THE DEPTH DISTRIBUTION OF THE ABSORBED DOSE OF THE ELECTRON BEAM IN THE TISSUE-EQUIVALENT MEDIUM

I.A. Miloichikova
Scientific advisor: Assistant Ye.S. Sukhiikh
Language advisor: As. Professor R.I. Tolbanova
Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050
E-mail: ircha1988@mail.ru

Annotation

In the research the methodology of clinical dosimetry of electron beams using plane-parallel ionization chamber and radiochromic dosimetry films (the GafChromic EBT3 film) in non-water phantom is considered.

In the introduction the actuality of the research is discussed.

In the main part the main parameters of the plane-parallel ionization chamber, radiochromic dosimetry films and the non-water phantom are described. General principles of the methodology of the depth dose measurement are given. The results of the depth dose measurement of 2 MeV betatron electron beams are presented.

In conclusion the comparative analysis of the results is given.

Keywords: radiotherapy, clinical electron dosimetry, depth dose distribution, plane-parallel ionization chamber, radiochromic dosimetry film.

Research field: nuclear physics, material-radiation interaction, dosimetry.

Related sciences: medical physics.

Introduction

Radiotherapy is the medical use of ionizing radiation as a part of cancer treatment to control malignant cells.

A multi disciplinary team of specialists in cancer treatment and care includes medical physicists. Medical physicists determine the time of radiation from a particular radiotherapy machine to get the right dose. In diagnostics and radiation therapy special attention is given to the control of the parameters of ionizing radiation source, it includes carrying out clinical dosimetry. Therefore, today medical physicists focus on the creation of new methodologies, techniques and devices to control these parameters with the necessary accuracy.

Up-to-date modern advances in the commercial development of linear accelerators with suitable energy and retractable x-ray targets as well as the development of new radiotherapy methods allow extensive use of electrons for radiation therapy of surface and shallow-lying tumors (for example breast cancer).

The main advantages of the electron beams are: 1 - high degree of dose homogeneity in the target volume;
2 - high dose gradient at the boundaries between target and healthy tissue. Thus, it is necessary to have a clear perception of scientific understanding and the methodology of clinical dosimetry of electron beams.

Research objective is to carry out clinical dosimetry of the electron beams.

The research tasks are to measure the depth dose distribution of the 2 MeV electron beams of the betatron using a plane-parallel ionization chamber and radiochromic dosimetry films (the GafChromic EBT3 film) in non-water phantom and to compare the results obtained.

Materials and methods

Source of emission

The irradiation was performed using the betatron prototype of a new generation. This device allows smooth changing of energy in a wide range of the dose depending on the clinical applications. The maximum kinetic energy of the electron is 3.5 MeV.

Dosimetry equipment

Plane-parallel ionization chambers are acceptable for relative dosimetry of electron beams. In the experiment the standard dosimeter AT5350/1 (date of gauging - 27.09.12) completed with a PTW-Freiburg Markus 23343 parallel-plate chamber (with the dose range 2 – 45 MeV; measuring volume - 0.055 cm$^2$; wall material was polyethylene) was used [1].

Radiochromic films are one of the most practical detectors used in non-water phantoms to obtain relative and absolute measurements for clinical electron fields [2]. In the experiment the GafChromic EBT3 radiochromic dosimetry film (the material is near the tissue-equivalent; the dose range was 1cGy to > 40 Gy) was used [3].

Measurement of the central-axis depth-dose curve can be done with a film placed between the plates of solid phantom parallel to the electron beam [2]. The fitted calibration curve allows calculating the value of the absorbed dose received from the given source of radiation in accordance with the value of the relative optical density of the film [4].

Nonwater phantom

In this work RW3 Slap Phantom T29672 was used. The material of the phantom is polystyrene (C$_8$H$_8$) containing 2 % (±0.4 %) of TiO$_2$ by mass. The density of the phantom is 1.045 g/cm$^3$. The electron density of the phantom is 1.012 times higher than the electron density of water [5].

Measurements of the depth dose distribution of the electron beams

Provided secondary electron equilibrium exists (normally within a few millimeters of the surface) and the energy spectra at each position are identical, the dose in water at a depth (d$_{water}$) and the dose in the solid at a corresponding depth (d$_{med}$) are related by

$$D_{water}(d_{water}) = D_{med}(d_{med}) \left[\frac{\rho}{\rho_{water}}\right]_{med} \left[\frac{\rho}{\rho_{water}}\right]_{water}$$

(1)

where $\left[\frac{\rho}{\rho_{water}}\right]_{med}$ is the ratio of the mean unrestricted mass collision stopping power in water to that in the
solid. \( \phi_{\text{water}} \) is the fluence factor, that is, the ratio of the electron fluence in water to that in the solid phantom. In the first approximation the fluence factor could be equal to 1.

The depth in the nonwater phantom can be converted to water-equivalent. The water-equivalent depth can be approximated using a density determined from the ratio of the depth of 50% ionization \( R_{50} \) penetrations by

\[
d_{\text{water}} = d_{\text{med}} \times \rho_{\text{eff}} = d_{\text{med}} \left( \frac{R_{50}^{\text{water}}}{R_{50}^{\text{med}}} \right),
\]

i.e., the effective density, \( \rho_{\text{eff}} \) given by the ratio of the \( R_{50} \) in water to that in the nonwater material.

Recommended effective density of scaling depth from nonwater polystyrene phantoms to water phantoms for electron beams is 0.975.

In this case, considering the equation (1), the percent depth dose in water can be given by

\[
\%D_{\text{water}}(d_{\text{water}}) = \left[ \frac{D_{\text{med}}(d_{\text{med}} \left( \frac{S}{\rho_{\text{eff}}} \right)_{\text{med}} \phi_{\text{water}}^{\text{med}})}{D_{\text{med}}(d_{\text{med}} \left( \frac{S}{\rho_{\text{eff}}} \right)_{\text{max}} \phi_{\text{water}}^{\text{med}}} \right] \times 100 ,
\]

where the denominator equals the value of the numerator at the depth-of-maximum dose. [6]

Results and discussion

In figure 1 the results of the depth dose measurement of the 2 MeV electron beams of the betatron using the plane-parallel ionization chamber and the GafChromic EBT3 films in the phantom are shown.

---

**Fig. 1. Comparison of the film dosimetry results with the ionization chamber results**

(2 MeV electron beams of the betatron):
- the depth dose distribution using plane-parallel ionization chamber in the non-water phantom;
- the depth dose distribution using plane-parallel ionization chamber in water;
- the depth dose distribution using the GafChromic EBT3 radiochromic dosimetry films in water.
Conclusion

The measurements performed on the 2 MeV electron beams of the betatron show that the qualitative results obtained with the help of the GafChromic EBT3 films and the plane-parallel ionization chamber are in good agreement.

However, the values of the absorbed dose to the depth dose curves on the central axis quantitatively differ in the beginning of recession. This phenomenon can be explained by the fact that the betatron is being under development, consequently, the betatron did not work continuously and the measurements were carried out in different days.

1. User manual Markus chamber Type 23345 D273.131.00/07 2006-07 Hn
5. Instruction manual RW3 Slab Phantom T29672 and T40006.1.001 D188.131.00/04 2007-07 Chr/zi/Sa