Helical Tomotherapy

Departments of Radiation Oncology & Medical Physics
Tata Memorial Centre (TMH & ACTREC), Mumbai

radonco@tmc.gov.in
http://tmc.gov.in
Changing Technology Impacts Every Sphere of Life
Radiotherapy: The Technology Conundrum

- 3D CRT
- SRS/SRT
- IMRT/IMRS
- IGRT
- CART
- Proton Beam RT
- Robotic RT
- BIO-ART
3-D CRT

Uniform intensity

IMRT

Non-uniform intensity
IMRT strategy

Relatively simple to understand, quite complex to implement
IMRT Using Conventional MLC’s

Varian → Siemens→ Elekta
Limitations of conventional LA based IMRT

• Limitations of field size & MLC overtravel restricts magnafield IMRT

• Feathering & abutment dosimetry uncertain; prone to error

• Consists of small MUs & small segments; poor linearity

• Non-coplanar fields - range of possible beam angles is circumscribed by the need to avoid collision of LA head and treatment couch

• Uncertainty of tumor or OAR geometry at each treatment fraction - average positioning based on anatomy at time of planning image acquisition
TomoTherapy: Is it REALLY new?

Serial Tomotherapy was delivered using number of discrete arcs or indexed arcs of finite width between which treatment couch was moved longitudinally. NOMOS introduced the PEACOCK system with intensity modulation provided by Multileaf Intensity Modulating Collimator (MIMiC)
TOMO is the Buzzword in Imaging Technology

Computed TOMOgraphy

Helical TOMOtherapy

SPECT TOMOgraphy

Positron TOMOgraphy

MR TOMOgraphy

All these revolutionary technologies are based on ring gantry design
Helical TomoTherapy: Revolutionary Novel Technology

- MLC leaves that move at 250 cm/s to open or shut in milliseconds
- Thousands of beamlets throughout multiple 360 degree rotations
- Coverage of a target extent up to 160 cm in length with no matching
What is Helical TomoTherapy?

- TomoTherapy literally means “Slice Therapy”
- It is derived from the word ‘Tomography’
- Helical Tomotherapy is the delivery of IMRT using helical rotational delivery in the manner of a CT scanner
- A modified Linac fitted into CT ring gantry configuration for therapeutic radiation using rotating fan beam modulated by multileaf collimators
- System uses tomographic imaging for treatment verification and tomographic reconstruction for optimal treatment
Helical TomoTherapy Features

- Up to 850 cGy/min @ axis
- 85 cm diameter gantry bore
- 64 pair of MLCs with 6.25 mm resolution @ axis
- 40 cm x 160 cm maximum field @ axis
- Slice field width from 5 mm to 40 mm @ axis
- Minimum beamlet size 5 mm x 6.25 mm @ axis
- Xenon CT detectors with per pulse acquisition
- 0.25 mm precision CT couch
- Leaves 10 cm thick, 95% tungsten alloy
- Primary collimator 22 cm thick 95% tungsten alloy
What’s different about Helical TomoTherapy

- No flattening filter (inherently modulated beam)
- No machine isocentre
- No accessories (wedges, blocks, compensators)
- No field sizes or equivalent squares
- No electrons (nor high energy photons)
- No junctions (forget abutment dosimetry)
- No couch, collimator, gantry angles
Helical TomoTherapy Processes

- Imaging / Contouring
- Planning / Optimizing
- In-room megavoltage CT imaging
- Image Registration (IGRT)
- Treatment delivery
- Adaptive Radiotherapy
  - Dose Guidance (Recalculation / Reconstruction)
  - Dose Modification
Why Image Guidance?

“If you can’t see it, you can’t hit it.
If you can’t hit it, you can’t cure it”

H.E. Johns or W. Powers
Helical TomoTherapy

☼ Is it the ultimate form of photon teletherapy

☼ What are its current clinical applications

☼ What is its future potential
How small can TOMO treat?

1 cc PTV

0.6 cc PTV

$\frac{V_{\text{presc}}}{V_{\text{PTV}}}$

19-24 Gy PTV dose

CI = 1.10

20 Gy prescription dose

19.5-23 Gy PTV dose

CI = 1.14

Still very good!
How long/large can TOMO treat?

- **6500 cc**
- **5000 cc**
- **2500 cc**
Single fraction Radiosurgery

Image-guided setup with MVCT

Delivery time:
16 minutes for 15 Gy

Ave. dose gradient:
11% per mm
(100%-50% in 4.5 mm)
Balance of size and complexity for precision radiotherapy

- Helical Tomotherapy
- Conventional MLC
- Intensity-Modulated Protons
- Robotic Therapy
- Mini-MLC
- Stereotactic Radiosurgery

Circular to Highly Irregular Complexity

- 1m
- 10 cm
- 1 cm
Current Clinical Applications of Helical TomoTherapy

- Whole Bone
- Mantle
- Head and Neck
- Lung
- Prostate
- Stereotactic Radiotherapy

Circular Complexity Highly Irregular
Arc SRS/SRT vs. Conventional IMRT vs. Helical TomoTherapy vs. CyberKnife vs. IM Arcs (AMOA)

TomoTherapy provides best overall indices:

Target coverage, Conformity index, and OAR sparing
Exciting Clinical Applications

**Magnafield radiotherapy – Large Field IMRT**
- Total Marrow Irradiation (TMI) & Total Lymphoid Irradiation (TLI)
- Whole Abdominopelvic Radiotherapy (WAR)
- Craniospinal Irradiation (CSI)
- Mantle, Mini-Mantle, Extended Mantle field
- Inverted-Y, Spade field

**Simultaneous targeting of multiple lesions**
- Synchronous double primaries
- Multiple metastases closely or far apart
- Primary plus metastatic lesions

**Conformal avoidance**
- Whole Brain sparing scalp radiotherapy
- Scalp sparing Whole brain radiation therapy (WBRT)
- Hippocampal & neural stem cell sparing WBRT
- Cardiac sparing mediastinal radiotherapy
Newer Perspectives & Future Potential

• Planned ADAPTIVE: Dose-Guided Radiation Therapy (DGRT)

• Deformation mapping-modeling and Adaptive Radiotherapy (ART)

• Scan, Plan, Treat (SPT): Quick-fix solution for palliative treatments

• TopoTherapy (Static gantry for breast treatments)

• Intensity Modulated Helical Proton Therapy (IMHPT)
Nearly doubles the incidence of second cancers at 10 years
EDITORIAL

OVERPRICED TECHNOLOGY IN RADIATION ONCOLOGY

EDWARD C. HALPERIN, M.D.

Departments of Radiation Oncology and Pediatrics, Duke University Medical Center, Durham, NC


ICTR 2003

Translational Research and Pre-Clinical Strategy Study

HIGH-TECH IN RADIATION ONCOLOGY: SHOULD THERE BE A CEILING?

SØREN M. BENTZEN, M.Sc., Ph.D., D.Sc.

Gray Cancer Institute and the Cancer Centre, Mount Vernon Hospital, Northwood, Middlesex, England
High-cost Technology in Radiation Oncology: A value judgment

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV</td>
<td>Kilovoltage X-rays</td>
</tr>
<tr>
<td>MV</td>
<td>Megavoltage X-rays</td>
</tr>
<tr>
<td>3D-CRT</td>
<td>3D-Conformal Radiotherapy</td>
</tr>
<tr>
<td>SiMAT</td>
<td>Simplified Intensity Modulated Arc Therapy</td>
</tr>
<tr>
<td>IMAT</td>
<td>Intensity Modulated Arc Therapy (X-rays)</td>
</tr>
<tr>
<td>IMRT</td>
<td>Intensity Modulated Radiotherapy (X-rays)</td>
</tr>
<tr>
<td>IGRT</td>
<td>Image Guided Radiotherapy (Tomo etc.)</td>
</tr>
<tr>
<td>Hi-LET</td>
<td>High LET radiation (Charged particles)</td>
</tr>
<tr>
<td>IMRT+Hi-LET</td>
<td>Combination</td>
</tr>
</tbody>
</table>
TATA MEMORIAL CENTRE

MISSION

SERVICE

EDUCATION

RESEARCH
Dosimetric validation of first helical tomotherapy Hi-Art II machine in India

Rajesh A. Kinhikar¹, Swamidas V. Jamema¹, Reenadevi³, Rajeshri Pai³, Master Zubin³, Tejpal Gupta³, Deepak S. Dhote⁴, Deepak D. Deshpande¹, Shyam K. Shrivastava¹, Rajiv Sarin³

¹Department of Medical Physics, Tata Memorial Hospital, Parel, Mumbai, ²Department of Radiation Oncology, Tata Memorial Hospital, Parel, Mumbai, ³Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Kharghar, Navi Mumbai, ⁴Brijlal Biyani Science College, Amravati, India
Indications for TomoTherapy based IG-IMRT

**Palliative intent treatment**
- To streamline workflow/process: brain, bone, liver metastases
- Multiple sites: Primary + metastases; multiple metastases
- Complex geometry: pleural mesothelioma; whole skull

**Radical intent treatment**
- Brain (low-grade/benign tumors; whole ventricular; CSI)
- Head/Neck (mucosal; sinonasal; skull base; orbital; scalp)
- Thorax (lung primary; chest wall; mediastinum; paravertebral)
- Abdomen (hepatobiliary; pancreatic; paraaortic nodes)
- Pelvis (prostate only; prostate + pelvis; bladder; cervix)
- Large-field IMRT (EFRT; WAR; CSI; TMI)
- Complex geometry (scalp/skull; WBRT + SIB mets; extended Mantle)
- Re-irradiation with curative intent
Stat-bites

Over 200 patients accrued (2008-2009 May)

- CNS: 23%
- H&N: 15%
- THORAX: 12%
- ABDOMEN: 17%
- PELVIS: 20%
- MISC: 13%

- <= 10 #: 66%
- 11-24#: 9%
- >=25#: 25%

- Adults
- Children
Esthesioneuroblastoma with local recurrence and scar implantation
Planning and Delivery of Whole Brain Radiation Therapy with Simultaneous Integrated Boost to Brain Metastases and Synchronous Limited-field Thoracic Radiotherapy Using Helical TomoTherapy: A Preliminary Experience

T. Gupta, MD, DNB1
A. Basu, MD2
Z. Master, MS1
R. Jalali, MD2
A. Munshi, MD, DNB2
R. Sarin, MD, FRCR1

Dose Volume Histogram - Cumulative Mode Relative

Dose metrics* for target volume coverage, conformity, and homogeneity.

<table>
<thead>
<tr>
<th>Volume</th>
<th>V95%</th>
<th>V99.7%</th>
<th>D1%</th>
<th>D98%</th>
<th>Dmean</th>
<th>Dmax</th>
<th>DHI</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV-WB</td>
<td>99.47%</td>
<td>3.92%</td>
<td>119.33%</td>
<td>96.58%</td>
<td>103.60</td>
<td>0.07</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(1.63)</td>
<td>(4.01)</td>
<td>(2.38)</td>
<td>(1.26)</td>
<td>(0.01)</td>
<td>(0.07)</td>
<td></td>
</tr>
<tr>
<td>PTV-BM</td>
<td>99.58%</td>
<td>0</td>
<td>104.04%</td>
<td>97.31%</td>
<td>102.06</td>
<td>0.04</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.34)</td>
<td>(0)</td>
<td>(1.48)</td>
<td>(1.16)</td>
<td>(0.67)</td>
<td>(0.02)</td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>PTV-Chest</td>
<td>99.27%</td>
<td>0.19%</td>
<td>104.56%</td>
<td>95.45%</td>
<td>102.88</td>
<td>0.03</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(0.25)</td>
<td>(1.93)</td>
<td>(3.02)</td>
<td>(1.51)</td>
<td>(0.02)</td>
<td>(0.06)</td>
<td></td>
</tr>
</tbody>
</table>

*All values expressed as mean (with standard deviation in parentheses). Dose percentages (D1%, D98%, Dmean) are with respect to prescription dose. PTV, Planning Target Volume; WB, Whole brain; BM, Brain metastases; DHI, Dose Homogeneity Index; CI, Conformity index.
Whole Abdomen Radiotherapy & Extended field Radiotherapy
CONVEXITY MENINGIOMA
WBRT & SIB-METS
Prostate plus pelvic lymph nodes irradiation
ANAL CANCER with SOLITARY LIVER METASTASIS
CAUTION: 10% isodose not all over but even outside
IMRT on TomoTherapy: Brilliant DVH
Exciting Clinical Applications

- Total Marrow Irradiation (TMI)/Total Lymphoid Irradiation (TLI)
- Cardiac-sparing mediastinal radiotherapy
- Brain-sparing holocranial radiotherapy
- Adaptive bladder radiotherapy

Achievable & Applicable
PHYSICS CONTRIBUTION

IMAGE-GUIDED TOTAL MARROW AND TOTAL LYMPHATIC IRRADIATION USING HELICAL TOMOTHERAPY

TIMOTHY E. SCHULTHEISS, Ph.D.,* JEFFREY WONG, M.D.,* AN LIU, Ph.D.,* GUSTAVO OLIVERA, Ph.D.,† AND GEORGE SOMLO, M.D.‡

Department of *Radiation Oncology and †Medical Oncology, City of Hope Cancer Center, Duarte, CA; ‡Tomotherapy, Inc., Madison, WI
Brain-sparing holocranial radiotherapy

Dose-Volume Histogram - Cumulative Mode Relative

DVH Legend
- Eye R
- Eye L
- ON R
- ON L
- Optic Chiasm
- Pituitary
- Brain Stem
- temporal R
- temporal L
- PTV
- Brain - PTV
Adaptive bladder radiotherapy
Some of the ‘dream’ applications

• Brain sparing Whole Meningeal Radiotherapy

• Marrow sparing Total Skin Irradiation

• Brachytherapy type dose distributions

_Probably utopian, may never be realized_
Is there a flip side?

- **Larger volumes of low doses** (i.e. increased whole body integral doses)
- **Higher costs and reimbursement issues**
- **Longer treatment times (reduced throughput)**
- **Environment sensitive machine (high maintenance costs)**
- **Steep learning curve (for physicians, physicists, technologists)**
- **Limited clinical outcome data (mostly dosimetric studies)**
- **Everything is IMRT (certainly not necessary for all cases)**
- **Questionable versatility as a single machine in a RT department**
What is the level of evidence for Helical TomoTherapy?

- No RCTs involving Helical Tomotherapy as yet
- No controlled comparison of LINAC based IMRT with TomoTherapy
- Limited prospective evaluation of this promising technology
- Literature largely limited to dosimetric & planning studies
- Relatively sparse clinical outcome data (gradually building up)
- Need more robust quality data & mature follow up

_No high-quality evidence yet_