Original research article

COMPARISON OF ELECTRON BEAM TRANSMISSION OF DIFFERENT ENERGIES WITH TWO DIFFERENT BLOCK MATERIALS AT DIFFERENT PLACEMENT POSITIONS WITHIN THE APPLICATOR

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Abstract

Introduction: Superficial tumors are treated with electron beams. Shielding blocks are used to conform to the shape of the tumor. These shielding blocks are usually kept at lower level of the applicator which is near the skin surface. The scattering property of electron may increase the surface dose which will increase with increasing electron energies. The purpose of this study is to compare electron beam transmissionof different energies with two different block materials at different placement positions within the applicator.

Material and Methods: Cerrobend alloy (50%bismuth, 26.7%lead, 13.3%tin and 10%cadmium) and 1mm thick lead sheets (94%lead, 6%alloy) inVarian Clinac2300C/D linear accelerator with electron energies 6,9,12,16 and 20MeVs using 10x10 applicator at 3 different holding levels was used. Measurements with RW3 Slab phantom(Water equivalent),PPC05 Parallel Plane Chamber, dose 1 electrometer was done. The slab phantom 30x30x10 cm3 aligned with PPC05 Parallel Plane Chamber (at R85 of respective energies). Readings measured for open and block fields, for different thickness of shielding material, at different placement positions within the applicator. The percentage transmission calculated manually.

Results: Using electron energies 6,9,12,16, and 20MeVs respectively the transmission% were: with lead sheet 1mm thickness-2.48%,8.69%,16.05%, 28.03% and 39.50% at lower placement position, 1.19%,3.76%,7.75%,15% and 23.99% at center placement and 0.96%,3.02%,6.15% and 20.27% for upper placement; with 2mm thickness-0.89%,1.62%,3.66%, 8.95% and 16.35% at lower level, 0.60%,1.28%,2.54%,5.74% and 10.72% at center level and 0.57%,0.94%, 2.12%,4.85% and 9.22% at upper level; with 3mm thickness-0.80%,1.53%,2.88%,5.29% and 9.42% at lower position, 0.52%,1.25%,2.06%,4.03% and 7.36% at center position and 0.51%, 0.90%,1.78%,3.66% and 6.43% at upper position; with 4mm thickness- 0.75%,1.40%,2.71%,4.81% and 7.76% at lower level, 0.50%,1.18%,1.95%,3.68% and 6.31% at center level and 0.51%,0.80%, 1.70%,3.34% and 5.65% at upper level; with 5mm thickness-0.73%,1.30%,2.57%,4.56% and 7.20% at lower level, 0.45%,1.06%,1.81%,3.48% and 5.68% at center level and 0.47%,0.79%,1.61%,3.13% and 5.24% at upper level. For Cerrobend material 5mm thickness, the transmission at lower level are 0.79%,1.50%,2.98%,5.58% and 10.39%, at center level are 0.52%,0.99%,2.09%,4.12% and 7.67% and at upper level are 0.49%,0.91%,1.82%,3.75% and 6.90% for the energies 6,9,12,16 and 20 MeV's respectively.

Conclusion: There is not much difference in the transmission values at centre and upper levels so as to keep nearer the skin, the centre position in electron applicator may be optimum. Lead sheets can be used since easy to prepare especially for rectangular or square shapes.

Keywords: Electron beam transmission, cerrobend alloy, lead.

INTRODUCTION

High energy electrons have been used in radiotherapy. This beam was extracted mostly from linear accelerators. The most clinically useful energy range for electrons is 6 to 20 MeV. At these energies, the electron beams can be used for treating superficial tumors (< 5 cm deep) with a characteristically sharp drop-off in dose beyond the tumor. The principal applications are skin cancer, lip cancer and chest wall irradiation for breast cancer.[1]

Extensive field shaping is sometimes required in electron beam therapy. Lead cutouts are often used to give shape to the treatment area and to protect the surrounding normal

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tissue or a critical organ. These cutouts are placed either directly on the skin or at the end of the treatment applicator. For low energy electrons, less than 5 mm thickness of lead is required for adequate shielding. Lead sheets of this thickness can be molded to conform more or less to the surface contour and, can be placed directly on the skin surface. For higher energy electrons, however, thicker lead is required and cannot be so easily contoured. Moreover, a heavy lead mask may cause discomfort to the patient. The alternative method is to support a lead cutout at the end of the treatment cone or the field trimmers. Shields to be used in such a configuration can be designed from pure lead sheets or a low melting alloy such as Cerrobend.

These shielding blocks are usually kept at lower level of the applicator which is near the skin surface. The scattering property of electron may increase the surface dose which will increase with increasing electron energies. The purpose of this study is to compare electron beam transmission of different energies with two different block materials at different placement positions within the applicator.

MATERIAL AND METHODS

Two different lead alloys were used for this study. That are Cerrobend alloy (50%bismuth, 26.7%lead, 13.3%tin and 10%cadmium) and 1mm thick lead sheets (94%lead, 6%alloy).[4,5] The Varian Clinac2300C/D linear accelerator with electron energies 6,9,12,16 and 20MeVs with 10x10 applicator at 3 different holding levels were used. Measurements were carried out with RW3 Slab phantom (Water equivalent),PPC05 Parallel Plane Chamber, Dose 1 electrometer. The slab phantom 30x30x10 cm^3 aligned with PPC05 Parallel Plane Chamber (at R85 of respective energies). Readings measured for open and block fields, for different thickness of shielding material at different placement positions within the applicator. The percentage of transmission calculated manually.

RESULTS

The shielding block transmission values were measured for different energies with different thickness of lead sheets and 5 mm Cerrobend blocks at three different places within the applicator. That the results were shown in the Table-1, Table-2, Table-3, Table-4 and Table-5 for the energies 20 MeV, 16 MeV, 12 MeV, 9 MeV and 6 MeV respectively.

Table-1 shows the transmission value for Cerrobend 5 mm thickness of 6.82 %, 7.57% and 10.27 at upper, center, and lower level respectively. For 5 mm lead sheet, transmission values are 5.24%, 5.68% and 7.20 % at upper, center and lower level respectively. Comparatively lead sheets gives lesser transmission than Cerrobend for the same thickness. Still all the values are more than the tolerance value that is 5%. 5 mm of neither leadsheet nor Cerrobend sufficient for 20 MeV energy. So it is understood that for 20 MeV more than 5 mm required by either of the material.

Table-1: Transmission results for 20 MeV electron energy at three different levels with two different materials

Energy: 20MeV		MU: 100			Depth: R_{85} (6.8 cm)		
All Meter Readings are in nanoColoumb ($x10^{-9}C$)							
BLOCK POSITION	**Open**	**Lead Equivalence sheet**					**Cerrobend**
	Field	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	**5mm**
	MR	**MR**	**MR**	**MR**	**MR**	**MR**	**MR**
LOWER LEVEL	1.541	0.609	0.251	0.1452	0.12	0.1106	0.158
	1.537	0.607	0.252	0.1448	0.119	0.1109	0.158
	1.54	0.608	0.252	0.145	0.1195	0.1108	0.158
Average	**1.539**	**0.608**	**0.0251**	**0.145**	**0.1195**	**0.1108**	**0.158**
Transmission %		**39.5**	**16.35**	**9.42**	**7.76**	**7.2**	**10.27**
CENTER	1.541	0.37	0.165	0.1133	0.0974	0.0873	0.1168
LEVEL	1.537	0.369	0.165	0.1133	0.097	0.0877	0.1163
	1.54	0.369	0.165	0.1133	0.0972	0.0875	0.1165
Average	**1.539**	**0.3693**	**0.165**	**0.1133**	**0.0972**	**0.0875**	**0.1165**
Transmission %		**23.99**	**10.72**	**7.36**	**6.31**	**5.68**	**7.57**
UPPER	1.541	0.312	0.143	0.0991	0.087	0.081	0.1053
LEVEL	1.537	0.313	0.142	0.0989	0.087	0.0804	0.1045
	1.54	0.311	0.141	0.0989	0.087	0.0808	0.1049
Average	**1.539**	**0.312**	**0.142**	**0.099**	**0.087**	**0.0807**	**0.1049**
Transmission %		**20.77**	**9.22**	**6.43**	**5.65**	**5.24**	**6.82**

Table-2 shows the transmission value for Cerrobend 5 mm thickness of 3.75 %, 4.12% and 5.58% at upper, center, and lower level respectively. For 5 mm lead sheet, transmission values are 3.13%, 3.48% and 4.56 % at upper, center and lower level respectively. Comparatively lead sheet gives lesser transmission than Cerrobend for the same thickness. And if we place lead sheet at upper level 2mm thickness is sufficient and if we place at center level 3mm will be adequate. Same way if we place at lower level 4mm thickness is required. In Cerrobend measurements even 5 mm thickness is not sufficient if place at lower level.

Table-2: Transmission results for 16 MeV electron energy at three different levels with two different materials

Energy: 16MeV		MU: 100			Depth: R_{85} (5.6 cm)		
All Meter Readings are in nanoColoumb ($x10^{-9}C$)							
BLOCK POSITION	**Open**	**Lead Equivalence sheet**					**Cerrobend**
	Field	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	**5mm**
	MR	**MR**	**MR**	**MR**	**MR**	**MR**	**MR**
LOWER LEVEL	1.521	0.426	0.136	0.081	0.0732	0.0694	0.084
	1.52	0.427	0.136	0.08	0.0731	0.0691	0.0855
	1.519	0.425	0.136	0.08	0.073	0.0693	0.0848
Average	**1.52**	**0.426**	**0.136**	**0.0803**	**0.0731**	**0.0693**	**0.0848**
Transmission %		**28.03**	**8.95**	**5.29**	**4.81**	**4.56**	**5.58**
CENTER	1.521	0.228	0.0875	0.0616	0.0559	0.0528	0.0627
LEVEL	1.52	0.229	0.087	0.061	0.0559	0.0529	0.0626
	1.519	0.227	0.0872	0.0613	0.0559	0.053	0.06265
Average	**1.52**	**0.228**	**0.08723**	**0.0613**	**0.0559**	**0.0529**	**0.06265**
Transmission %		**15**	**5.74**	**4.03**	**3.68**	**3.48**	**4.12**
UPPER	1.521	0.186	0.0737	0.0557	0.0507	0.0477	0.0569
LEVEL	1.52	0.185	0.0737	0.0556	0.051	0.0475	0.057
	1.519	0.187	0.0737	0.0555	0.0508	0.0476	0.05695
Average	**1.52**	**0.186**	**0.0737**	**0.0556**	**0.0508**	**0.0476**	**0.05695**
Transmission %		**12.24**	**4.85**	**3.66**	**3.34**	**3.13**	**3.75**

Table-3 shows that 2mm thickness of lead sheets are sufficient to reduce the transmission to less than 5% and Cerrobend cutout gives less transmission value.

Table-3: Transmission results for 12 MeV electron energy at three different levels with two different materials

Energy: 16MeV		MU: 100			Depth: R_{85} (4.3 cm)		
All Meter Readings are in nanoColoumb ($x10^{-9}C$)							
BLOCK POSITION	**Open**	**Lead Equivalence sheet**					**Cerrobend**
	Field	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	**5mm**
	MR	**MR**	**MR**	**MR**	**MR**	**MR**	**MR**
LOWER LEVEL	1.508	0.243	0.0552	0.0433	0.0408	0.0389	0.045
	1.507	0.241	0.0552	0.0435	0.0414	0.0386	0.0447
	1.507	0.242	0.0552	0.0434	0.0404	0.0388	0.0448
Average	**1.507**	**0.2419**	**0.0552**	**0.0434**	**0.0409**	**0.0388**	0.0448
Transmission %		**16.05**	**3.66**	**2.88**	**2.71**	**2.57**	**2.98**
CENTER	1.508	0.1168	0.0382	0.031	0.0294	0.0275	0.031
LEVEL	1.507	0.1167	0.0382	0.031	0.0296	0.0271	0.032
	1.507	0.117	0.0382	0.031	0.0292	0.0273	0.0315
Average	**1.507**	**0.1168**	0.0382	**0.031**	**0.0294**	**0.0273**	**0.0315**
Transmission %		**7.75**	**2.54**	**2.06**	**1.95**	**1.81**	**2.09**
UPPER	1.508	0.0929	0.0318	0.0269	0.0256	0.024	0.028
LEVEL	1.507	0.0927	0.0321	0.0271	0.0258	0.0244	0.027
	1.507	0.0926	0.032	0.0267	0.0257	0.0242	0.0275
Average	**1.507**	**0.0927**	**0.032**	**0.0269**	**0.0257**	**0.0242**	**0.0275**
Transmission %		**6.15**	**2.12**	**1.78**	**1.7**	**1.61**	**1.82**

Table-4 shows 2mm thickness of lead sheet is sufficient to reduce the transmission to less than 5 %. Cerrobend also gives good agreement.

Table-4: Transmission results for 9 MeV electron energy at three different levels with two different materials

Energy: 9MeV		MU: 100			Depth: R_{85} (3.0cm)		
All Meter Readings are in nanoColoumb ($x10^{-9}C$)							
BLOCK POSITION	**Open**	**Lead Equivalence sheet**					**Cerrobend**
	Field	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	**5mm**
	MR	**MR**	**MR**	**MR**	**MR**	**MR**	**MR**
LOWER LEVEL	1.507	0.13	0.024	0.024	0.021	0.0197	0.0225
	1.502	0.131	0.025	0.022	0.0211	0.0194	0.0227
	1.504	0.131	0.024	0.023	0.0209	0.0196	0.0226
Average	**1.504**	**0.1307**	**0.0243**	**0.023**	**0.021**	**0.0196**	**0.0226**
Transmission %		**8.69**	**1.62**	**1.53**	**1.4**	**1.3**	**1.5**
CENTER	1.507	0.0567	0.0192	0.0186	0.0178	0.0161	0.015
LEVEL	1.502	0.0564	0.0192	0.0191	0.0177	0.0159	0.0148
	1.504	0.0566	0.0192	0.0189	0.0176	0.016	0.0149
Average	**1.504**	**0.0566**	**0.0192**	**0.0189**	**0.0177**	**0.016**	**0.0149**
Transmission %		**3.76**	**1.28**	**1.25**	**1.18**	**1.06**	**0.99**
UPPER	1.507	0.0454	0.0144	0.0135	0.0122	0.0118	0.0135
LEVEL	1.502	0.0455	0.0139	0.0135	0.0121	0.0121	0.0138
	1.504	0.0454	0.0142	0.0136	0.012	0.0119	0.0136
Average	**1.504**	**0.0454**	**0.0142**	**0.0135**	**0.0121**	**0.0119**	**0.0136**
Transmission %		**3.02**	**0.94**	**0.9**	**0.8**	**0.79**	**0.91**

Table-5 shows that 1 mm thickness of lead sheet is sufficient to reduce the transmission to less than 5%.

DISCUSSION

The purpose of this study was to compare electron transmission of different energies with two different block materials at different placement positions within the applicator. From this Study it is found that there is a significant difference in the transmission value between lower level, central level and upper level placements. At higher energy this transmission values crosses the tolerance value due to higher electron contamination, the thickness of the shielding blocks also increase with increase in energy and less than the decimal transmission values are result of bremsstrahlung radiation produced by electron while interacting with high atomic number material that is shielding blocks.

Table-5: Transmission results for 6 MeV electron energy at three different levels with two different materials

Energy: 6MeV		MU: 100			Depth: R_{85} (2.0 cm)		
All Meter Readings are in nanoColoumb ($x10^{-9}C$)							
BLOCK POSITION	**Open**	**Lead Equivalence sheet**					**Cerrobend**
	Field	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	**5mm**
	MR	**MR**	**MR**	**MR**	**MR**	**MR**	**MR**
LOWER LEVEL	1.433	0.0356	0.0128	0.011	0.0107	0.0099	0.0114
	1.433	0.0354	0.0127	0.0112	0.0111	0.0109	0.0114
	1.435	0.0358	0.0127	0.012	0.0104	0.0106	0.0114
Average	**1.434**	**0.0356**	**0.0127**	**0.0114**	**0.0107**	**0.0105**	0.0114
Transmission %		**2.48**	**0.89**	**0.8**	**0.75**	**0.73**	**0.79**
CENTER	1.433	0.017	0.0087	0.0075	0.0073	0.0064	0.0077
LEVEL	1.433	0.0173	0.0087	0.0079	0.007	0.0064	0.0072
	1.435	0.0169	0.0084	0.0071	0.0071	0.0064	0.00745
Average	**1.434**	**0.0171**	**0.0086**	**0.0075**	**0.0071**	**0.0064**	0.00745
Transmission %		**1.19**	**0.6**	**0.52**	**0.5**	**0.45**	**0.52**
UPPER	1.433	0.0136	0.0083	0.0078	0.0075	0.0067	0.007
LEVEL	1.433	0.0137	0.0082	0.0074	0.0072	0.0068	0.007
	1.435	0.0138	0.0081	0.0069	0.0073	0.0066	0.007
Average	**1.434**	**0.0137**	**0.0082**	**0.0074**	**0.0073**	**0.0067**	0.007
Transmission %		**0.96**	**0.57**	**0.51**	**0.51**	**0.47**	**0.49**

Iftikhar A et al compared the effects of lead and cerrobend shielding blocks on incident photon beam and concluded that the effect of shielding on the beam output increases with field size, beam energy and shield size.[2] The dose under shielded area was due to three main contributions. First, due to primary electron beam transmitted through the block which has higher thickness for higher energy. Second, due to scattered electrons which are scattered from shielding material edges. Third, due to contamination photon that is produced by bremsstrahlung radiation. This bremsstrahlung radiation contribution under the shielded area was discussed in detail in Cristina Di Venanzio et al[3] study.

Petkovaska et al[4] studied about transmission comparison of two different materials that were cerrobend and cadmium free alloy. The difference in the alloy curve was not more than 0.12%, further it was seen that cerrobend produces poisonous gas during the process and thus cadmium free alloy has advantage that is not producing fumes. But since it has a higher temperature as melting point, will create a greater potential for serious burns. So they concluded that a new material with higher attenuation, easy to fabricate and friendly to the environment[5-7] used as a substitute of lead.

Bas M et al studied the use of pure lead in comparision to lipowitz alloy. The measurements taken using 10 MV photon ray showed that the field protected by pure lead had the least radiation transmission, and it was accepted to have 27.3% less transmission compared to the field protected by cerroband alloy. The measurements taken using 25 MV photon ray showed that the field protected by pure lead had 38.4 % less transmission compared to the field where a Lipowitz metal block is used, so it was proved that the pure lead blocks have the least radiation transmission.[8]

So the lead sheets used for this study can be used as an electron shielding in radiotherapy since it is easy to prepare and no fumes during the preparation. And the thickness of the shielding block can be optimized according to the energy selection. Also the placement of the shielding block with in the applicator can optimize the transmission. If the distance between shielding material and skin decreases, electron transmission increases. If the distance increases, transmission decreases and field size losing the field definition at the field edges. This will ultimately create cold spot at the field edges.So it is optimum to place shielding material at central level of the applicator.

CONCLUSION

Even though there is a difference in the transmission values at lower centre and upper levels, so as to keep nearer the skin, the centre position in electron applicator may be optimum. Lead sheets can be used since easy to prepare especially for rectangular or square shapes. This will reduce radiotherapy technologist work load and reduce the treatment prescription to execution time.

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