# Dose distribution and scatter analysis

It is seldom possible to measure dose distribution directly in patients treated with radiation. Data on dose distribution are almost entirely derived from measurements in phantoms tissue equivalent materials, usually large enough in volume to provide full-scatter conditions for the given beam. These basic data are used in a dose calculation system devised to predict dose distribution in an actual patient.

## PHANTOMS

Basic dose distribution data are usually measured in a water phantom, which closely approximates the radiation absorption and scattering properties of muscle and other soft tissues.

Another reason for the choice of water as a phantom material is that it is universally available with reproducible radiation properties.

A water phantom, however, poses some practical problems when used in conjunction with ion chambers and other detectors that are affected by water, unless they are designed to be waterproof. In most cases, however, the detector is encased in a thin plastic (water equivalent) sleeve before immersion into the water phantom.

Since it is not always possible to put radiation detectors in water, solid dry phantoms have been developed as substitutes for water. Ideally, for a given material to be tissue or water equivalent, it must have the:

1. Same effective atomic number
2. Same number of electrons per gram
3. Same mass density.

Anthropomorphic phantoms are frequently used for clinical dosimetry. One such commercially available system, known as Alderson Rando Phantom,' incorporates materials to simulate various body tissues muscle, bone, lung, and air cavities. The phantom is shaped into a human torso and is sectioned transversely into slices for dosimetric applications.

## DEPTH DOSE DISTRIBUTION

- As the beam is incident on a patient (or a phantom), the absorbed dose in the patient varies with **depth**.
- This variation depends on many conditions:
  beam energy, depth, field size, distance from source, and beam collimation system.

Thus the calculation of dose in the patient involves considerations in regard to these parameters and others as they affect depth dose distribution.

An essential step in the dose calculation system is to establish depth dose variation along the central axis of the beam.

A number of quantities have been defined for this purpose, major among these being percentage depth dose tissue-air ratios, tissue-phantom ratios, and tissue-maximum ratios. These quantities are usually derived from measurements made in water phantoms using small ionization chambers.

Although other dosimetry systems such as TLD, diodes, and film are occasionally used, ion chambers are preferred because of their better precision and smaller energy dependence.

## PERCENTAGE DEPTH DOSE

One way of characterizing the central axis dose distribution is to normalize dose at depth with respect to dose at a reference depth. The quantity percentage (or simply percent) depth dose may be defined as the quotient, expressed as a percentage, of the absorbed dose at any depth **d** to the absorbed dose at a fixed reference depth do, along the central axis of the beam. Percentage depth dose (P) is thus:

$$P = \frac{D_d}{D_{d_0}} \times 100$$

For orthovoltage (up to about 400 kVp) and lower-energy x-rays, the reference depth is usually the surface ($d_o = 0$). For higher energies, the reference depth is taken at the position of the peak absorbed dose ($d_o = d_m$).

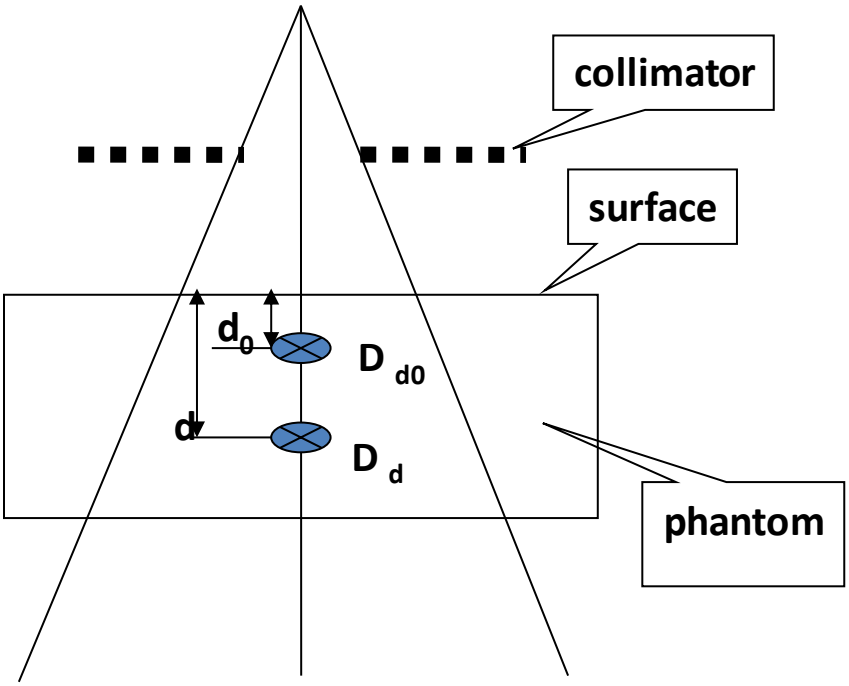


**FIG.1** Percentage depth dose is *(DdlDdo)* x 100, where *d* is any depth and $d_o$ is: reference depth of maximum dose.

In clinical practice, the peak absorbed dose on the central axis is sometimes called the *maximum dose*, the *dose maximum*, the *given dose*, or simply the $D_{m,}$. Thus,

$$D_{max} = \frac{D_d}{P} \times 100$$

*A number of parameters affect the central axis depth dose distribution*. These include :

1. Beam quality or energy
2. Field size and shape,
3. Source to surface distance
4. Beam collimation.

**Dependence on Beam Quality and Depth**

The percentage depth dose (beyond the depth of maximum dose) increases with beam energy. Higher-energy beams have greater penetrating power and thus deliver a higher percentage depth dose.

The physics of dose buildup may be explained as follows:

(a) As the high-energy photon beam enters the patient or the phantom, high-speed electrons are ejected from the surface and the subsequent layers

(b) These electrons deposit their energy a significant distance away from their site of origin

(c) Because of (a) and (b), the electron fluence and hence the absorbed dose increases with depth until they reach a maximum.

- However, the photon energy fluence continuously decreases with depth and, as a result, the production of electrons also decreases with depth.
- The net effect is that beyond a certain depth the dose eventually begins to decrease with depth.
- It may be instructive to explain the buildup phenomenon in terms of absorbed dose and a quantity known as kerma (from kinetic energy released in the medium).

*** the kerma (K) defined as "the quotient of dE,, by dm, where dE,, is the sum of the initial kinetic energies of all the charged ionizing particles (electrons) liberated by uncharged ionizing particles (photons) in a material of mass dm.

$$K = \frac{dE_{tr}}{dm}$$

- Because kerma represents the energy transferred from photons to directly ionizing electrons, the kerma is maximum at the surface and decreases with depth because of the decrease in the photon energy fluence.
- The absorbed dose, on the other hand, first increases with depth as the high-speed electrons ejected at various depths travel downstream. As a result, there is an electronic build-up with depth.
- However, as the dose depends on the electron fluence, it reaches a maximum at a depth approximately equal to the range of electrons in the medium. Beyond this depth, the dose decreases as kerma continues to decrease, resulting in a decrease in secondary electron production and hence a net decrease in electron fluence.
- As shown in figure below the kerma curve is initially higher than the dose curve but falls below the dose curve beyond the build-up region. This effect is explained by the fact that the areas under the two curves taken to infinity must be the same.

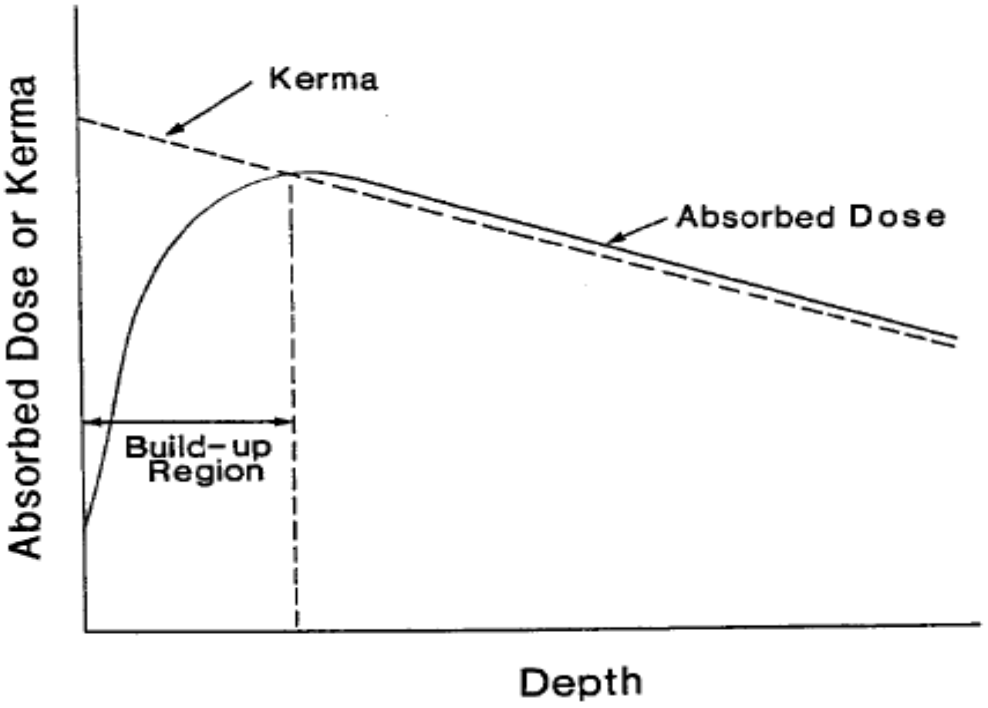


Figure: Schematic plot of absorbed dose and kerrna as function of depth.