Conf-901226--2

DISCLAIMER

BNL--45930

DE91 011028

DOSE MEASUREMENTS AND CALCULATIONS IN THE EPITHERMAL NEUTRON BEAM AT THE BROOKHAVEN MEDICAL RESEARCH REACTOR (BMRR)

V.Benary[1,2], R.G. Fairchild[1], J. Kalef-Ezra[1,3], D. Greenberg[1], Y. Kamen[1], S. Fiarman[1], and L. Wielopolski[1,4]

[1]Medical Dept., Brookhaven National Laboratory, Upton, NY, USA
[2]Tel Aviv University, Tel-Aviv, Israel
[3]University of Ioannina, Ioannina, Greece
[4]Radiation Oncology Dept., SUNY-SB, Stony Brook, NY, USA

INTRODUCTION

The characteristics of the epithermal neutron beam at BMRR were measured, calculated, and reported by R. G. Fairchild (1). This beam has already been used for animal irradiations. We anticipate that it will be used for clinical trials. Thermal and epithermal neutron flux densities distributions, and dose rate distributions, as a function of depth were measured in a lucite dog-head phantom. Monte Carlo calculations were performed and compared with the measured values.

MEASUREMENTS AND CALCULATIONS

Dog-Head phantom. A lucite dog-head phantom similar in size and shape to that of a Labrador retriever (Fig. 1) was constructed in our laboratory. The central part was cored to a rectangular well 4½" in depth, 3½" in length, and 3¼" in width. This was filled with different sets of horizontal lucite plates. Each set of plates had precisely machined grooves, to accommodate either foils, cadmium capsules with foils, TLD's, or silicon diodes (Fig. 2). This arrangement allowed for measurements at precise depths on the central axis. The composition and the density of lucite is, for our purposes, very similar to tissue. The phantom was irradiated with its central axis (center of the plates) aligned with the central axis of the port. A series of irradiations were conducted with the phantom touching the bare 10" x 10" port. Another series had the phantom placed against a 2"-thick LiOH collimator, with an aperture of about 4" x 4", inserted in the port. The experiments were designed:

- To check the dosimetry in an asymmetric geometrical configuration;
- To obtain dosimetric data for animal irradiations;
- To assess the influence of beam delimiters (collimators);
- To compare the measured values with the Monte Carlo calculations.

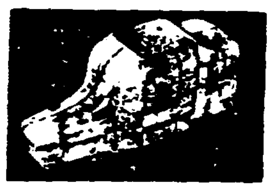

Fig. 1

Calculations. The Monte Carlo computer program MCNP was used to generate neutron fluence rates and dose rates in a dog phantom. The neutron source used in the calculations had a pancake geometry of 10" x 10" and was situated directly in front of the phantom or the collimator, when one was used. The energy spectrum of the source was the calculated spectrum reported by Wheeler et al.(2). The calculated values were compared to the measured results. The main discrepancy was observed in the calculations of the γ dose.

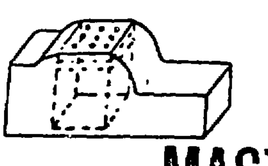

Fig. 2

Thermal and epithermal neutron fluence rates. Bare and cadmium-encapsulated gold foils were used to measure the thermal and epithermal neutron flux. The epithermal neutron fluence rate was calculated by the cadmium ratio method. The measured values of the neutron fluence rates with and without a collimator are shown in Fig. 3, and the calculated (MCNP) values are given in Fig. 4. When we compared the ratio: thermal neutron fluence rate (bare port)/thermal neutron fluence rate (collimator) at the peak and at the surface of the phantom, a skin-sparing effect was suggested when a collimator was used. The magnitude of this effect will be influenced by the combined geometry of the collimator and the phantom. The measured and the calculated values are in good agreement; however, the calculated epithermal neutron fluence rate drops faster with depth in phantom.

Effective Dose Rate. The effective dose rates for phantom irradiations on the bare port and with a collimator are given in Figs. 5 and 6 at a power of 1 MW. For the $^{14}N(n,p)^{14}C$ reaction, a N content of 1.84% by weight and an RBE of 1.6 were used. The same RBE was used for the fast neutron effective dose. The RBE used for the $^{10}B(n,\alpha)^{7}Li$ reaction was 2.3. The shape of the curves in Fig. 6 was influenced by the irregular shape of the phantom.

THERMAL AND EPITHERMAL FLUENCE RATE IN LUCITE DOG PHANTOM

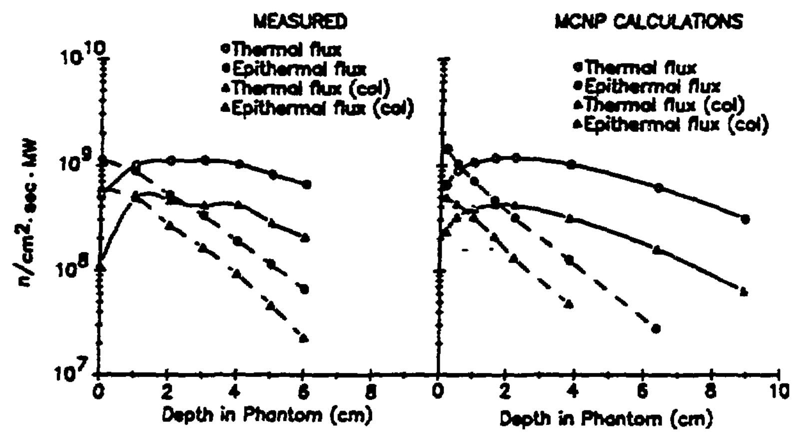

Fig. 3

Fig. 4

MEASURED DOSE DISTRIBUTIONS IN DOG PHANTOM—1MW

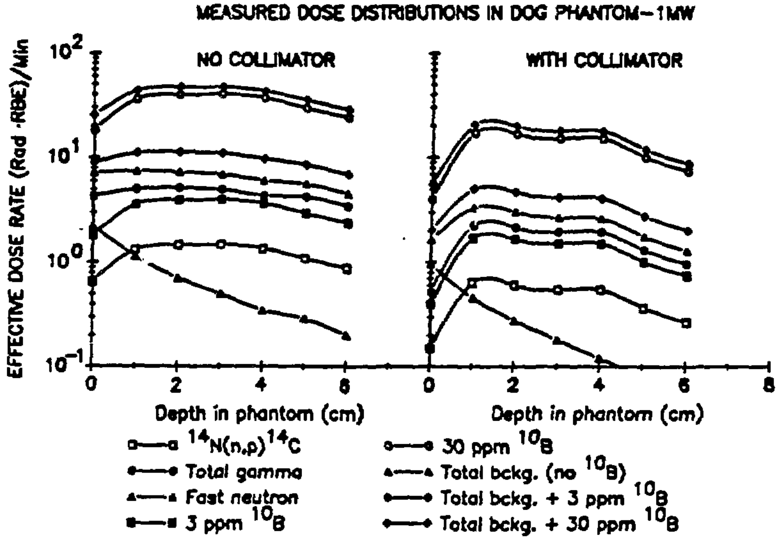

Fig. 5

Fig. 6

The calculated (MCNP) dose distributions were in good agreement with the measured values with the exception of the calculated γ doses. As can be seen in Table 1, the γ doses were much lower, probably due mainly to the cross sections used.

Table 1. Beam Parameters in Dog Phantom.

	Measured		MCNP	
	Bare	Coll	Bare	Coll
Fast neutron dose rate at 0 depth rad·rbe/MW·min	2.2	0.95	2.03	0.85
Peak total γ dose rate rad·rbe/MW·min	5.19	2.25	2.79	0.84
Fast neutron dose/th. neutron at peak rad·rbe/n·cm	$3.2 \cdot 10^{-11}$	$3.2 \cdot 10^{-11}$	$3 \cdot 10^{-11}$	$3.3 \cdot 10^{-11}$
Peak γ dose/th. neutron at peak rad·rbe/n·cm	$7.7 \cdot 10^{-11}$	$7.7 \cdot 10^{-11}$	-	-
Peak bckgr (no ^{10}B) dose rate rad·rbe/MW·min	7.53	3.35	-	-
Peak bckgr 3 ppm ^{10}B dose rate rad·rbe/MW·min	11.34	5.05	-	-
Peak bckgr 30 ppm ^{10}B dose rate rad·rbe/MW·min	47.16	20.35	-	-

INTERCALIBRATION OF EPITHERMAL NEUTRON BEAMS

Measurements and/or calculations of beam parameters in air are not enough to characterize a neutron beam. Dose components must be measured and calculated in a phantom. The compositions, shapes, and sizes of the phantoms, as well as the geometry of the beam, make it difficult to compare the performance of the different neutron beams. We suggest standardizing the phantom and the reported measured or calculated parameters in a manner similar to that which follows.

Phantom. A simple, inexpensive, and easily machined lucite right circular cylinder, 16.5 cm in diameter, 25 cm high, was built. A thin lucite tube was inserted along its central axis. Lucite rods were inserted in the tube. Each set of rods had indentations to allow the insertion of detectors (foils, TLDs, or solid state silicon diodes) at well-defined depths in the phantom. A provision is made for the insertion of a lucite tube off axis, in which measurements can be made for calculation benchmarking.

Beam Parameters in Air. It is our opinion that the parameters, measured and/or calculated at the irradiation port face, which must be reported in order to characterize the epithermal beam are:

- Neutron spectrum;
- Epithermal neutron flux density;
- Absorbed dose rate from gammas and fast neutrons free in air;
- Gamma dose and fast neutron dose per epithermal neutron.

Beam Parameters in Standard Phantom. Graphic representations of the thermal neutron flux density and dose rate distributions as a function of depth in phantom must be reported.

A beam aperture of 10 by 10 cm is suggested. In any case, the irradiation geometry must be well defined. The advantage depth and the therapeutic gain will complete the data necessary for an effective intercalibration of epithermal neutron beams.

REFERENCES

1. R.G. Fairchild et al. Installation and testing of an optimized neutron beam at the BMRR. Neutron Beam Design, Development and Performance for Neutron Capture Therapy. O.K. Harling, J.A. Bernard and R.G. Zamenhof, Eds. Basic Life. Sciences, Vol. 54, 185, Plenum Press, New York (1990).
2. F.J. Wheeler et al. Physics design for the BMRR epithermal neutron source. Neutron Beam Design, Development and Performance for Neutron Capture Therapy. O.K. Harling, J.A. Bernard and R.G. Zamenhof, eds. Basic Life Science, Vol. 54, 83, Plenum Press, New York (1990).

(Research supported by US DOE contract DE-AC02-76CH00016)