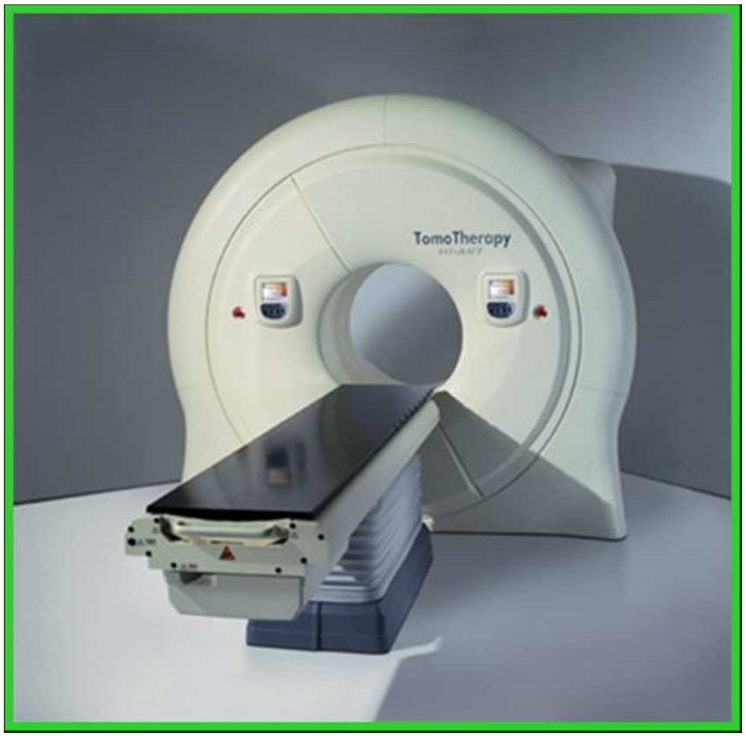


Helical Tomotherapy

Departments of Radiation Oncology & Medical Physics

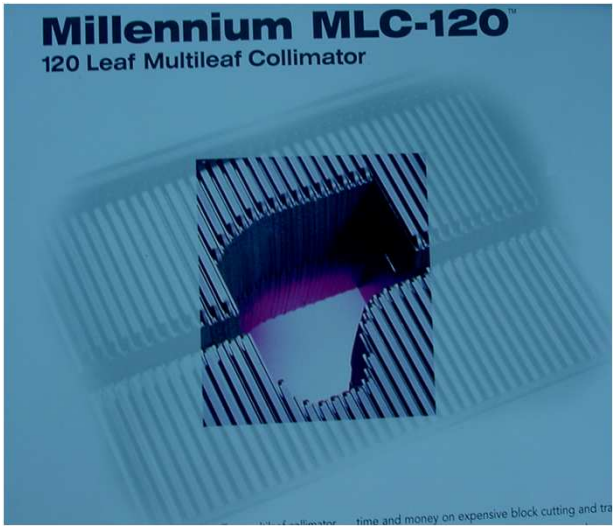
Tata Memorial Centre (TMH & ACTREC), Mumbai

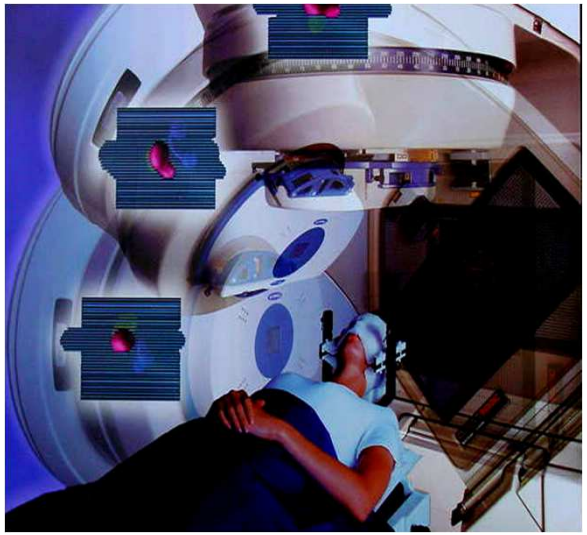
radonco@tmc.gov.in

http://tmc.gov.in

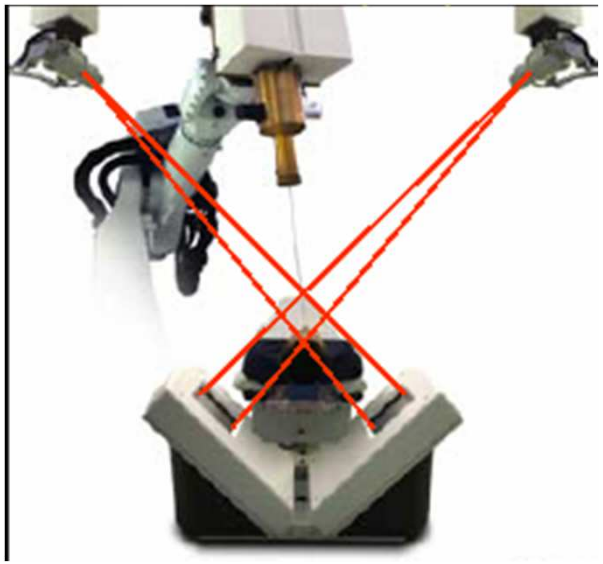
Changing Technology Impacts Every Sphere of Life

Radiotherapy: The Technology Conundrum

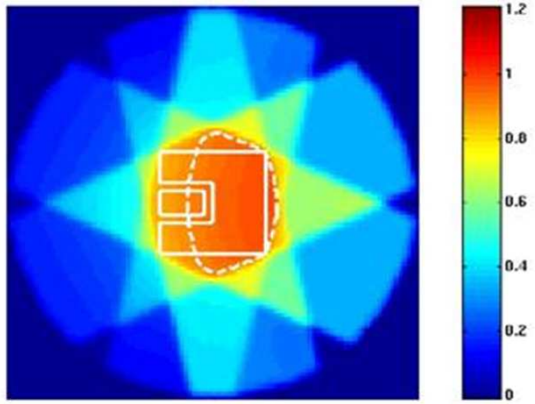


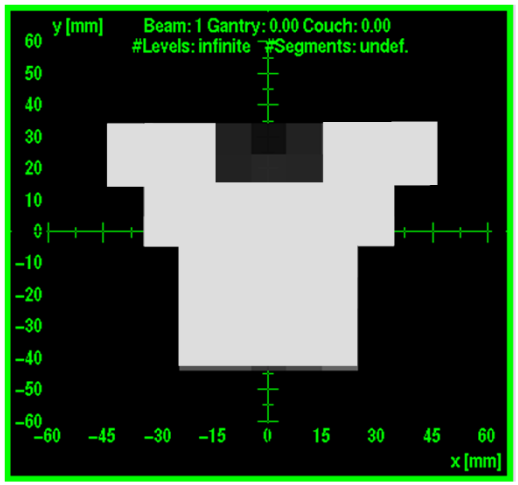


- *3D CRT*
- *SRS/SRT*
- *IMRT/IMRS*
- *IGRT*
- *CART*
- *Proton Beam RT*
- *Robotic RT*
- *BIO-ART*



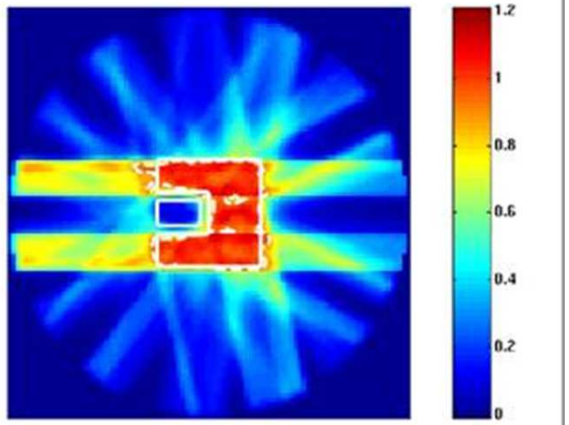
3-D CRT

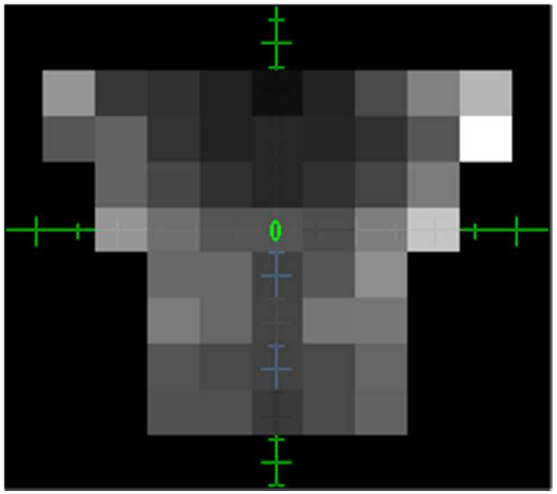




Uniform intensity

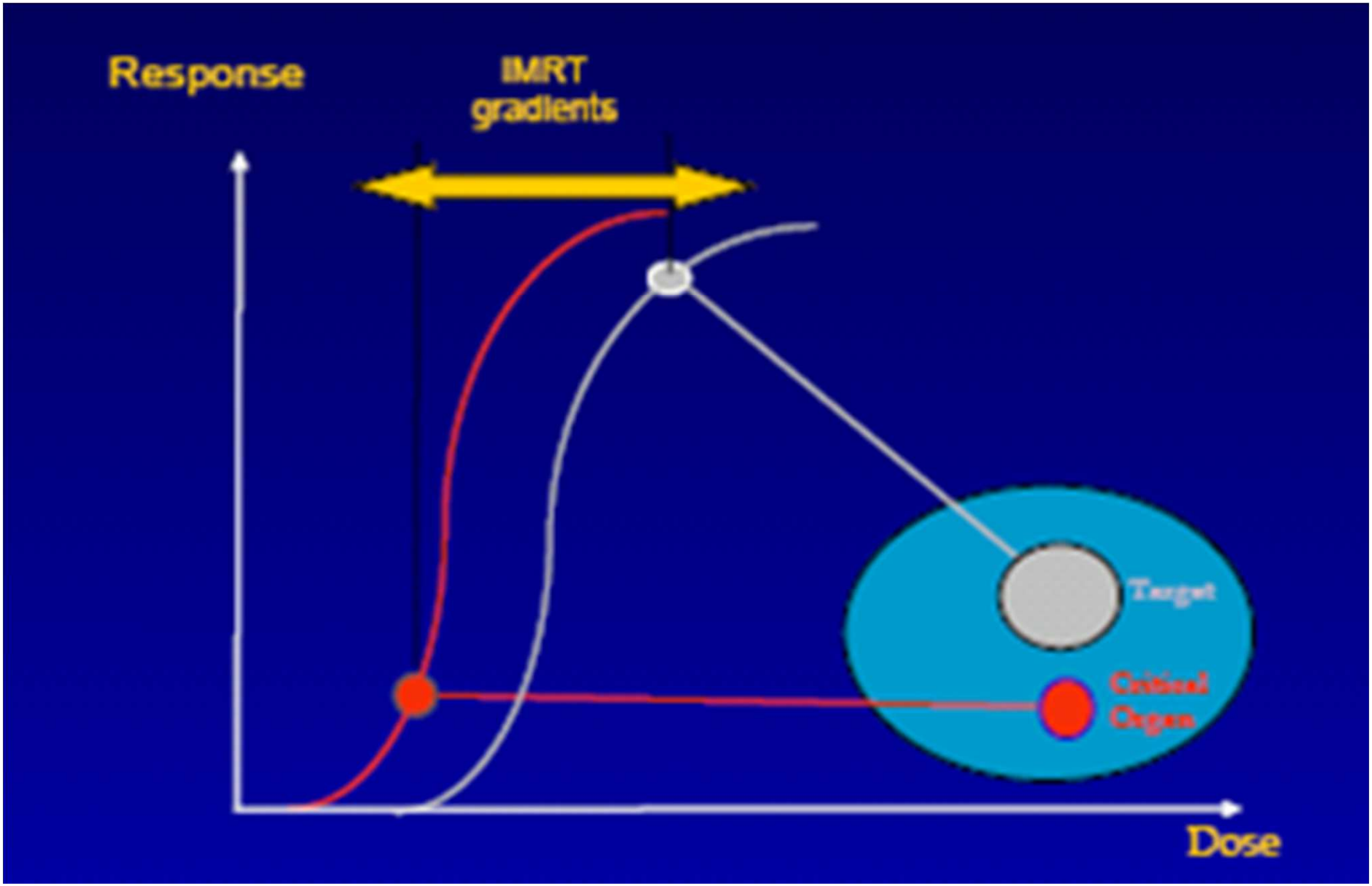
IMRT





Non-uniform intensity

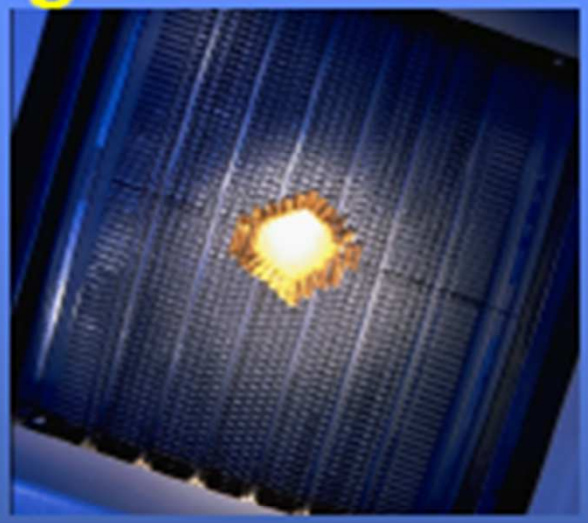
IMRT strategy



Relatively simple to understand, quite complex to implement

IMRT Using Conventional MLC's

Siemens



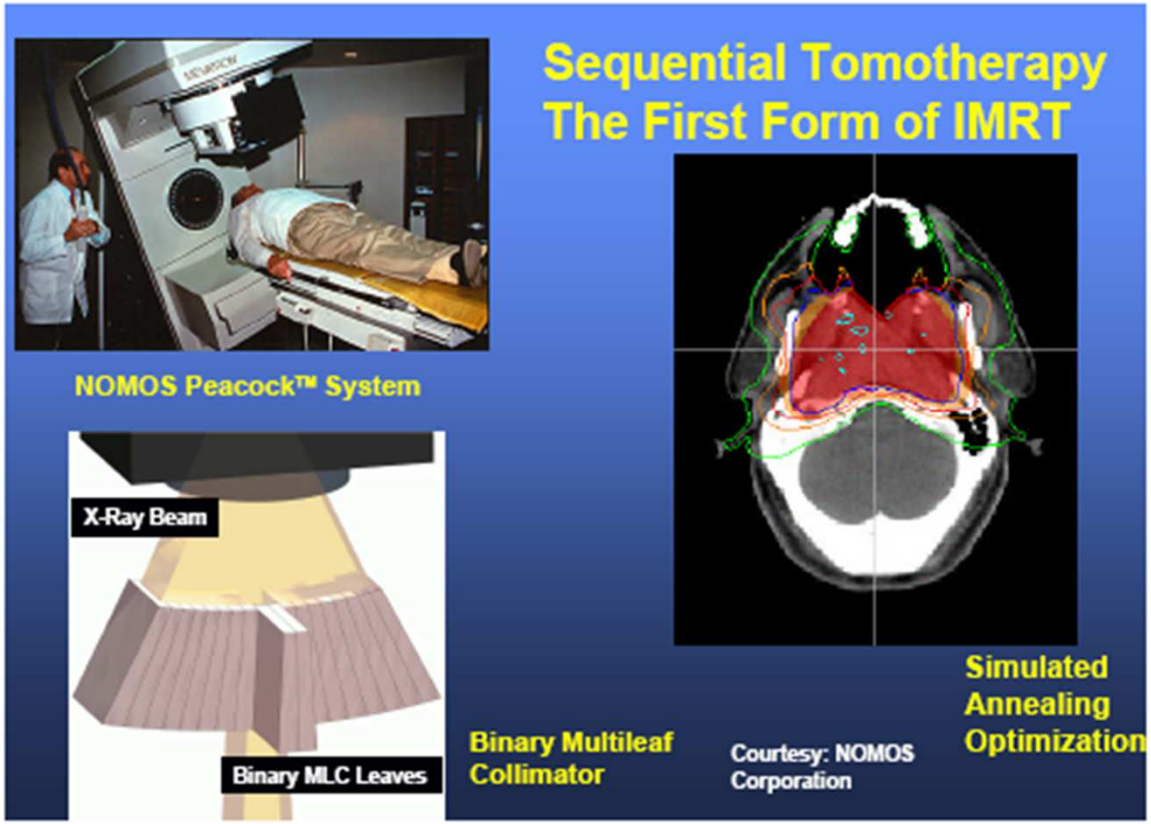
Varian

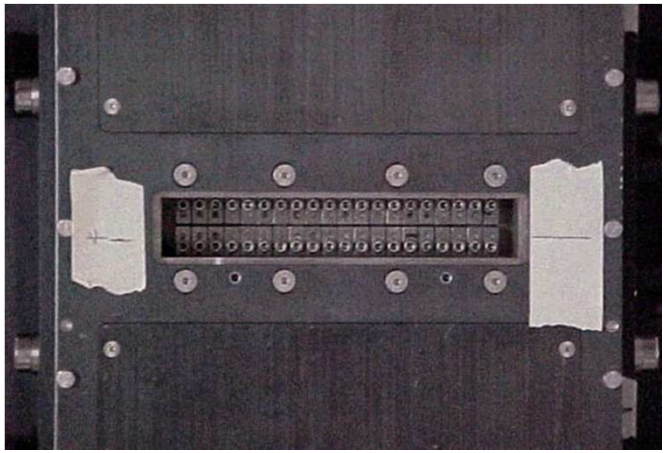
Elekta

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?





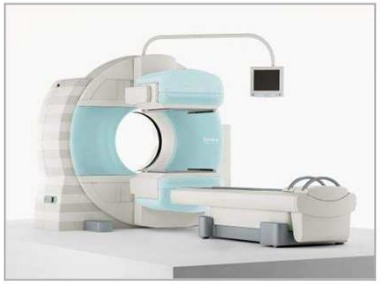
Serial Tomotherapy was delivered using number of discrete arcs or indexed arcs of finite width between which treatment couch was moved longitudinally. NOMOS introduced the PEACOCK system with intensity modulation provided by Multileaf Intensity Modulating Collimator (MIMiC)

TOMO is the Buzzword in Imaging Technology

Computed TOMOgraphy

Helical TOMOtherapy

SPECT TOMOgraphy



Positron TOMOgraphy

MR TOMOgraphy

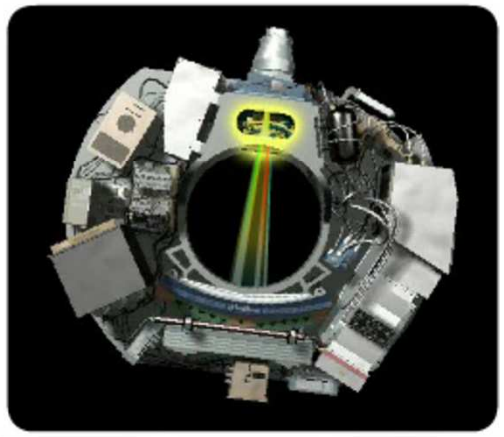
All these revolutionary technologies are based on ring gantry design

Helical TomoTherapy: Revolutionary Novel Technology

Fast Binary MLC

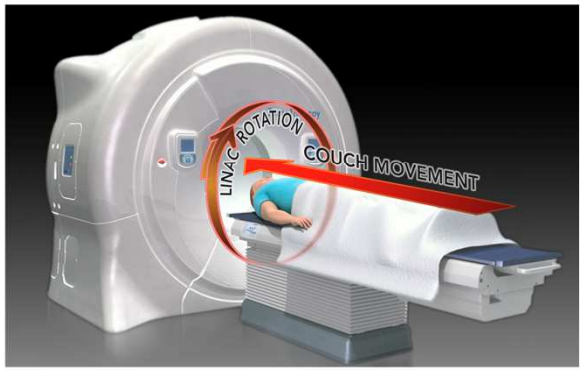
+

Continuous Gantry Rotation

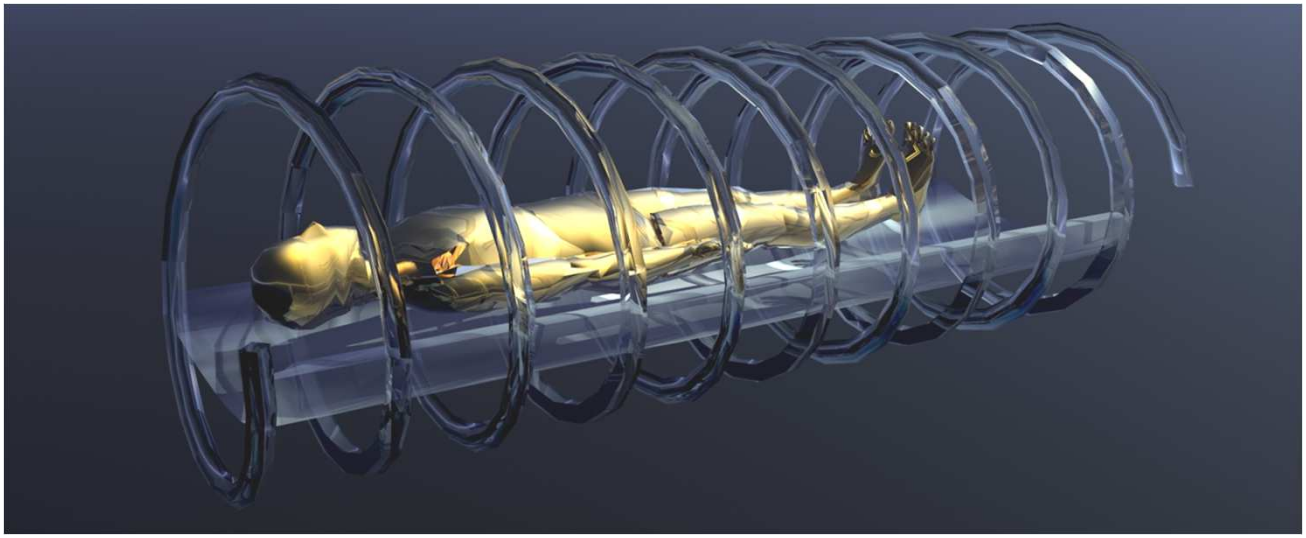


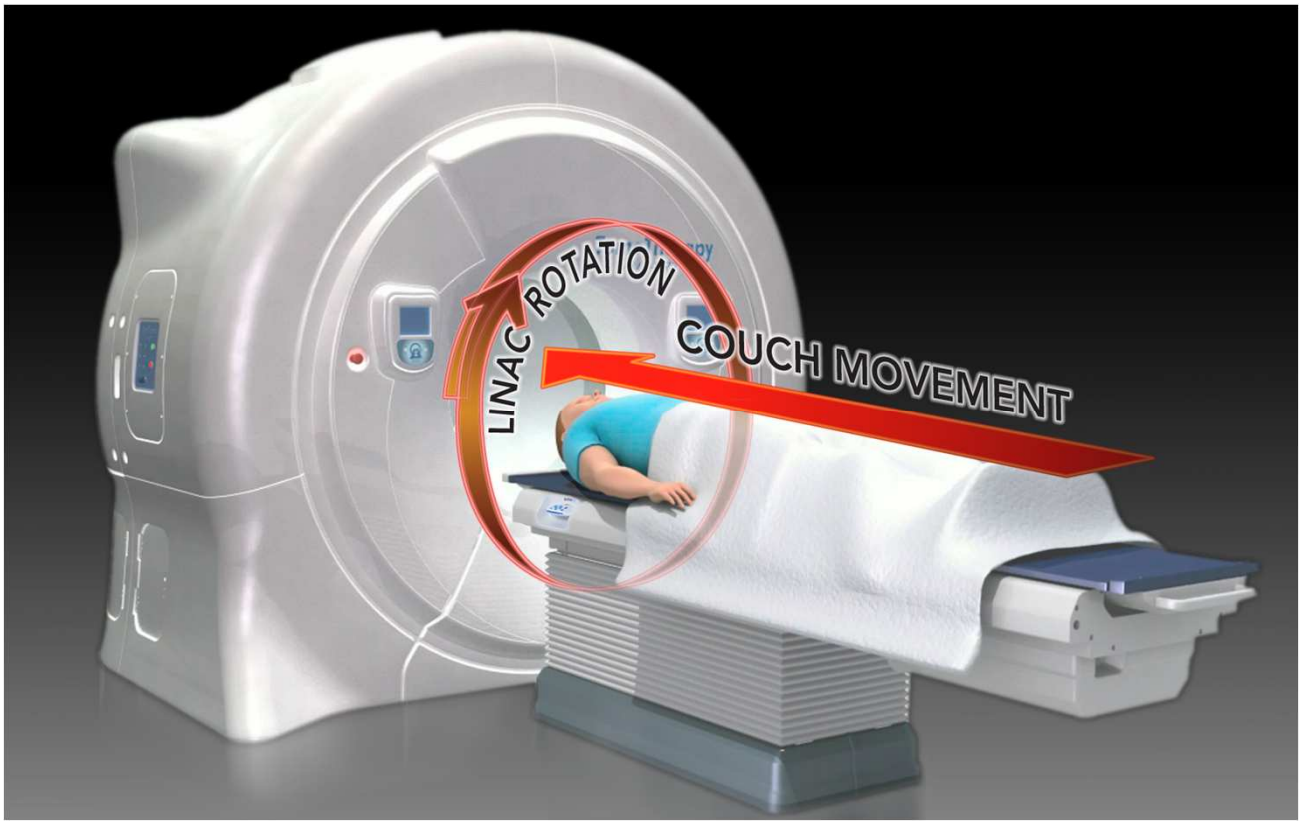
+

Simultaneous Couch Movement



- 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




LINAC ROTATION
COUCH MOVEMENT

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

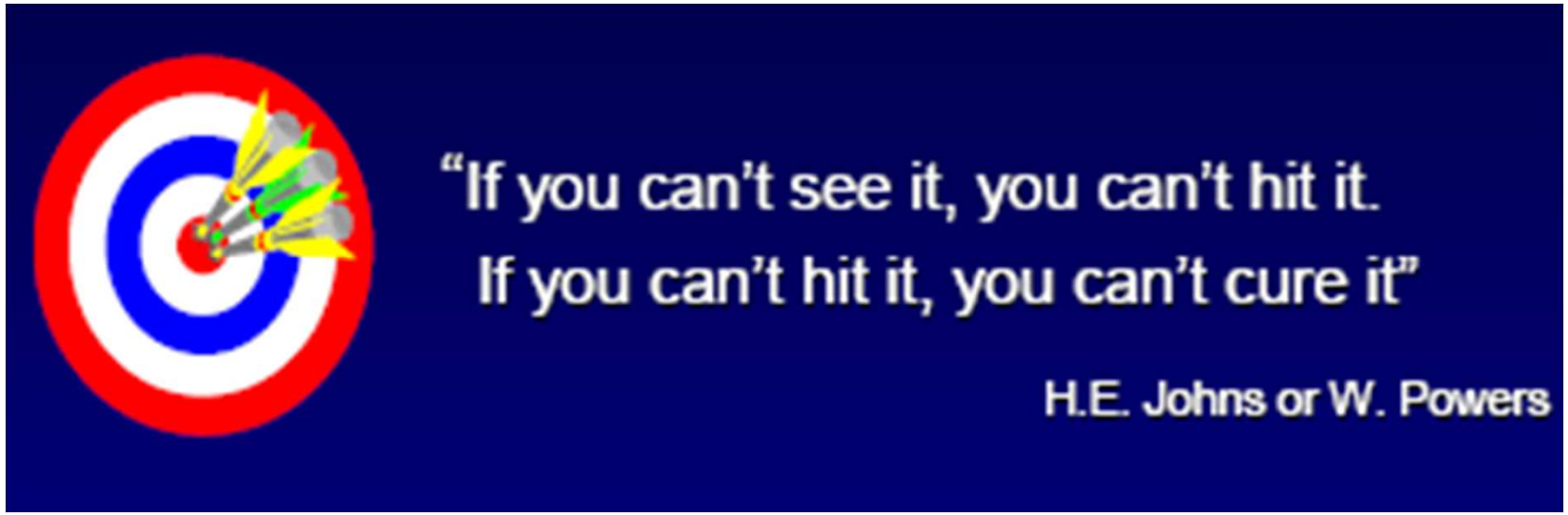
What's different about Helical TomoTherapy

- 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

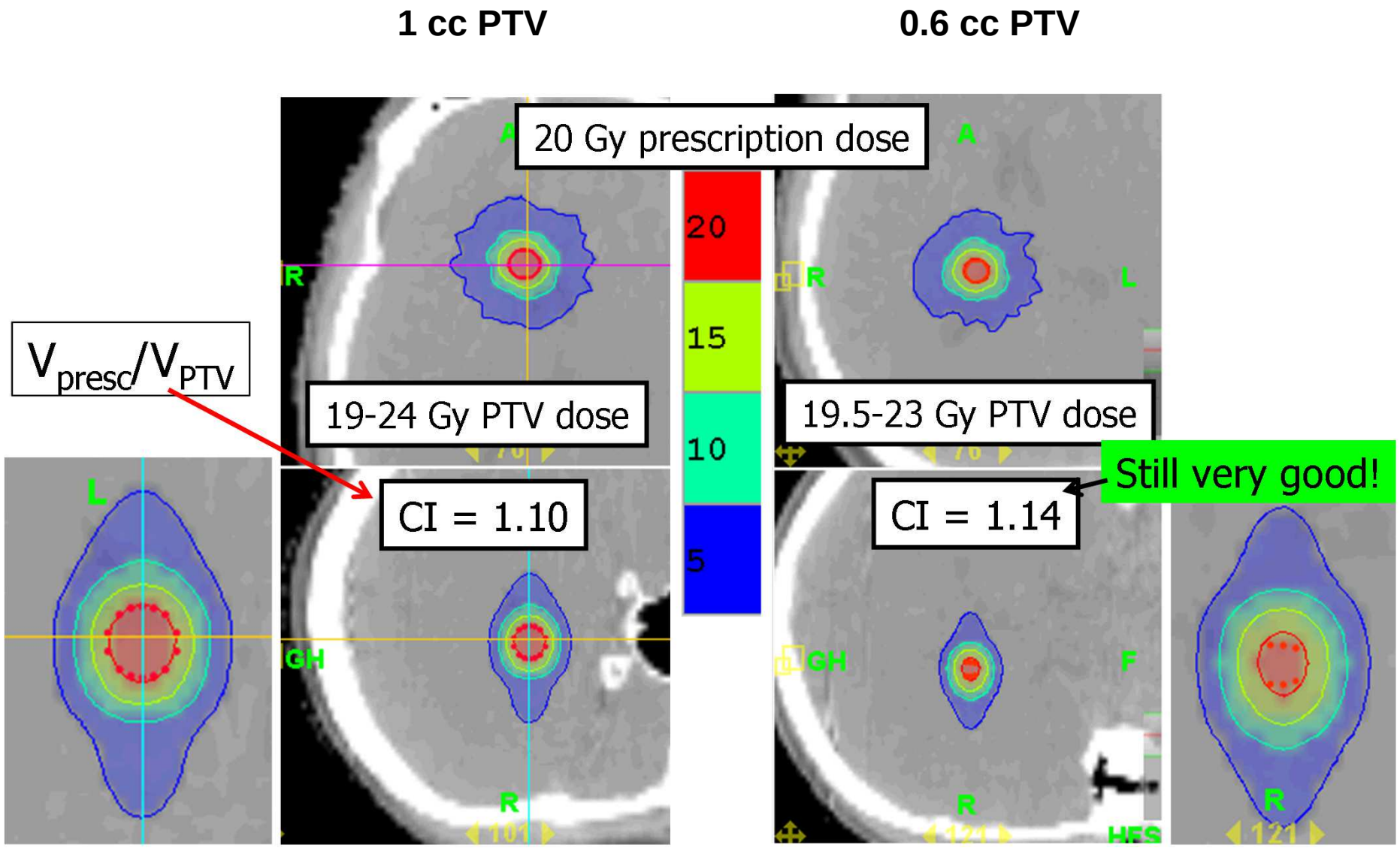
Why Image Guidance?



Helical TomoTherapy

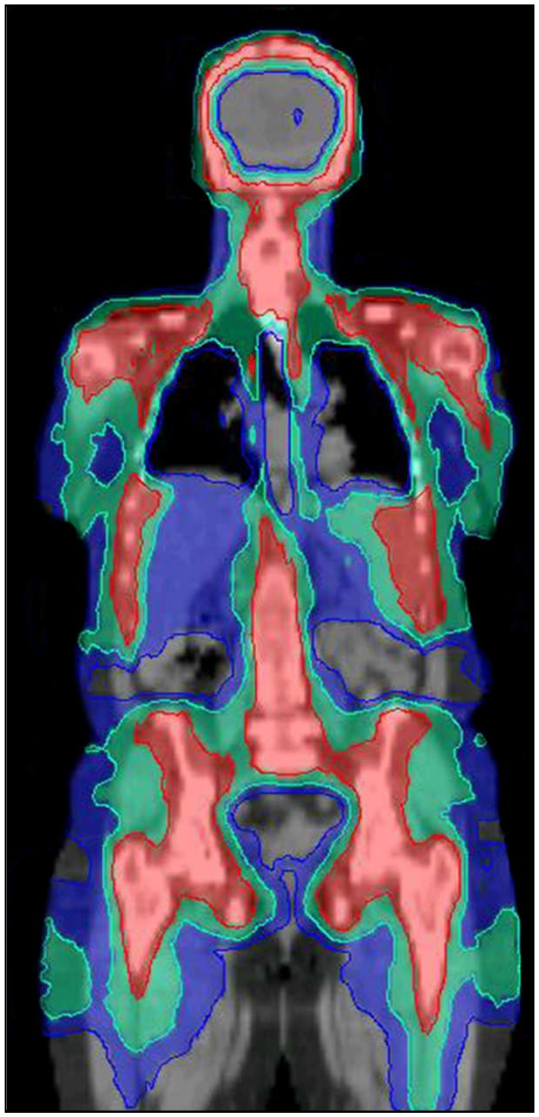
- Is it the ultimate form of photon teletherapy
- What are its current clinical applications
- What is its future potential

How small can TOMO treat ?



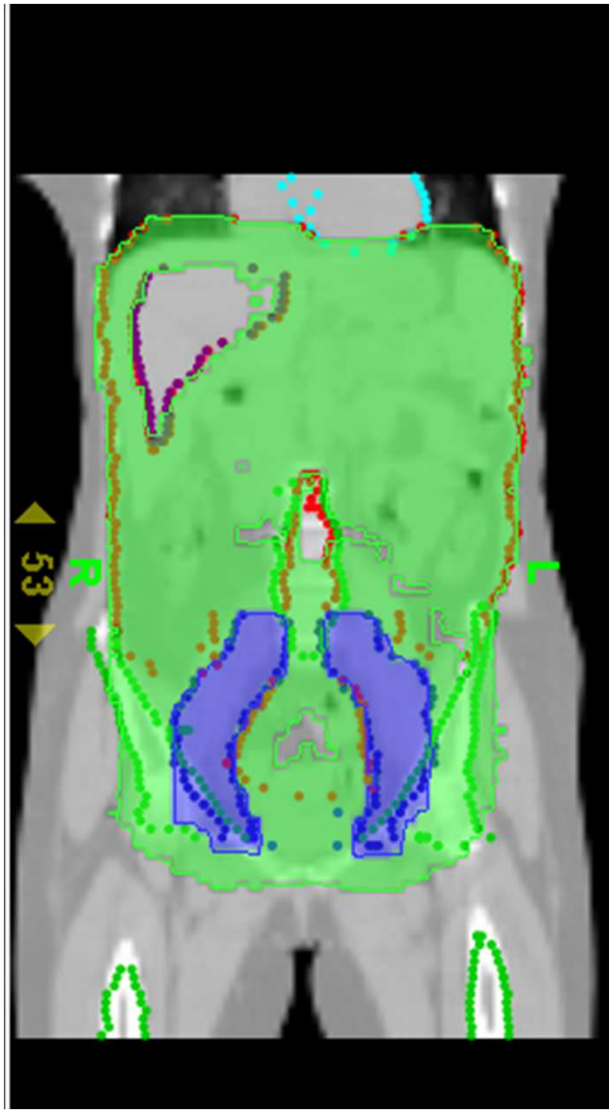
How long/large can TOMO treat?

6500 cc



TMI/TLI

5000cc

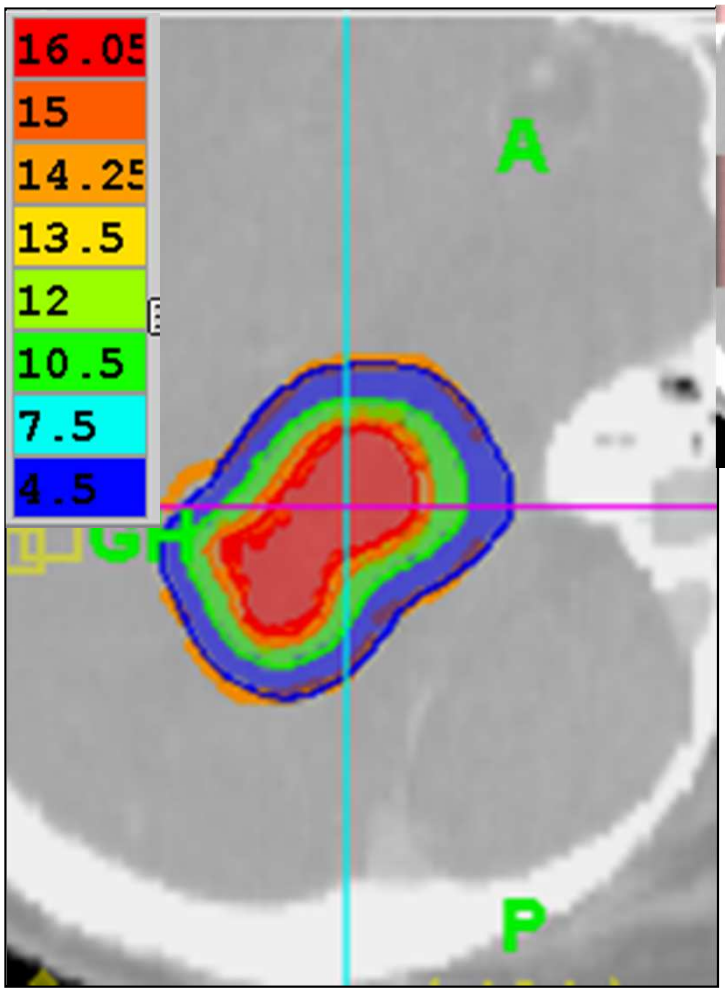


WAR

2500 cc

CSI

Single fraction Radiosurgery



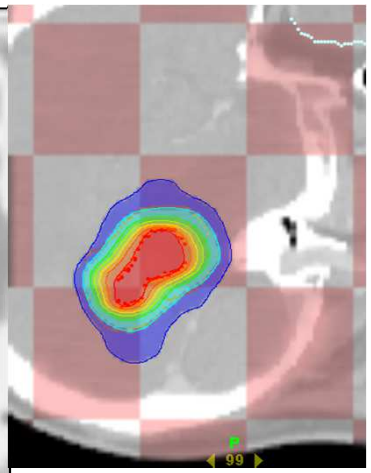
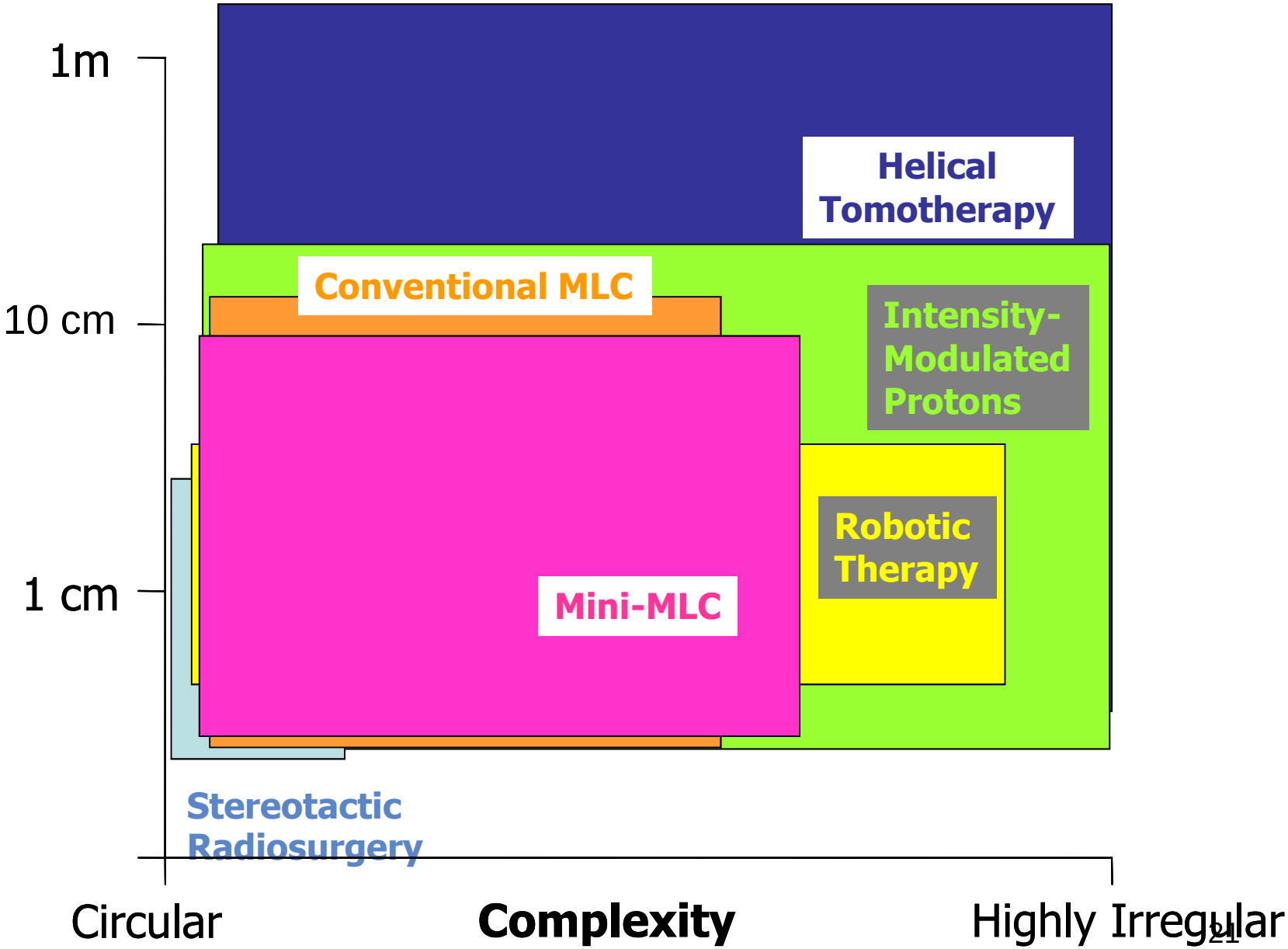


Image-guided setup with MVCT

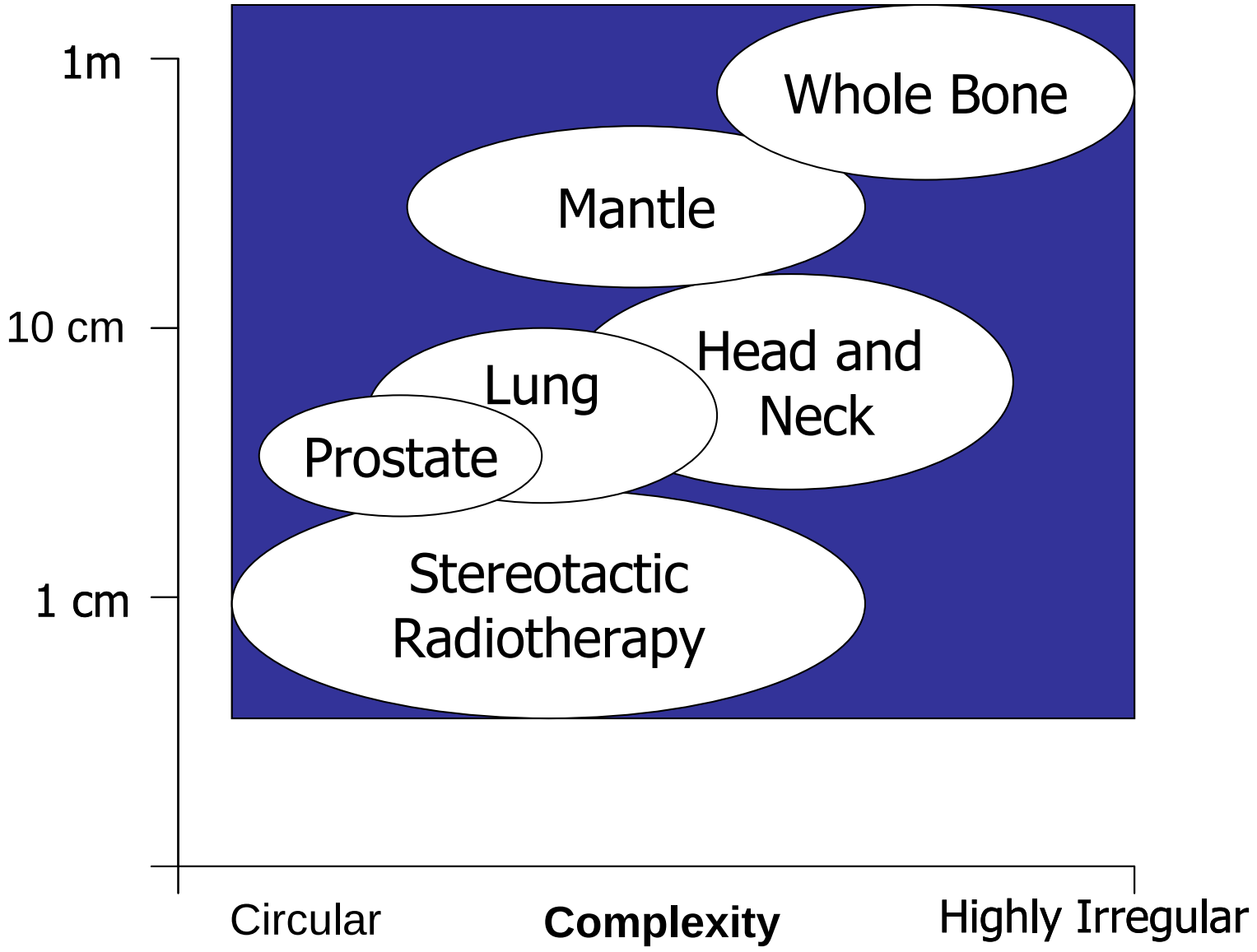
Delivery time:
16 minutes for 15 Gy

Ave. dose gradient:
11% per mm
(100%-50% in 4.5 mm)

Balance of size and complexity for precision radiotherapy



Current Clinical Applications of Helical TomoTherapy



Radiotherapy and Oncology 80 (2006) 268–273
www.thegreenjournal.com

Medical Physics

Comparison of advanced irradiation techniques with photons for benign intracranial tumours

L. Cozzi[a,*], A. Clivio[a,b], G. Bauman[c], S. Cora[e], G. Nicolini[a], R. Pellegrini[d], E. Vanetti[a,b], S. Yartsev[c], A. Fogliata[a]

[a]Oncology Institute of Southern Switzerland, Medical Physics, Bellinzona, Switzerland, [b]University of Milan, Medical Physics Specialisation School, Milan, Italy, [c]London Regional Cancer Program, London Health Sciences Centre, London, Ont., Canada, [d]3-D Line Medical Systems srl. Milan, Italy, [e]Ospedale di Vicenza, Medical Physics, Vicenza, Italy

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)**

RADIATION-INDUCED SECOND CANCERS: THE IMPACT OF 3D-CRT AND IMRT

ERIC J. HALL, D.SC.* AND CHENG-SHIE WUU, PH.D.†

INTENSITY-MODULATED RADIATION THERAPY, PROTONS, AND THE RISK OF SECOND CANCERS

ERIC J. HALL, D.PHIL., D.SC.

The Inaugural Frank Ellis Lecture — Iatrogenic Cancer: The Impact of Intensity-modulated Radiotherapy☆

E. J. Hall

Center for Radiological Research, Columbia University Medical Center, College of Physicians and Surgeons, New York, NY, USA

Nearly doubles the incidence of second cancers at 10 years

Int. J. Radiation Oncology Biol. Phys., Vol. 48, No. 4, pp. 917–918, 2000

0360-3016/00/$–see front matter

PII S0360-3016(00)00756-2

EDITORIAL

OVERPRICED TECHNOLOGY IN RADIATION ONCOLOGY

EDWARD C. HALPERIN, M.D.

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

Int. J. Radiation Oncology Biol. Phys., Vol. 58, No. 2, pp. 320–330, 2004

0360-3016/04/$–see front matter

doi:10.1016/j.ijrobp.2003.09.057

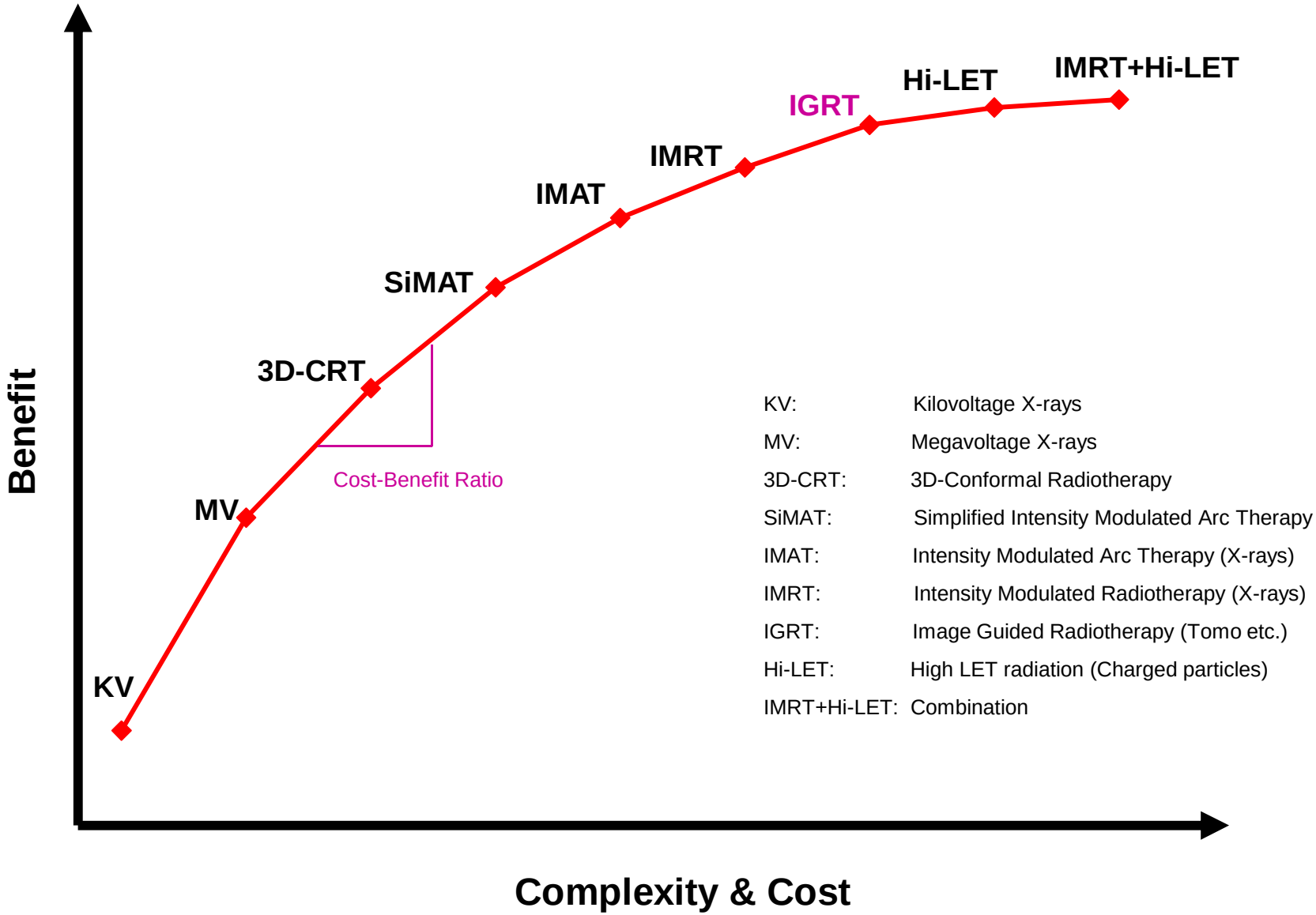
ICTR 2003 **Translational Research and Pre-Clinical Strategy Study**

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

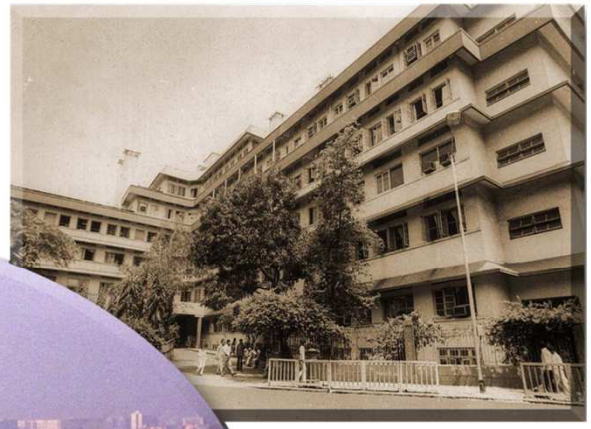
High-cost Technology in Radiation Oncology: A value judgment



KV:	Kilovoltage X-rays
MV:	Megavoltage X-rays
3D-CRT:	3D-Conformal Radiotherapy
SiMAT:	Simplified Intensity Modulated Arc Therapy
IMAT:	Intensity Modulated Arc Therapy (X-rays)
IMRT:	Intensity Modulated Radiotherapy (X-rays)
IGRT:	Image Guided Radiotherapy (Tomo etc.)
Hi-LET:	High LET radiation (Charged particles)
IMRT+Hi-LET:	Combination

TATA MEMORIAL CENTRE

MISSION

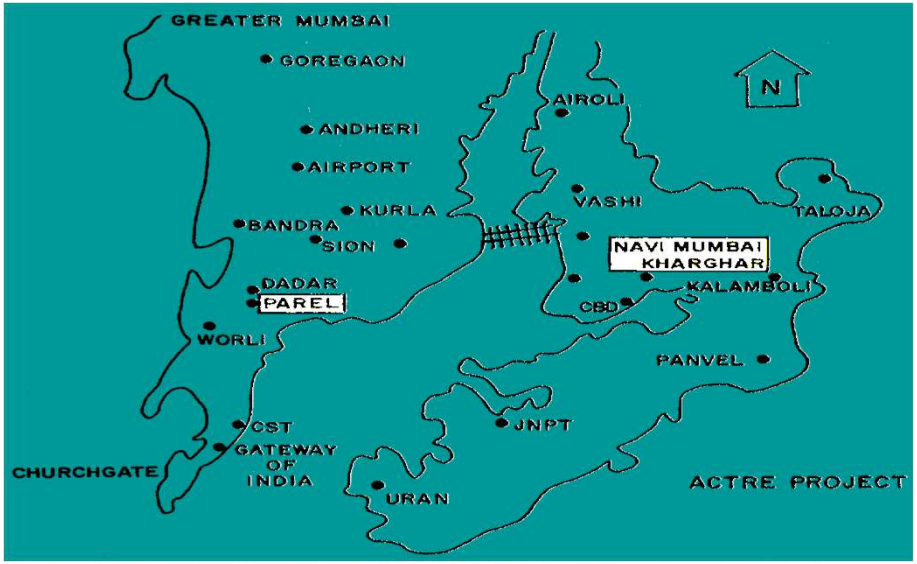


SERVICE

EDUCATION

RESEARCH

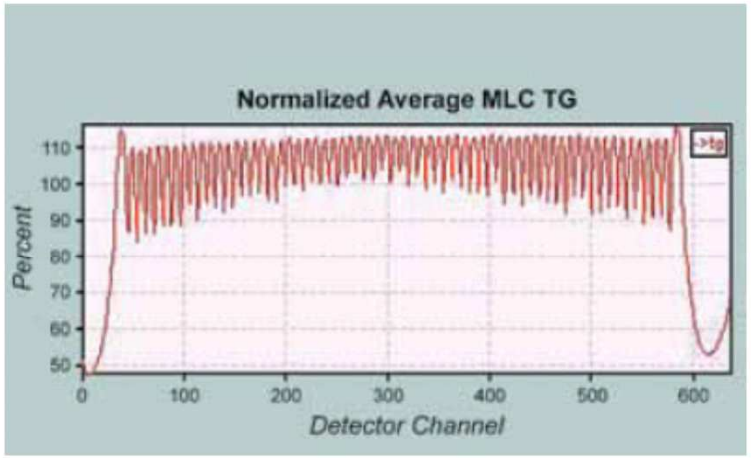
ACTREC – KHARGHAR - NAVI MUMBAI

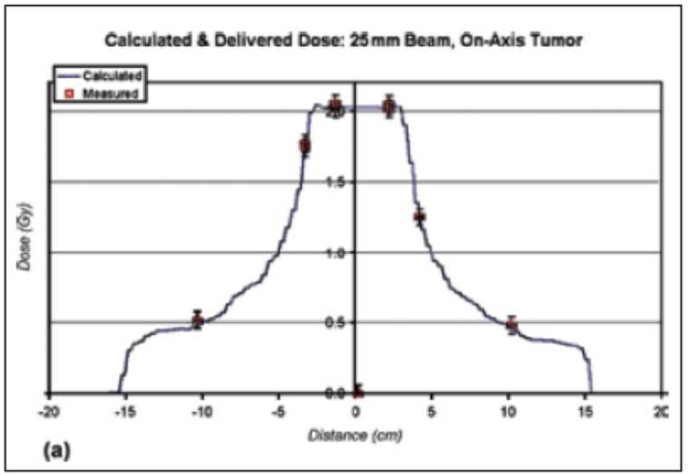


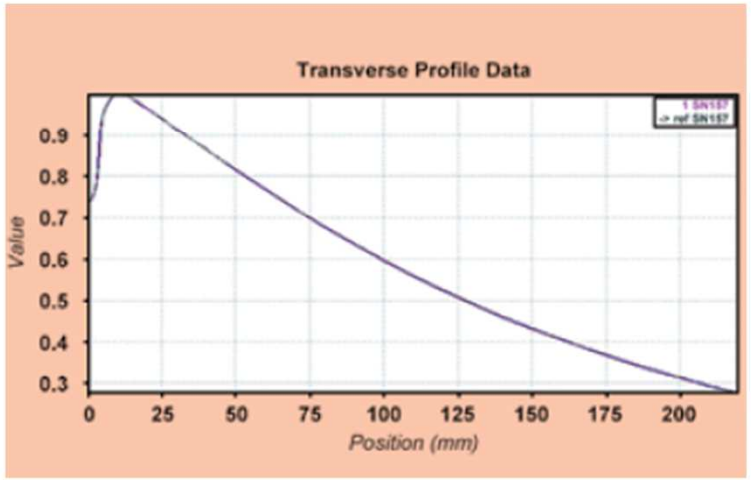
Dosimetric validation of first helical tomotherapy Hi-Art II machine in India

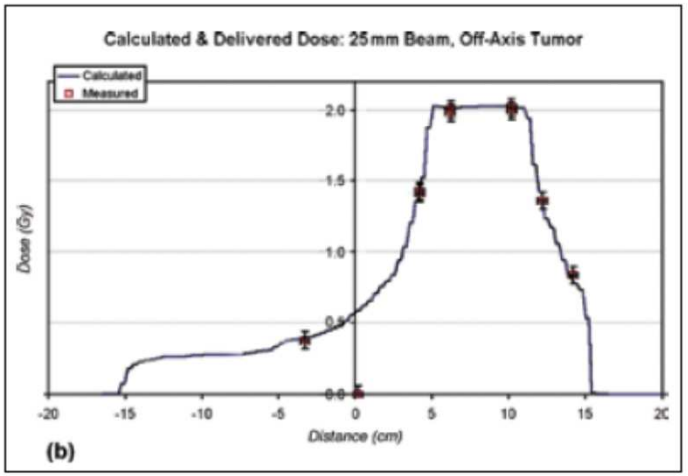
Rajesh A. Kinhikar[1], Swamidas V. Jamema[1], Reenadevi[3], Rajeshri Pai[3], Master Zubin[3], Tejpal Gupta[3], Deepak S. Dhote[4], Deepak D. Deshpande[1], Shyam K. Shrivastava[1], Rajiv Sarin[3]

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









Indications for TomoTherapy based IG-IMRT

Palliative intent treatment

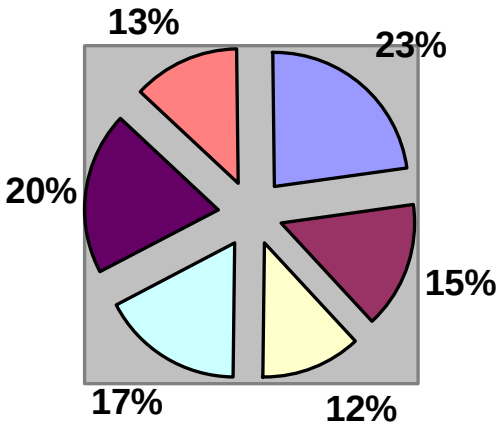
- To streamline workflow/process: brain, bone, liver metastases
- Multiple sites: Primary + metastases; multiple metastases
- Complex geometry: pleural mesothelioma; whole skull

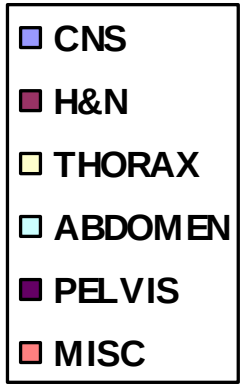
Radical intent treatment

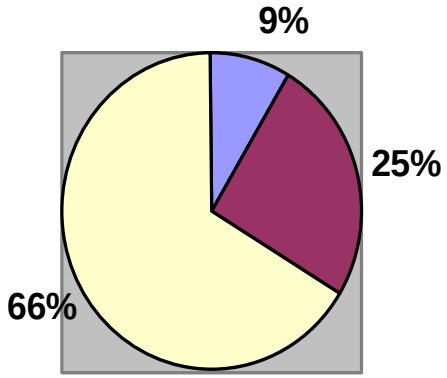
- Brain (low-grade/benign tumors; whole ventricular; CSI)
- Head/Neck (mucosal; sinonasal; skull base; orbital; scalp)
- Thorax (lung primary; chest wall; mediastinum; paravertebral)
- Abdomen (hepatobiliary; pancreatic; paraaortic nodes)
- Pelvis (prostate only; prostate + pelvis; bladder; cervix)
-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

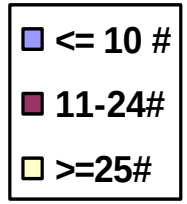
Stat-bites

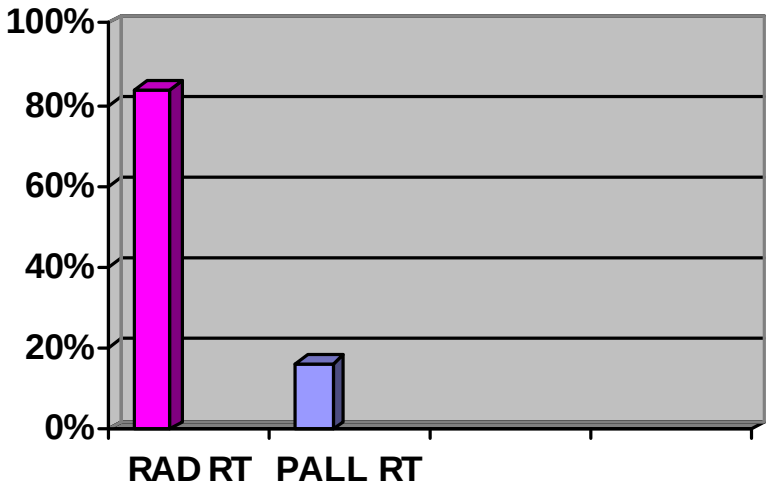
Over 200 patients accrued (2008-2009May)

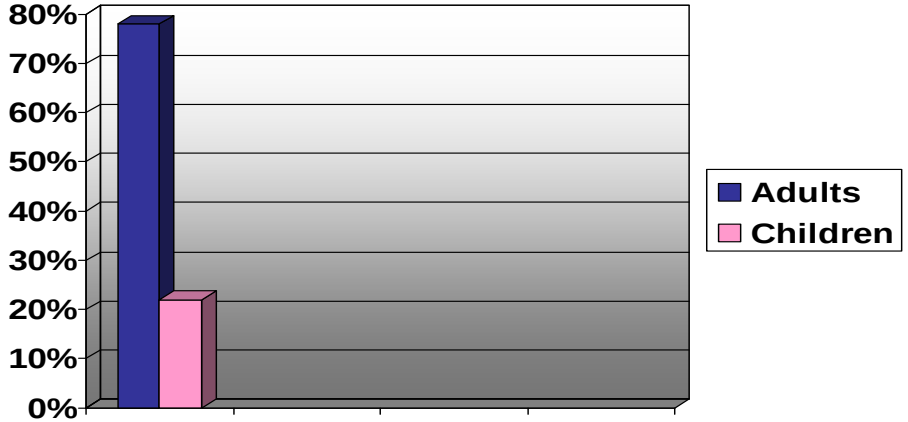




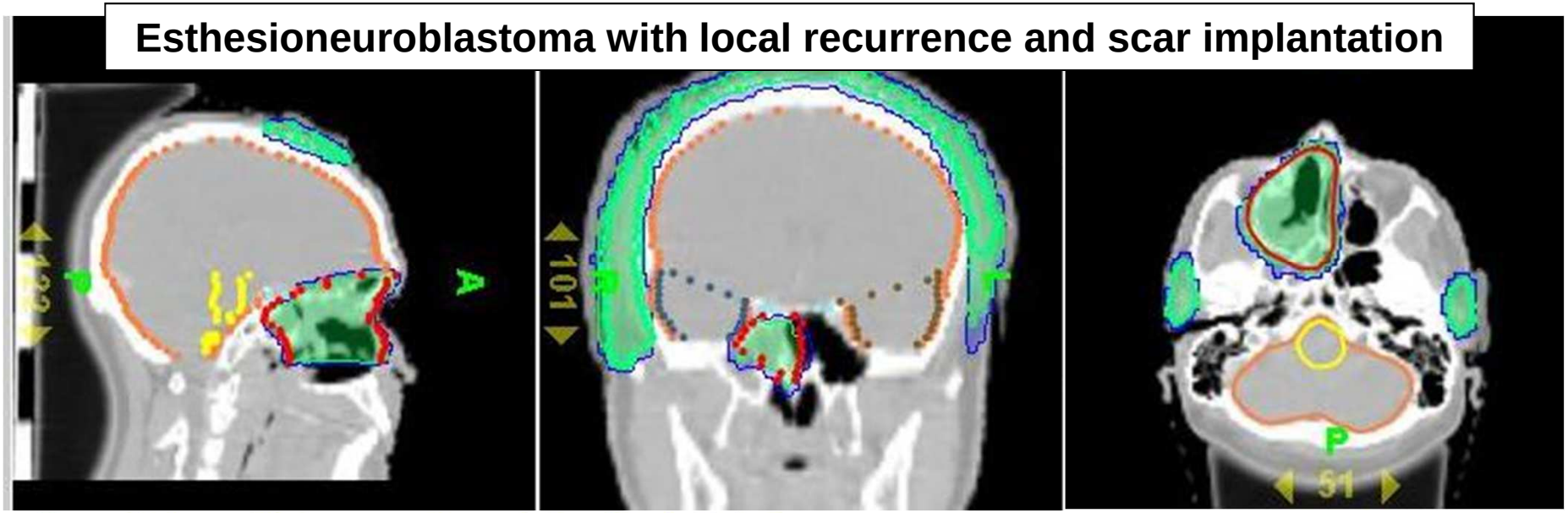


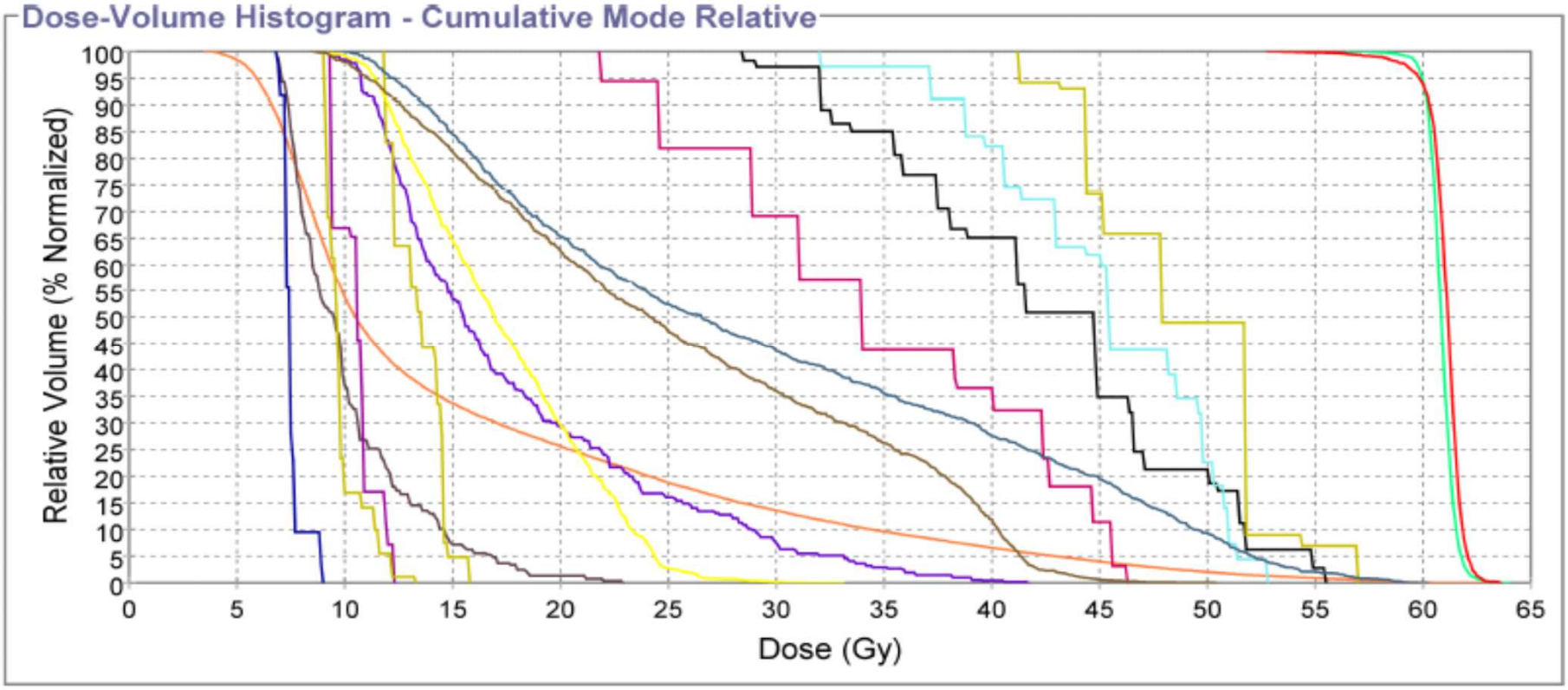






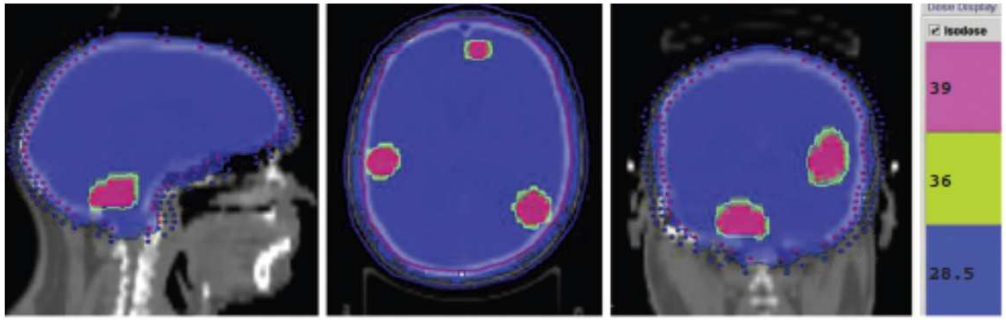
Esthesioneuroblastoma with local recurrence and scar implantation

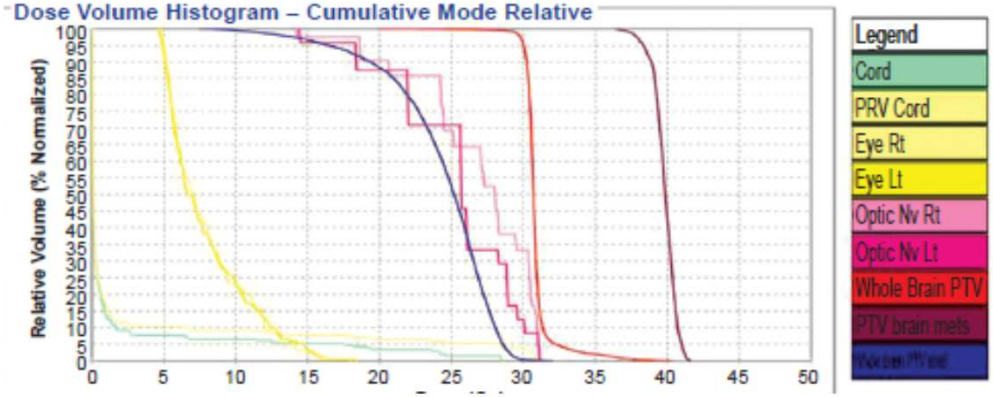




Planning and Delivery of Whole Brain Radiation Therapy with Simultaneous Integrated Boost to Brain Metastases and Synchronous Limited-field Thoracic Radiotherapy Using Helical TomoTherapy: A Preliminary Experience

T. Gupta, MD, DNB[1,*]
A. Basu, MD[2]
Z. Master, MS[1]
R. Jalali, MD[2]
A. Munshi, MD, DNB[2]
R. Sarin, MD, FRCR[1]

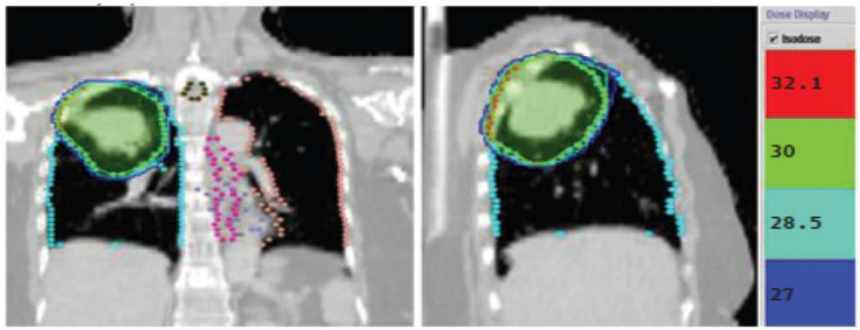


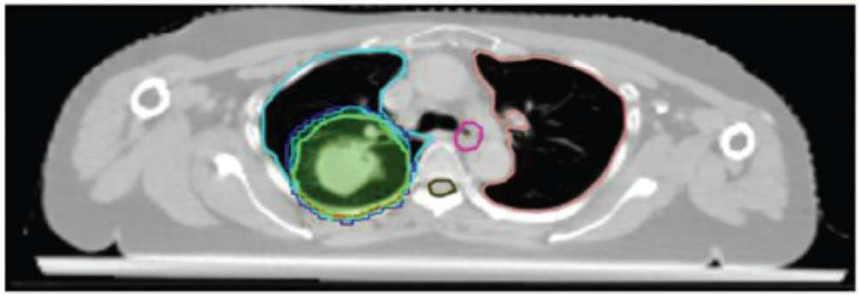


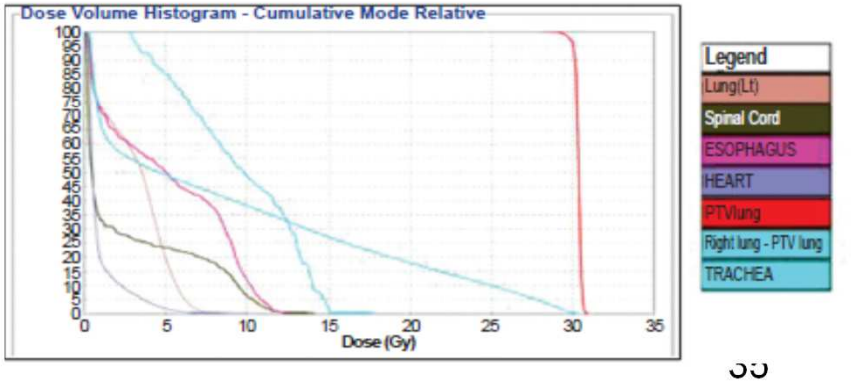
Dose metrics* for target volume coverage, conformity, and homogeneity.

	$V_{95\%}$	$V_{107\%}$	$D_{1\%}$	$D_{99\%}$	$D_{mean\%}$	DHI	CI
PTV-WB	99.47% (0.53)	3.92% (1.63)	119.33% (4.01)	96.58% (2.38)	103.60 % (1.26)	0.07 (0.01)	0.79 (0.07)
PTV-BM	99.58% (0.34)	0 (0)	104.04% (1.48)	97.31% (1.16)	102.06 % (0.67)	0.04 (0.02)	0.57 (0.22)
PTV-Chest	99.27% (0.74)	0.19% (0.25)	104.56% (1.93)	95.45% (3.02)	102.88 % (1.51)	0.03 (0.02)	0.77 (0.06)

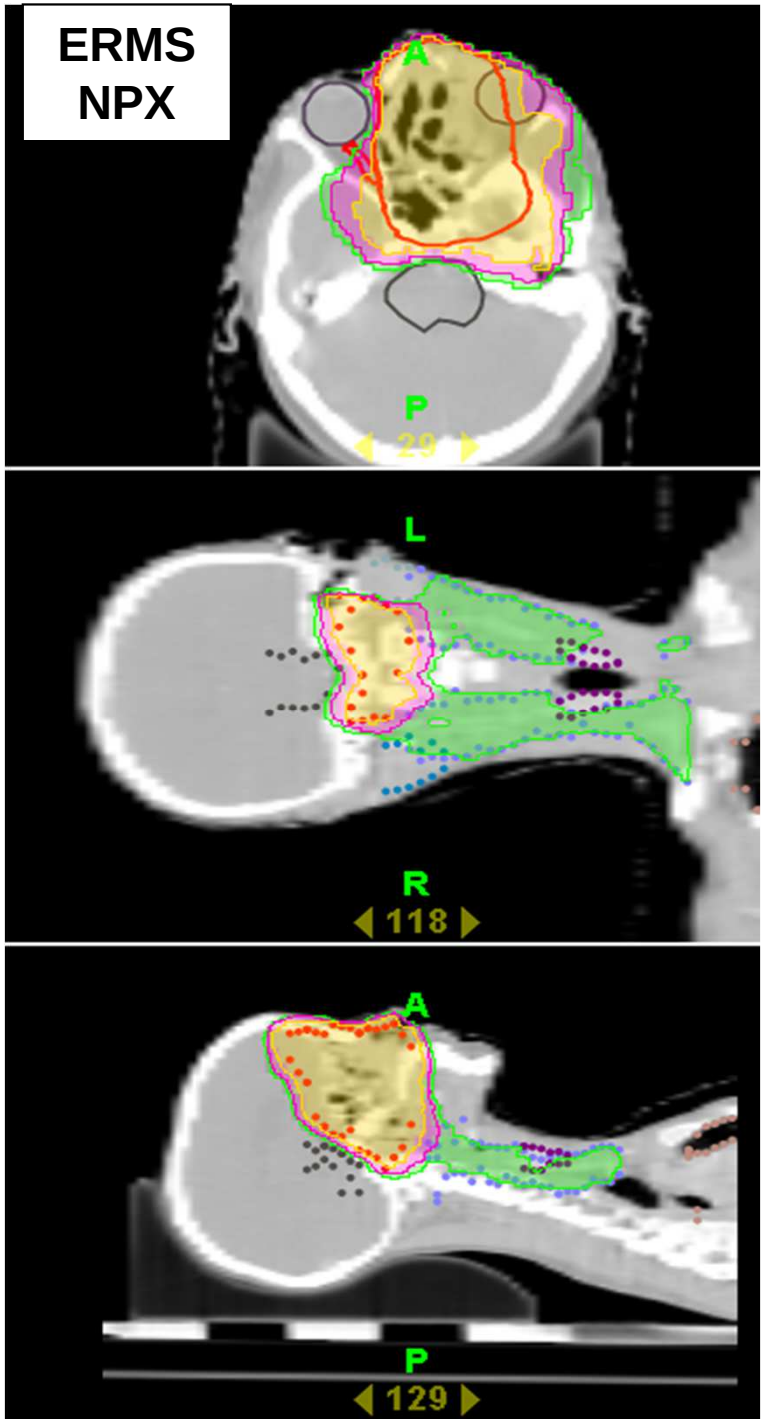
*All values expressed as mean (with standard deviation in parentheses). Dose percentages ($D_{1\%}$, $D_{99\%}$, $D_{mean\%}$) are with respect to prescription dose. PTV, Planning Target Volume; WB, Whole brain; BM, Brain metastases; DHI, Dose Homogeneity Index; CI, Conformity index.

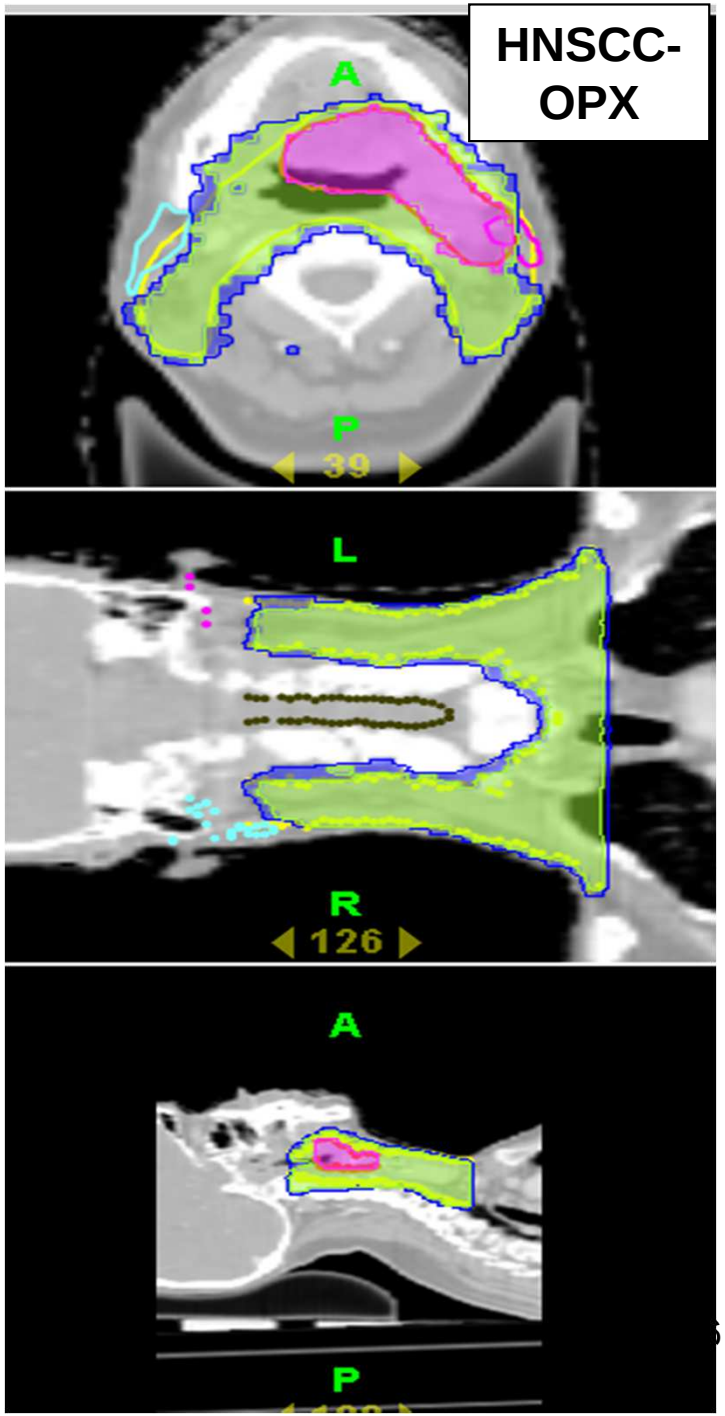


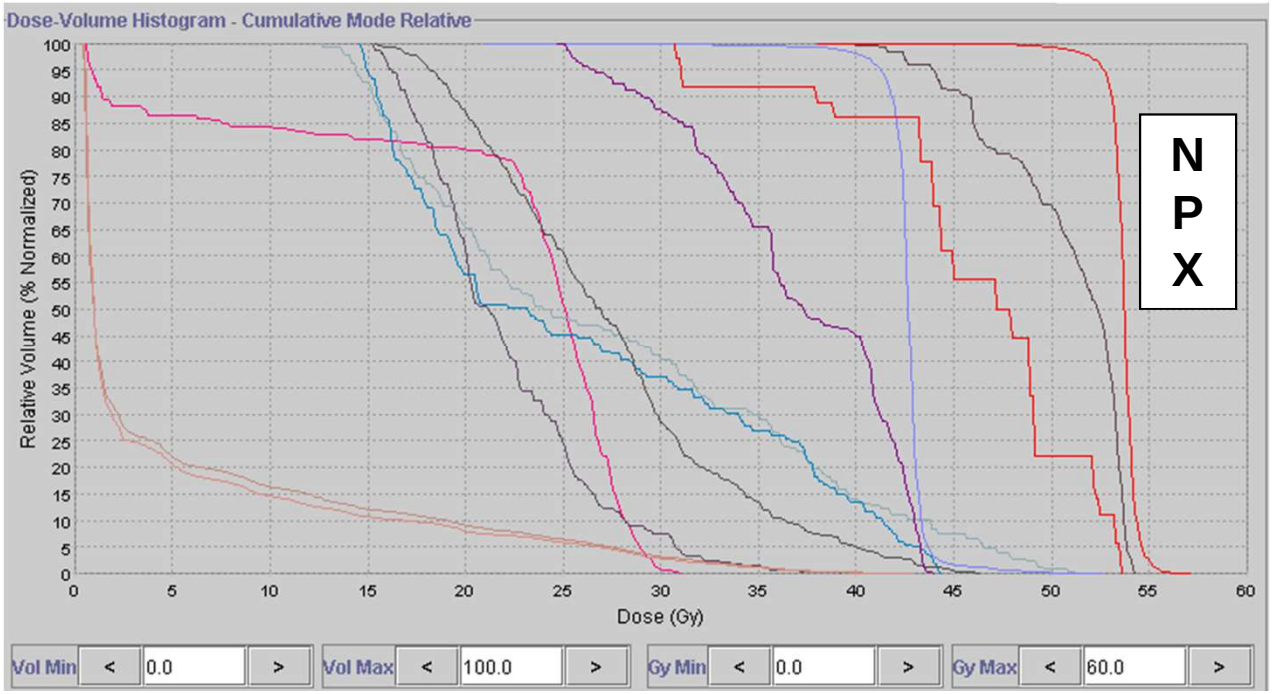


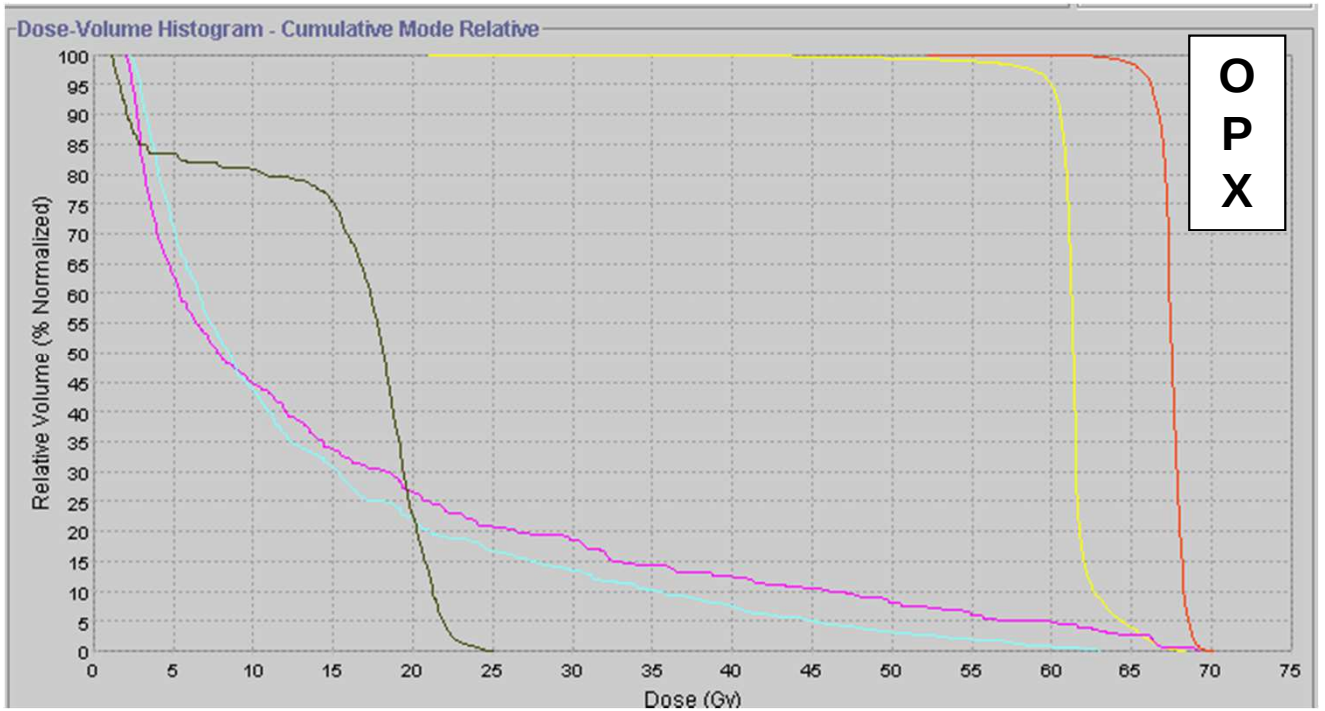


TCRT: Feb 2009

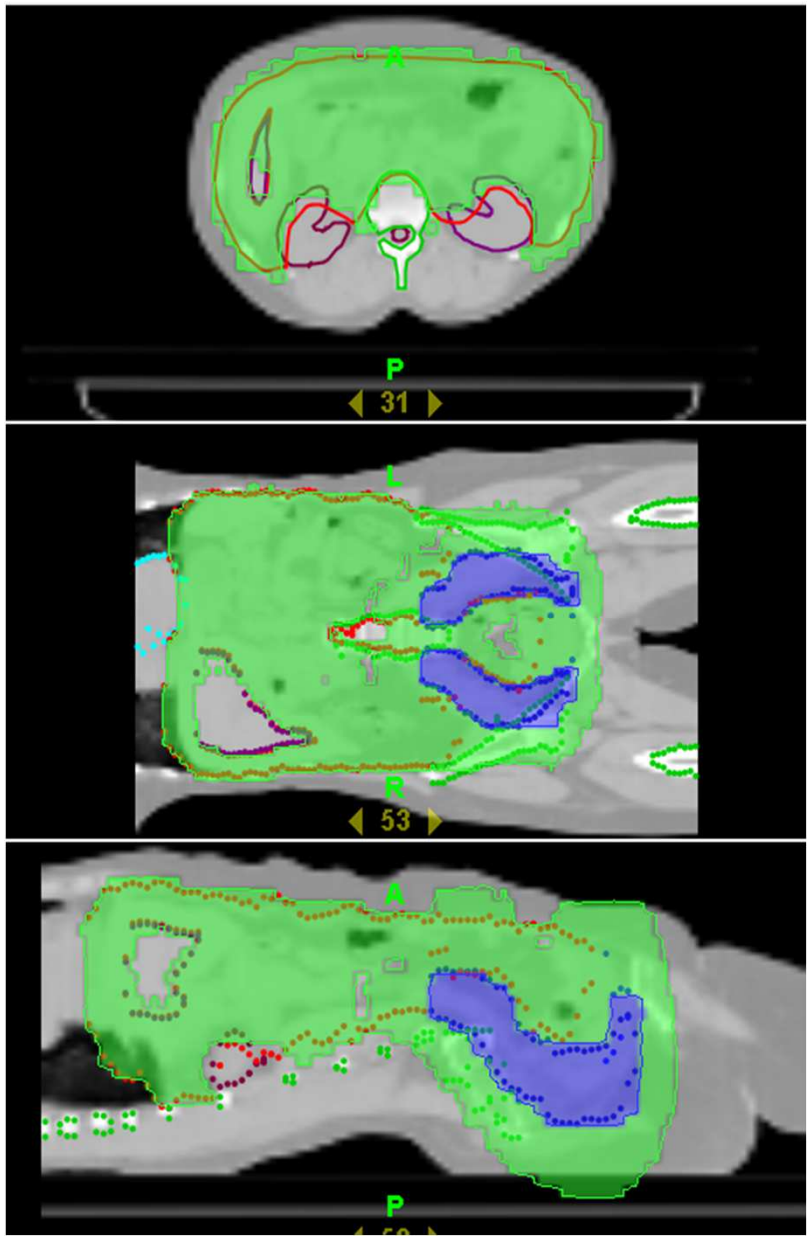

ERMS
NPX
A
P
29
L
R
118
A
P
129

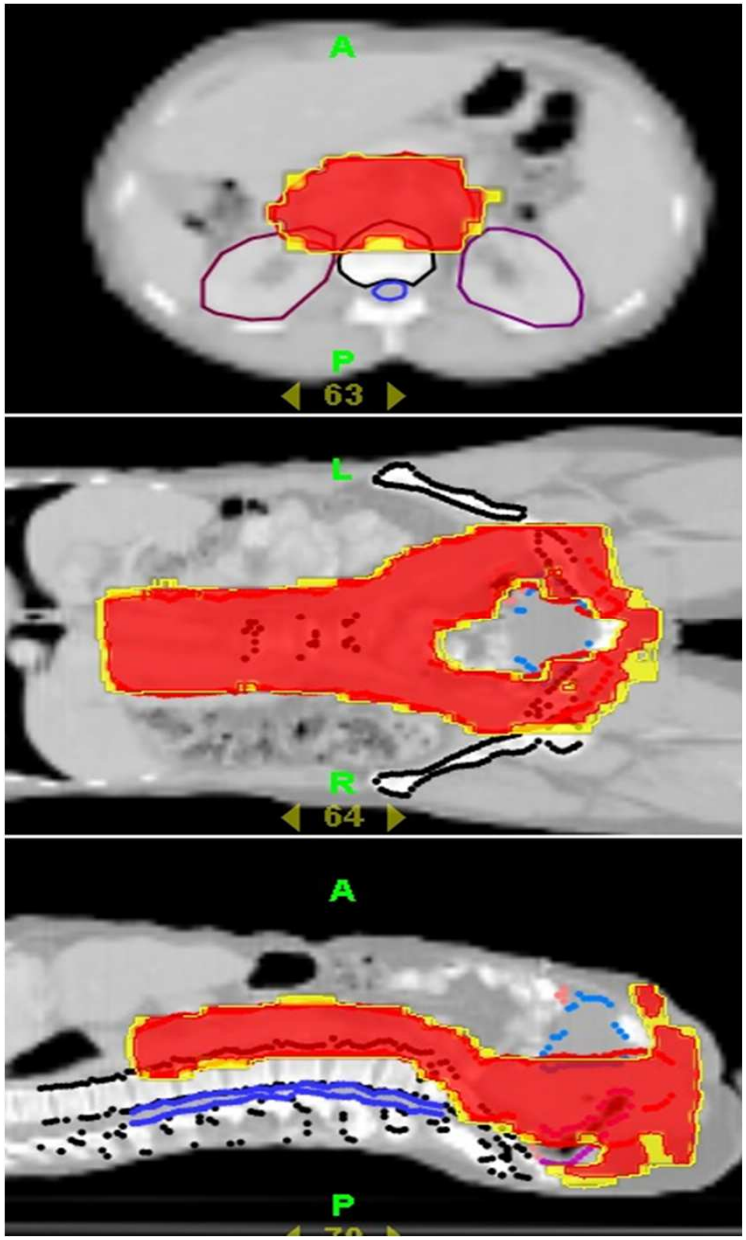

HNSCC-
OPX
A
P
39
L
R
126
A
P

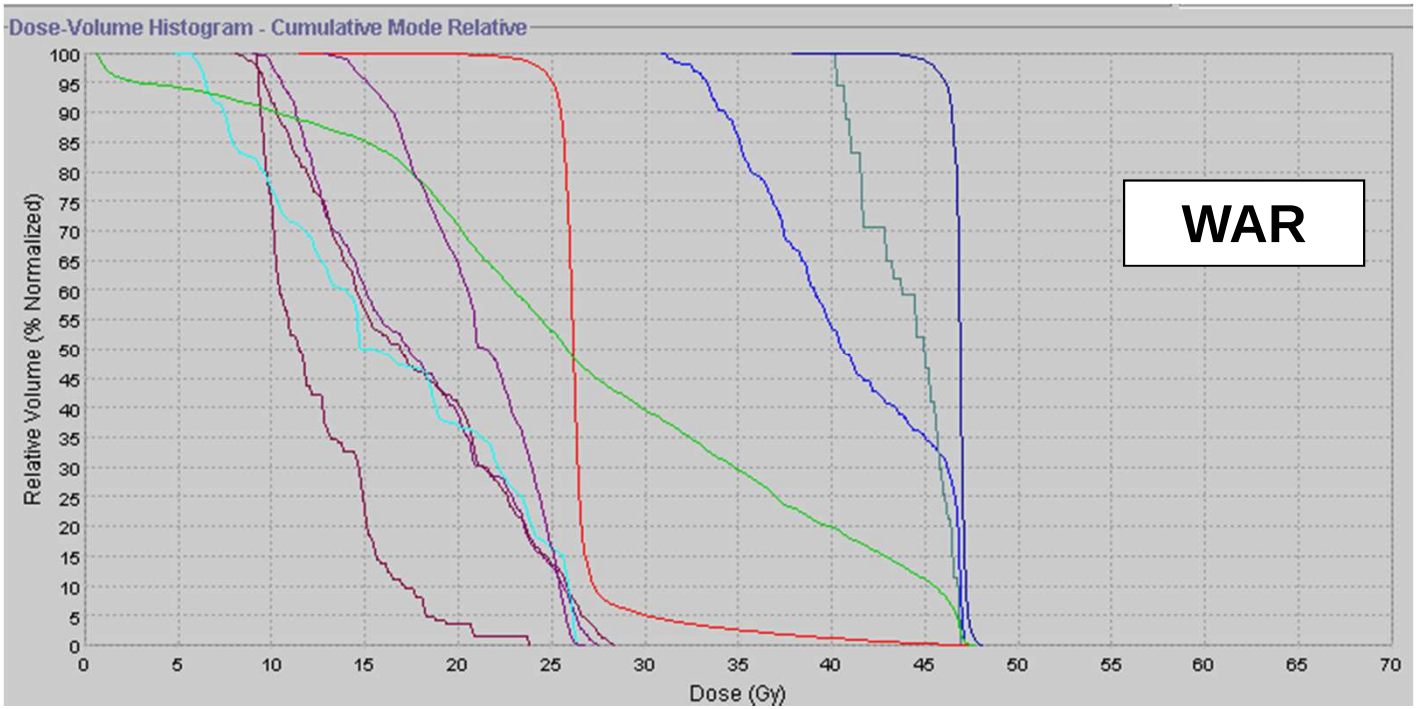

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
NPX
Vol Min < 0.0 >
Vol Max < 100.0 >
Gy Min < 0.0 >
Gy Max < 60.0 >

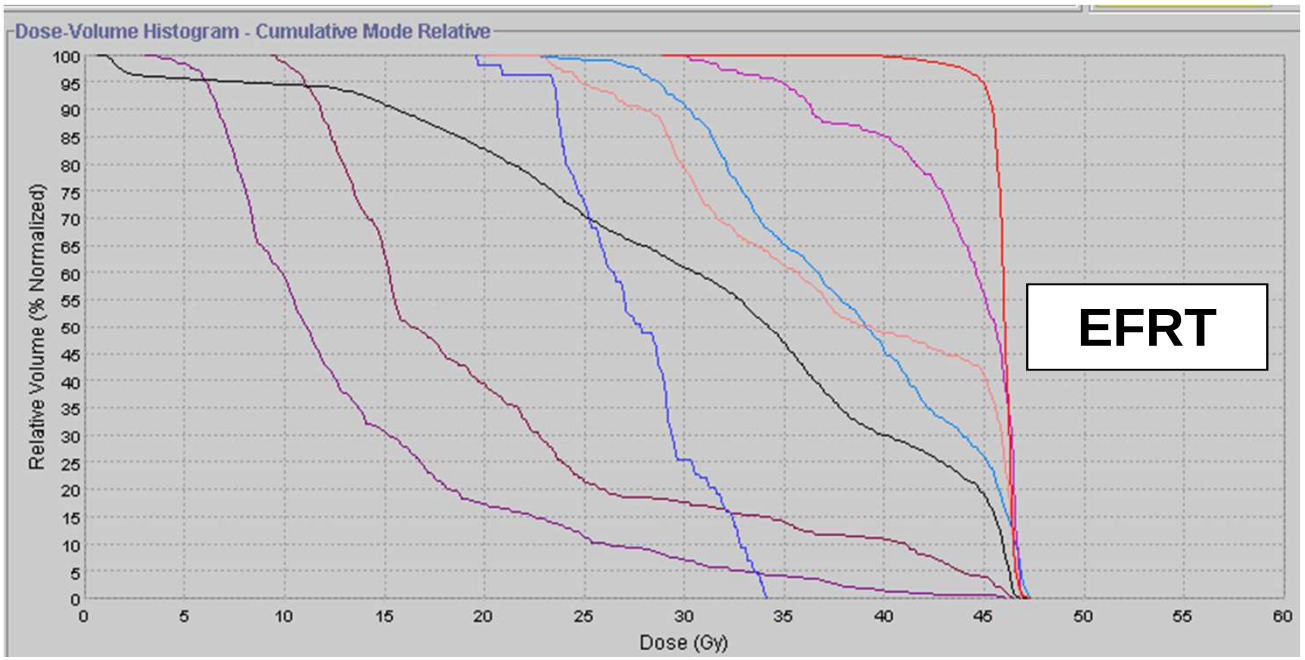

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
OPX

Whole Abdomen Radiotherapy & Extended field Radiotherapy

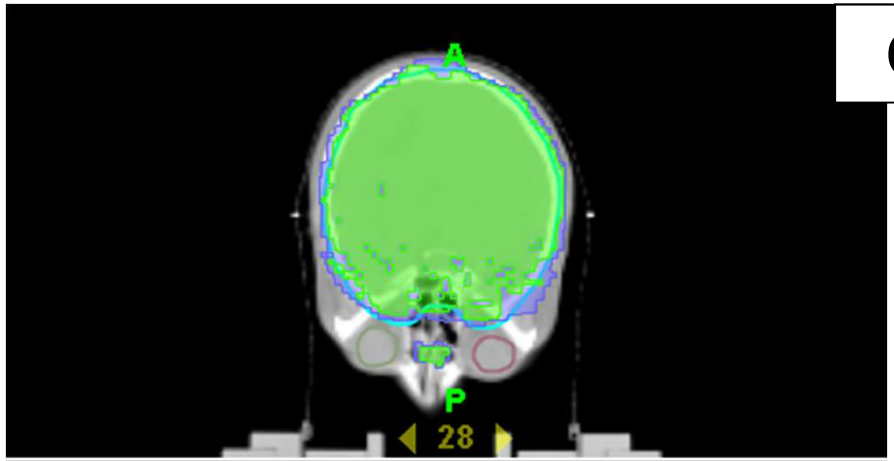


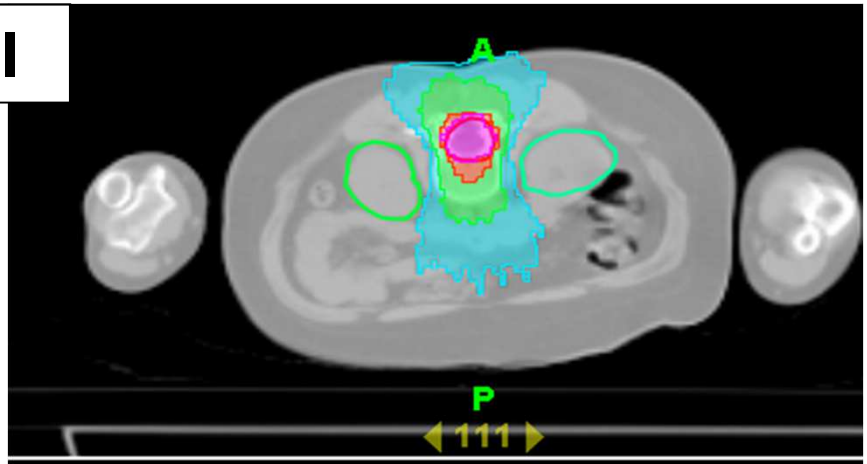


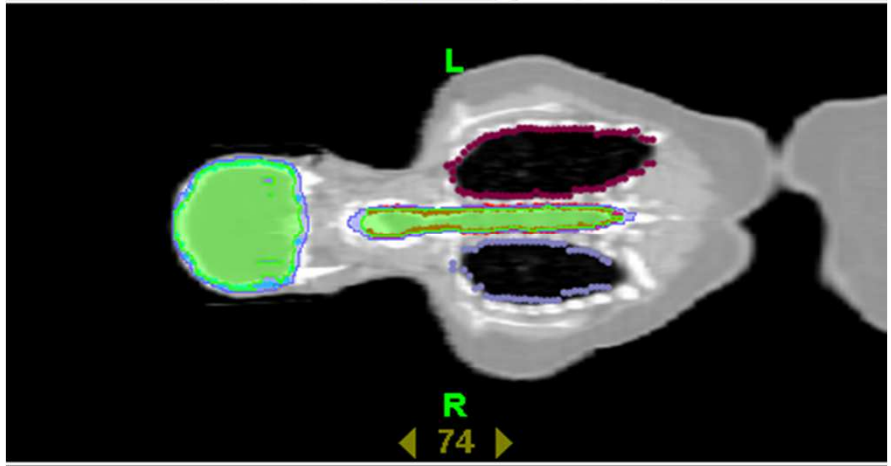

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
WAR

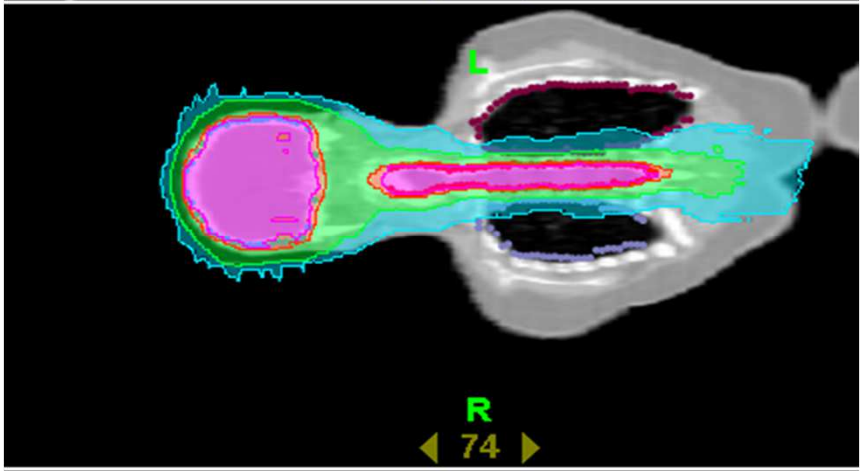

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
EFRT

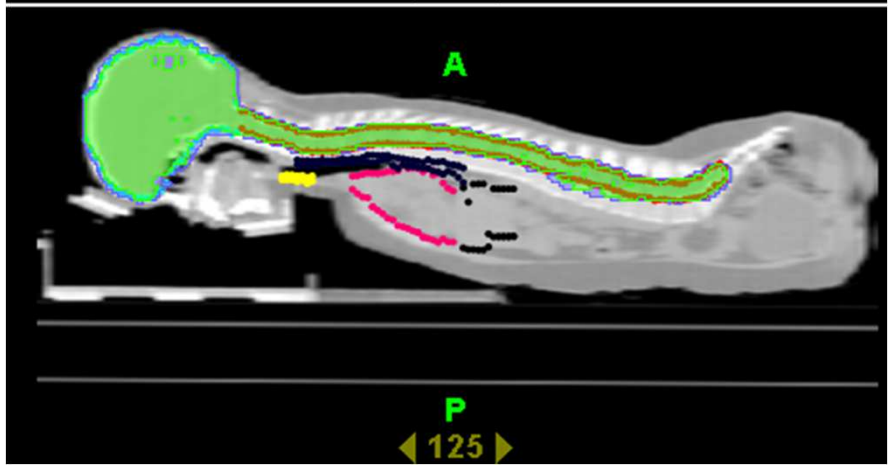
CSI

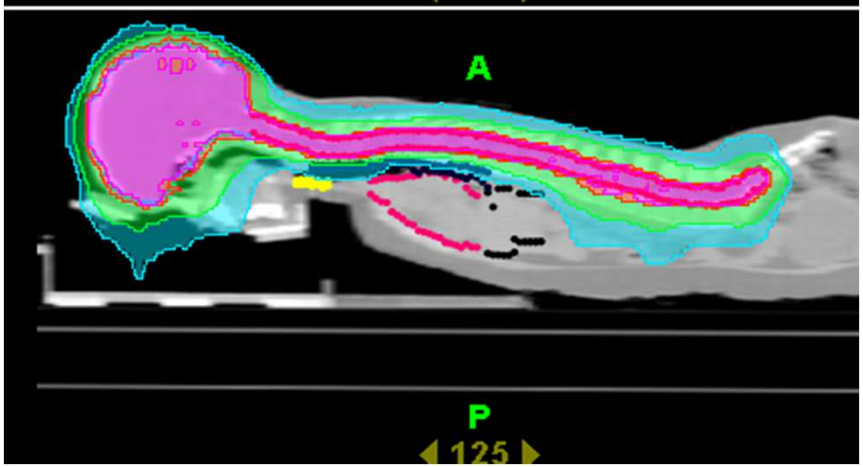




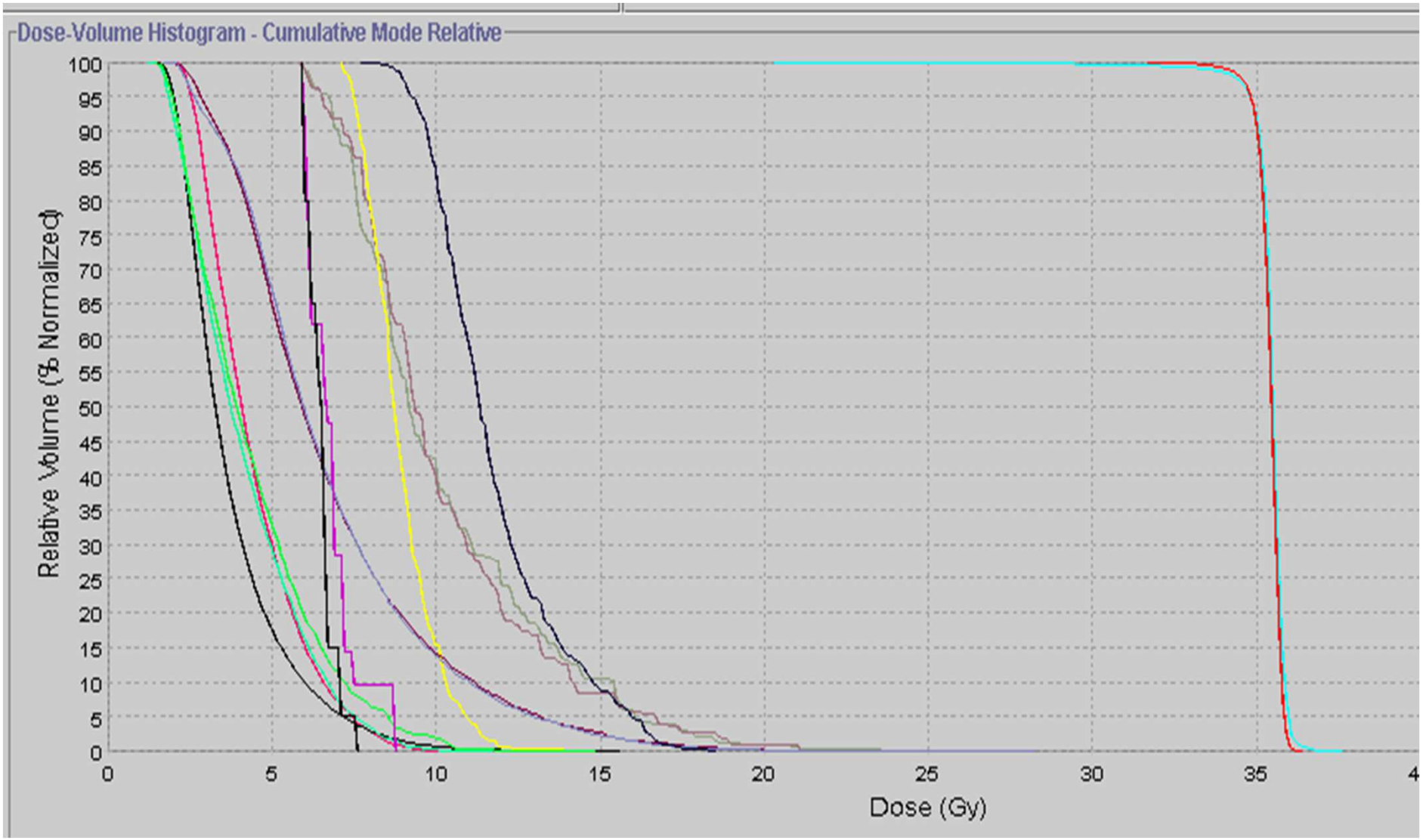




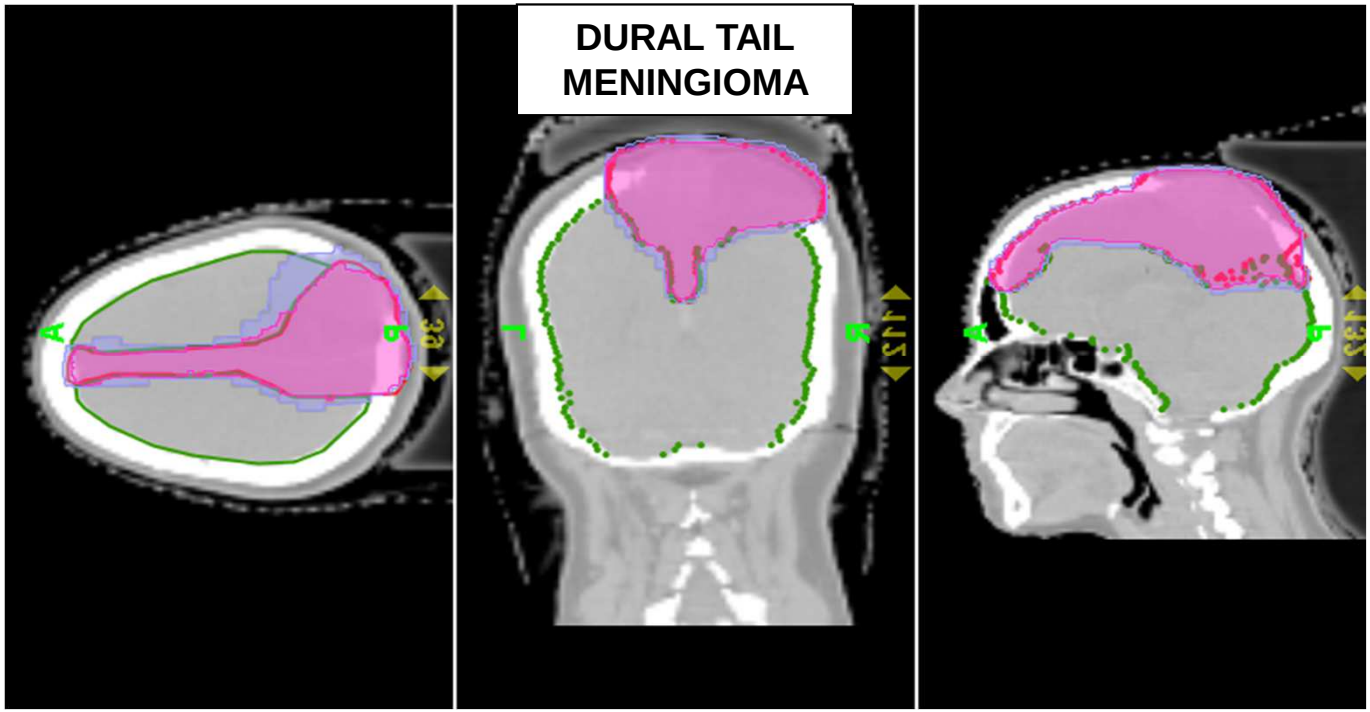


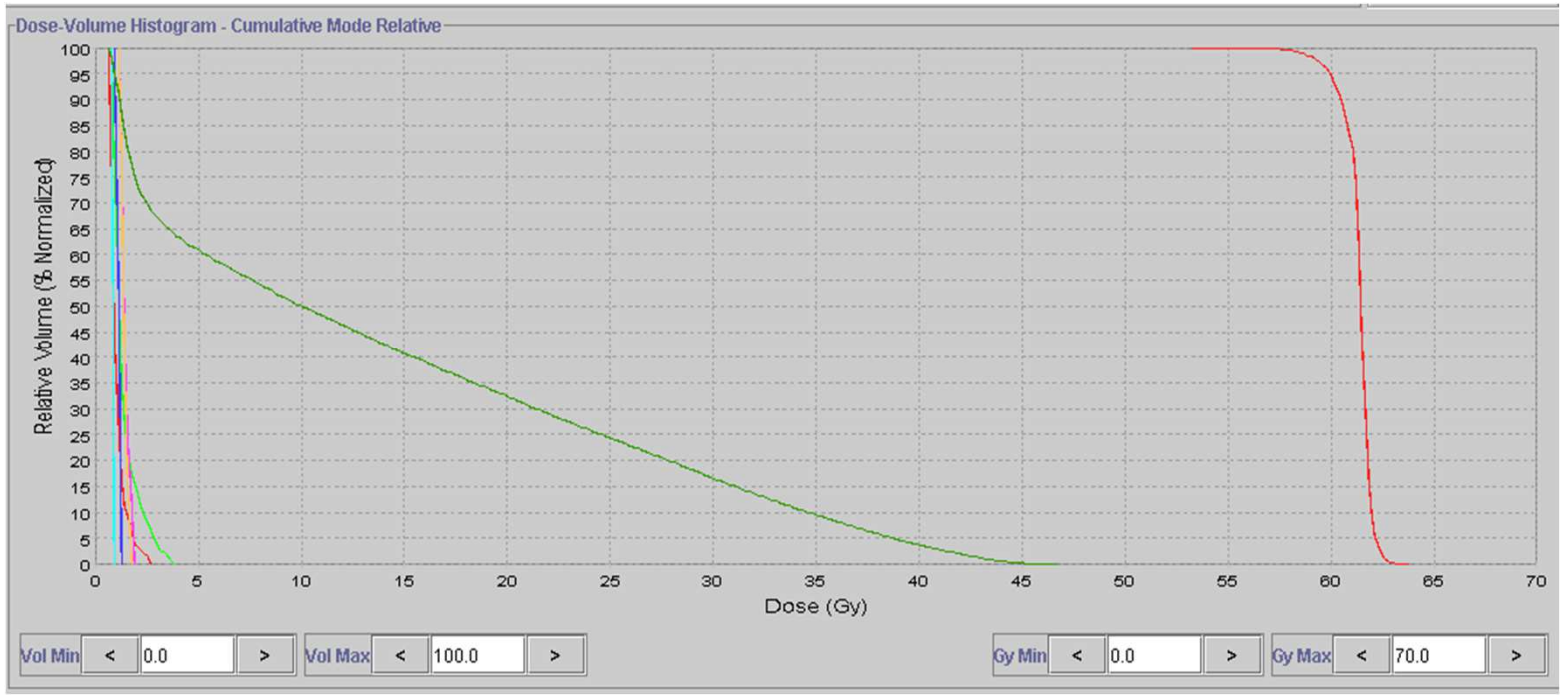


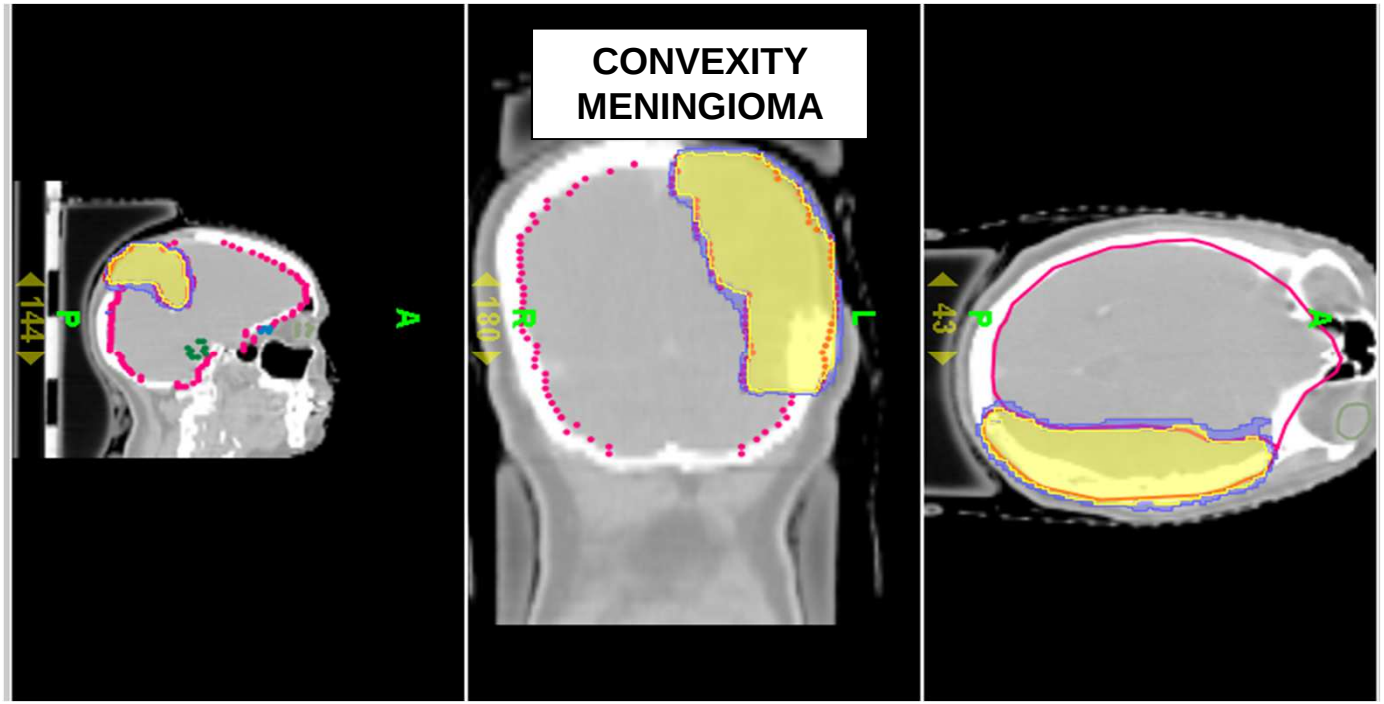
CSI

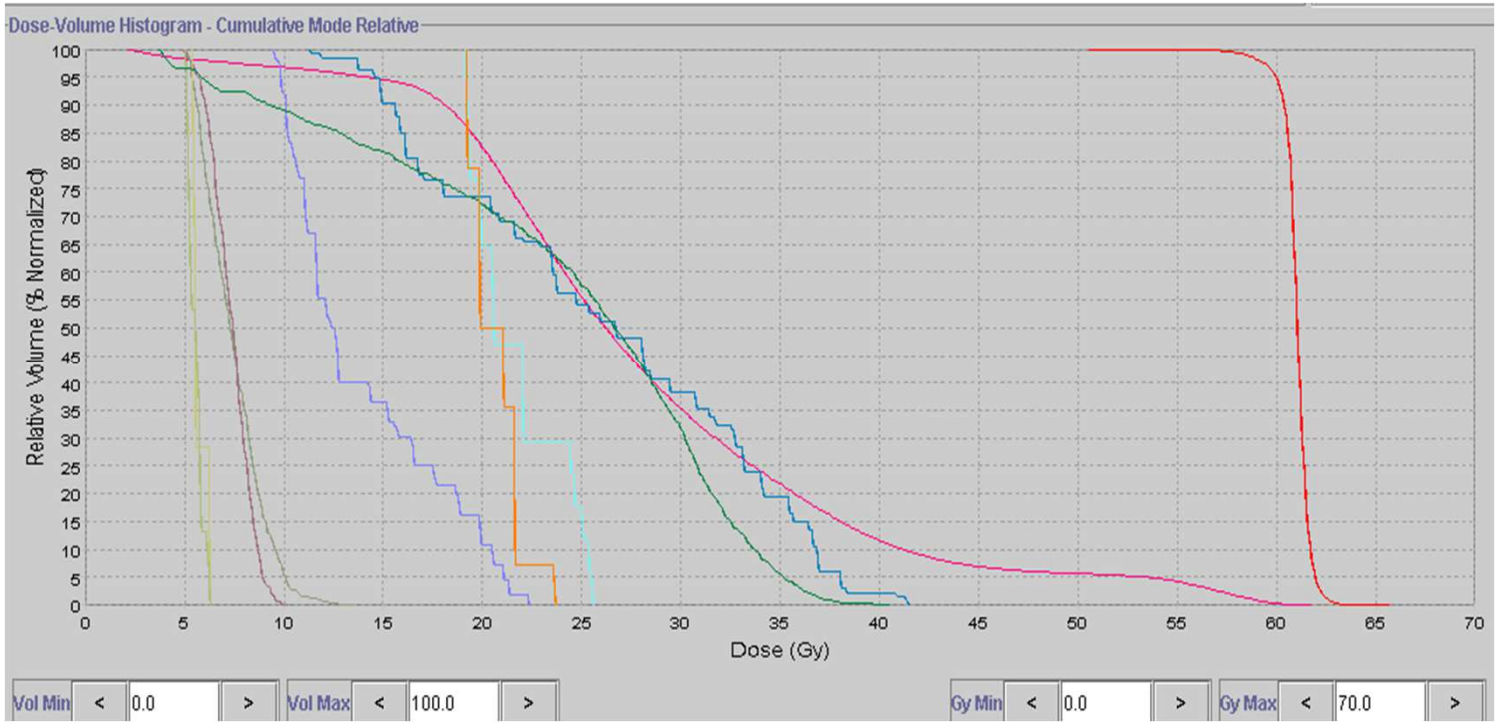

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
Dose (Gy)

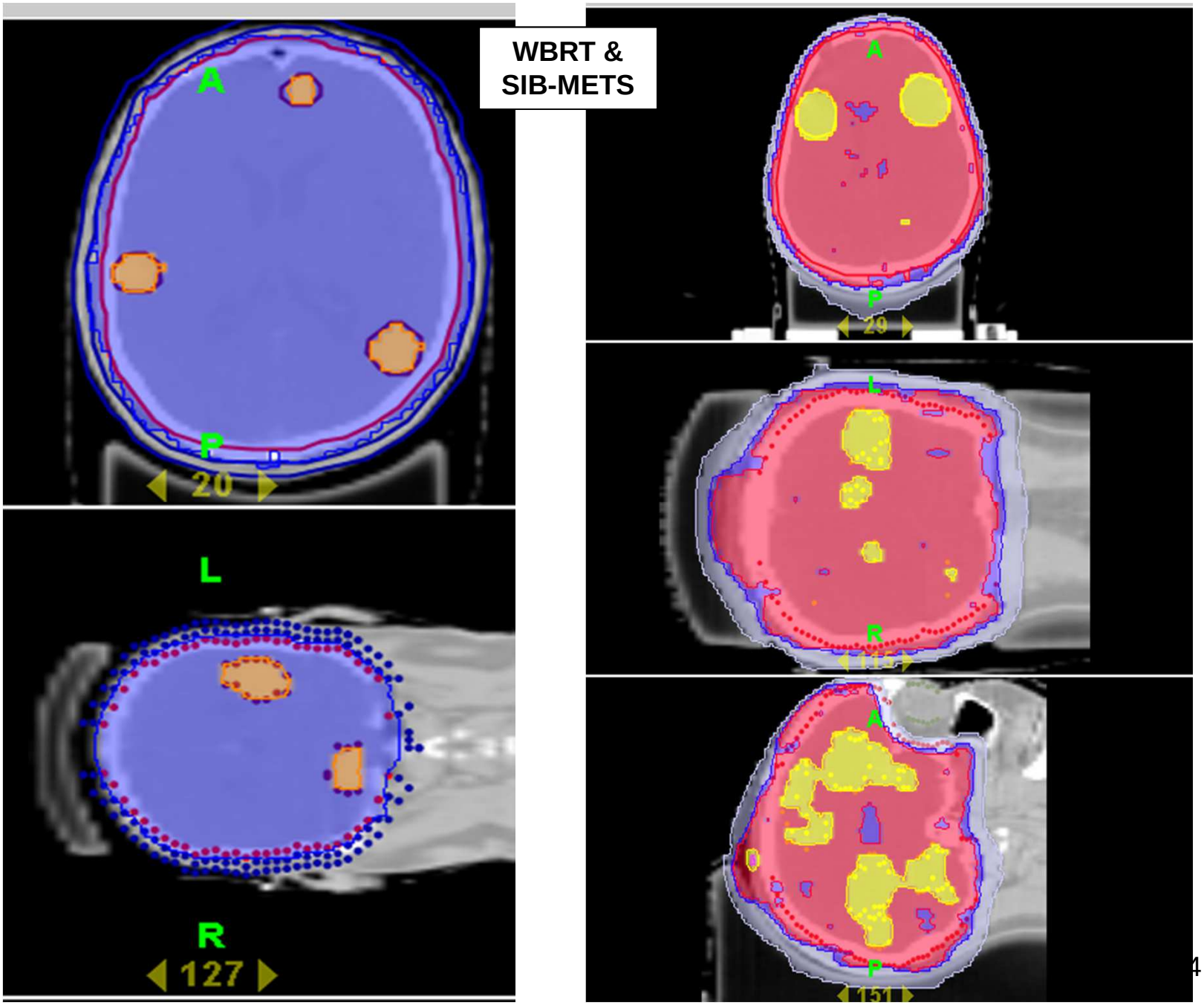
DURAL TAIL MENINGIOMA



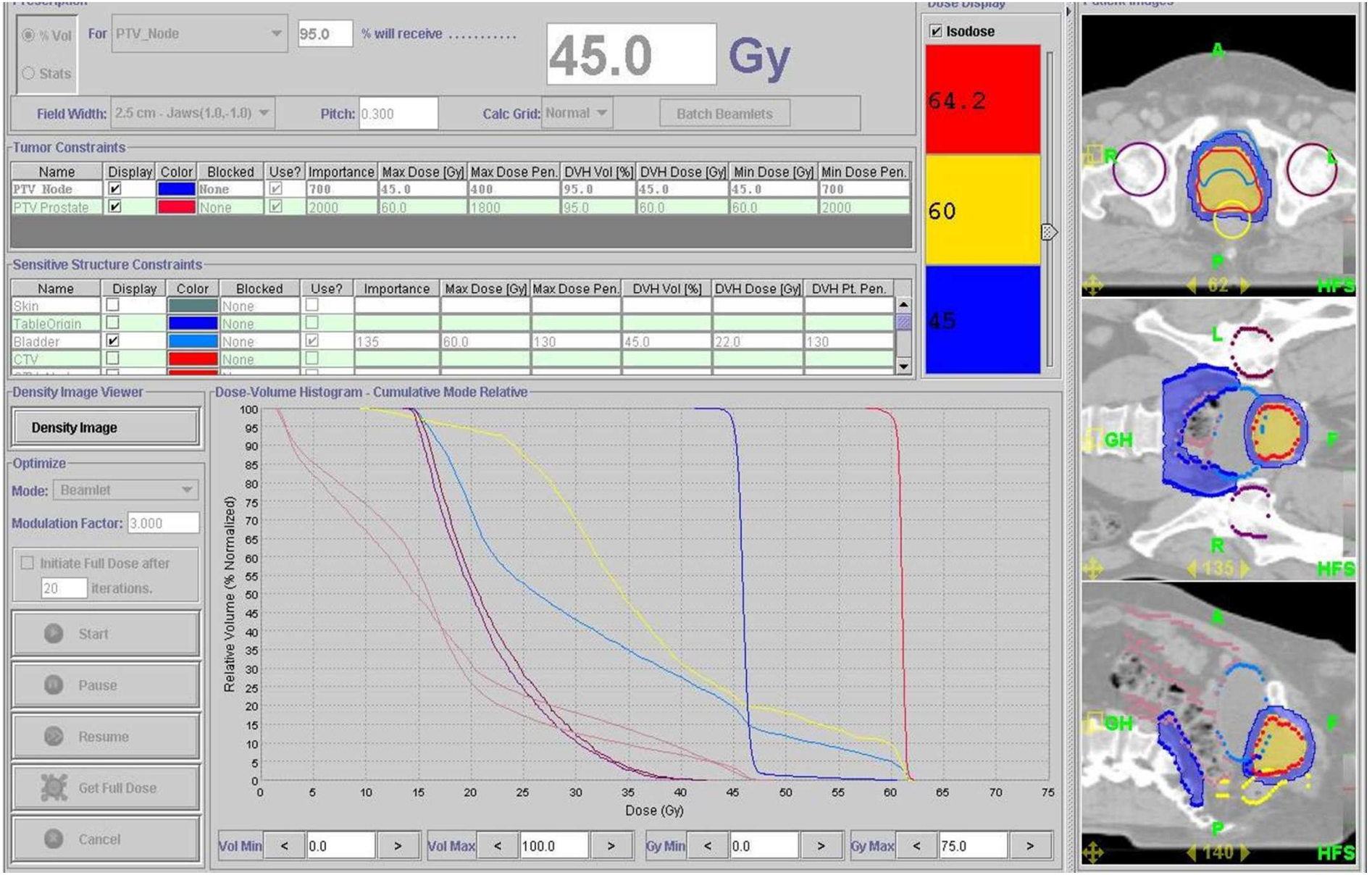


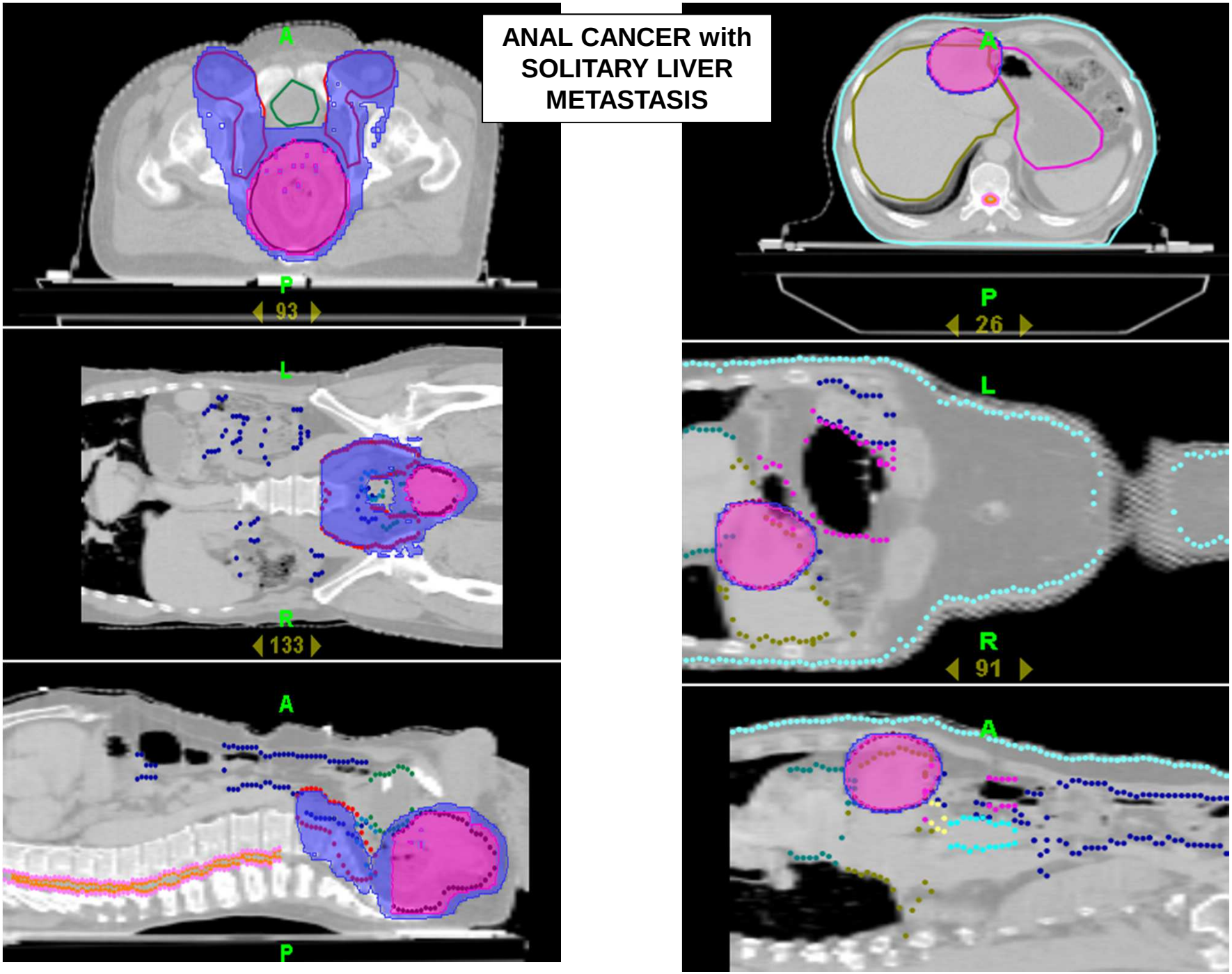

CONVEXITY
MENINGIOMA
144
P
A
180
R
L
43
P
A

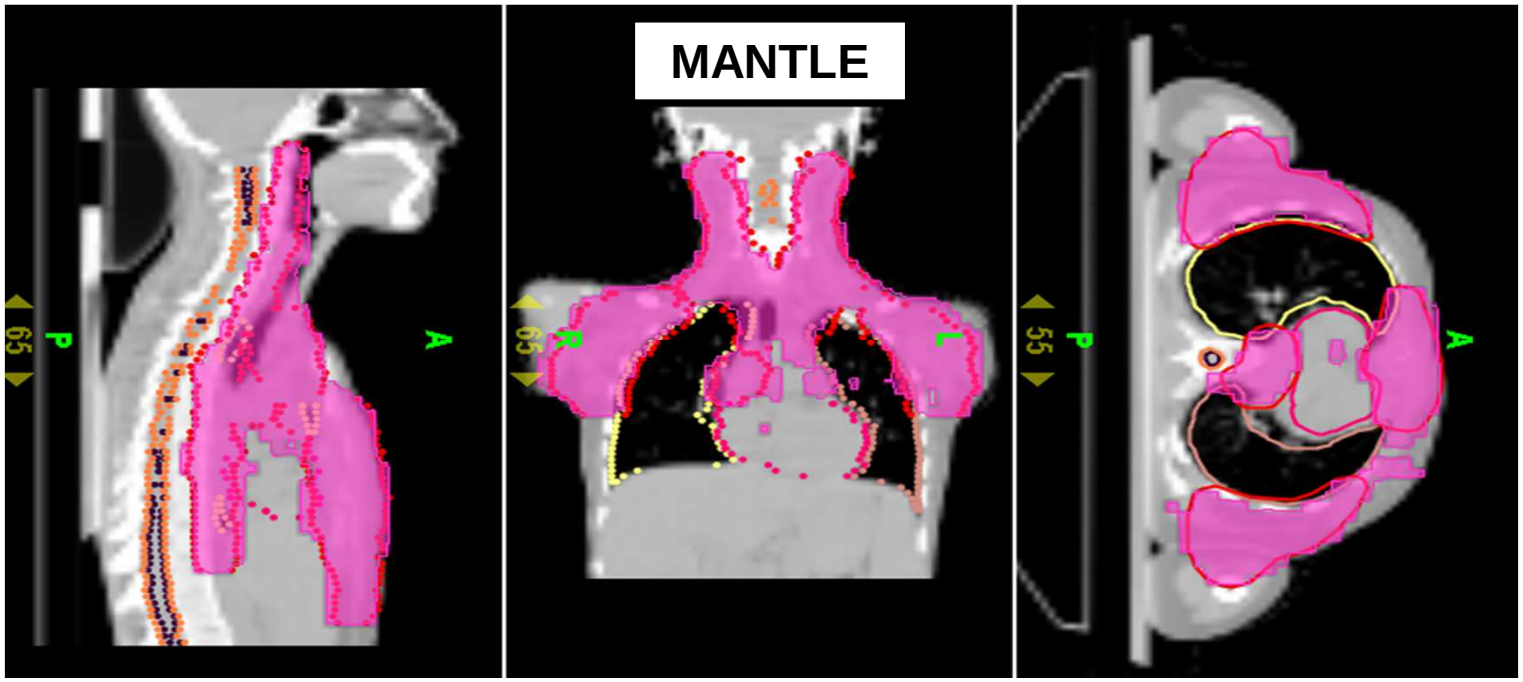

Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
Vol Min
0.0
Vol Max
100.0
Gy Min
0.0
Gy Max
70.0

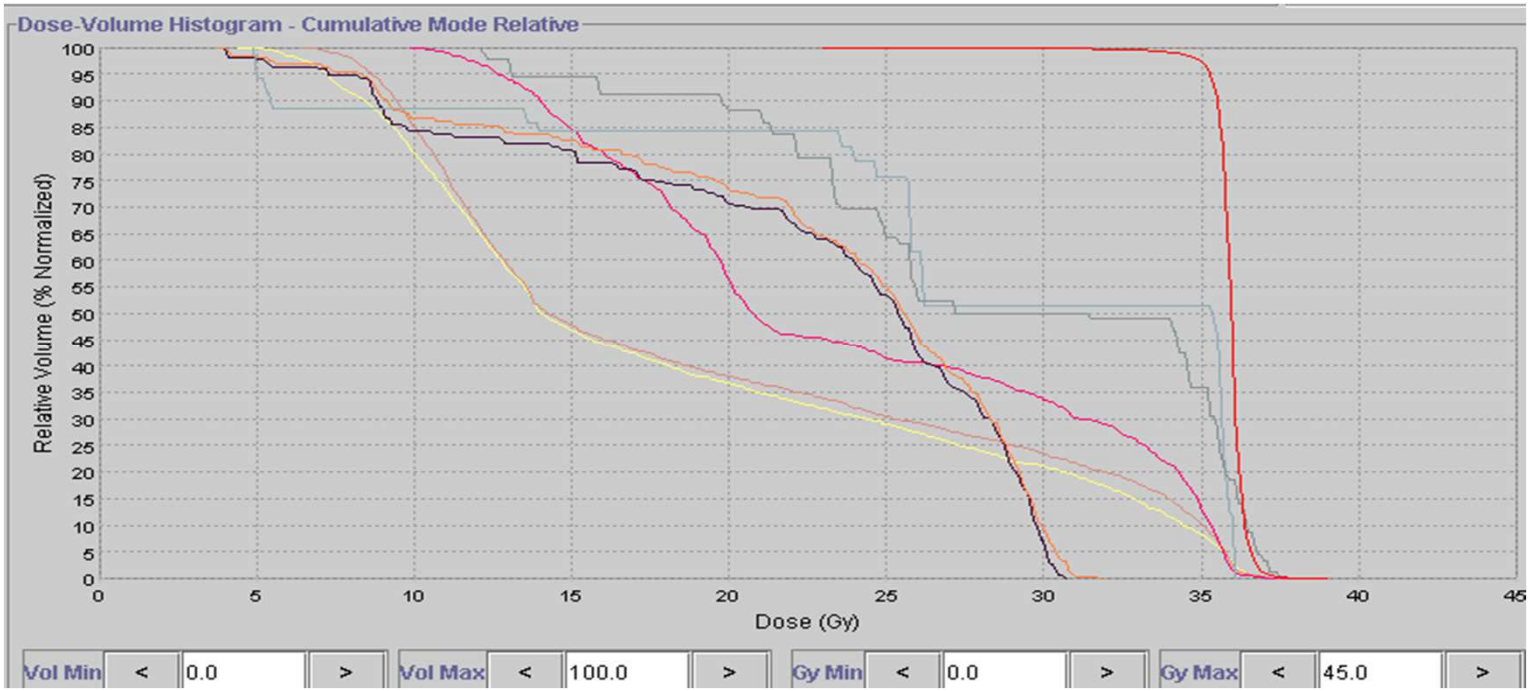

WBRT &
SIB-METS
A
P
20
L
R
127
A
P
29
L
R
A
P
151

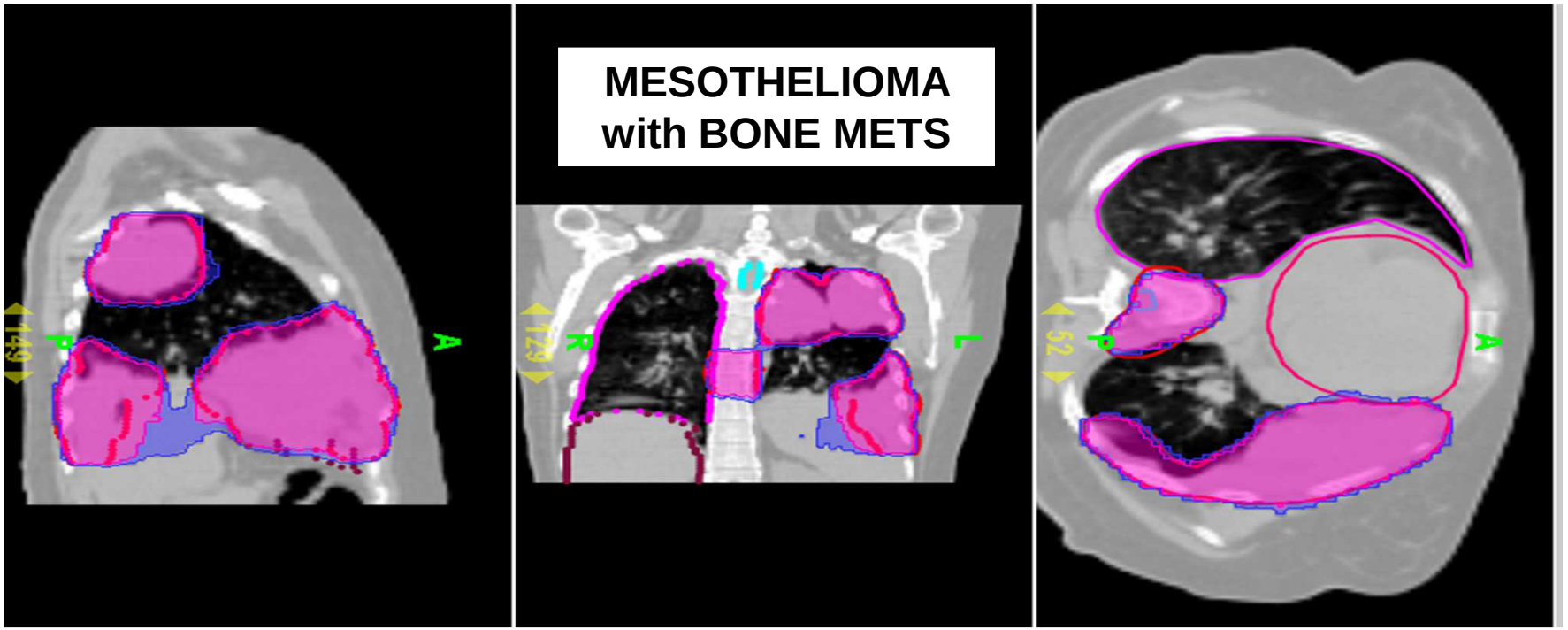
Prostate plus pelvic lymph nodes irradiation

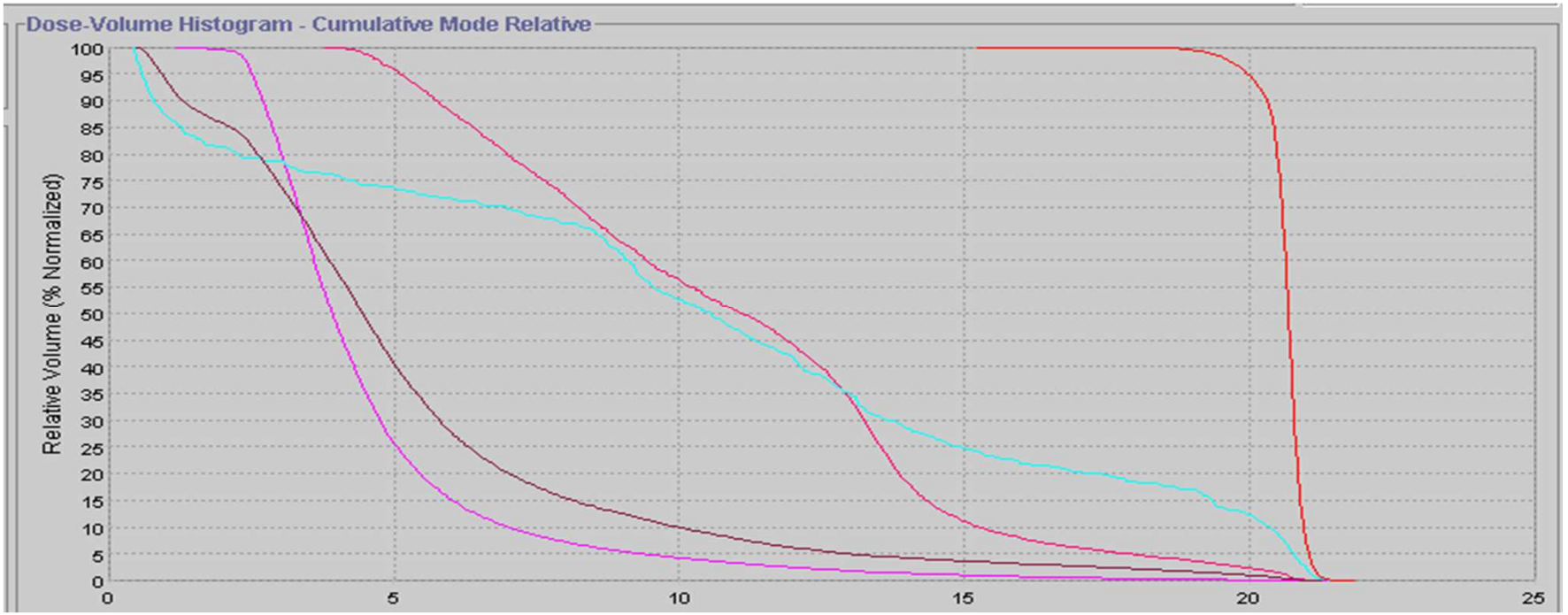


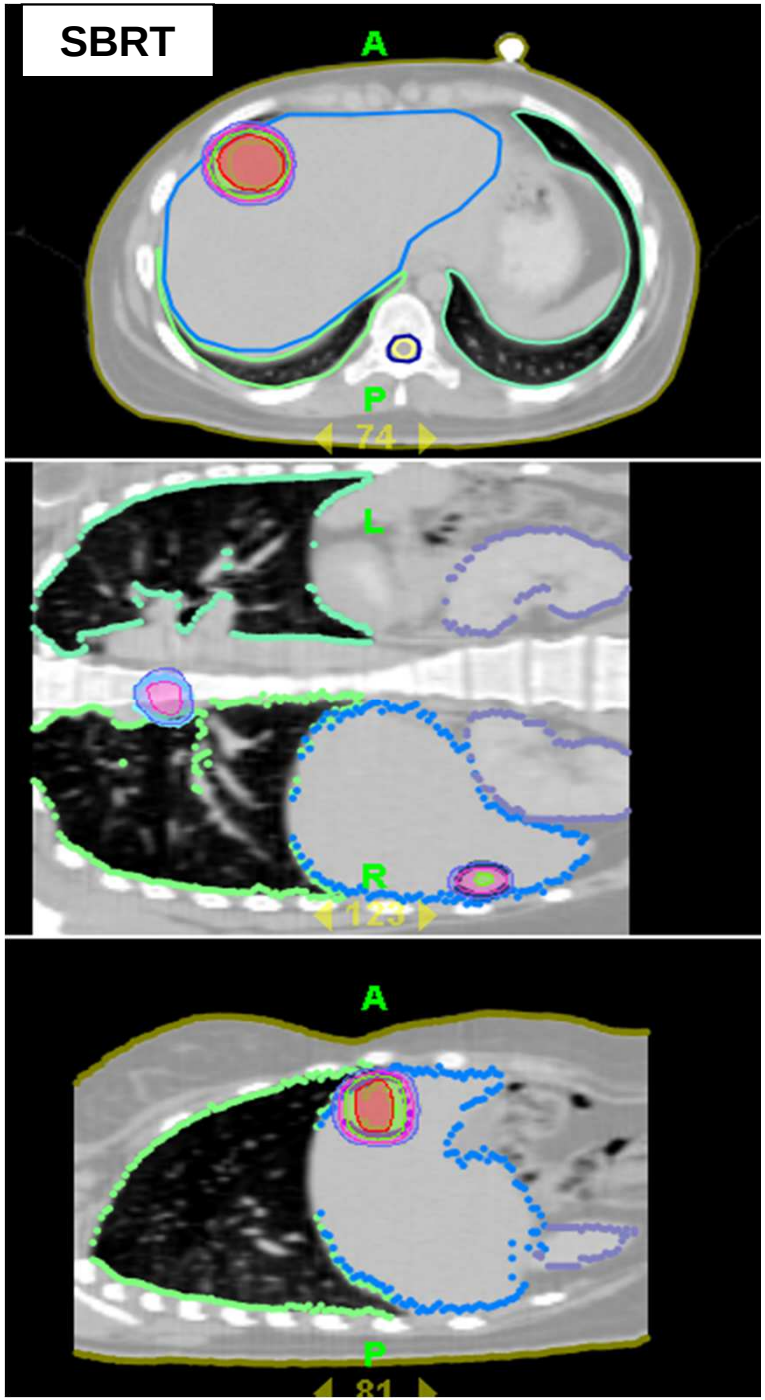

ANAL CANCER with SOLITARY LIVER METASTASIS
A
P
93
L
R
133
A
P
A
P
26
L
R
91
A

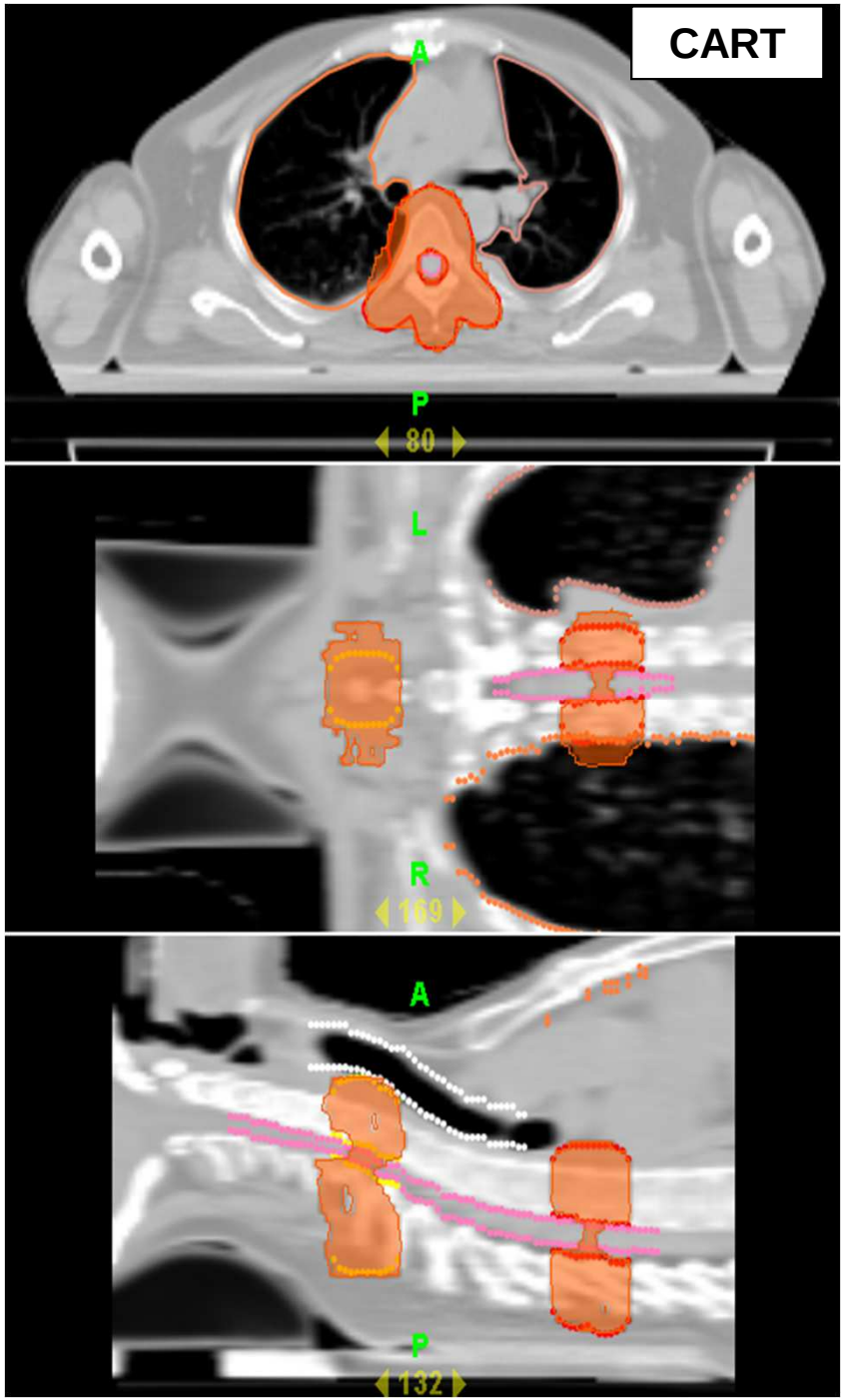

MANTLE
P
A
65
R
L
65
P
A
55


Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)
Vol Min
0.0
Vol Max
100.0
Gy Min
0.0
Gy Max
45.0

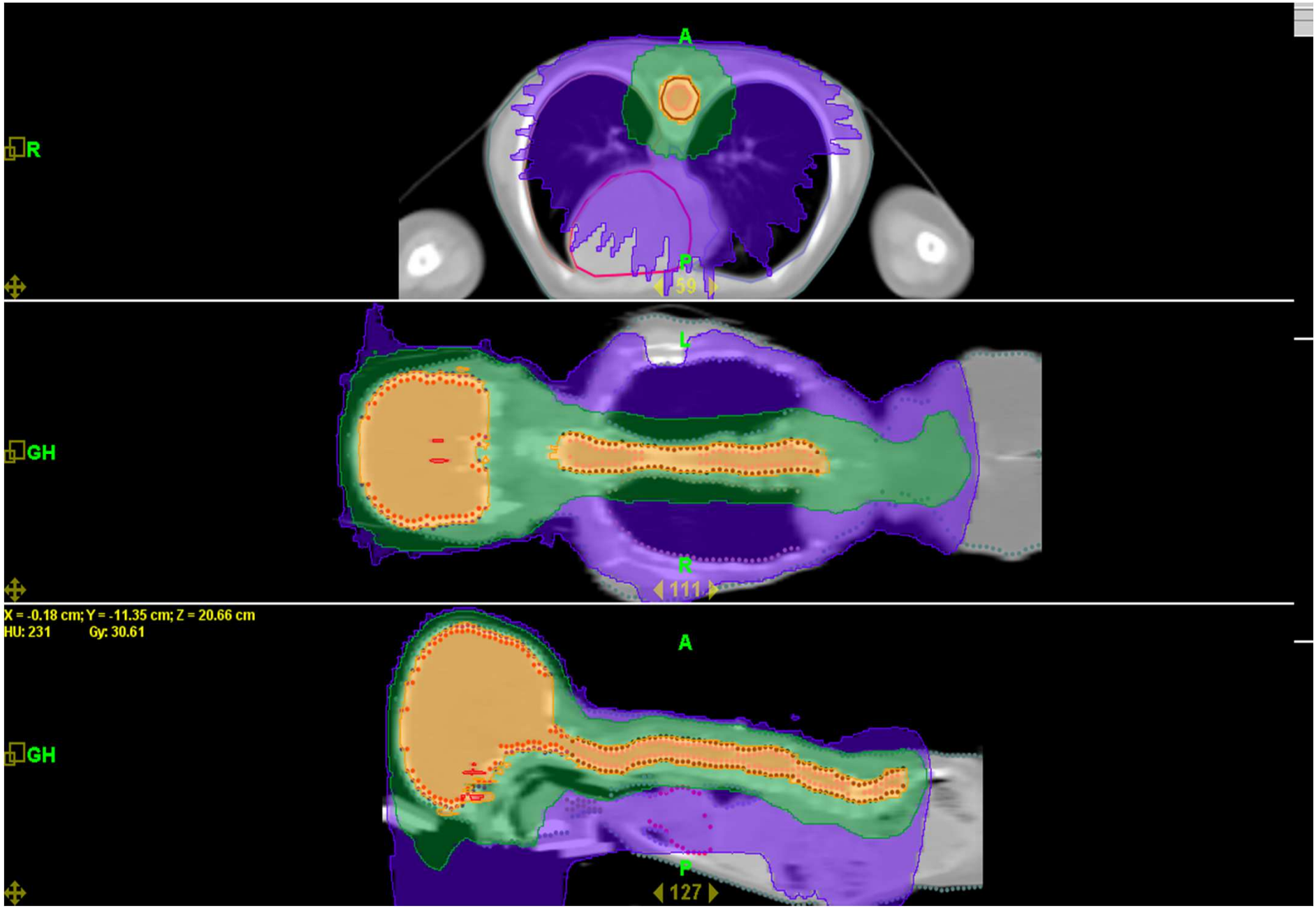

MESOTHELIOMA
with BONE METS
149
P
A
129
R
L
52
P
A


Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25

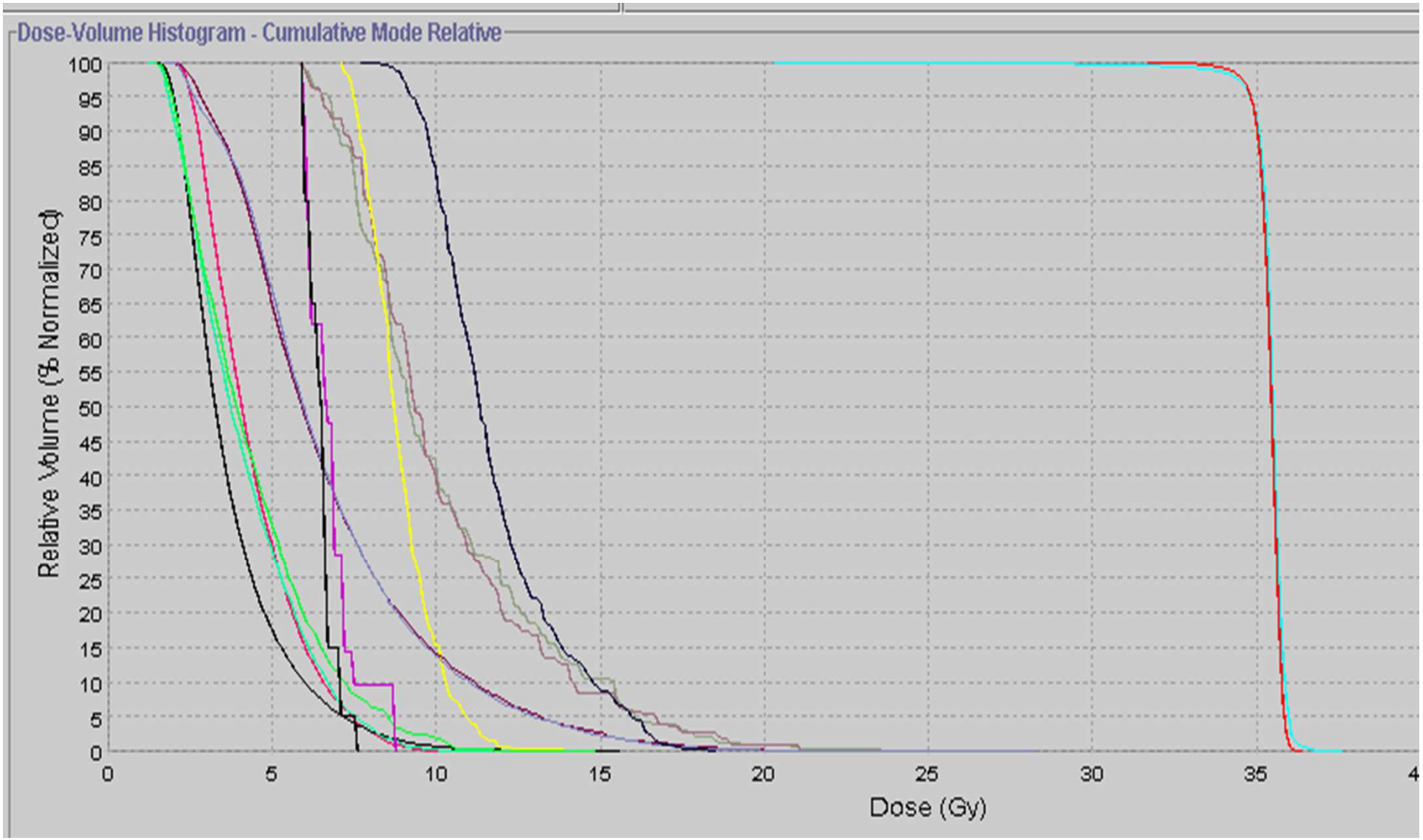

SBRT
A
P
74
L
R
123
A
P
81


CART
A
P
80
L
R
169
A
P
132

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

Int. J. Radiation Oncology Biol. Phys., Vol. 67, No. 4, pp. 1259–1267, 2007

0360-3016/07/$–see front matter

doi:10.1016/j.ijrobp.2006.10.047

PHYSICS CONTRIBUTION

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

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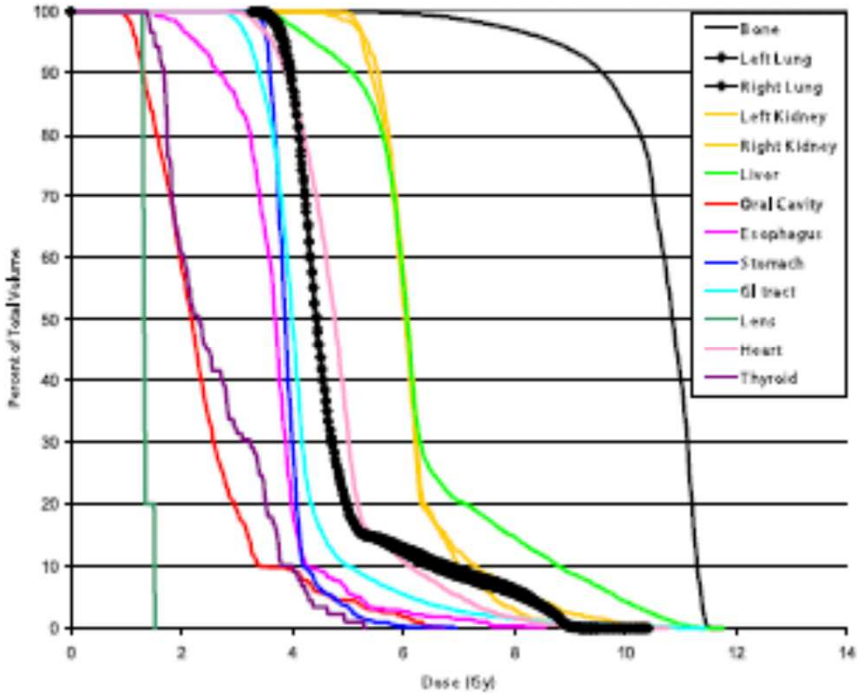
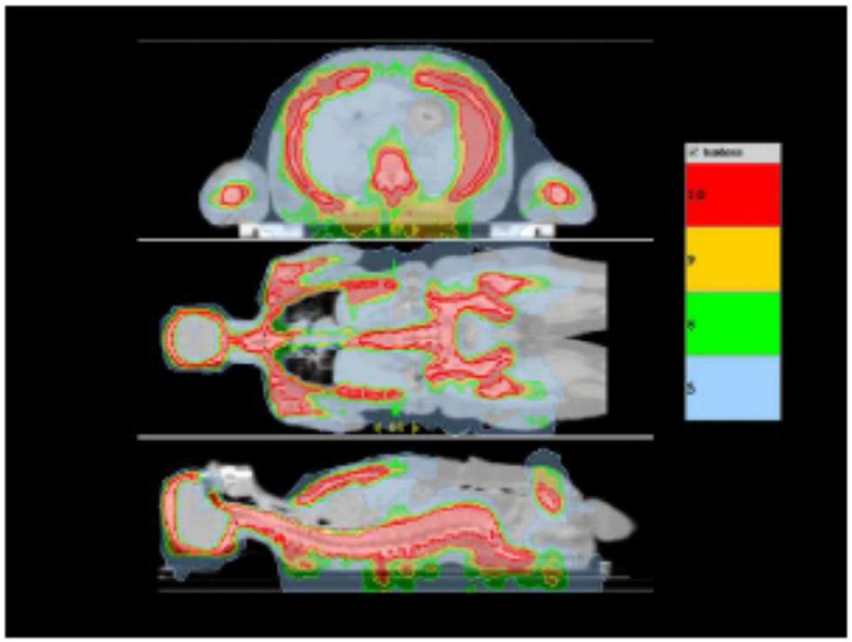
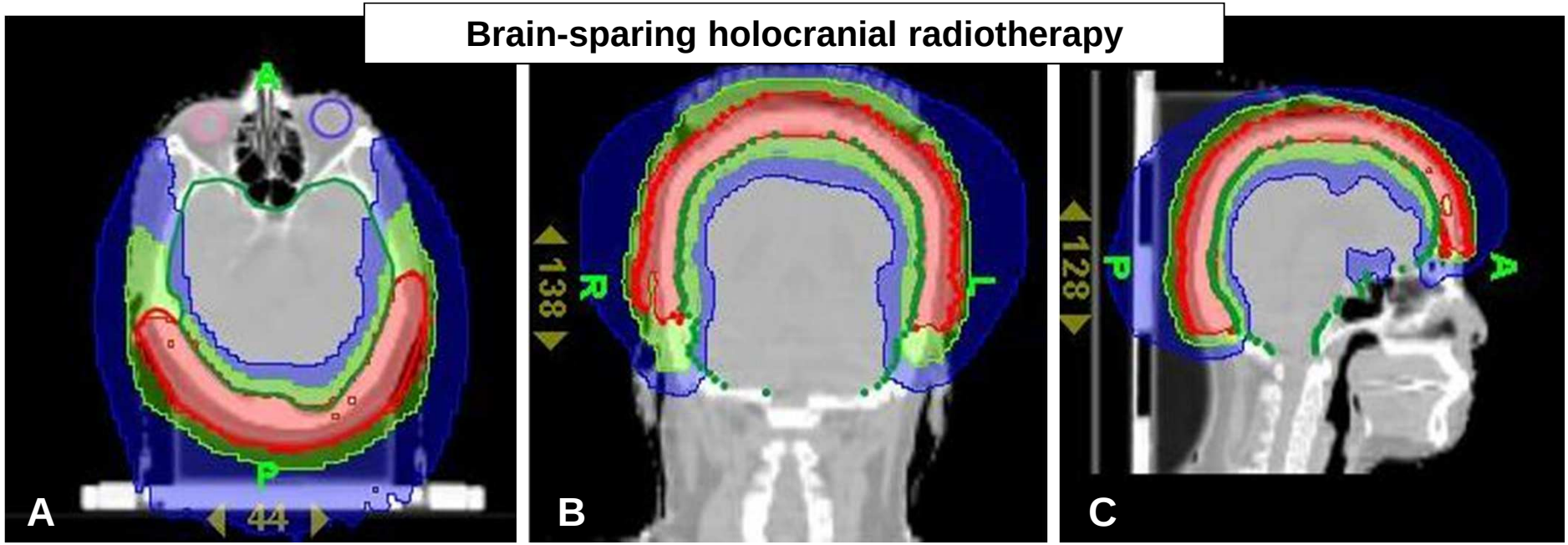
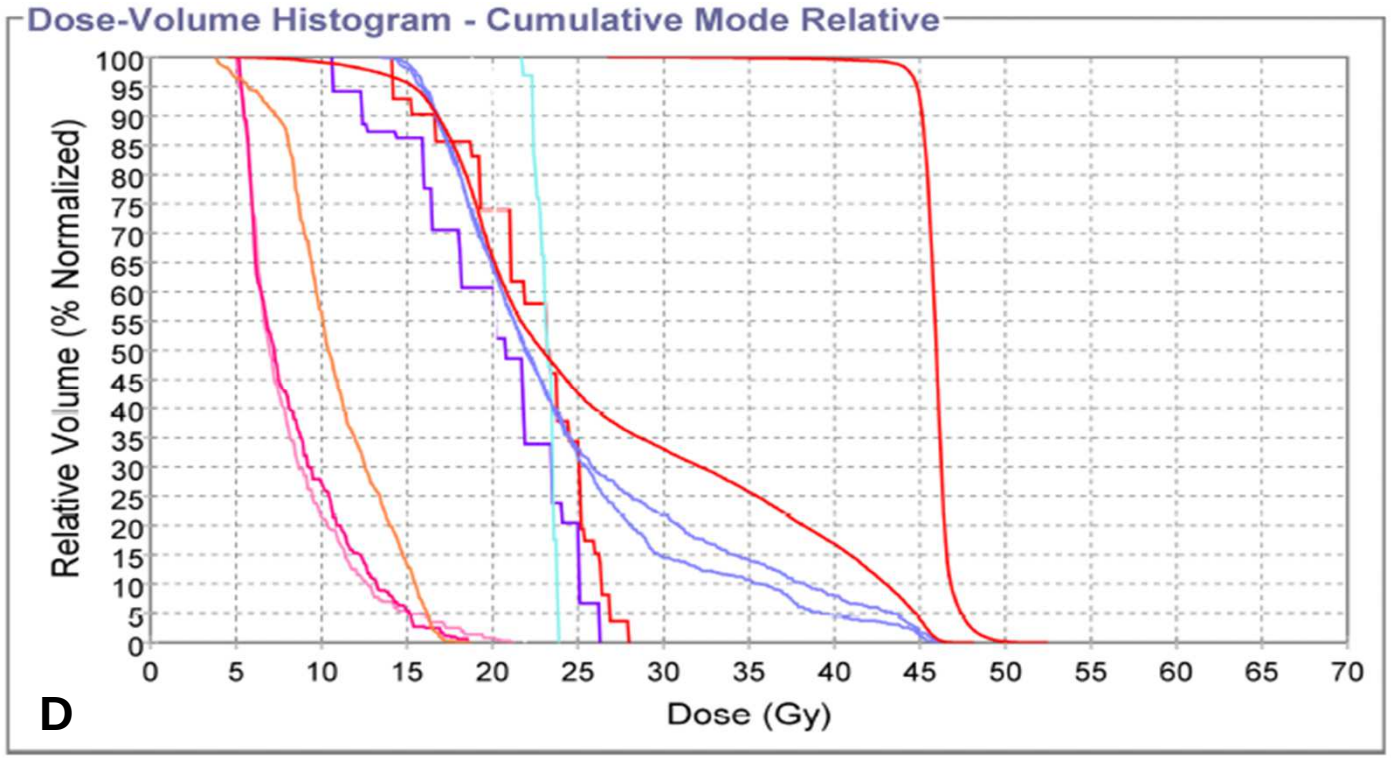
Department of *Radiation Oncology and ‡Medical Oncology, City of Hope Cancer Center, Duarte, CA; †Tomotherapy, Inc., Madison, WI

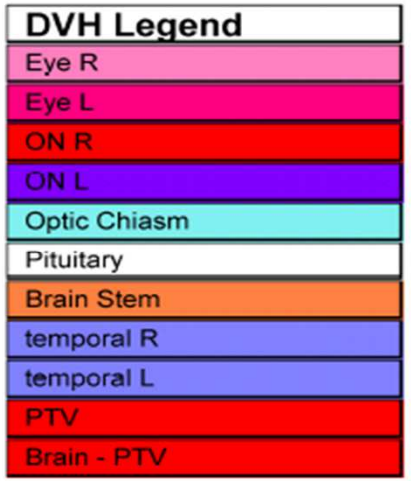




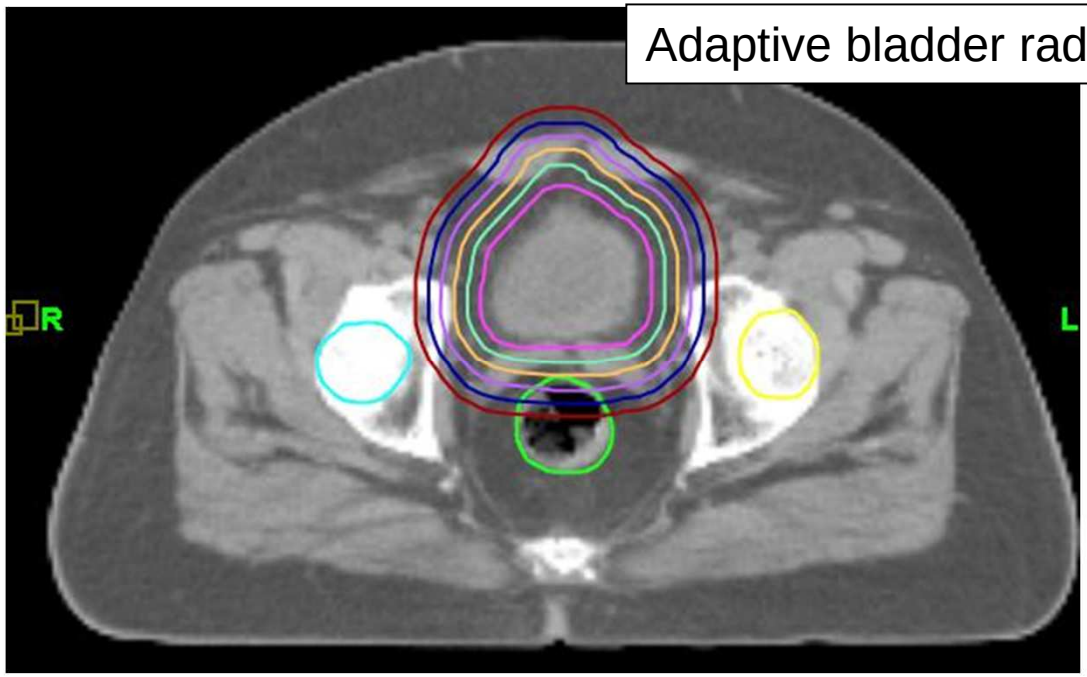
Brain-sparing holocranial radiotherapy

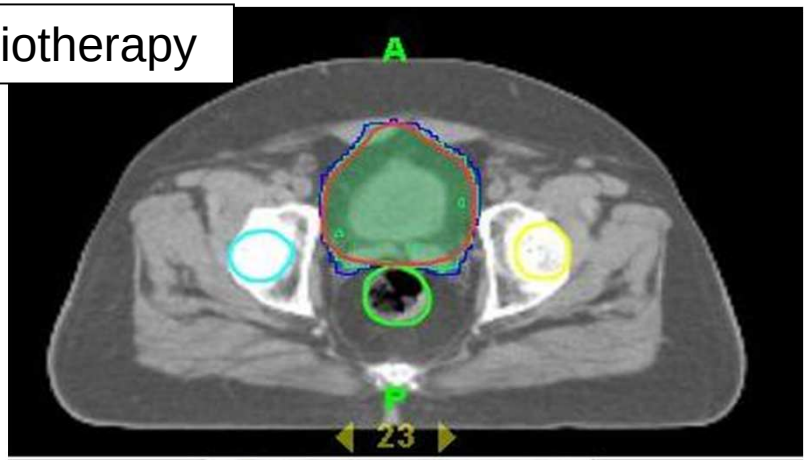


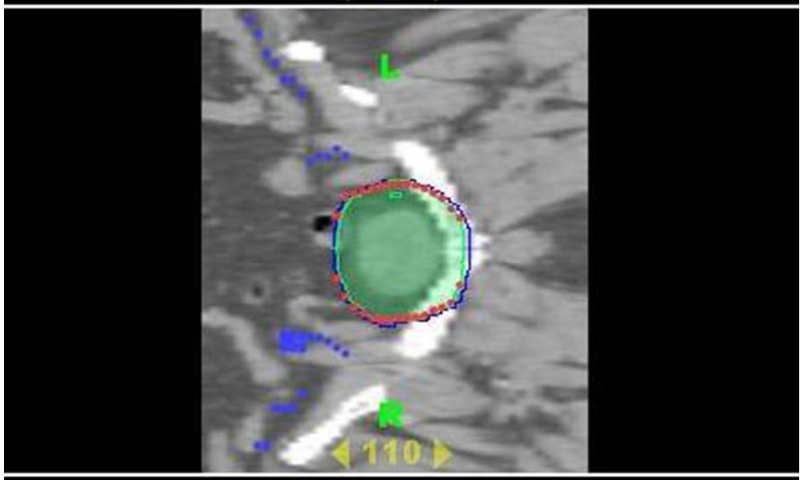


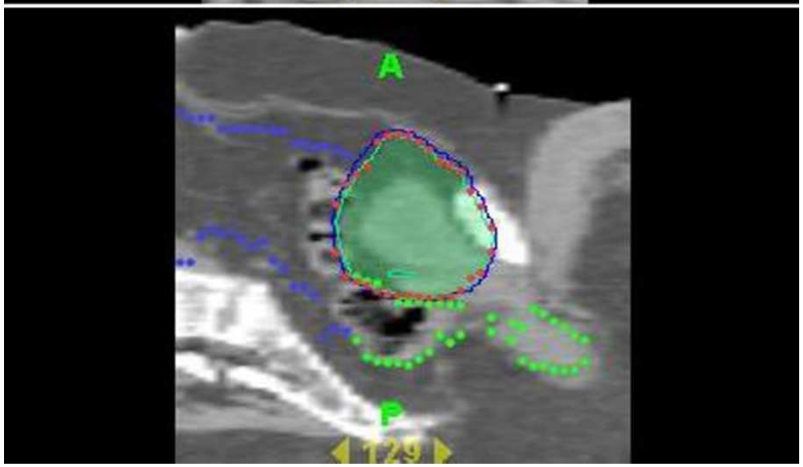


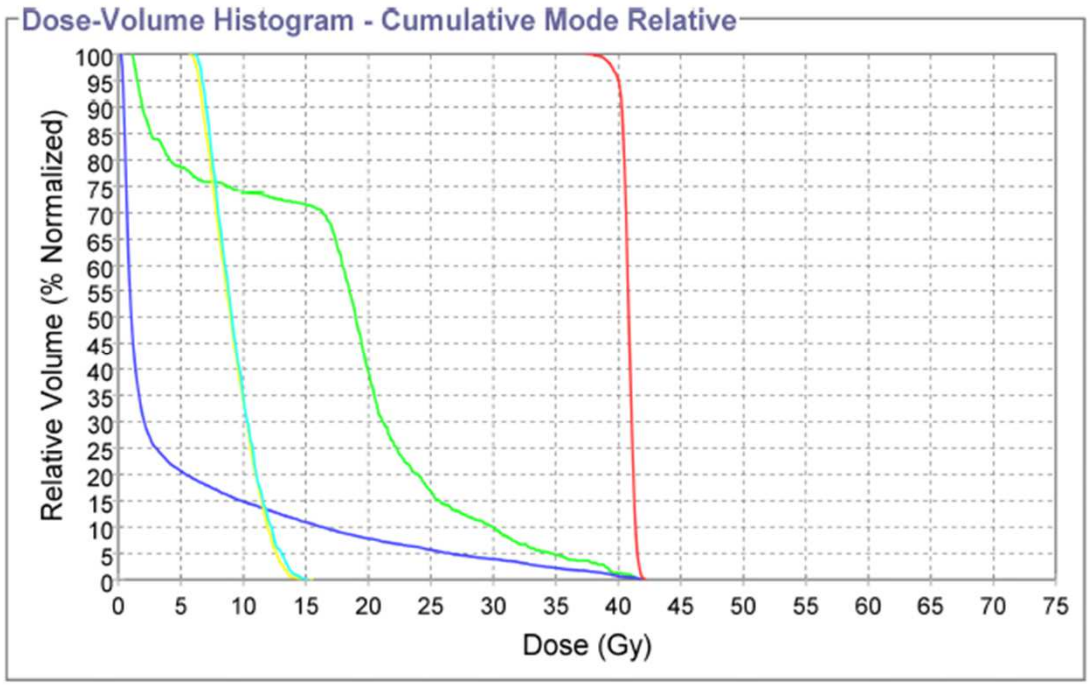
Adaptive bladder radiotherapy











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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