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Measurement of backscattered dose at metallic interfaces using high energy electron beams

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background The amount of backscattered electrons depends on the thickness of the backscattering metal. The electron backscatter increases with the increase in thickness of the metal until a saturation level is reached and thereafter no change in scatter enhancement is noticed.

Aim Electron backscatter effects at metallic interfaces were analysed in this study. High energy electron beams ranging from 6 to 20MeV were used.

Materials/Methods Measurements were carried out with a PTW thin-window parallel plate ionization chamber and an RDM-1F electrometer. Thin sheets of aluminium, copper and lead were used as inhomogeneities. The chamber was positioned below the inhomogeneities with the gantry maintained under the couch.

Results The electron backscatter factor (EBSF) increases with increase in energy for aluminium, copper and lead. With low atomic number materials EBSF increases with increase in scatterer thickness and for lead it attains saturation within a few millimetres.

Conclusions The information from this study could be useful in predicting the increase in dose at the metal-tissue interface due to electron backscatter.

Key words **metallic interface • electron backscatter • beam quality • heterogeneity**

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BACKGROUND

The presence of metallic heterogeneities in an electron beam increases the dose at the tissue heterogeneity interface during radiotherapy due to the backscattered electrons [1,2]. These backscattered electrons are expected to affect the charged particle equilibrium, and hence the dose distribution in the interface region between two media [3–6]. The dose at such an interface increases with increase in the atomic number of the backscattering inhomogeneity and decreases with the decrease in incident electron energy [7,8]. A dose enhancement of 20% to 60% was reported at tissue-lead interface for therapeutic electron beams [9]. The amount of backscattered electrons depends on the thickness of the backscattering metal. The electron backscatter increases with the increase in thickness of the metal until a saturation level is reached and thereafter no change in scatter enhancement is noticed. The quantum of electron backscatter is dependent on the electron energy at the metallic surface rather than the energy at the phantom surface [10].

The attenuation of backscatter electrons was found to decrease exponentially with depth, differing considerably from that of the primary electron beam depth dose pattern. The variation was attributed to the differential scattered electron energy spectrum at the metallic interface [6]. An increase of 7–20% in dose was reported at the bone-tissue interface for 15MeV therapeutic electron beam [1]. The dependency of electron backscatter factor with the mean electron energy and the backscatter material atomic number using semi-empirical depth dose-code EDMULT was attempted [11].

Due to the short range of backscattered electrons, the increase in dose at the tissue-metal interface might result in immediate and late complications. The commercially available treatment planning systems do not take into account the electron interface effects. Hence, it was felt that a detailed analysis of the quantum of electron beam scatter is necessary at different metallic interfaces with electron beams used commonly in clinical practices. The backward scattering of secondary electrons from the metallic inhomogeneities depends on many parameters such as electron energy, width and thickness of the inhomogeneity, distance from the inhomogeneity, thickness of the medium overlying the interface, atomic number of the inhomogeneity and the field size of the electron beam.

AIM

In this study the backscattering effect of 6–20MeV electron beams was investigated using aluminium, copper and lead inhomogeneities.

MATERIALS AND METHODS

Electron beam energies of 6, 9, 12, 16 and 20MeV from a Clinac 1800 (Varian Associates, Palo Alto, CA, USA) linear accelerator were used in this study. All ionometric measurements were carried out with a PTW thin-window, parallel plate ionization chamber (B23344-036), which has a sensitive volume of 0.2cc and an electrode separation of 1.5mm. The resultant ionization was recorded using an RDM-1F electrometer (Therados) with a digital readout. The charge measurements were carried out with a positive 400V bias voltage. Chamber sensitivity and linearity were checked prior to the measurements. The charge readout dosimetry system was found to have negligible polarity and ion recombination effects. The parallel plate chamber was positioned in a clear polystyrene phantom of 25×25cm^2 that was machined to provide a close fit for both the chamber and the sleeve. All the measurements were made with a standard electron cone of 10×10cm; fitted with manufacturer provided 4×4cm^2 tungsten cut-out. Chamber reproducibility was found to be within 0.2% and there was no leakage current observed during the measurements. The overall measurement uncertainty is within 1%.

During the measurements the front window of the parallel plate chamber was maintained at 1cm depth in the polystyrene phantom for 6 and 9MeV and at 2cm depth for 12, 16 and 20MeV electron energies. The chamber front window was positioned at 100cm focus-to-surface distance (FSD) with the gantry maintained under the couch at 180° for the measurement of the dose at the metal-polystyrene interface. The parallel plate chamber front window was placed close to the metallic inhomogeneity. Varying thickness of high-purity aluminium (Z=13), copper (Z=29) and lead (Z=82) sheets were placed between the chamber and the polystyrene phantom at 20cm thickness (Figure 1).

The dose above or below the metallic inhomogeneity can be found out by multiplying the dose in the homogeneous phantom with the forward or backscatter dose factors for a photon beam [12,11]. On a similar basis the electron backscatter factor can be defined as

$$EBSF=D_i/D_h \tag{1}$$

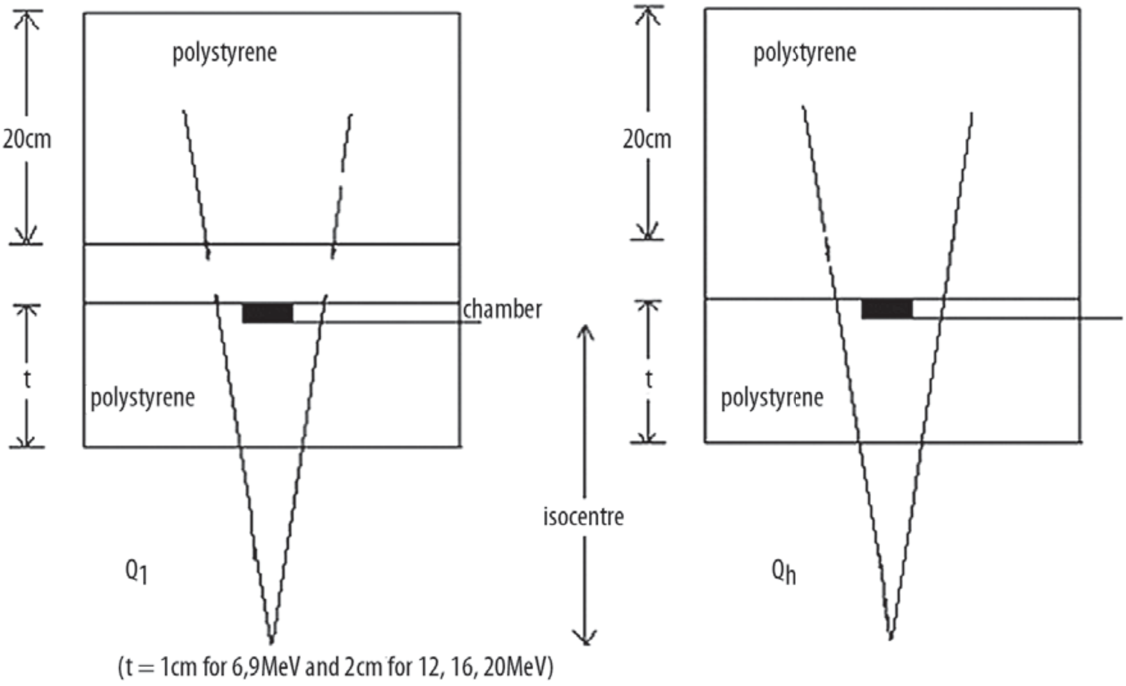

Figure 1. Experimental setup showing the measurement of electron backscatter factor using parallel-plate chamber with the gantry positioned under the couch.

where D_i is the dose at the interface between the metallic inhomogeneity and the polystyrene phantom, and D_h is the dose at the same point in the homogeneous polystyrene phantom material without metallic interface. Since the measurement conditions for both cases were similar, the dosimeter dependent factors and the measured charge influencing factors are the same. Hence, the equation for EBSF is reduced to the ratio of the charges measured and can now be written as

$$EBSF=Q_i/Q_h \qquad (2)$$

where Q_i is the measured charge at the metal-phantom interface and Q_h is the charge at the same point within the phantom without the metallic inhomogeneity. EBSF was also calculated based on the empirical formula [11]

$$EBF\ (Z)=A–B[\exp(-kZ)] \qquad (3)$$

where the equation parameters A, B and k are coefficients which depend on the electron energy at the scatter surface, and Z is the atomic number of the scatterer.

The electron energy at the scatter surface can be evaluated from equation [5]

$$E_m=E_0(1-z/R_p) \qquad (4)$$

where E_0 is the initial energy, R_p is the practical range and 'z' is the depth in the phantom.

RESULTS

Electron backscatter factor (EBSF) variation for varying thickness of aluminium, copper and lead inhomogeneities is shown in Figures 2A, 2B and 2C. For all the energies studied, EBSF increases initially reaching the saturation value and thereafter remains almost constant. It can be noticed that EBSF reaches the saturation value within a few millimetres of the lead inhomogeneity for all the electron energies studied. The metallic inhomogeneity thickness at which the saturation value of EBSF is reached seems to depend on the atomic number of the inhomogeneity. EBSF attains the saturation value at lesser thickness for higher atomic number inhomogeneities as reported earlier [2,5,6,10,13].

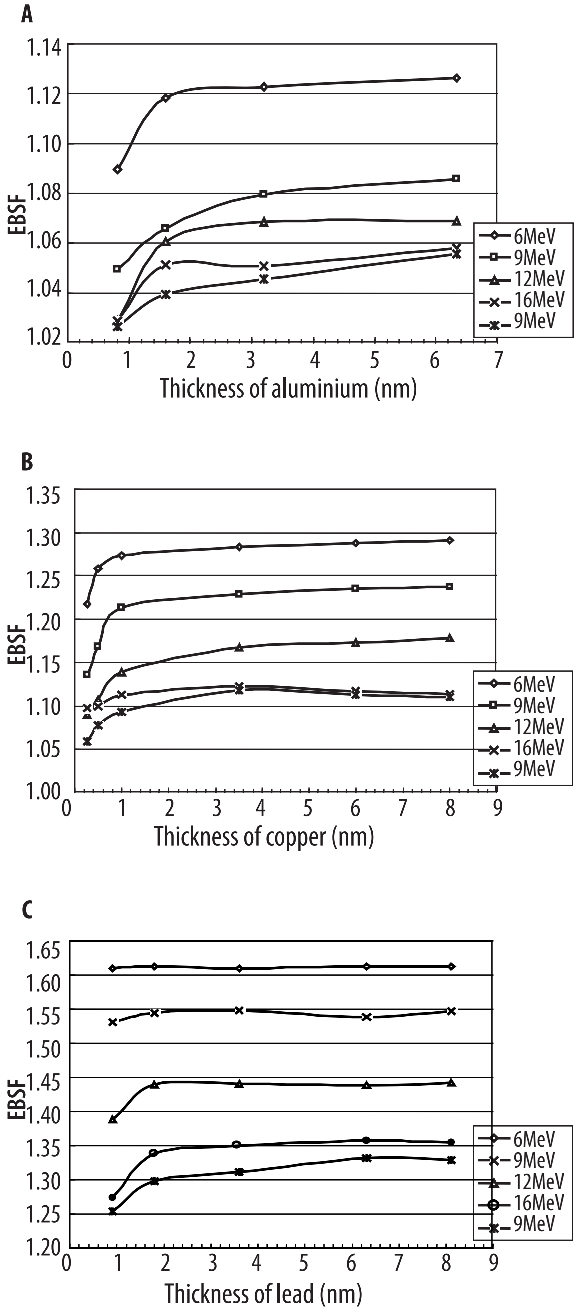

Figure 2A–C. Variation of electron backscatter factors for 10×10cm^2 field size at 100cm FSD for 6, 9, 12, 16 and 20MeV for (**A**) aluminium, (**B**) copper, (**C**) lead.

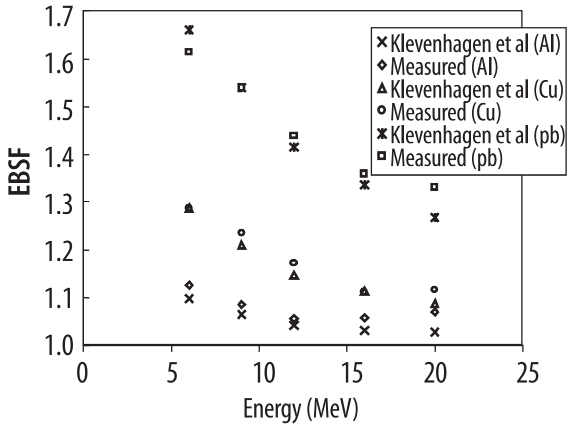

Figure 3. Measured and calculated electron backscatter for various inhomogeneities plotted as a function of mean energy at the phantom surface.

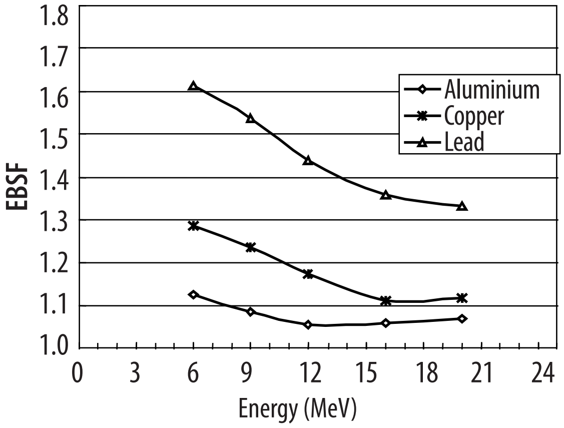

Figure 4. Variation of electron backscatter factor as a function of mean energy at the phantom surface.

The thickness at which the saturation value of EBSF was produced was found to be dependent on the nominal electron energy at the phantom surface. For 6MeV electron the saturation is attained at less than 1mm itself, whereas for 16MeV and 20MeV electrons EBSF becomes constant beyond 6mm. The amount of backscattered dose contribution is more for all the energies with high-Z (lead) inhomogeneity. It has been found that the increase in dose is about 61% for 6MeV, 44% for 12MeV and about 33% for 20MeV electrons with lead inhomogeneity at saturation level (Figure 2C). Though the trend in variation of EBSF is similar for aluminium and copper inhomogeneities, the amount of scatter significantly decreases (Figure 2A and 2B). The maximum increase in dose is only 12.5% and 28% for aluminium and copper, respectively, for 6MeV electrons, and the corresponding variation is 5.5% and 12% for 20MeV electrons.

The measured value of EBSF coincides with that of EBSF calculated (Figure 3) using equation (4) for all the inhomogeneities at all electron energies studied. The graph indicating the variation of EBSF with energy shows higher slope for lead inhomogeneity compared to that of copper and aluminium inhomogeneity (Figure 4). Hence, the variation of EBSF with lead inhomogeneity could be used to specify the quality of electron beam.

DISCUSSION

The increase in dose at the inhomogeneity is due to the backscattered electrons. Though the bremsstrahlung radiation produced due to the slowing down of secondary electrons can add to an increase in dose, its amount will be minimal, and hence it can be neglected. The amount of backscattered secondary electrons contributing to the increase in dose increases as the thickness of the inhomogeneity increases. EBSF reaches the saturation value when the thickness of the embedded inhomogeneity increases beyond the range of the backscattered electrons. Since the scattering cross section is more with high-Z materials for electrons, the minimum thickness of the inhomogeneity to produce the saturation value of EBSF is less for high-Z metals compared to the low-Z inhomogeneities.

CONCLUSIONS

Since the factors affecting EBSF at the interface are energy dependent, it is expected that the variation in EBSF will also be sensitive to beam energy. Hence the measurement of EBSF with high-Z inhomogeneity can be a measure of nominal electron beam energy. For clinical use the increase in dose at the metallic interface can be calculated by the simple empirical formula [11], which is quite accurate.

REFERENCES:

1. Almon SS, Kenneth RH: Dose in bone and tissue near bone-tissue interface from electron beam. Int J Radiat Oncol Biol Phys, 1991; 21: 695–702
2. Gagnon WF, Cundiff JH: Dose enhancement from backscattered radiation at tissue-metal interfaces irradiated with high energy electrons. Br J Radiol, 1980; 53: 446–70
3. Werner BL: The perturbation of electron beam dose distributions at medium interfaces. Med Phys, 1985; 12: 754–63
4. Das IJ, Lawrence RC, Tatsuo T: Harvesting backscatter electrons for radiation therapy. Int J Radiat Oncol Biol Phys, 1995; 33: 695–703
5. ICRU 1972 Radiation Dosimetry: Electrons with Initial Energies between 1 and 50MeV Report 21 (ICRU Publications, PO Box 30165, Washington DC 20014, USA)
6. Lambert GD, Klevenhagen SC: Penetration of backscattered electrons in polystyrene for energies between 1 and 25MeV. Phys Med Biol, 1982; 5: 721–5
7. AAPM American Association of Physicists in Medicine, Task Group 21, Radiation therapy Committee. AAPM, Protocol for the determination of absorbed dose from high-energy photon and electron beams. Med Phys, 1998; 10: 741–71
8. AAPM American Association of Physicists in Medicine, Task Group 51. AAPM's TG 51 Protocol for clinical reference dosimetry of high energy photon and electron beams. Med Phys, 1999; 26: 1847–70
9. Tabata T, Rinsuke I: Simple calculation of the electron-backscatter factor. Med Phys, 1992; 19: 1423–6
10. Klevenhagen SC: Implication of electron backscattering for electron dosimetry. Phys Med Biol, 1991; 36: 1013–8
11. Ravikumar M, Ravichandran R, Sathiyan S, Supe SS: Backsattered dose perturbation effects at metallic interfaces irradiated by high energy X and gamma ray therapeutic beams. Strahlenther Onkol, 2004; 3: 173–8
12. Ravikumar M, Ravichandran R, Supe SS: Forward scatter dose effect at metallic interface irradiated by X and gamma ray therapy beams. Strahlenther Onkol, 2001; 11: 611–5
13. Klevenhagen SC, Lambert GD, Arbabi A: Backscattering in electron beam therapy for energies between 3 and 35MeV. Phys Med Biol, 1982; 27: 363–73