Electron Beam Treatment Planning

High-energy electron beams are considered crucial treatment modalities in radiotherapy. Electron therapy may be used for the treatment of superficial tumors (<5 cm deep), such as cancers of the skin and lips, chest wall boost in the breast treatment, and boost to various nodes in the body.

Depth Dose Profiles

Percent depth doses for electron beams are measured in a water phantom similar to those for photon beams. There are, however, fewer standard square fields (cones or applicators), designed for electron beam delivery. Electron depth dose curves vary with varying field size, beam energy, and SSD (the source-surface distance).

Figure (1) shows a typical electron depth dose distribution in water. A number of important parameters associated with the electron PDD are presented and explained below:

D_{surf}-Surface dose

R_{90}-Depth of 90% dose beyond d_m

R_{50}-Depth of 50% dose

R_p - Practical range; the depth to the point where tangent to the descending linear portion of PDD intersects the extrapolated x-ray contamination, as shown in Fig. (1).

$D_{x\text{-}ray}$ - Bremsstrahlung x-ray contamination beyond practical range.

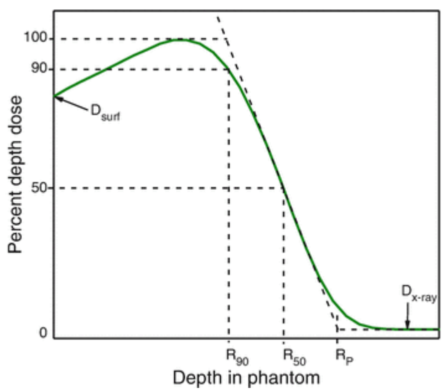

Fig. (1) Typical electron beam depth dose curve demonstrating the concepts of R_{90} R_{50}. R_p Dsurf, and $D_{x\text{-}ray}$

Variation with Beam Energy

As expected, the percent depth dose increases with increase in electron energy for a given field size Fig. (2). A unique behavior shown by these percent depth doses is that the surface dose increases with increasing electrons energy. This phenomenon may be explained by understanding the electron scattering properties. Electrons at lower energies scatter through larger angles, and their scattering probability is also higher. This results in a higher electron fluence at a shorter distance relative to the fluence on the surface. **Therefore, the ratio of these fluences is less for the low-energy electrons compared to the high-energy electrons**.

Variation with Field Size

Percent depth dose increases with field size, due to increased scatter from the collimator and the phantom (Fig. 3). Most of the electron beams are shaped by various applicator (cone) sizes and inserts (cutouts), provided a recommended fixed jaw opening. With the fixed jaw settings, variation in cone scatter is minimum and beam output is almost constant. The use of the applicators is essential for producing a uniform fluence at the patient surface.

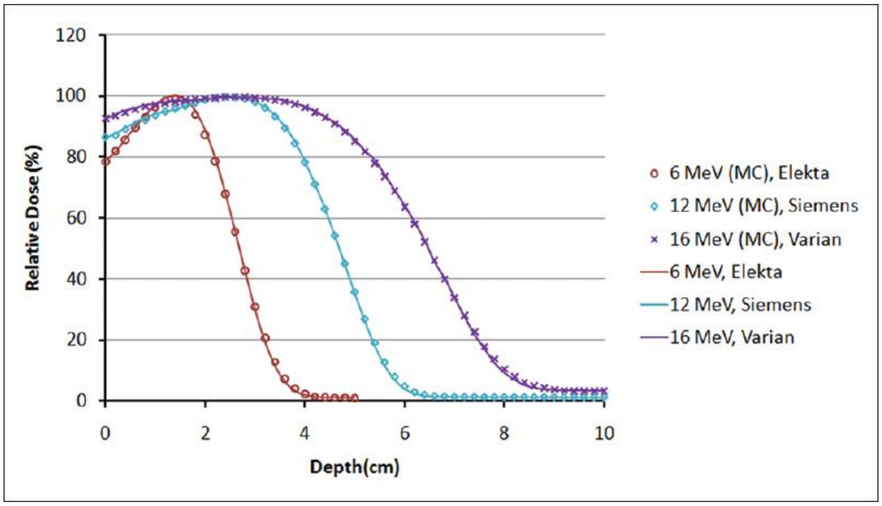

Fig. (2) Depth dose variation with increasing beam quality

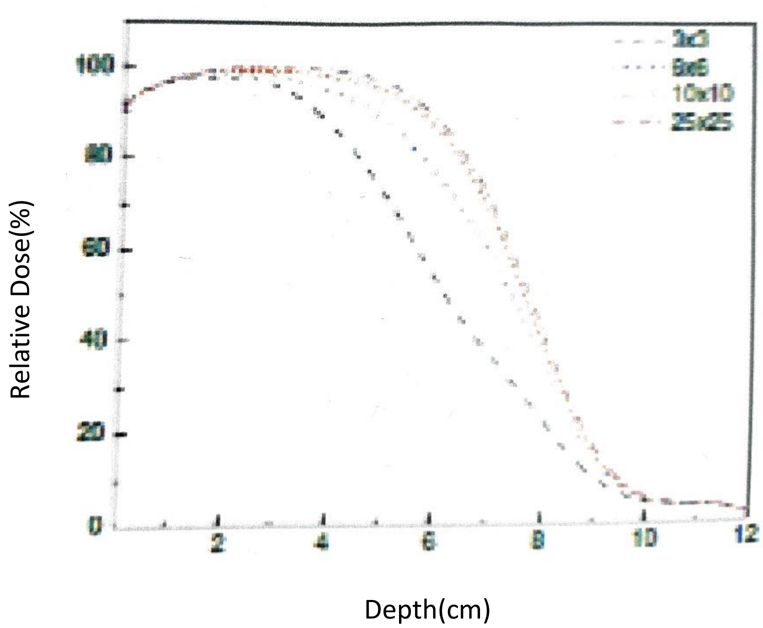

Fig. (3) Applicator/conesize dependence on % depth dose distribution for 18 MeV an electron beam.

Electron Beam Energy Specification

A number of different parameters are used to describe the electron beam energy.

The energy of electron beam on the phantom surface is expressed by the most probable energy $E_{p,o}$ and the mean energy $\overline{E_0}$. The most probable energy ($E_{p,o}$) is the energy carried by most of the electrons and may be estimated by the following relation:

$$E_{p,o}\ (MeV)\ =\ 0.022\ + 0.198\ R_p\ + 0.00011 R_p^2 \qquad (1)$$

Where R_p is in mm and $E_{p,0}$ in MeV.
The mean energy ($\overline{E_0}$) at the phantom surface may be calculated as follows

$$\overline{E_0} = 2.33\ R_{50} \qquad (2)$$

Isodose Curves

The isodose curves measured for the electron beams are much different than those for the photons (Fig. 4). The dose distribution expands with depth in the medium due to side scattering of the electrons. The spread of the individual isodose curve varies as a function of the isodose level, beam quality, and field shape, only low-level isodoses expand laterally in case of high-energy electron beams.
The higher-value isodoses (>80%) narrow down for high-energy beams.
Figure (4) a and b shows the isodose curves for 6 MeV and 18 MeV electron beams, respectively.

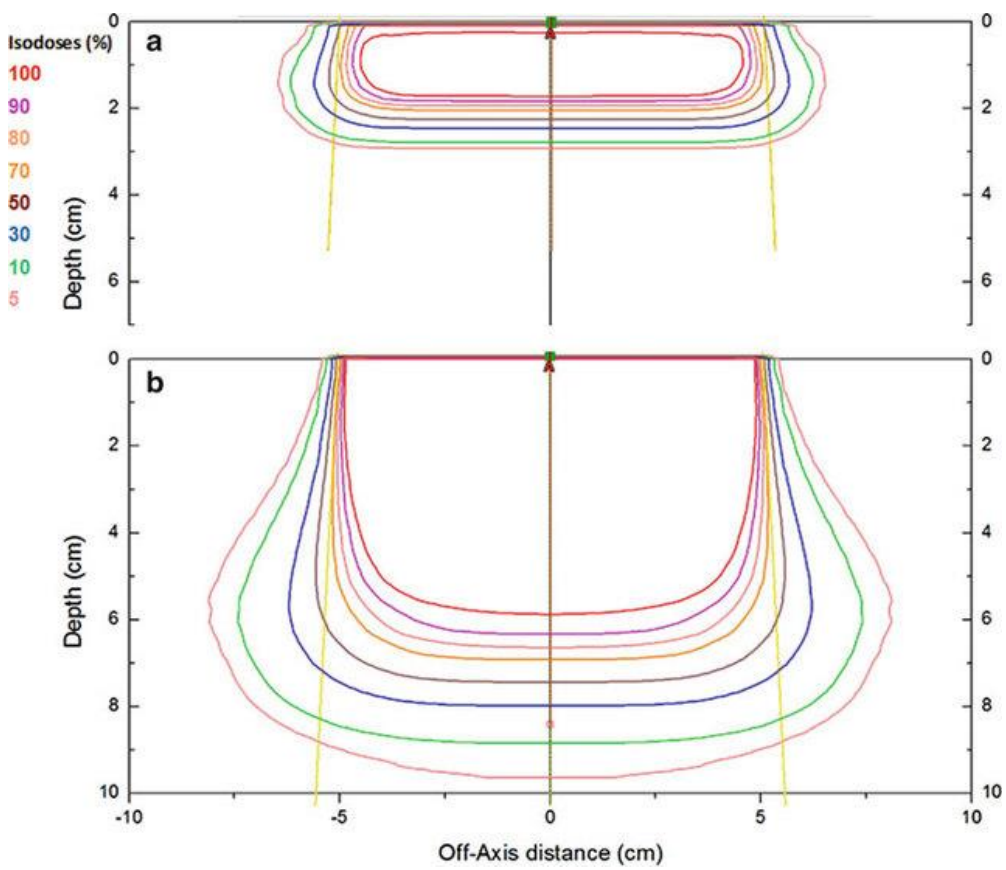

Fig. (4) Isodose distribution of electron beams with, (a) 6 MeV and (b) 18 MeV

Treatment Planning

Surface lesions extending to a depth of up to 5 cm may be easily treated with a single direct electron beam. The following practical considerations should be noted when preparing a treatment plan.

Treatment Setup

The majority of electron beam treatments are carried out with a single field and fixed SSD. A nominal treatment SSD of 100 cm is typically used. If required, however, extended SSDs may also be used. During lateral neck boost, an SSD of 115 cm is commonly used to avoid hitting of the patient shoulders by applicator.

Beam Energy and Field Size

Based on the above discussion on the electron isodose distribution, the beam energy and field size should be appropriately selected to provide adequate coverage of the lesion within the 80-90% isodose.

Field Shaping

Electron applicators (cones) as shown in Fig. 5a are typically used for field shaping and collimation. When required additional shielding cutouts may also be used.

The photon beam collimation system (movable jaws) alone cannot be used for electron beam shaping because of multiple scatterings in the space between the electron exit window and the patient. Electron dose uniformity in this case will be unacceptable for the treatment purposes. Electron beam applicators or cones are attached to the treatment unit head.

For irregular field shapes, lead or Cerrobend cutouts (Fig. 5b) may be placed in the distal end of the applicator.

Figure 5b shows an external shield to be used with a specific applicator.

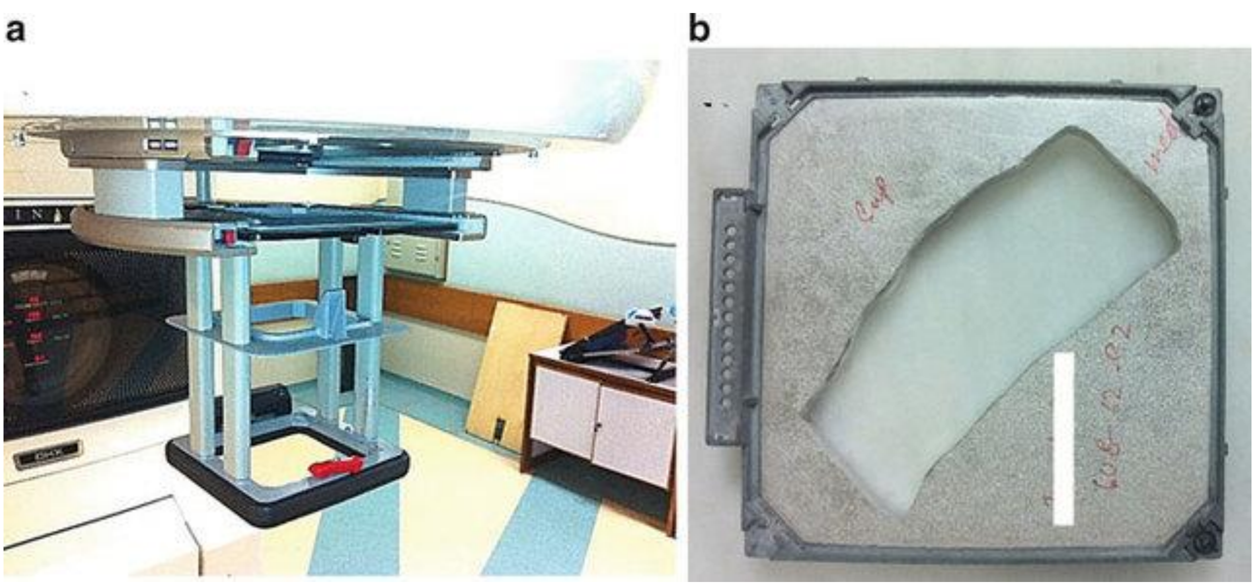

Fig. 5 (a) Electron applicator/cone (Courtesy: Varian Medical Systems, Palo Alto, CA),
(b) Cerrobend cutout