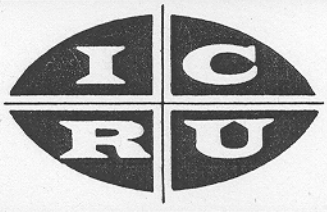
ICRU REPORT 62

Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50)



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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

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.