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
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 beams 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)

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")

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 energy (FF vs FFF)

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

Rotation therapy (VMAT) examples

- 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 becomes 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

Comparison of fixed field and rotation therapy

• In more advanced IMRT approaches non-coplanar fixed fields can be used
• Multiple non-coplanar arcs are also often used (Brain, LHS figure)
• Again, with fixed fields some areas can be completely spared

Comparison of fixed field and rotation therapy

• Coplanar arcs: gantry/collimator rotations, couch does not move
• Non-coplanar approach involves addition of fixed angle couch rotations for each arc with intensity modulation optimization
• In "4π" approach – theoretically everything is optimized, including gantry/couch/collimator angle and intensity modulation

Rotation therapy trends
A 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: \( f = \frac{\text{Energy imparted to the target volume}}{\text{Total energy imparted to patient}} \)

\[ f = 0.14 \text{ (Co-60)} \]
\[ f = 0.17 \text{ (22MeV)} \]

Example 4

- 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