Short Communication

Effect of Material and Wall Thickness Buildup Caps on the Head Scatter Factor Measurements in Irregular Fields Shielded by Cerrobend

Abstract

The head scatter factor (S_c) is important to measurements radiation beam and beam modeling of treatment planning systems used for advanced radiation therapy techniques. This study aimed to investigate the design of a miniphantom to measurement variations in collimator S_c in the presence of shielding blocks for shaping the beam using different field sizes. Copper, Brass, and Perspex buildup caps were designed and fabricated locally as material with three different thicknesses for buildup caps (miniphantoms). Measurements were performed on an Elekta Compact medical linear accelerator (6 MV) in Shafa Kerman Hospital, Iran. The Farmer-type ion chamber FG65-P (Scanditronix, Wellhofer) was used for all measurements. To measure the S_c, miniphantom was positioned in a stand vertical to the beam central axis. The data indicate that the S_c measurements using different buildup cap materials and thicknesses in 5 × 10, 7.5 × 7.5, and two 10 × 10 cm Cerrobend shield blocks ranged 0.98 to 1.00, 1.04 to 1.05, and 1.04 to 1.06, respectively. Also, it was observed that by increasing the block shield area from 50 cm^2 to both 56.25 and 100 cm^2, the S_c increased in all situations. Results showed that using Brass compared to Perspex and Copper has less uncertainty due to its simple preparation and cutting which is useful to measurement of variations in collimator S_c and shaping the photon beam.

Keywords: *cerrobend block, linear accelerator, miniphantom, radiation therapy, scatter collimator factor*

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Introduction

Radiation therapy (RT) uses high photon energy radiation beam which generated by medical linear accelerators (Linacs) is applied to destruction cancerous tissue.[1-3] The goal of RT is to deliver the prescribed dose to the planning target volume and simultaneously minimizing the unnecessary dose to the critical organs at risks (OARs).[3-5] To delivery tumor dose accurately and minimizing the dose to the OARs, new RT techniques, such as 3D-conformal RT, intensity modulated RT, and volumetric modulated arc therapy have been developed.[6] Each step in the integrated process of RT needs quality control and quality assurance to prevent errors and to give high confidence, those patients will receive the prescribed treatment correctly.[6] Modern RT treatment planning systems use advanced model-based algorithms to achieve a high degree of accuracy with motorized multileaf collimators (MLCs) which installed on the head of Linacs, and standard lead or Cerrobend shields for OARs. However, MLC is an optional on the head of Linacs and unavailable to all RT centers, particularly in Iran. Therefore, instead of using MLCs, Cerrobend shield blocks can be used for customized beam shaping which consists in a low melting point alloy.[7] Cerrobend is an alloy of 50% bismuth, 26.7% lead, 13.3% tin, and 10% cadmium by weight. Due to different OARs sizes, Cerrobend blocks can provide any shielding field sizes in radiotherapy.[8]

The absorbed dose at a point within a patient/phantom can be divided into two components: primary radiation which is contributed by the primary or original photons emitted from the source and scattered photons which is scattered in the treatment head and phantom. Head scattered radiation is photon with a history of scattering from all structures in the treatment unit head called collimator scatter factor (S_c).[9] S_c describes the change of in-air output as a function of the collimator

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settings. According to the task group report No.74 from American Association of Physicists in Medicine, S_c is defined as the ratio of collision water kinetic energy released per unit mass in the free space of an arbitrary field to that of a reference field size (10 × 10 cm).[9]

Scatter collimator factor depends on collimator design, scattering from the flattening filter, scattering from the dose monitoring chambers, beam-modifying devices, field sizes, thicknesses, and materials of buildup cap.[10]

To measure the S_c, it is important to design the buildup cap or miniphantom, to use together with a suitable detector. The buildup cap thickness should provide full charged particle equilibrium (CPE) as in water medium, without any photon scattering, and be small enough to be fully covered by the radiation beam. The thickness of buildup cap should be equal to the depth of maximum dose (D_{max}), to provide CPE.[4]

Several authors have been investigated the measurement of S_c, suitable materials for miniphantom design, and the buildup cap thicknesses.[3,9,11-13] Li and Zhu[3] showed that the in-air output ratio correction factors increase with miniphantom thickness for all the materials and for different energies. Iftikhar *et al*.[12] showed that the block tray factor increased with field size for both 6 and 15 MV photon beams. Farajollahi *et al*.[11] showed that there was no significant differences between lead and Cerrobend shielding methods for different field sizes in measuring S_c for Cobalt-60 therapy. Iftikhar[13] also found that the use of buildup caps with Z_{eff} close to that of water such as acrylic is a good choice of output factors measurements.

To the best of our knowledge, there is no study on assessment of buildup cap thicknesses and material for Cerrobend block fields using x-ray photon therapy. This study aimed to investigate the variation of collimator S_c in the presence of shielding blocks in the path of radiation beam using different wall thickness, material of buildup caps dependence.

Material and Methods

Photon beam, shield, and buildup cap design

The measurements were performed on an Elekta Compact linear accelerator (6 MV) at RT center in Shafa Kerman Hospital. Ionization chamber is the best choice for output factor measurements in extended water phantom for large field sizes,[14] which is reason why the Farmer type ionization was used here for all dose measurements. The Farmer-type ion chamber FC65-P (Scanditronix, Wellhofer) is a cylindrical ionization chamber with a fairly small sensitive volume of 0.65 cm^3, outer diameter of 7 mm, inner diameter of 6.2 mm, and total active length of 23.1 mm with an inner electrode of aluminum, which used for all measurements.[14] Block shields were produced through melting of Cerrobend. It is normally fabricated in the molding room using the styrofoam block cutter system (PAR Scientific Model ACD-4MK4, Odense, Denmark).[11] This shielding block has been used to compare the effect of block shield sizes on the head S_c measurements [Figure 1].

Copper, Brass and, Perspex buildup caps (miniphantom) were designed locally to have different material with three different wall thicknesses, to evaluate the effects of material and the wall thickness of buildup cap on S_c measurements. The Brass was designed with a wall thickness of 6 mm (equal to D_{max}) and two wall thicknesses larger than D_{max} (7 and 8 mm). The Copper buildup cap was designed with a wall thickness of 12 (equal of D_{max}) and two wall thicknesses larger than D_{max} (14 and 16 mm) and Perspex designed with a wall thickness of 14 (equal to D_{max}) and two wall thicknesses larger than D_{max} (17 and 19 mm) [Table 1].

Head scatter factor measurement

To measure the head S_c, the designed miniphantoms were positioned in a stand vertical to the beam central axis and the measurements were performed using ion chamber for (10 × 10, 15 × 15, and 20 × 20 cm) field sizes to compare the effect of different field sizes on S_c measurements [Figure 2]. In this situation, the field size is fully covering the miniphantom. Table 1 shows the buildup caps material, the wall thicknesses, and block shield sizes.

Table 1: Material and wall thickness buildup caps for 6 MV photon beam and Cerrobend block sizes

Buildup cap material	Wall thickness (mm)/ notification	Shield size (cm)
Brass	6/Brass 1	5 × 10
	7/Brass 2	7.5 × 7.5
	8/Brass 3	5 × 10a
Perspex	14/Perspex 1	5 × 10
	17/Perspex 2	7.5 × 7.5
	19/Perspex 3	5 × 10a
Copper	12/Copper 1	5 × 10
	14/Copper 2	7.5 × 7.5
	16/Copper 3	5 × 10a

[a]Two block shields (5 × 10 cm) were used in the open field size (20 × 20 cm).

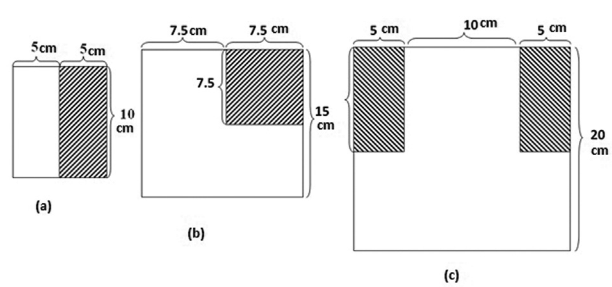

Figure 1: Design of the block shield size for 6 MV photon beam. The dashed area illustrates the block shield region. (a) Shield (5 × 10 cm) was used in (10 × 10 cm) open field size, (b) shield (7.5 × 7.5 cm) was used in (15 × 15 cm) open field size, (c) two shield (5 × 10 cm) was used in (20 × 20 cm) open field size.

Measurements were carried out with perpendicular orientation of the chamber to the beam axis with a source-to-axis distance (SAD) 100 cm.[9] For each measurement, the SAD sets to source to central electrode of chamber which was different for each miniphantom. The measurements were also carried out for different block Cerrobend shield sizes to evaluate the effect of shield size on the S_c measurements. The field sizes were big enough to cover the buildup cap. Indeed, the chamber was not positioned behind the block shield to prevent the block attenuation effect.

Each measurement was performed three times and then, the average and standard deviation values were calculated from the measurements. To obtain the head S_c, the average values were normalized to the reference open field (10 × 10 cm) readings.

Results

The measurements were performed in air, using Farmer chamber type placed in Perspex, Copper, and Brass buildup caps on a 6-MV photon energy Linac. The S_c was measured at isocenter for various open square fields as well as different block shielded as described in previous section.

Table 2 shows the average reading of standard open and block shielded fields, S_c measurements with different buildup caps, and the S_c value obtained during commissioning of Linac.

Table 3 represents the measured S_c values for 15 × 15 open field size which shielded by 7.5 × 7.5 cm Cerrobend block shield as illustrated in Figure 1. The comparison of the head S_c with and without shield (commissioning data) presents a maximum and minimum deviation of 4.90 and 1.96% for Perspex 1 and Copper 2, Copper 3, Brass 2, respectively.

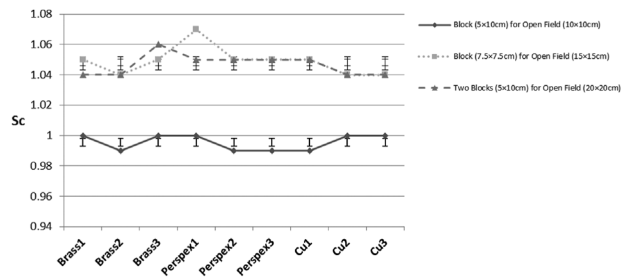

Figure 2: The miniphantom and chamber position during scatter factor measurements.

Table 2: Head scatter factor for the block shield (5 × 10 cm) and deviation relative to open field (10 × 10 cm)

Buildup cap	Open standard field reading (nC) (mean ± SD)	Block shielded reading (nC) (mean ± SD)	S_c (open)	S_c (with shield)	% Deviation of S_c (open and shield fields)
Copper 1	15.54 ± 0.02	15.43 ± 0.02	1.00	0.99	1.01
Copper 2	14.86 ± 0.01	14.89 ± 0.01		1.00	0.00
Copper 3	14.28 ± 0.01	14.26 ± 0.02		0.99	1.01
Brass 1	17.37 ± 0.02	17.44 ± 0.03		1.00	0.00
Brass 2	17.05 ± 0.01	16.99 ± 0.02		0.99	1.01
Brass 3	16.46 ± 0.02	16.58 ± 0.02		1.00	0.00
Perspex 1	15.86 ± 0.02	15.87 ± 0.01		1.00	0.00
Perspex 2	15.84 ± 0.01	15.67 ± 0.03		0.98	2.04
Perspex 3	15.87 ± 0.02	15.80 ± 0.01		0.99	1.01

SD = standard deviation.

Table 3: Head scatter factor for the block shielded (7.5 × 7.5 cm) and deviation relative to open field (15 × 15 cm)

Buildup cap	Open standard field reading (nC) (meane ± SD)	Block shielded reading (nC) (mean ± SD)	S_c (open)	S_c (with shield)	% Deviation of S_c (open and shield fields)
Copper 1	15.54 ± 0.02	16.30 ± 0.02	1.02	1.05	2.94
Copper 2	14.86 ± 0.01	15.52 ± 0.02		1.04	1.96
Copper 3	14.28 ± 0.01	14.83 ± 0.01		1.04	1.96
Brass 1	17.37 ± 0.02	18.21 ± 0.03		1.05	2.94
Brass 2	17.05 ± 0.01	17.81 ± 0.04		1.04	1.96
Brass 3	16.46 ± 0.02	17.24 ± 0.03		1.05	2.94
Perspex 1	15.86 ± 0.02	16.91 ± 0.02		1.07	4.90
Perspex 2	15.84 ± 0.01	16.69 ± 0.02		1.05	2.94
Perspex 3	15.87 ± 0.02	16.63 ± 0.02		1.05	2.94

SD = standard deviation.

Table 4 shows the S_c measurements for field size (20 × 20 cm) and two block shielded field (5 × 10 cm). It is clear that among all buildup caps, Perspex 3 has the maximum deviation (4.9%).

Figure 3 shows a comprehensive comparison of S_c with buildup cap materials, wall thicknesses using different block shield in different open field sizes. It is obvious that by increasing the block shield area from 50 cm^2 (in an open 10 × 10 cm field size) to both shield areas of 56.25 cm^2 (in an open 15 × 15 cm field size) and 100 cm^2 (in an open 20 × 20 cm field size), the measured S_c in all situations increased.

Discussion

In the most RT centers in Iran (except modern centers which have MLCs adjusted to the accelerator head), protection of normal tissues is usually accomplished by either Cerrobend or lead block shielding. Cerrobend block is the most common system for customized beam shaping due to its low melting point, high attenuation coefficient for photon beam and nontoxicity, and also reduction of bremsstrahlung rays by electron beam. Using materials with atomic number close to the tissue is recommended as a suitable material for designing Cerrobend.

Interaction of radiation with matter causes its intensity reduced or attenuated exponentially which means that they do not have a fixed range in materials. The increase in thickness of the material resulted in photon intensity decrease. In this work, Perspex, Copper, and Brass with different thickness were used as buildup materials for attenuation photon intensity or shaping the photon beam. Findings of the present study showed that the value of $D_{\max}$ for photon in water is about 1.5 cm; hence, the CPE conditions existed.

Variations in the S_c factor (in-air output, collimator scatter, or head scatter) of buildup cap were observed with increases of the thickness of the used materials. As can be seen from Tables 2 to 4, increases in buildup cap thickness resulted in decreasing the amount of reading doses and are in good agreement with the exponentially law of attenuation ($I = I_0 e^{-\mu x}$). The atomic number of the materials used in buildup caps had been shown previously to have an effect on the measurement of head S_c.[11,14]

Table 2 demonstrated that maximum deviation of measured S_c in block shield situations relative to the commissioning data observed in Perspex 2 which was 2.04%. However, there is a same deviation (1.01%) using Copper 1, Copper 3, Brass 2, and Perspex 3, but no deviation was obtained for Copper 2, Brass 1, Brass 3, and Perspex 1. The S_c deviation using the same buildup cap material is more prominent between Perspex 1 and Perspex 2 by 2.04%.

As Table 3 showed, the deviation of measured S_c relative to the S_c measured in commissioning process using Perspex buildup caps is prominent than Copper and Brass materials. While the deviation of S_c among Brass and Copper buildup caps is less than 1.00%, the deviating between Perspex 1 and Perspex 2/Perspex 3 is 1.90%. Table 4 illustrated that using the same buildup cap, the maximum deviation observed between Perspex 1/Perspex 2 (66.67%). Moreover, no deviation observed between Copper 2/Copper 3, Brass 1/

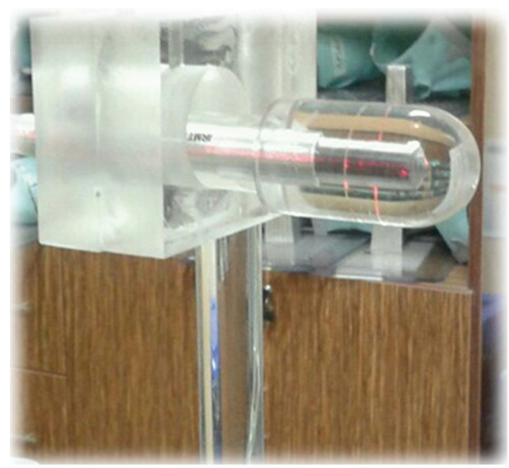

Figure 3: Variation of scatter factor measurements using different buildup cap materials, wall thicknesses, block shield areas, and open field sizes.

Table 4: Head scatter factor for the two-shielded blocks (5 × 10 cm) and deviation relative to open field (20 × 20 cm)

Buildup cap	Open field reading (nC) (mean ± SD)	Block shielded reading (nC) (mean ± SD)	S_c (open)	S_c (with shield)	% Deviation of S_c (open and shield fields)
Copper 1	15.54 ± 0.02	16.34 ± 0.01	1.03	1.05	1.94
Copper 2	14.86 ± 0.01	15.50 ± 0.02		1.04	0.97
Copper 3	14.28 ± 0.01	14.80 ± 0.01		1.04	0.97
Brass 1	17.37 ± 0.02	18.01 ± 0.03		1.04	0.97
Brass 2	17.05 ± 0.01	17.76 ± 0.02		1.04	0.97
Brass 3	16.46 ± 0.02	17.41 ± 0.02		1.06	2.91
Perspex 1	15.86 ± 0.02	16.71 ± 0.02		1.05	1.94
Perspex 2	15.84 ± 0.01	16.63 ± 0.01		1.05	1.94
Perspex 3	15.87 ± 0.02	16.61 ± 0.01		1.05	1.94

SD = standard deviation.

Brass 3, and Perspex 2/Perspex 3. Figure 3 indicated that by increasing the thickness of buildup caps, in the case of two-block 5 × 10 and 7.5 × 7.5 cm, the S_c was decreased. In block shield (5 × 10 cm), Brass 2 had the minimum value and the shield (two blocks 5 × 10 cm) increasing with wall thicknesses and for the shield (7.5 × 7.5 cm), no variation was observed. In shield (5 × 10 cm), Perspex 2 had the minimum value. Moreover, other shield blocks decrease with thickness of buildup caps.

The amount of variations in the S_c of fields with and without shield results had consistency with literature that as field size increases, the outer regions of the filter became exposed to the detector and buildup cap.[7,9,11,14] Another key point finding here is that the ratio of area to surface of shields is an important factor.

When a Cerrobend block is placed in the path way of an x-ray beam, scatter radiation will not be produced and hence, scatter radiation will be decreased. Increases in incident photon flow of less than 2% were observed due to the less scatter of a Cerrobend block. This amount of scatter depends on the length of the inner edge of the block and block size which is irradiated. Variations of the collimator setting could change the photon energy fluence, hence affecting the shape of photon beam.

Results of the present work and other researchers have shown that only minor deviations in the resulting S_c values presented when the construction details of collimator were changed.[11,14] Overall, use of melt shielding methods and Brass material is a very easy and fast shield-making technique to reduce variations of the S_c.

Conclusion

Results showed that using Brass compared to Perspex and Copper has less uncertainty due to its simple preparation and cutting. Also, its application as a Cerrobend block is recommended for measuring the variations of collimator S_c.

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Conflicts of interest

There are no conflicts of interest.

References

1. Shahbazi-Gahrouei D, Gookizadeh A, Abdolahi M. Comparison of conventional radiotherapy techniques with different energies in treating prostate cancer, employing a designed pelvis phantom. J Med Sci 2008;8:429-32.
2. Rezaee V, Shahbazi-Gahrouei D, Monadi S, Saeb M. Evaluation of error doses of treatment planning software using solid anthropomorphic phantom. J Isfahan Med Sch 2016;34:908-13.
3. Li J, Zhu TC. Monte Carlo simulation of the effect of miniphantom on in-air output ratio. Med Phys 2010;37:5228-37.
4. Jursinic P. Measurement of head scatter factors of linear accelerators with columnar miniphantoms. Med Phys 2006;33:1720-8.
5. Karbalee M, Shahbazi-Gahrouei D, Tavakoli MB. An approach in radiation therapy treatment planning: A fast GPU-based Monte Carlo method. J Med Signals Sens 2017;7:108-13.
6. Ishikura S. Quality assurance of radiotherapy in cancer treatment: Toward improvement of patient safety and quality of care. Jpn J Clin Oncol 2008;38:723-9.
7. Sigamani A, Arunai N, Sujit Nath S, Girigesh Y, Rajesh T, Kothanda R, *et al.* Comparison of head scatter factor for 6 MV and 10 MV flattened (FB) and unflattened (FFF) photon beam using indigenously designed columnar miniphantom. J Med Phys 2014;39:184-91.
8. Tahmasbi-Birgani M, Seif F, Bayatiani MR. Dosimetric characteristics of mercury and cerrobend blocks in megavoltage radiation therapy. J Radioanal Nucl Chem 2015;303:1843-50.
9. Zhu T, Ahnesjö A, Lam KL, Li XA, Ma CM, Palta JR. Report of AAPM Therapy Physics Committee Task Group 74: In-air output ratio, S_c, for megavoltage photon beams. Med Phys 2009;36:5261-91.
10. Eaton D, Twyman N, Thomas S. Commissioning a miniature multileaf collimator for small field radiotherapy. Med Dosim 2010;35:1-6.
11. Farajollahi A, Bouzarjomehri F, Kiani M. Comparison between clinically used irregular fields shielded by Cerrobend and standard lead blocks. J Biomed Phys Eng 2015;5:77-82.
12. Iftikhar A, Wazir M, Kakakhail MB, Sbilal A, Amjad H, Khwaja A. Comparison of lead and Cerrobend blocks for incident photon flux of 6 and 15 MV X-rays. Iran J Cancer 2011;10:10-4.
13. Iftikhar A. Measurements of output factors using different ionization chambers and build up caps. Iran J Radiat Res 2012;10:10-4.
14. Mukhtar A, Samat SB, Dolah MT. Long term stability of farmer type ionization chamber calibration coefficient belonging to local radiotherapy centers in Malaysia. Malays J Anal Sci 2014;18:7-14.