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DOSIMETRIC STUDY OF SMALL CIRCULAR CUTOUTS FOR ELECTRON BEAM THERAPY

Clinical Science

Resmi K
Bharathan

ABSTRACT

Use of cerrobent cutouts is a usual practice in the electron beam therapy for superficial tumors. Placement of cutouts in between the beam causes some effects in the dosimetric parameters. It may shift the PDD curve to the surface, decrease the mean energy, decrease the output factor. These effects become more prominent in the case of small area cutouts below the condition of lateral scatter equilibrium. To treat a patient with small area cutout, patient specific dosimetry to be done. The aim of the study was to find out the effect of small area cutout in the megavoltage electron beams.Small circular cutout with diameter 2cm to 8 cm were taken and dosimetric parameters R_{100},R_{90},R_{80}.R_{50},R_P,E_{0mean}, output factor are studied. All the parameters are fitted in a best fitting equation, and there by there is no need to carry out dosimetry patient specifically.

KEYWORDS

INTRODUCTION

Radiation therapy is becoming an indomitable tool in defeating cancer. External beam Radiation treatment can be classified in to two in a broad manner. That is photon beam therapy and electron beam therapy, (even though heavy particle beam therapy is in use they are not well established). Electron beam therapy is used mainly for treating superficial tumor since early 1950's.

To achieve a conformal dose distribution cast cerrobend alloy cutouts made according to the size and shape of the tumor is being used. It is an alloy having 50% bismuth, 26.7% lead, 13.3% tin , and 10% cadmium by weight. We have used cadmium free cerrobend. Use of cutouts have some effects in the dosimetric parameters of electron beam such as the PDD curve therapeutic range mean energy and output factor. Usually these effects will be like shift of therapeutic ranges towards the surface, decrease in the output factors and so on. These changes will be more pronounced in the case of small area cutouts because the lateral scatter equilibrium will fail in the case of small area cutouts.

Lateral scatter equilibrium will exist only when the distance between the central axis and field edge is more than lateral range of scattered electrons. An empirical equation gives Req which is the minimum radius required for the existence of lateral scatter equilibrium.

$$Req=0.88x\sqrt{Ep0}$$

Where Ep0 is the most probable energy given by following equation

$$Ep0=0.22+1.98Rp+0.0025Rp2$$

Rp in this equation is practical range which Is the depth at which the tangent plotted through the steepest section of the electron depth dose curve intersects with the extrapolation line of the background due to Bremsstrahlung.

Use of cutouts having radius smaller than Req will cause some difference in the dosimetric parameters. Ignoring these effects may decrease the quality of treatment. Doing dosimetry for each patient will be difficult every institution. So aim of this study is to find out the changes occurring in the dosimetric parameters of megavoltage electron beams while using small area cutouts and to fit those changes in a curve as a function of cavity area.

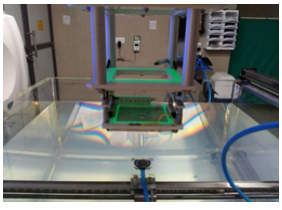
MATERIALS AND METHODS

The study is carried out in the linear accelerator ELEKTA VERSA HD having six different electron energies , 4MeV, 6 MeV , 8 MeV 10MeV 12 MeV and 15MeV. Using 40x40x40 PTW (PTW Freiburg, Germany) radiation field analyzer. Measurements are done with 100 cm Source to Surface Distance and 10x 10 applicator. Circular cutout diameters 2cm 3cm 4cm 5cm 6cm 8cm (with cavity area 3.14cc 7.06cc 12.56cc 19.6cc 28.26cc 50.24cc) and an open 10x10 field were selected. PDD , Beam profile was taken in RFA using PTW Markus plane parallel chamber 0.055cc volume as field detector and PTW Semiflex cylindrical chamber as reference detector.

PDD and Beam profiles were taken with both detectors ON for all energy and all area cutouts , Data obtained using Mephysto Navigator software. Values of R100 R90 R80 R50 R20 Rp qnd E0(mean) are taken from the PDD curve. Output of each cutout for each energy is found using water equivalent white polystyrene slab phantom and Markus chamber at Zref as per TRS 398. Output factor obtained by taking ratio of output with cutout and output of the reference 10 x10 open field.



Setup to find output factor



Setup to take PDD and Profile

RESULT AND DISCUSSION

R_{100}, R_{90} ,R_{80} , R_{50}, R_p E_{0mean} and Output factor for all cut outs for six different energy is found. The obtained data is analyzed and curve for each energy is plotted as cutout area versus the dosimetric parameter. Curve fitting is done using GNU plot software . Equations for each parameters for all energy is found as a function of cutout area with minimal reduced chi square value.

4MeV

The effect of small area cutouts found to be less pronounced in the case of lower energy. The data obtained in the case of 4mev electron beam is shown in table 1.1. Rq for 4MeV will be approximately 1.75 cm so the cutout diameter below which the lateral scatter equilibrium expected to break is 3.5 cm. the effects of small area cutout do not made much difference in the dosimetric parameters of the beam only 3mm difference was found in the R_{100}, No difference was found in the values of other dosimetric parameters such as R_{90},R_{80},R_{50},R_p and E_{0mea}

Table : Dosimetric parameters for different cutout for 4MeV

4MeV							
AREA (cm2)	R100 (mm)	R90 (mm)	R80 (mm)	R50 (mm)	RP (mm)	E0 MEAN (MeV)	O/P FACTOR
3.14	4.04	9.23	11.03	14.95	20.83	3.48	0.6982
7.065	7.03	11.03	12.56	16	21.28	3.73	0.8715
12.56	6.97	10.07	11.58	14.83	19.86	3.46	0.9432
19.625	7	10.5	12.01	15.19	20.2	3.54	0.9699
28.26	7	10.44	11.98	15.21	20.15	3.54	0.9831
50.14	6.99	10.45	12	15.25	20.26	3.55	0.9922
100	7	10.45	11.98	15.29	20.32	3.56	1

The output factor showed a visible variation from the reference field, the plot of cutout area versus output factor is shown in the figure

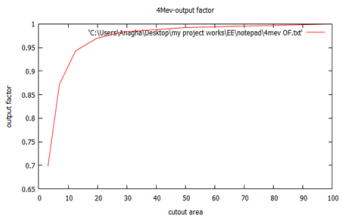


Figure 5.1.: cutout area vs output factor for 4MeV

The graph shows the trend of a logistic growth model. The best fitted equation for this is Output factor=0.987/(1+0.929*exp(-0.263*A) Where A is the cutout area.

6MeV

Similar to the 4MeV the dosimetric parameters do not shows a considerable difference. Rq for 6MeV is approximately 2.2cm so the cut out diameter minimum required for the existence of lateral scatter equilibrium will be 4.5 cm .The data for 6MeV is shown in the table

Table : Dosimetric parameters for different cutout for 6MeV

6MeV							
AREA (cm2)	R100 (mm)	R90 (mm)	R80 (mm)	R50 (mm)	RP (mm)	E0 MEAN (MeV)	O/P FACTOR
3.14	6	12.37	15.13	21.25	30.72	4.95	0.7099
7.065	10	16	18.62	23.75	31.38	5.53	0.8623
12.56	10.98	16.14	18.33	23	29.8	5.36	0.9391
19.625	11.01	16.74	18.84	23.39	31.19	5.45	0.9624
28.26	11	16.66	18.82	23.34	29.98	5.44	0.9771
50.14	11.97	16.72	18.85	23.35	30.12	5.44	0.9922
100	10.99	16.55	18.69	23.29	30.18	5.43	1

R100 changes in millimeter range (up to 4mm). the difference is further decreased in the case if other dosimetric parameters such as R90 R80 R50 Rp and E0mean. Output factor shows some difference which is illustrated in the figure

The best fitted equation for this is

Output factor=0.987/(1+0.929*exp(-0.263*A)

Where A is the cutout area.

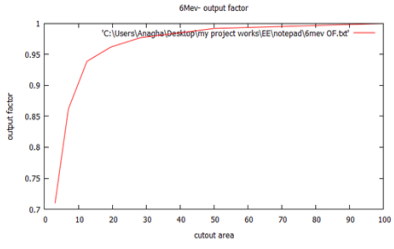


Figure: cutout area vs output factor for 6MeV

8MeV

In the case of 8MeV the effect became more visible than in the case of low energy electron beams. Rq value is approximately 2.5cm in the case of 8MeV electrons. The minimum diameter required for the existence of lateral scatter equilibrium is expected to be 5cm. The dosimetric data obtained for 8MeV is given in the table

Table: dosimetric data for 8MeV

8MeV							
AREA (cm2)	R100 (mm)	R90 (mm)	R80 (mm)	R50 (mm)	RP (mm)	E0 MEAN(MeV)	O/P FACTOR
3.14	6.01	14.74	17.97	26.01	38.5	6.06	0.6841
7.065	11.02	19.92	23.04	30.13	40.52	7.02	0.8370
12.56	12.99	20.97	23.95	30.15	39.1	7.03	0.9218
19.625	14.02	22.22	25.02	30.82	39.14	7.18	0.9631
28.26	14.03	22.43	25.08	30.88	39.21	7.19	0.9768
50.14	15.01	22.35	2513	30.88	39.45	7.19	0.9907
100	15.03	22.08	25.02	30.78	39.42	7.17	1

R100 R90 R80 and output factor shows considerable difference, but the effect is less for R50 and Rpand E0mean which can be neglected.All the parameters for 8MeV electrons has plotted against cutout area , which is given below

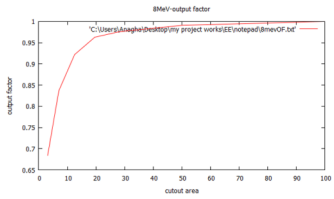


Figure:8MeV - output factor vs cutout area

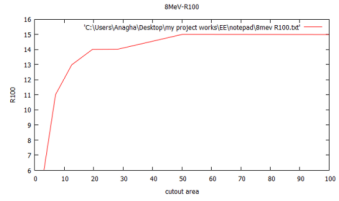


Figure:8MeV - R100 vs cutout area

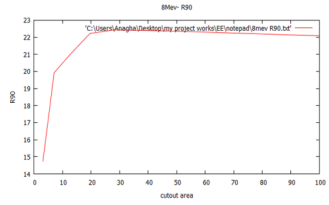


Figure:8MeV–R90-cutoutarea

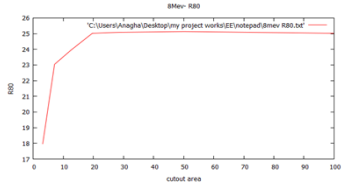


Figure: 8MeV R80 vs cutout area

All the plots shows almost same trend . the best fit model for these data is logistic growth model. Equation used to fit these data is

P= a/(1+b*exp(-c*A)) Eq(A)

The P be any one of the dosimetric parameter and A be the cutout area a,b,c are the coefficients which is obtained by fitting the data using GNU plot software.

Values of coefficients a,b,c and their expected variations for the fitted data of 8MeV is shown in the table below.

Table: 8MeV- coefficients for equation

Parameter	Coefficients		
	a	b	C
output factor	0.9869±0.006	0.8199±.076	0.2034±0.0119
R100	14.455±0.312	3.6434±0.1163	.3238±0.0626
R90	22.1575±0.218	1.428±0.308	0.3379±0.055
R80	24.95±0.184	1.169±0.233	0.3547±0.054

5.4. 10MeV

In the case of 10MeV the approximate Rq value is 2.75cm so the minimum diameter required for the cutout to achieve lateral scatter equilibrium is about 5.5cm.The dosimetric parameters shows a notable difference in the case of 10 MeV. The rage R100 shifted to surface by 1 cm in the case of smallet cut out. All other parameters except Rp shows these difference, but in the case of Rp the change is negligible. Data obtained in the case of 10 MeV is shown in the table5.5.

Table: Dosimetric parameters for different cutout for 10MeV

10MeV							
AREA (cm2)	R100 (mm)	R90 (mm)	R80 (mm)	R50 (mm)	RP (mm)	E0 MEAN(MeV)	O/P FACTOR
3.14	7.97	17.15	20.87	30.06	45.24	7	0.673549

7.065	12.97	22.89	26.84	35.55	48.57	8.28	0.82388
12.56	15.96	25.44	29.09	36.62	46.99	8.53	0.909443
19.625	18	27.57	30.9	37.59	47.17	8.76	0.945636
28.26	18.01	28.05	31.24	37.85	47.27	8.82	0.974674
50.14	18.99	28.02	31.25	37.69	46.84	8.78	0.991686
100	18.99	28	31.26	37.74	47.36	8.79	1

All the parameters for 8MeV electrons has plotted against cutout area , which is given in figure5.7:figure5.12

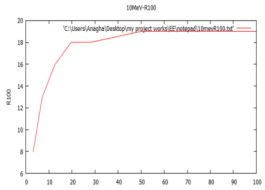


Figure:10 MeV – R100 vs cutout area

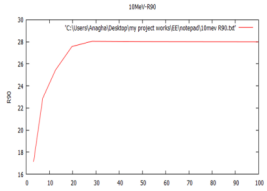


Figure: 10MeV-R90vs cutout area

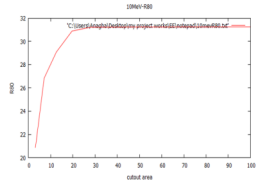


Figure5.9: 10 MeV-R80 vs cutout area

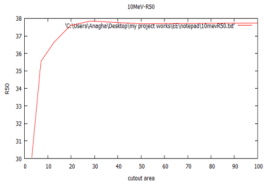


Figure5.10: 10MeV-R50 vs cutout area

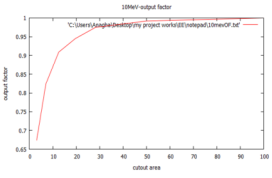


Figure:10MeV- output factor vs cutout area

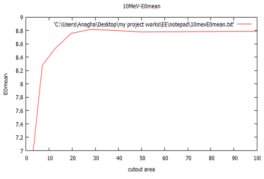


Figure : 10MeV-mean energy vs cutout area

All these graphs followed same trend. In which as the cut out area increased the value increased and then after a particular value it become almost constant for all cut out area. A best fitting equation is found for each curve. The best fitting equation is found to be equation (5.3) itself. The coefficients for all the parameters with their expected variations are given in the table5.6

Table :10MeV- coefficients for equation

Parameter	Coefficients		
	a	B	C
output factor	0.9861±0.009	0.7836±.09	0.1796±.022
R100	18.61±0.29	2.591±0.45	0.233±0.029
R90	27.96±0.236	1.23527±0.14	0.2248±0.023
R80	31.158±0.22	1.0377±0.227	0.2452±0.0269
R50	37.6225±0.17	0.7224±0.119	0.3386±0.045
E0mean	8.7652±0.04	0.7218±0.119	0.337±0.04

5.5. 12MeV

Rq value for 12MeV is approximately 3cm so the minimum diameter of cutout required to satisfy lateral scatter equilibrium will be 6cm. The dosimetric parameters have changed in a noticeable way in the case of 12Mev. Therapeutic ranges shifted to the surface except in the case of Rp for which no considerable difference is noted, and also mean energy has decreased with the use of small area cutouts. The data obtained for 12Mev is given in the table

Table: Dosimetric parameters for different cutout for 12MeV

12MeV							
AREA (cm2)	**R100 (mm)**	**R90 (mm)**	**R80 (mm)**	**R50 (mm)**	**RP (mm)**	**E0 MEAN(MeV)**	**O/P FACTOR**
3.14	7.04	19.1	23.39	33.69	50.75	7.85	0.64847
7.065	11.02	25.57	30.09	40.42	56.05	9.42	0.81137
12.56	14.97	28.65	33.24	42.66	55.21	9.94	0.90732
19.625	18.03	31.94	36.26	44.37	55.63	10.34	0.94273
28.26	20.99	33.02	37.02	44.72	55.5	10.42	0.96881
50.14	21.97	33.36	37.32	44.81	55.32	10.44	0.99464
100	21.82	33.36	37.18	44.66	55.32	10.44	1

Like 10MeV this beam also has larger effects in the dosimetric parameters. As seen in the previous energy, R50 do not show much difference which can be neglected.

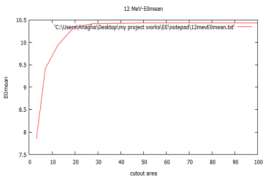


Figure : 12MeV- E0mean vs cutout area

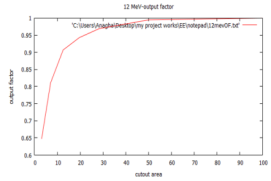


Figure : 12Mev-output factor vs cutout area

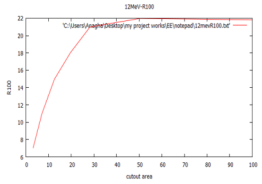


Figure: 12MeV-R100 vs cutout area

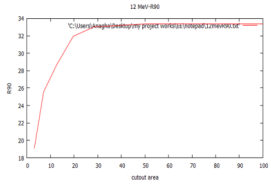


Figure: 12MeV- R90 vs cutout area

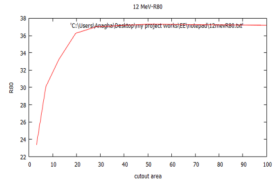


Figure : 12MeV –R80 vs Cutout area

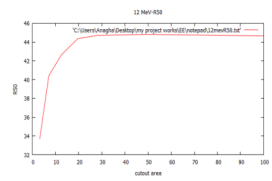


Figure : 12MeV –R50 vs Cutout area

All these graphs followed same trend. In which as the cut out area increased the value increased and then after a particular value it become almost constant for all cut out area. A best fitting equation is found for each curve. The best fitting equation is found to be equation itself. The coefficients for all the parameters with their expected variations are given in the table

Table: coefficients of equation for 12 MeV

Parameter	coefficients		
	A	b	c
output factor	0.9845±0.0098	0.9095±0.115	0.1909±0.025
R100	21.867±0.323	2.993±0.3033	0.1447±0.0113
R90	33255±0.3759	1.2194±0.139	0.17625±0.02
R80	37.1546±0.322	1.02849±0.1067	0.190156±0.02
R50	44.611±0.2323	0708582±0.0813	0.2547±0.0279
E0mean	10.404±0.055	0.7065±0.082	0.2525±0.0282

5.6. 15MeV

15 MeV is the highest energy used for the study. The trends shown by other higher energies are followed in this case too. The Rq value for 15 MeV nearly 3.5cm, so the lateral scater equilibrium will be achieved above 7cm diameter. Ranges except Rp shows considerable variation from that of reference data. Mean energy and output factor also varies considerably. The data obtained for 15 MeV is shown in table5.9

Table5.9: Dosimetric parameters for different cutout for 15MeV

15MeV							
AREA (cm2)	**R100 (mm)**	**R90 (mm)**	**R80 (mm)**	**R50 (mm)**	**RP (mm)**	**E0 MEAN(MeV)**	**O/P FACTOR**
3.14	7.02	22.16	27.23	39.56	56.19	9.22	0.6188
7.065	9.05	28.7	34.37	47.61	67.58	11.09	0.78950
12.56	11	32.23	38.59	51.77	70.18	12.06	0.88545
19.625	13.04	36.39	42.78	55.96	70.93	12.08	0.93049
28.26	16	38.32	44.59	55.97	70.39	13.04	0.95704
50.14	17.99	40.15	46.17	56.56	70.36	13.18	0.98274
100	18.02	40.25	46.18	56.49	70.28	13.16	1

All the parameters are plotted against cutout area . the graph is shown

below

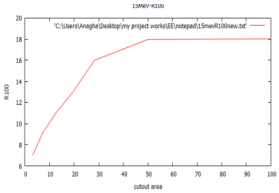


Figure: 15 MeV- R100 vs cutout area

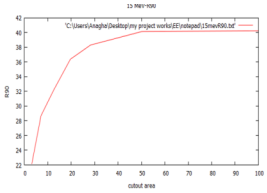


Figure: 15 MeV- R90 vs cutout area

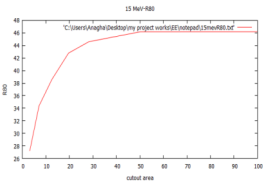


Figure: 15 MeV-R80 vs cutout area

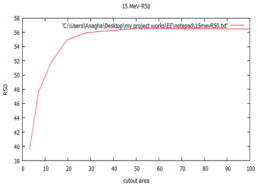


Figure :15MeV-R50 vs cutout area

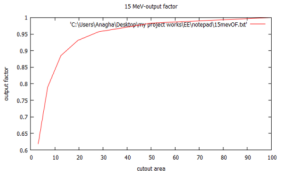


Figure: 15 MeV- output factor vs cutout area

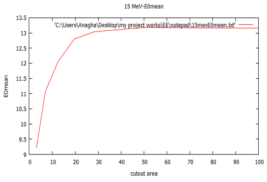


Figure:15MeV- mean energy vs cavity area

All these curves are fitted using GNU plot software, since it follows the same trends as in other higher energies, the best fitted equation is found to be equation(5.3) itself. The coefficient a,b,c for each parameters are given in the table5.10

Table :coefficient of equation for 15MeV

Parameter	coefficients		
	A	B	c
output factor	0.977±0.012	0.97384±0.138	0.18135±0.0209
R100	18.2208±0.27	2.0454±0.1466	0.0899±0.0065
R90	40.005±0.528	1.10706±0.106	0.125655±0.013
R80	45.948±0.459	0.997117±0.08	0.136423±0.012
R50	56.3208±320	0708582±0.055	0.18006±0.0154
E0mean	13.1222±0.07	0.72236±0.055	0.17937±0.0153

The beam profile for all the cutouts are taken using the same setup. The figure5.24 shows how the beam profile changes according to the use of cut outs

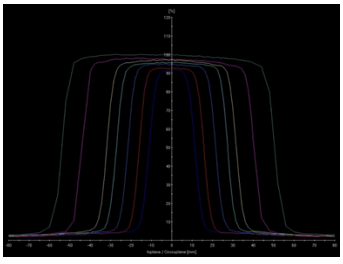


Figure: profile for different cut out dimeters

CONCLUSION

This work explore the impact of use of small area cut outs for electron beam therapy, which is usual practice in radiotherapy treatment for superficial tumors. This study concludes that there are some changes in the dosimetric parameters occurred due to the placement of cutouts in the megavoltage electron beams. The effects are decrease in output factor, decrease in mean energy and shifting of PDD curve to the surface.

Variation in the values showed almost same trend, each parameter for each energy is fitted and equation is made as a function of cavity area, and the equation is given by

$$P = a/(+b*\exp(-c*A))$$

Any of the dosimetric parameter R100 R90 R80 R50 output factor and E0 mean can be found using this equation for any cutout with known cutout area , so there is no need of doing dosimetry for each patient specifically.

The results obtained using this project is verified using a clinically used cutout made for a buccal mucosa case, and the result is proved correct

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