Intensity-Modulated Radiation Therapy Using Serial Tomotherapy

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Ann Arbor, MI

Overview

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

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

MedPhys ListServer Thread

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?

Jack Cunningham

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. . . .

Darrell O. Poole

Brief History

- Early Theoretical Work
  - Brahme (Radiother. Oncol. 12, 1988)
  - Bortfeld (Phys. Med. Biol. 35, 1990)
- Initial Development
  - Swerdloff, Holmes, Mackie (U Wisc)
  - Carol, Campbell, Scherch (NOMOS Corp)

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

What is Serial Tomotherapy?

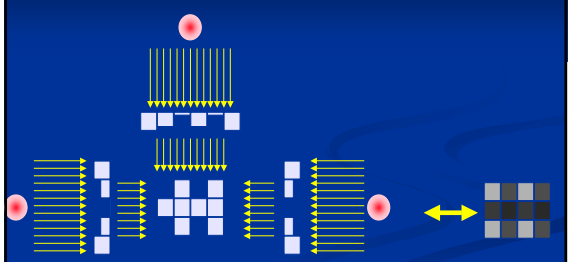
INTENSITY-MODULATED RADIOTHERAPY: CURRENT STATUS AND ISSUES OF INTEREST

Intensity Modulated Radiation Therapy Collaborative Working Group
Int. J. Radiation Oncology Biol. Phys., Vol. 51, No. 4, pp. 880–914, 2001

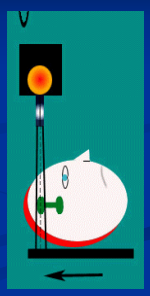
Tomotherapy: The delivery of intensity modulated rotating fan beams.

- *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).

Intensity-Modulated Treatment



Tomotherapy Delivery



Courtesy, NOMOS Corporation

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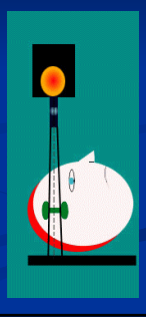

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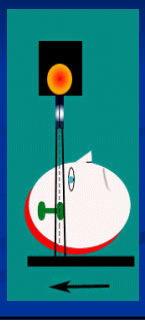


Courtesy, NOMOS Corporation

Serial Tomotherapy

Courtesy, West Penn Hospital

Why Use Tomotherapy?

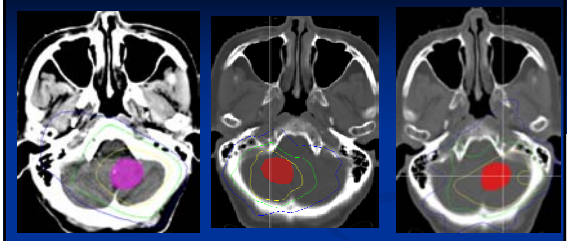
- Allows large search space of possible beamlets
  - 55/27 beam positions per 290° arc (5° or 10° steps)
  - 20 beamlets per position (1,100 beamlets/arc)
  - 11 intensity levels for each beamlet (0 – 100%)
- Large gantry angle space for finding tangents
- Efficient delivery with complex modulation
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

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 fld non-coplanar 3D plan (Pinnacle) vs.
  - IMRT- MIMiC (Corvus) vs.
  - 5 fld MLC-IMRT (Corvus)

Courtesy, UCSF

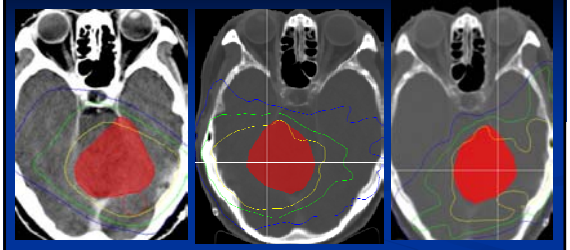
3D-CRT IMRT-MIMiC IMRT-MLC



60 Gy, 45 Gy, 30 Gy

Courtesy, UCSF

3D-CRT IMRT-MIMiC IMRT-MLC



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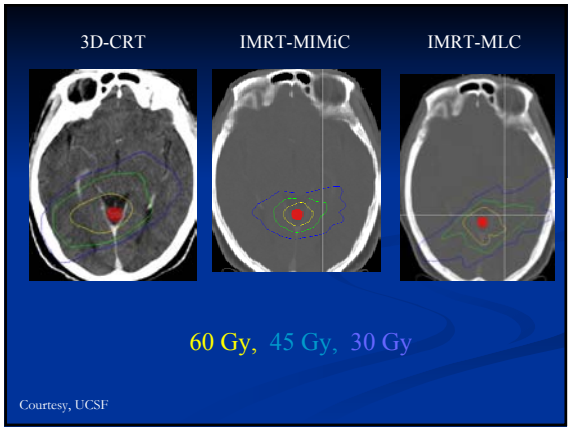
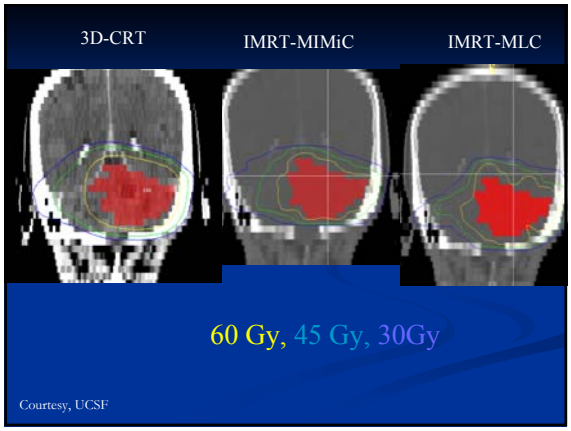
Courtesy, UCSF


3D-CRT
IMRT-MIMiC
IMRT-MLC
60 Gy, 45 Gy, 30 Gy
Courtesy, UCSF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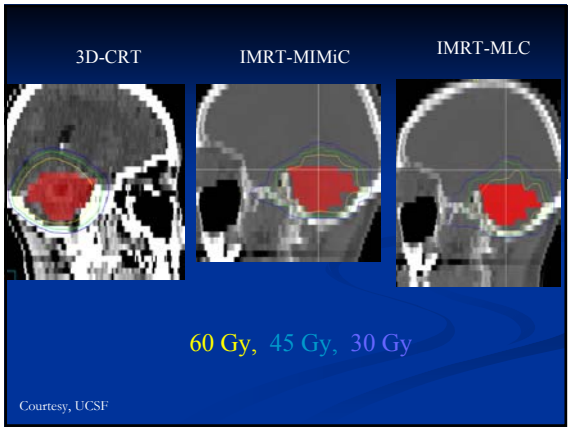
3D-CRT
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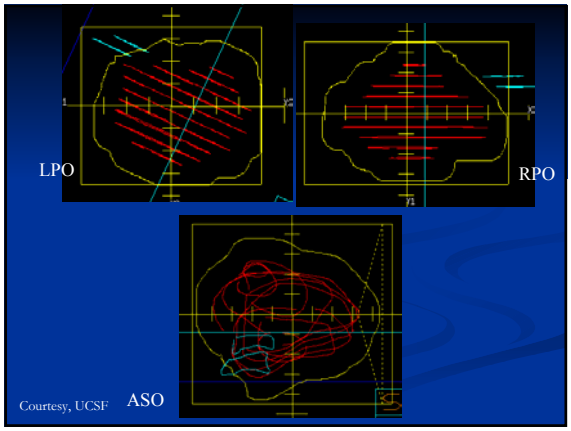
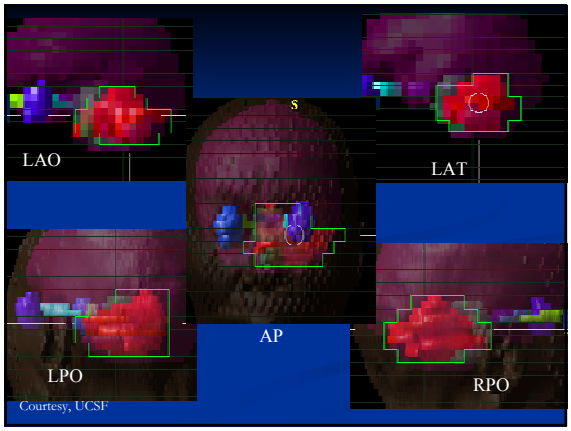
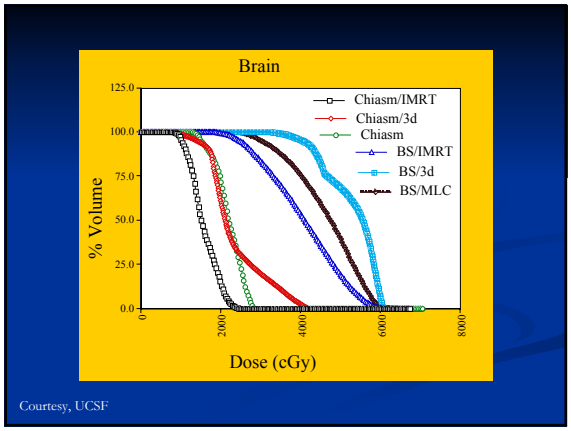
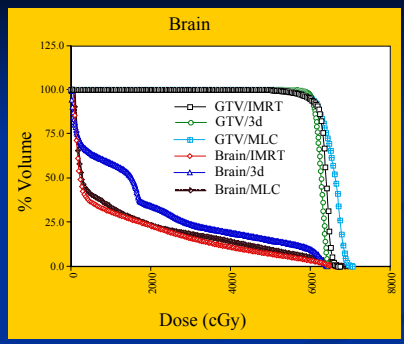

LPO
RPO
ASO
Courtesy, UCSF


LAO
LAT
AP
LPO
RPO
Courtesy, UCSF


Brain
Chiasm/IMRT
Chiasm/3d
Chiasm
BS/IMRT
BS/3d
BS/MLC
% Volume
125.0
100.0
75.0
50.0
25.0
0.0
0
2000
4000
6000
8000
Dose (cGy)
Courtesy, UCSF



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

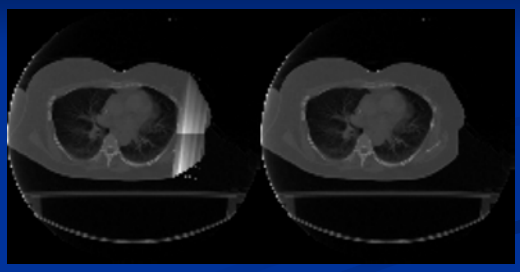
Courtesy, UCSF

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.

Courtesy, UCSF

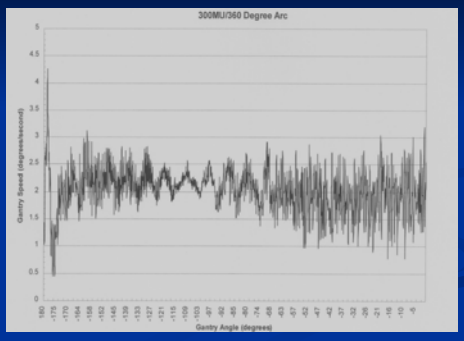
Tomotherapy Delivery Example



Courtesy, Rock Mackie

Tomotherapy Constraints

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



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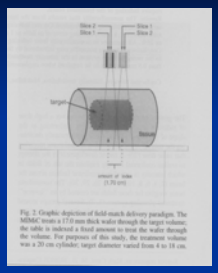

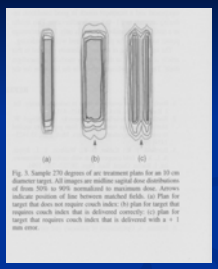

2% / 0.1mm Accuracy Requirement (Low et al)

Tomotherapy Constraints

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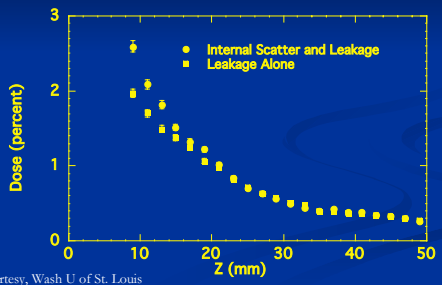
The head and whole-body phantom used to measure the whole-body dose data

Courtesy, Wash U of St. Louis

Scatter and leakage dose distribution along the gantry axis of rotation



Courtesy, Wash U of St. Louis

Whole-body dose equivalent (40 cm from field edge): 70 Gy target dose

- Followill *et al.* - 543 mSv - Three arcs, 20 X 20 cm^2 fixed beam data, and 3.24 MU cGy^{-1} per arc
- Our calculation - 315 mSv - Five arcs, 10 X 10 cm^2 fixed beam data, and 1.8 MU cGy^{-1} per arc
- Our measurements - 271 mSv

Courtesy, Wash U of St. Louis

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%

Courtesy, Wash U of St. Louis

Tomotherapy Constraints

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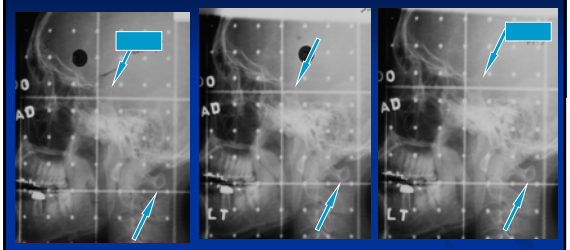
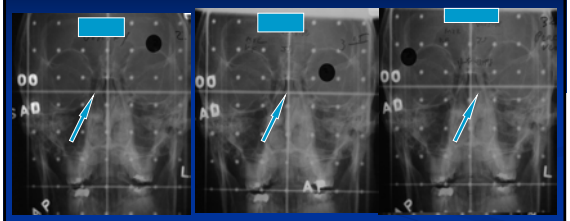
Three Sets of Orthogonal Films



0 Minutes **15 Minutes later** **30 Minutes later**

Courtesy, UCSF

Three Sets of Orthogonal Films



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Courtesy, UCSF

Tomotherapy Constraints

- Rotational Speed Accuracy
- MU/Degree Accuracy
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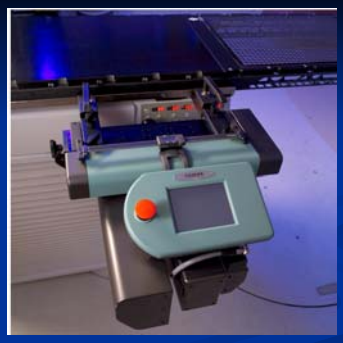
- Immobilization
- *Delivery Time*

Delivery Time Issues

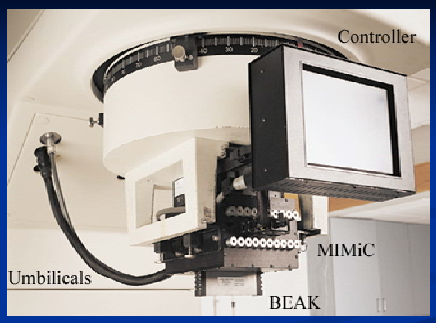
- Accurate Indexing
- Multiple Rotations / Treatment
- Dose Rate
- MU Efficiency



Courtesy, NOMOS Corporation

Implementation of Serial Tomotherapy

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



Courtesy, NOMOS Corporation

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Installation / Commissioning

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

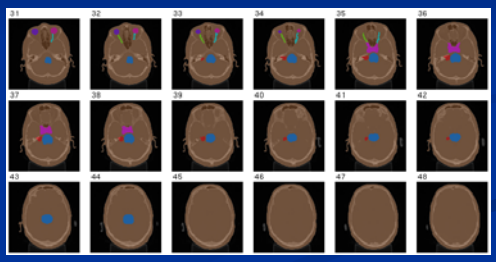
Alignment Films

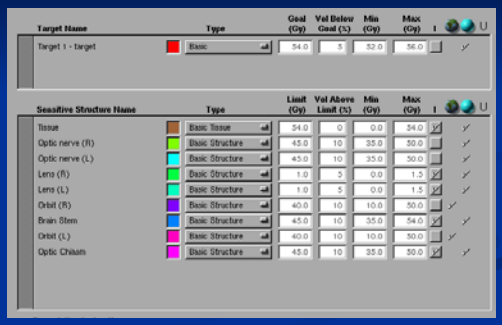
Radial Alignment Film
(90 / 270 gantry angle w/ film 15cm off isocenter

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

Indexing Test

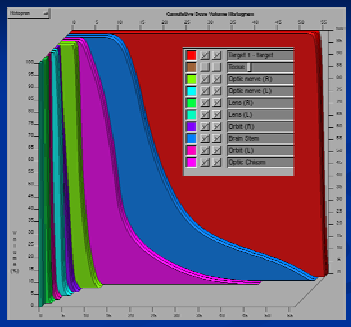
Serial Tomotherapy Example

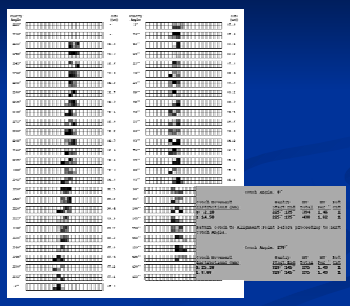


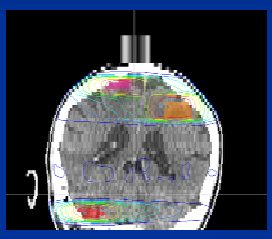


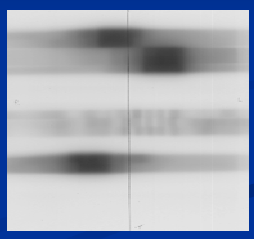
Target Name	Type	Goal (Gy)	Vol Below Goal (%)	Min (Gy)	Max (Gy)	I	U
Target 1 - target	Basic	54.0	5	52.0	56.0		✓

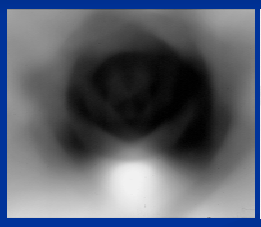
Sensitive Structure Name	Type	Limit (Gy)	Vol Above Limit (%)	Min (Gy)	Max (Gy)	I	U
Tissue	Basic Tissue	54.0	0	0.0	54.0	✓	✓
Optic nerve (R)	Basic Structure	45.0	10	35.0	50.0		✓
Optic nerve (L)	Basic Structure	45.0	10	35.0	50.0		✓
Lens (R)	Basic Structure	1.0	5	0.0	1.5	✓	✓
Lens (L)	Basic Structure	1.0	5	0.0	1.5	✓	✓
Orbit (R)	Basic Structure	40.0	10	10.0	50.0		✓
Brain Stem	Basic Structure	45.0	10	35.0	54.0	✓	✓
Orbit (L)	Basic Structure	40.0	10	10.0	50.0		✓
Optic Chiasm	Basic Structure	45.0	10	35.0	50.0	✓	✓

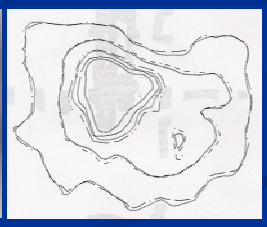


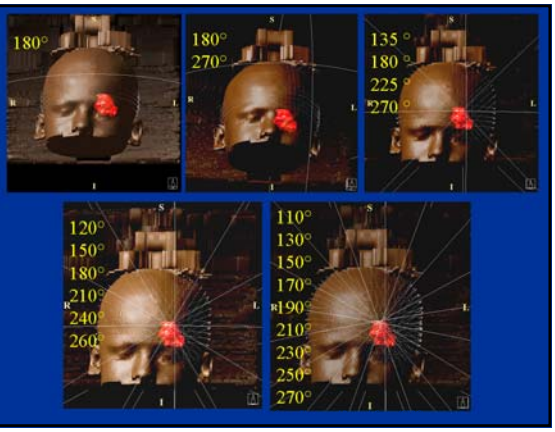


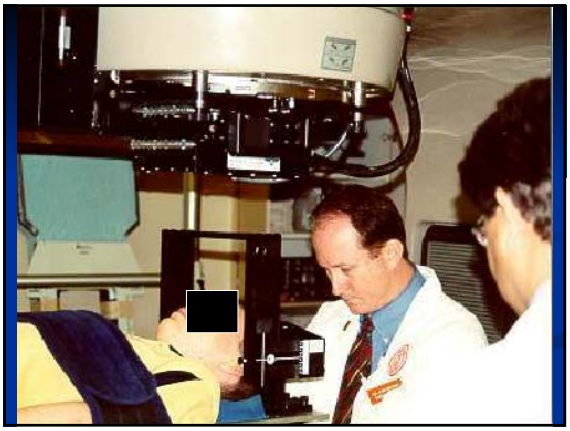






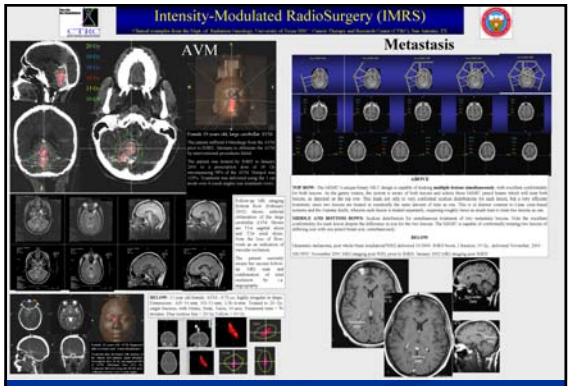




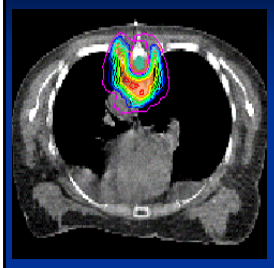


University of Texas Health Science Center / Cancer Therapy and Research Center (CTRC)
San Antonio, Texas
1998

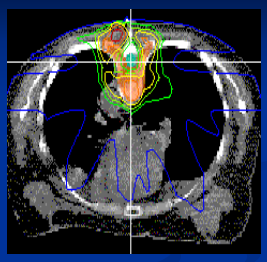
University of Texas Health Science Center / Cancer Therapy and Research Center (CTRC)
San Antonio, Texas



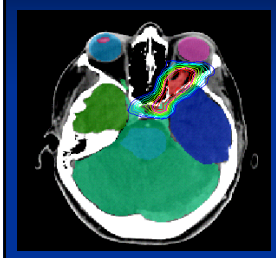
Clinical Cases



Tomotherapy



MLC



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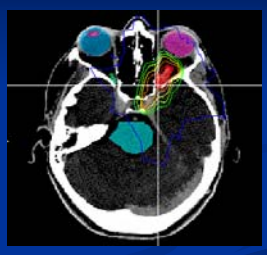
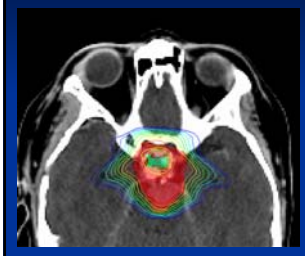
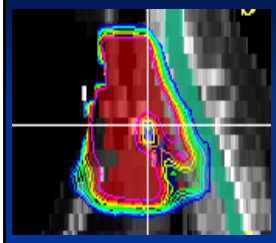


MLC

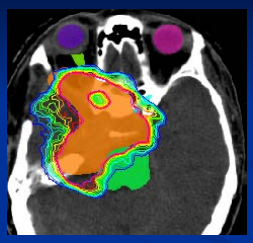


Craniopharyngioma encompassing the optic chiasm

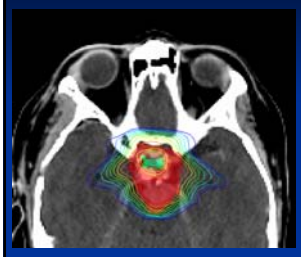
Acoustic neuroma adjacent to brain stem

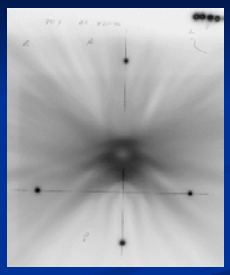


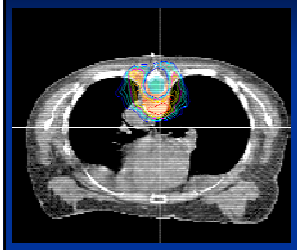
Mediastinal mass with sparing of bronchus

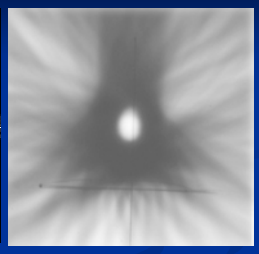


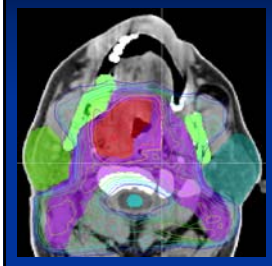
Meningioma with sparing of optic nerve

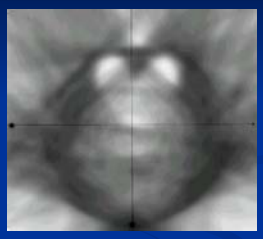












Thank you