Treatment Advances in Treatment Delivery
Radiation Oncology

DEPARTMENTS OF
RADIATION ONCOLOGY & MEDICAL PHYSICS
Tata Memorial Hospital, Mumbai, India

Varanasi, ICRO April, 2011
Cancer Incidence 2002-2050

Asia

Europe & N. America

2050
2020
2002

Varanasi, ICRO April, 2011
Globocan 2010
Team Work
Team work for optimal management

- Oncologist: Radiation, Surgical & Medical
- Medical Physicist
- Radiotherapy Technologists
- Nursing staff
- Dental Surgeon/ Anesthesiologist
- Nutritionist
- Medical Social Workers
- Occupational/ Speech therapist
Teletherapy

Varanasi, ICRO April, 2011
Steps in Radiation Therapy

Reference imaging
Tumor delineation
Tx planning
dose calculation
Tx delivery
verification
Outcome analysis

Varanasi, ICRO April, 2011
Conventional Physical Simulation

- Ability to simulate treatment machine mechanically
- High-definition real-time fluoroscopic images
Physical simulator in plan implementation and verification

- Implementation and verification of TPS Plan isocenter on patient
- Verification of treatment port
Conventional Radiotherapy
Tumor Shape? Normal organ

Varanasi, ICRO April, 2011
DMLC (Dynamic Multileaf Collimator)  
A multileaf collimator with computer-controlled leaves that move during radiation delivery to produce intensity modulated fields.
CT Simulators

Widely available
CT scans for treatment planning
Patient localization lasers in room
Operated by RT personnel
Flat couch
Virtual simulation software.
Physical Simulation

- 4/2 sections are acquired Separately & Quard merge using separate software
- MLCs are overlay on a vision workstation

Virtual Simulator

- 5-8 mm CT slices
- MLCs shaping on DRR

- Need of separate software
- Time consuming
Multileaf collimators (MLC)
3D tumour volume based planning

Field shaping based on 3D shape of PTV & OAR

Ca. Prostate

30 April, 2011
Stereotactic radiosurgery

Stereos - solid

- Gamma knife
- Modified Linacs
- Proton beam

Firm immobilisation (stereotactic frames)
Treatment planning (dedicated workstations)
Precise treatment delivery (high QA)

Varanasi, ICRO April, 2011
GAMMA KNIFE

No. Sources - 201
Each Source - 30 Ci
Total ~ 6000 Ci activity

Each Source:
- Length - 2 cm
- Diameter - 1 mm
- 12-13 pellets in each source

Varanasi, ICRO April, 2011
LA based Radiosurgery

Lutz IJROBP 1988; 14: 373-81
3D CRT

Uniform Beam Intensity

☐ Large body of evidence including prospective and randomised data in various sites
☐ reduction of side effects
☐ possible dose escalation

Varanasi, ICRO April, 2011
Virtual Simulation
(Use CT image set to choose ‘good’ beam directions)

3D Dose calculation/display

3DCRT
• Revolutionary concept
• Change the MLC leaves to create desired intensities
CRT

Uniform intensity

Varanasi, ICRO April, 2011
IMRT

Beamlets

VOXELS
Volume delineation

critical step
Inverse planning
Dose constraints

- Clinical data for all organs not available, a bit arbitrary
- Experience is needed to determine which constraints are more important
Treatment Planning and delivery
Daily verification

Electronic Portal Imaging Device (EPID)

Cone CT

Varanasi, ICRO April, 2011
IMRT for Head and neck cancers

a lot of potential; very exciting

Characteristics
- Sparing of spinal cord
- Sparing of parotid gland
- Dose escalation possible

Varanasi, ICRO April, 2011
PET used in cancers of lung, head & neck, cervix, brain

Biological target Volume (BTV)

Varanasi, ICRO April, 2011
Phase III randomised trial

Randomised trial of standard 2D radiotherapy (RT) versus intensity modulated radiotherapy (IMRT) in patients prescribed breast radiotherapy

Ellen Donovan¹, Natalie Bleakley¹, Erica Denholm², Phil Evans¹, Lone Gothard³, Jane Hanson³, Clare Peckitt², Stephanie Reise¹, Gill Ross⁴, Grace Sharp³, Richard Symonds-Tayler¹, Diana Tait³, John Yarnold³,*, on behalf of the Breast Technology Group

¹Joint Department of Physics, Royal Marsden Hospital and Institute of Cancer Research, Sutton, Surrey, UK, ²Clinical Trials & Statistics Unit (ICR-CTSU), Institute of Cancer Research, Sutton, Surrey, UK, ³Department of Radiotherapy, Royal Marsden Hospital, Sutton, Surrey, UK, ⁴Department of Radiotherapy, Royal Marsden Hospital, Chelsea, London, UK
DO ALL PATIENTS OF BREAST CARCINOMA NEED 3-DIMENSIONAL CT-BASED PLANNING? A DOSIMETRIC STUDY COMPARING DIFFERENT BREAST SIZES

ANUSHEEL MUNSHI, M.D., D.N.B., RAJESHRHI H. PAI, M.SC., D.R.P., 
REENA PHURAILATPAM, M.SC., D.R.P., ASHWINI BUDRUKKAR, M.D., D.N.B., 
RAKESH JALALI, M.D., RAJIV SARIN, M.D., F.R.C.R., D.D. DESHPANDE, M.SC., 
SHYAM K. SHRIVASTAVA, M.D., D.N.B., and KETAYUN A. DINSHAW, F.R.C.R. 
Department of Radiation Oncology, Tata Memorial Hospital, Parel, Mumbai, Maharashtra, India

<table>
<thead>
<tr>
<th>Breast Size</th>
<th>Superior slice</th>
<th>Inferior slice</th>
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</thead>
<tbody>
<tr>
<td>Large Breast</td>
<td>9%</td>
<td>15%</td>
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<tr>
<td>Medium Breast</td>
<td>8%</td>
<td>8%</td>
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<tr>
<td>Small Breast</td>
<td>5%</td>
<td>5%</td>
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</table>

Varanasi, ICRO April, 2011
Potential of IGRT

Removal of motion encompassing margins may reduce normal tissue dose

Reduction in normal tissue dose may facilitate tumour dose escalation

Higher doses delivered to the tumour could result in an improved cure rate

Varanasi, ICRO April, 2011
Deep Inspiration Breath Hold

Real-time Position Management (RPM) Respiratory Gating System

Components:
- Infrared illuminator / CCD camera
- Reflective external markers placed on abdomen or chest
- Workstation to process signals & generate trigger (CT) or gate beam (linac)
Modern radiotherapy techniques are dependent upon imaging for planning and verification

High Precision techniques (3D CRT, SRS/SRT, IMRT) depend upon imaging (CT, MRI, PET etc) for accurate tumour and critical structure delineation on the planning computer

A margin is given around the gross tumour to account for imaging uncertainties/ microscopic extensions (CTV)

A margin is also given for daily inaccuracies during 6-7 weeks of daily radiotherapy (PTV)

Both margins can be potentially reduced to improve dose conformality and reduce doses to critical structures and possibly dose escalation
Tomotherapy
72yrs/M/Recurrent GBM
Proton Therapy

Varanasi, ICRU April, 2011
Cost of radiation therapy

Cost of Radiation Therapy per patient = 97.702 x Years - 191843

R² = 0.5902

Year of publication


Varanasi, ICRO April, 2011

Ploquin et al, Radiotherapy and Oncology 2008
Continuous, hyperfractionated, accelerated radiotherapy (CHART) versus conventional radiotherapy in non-small cell lung cancer: mature data from the randomised multicentre trial

Michele Saunders, Stanley Dische, Ann Barrett, Angela Harvey, Gareth Griffiths, Mahesh Parmar (on behalf of the CHART Steering committee)

Marie Curie Research Wing, Mount Vernon Hospital, Northwood, Middlesex, UK
Beatson Oncology Centre, Western Infirmary, Glasgow, UK
Medical Research Council Cancer Trials Office, Cambridge, UK

WHO performance status of 0 or 1
Pathologically proven, inoperable NSCLC,
First Phase: Tumour, mediastinum, ipsilateral hilar, paratracheal nodes with a 1 cm margin.
Second phase, primary tumour and known nodal involvement with a 1 cm margin

Varanasi, ICRO April, 2011
## CHART Results (Absolute %)

<table>
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<tr>
<th>Endpoints</th>
<th>2-Year</th>
<th></th>
<th>3-Year</th>
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<tr>
<td></td>
<td></td>
<td>Conventional (%)</td>
<td>CHART</td>
<td>Difference</td>
<td>95% C.I.</td>
<td>Conventional</td>
<td>CHART</td>
<td>Difference</td>
<td>95% C.I.</td>
<td>Hazard ratio</td>
<td>95% C.I.</td>
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<td>All patients</td>
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<td>Survival</td>
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<td>21</td>
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<td>9</td>
<td>2, 16</td>
<td>13</td>
<td>20</td>
<td>7</td>
<td>2, 13</td>
<td>0.78</td>
<td>0.65-0.94</td>
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<td>Local tumour control</td>
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<td>16</td>
<td>23</td>
<td>7</td>
<td>1, 15</td>
<td>12</td>
<td>17</td>
<td>5</td>
<td>1, 14</td>
<td>0.86</td>
<td>0.70-1.06</td>
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<td>Disease-free interval</td>
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<td>13</td>
<td>18</td>
<td>5</td>
<td>-2, 11</td>
<td>9</td>
<td>12</td>
<td>3</td>
<td>-1, 10</td>
<td>0.79</td>
<td>0.63-0.98</td>
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<tr>
<td>Metastasis-free interval</td>
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<td>44</td>
<td>48</td>
<td>4</td>
<td>-5, 13</td>
<td>33</td>
<td>40</td>
<td>7</td>
<td>-4, 14</td>
<td>0.89</td>
<td>0.69-1.14</td>
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<td>Squamous only</td>
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<td>Survival</td>
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<td>33</td>
<td>13</td>
<td>5, 20</td>
<td>11</td>
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<td>10</td>
<td>4, 17</td>
<td>0.70</td>
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<td>17</td>
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<td>2, 16</td>
<td>0.73</td>
<td>0.57-0.93</td>
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<td>52</td>
<td>10</td>
<td>1, 20</td>
<td>31</td>
<td>43</td>
<td>11</td>
<td>1, 21</td>
<td>0.75</td>
<td>0.56-0.99</td>
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<td>Non-squamous only</td>
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</tr>
<tr>
<td>Survival</td>
<td></td>
<td>27</td>
<td>21</td>
<td>-6</td>
<td>-18, 8</td>
<td>21</td>
<td>15</td>
<td>-6</td>
<td>-15, 8</td>
<td>1.22</td>
<td>0.80-1.85</td>
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</tr>
<tr>
<td>Local tumour control</td>
<td></td>
<td>25</td>
<td>22</td>
<td>-3</td>
<td>-17, 14</td>
<td>19</td>
<td>11</td>
<td>-8</td>
<td>-16, 6</td>
<td>1.12</td>
<td>0.67-1.87</td>
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<tr>
<td>Disease-free interval</td>
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<td>23</td>
<td>14</td>
<td>-9</td>
<td>-19, 6</td>
<td>21</td>
<td>17</td>
<td>-4</td>
<td>-15, 14</td>
<td>1.36</td>
<td>0.84-2.18</td>
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<tr>
<td>Metastasis-free interval</td>
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<td>57</td>
<td>40</td>
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<td>-36, 2</td>
<td>42</td>
<td>24</td>
<td>-18</td>
<td>-32, 2</td>
<td>1.62</td>
<td>0.95-2.75</td>
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</tr>
</tbody>
</table>

Varanasi, ICRO April, 2011
Quality research for optimal resource utilisation

Five versus six fractions of radiotherapy per week for squamous-cell carcinoma of the head and neck (IAEA-ACC study): a randomised, multicentre trial

Jens Overgaard, Bidhu Kaylan Mohanty, Naseem Begum, Rubina Ali, Jai Prakash Agarwal, Maire Kuddu, Suman Bhasker, Hideo Tatsuzaki, Cai Grau

Lancet Oncology 2010

Figure 2: Locoregional tumour control

<table>
<thead>
<tr>
<th>Recruiting centre</th>
<th>Five fractions per week (N=448)</th>
<th>Six fractions per week (N=452)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Delhi</td>
<td>126 (28%)</td>
<td>128 (28%)</td>
</tr>
<tr>
<td>Peshawar</td>
<td>104 (23%)</td>
<td>105 (23%)</td>
</tr>
<tr>
<td>Islamabad</td>
<td>70 (16%)</td>
<td>69 (15%)</td>
</tr>
<tr>
<td>Mumbai</td>
<td>64 (14%)</td>
<td>63 (14%)</td>
</tr>
<tr>
<td>Tallinn</td>
<td>53 (12%)</td>
<td>53 (12%)</td>
</tr>
<tr>
<td>Santiago</td>
<td>14 (3%)</td>
<td>12 (3%)</td>
</tr>
<tr>
<td>Riyadh</td>
<td>9 (2%)</td>
<td>10 (2%)</td>
</tr>
<tr>
<td>Cape Town</td>
<td>6 (1%)</td>
<td>10 (2%)</td>
</tr>
<tr>
<td>Bajinut</td>
<td>2 (1%)</td>
<td>2 (1%)</td>
</tr>
</tbody>
</table>

Varanasi, ICRO April, 2011
Radiation Therapy Units: Expansion

![Graph showing the expansion of radiation therapy units from 1980 to 2010.](image)

- Co-60
- LA
- Brachy. (R)

May 05
Varanasi, ICRO April, 2011
Accelerators in India 164: December 2010

Varian

Elekta

Siemens
Fluence transfer for milling

Lesser MUs with compensator based IMRT
A commercial telecobalt adapted for prototype Co-60 tomotherapy

Varanasi, ICRO April, 2011
Impact

- Dosimetric precision - <2%
- Precision in target volume definition: Obstacle
- Functional Imaging:
  - Clinical Target volume – Real Target volume
- Cost benefit
  - Hypo-fractionation (Breast, Prostate...)
- Evidence Based Radiotherapy
  ......Long way to go......
It's Monday, go to work!