Chapter 12
Treatment Planning – Combination of Beams

Radiation Dosimetry I

http://www.utoledo.edu/med/depts/radther

Outline
• Opposing pairs of beams
• Combination of opposing pairs
• Angled fields and wedge pairs
• Three-field approaches
• Rotational therapy

Combination of beams
• Achieve high dose conformity to the target
• Spare healthy surrounding tissues
• Several general approaches:
  – Opposing pairs of beams and their combination
  – Angled fields and wedge pairs
  – Rotation therapy

Opposing pairs of beams
• The simplest combination of two fields is achieved by directing them along the same axis from opposite sides
• The variation in dose along the axis of opposing pair of beams depends on the field separation and beam energy
• It can be made very small, yielding an almost uniform dosage from one beam entrance to the other

Unequal dose to the opposing fields

• An arrangement often used for treatment of a tumor situated approximately midway between two parallel surfaces
• High energy beams must be used to avoid the dip in the middle

Figure 12-1. Isodose distribution obtained by combining two opposing irradiation beams. Beams are at 100 x 100 cm, with uniform radiation and the intensity and the beam energy are 100 cm. The isodose distribution is normalized for the isodose of 100 cm. The variation in dose along the axis of opposing pair of beams depends on the field separation and beam energy. It can be made very small, yielding an almost uniform dosage from one beam entrance to the other.

Figure 12-2. Relative dose for 10 x 10 cm beam of cobalt, 20 MV and 23 MV radiation. The single beam is normalized as a reference of 100 cm. The isodose distribution is normalized for the isodose of 100 cm. The variation in dose along the axis of opposing pair of beams depends on the field separation and beam energy. It can be made very small, yielding an almost uniform dosage from one beam entrance to the other.
Opposing pairs of beams

- For small separations (<10 cm) low MV energy beams are well suited: extended region of uniform dose with relatively flat plateau between the maxima
- For larger separations (>15 cm) high energy beam are required to avoid hot spots in the regions of both maxima
- Many anatomical sites can adequately be treated with parallel-opposed beams (lung, brain, head and neck lesions)

Figure 12-3. Isodose distributions in planes perpendicular to the axis of opposing fields of (a) cobalt-60 and (b) 25 MV radiation. The beams are isocentric, 10 × 10 cm and the separation is 20 cm.

- A uniform “box” coverage is achieved in planes perpendicular to the axis of opposing fields

Opposing pairs of beams

- In practice the isodose distribution is altered by curved surfaces and has to be properly adjusted (blocks, etc.)

Combination of opposing pairs

- Allows for higher dose in the beam intersection region
- Four-field box (two opposing pairs at 90° angle) used most often for treatment of pelvis with centrally located lesions (prostate, bladder, uterus)
- Three-field box (two wedged opposing beams and 3rd beam at 90°) for lesions closer to the surface (rectum)

Split fields

- Can be used to protect sensitive critical structures in the middle of the field
Angled fields and wedge pairs

- Often used for irradiation of a small tumor through the same skin surface
- Although the fields are directed towards the point P, the high dose region occurs much nearer the surface, therefore the beams should be aimed considerably below P ("past pointing").

Parameters of the wedge beams:

- $\theta$ is wedge angle, $\Phi$ is hinge angle, and $S$ is separation
- Isodose curves for each wedge field are parallel to the bisector
- An optimum relationship between the wedge angle $\theta$ and the hinge angle $\Phi$ that provides the most uniform distribution of radiation dose in the plateau:

\[
\theta = 90^\circ - \frac{\Phi}{2}
\]

Three field technique

- Provides better dose homogeneity within the tumor
- Homogeneity can be further improved with tissue compensators

Example 1

- Which one of the following plans has the wedges in the correct orientation?

Example 2

- The wedge angle that would give the most homogeneous distribution in the "wedged pair" in the diagram below is ___ degrees. (Field axes are at 90°).

Example 3

- Which of the following isodose patterns is consistent with the field configurations and wedges shown?
Rotation therapy

- Provides maximum dose uniformity within the tumor and the most of healthy tissue sparing:
  a) patient in a rotating chair; b) source is moved around a stationary patient; c) source moves in a circular path and simultaneously transverse horizontally to cover the surface of a cylinder; d) x-ray head moves about a spiral with the beam always directed to one point below the surface; e) patient lies on a couch that rotates about a vertical axis; f) beam is offset from the axis of rotation to cover an annular ring about the center of rotation (chest wall irradiation).

Rotation therapy: isodose distributions

- Calculations are generally based on the superposition of single beam isodose charts, with isodose lines normalized to 100% at the axis of rotation.
- The total dose at a point in a patient is obtained by adding together the contributions from a series of fixed fields spaced at equal angular intervals.

Rotation therapy: effect of energy

- Penetration depth and skin sparing govern the choice of the beam energy.

Rotation therapy: effect of arc length

- As the degree of rotation becomes less than 360°, the isodose curves are deformed in such a way that the side opposite the beam entrance surface become flatter with the decrease in the arc angle.
- When the arc angle is 180° or less, the isodose curves tend to be pinched in at the sides and the lower portion again moves further from the axis.
Rotation therapy: effect of arc length

- An example of dynamic-arc conformal avoidance plan for reirradiation of spinal metastases


Rotation therapy: effect of field size

- The length of the field has a little effect, while the width has a profound effect on the isodose distribution
- Rotational therapy is not recommended if wide fields must be used, due to high dose delivered outside of the target

Comparison of fixed field and rotation therapy

- In rotation therapy the skin dose is less than with fixed field therapy (~15% vs. 40%) because rotation therapy is equivalent to using 8 to 12 fields
- The isodose curves for rotation therapy are smoother around the tumor region; with fixed fields “horns” between adjacent fields are present
- However, with fixed fields some areas can be completely spared

Figure of merit

- A treatment plan should deliver a high and uniform dose over a target volume, but minimum dose to all outside structures
- Figure of merit:  

\[ f = \frac{E_{\text{target}}}{E_{\text{patient}}} \]

\[ f = 0.14 \ (\text{Co-60}) \]

\[ f = 0.17 \ (22\text{MeV}) \]

- A patient is planned for equally weighted, parallel-opposed 6 MV photon fields treating the mediastinum. AP thickness 22 cm. If the beam energy is changed to 18 MV photons, all of the following would decrease except:
  
A. MU  
B. Skin dose  
C. Depth of maximum tissue dose  
D. Percent variation in dose across the treated volume
Example 5

• In a 3-field plan to treat the rectum using open PA and wedged lateral fields, a homogeneous distribution can be obtained in the PTV with either 45° or 60° wedges. With 60° wedges, the relative dose at the isocenter for the PA field would be ___ that in the 45° wedged plan.

A. Greater than  
B. Less than  
C. The same as

Lateral wedges compensate for depth-dose fall-off of the PA field. The greater is the contribution from PA field, the larger is the wedge angle required.

Summary

• Opposing pairs of beams  
• Combination of opposing pairs  
• Angled fields and wedge pairs  
• Three-field approaches  
• Rotational therapy