The Evolution of Radiation Therapy

Intensity Modulated Radiation Therapy (IMRT) is the logical evolution of Radiation Therapy, starting from the first fractionated irradiation of patients in a conventional way, evolving into a conformal radiation therapy model, when automatic field sequencing and controlled conformal treatments were developed as a long way to achieve better QA of the radiation therapy process, and finally arriving at modulation of the beam for higher conformality. This evolution can be interpreted as the natural path from 1D treatments to a full 3D treatment process.

Conventional Radiotherapy

Based on the combination of several fields at different gantry angles, conventional treatments are still in use for several clinical applications.

- In order to achieve conformality, blocks and wedges are applied to the original fields.
- ICRU criteria are in many situations difficult to comply.
- To optimize the treatment process, MLC shaped fields were introduced and later with automatic wedges (virtual wedges).

Conformal Radiotherapy

- Not a new concept: 1950-60 Proimos and Takahashi.
- Main idea: high doses to the tumor; minimum doses to the normal tissues.
- Purpose: to conform selected isodoses around the tumor and avoid critical structures.

Intensity Modulated Radiation Therapy

- Several fields (6 - 10)
- Comparative analysis
  - DVH, max. and min. doses
  - Average doses
  - Biological effect doses
- MLC shapes, wedges
**Intensity Modulated Radiotherapy**


“Conformal radiotherapy (CRT) is based on three hypotheses:

- a higher rate of local control may improve the survival rate;
- dose escalation may increase tumor control;
- delivery of higher doses by decreasing the incidence of late effects.

These postulates are now supported by several clinical data …”

“However, there are situations for which 3D-CRT cannot produce a satisfactory treatment plan because of complex target volume shapes or the close proximity of sensitive normal tissues. This is why intensity-modulated radiation therapy (IMRT) was introduced. Its aim is to overcome the limitations of 3D-CRT by adding modulators of beam intensity to beam shaping. IMRT can achieve nearly any dose distribution …”

**Why IMRT?**

- To spare organs-at-risk
- For irregular shaped targets
- To treat multiple targets simultaneously
- To enable dose escalation
- To treat regions with prior radiation

**Economic Benefits of IMRT**

- Incremental patients from current patient base
- New clinical applications for radiotherapy
- Improved reimbursement profile
- Optimal utilization of existing equipment

**The Siemens IMRT Approach**

Improved verification, accuracy and efficiency for increased delivery safety, the Cinematic IMRT™ approach of segmental techniques is based on:

- Encrypting algorithms
- Utilization of optimization tools.

**What is Intensity Modulation?**

- Intentionally non-uniform fluence distribution.
- Defines patient result, not method of delivery.
- IMRT is 3-D treatment delivery of a 3-D plan by modifying the intensity across each beam in complex ways.
- Methods: compensators, wedges, dynamic, static, cinematic

**IMRT: Intensity Modulation of the Beam**

In the interior of the shaped field, the doses are homogeneous.
Qualitatively conforms to the shape of the target and minimizes dose to critical structures through selection of beam directions and beam shapes.

In the interior of the shaped field, the doses are heterogeneous, for dose modulation.
Produces dose distributions that conform tightly to the 3D shape of the target by varying the beam intensity across the shaped fields.

**Figure 4 - Conformal vs. Conventional: better isodose conformity, less dose to the normal tissues.**

**Figure 5 - IMRT: sculpt the doses (isodoses) to the tumor, avoiding the surrounding healthy tissues.**

**Figure 6 - IMRT, a higher level of modulation**
What is an Intensity Map?

An intensity map is a matrix of pencil beams with different weights and different intensity levels (relative units). It reflects the sculpted desired dose for each field and their combination. The initial continuous map is transformed into segments with different intensity levels. That is the basis of MLC segments.

Fluence or Intensity Modulation?

"Strictly speaking, it is the fluence distribution that is modulated by the motion of jaws and leaves, but the term ‘intensity modulation’ has appeared in the literature ..."

(Medical Physics 21 (7) May 1996)

Why do it?

IMRT creates superior dose volume histograms compared to conventional RT. At the DVH, the separation between target dose and Organ at Risk (OAR) doses is greater. In theory, that allows for dose escalation to the target, if necessary.

- The concept of conformal avoidance takes place.

IMRT: modalities

By planning:
- Forward planned IMRT
- Aperture based IMRT
- Inverse planned IMRT
- Monte Carlo based IMRT

By delivery systems:
- Multileaf Collimators MLC
- Micro-, Mini-, Virtual-Micro MLC
- Tomotherapy devices

By treatment techniques:
- Segmented sequential (step and shoot)
- Cinematic sequential (Cinematic IMRT)
- Dynamic sequential (sliding window)
- Intensity Modulated Arc Therapy (IMAT)
- Tomotherapy

General Definitions

Static IMRT
- Nothing moves when the beam is on
- Fields with segmentation
- Also known as ‘step and shoot’ method

Dynamic IMRT
- Leaves (modifiers) move when the beam is on
- Fields with segmentation plus contribution of the doses between segments
- Sliding window
- Arc-therapy with IMRT