The Modern Technology of Radiation Oncology

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26 October 2017
Disclosures

• License agreement with Modus Medical Devices, London, Canada
  – QUASAR™ QA devices

• Author/Editor of 3 Volumes on *The Modern Technology of Radiation Oncology*
  – Medical Physics Publishing

~2100 pages!
In 15 minutes?
Description, acceptance, commissioning & QC
Objective

- To provide an overview of the technology of radiation oncology for non-experts in radiation oncology
Road Map

• Brief history
• Radiation therapy linacs
• Radiation treatment process
• Practical considerations
• Trends in Radiation Oncology
<table>
<thead>
<tr>
<th>Phase</th>
<th>Time</th>
<th>Technology</th>
<th>Issues/Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1895-1940s</td>
<td>100-400 kV x-rays</td>
<td>Non-uniform dose at depth, high skin dose, high bone dose</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brachytherapy</td>
<td>Radium/radon, calculation systems</td>
</tr>
<tr>
<td>2</td>
<td>1950s</td>
<td>Cobalt-60</td>
<td>Skin sparing, uniform dose at depth, manual treatment planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-8 MeV linacs</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>≥20 MeV betatrons</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1960s-70s</td>
<td>Multi-modality linacs</td>
<td>Rotational machines, more physicists, detailed QA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tr Planning Systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simulators</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1970s-80s</td>
<td>CT, 3D-CRT, LDR/HDR brachy afterloading</td>
<td>Improved targeting, improved dose computations</td>
</tr>
<tr>
<td>5</td>
<td>1990s-now</td>
<td>MLC, IMRT, IGRT, ART, 4-D, US, PET/CT, SPECT, MRI/MRS</td>
<td>In-room imaging, dose escalation, arc therapy, gating, smaller margins</td>
</tr>
</tbody>
</table>
Evolution of Radiation Therapy

Time

Fixed SSD RT
Isocentric RT
Conformal RT
IMRT
IGRT
Adaptive RT

Tumour Margin Size

Better set-up
Better targeting
Better dose control
Less patient variability

Computer planning
3D planning
Inverse planning
4D planning
RT...The Past to the Present

1950s ...

Megavoltage Isocentric

Blocks Wedges Comps

2000s

IGRT, 4D

MLC Dynamic treatments

Lichter, Fraass, McShan 1988
JVD in Geneva 1974-75

- Centre de Radiothérapie de Génève, l’Hôpital Cantonal de Génève
  - Siemens betatron donated to CERN
    - For bubble chamber experiments
  - Installed Varian Clinac-18 ... first in Europe
    - 10 MV photons; 6, 9, 12, 15, & 18 MeV electrons
    - No portal imaging
      - Port films
    - CERN scientist performed neutron measurements with various detectors
Technologies on Linacs

• Electronic portal imaging … MV … 1980s
• Multi-leaf collimator … 1990s
  – IMRT
• Cone-beam CT … kV or MV … 2000s
  – IGRT
• Digital/solid state controls
  – Improved stability
  – “Golden” data sets
    • 2000s
Daily Treatment Set-up

- Image-guided radiation therapy (IGRT)

Meyer et al, Front RT & Oncol. 40:10; 2007
Linac with IMRT & IGRT … today

- Accelerator
- MLC
- Flat panel kV x-ray detector for CBCT
- Flat panel MV x-ray detector
- Electronic Portal Imaging Device (EPID)
- Cone-Beam CT (CBCT)
TomoTherapy … 2003

- One of 1\textsuperscript{st} 3 prototypes in London, Canada
- On-board CT guidance
- Helical imaging … fan beam … MV CT
- Helical delivery … fan beam … Binary MLC
Tomotherapy MV CT Image Guidance

Manual alignment or grey scale alignment with mutual information algorithm
HT Simulation: Head and Neck

Dose Rate

Total Dose

0 to 30%  30 to 90%  90 to 100%
Varian Halcyon ... 2017

Courtesy Paritosh Ambekar, Varian
## TECHNICAL SYSTEM OVERVIEW

<table>
<thead>
<tr>
<th><strong>GANTRY</strong></th>
<th>100 cm bore, linear-drive ring motor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STAND</strong></td>
<td>Small footprint, no modulator cabinet, beam stopper</td>
</tr>
<tr>
<td><strong>BEAM</strong></td>
<td>6 FFF @ 800 cGy/min Cone beam ... Max field size: 28 cm x 28 cm</td>
</tr>
<tr>
<td><strong>COLLIMATION</strong></td>
<td>New, patented dual-layer MLC</td>
</tr>
<tr>
<td><strong>IMAGING</strong></td>
<td>100% IGRT, ~15 second MV CBCT Optional kV CBCT</td>
</tr>
<tr>
<td><strong>CONSOLE &amp; CONTROL SYSTEM</strong></td>
<td>Shared with TrueBeam™</td>
</tr>
</tbody>
</table>

Courtesy Paritosh Ambekar, Varian
# Power Specifications

## Table 9: Supported Power Configuration Specifications

<table>
<thead>
<tr>
<th>Specifications</th>
<th>380 V: 50/60 HZ² Or 400–480 V: 50/60 HZ</th>
<th>18 kVA² Or 15 kVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage for 3 Phase AC Power¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Power¹</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Configuration depends on the country of use.

² Requires a transformer that will be included with the system.
Varian Halcyon ... 2017

Day 1 - August 12, 2017
Varian Halcyon ... 2017

SMALL FOOTPRINT

Isocentre height
110 cm

Bolted to floor, Pit dimensions
5’6” x 2’4.25” x 12” (W x L x D)
4D-CT based IGRT

Courtesy Stewart Gaede
Stages in Radiation Treatment Process

- Patient Assessment
- Decision to Treat
- Prescribing Treatment
- Positioning & Immobilization
- Patient Imaging
- Volume Determination
- Treatment Planning
- Data Transfer
- Patient Set-up
- Treatment Set-up Verification
- Treatment Delivery

x N fractions
Radiation Therapy Equipment

• Not only ‘treatment’ equipment, e.g., linacs
• Diagnostic equipment
• Patient immobilization
• CT-simulator
• Treatment planning system
• In-treatment room verification or image-guidance equipment
• Dosimetry and QA equipment
Cost Drivers

• Facilities

• Equipment

• Personnel
Relative Component Costs

Atun et al, Lancet Oncol 16: 1153-86; 2015
Trends Related to Technology Evolution

• Computer technology continues to evolve (>exponentially)
  – Daily imaging, real time optimization/adaptation, Monte Carlo dose calculations
  – More automated patient set-up/robotics
  – “Turnkey” installations
  – More hybrid, e.g., Linac + MR
  – Robust optimization accounting for uncertainties
  – More efficient commissioning & automated QC
  – More automated treatment planning
• Resource considerations and cost-benefit analysis
• Increased regulatory oversight … error reporting
• Increased use of radiobiological models
• Increased use of particle beams
• More hypofractionation (higher doses/fraction)