, and continuing efforts are being devoted by radiation researchers to the development of more reliable, effective and safe instruments, and to the further improvement of dosimetric accuracy for all the types of ionizing radiation used. In the last decade, development of new techniques and instrumentation has been particularly rapid in the fields of medical diagnostic and therapeutic radiology.

The IAEA has held a continuing series of meetings on dosimetry in medicine and biology, the previous symposium having been in Vienna in 1975. The Agency symposia are unique in providing a means for all those concerned with the practice of radiation dosimetry in biology and medicine as well as in related fields to meet and exchange ideas. The resulting publications are frequently quoted, since they have proved to be useful collections of worldwide experience and summaries of progress. The present symposium, jointly organized by the IAEA and WHO, and held in Paris in October 1980, was attended by 250 participants and observers from 34 countries and three international organizations.

The symposium programme reflected the considerable advances that have been made in the field of radiation dosimetry – in instrumentation and techniques, in standardization and calibration, and in the development of new systems for high-dose dosimetry, useful too for radiation processing.

The problems arising in connection with the introduction of SI units were discussed. The investigations relating to the physical aspects of radiation-dosimetry techniques and the development of methods suited to practical application in the biomedical field were reported. It was realized that there have been remarkable improvements in and developments of the techniques applied in clinical dosimetry for both photon and particle beams. Studies on absorbed-dose and dose-distribution determination in the human body allowing for the inhomogeneities of various organs and tissues were reported for neutron and photon radiation.

It became clear that standardization of radiation dose measurement is the major aim, both with regard to instrumentation and working procedures.

Ionization chambers, calorimeters and chemical systems are all being used as basic elements in dose standardization. Improved calibration techniques for clinical radiology have been introduced. In particular the free-radical dosimetry systems such as alanine/ESR and glutamine/lyoluminescence have shown their great possibilities as standard and routine dose meters. It was noted that emphasis on the intercomparison and calibration work in the national standardizing laboratories and SSDLs is vital if improvements in mensuration are expected in the future.

The organizers of the symposium are indebted to the Government of France for hosting the meeting, which took place in the Palais des congrès. They would like to thank the staff of the Commissariat à l'énergie atomique, in particular of the Laboratoire de métrologie des rayonnements ionisants du Centre d'études nucléaires de Saclay, whose support and co-operation played a notable part in the success of the meeting.

EDITORIAL NOTE

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ADDENDUM

Session I

GENERAL ASPECTS IN DOSIMETRY

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SPECIFICATION OF ABSORBED DOSE FOR REPORTING A THERAPEUTIC IRRADIATION

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Abstract

SPECIFICATION OF ABSORBED DOSE FOR REPORTING A THERAPEUTIC IRRADIATION.

The problem of dose specification in external beam therapy with photons and electrons has been dealt with in ICRU Report 29 (1978). This problem arises from the fact that the absorbed dose distribution is usually not uniform in the target volume and that for the purpose of treatment reporting a nominal absorbed dose – which will be called *target absorbed dose* – has to be selected. When comparing the clinical results obtained between radiotherapy centres, the differences in the reported target absorbed doses which can be introduced by differences in the methods of dose specification often are much larger than the differences related to the dosimetric procedures themselves. This shows the importance of the problem. In this paper, some definitions of terms and concepts currently used in radiotherapy are first recalled: tumour volume, target volume, treatment volume, etc. These definitions have been proposed in ICRU Report 29 for photon and electron beams; they can be extended to any kind of irradiation. For external beam therapy with photons and electrons, the target absorbed dose is defined as the absorbed dose at selected point(s) (specification point(s)) having a meaningful relation to the target volume and/or the irradiation beams. Examples are discussed for typical cases. As far as interstitial and intracavitary therapy is concerned, the problem is more complex and no recommendations have so far been made by the ICRU Commission. A major difficulty arises from the sharp dose gradient as a function of the distance to the sources. The particular case of the treatment of cervix carcinoma is considered and some possible methods of specification are discussed: (1) the indication of the sources (in adequate units) and the duration of the application, (2) the absorbed doses at selected reference points (bladder, rectum, bony structures) and (3) the description of the tissue volume (height, width, thickness) encompassed by a given isodose surface (60 Gy).

1. INTRODUCTION - POSITION OF THE PROBLEM

The interest in having dosimetric intercomparisons between different radiotherapy centres is universally recognized. In particular several dosimetric intercomparisons were performed in collaboration by IAEA and WHO, and were proven to be very useful. Some recent data in this field are reported in these proceedings {1}.

Besides this search for a normalization of the dosimetric procedures, the problem must be raised of the specification of absorbed dose for reporting a therapeutic irradiation. As a matter of fact, the dose distribution which can be achieved throughout the target volume is generally not uniform and, for reporting purposes, the target absorbed dose must often be specified by means of only one parameter (or few parameters).

In fact, when comparing the techniques and the results from various radiotherapy centres, the differences introduced by the method of specification of the target absorbed dose often are much larger than those related to the dosimetric procedures themselves.

In order to illustrate the problem, Fig. 1a displays the computerized dose distribution obtained in a patient treated by three converging beams (for example for a cancer of the oesophagus) {2}. For the same patient, Fig. 1b represents the dose distribution in the target area with the maximum, modal and minimum target absorbed dose. The absorbed dose at the intersection point of the central axes of the three beams (unambiguously related to the beams) is in fact the maximum target absorbed dose. The minimum absorbed dose can be regarded as critical with respect to local tumour control, whereas the modal absorbed dose is probably more representative of the dose distribution and probably more meaningful from a radiobiological point of view.

The problem we are dealing with is the selection of the absorbed dose level which would be (a) representative of the dose distribution in the target volume and (b) clearly and unambiguously defined for reporting purposes and for comparing treatments performed in different centres.

In this particular example, due to an adequate choice of the beam arrangement (wedges and weighting), the dose distribution is rather uniform (the

difference between the maximum and minimum target absorbed dose being less than 10%). However, in many cases the dose distribution, which can be achieved in external beam therapy, is less uniform, which makes the problem of specification of the target absorbed dose more important from a practical point of view.

In interstitial and intracavitary therapy, the situation is far more complex since the dose gradient over the target volume is very high, resulting from a rapid decrease of the dose with the distance to the sources (Fig. 2).

In 1978, ICRU published recommendations (Report 29 {2}) on "Dose specification for reporting external beam therapy with photons and electrons" [1]. The first part of this report contains definitions of terms and concepts currently used in radiotherapy such as tumour volume, target volume, treatment volume, irradiated volume, organs at risk, maximum, minimum, mean, median, modal target absorbed dose and hot spots. These terms and concepts, defined in Report 29 for external beam therapy with photons and electrons are now widely accepted and are a priori applicable to any kind of irradiation technique. The second part of Report 29 contains recommendations for reporting absorbed dose in external beam therapy; some of these recommendations will be recalled in the first part of the present paper.

After completion of Report 29, ICRU has set up a reporting committee to deal with the problems of specification of absorbed dose for reporting interstitial and intracavitary therapy [2]: no definite recommendations have been adopted up to now. Some aspects of these problems which are particularly complex will be reviewed in the second part of the present paper and some possible solutions will be discussed.

More recently, the specific problems raised by dose specification in neutron therapy have also been considered by the ICRU Commission. These specific problems have been discussed partly in a recent publication {4} and will not be dealt with in the present paper.

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[1] T. Landberg (Chairman), P. Almond, J.M.V. Burgers, M. Busch, C.A. Joslin and J.P. Paunier (Members), M. Cohen, A. Dutreix and T.R. Möller (Consultants), A. Wambersie (Commission Sponsor).

[2] D. Chassagne (Chairman), P. Almond, J.M.V. Burgers, M. Busch and C.A. Joslin (Members), A. Dutreix and T. Landberg (Consultants), A. Wambersie (Commission Sponsor).

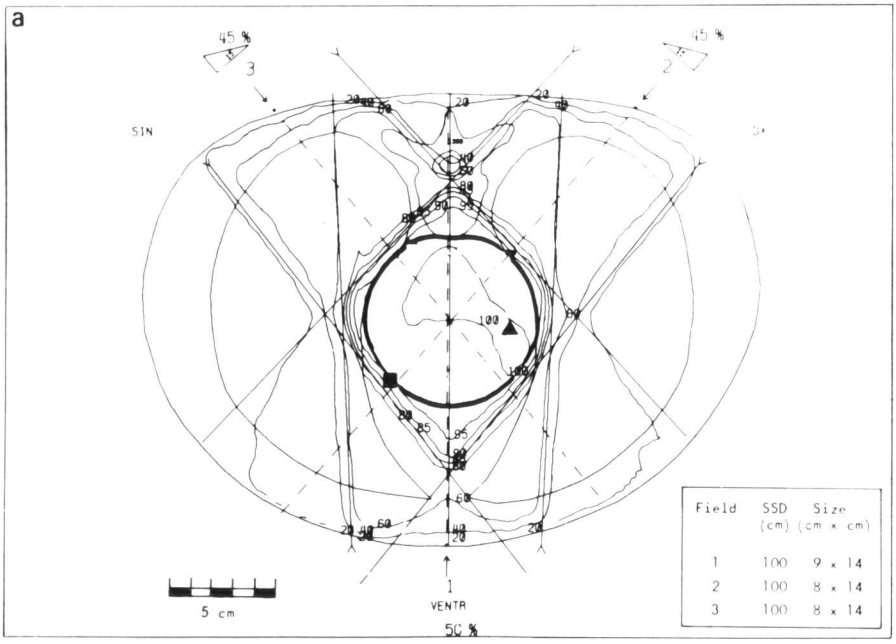

FIG. 1 a. Computerized calculation of the absorbed dose distribution (8 MV X-rays) for a patient with carcinoma of the oesophagus, treated only in the prone position. The computation is made in the transverse section containing the central beam axes. The border of the target area is indicated by the thick line. The display gives the distribution of the absorbed dose and also the position of the maximum (closed triangle) and the minimum (closed square) target absorbed dose. In this special case, the weighting of the beams (peak absorbed dose 50%, 45% and 45%, respectively) was chosen to give an absorbed dose of 100% at the point of intersection of the central axes of the three beams. (Example taken from ICRU Report 29 (1978), p.9 {2}.)

2. ICRU RECOMMENDATIONS FOR REPORTING ABSORBED DOSE IN EXTERNAL BEAM THERAPY WITH PHOTONS AND ELECTRONS

2.1. Definition of terms

2.1.1. Target volume

The target volume is defined as the volume containing those tissues that are to be irradiated to a specified absorbed dose according to a specified

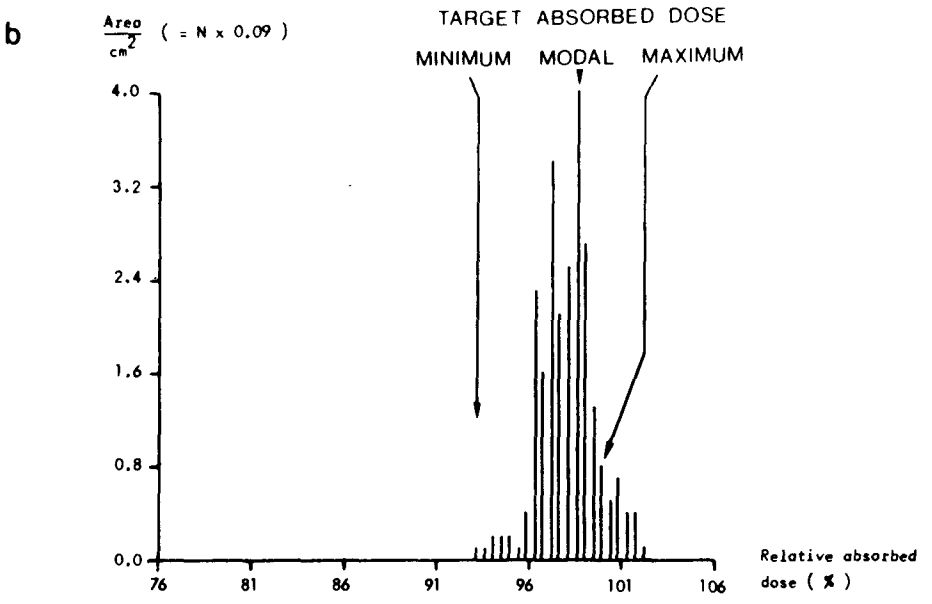

FIG.1 b. For the same patient a histogram is given to demonstrate the distribution of absorbed dose in the target area. The computation of the histogram gives sizes of areas (one lattice point representing an area of 3 mm X 3 mm = 0.09 cm^2) for 21 equally large intervals of absorbed dose percentage values, ranging from 102 to 93%. The maximum target absorbed dose considered to be meaningful and to be used for reporting (see text in Ref. {2}) is 100%. The modal target absorbed dose is 99%, and the media 98%. The computation also gives the mean target absorbed dose (98%). (From ICRU Report 29 (1978), p. 9 {2}.)

time-dose pattern (taking into account the introduction of high-LET radiations, one should add : for a specified radiation quality). For curative treatment, the target volume consists of the demonstrated tumour(s), if present, and any other tissue with presumed tumour (Fig. 3).

The delineation of the target volume will require such considerations as the local invasive capacity of the tumour and its potential to spread to regional lymph nodes. Consideration needs to be given to the presence of any specially radiosensitive normal tissue (organs at risk) as well as to other factors such as the general condition of the patient. For any given situation there may be more than one target volume (see for example Fig. 6).

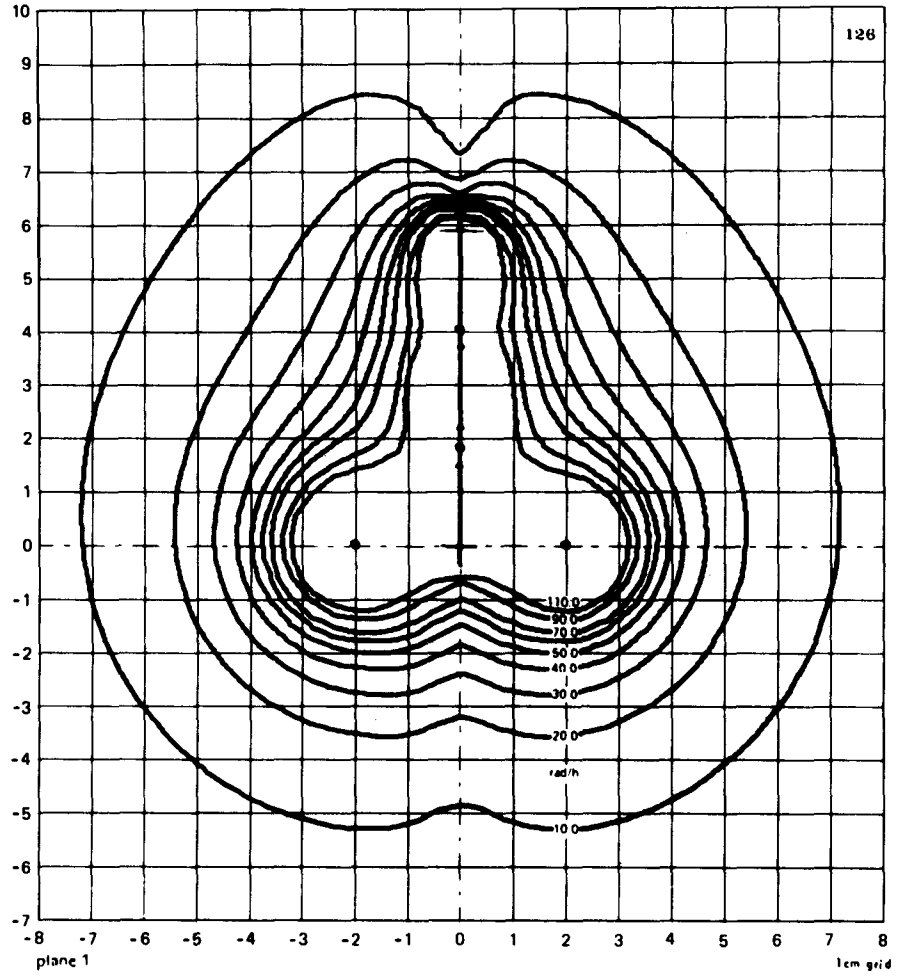

FIG.2. Intracavitary radium application for cancer of the cervix. Three intra-uterine sources (10 mg, 1 mm Pt filtration, 1.5 cm active length) and two vaginal sources (20 mg, 1 mm Pt filtration, 1.5 cm active length) are used. The dose rates are computed in the oblique frontal plane of the intra-uterine sources: the different curves correspond to 110, 90, 70, 60, 50, 40, 30, 20 and 10 rad·h^{-1}. (From IAEA, Atlas of Radiation Dose Distributions, Vol. IV (1962), p. 126 {3}.)

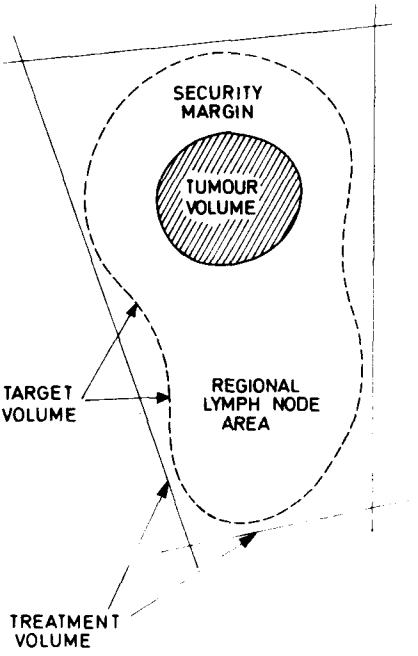

FIG.3. Schematic drawing of the different 'volumes'. The tumour volume *or demonstrated tumour. The* target volume *(see text), which includes besides the demonstrated tumour, a security margin and the regional lymph node areas. Due to the limitations of the available treatment techniques, it is impossible to administer the prescribed dose exclusively to the target volume. The* treatment volume *is defined as the volume enclosed by an isodose surface, the value of which being, in principle, the minimum target dose.*

The target volume must always be described, independently of the dose distribution, in terms of the patient's anatomy and topography, and the physical dimensions given.

Physical treatment planning is then performed taking into account the delineation of the target volume(s) and the prescription of the target absorbed dose.

2.1.2. Target absorbed dose

As the dose distribution is usually not uniform in the target volume, for the purpose of treatment reporting, a nominal absorbed dose has to be selected, which will be called target absorbed dose. The use of the expression 'tumour absorbed dose' (or 'tumour dose') is no longer recommended.