COMPARISON OF CALCULATION ACCURACY OF THE CADPLAN AND ALFARD RADIOTHERAPY COMPUTER PLANNING SYSTEMS IN Co - 60 TELETHERAPY

Rembielak A[1], Ślosarek K[2], Grządziel A[2]

[1] Brachytherapy Department, Radiobiology Department, [2] Treatment Planning Unit, Centre of Oncology - Institute, Wybrzeże Armii Krajowej 15, 44-101 Gliwice, Poland

Received 20 October 1998; revision received 15 April 1999; accepted 23 May 1999.

Key words: radiotherapy, treatment planning system, calculation accuracy.

ABSTRACT

Purpose: The purpose of this work was to determine the agreement of the measured and calculated values of the isodose distance (depth) along the central axis and penumbra.

Materials and methods: Isodose distributions were measured with an ionization chamber in a water phantom. Photon beams were generated by a Co^{60} teletherapy unit. Beam data were transferred to the treatment planning systems.
The analysis was performed for open or 30, 45, 60 degree wedged fields, field sizes of 6 x 6 cm, 10 x 10 cm, 14 x 14 cm and SSD = 80 cm. The relative errors between the measured values and the calculated values by CADPLAN 2.7 and calculated by ALFARD were evaluated.

Results: In the case of open fields, the relative error of the calculated isodose depth along the central axis is comparable for both systems, whereas for wedged fields the relative error is smaller in CADPLAN calculations. Generally, both systems underestimate the calculated values as compared with those measured. The penumbra values are smaller for the CADPLAN system than those for the ALFARD.

Conclusion: Quantification of calculation accuracy constitutes an essential part of the verification of radiotherapy planning systems.

INTRODUCTION

The plan of the treatment refers to all aspects of the patient's therapy course: surgery, chemotherapy, radiation therapy and other medical modalities. The treatment planning in radiation therapy is synonymous with a specifying dose prescription to achieve the desired radiation dose distribution in planning the target volume [Bentel, 1989]. It includes a dose fractionation schedule and beam arrangement. The treatment planning process for a given patient begins with a clear designation of the treatment site and critical radiation-sensitive organs in or near this volume.

Measurements accomplish a double task:

1. They let us control if the radiation therapy treatment machine works properly, i.e. if a set dose value is really emitted,
2. Measurements of radiation beam characteristics are used as the basic data in the treatment planning calculations; a comparison of calculated dose distributions based on measurements and those measured enable us to avoid mistakes in planning, for example, the entrance of the beam data to a computer system It is the second task that is the purpose of this study.

MATERIALS AND METHODS

a) MEASUREMENTS IN A WATER PHANTOM

Our measuring equipment consisted of a PTW Freiburg water phantom, ionization chamber NE 2571 0,6 cm^3 as a radiation dosimeter, and a PTW Freiburg electrometer. The water phantom is intended for automatic measurements of radiation beam characteristics [Powers et al. 1976] (percentage depth dose, dose profile), used as basic data in the treatment planning systems. This self-contained system works under a computer control (Mephisto program) and shows isodose distributions on a computer screen, plots or prints results, records them on a disk or feeds the data directly to a treatment planning system. In our case, PDDs were measured to a depth of 30 centimeters with 5 mm intervals at most, and 2,5 mm intervals in the build-up region of the PDD. The profiles were measured at least 3 cm beyond the shadow of the jaws for each profile depth, taking into account the divergence of the field at each depth. The

profile data were collected at 2,5 mm intervals at most, and at 2 mm intervals for the penumbra region of the profiles [3].
The measurements were taken for the following conditions:

- ^{60}Co beam
- SSD = 80 cm
- field sizes: 6 x 6 cm, 10 x 10 cm, 14 x 14 cm
- open or 30°, 45°, 60° wedged fields

b) ALFARD CALCULATIONS

The Alfard computer system (Center of Oncology - Institute, Gliwice, Poland) calculates isodose distributions based on the following data:

- Tissue - Phantom Ratio (TPR) for square fields
- dose profile at a single depth, chosen by the user, for any number of field sizes
- relative dose - distributions normalized to a dose rate for 10 x 10 cm field size at the reference depth
- absolute dose rate specified under the reference conditions

c) CADPLAN CALCULATIONS

The Cadplan 2.7 computer system (Dosetek Varian) calculates the isodose distributions based on the following data:

- Percent Depth Dose (PDD) values
- profiles at 5 depths
- relative dose - distributions for rectangular fields, normalized to a dose rate for 10 x 10 cm field size at the reference depth
- absolute dose rate specified in the reference conditions

All treatment unit data were acquired, configured and imported into the treatment planning programs precisely according to manufacturer manuals [3].

d) COMPARISON OF THE ISODOSE DISTRIBUTIONS

By the combination of the field size and open or wedged field , 12 variants of the dose distribution were taken into consideration (see Figure 1) : 12 isodose distributions calculated by Cadplan, 12 isodose distributions calculated by Alfard and 12 isodose distributions measured in the water phantom.
For each isodose distribution measured in the water phantom and calculated by Cadplan or calculated by Alfard, the isodose depth and the penumbra were compared by evaluating the relative errors. The values of the isodose depth and penumbra were taken from a plotter graph.
The relative error was obtained from the equation:

$$\delta(a) = \frac{(a - A) \times 100\%}{A}$$

where:
a is the isodose depth calculated by Alfard or by Cadplan, and **A** is the isodose depth measured in the water phantom

In the above equation, the absolute value in the numerator was left out deliberately of the calculation to analyze the possible tendency to underestimate or overestimate the calculation results by computer programs.
The isodose depth was measured along the central axis for 90%, 80%, 70% isodose etc. The penumbra value was taken between 20% and 80% isodose at the 85% isodose depth along the central axis.

^{60}Co BEAM
SSD=80 cm

FIELD	6 x 6 cm	10 x 10 cm	14 x 14 cm
open	+	+	+
wedge 30°	+	+	+
wedge 45°	+	+	+
wedge 60°	+	+	+

= 12 variants

Fig. 1. Field data for measurements in a water phantom and calculations by the Cadplan and the Alfard computer treatment planning systems.

RESULTS

a) ISODOSE DEPTH

The isodose depths were measured for each isodose along the central axis for the Cadplan calculations, Alfard calculations and Mephisto measurements. Afterwards the relative errors between the Cadplan calculations and measurements and between the Alfard calculations and measurements were evaluated.
Table 1 shows, as an example, the data measured in the water phantom and those calculated by two treatment planning systems for the open field of 6 x 6 cm.
In the same way, the isodose depths for all 12 variants of the dose distributions were analyzed.

6x6, open	depth [cm]	depth [cm]	depth [cm]	Cad-Meph	Alf-Meph
isodose [%]	Cadplan	Alfard	Mephisto	rel. error [%]	rel. error [%]
90	2,4	2,35	2,45	- 2,04	- 4,08
80	4,2	4,15	4,25	- 1,18	- 2,35
70	6	6,05	6,1	- 1,64	- 0,82
60	8,15	8,1	8,2	- 0,61	- 1,22
50	10,6	10,6	10,6	0,00	0,00
40	13,5	13,5	13,5	0,00	0,00
30	17,15	17,1	17,2	- 0,29	- 0,58
20	22,35	22,25	22,35	0,00	- 0,45
10	31,2				
				rel. error 0,72%	*rel. error 1,19%*

Table 1. Isodose depths calculated by the computer systems: Cadplan, Alfard, measured by the Mephisto and relative errors between calculations and measurements for open field 6 x 6 cm

b) PENUMBRA

Also the penumbra values measured in the water phantom and those calculated by two computer systems were compared. Due to the asymmetric isodose curves in wedged fields the penumbras were referred to as Penumbra 1 and Penumbra 2. The penumbra values for the isodoses calculated by Cadplan, by Alfard, measured by Mephisto and the relative errors between calculations and measurements are shown in Table 2 and 3.

In the case of open fields the isodose distribution is symmetrical to that for the central axis. In the wedged fields the isodose distribution is asymmetrical (Penumbra 1 differs Penumbra 2) [Sewchand et al. 1978].

	penumbra 1	d [cm]	d [cm]	d [cm]	Cad-Meph	Alf-Meph
open field	side [cm]	Cadplan	Alfard	Mephisto	rel.error [%]	rel.error [%]
	6	1,5	1,2	1,5	0,00	- 20,00
	10	1,7	1,6	1,7	0,00	- 5,88
	14	2	1,75	1,9	5,26	- 7,89
WEDGE						
30 degree	6	1,2	1,1	1,2	0,00	- 8,33
	10	1,3	1,2	1,35	- 3,70	- 11,11
	14	1,45	1,35	1,45	0,00	- 6,90
45 degree						
	6	1,2	1,1	1,2	0,00	- 8,33
	10	1,4	1,35	1,4	0,00	- 3,57
	14	1,6	1,5	1,6	0,00	- 6,25

60 degree						
	6	1,25	1,25	1,35	**- 7,41**	**- 7,41**
	10	1,75	1,7	1,8	**- 2,78**	**- 5,56**
	14	2,15	2,1	2,15	**0,00**	**- 2,33**

Table 2. Penumbra 1 values for the isodoses calculated by Cadplan, calculated by Alfard, measured by Mephisto and relative errors between calculated and measured values.

	penumbra 2	d [cm]	d [cm]	d [cm]	**Cad-Meph**	**Alf-Meph**
open field	side [cm]	**Cadplan**	**Alfard**	**Mephisto**	rel.error [%]	rel.error [%]
	6	1,5	1,2	1,5	**0,00**	**- 20,00**
	10	1,7	1,6	1,7	**0,00**	**- 5,88**
	14	2	1,75	1,9	**5,26**	**- 7,89**
WEDGE						
30 degree	**6**	2,6	2,8	2,6	**0,00**	**7,69**
	10	4,6	4,7	4,7	**- 2,13**	**0,00**
	14	6,75	6,7	6,8	**- 0,74**	**- 1,47**
45 degree						
	6	3,05	3	3,1	**- 1,61**	**- 3,23**
	10	5	5	5	**0,00**	**0,00**
	14	7	6,9	7	**0,00**	**- 1,43**
60 degree						
	6	3,2	3,1	3,2	**0,00**	**- 3,13**
	10	5,1	5	5,1	**0,00**	**- 1,96**
	14	6,95	7,05	7	**- 0,71**	**0,71**

Table 3. Penumbra 2 values for the isodoses calculated by Cadplan, calculated by Alfard, measured by Mephisto and relative errors between calculated and measured values.

DISCUSSION OF THE RESULTS

The Quality Assurance program in radiation therapy involves a large number of procedural steps concerning the computer program, system documentation, sources of uncertainties and suggested tolerances, initial system checks, repeated system checks and quality assurance through manual procedures. One of the most important parts in the computed radiotherapy planning is the user's ability to check the correctness of the measured data loaded into a computer and used afterwards in the dose distribution calculations. The authors did not intend to check calculation algorithms in the computer program. We assume that those algorithms were satisfactorily tested by the manufacturer so the purpose of this paper was to check if the measured data were properly loaded into the treatment planning system.

A comparative analysis of isodose depths and penumbras measured in the water phantom and those calculated by the two treatment planning systems, was performed by evaluating the relative errors between calculations and measurements. The comparison of the mean values of the relative errors for the Cadplan and the Alfard calculations for open and wedged fields is shown in Figures 2 and 3.

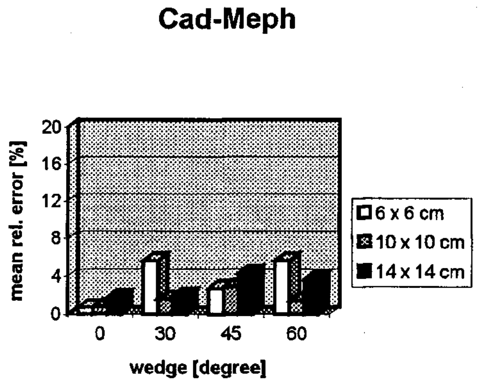

Fig. 2.

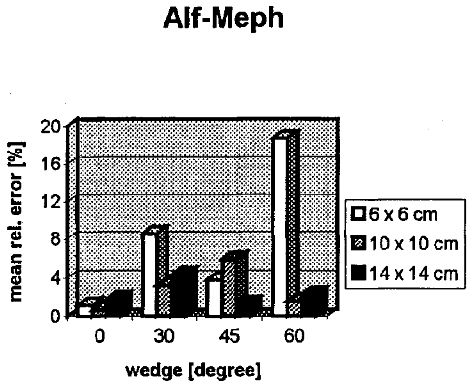

Fig. 3.

Mean relative error of depth doses between Cadplan / Alfard calculations and Mephisto measurements for field sizes: 6x6 cm, 10x10 cm, 14x14 cm open (wedge „0" degree) and wedged.

The mean values of the relative errors of depth doses for open fields in both system calculations do not exceed 2%. The errors are smaller in the Cadplan calculations for 30° wedged field irrespective of field size and for 45°, 60° wedged fields for field sizes of 6 x 6 cm and 10 x 10 cm. The Alfard calculations are more precise for field size of 14 x 14 cm in 45° and 60° wedged fields.

The relative errors of all the Cadplan analyzed calculations, i.e. for open and wedged fields, are as follows:

field 6 x 6 cm = 3,7 %
field 10 x 10 cm = 1,7 %
field 14 x 14 cm = 2,95 %

in the Alfard calculations

field 6 x 6 cm = 8,1 %
field 10 x 10 cm = 2,85 %
field 14 x 14 cm = 2,4 %

The Cadplan calculations of penumbra the values are equal to those from the measurements in 15 out of 24 analyzed cases, in the Alfard calculations, there are equal only in two cases. The Cadplan calculations are consistent with the measurements both for open and wedged fields. There are no significant differences in the relative errors of penumbra 1 or penumbra 2 values calculated by Cadplan and Alfard, however there is a stronger tendency to underestimate the calculations by the Alfard system. Generally, the penumbra depends on the radiation machine. For the same Co^{60} teletherapy unit, the larger field size, the larger is the penumbra value, and this is confirmed by this paper.

More significant differences in dose distributions between the Alfard calculations and measurements can be interrelated with one dose profile used in the Alfard computer system, irrespective of the measuring depth.

The Cadplan system works on the data base consisting of five dose profiles for various measuring depths [Guide to.., 1998]. Moreover, in the Alfard system the minimum distance between the points where the dose is calculated is 5 mm, whereas in Cadplan it is 1,25 mm.

Some authors have made recommendations as to the level of accuracy that should be achievable with the treatment planning systems. The criteria of acceptability for a photon and electron beam suggested by Van Dyk et al. [Van Dyk et al., 1993] are in the range of 2÷3% for the central ray data, except in the build - up region (homogenous calculations).

There are two reasons for comparing the depth [cm] of the properly measured and calculated isodoses, suggested by the authors instead of comparing isodoses [%] for selected depths:

1. Comparison of the depth of the measured and calculated adequate isodoses allows a quick analysis of the plotted or printed isodose distributions.
2. Defining the relative error formula as δ (a) = (a - A) x 100% x A^{-1} (where a is the depth from the calculated isodose distributions, A is the depth from the measured isodose distributions) we take into account that the relative errors between the calculated and

measured isodoses at smaller depths (where an absorbed dose is higher, which is more significant in clinical practice) are larger than those for the same difference between isodoses but at the greater depth.

CONCLUSIONS

Based on the present study the following conclusions can be reached :

1. In general, the CADPLAN and ALFARD treatment planning systems underestimate the calculated values compared with those measured.
2. In the case of open fields, the relative errors of the calculated isodose depths along the central axis are comparable for both systems, whereas for wedged fields the relative errors are smaller in the CADPLAN calculations.
3. Penumbra values are smaller for the CADPLAN system than those for the ALFARD.

REFERENCES

Bentel G: Treatment Planning and Dose Calculation in Radiation Oncology, Pergamon Press, New York (1989).

Cadplan - User's Manual.

Guide to Acqusition and Configuration of Treatment Data - Manual for Cadplan Users. (1998).

Powers W E, Korba A, Purdy J A et al: Dose profiles in treatment planning. Radiology. (1976); 121: 741-742.

Sewchand W, Khan F M, Wiliamson J: Radiation in depth dose data between open and wedged fields 4 MV X-rays. Radiology. (1978); 127: 789.

Van Dyk J, Barnett R B, Cygler J E et al: Commissioning and quality assurance of tratment planning computers. Int. J. Radiation Oncology Biol. Phys. (1993); 26: 261-273.