Megavoltage Images in Radiation Therapy

Hamid R. Tizhoosh
Systems Design Engineering
PAMI :: MIAMI :: WIHIR
→ Cancer Statistics

→ Radiation Therapy

→ Patient Setup Verification

→ Megavoltage Images (Portal Images)
Canada 2004:

145,500 new cases of cancer

68,300 Canadians will die

2,798 Canadians diagnosed with cancer every week

1,313 Canadians will die of cancer every week

Source: Canadian Cancer Society
38% of women and
43% of men
will develop cancer during their lifetimes.

Source: Canadian Cancer Society
Cancer Treatment

Surgery
Chemotherapy
Hormone Therapy
Immunotherapy (Biological Therapy)
Stem Cell Transplantation
Radiation Therapy
The use of high-energy penetrating rays or subatomic particles to destroy the tumor.

Goal: Killing cancerous cells by delivering a high dose of radiation to the tumor while preserving/sparing healthy tissues.
Internal Radiotherapy
(Brachytherapy)

Implanting radioactive material (seed) directly into the tumor or close to it.

Source: Proxima Therapeutics
External Radiotherapy

Delivering a beam of high-energy x-rays to the tumor. The beam is generated outside the patient by a linear accelerator (LINAC).

Source: Varian
A machine that creates high-energy radiation to treat cancer, using electricity to form a stream of fast-moving subatomic particles.

Also called megavoltage linear accelerator or a LINAC.
LINAC accelerates electrons in a part of the accelerator (wave guide) and then allows these electrons to collide with a heavy metal target.

As a result, high energy x-rays are scattered from the target. A portion of these x-rays is collected and then shaped to form a **beam**.

The beam comes out of a part of the accelerator called a **gantry**, which rotates around the patient.
The Port

Port (also treatment field)

The area of the body through which external beam radiation is directed to reach a tumour.
Conformal Radiation Therapy

Radiation that is shaped, or "conformed“, to the shape of a tumour in all three dimensions.

Accurate shaping of the beam: deliver radiation to the tumour, not to surrounding healthy tissue.
Ionizing Radiation

Radiation of sufficient energy to displace electrons from the atoms of cells and produce ions.

Ionized cells are damaged and will die.

Healthy (normal) cells are able to repair themselves; cancerous cells are not.
Intensity-Modulated Radiation Therapy

→ High-precision radiotherapy

→ Computer-controlled x-ray accelerators

→ Radiation dose conforms to the 3-D shape of the tumor by modulating the intensity of the radiation beam (higher radiation dose to the tumor and minimum radiation exposure of healthy tissues)
1) **Simulation** (x-ray images, CT, MRI)
Determining the treatment area, measuring the patient’s body, individual set-up

2) **Treatment Planning**
Software + expert knowledge:
- numbers of radiation beams at different angles,
- different beam shapes,
- beam weightings,
- beam energies,
- ...
4) Treatment
Aligning the patient on the treatment table (under LINAC)
Immobilizing the patient
Using positioning lasers/field light to accurately set-up the patient in the correct position
Treatment Duration: 4-6 weeks (fractions of 15-30 minutes)
Plastic Mesh (hard plastic that when wet, it conforms to the contour of the treated area. It will dry very quickly.)

Foam Cradles (for chest, abdomen and pelvis areas)

Breast Arm Board (for the breast and chestwall areas)
The Dilemma of Patient Set-Up

In spite of immobilization

*patients move!*

→ External motion

→ Internal (organ) motion

Set-up verification necessary!
Effect of Motion

Healthy tissue
tumor
Healthy tissue

Effect of Motion

tumor
1) load a film into a film/screen cassette
2) carry the cassette to the examination room
3) insert the cassette into the x-ray table
4) position the patient
5) make the x-ray exposure
6) carry the cassette back to develop the film
7) check the processed film for any obvious problems
   → takes several minutes: the patient remains immobilized
   → increased chance of localization error (up to 5mm)
Film versus EPI

**Conventional x-ray**
- Low energy
- High contrast

**Portal imaging**
- High energy
- Low contrast
EPIs or Megavoltage Images
 Enhancement of MVIs
Enhancement of MVIs
Electronic Portal Imaging

- Fast image acquisition/processing
- Lower dose required
- Less localization error
### Film versus MVI

<table>
<thead>
<tr>
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<th>Film</th>
<th>MVI</th>
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<tbody>
<tr>
<td>Speed</td>
<td>- -</td>
<td>++</td>
</tr>
<tr>
<td>Information content</td>
<td>++</td>
<td>+(+)</td>
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<tr>
<td>Practicality</td>
<td>+</td>
<td>++</td>
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<tr>
<td>Online</td>
<td>- -</td>
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<tr>
<td>Complexity</td>
<td>++</td>
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LIC Technology

Liquid-filled Ionization Chamber

Matrix 256×256
Pixel size 1.2 mm
Field size 32 × 32 cm²
Amorphous Silicon Technology

- Metal plate
- phosphor
- a-Si
- Glass substrate
- TFT
- X-ray converter
- X-ray
- electrons
In clinical use since spring 2000

Good image quality
(high contrast/spatial resolution, large SNR)

Higher speed (7 Frames/sec)

No geometrical distortions

Quasi-linear dose response

Disadvantage: cost & „dead pixels“
Electronic Portal Imaging Devices

Siemens

Varian

Theraview  
(Elekta LINAC)
EPIDs: Phantom Images

a-Si

LIC
EPIDs: LIC versus a-Si
EPI-Based Online Verification

LINAC

adjustment

EPIID

Online EPI

Verification

Offline images