Clinical Radiation Generators

4.1 KILOVOLTAGE UNITS

Up to about 1950, most of the external beam radiotherapy was carried out with x-rays generated at voltages up to 300 kVp. Subsequent development of higher energy machines and the increasing popularity of the cobalt-60 units in the 50s and the 60s resulted in a gradual demise of the conventional kilovoltage machines. However, these machines have not completely disappeared. Even in the present era of the megavoltage beams, there is still some use for the lower energy beams, especially in the treatment of superficial skin lesions.

In Chapter 3, we discussed in general the principle and operation of an x-ray generator. In this chapter, we will consider in particular the salient features of the therapy machines.

On the basis of beam quality and their use, the x-ray therapy in the kilovoltage range has been divided into subcategories (1, 2). The following ranges are more in accordance with Ref. 2.

A. Grenz-ray Therapy

The term "grenz-ray therapy" is used to describe treatment with beams of very soft (low energy) x rays produced at potentials below 20 kV. Because of the very low depth of penetration (Fig. 4.1a), such radiations are no longer used in radiotherapy.

B. Contact Therapy

A "contact therapy" machine operates at potentials of 40--50 kV and facilitates irradiation of accessible lesions at very short source (focal spot) to surface distances (SSD). The machine operates typically at a tube current of 2 mA. Applicators available with such machines can provide an SSD of 2.0 cm or less. A filter of 0.5 to 1.0-mm thick aluminum is usually interposed in the beam to absorb the very soft component of the energy spectrum.

Because of very short SSD and low voltage, the contact therapy beam produces a very rapidly decreasing depth dose[1] in tissue. For that reason, if the beam is incident on a patient, the skin surface is maximally irradiated but

[1] The term dose or absorbed dose is defined as the energy absorbed per unit mass of the irradiated material.

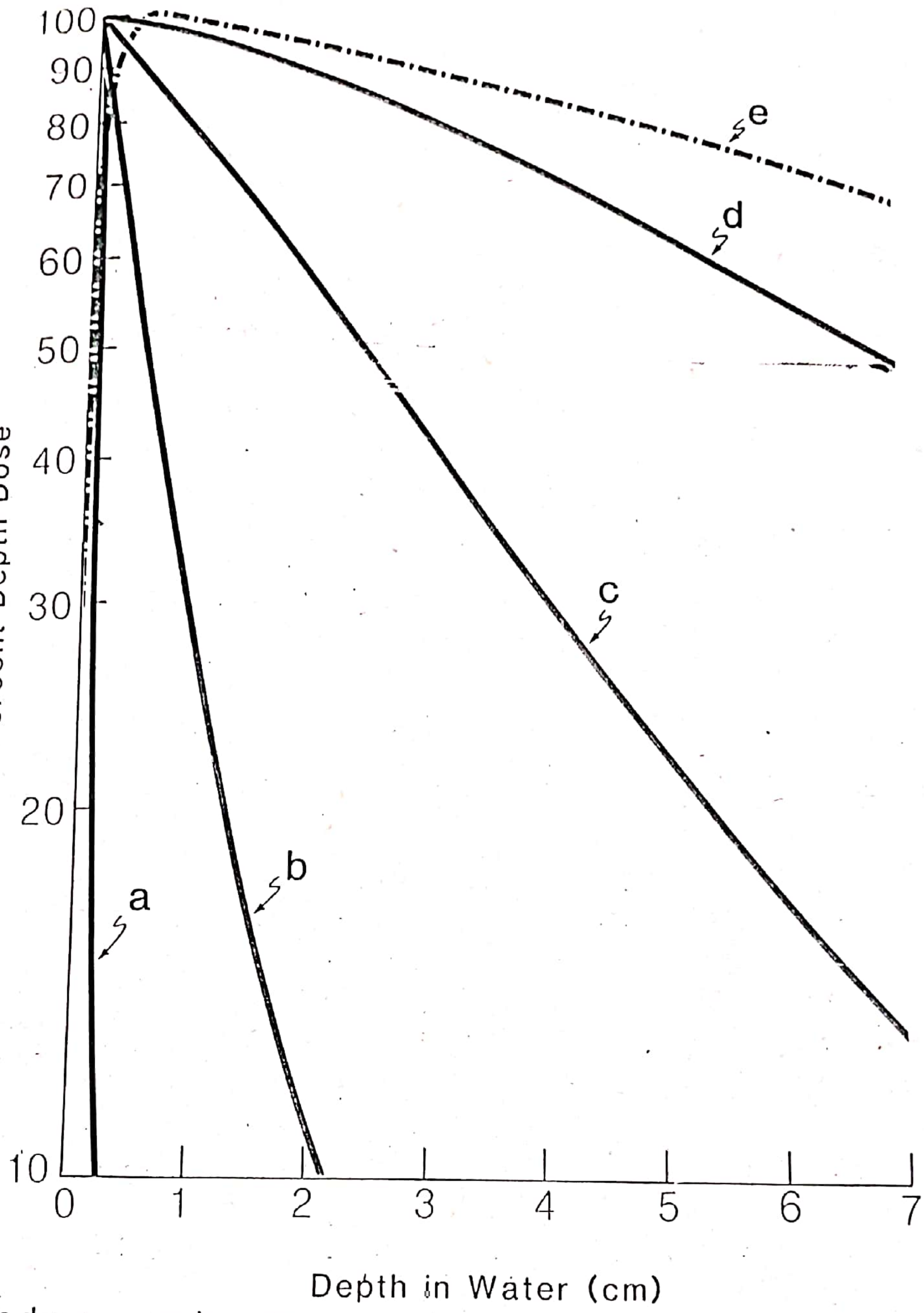

Figure 4.1. Depth dose curves in water or soft tissues for various quality beams. [Plotted from data in Cohen M, Jones DEA, Green D (eds): *Central Axis Depth Dose Data for Use in Radiotherapy. Br J Radiol.* (Suppl 11) The British Institute of Radiology, London, 1978.] (a) Grenz rays, HVL = 0.04 mm Al, field diameter ≃ 33 cm, SSD = 10 cm. (b) Contact therapy, HVL = 1.5 mm Al, field diameter = 2.0 cm, SSD = 2 cm. (c) Superficial therapy, HVL = 3.0 mm Al, field diameter = 3.6 cm, SSD = 20 cm. (d) Orthovoltage, HVL = 2.0 mm Cu, field size = 10 × 10 cm, SSD = 50 cm. (e) Cobalt-60 γ rays, field size = 10 × 10 cm, SSD = 80 cm.

the underlying tissues are spared to an increasing degree with depth. The dose *vs.* depth curve or simply the depth dose curve of a typical contact therapy beam is shown in Fig. 4.1b. It is readily seen that this quality of radiation is useful for tumors not deeper than 1–2 mm. The beam is almost completely absorbed with 2 cm of soft tissues.

C. Superficial Therapy

The term "superficial therapy" applies to treatment with x-rays produced at potentials ranging from 50 to 150 kV. Varying thicknesses of filtration (usually 1–6-mm aluminum) are added to harden the beam to a desired degree. As mentioned in Section 3.5, the degree of hardening or beam quality can be expressed as the half-value layer (HVL). The HVL is defined as the thickness of a specified material which, when introduced into the path of the beam, reduces the exposure rate by one-half. Typical HVLs used in the superficial range are 1.0- to 8.0-mm Al.

The superficial treatments are usually given with the help of applicators or cones attachable to the diaphragm of the machine. The SSD typically ranges between 15 and 20 cm. The machine is usually operated at a tube current of 5–8 mA.

As seen in Fig. 4.1c, a superficial beam of the quality shown is useful for irradiating tumors confined to about 5-mm depth (~90% depth dose). Beyond this depth, the dose drop-off is too severe to deliver adequate depth dose without considerable overdosing of the skin surface.

D. Orthovoltage Therapy or Deep Therapy

The term "orthovoltage therapy" or "deep therapy" is used to describe treatment with x-rays produced at potentials ranging from 150–500 kV. Most orthovoltage equipment is oeprated at 200–300 kV and 10–20 mA. Various filters have been designed to achieve half-value layers between 1–4-mm Cu. An orthovoltage machine is shown in Fig. 4.2.

Although cones can be used to collimate the beam into a desired size, a movable diaphragm, consisting of lead plates, permits a continuously adjustable field size. The SSD is usually set at 50 cm.

Figure 4.1d shows a depth dose curve for a moderately filtered orthovoltage beam. Although the actual depth dose distribution would depend on many conditions such as kilovoltage, HVL, SSD, and field size, some generalizations can be made from this curve about the orthovoltage beam characteristics. The maximum dose occurs close to the skin surface, with 90% of that value occurring at about 2-cm depth. Thus, in a single field treatment, adequate dose cannot be delivered to a tumor beyond this depth. However, by increasing beam filtration or HVL and combining two or more beams directed at the tumor from different directions, one can deliver higher dose to deeper tumors. As will be discussed in further detail in Chapter 11, there are severe limitations to the use of orthovoltage beam in treating lesions deeper than 2–3 cm. The greatest limitation is the skin dose which becomes prohibitively large when adequate doses are to be delivered to deep seated tumors. In the early days of radiotherapy, when orthovoltage was the highest energy available, treatments were given until radiation tolerance of the skin was reached. Although methods were developed to use *multiple beams* and other techniques to keep the skin dose under tolerance limits, the problem of high skin dose remained an