In the last decade, I have become increasingly concerned with the rapid development of advanced radiotherapy treatment techniques. Unfortunately, the motivation for this expansion appears to be market driven ("Come receive treatment at OUR centre, where we offer IMRT, etc...""). This U.S.-initiated trend is now beginning to spread to Canada and Western Europe.

Can an isolated physicist at a remote clinic achieve the same confidence and expertise found at a larger institute? Are we not doing patients a disservice by employing devices and/or techniques without a total understanding of their use?

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**MedPhys ListServer Thread**

... However, after our experience with what I refer to as true IMRT (the binary operated collimator with multiple independently controlled beamlets), I must confess that our clinical results have been extremely satisfying. Four-plus years after treatment, we have many cases where there is no sign of xerostomia or tumour recurrence. The patients are happy, we are happy and their dentists are very happy. Similarly with abdominal treatments. We do not observe the typical bowel complications. Again the patients are much happier and so of course are we...

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**Jack Cunningham**

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**MedPhys ListServer Thread**

- Early Theoretical Work
  - Brahme (Radiother. Oncol. 12, 1988)

- Initial Development
  - Swerdluff, Holmes, Mackie (U Wisc)
  - Carol, Campbell, Scherch (NOMOS Corp)

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**Darrell O. Poole**

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**Overview**

- Introduction / Brief History
- Characteristics
  - Advantages / Constraints
- Implementation
  - Installation / Commissioning
  - Daily Setup / Patient QA
- Clinical Results

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**Acknowledgements**

- UCSF (Xia et al)
- NOMOS Corporation
- Washington U (Low et al)
- Tomotherapy Inc. (Rock Mackie et al)
- The Amazing The Incredible Superdog
  - Written by Crosby Bonsall
  - Published by Harper

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**Brief History**
**Brief History**

- **Initial Clinical Implementation**
  - Grant, Butler (TMH / Baylor)
  - Tsai, Curran, Wazer (NEMC / Tufts)
  - Low, Mutic, Chao (MIR / Washington U)

- **Current State**
  - ~120 Clinical Systems in Use (10,000 patients)
  - ~15 Helical Tomotherapy Systems in process

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**What is Serial Tomotherapy?**

- **Serial tomotherapy** is the delivery of multiple fan beams with discrete table increments between each axial gantry arc.

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**Intensity-Modulated Treatment**

- **Tomotherapy:** The delivery of intensity modulated rotating fan beams.
  - **Serial tomotherapy** is the delivery of multiple fan beams with discrete table increments between each axial gantry arc.
  - **Helical tomotherapy** makes use of helical CT type motions (continuous synchronized gantry and table motion).

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**Tomotherapy Delivery**

[Image: Courtesy, NOMOS Corporation]
**Tomotherapy Delivery**

*Courtesy, NOMOS Corporation*

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**Serial Tomotherapy**

*Courtesy, West Penn Hospital*

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**Why Use Tomotherapy?**

- Allows large search space of possible beamlets
  - 55/27 beam positions per 290° arc (5° or 10° steps)
  - 20 beamlets per position (1,100 beamlets/arc)
  - 11 intensity levels for each beamlet (0 – 100%)
- Large gantry angle space for finding tangents
- Efficient delivery with complex modulation
  - Modulation complexity does not affect MU

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**Clinical Comparisons – II**

- Brain tumor - GBM
  - 75 y.o. Asian female w. dizziness, weakness and gait disturbance
  - Left cerebellar mass on MRI and CT-guided biopsy
- Dose constraints:
  - 60 Gy to GTV
  - 45 Gy max to BS and optic chiasm
- Plan comparisons:
  - 3 bid non-coplanar 3D plan (Pinnacle) vs. IMRT- MIMiC (Corvus) vs.
  - 5 bid MLC-IMRT (Corvus)

*Courtesy, UCSF*

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**3D-CRT**

**IMRT-MIMiC**

**IMRT-MLC**

*Courtesy, UCSF*

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**60 Gy, 45 Gy, 30 Gy**

*Courtesy, UCSF*
**Comparison Results – II**

**Brain**

- Much reduced dose to brainstem for IMRT compared to 3D (MIMiC better than MLC-IMRT)
  - dose-limiting structure for this tumor
- IMRT plans more conformal than 3D with less dose to brain outside GTV
  - could be particularly important for pediatric patients

**Conclusions**

- In general, MIMiC Plans are more conformal than MLC-IMRT plans.
- Requirement in patient immobilization for MIMiC treatment is more stringent, especially for intra-treatment movement.
- Couch index error can produce significant dose error and rigorous QA procedure is necessary.

**Tomotherapy Delivery Example**

**Tomotherapy Constraints**

- Rotational Speed Accuracy
- MU/Degree Accuracy
- Slice Indexing Accuracy
- Whole Body Dose / Shielding
- Immobilization
- Delivery Time
Tomotherapy Constraints

- Rotational Speed Accuracy
- MU/Degree Accuracy
- Slice Indexing Accuracy
- Whole Body Dose / Shielding
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- Delivery Time

2% / 0.1mm Accuracy Requirement (Low et al)

The head and whole-body phantom used to measure the whole-body dose data

Scatter and leakage dose distribution along the gantry axis of rotation

Courtesy, Wash U. of St. Louis

Internal Scatter and Leakage
Leakage Alone
Whole-body dose equivalent (40 cm from field edge): 70 Gy target dose

- Followill et al.: 543 mSv - Three arcs, 20 X 20 cm² fixed beam data, and 3.24 MU cGy⁻¹ per arc
- Our calculation: 315 mSv - Five arcs, 10 X 10 cm² fixed beam data, and 1.8 MU cGy⁻¹ per arc
- Our measurements: 271 mSv

Conclusions (Low et al)

Estimated fatal secondary cancer (fatal leukemia) due to a 70 Gy course of radiation therapy:

- Conventional Therapy: 0.4%
- Followill et al. – Tomotherapy: 2.8%
- Measured - Tomotherapy: 1.4%

Tomotherapy Constraints

- Rotational Speed Accuracy
- MU/Degree Accuracy
- Slice Indexing Accuracy
- Whole Body Dose / Shielding
- Immobilization
- Delivery Time

Three Sets of Orthogonal Films

0 Minutes 15 Minutes later 30 Minutes later

Tomotherapy Constraints

- Rotational Speed Accuracy
- MU/Degree Accuracy
- Slice Indexing Accuracy
- Whole Body Dose / Shielding
- Immobilization
- Delivery Time
**Delivery Time Issues**

- Accurate Indexing
- Multiple Rotations / Treatment
- Dose Rate
- MU Efficiency

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**Implementation of Serial Tomotherapy**

- Currently available from a single vendor
  - NOMOS Corporation, Cranberry Township, PA

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**Installation / Commissioning**

- Mechanical Installation
  - Power & Air Cabling through gantry
  - Table indexing apparatus
  - MIMiC Alignment pins / attachment
- Commissioning
  - Alignment
  - Index determination

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*Courtesy, NOMOS Corporation*
Alignment Films

Radial Alignment Film
90 / 270 gantry angle w/ film 15cm off isocenter

Transverse Alignment Film
90 / 270 checkerboard w/ film at isocenter

Indexing Test

Serial Tomotherapy Example

Serial Tomotherapy Example
Clinical Cases

Tomotherapy MLC

Craniopharyngioma encompassing the optic chiasm

Acoustic neuroma adjacent to brain stem
Mediastinal mass with sparing of bronchus

Meningioma with sparing of optic nerve

Thank you