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Measurement of stereotactic beam data of 9 MV X-rays using diode detector

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ABSTRACT

Background: Radiosurgery is a focal brain irradiation technique that delivers, usually in a single session, high dose of ionizing radiation. The presence of lateral electronic disequilibrium and steep dose gradients in small fields demands special attention to the selection of a suitable detector with respect to its size, composition and response.

Materials and Methods: Small circular fields were produced by home-made collimators attached to a 9MV Neptun 10 PC linac ranging from 12.5mm to 25 mm at isocenter level in 2.5 mm increment. Stereotactic beam data including percent depth dose, off axis ratio and output factor were measured using p-type silicon chip detector in a water phantom. Beam data were plotted for all available collimator sizes.

Results: Percent depth dose values at depth of 100 cm show 10 percent increase with enlargement of the field sizes from 12.5 mm to 25mm. Small overestimation of output factor has been observed using diode detector.

Conclusion: It is concluded for stereotactic radiosurgery with higher energy photon diode detector could be a good and reasonable choice to measure percent depth dose and off axis ratio. Regarding the output factor, it is better to compare the results with those obtained by other detectors. *Iran. J. Radiat. Res., 2004; 2 (2): 79-84*

Keywords: *Stereotactic radiosurgery, diode detector, beam data, auxiliary collimator.*

INTRODUCTION

Stereotactic radiosurgery (SRS) is used for precise irradiation of small inoperable intracranial lesions (volumes typically less than 25 cm^3). Radiosurgery was introduced in 1951 by a Swedish neurosurgeon, Lars Leksell (1951). Small radiation beams ranged from 5mm to 30 mm in diameter cross fire target through various gantry and couch angles. When X-ray energy is so high, or the beam size is so small the electron range may exceed the edge of the field giving rise to a phenomenon, called, lateral electronic disequilibrium (Rice *et al.* 1987). It means that the numbers of scattered electrons carrying energy into and out of measured point are not the same in small radiation fields; this may cause some underestimation of the dose. This effect imposes some limitation on selection of detectors used for dosimetry in view of size, composition and response. Many detectors including, diodes, radiochromic films, ionization chambers and radiographic films have been used for this purpose (Duggan and Coffery 1998, Ron Zhu and Allen 2000, Wanc and Hung 2001).

Diode detectors offer advantages over conventional ionization chambers, such as high spatial resolution, small sensitive volume (Scanditronix p-type 0.2-0.3 mm3) and good stability (Rikner and Grussel 1983, 1985, Grussel and Rikner 1993).

Diode detectors, having a density more than one, are relatively more sensitive to scattered radiation. They are wrapped up with a tungsten /

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epoxy layer, a property giving a substantial angular response which should be taken in to consideration for the interpretation of the results (Somaglia *et al.* 1999).

The scope of this paper was to present dosimetric features of homemade collimators in terms of beam characteristics in view of diode detector application.

MATERIALS AND METHODS

Linac

A 9 MV X- ray beam from a Neptun 10 PC linear accelerator equipped with home-made radiosurgery hardware was used for all measurements. We constructed six tertiary collimators with internal diverging canal to form specified field diameter at isocenter level. For all of measurements secondary collimator jaws were set at 40×40 mm^2.

Detector

Photon field detector from Scanditronix (RFA, PFD) based on p-si semiconductor was used to measure stereotactic beam data including percent depth dose, off axis ratio and output factor. Radiation field diameters ranged from 12.5 mm to 25 mm in 2.5 mm increment at isocenter level.

The active region dimensions were 2.5 and 0.06 mm perpendicular and parallel to beam axis respectively. The latter position was used for all measurements to achieve a higher resolution.

Treatment planning software

Ergo V.3.1 (3D line society, Italy) was implemented for target localization and calculation of dose distribution and monitor units. This treatment planning software requires tissue phantom ratio (obtained from internal conversion of given percent depth dose by the software), off axis ratio and output factor for each collimator.

RESULTS

Percent depth dose: is obtained as follows (Rice *et al.* 1987):

$$PDD=D(s, 0, d)/D(s, 0,d_{max})$$

Where s is collimator diameter, dmax is depth of maximum dose and d is depth of measurement. Figure 1 shows PDD variation as a function of depth for available collimator sizes ranging from 12.5mm to 25mm.

Variation of percent depth doses with collimator diameter at depth of 10 cm is 10%. As measurement of TPR is difficult and time-consuming percent depth doses was converted to Tissue phantom ratio by treatment planning software implementing the following equation (Podgorsak 1992):

$$TPR\ (d,s)/PDD(d,c') = (f+d/f+d_N)2$$

Where d is depth of measurement, d_N is depth of normalization of TPR, f is source to surface distance in PDD measurement, c' is field size on the surface and s=c' (f+d)/f is field size at depth of d.

All measurements were carried out at source to surface distance of 1000 mm from depth of 250 mm to 0 mm. Measured PDD values for developed collimators are summarized in table 1.

Off Axis Ratio: is defined as:

$$OAR=D(s,q,d)/D(s,0,d)$$

Where q is lateral off axis distance from central axis, d is depth of measurement (Rice et al. 1987) which was equal to 70 mm for our set up.

Source to water phantom surface was kept at 930 mm. According to AAPM Report no.54 for

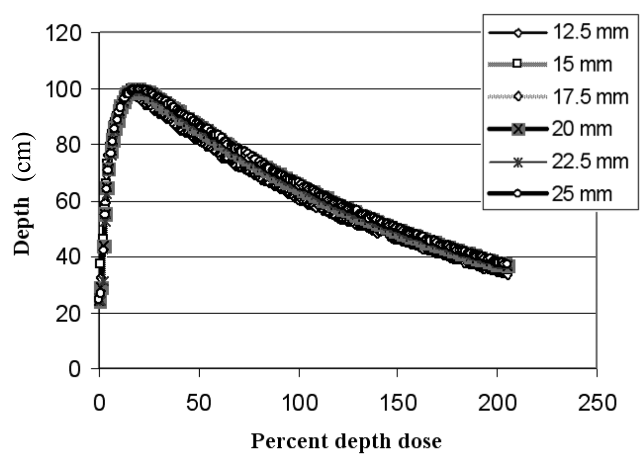

Figure 1. PDD curves for developed collimators ranged from 12.5mm to 25mm for depth of 0 to 250 mm of depth.

Table 1. Measured PDD values for developed collimators. Depths are selected for showing trend of values.

Depth (cm)	12.5 mm	15 mm	17.5 mm	20 mm	22.5 mm	25 mm
0.0	0.252	0.232	0.241	0.241	0.252	0.247
0.2	0.444	0.461	0.275	0. 439	0.313	0.423
0.4	0.696	0.659	0.648	0.645	0.629	0.639
0.6	0.824	0.791	0.777	0.777	0.763	0.765
0.8	0.902	0.866	0.866	0.859	0.847	0.855
1.0	0.950	0.908	0.920	0.921	0.910	0.915
1.2	0.982	0.951	0.964	0.953	0.949	0.957
1.4	0.998	0.983	0.984	0.980	0.980	0.981
1.5	1.000	0.988	0.997	0.987	0.989	0.980
1.6	0.994	0.998	0.994	0.988	0.992	0.990
1.7	0.993	0.987	1.000	0.991	0.993	0.998
2.0	0.976	1.000	0.997	1.000	1.000	0.999
2.2	0.959	0.985	0.991	0.992	0.996	1.000
3.0	0.917	0.942	0.960	0.960	0.967	0.967
4.0	0.867	0.900	0.906	0.913	0.913	0.917
5.0	0.830	0.846	0.856	0.859	0.870	0.872
6.0	0.776	0.807	0.810	0.815	0.829	0.833
7.0	0.730	0.746	0.766	0.770	0.779	0.785
8.0	0.698	0.704	0.728	0.734	0.736	0.746
9.0	0.651	0.672	0.658	0.695	0.694	0.698
10.0	0.604	0.631	0.647	0.652	0.657	0.664
11.0	0.586	0.600	0.609	0.615	0.623	0.626
12.0	0.545	0.566	0.579	0.583	0.589	0.592
13.0	0.516	0.540	0.550	0.550	0.554	0.562
14.0	0.489	0.499	0.520	0.525	0.526	0.529
15.0	0.467	0.475	0.491	0.495	0.503	0.502
17.0	0.417	0.424	0.438	0.444	0.448	0.454
19.0	0.376	0.380	0.393	0.394	0.399	0.402
21.0	0.329	0.341	0.354	0.356	0.361	0.363
23.0	0.301	0.307	0.317	0.320	0.325	0.326
25.0	0.270	0.274	0.286	0.288	0.292	0.296

measuring beam profiles, detector dimensions must be 2 mm or less. Parallel orientation of diode detector can readily meet these requirements. Off axis ratio versus off axis distance for various collimators is shown in figure 2.

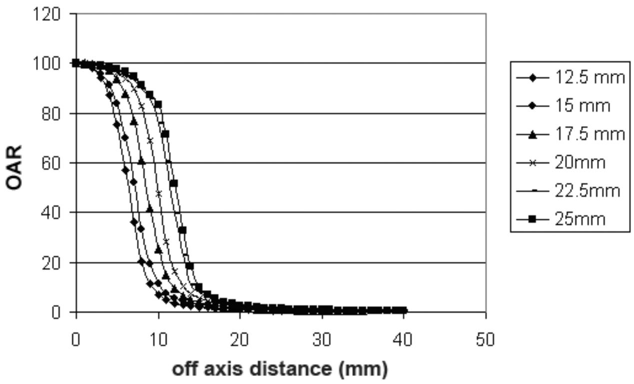

Figure 2. Off axis curves for 12.5mm to 25 mm collimators. Widths of scanning were four times the diameter of the collimator.

The only factor to be considered here is angular response of the detector (AAPM, no 54). This effect has not been observed in our measurements, as OAR curves widen more or less uniformly with increasing beam width. Full widths at half maximums were respectively 11.5mm, 14.4mm, 16.4mm, 19.2mm, 21.3mm and 23.8mm for aforementioned collimators. Sizes of penumbras corresponding to 20%-80% dose fall off region ranged from 3.4mm to 3.8mm (table 2).

Table 2. Beam characteristics for developed collimators.

Collimator size	**12.5 mm**	**15 mm**	**17.5 mm**	**20 mm**	**22.5 mm**	**25 mm**
Penumbra (mm)	3.40	3.60	3.64	3.65	3.70	3.82
FWHM	11.5	14.4	16.4	19.2	21.3	23.8
D100/D200	1.74	1.73	1.73	1.74	1.75	1.75
D_{max} (mm)	15	20	17	20	20	22

Output factor: is defined as:

$OF=D(s, 0,d_{max})/D\ (10cmx10cm, 0,d_{max})$

which is ratio of dose at depth of maximum dose on the central axis for collimator size" s "to dose measured at the same depth in a standard 10 × 10 cm2 calibration field (Rice 1987) .The output factors were determined by placing diode detector at a source to phantom surface distance of 1000 mm and at build up depth (21 mm) for collimated fields. All measurements were normalized to 100 × 100 cm2 field size.

The size and type of detector play more important role in output measurement than other stereotactic data (Somaglia *et al.* 1999).

Figure 3 shows increasing of output factor with enlargement of field size in a non-linear mode, which is in accordance to other similar reports (Arcovito *et al.* 1985, Houdek *et al.* 1992, Serago *et al.* 1992).

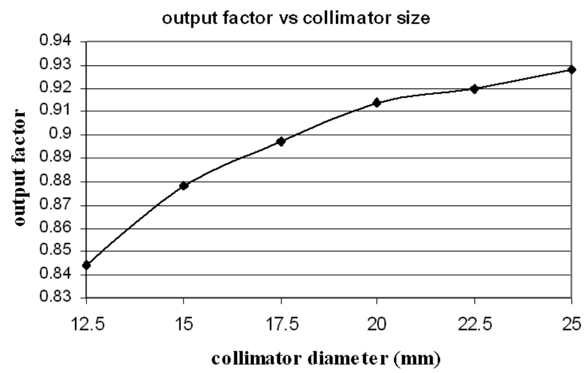

Figure 3. Output factor against collimator sizes for developed collimators.

DISCUSSION

To our knowledge few reports have been published with reference to measurements of stereotactic beam data employing diode detector for 9MV X-ray Radiosugery. Lateral electronic disequilibrium along with small overestimation claimed for diodes (Somaglia *et al.* 1999) and finally limited available data in literature make interpretation of results difficult and ambiguous.

With regard to percent depth dose, there is a good agreement between our results and those obtained in other studies (Arcovito *et al.* 1985, Houdek *et al.* 1992, Serago 1992). Ten percent increase of percent depth dose at depth of 100 mm with increasing field sizes from 12.5 mm to 25 mm is a promising index (Arcovito *et al.* 1985). Of course in the higher depths lateral electronic disequilibrium tends to show noticeable effect due to smaller field size. On the other hand, the presence of additional material surrounding measuring volume increases lateral scattering and, therefore, it will reduce lateral electronic disequilibrium. So, here we have two competing parameters and there should be a depth in which they neutralize each other.

It may be concluded that the values obtained at lower levels of water phantom are more reliable than corresponding values for upper levels, the fact that should be proved.

With respect to off axis ratio, the dimension of p-type diode detector provides a good resolution better than those obtained by utilizing other types of detectors such as smallest ionization chambers. Parallel positioning of diode to central axis reach active region size to 0.06 mm, which is optimum for this work. With regard to angular response, this effect should be negligible in small fields, a fact that is a direct deduction of uniform widening of OAR curves measured in our experiments. In case of smallest collimator size (12.5mm), we obtained poor signal to noise ratio, which was improved by increasing the number of samples taken for each point of measurement.

As far as output factor is concerned, the non-tissue equivalent silicon dies, as has already been mentioned; this will increase lateral scattering which may cause a small overestimation of output factor (Rikner and Grussel 1983). As all measurements were performed in a fixed depth, d_{max}, therefore, the effect of depth will be obviated. Comparison of our results with those presented by Wyscocka and Maciszewski (2000) who used the same machine output factor shows some sign of overestimation. Of course, we have no knowledge of their collimator design and construction of their collimator and condition under which their measurement have been carried out.

In conclusion we have shown p-type diode detector (Scanditronix) is a good and accessible choice for measuring small field beam data. It is recommended that the measured data to be compared by the results obtained with other detectors such as small ionization chambers especially for output factor (Rikner and Grussel 1983). As far as X-ray energy is concerned high-density detectors such as diodes could better compensate the problem of underestimation resulting from lateral electronic disequilibrium, which is more prominent in higher energy.

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