Reference dosimetry for fast neutron and proton therapy

Dan T. Jones

iThemba Laboratory for Accelerator based Sciences

In radiation therapy tumour control and normal tissue complication probabilities are both steep functions of absorbed dose which must therefore be accurately and reproducibly determined. Accuracy of ±3% is desirable, while reproducibility of ±2% is required. The requirements for a dosimeter depend on: the accuracy of the absorbed dose determination required; the sensitivity of the measuring system; the energy dependence of the dosimeter response; the spatial resolution required.

Fast neutrons and protons undergo fundamentally different interactions in tissue. The former interact with nuclei, while the latter, as in the case of photons, interact mainly with atomic electrons. Protons do, however, also undergo some nuclear interactions, the probability of which increases with energy. For both modalities the practical instruments for determining the reference absorbed dose in a patient are thimble ionization chambers. These provide indirect determination of absorbed dose as calibration factors measured in standard radiation fields as well as conversion factors which require knowledge of various physical data, have to be applied. In principle calorimeters give a direct determination of the absorbed dose (the energy imparted to a sensor is indicated by a temperature change) and therefore yield the smallest uncertainty, but they are not practical instruments for routine clinical use.

Several dosimetry protocols for both fast neutron and proton therapy have been published. All the protocols cecommend that, in the absence of a calorimeter, reference absorbed dose measurements in the clinical situation be made with ionization chambers having Co-60 calibration factors traceable to standards laboratories. The calibration factors can be given in terms of exposure, air kerma or absorbed dose to water. The latter is preferred as the uncertainties in the chamber-dependent factors used to convert measurements to absorbed dose are less, the formalism is simpler and easier to interpret and the probability of error is less.

Because of the nature of neutron interactions tissue-equivalent ionization chambers are used for neutron dosimetry The situation is complicated by the fact that neutron beams are always contaminated with gamma rays, which need to be accounted for. The universally accepted protocol was published as long ago as 1977 by the International Commission on Radiation Units and Measurements (ICRU) [1]. Proton dosimetry is inherently simpler and ionization chamber composition is not critical. In 1998 the ICRU also published a proton dosimetry protocol [2] which was adopted by most proton therapy centres. More recently the International Atomic Energy Agency (IAEA) published a proton dosimetry code of practice [3] using a formalism applicable to all therapy modalities (except neutrons).

The three protocols above will be descibed and discussed and the two proton protocols will be compared. Details of the measuring procedures, the formalisms and the physical quantities required to convert the measurements to absorbed doses will be given, together with estimates of the uncertainties.

The dosimetry of fast neutron and proton therapy beams is on a sound footing and meets internationally accepted standards.

REFERENCES

[1] ICRU Report 26. Neutron dosimetry for biology and medicine. ICRU, Bethesda MD (1977)

[2] ICRU Report 59. Clinical proton dosimetry Part 1: Beam production, beam delivery and measurement of absorbed dose. ICRU, Bethesda MD (1998)

[3] Code of practice for proton beams. In IAEA TRS 398. Absorbed dose determination in external beam beam radiation therapy. IAEA, Vienna (2000)135

Email: jones@tlabs.ac.za