

Field shaping in electron beam therapy

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ABSTRACT

In the treatment of superficial lesions with 8-13 MeV electrons, lead shields are often used to protect the underlying tissue. Measurements were made with film and ion chamber to analyse various aspects of external and internal shielding in electron beam therapy. Data were obtained on the thickness of lead required for shielding, the effect of blocking on dose-rate, electron-backscattering from lead and X-ray contamination. Practical applications of a lead clay for shielding are discussed.

The treatment of superficial tumors with electron beams sometimes requires considerable beam shaping. Although circular and rectangular cones of various sizes are usually available, lead cut-outs are often needed to give shape to the treated area and to protect the surrounding normal tissue or a critical organ. In situations such as treatment of lesions in the lip or buccal mucosa, additional shielding is required to protect the internal structures beyond the treatment volume.

This paper discusses the problems of external and internal shielding in the radiotherapy of superficial lesions with 8-13 MeV electrons.

APPARATUS AND PROCEDURE

The electron beams of energy, 8, 10, 12, and 13 MeV used in this investigation were produced by the Toshiba linear accelerator, Model LMR/13. The doses were measured with two dosimetry systems, ionization chamber and film. The former was a 0.6 cm³ Farmer chamber with the Capintec Digital Exposure Meter, Model 192. The film was Kodak RP/V. The characteristics of this film for electron beam dosimetry have been discussed by Feldman, *et al*, (1974).

The response of film exposed to the electron beam at various depths in a polystyrene phantom ($\rho=1.05$ g/cm³) was compared with the ion chamber measurements. An automatic rapid processor was used to process the films. Optical densities were obtained with a Macbeth Densitometer (TD-500, aperture size 1 mm). For related data, films were processed sequentially to minimize variations in processing conditions. Optical densities were converted into doses using sensitometric curves obtained as controls. These curves did not change significantly for different films from the same batch and when processed at different times.

The chamber measurements were made in the polystyrene phantom. The depths were corrected for displacement, perturbation (Harder, 1968), and changes in C_E with depth (I.C.R.U., 1972).

The results of the film versus ion chamber are given in Fig. 1.

Figure 2 explains the three types of arrangement used in the experiments involving the film. The arrangement (Fig. 2a) was used for relative depth-dose measurements described above. Figure 2b illustrates the arrangement used to obtain transmission data for lead as well as the values for the electron back-scatter at the interface. In the latter case the lead was placed inside the phantom directly behind the film. Figure 2c was the arrangement to obtain the range of the back-scattered electrons and the modifications of the depth-dose distribution caused by these electrons.

RESULTS

External Shielding

1. *Thickness of lead shielding.* Figure 3 shows the dose at the phantom surface as a function of thickness of overlying lead. An important consideration in electron beam shielding is to make certain that the thickness is adequate to reduce the surface dose to an acceptable value. As seen in Fig. 3, if the

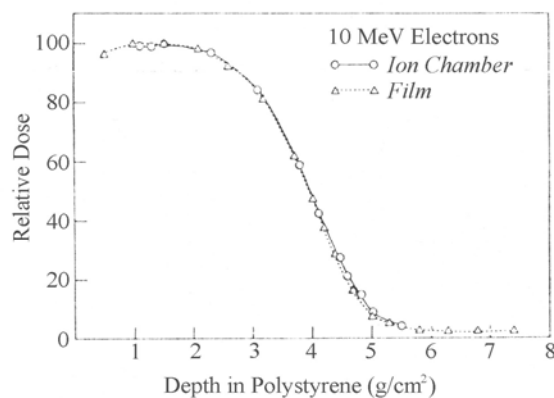
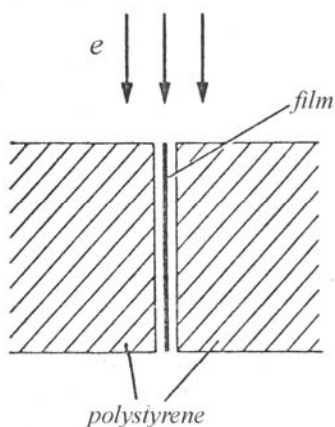


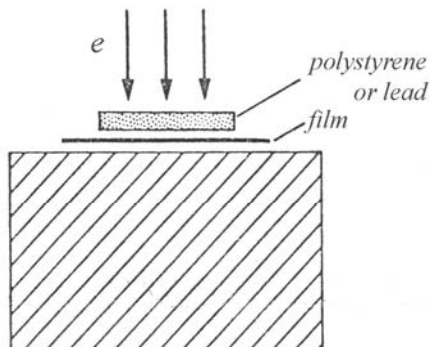
FIG. 1.
Comparison of film response with ion chamber measurements of relative depth dose for electrons.

F.M. Khan, V.C. Moore and S.H. Levitt

(a) Parallel Film



(b) Perpendicular Film



(c) Bent Film

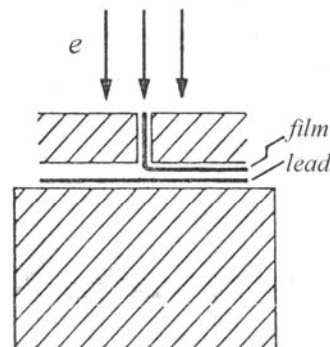


FIG. 2.

Diagrams illustrating film position with respect to beam axis.

lead is too thin the surface dose may even be enhanced. For example, if 1mm thick lead sheet is used for external shielding in a 13 MeV beam, the surface dose behind the lead is increased by 20% relative to the peak dose for the unshielded condition.

The X-ray contamination is slightly increased when using lead shields due to the bremsstrahlung interactions. This can be seen by comparing tail ends of the curves in Figs. 1 and 3. However, in treating small volumes this increase in X-ray contamination is not of much concern.

2. *Effect of blocking on dose-rate.* Blocking a portion of the electron beam field does not significantly alter the dose rate in the open portion of the field, provided the area of the open portion is not too small. Measurements indicated that blocking a 10 cm diameter cone to give a field 2 cm diameter did not change the dose rate. However, when the field was reduced further to 1 cm diameter the dose rate dropped steeply to 85 per cent of the open field value. Thus, if a field produced by a lead cut-out is smaller than the minimum size required for maximum lateral dose build-up, a special output calibration is necessary for that field.

Internal Shielding

1. *Electron back-scatter (EBS).* One of the problems in using lead for internal shielding is the increased back-scatter of electrons (EBS) from lead compared to soft tissue. This has been discussed by Okumura

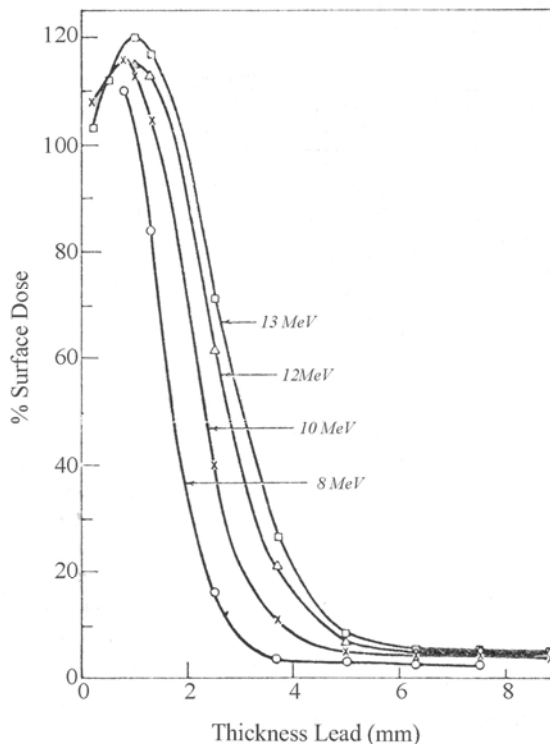


FIG. 3.

Phantom surface dose versus lead thickness as a percentage of the peak dose in phantom without lead. Cone size, 6 cm diameter.

Field shaping in electron beam therapy

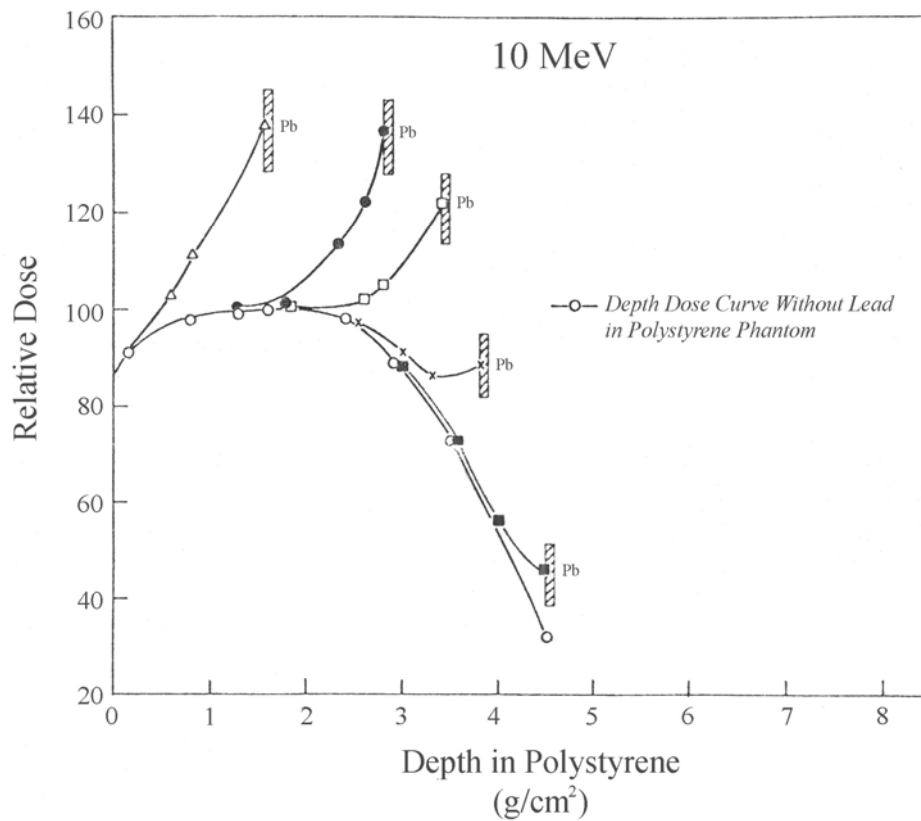


FIG. 4.

Modification of depth dose by lead placed at various depths in the phantom. Lead thickness = 1.7 mm.

et al., (1971), and Saunders and Peters (1974). The EBS is analysed here to study the effect in the range 8-13 MEV.

The thickness of lead used in these measurements was 1.7 mm. The minimum thickness of lead required to give full EBS was found to be about 1.0 mm at 10 MEV. As seen in Fig. 4, the dose at the lead interface decreases with depth. However, the percentage increase in dose at the interface relative to the dose expected at the same point in a homogeneous polystyrene phantom does not change significantly with depth. The range of EBS is about 1 cm, measured from the interface back toward the phantom surface.

Figure 5 gives the effect of energy on the amount and range of EBS. It is seen that although the percentage increase in EBS decreases with energy, the change is not substantial in the energy range studied. It may be noted that the magnitude of the increase in dose at the lead/polystyrene interface is 40 to 50 per cent depending on energy and depth. This

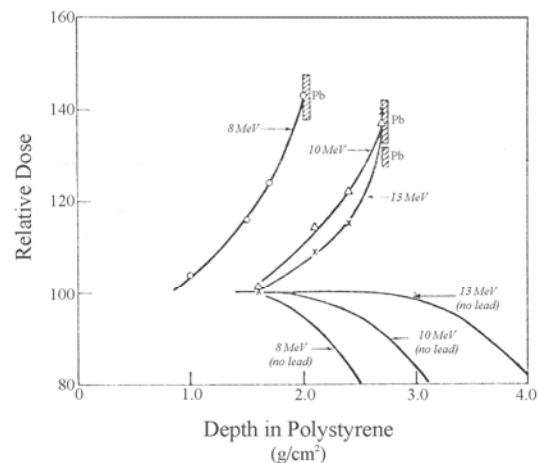


FIG. 5.

Modification of depth dose by lead for different energies. The lead was placed just beyond the region of peak dose in each case.

F.M. Khan, V.C. Moore and S.H. Levitt

differs significantly from the figures of Saunders and Peters (1974) who found a 68 per cent increase in dose at an interface depth of 2 cm with 7.7 MeV incident energy.

In clinical applications for the energy range discussed, 5 to 10 mm of tissue equivalent bolus may be placed between the internal shield and the preceding tissue surface to avoid excessive dose near the interface. Alternatively, it has been suggested that the lead should be sheathed with 2 mm of aluminum (Saunders and Peters, 1974).

2. Lead Clay for Internal Shielding. For internal shielding in the range of 8-13 MeV, about 2 mm lead placed beyond the region of peak dose in the tissue medium would be adequate. However, a lead sheet placed internally, such as for intra-oral shielding, may cause discomfort to the patient. A flexible lead clay* in this case would be advantageous. Because of the toxicity of the elemental lead in the lead clay, it should be wrapped in a thin plastic foil. The lead clay has a density of 4.5 g/cm³ and can be rolled into sheets of uniform thickness. Transmission measurements with the lead clay showed that it is 40 per cent as effective as lead in electron beam shielding. Thus, for internal shielding a 5 mm thick sheet of lead clay is adequate. EBS properties of lead clay are similar to those of the pure lead.

CONCLUSIONS

It has been shown that if thin lead is used in

*Manufactured by Reactor Experiment, Inc., San Carlos, California

electron beam shielding it may enhance rather than reduce the surface dose. A thickness of lead equivalent to the maximum range of the electrons would reduce the transmitted dose to a practical minimum.

Secondary blocking does not alter the dose rate in the open portion of the field, provided full lateral build-up of dose is achieved.

Lead shields used internally cause a significant back-scattering of electrons. In the range 8-13 MeV, this may result in a 40-50 per cent increase in dose at the interface. About 1-0 cm of tissue equivalent bolus between the lead and the tissue surface is required to dissipate this effect.

A lead clay, because of its flexibility, offers an advantage over lead for internal shielding. In electron beam absorption the lead clay is 40 per cent as effective as lead.

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