The Physics of Radiation Therapy

FAIZ M. KHAN, Ph.D.
Professor
Department of Therapeutic Radiology
University of Minnesota Medical School
Director
Radiation Physics Section, University Hospitals
Minneapolis, Minnesota

WILLIAMS & WILKINS
Baltimore/London

A. External Shielding

Several publications have reported the thickness of lead or low melting point lead alloy required for shielding in electron beam therapy (53–57). Figure 14.26 shows a set of transmission measurements through lead. The thickness for shielding can be chosen on the basis of allowable transmission (*e.g.* 5%). The shield thickness should be neither overly large nor so critical in measurement that a small change in thickness would cause a large change in the transmitted dose.

An important consideration in electron beam shielding is to make certain that the thickness is appropriate to reduce the dose to an acceptable value. As seen in Fig. 14.26, if the lead is too thin, the transmitted dose may even be enhanced directly behind the shield. Normally, if weight or thickness is no problem, one can use a shield of thickness greater than the required minimum. But there are practical limits on the amount of lead that can be used. For example, in the case of eyeshields (58) and internal shields, it is important to use the minimum thickness of lead to obtain the desired reduction in dose.

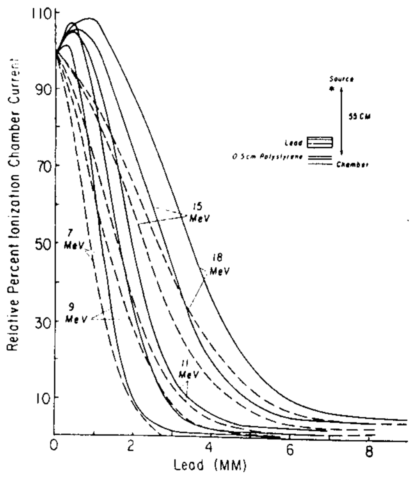

Figure 14.26. Transmission curves through lead for 7-, 9-, 11-, 15-, and 18-MeV electrons. Measurements made with a plane-parallel chamber in a polystyrene phantom, at a depth of 0.5 cm. Solid lines are 10.5 × 10.5 cm effective field size and dashed lines are for 6.3 × 6.3 cm effective field size. (Redrawn from Reference 53.)

D. Internal Shielding

In some situations such as the treatment of lip, buccal mucosa, and eyelid lesions, internal shielding is useful to protect the normal structures beyond the target volume. Lead shielding may be used to reduce the transmitted dose to an acceptable value. However, the electron backscatter from lead enhances the dose to the tissue near the shield. This effect has been discussed by several investigators (54, 60–65).

The enhancement in dose at the tissue-lead interface can be quite substantial, *e.g.* 30–70% in the range of 1–20 MeV. Figure 14.29 shows the increase in dose (relative to homogeneous phantom) as a function of the mean energy

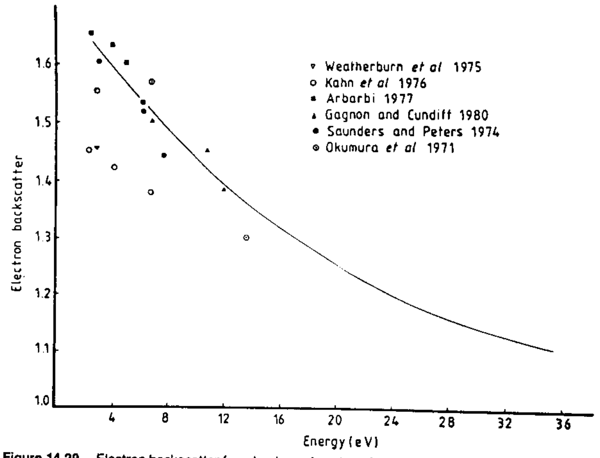

Figure 14.29. Electron backscatter from lead as a function of mean electron energy at the interface. The solid line represents the best fit to experimental data of Klevenhagen *et al.* (65). [Reprinted with permission from: Klevenhagen *et al.* (65).]

incident at the tissue-lead interface. The scatter in the experimental data is probably due to differences in the measurement techniques and the state of angular spread of the electron beam before incidence at the interface. The curve by Klevenhagen *et al.* (65) represents the best fit to his experimental data for polystyrene-lead interface and has been characterized by the following equation (65):

$$\mathrm{EBF} = 1 + 0.735 \exp(-0.052\, \bar{E}_Z)$$

where EBF is the electron backscatter factor, defined as the quotient of the dose at the interface with the lead present to that with a homogeneous polystyrene phantom at the same point. $\bar{E}_Z$ is the average electron energy incident at the interface.

Variation of electron backscatter with atomic number Z of the scattering material has also been studied (64, 65). Figure 14.30 gives the data by Klevenhagen *et al.* (65).

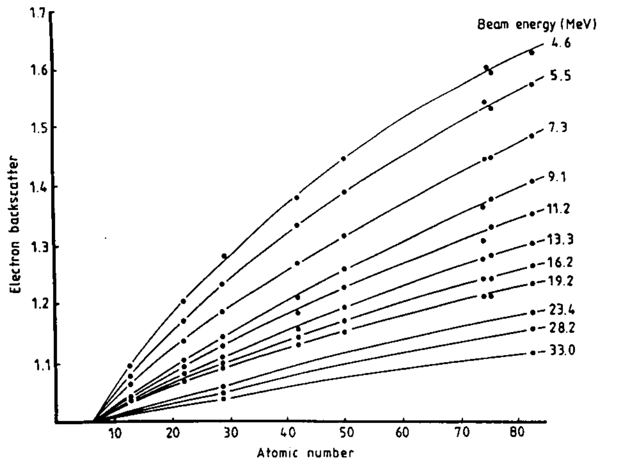

Figure 14.30. Variation of electron backscatter with atomic number Z of scattering material for different electron energies at the interface. [Reprinted with permission from: Klevenhagen *et al.* (65).]

An important aspect of the electron backscatter problem is the range of the backscattered electrons. Measurements of dose in the phantom layers preceding the lead have shown (54, 64) that for electrons in the range of 8–20 MeV the range of the backscattered electrons is about 1–2 g/cm² of polystyrene, depending on the energy of the incident electrons. The dose enhancement drops off exponentially with the distance from the interface on the entrance side of the beam. Figure 14.31 illustrates this effect for 10-MeV beam incident on a phantom with a sheet of lead placed at various depths.

In order to dissipate the effect of electron backscatter, a suitable thickness of low atomic number absorber such as bolus may be placed between the lead shield and the preceding tissue surface. Saunders and Peters (62) recommend the use of an aluminum sheath around any lead used for internal shielding. Oral shielding has also been accomplished by special oral stents made of dental acrylic which encompasses the lead (35). Such a shield provides lead protection for the tongue and other structures as well as reduces the electron backscatter from lead reaching the buccal mucosa.

Eyeshields are designed to protect the lens. Minimum thickness of lead is used to provide acceptable transmission value. Since a significant thickness of low Z material is required to absorb the electron backscatter, eyeshields cannot be coated with an adequate thickness of such materials without exceeding the size requirements. In such cases, it is desirable to coat the lead shield with a thin film of wax or dental acrylic (to absorb the very low energy electrons) and calibrate the setup for actual dose received by the lid.

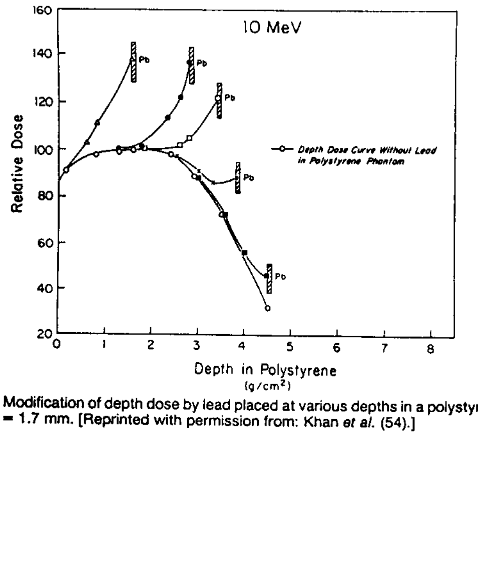

Figure 14.31. Modification of depth dose by lead placed at various depths in a polystyrene phantom. Lead thickness = 1.7 mm. [Reprinted with permission from: Khan *et al.* (54).]