
CyberKnife
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Purpose

- To familiarize Rad Onc PG students on the availability of newer conformal Radiotherapy equipments-Cyber Knife

- To know about Cyber Knife-Definition, Components, principles, advantages, limitations, clinical applications, future directions.

CyberKnife

- Image guided Robotic Radio surgery system that uses a compact Linear accelerator mounted on robotic arm to deliver concentrated beam of radiation to the targeted tumor from multiple positions and angles.

CyberKnife:

Frameless,

Fractionated/Single,

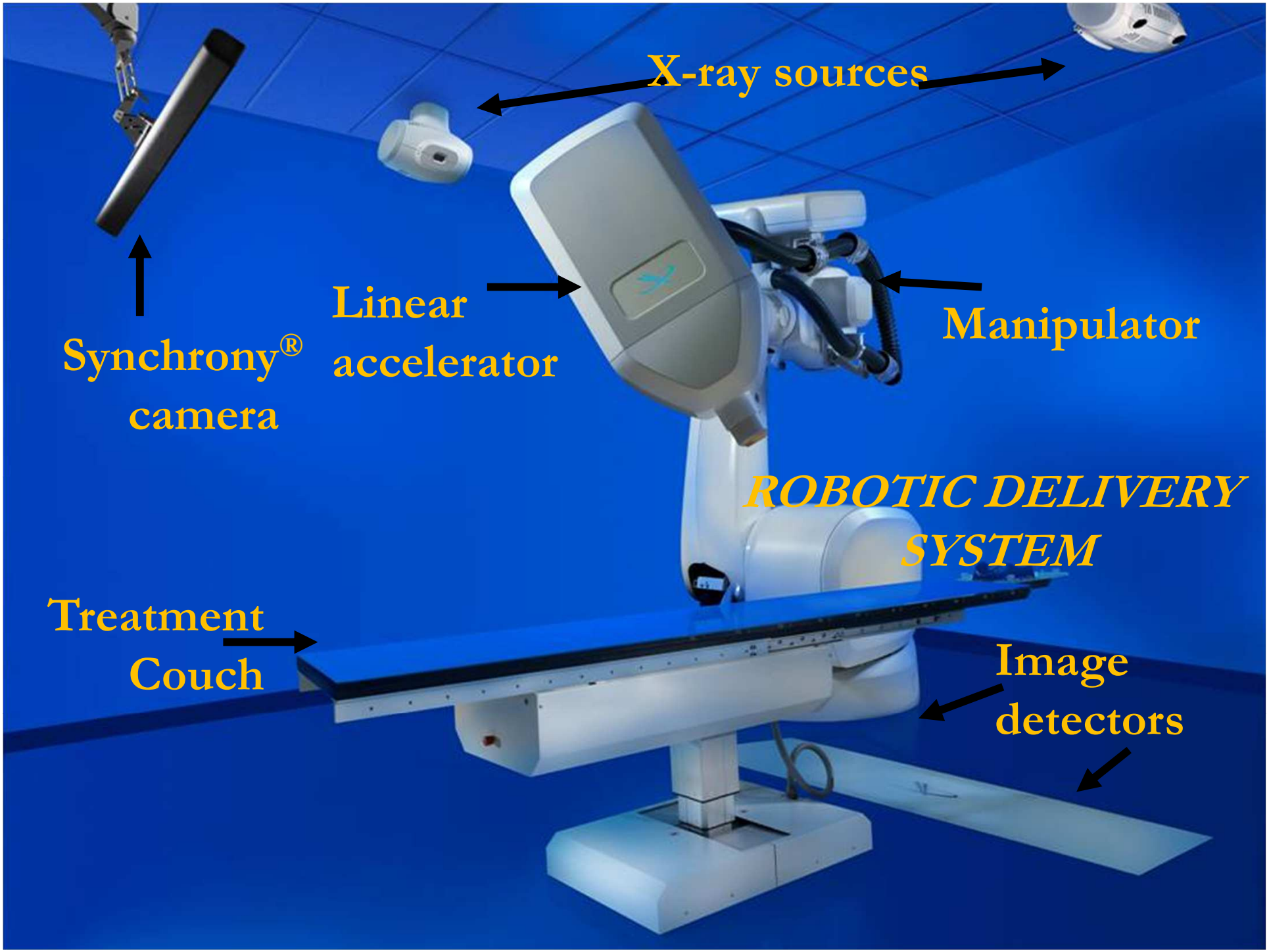
Image Guided,

Tracking,

Stereotactic,

(whole) Body Radiotherapy/Radio surgery (SBRT/SRS)

All in one


X-ray sources
Synchrony®
camera
Linear
accelerator
Manipulator
ROBOTIC DELIVERY
SYSTEM
Treatment
Couch
Image
detectors

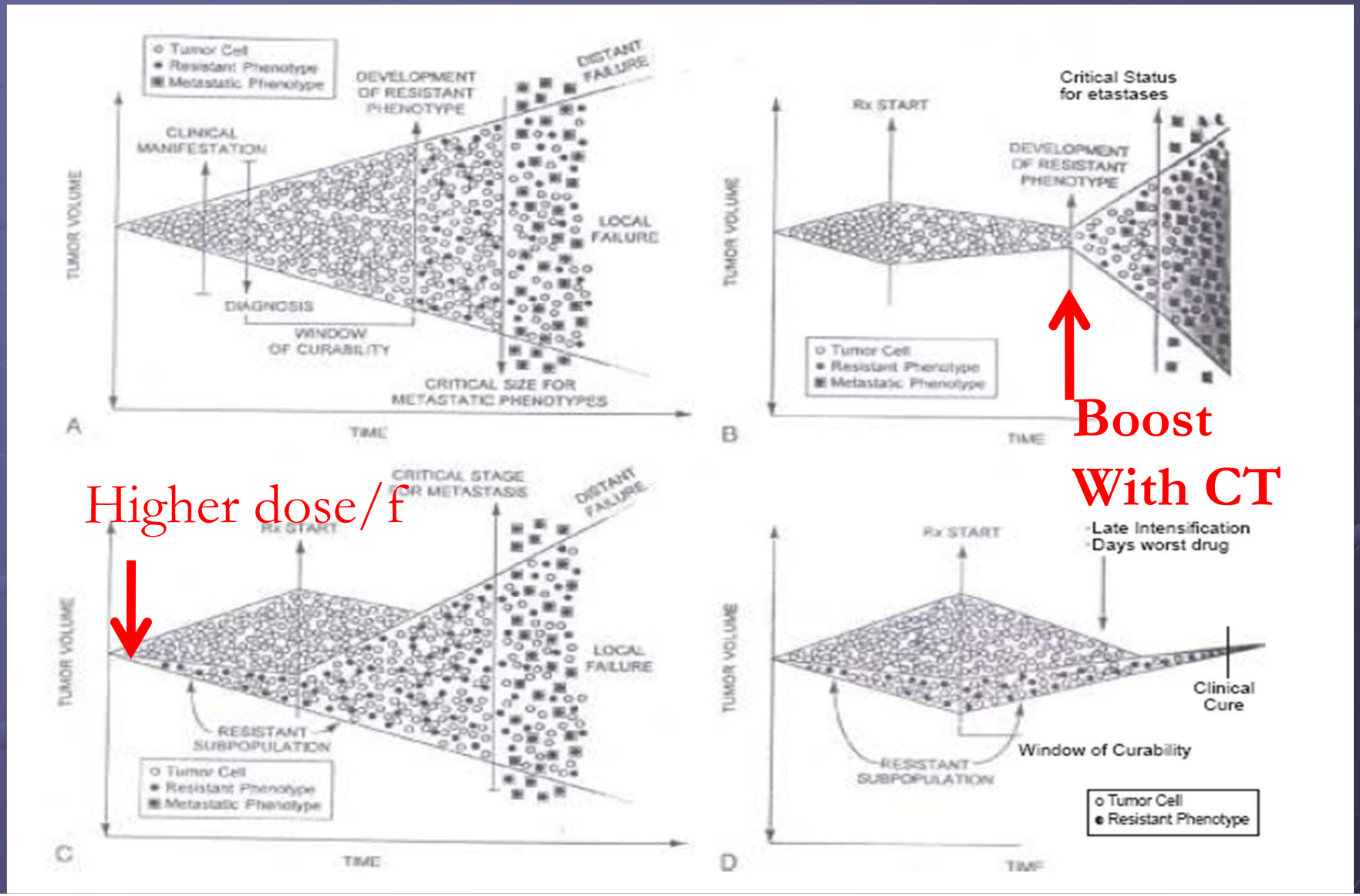
Radiobiology- Hypoxic model

Oxygen

- Migration

- Density of cells → Vascularization

Radiobiology-MTMT model of cancer therapy (Maximal Therapy Minimal Time)



Dose/fraction		TDF equivalent Conventional
4.8 Gy/5f (24.00 Gy)		40 Gy
5.1 Gy/5f (25.50 Gy)		45 Gy
6.1 Gy/5f (30.5 GY)		60 Gy
7.5 Gy/5f (37.5 Gy)		76 Gy

CyberKnife® Accuracy

- Sub-millimeter accuracy
- Treats all parts of the body
- Treats lesions that were previously untreatable
- So accurate, head and body frames are not required

CyberKnife® Conformality

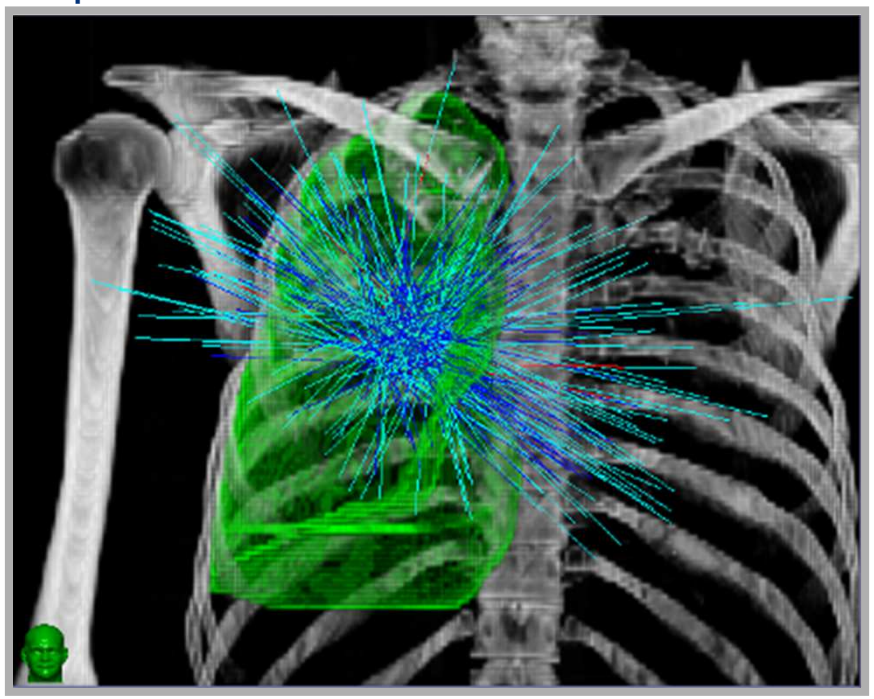
Non-Coplanar Beam Delivery, Non-Isocentric Beam Delivery

Highly collimated beams, Non-convergent beams

Automatically minimizes entrance/exit beam interactions

No patient or linac re-positioning required

Superior conformality while maximizing homogeneity



ACCURAY

CyberKnife® Treatment Overview

ACCURAY

CyberKnife® Treatment Procedure

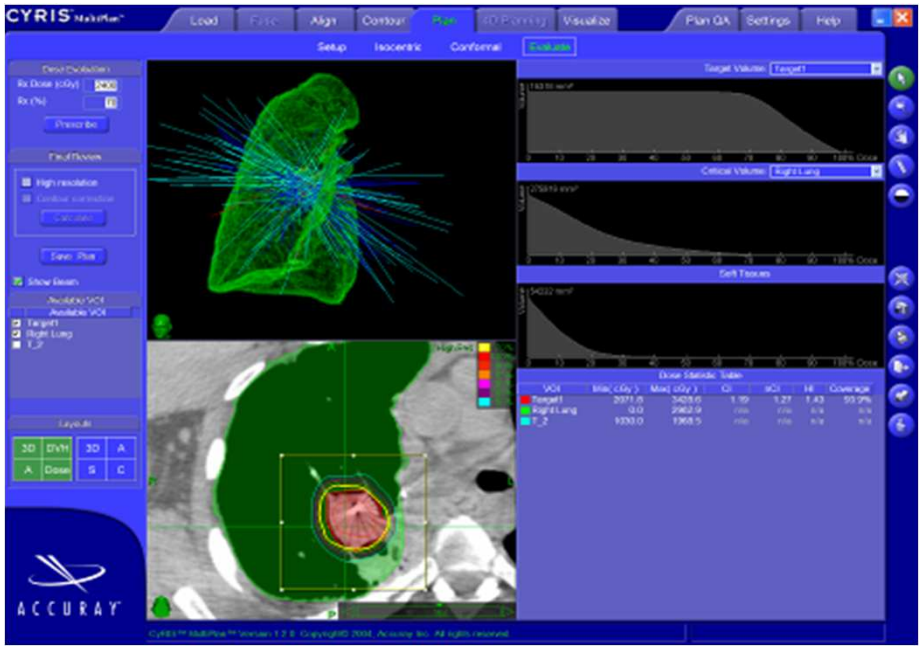
1. Patient Consult
2. Patient Setup
3. Image Acquisition
4. Treatment Planning
5. Treatment Delivery

ACCURAY

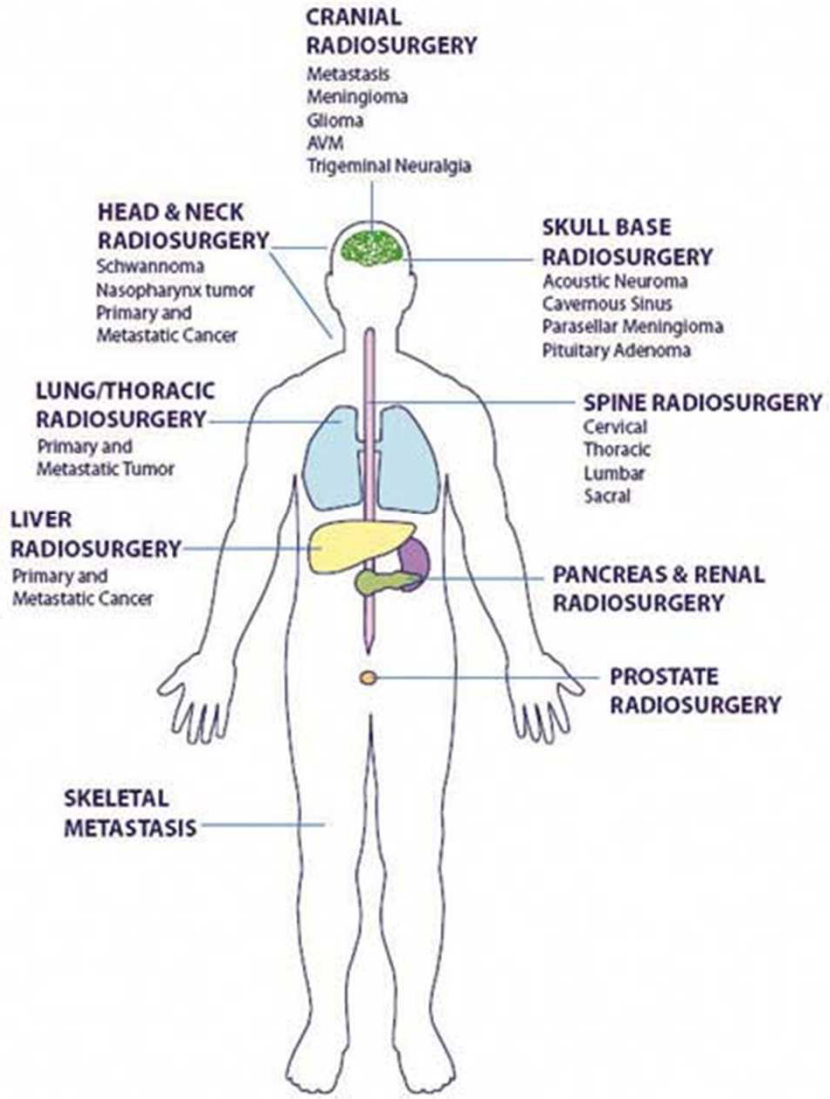
CyRIS™ MultiPlan™ Treatment Planning

Benefits

- Fast, multi-modality image fusion
- Simplified contouring
- Supports forward and inverse planning methods
- Achieves desired plan results quickly and efficiently
- Streamlines overall planning process
- Maximize the capabilities of CyberKnife System



Possible Treatment Areas



CASES

Intra Cranial

Metastasis

Glioma

Meningioma

Pituitary adenoma

Pineal region tumor

Craniopharyngioma

AVM

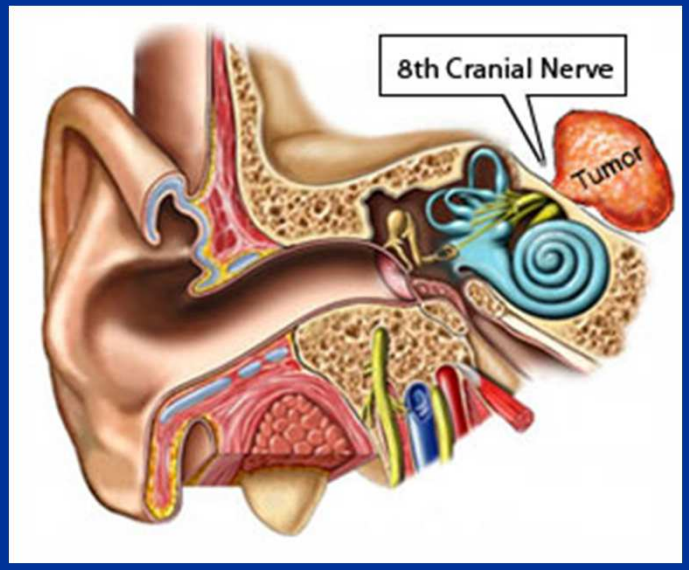
Trigeminal neuralgia

Functional disorders

28 yrs/M/AVM

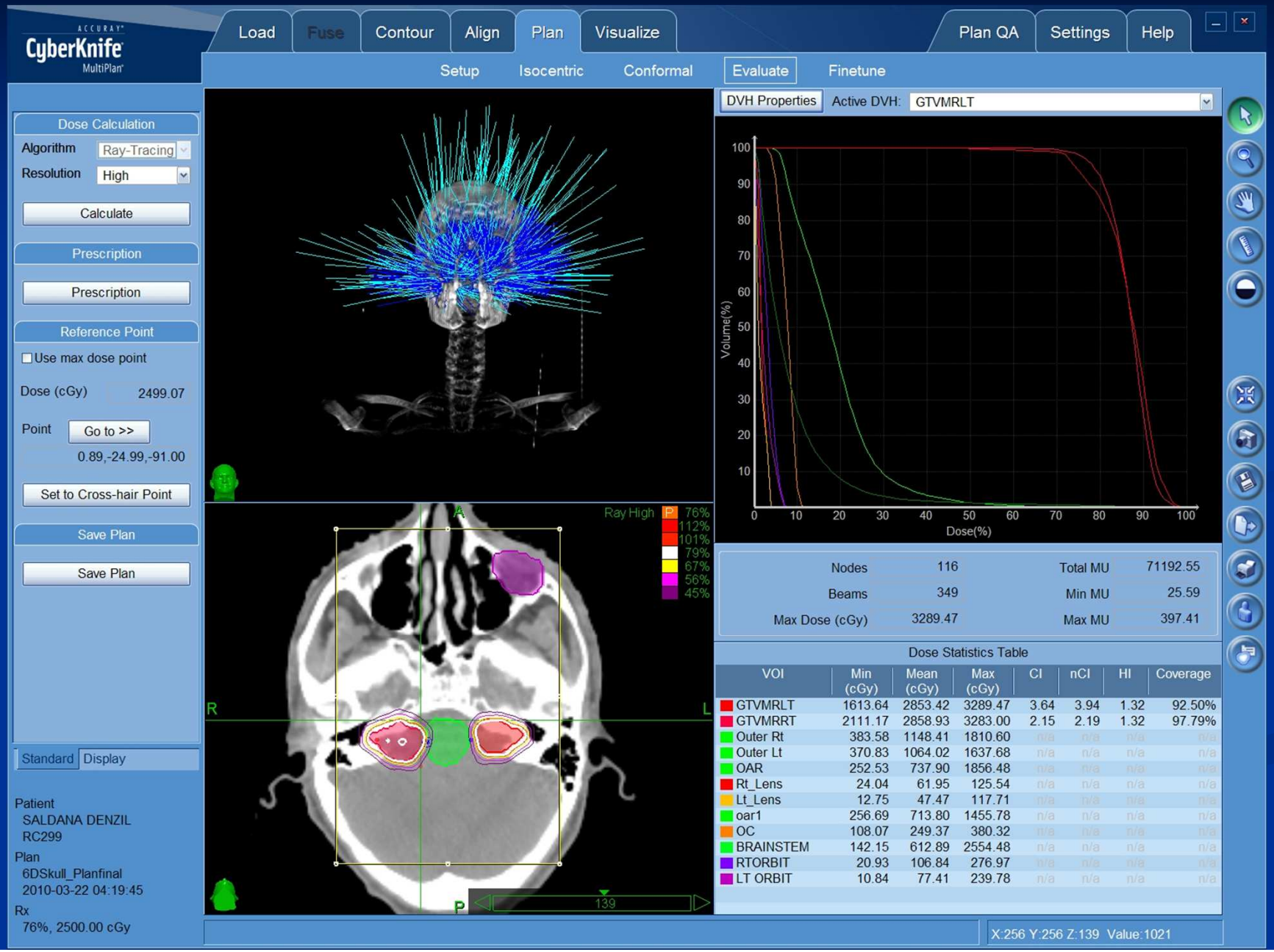

MultiPlan® System
Load
Fuse
Contour
Align
Plan
Visualize
Plan QA
Settings
Help
Setup
Isocentric
Conformal
Sequential
Evaluate
Finetune
Dose Calculation
Algorithm
Ray-Tracing
Resolution
High
Calculate
Prescription
Prescription
Reference Point
Use max dose point
Dose (cGy)
1803.21
Point
Go to >>
18.48,-45.71,-172.00
Set to Cross-hair Point
Save Plan
Save Plan
Standard
Display
Patient
KUMAR SHIVA
CKPLAN-02
Plan
6DSkull_Final
2009-07-19 12:01:15
Rx
72%, 1800.00 cGy
Ray High
72%
100%
80%
72%
75%
50%
40%
30%
DVH Properties
Active DVH:
CTV
Volume(%)
Dose(%)
Nodes
80
Beams
135
Max Dose (cGy)
2500.00
Total MU
14513.90
Min MU
5.89
Max MU
388.19
Dose Statistics Table
VOI
Min (cGy)
Mean (cGy)
Max (cGy)
CI
nCI
HI
Coverage
Inner Shell 648.09 1881.41 2500.00 1.00 1.52 1.39 65.80%
Outter Shell 195.39 883.41 1495.99 n/a n/a n/a n/a
CTV 1585.91 2063.68 2500.00 1.46 1.48 1.39 98.69%
Critical 11 124.90 584.30 939.57 n/a n/a n/a n/a
Rt EYE 71.22 75.68 86.67 n/a n/a n/a n/a
LT EYE 74.08 78.29 107.84 n/a n/a n/a n/a
OPTIC CHAISM 109.60 413.62 954.60 n/a n/a n/a n/a
RT ON 78.85 90.27 349.85 n/a n/a n/a n/a
LT ON 82.02 98.19 189.82 n/a n/a n/a n/a
PITUITARYFOSS 116.20 576.35 1704.47 n/a n/a n/a n/a
BRAINSTEM 83.05 468.23 1751.54 n/a n/a n/a n/a

Acoustic Neuroma



An acoustic neuroma, also known as a vestibular schwannoma, is a benign growth that occurs along the 8th cranial nerve

22yr/m/B/L Ac schwannoma



VOI	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage
GTVMRLT	1613.64	2853.42	3289.47	3.64	3.94	1.32	92.50%
GTVMRRT	2111.17	2858.93	3283.00	2.15	2.19	1.32	97.79%
Outer Rt	383.58	1148.41	1810.60	n/a	n/a	n/a	n/a
Outer Lt	370.83	1064.02	1637.68	n/a	n/a	n/a	n/a
OAR	252.53	737.90	1856.48	n/a	n/a	n/a	n/a
Rt_Lens	24.04	61.95	125.54	n/a	n/a	n/a	n/a
Lt_Lens	12.75	47.47	117.71	n/a	n/a	n/a	n/a
oar1	256.69	713.80	1455.78	n/a	n/a	n/a	n/a
OC	108.07	249.37	380.32	n/a	n/a	n/a	n/a
BRAINSTEM	142.15	612.89	2554.48	n/a	n/a	n/a	n/a
RTORBIT	20.93	106.84	276.97	n/a	n/a	n/a	n/a
LT ORBIT	10.84	77.41	239.78	n/a	n/a	n/a	n/a

Radiosurgical Rhizotomy for Trigeminal Neuralgia

- Linac-based & GammaKnife (GK) SRS are well established treatment options

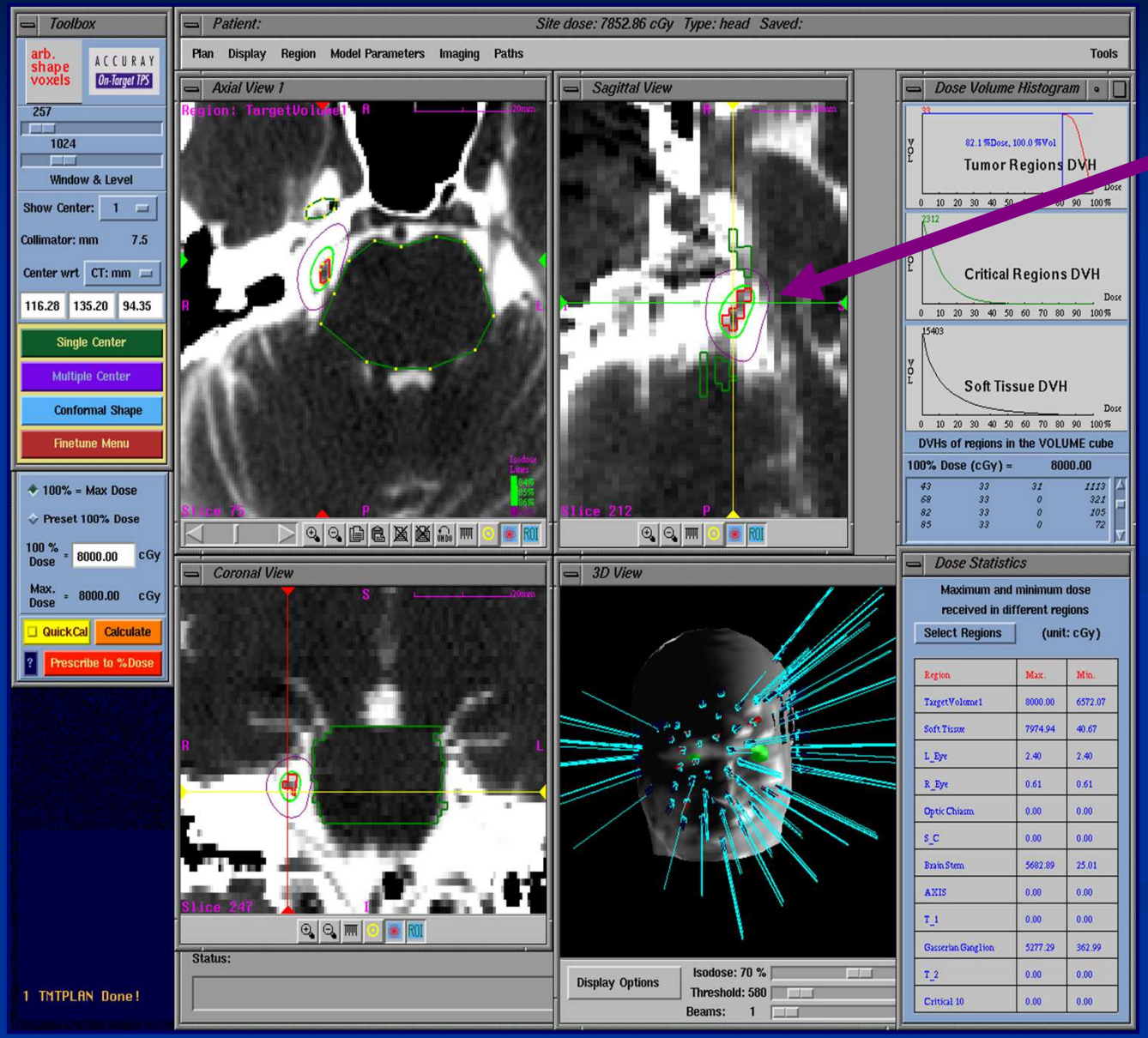
  Primarily a replacement for other “destructive” lesions (Gycerol, RF, etc.)

  Not a substitute for Micro Vascular Decompression!!

Patient Selection

CyberKnife radiosurgical rhizotomy was offered to medically-refractory TN patients that failed or refused surgery or were not suitable candidates for MVD due to age or medical contraindications.

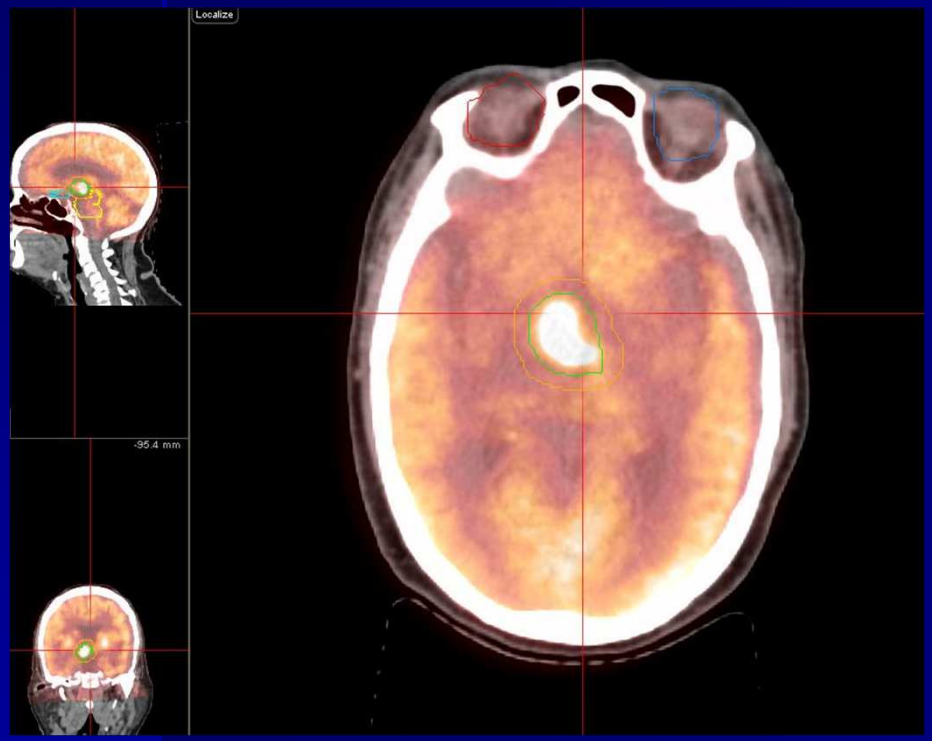
SRS for Trigeminal Neuralgia



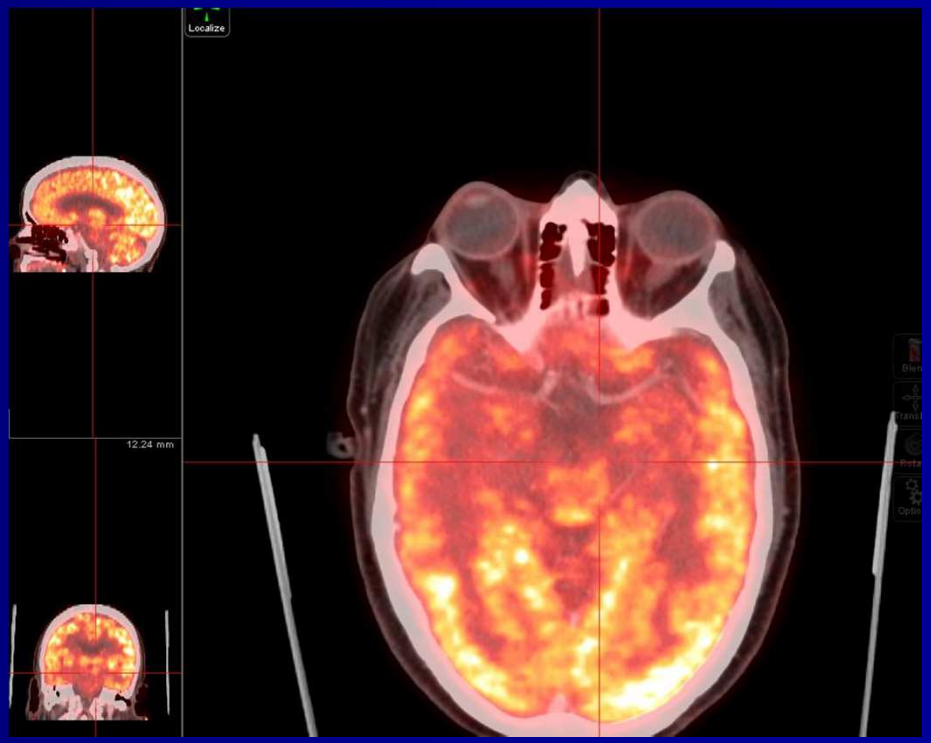
Measure length!!

High Grade Glioma – Supratentorial: 3 months Post CK – No Uptake

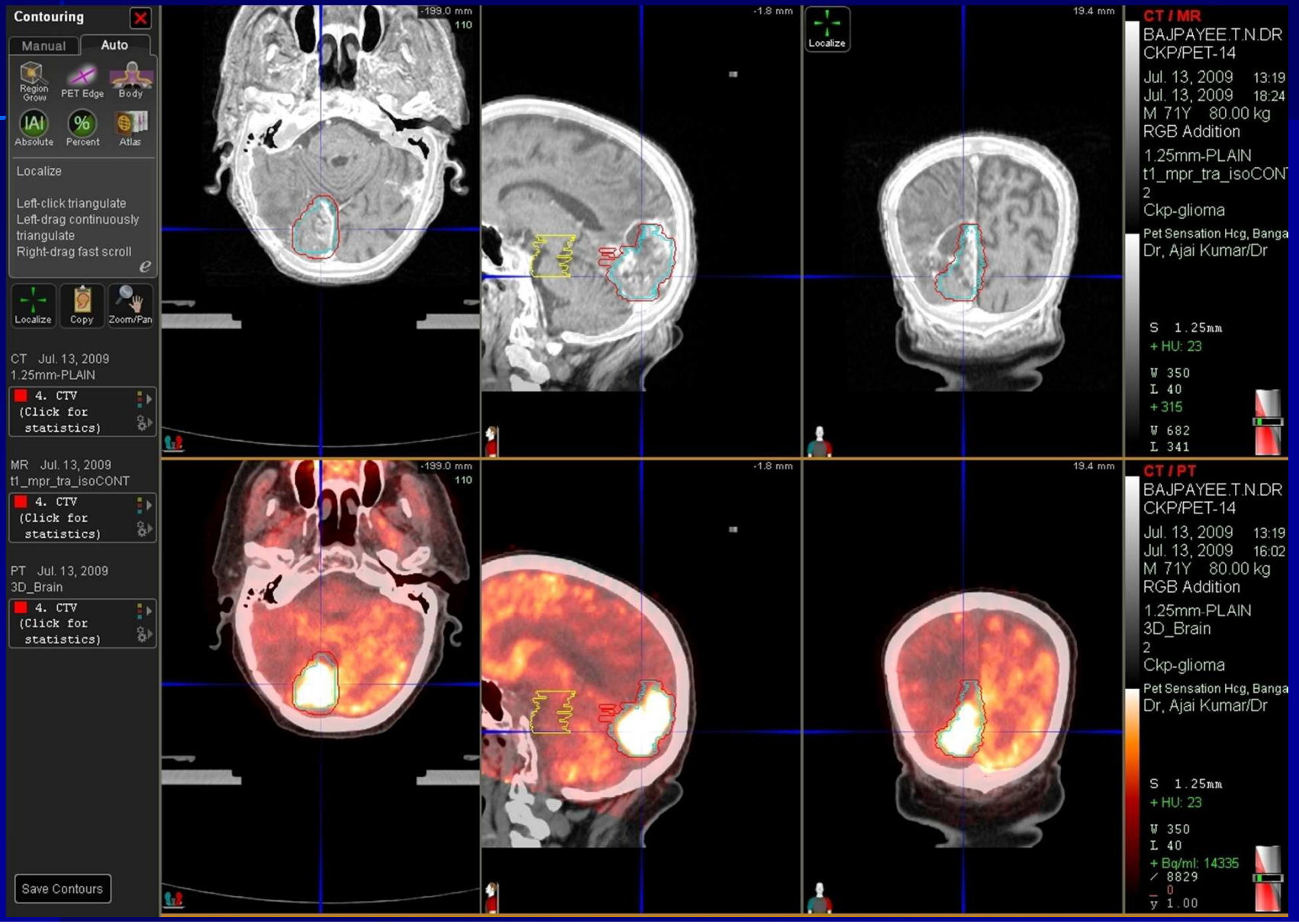
Pre-CK



Post-CK



72yrs/M/Recurrent GBM



72yrs/M/Recurrent GBM

adding life to years

Load | Fuse | Contour | Align | Plan | Visualize | Plan QA | Settings | Help

Setup | Isocentric | Conformal | Sequential | Evaluate | Finetune

Dose Calculation

Algorithm: Ray-Tracing

Resolution: High

Calculate

Prescription

Prescription

Reference Point

Use max dose point

Dose (cGy): 2400.41

Point: Go to >>

7.33,13.07,-175.25

Set to Cross-hair Point

Save Plan

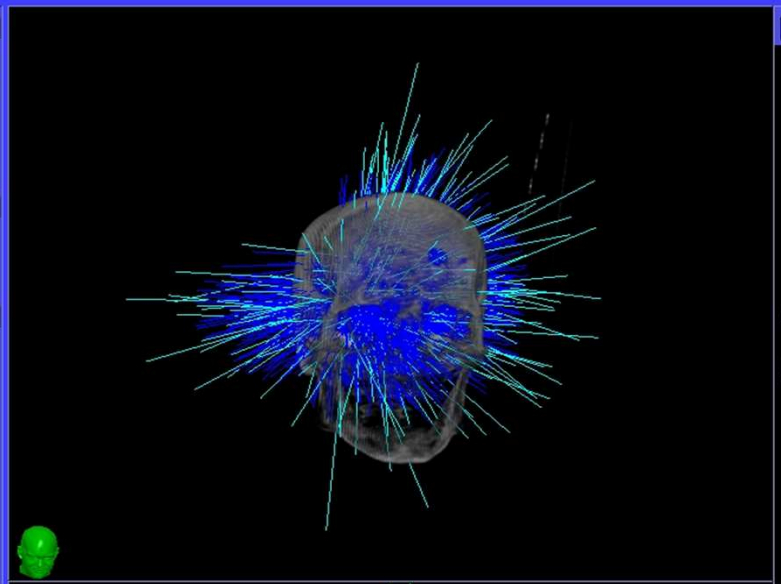
Save Plan

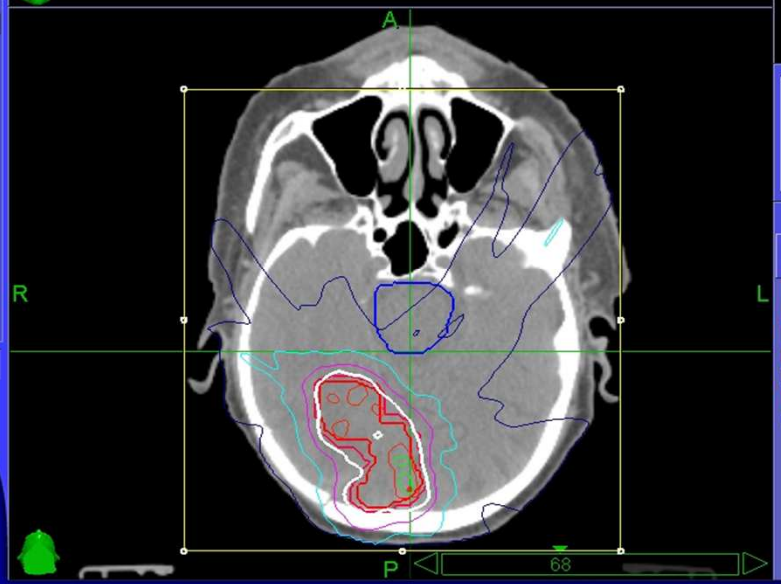
Standard | Display

Patient
T BAJPAYEE
RC25

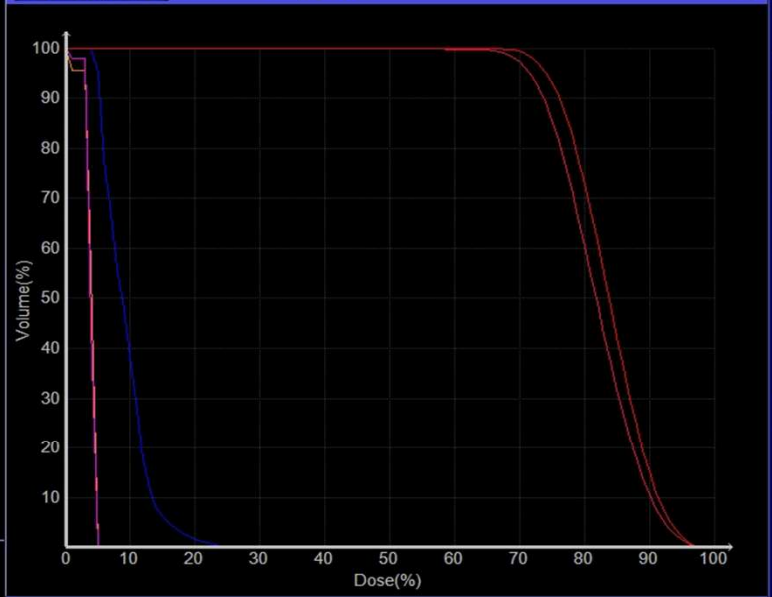
Plan
6DSkull_Plan_Final
2009-07-14 18:43:49

Rx
70%, 2400.00 cGy





DVH Properties | Active DVH: GTVPET



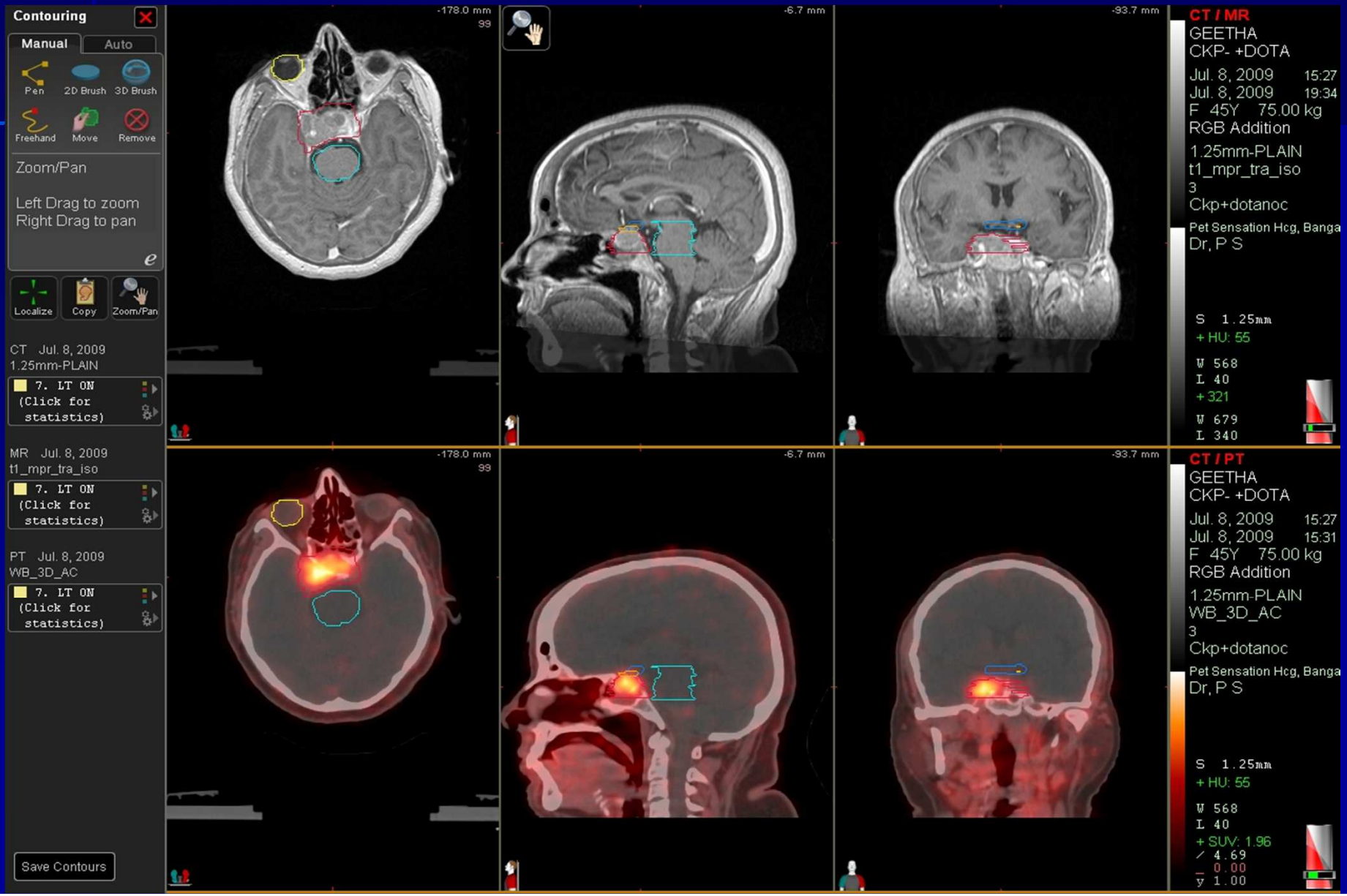
Nodes	97	Total MU	40297.25
Beams	161	Min MU	53.58
Max Dose (cGy)	3428.57	Max MU	596.41

Dose Statistics Table

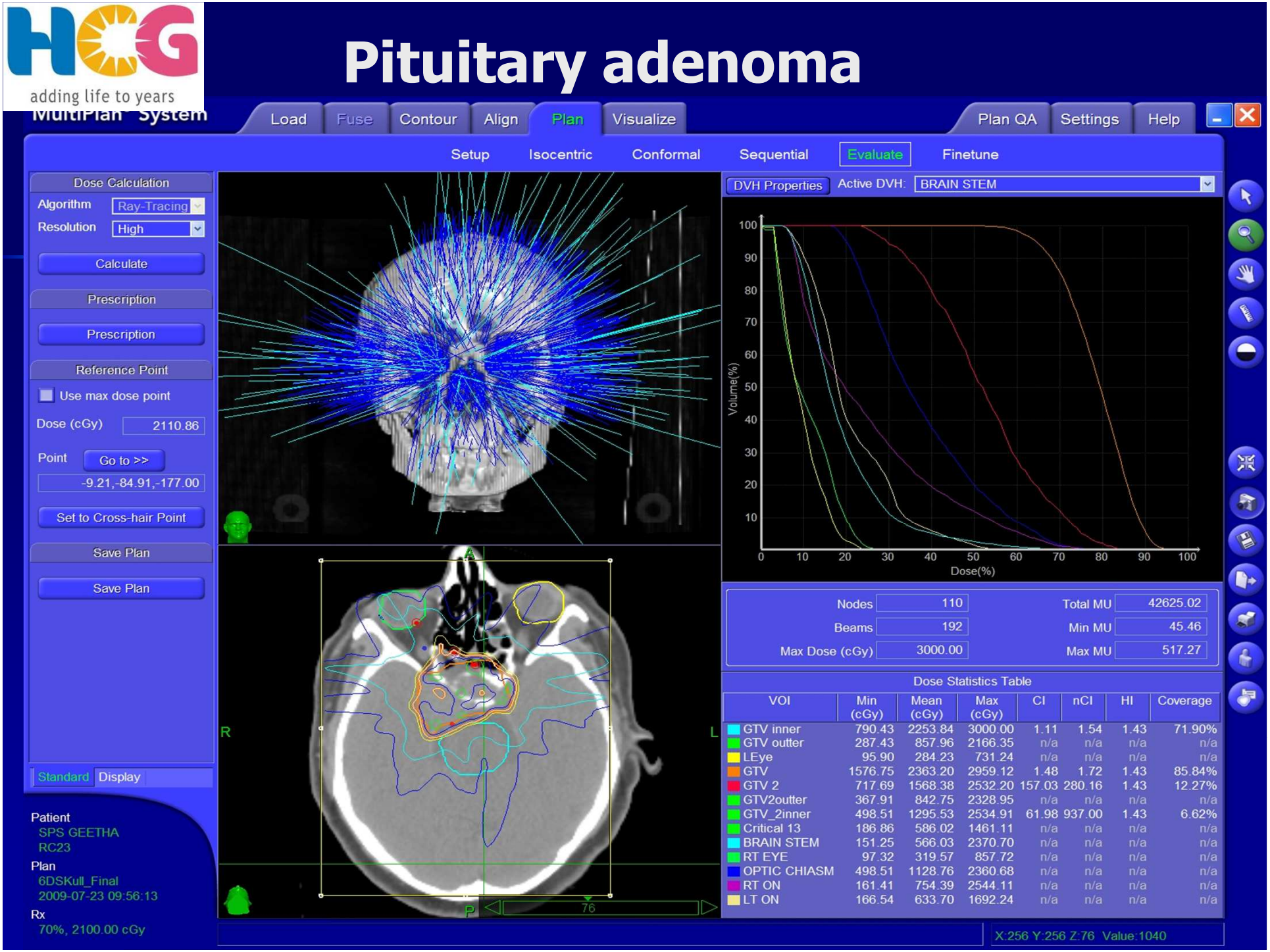
VOI	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage
GTVPET	2298.43	2872.15	3428.57	1.81	1.82	1.43	99.59%
CTV	2014.40	2807.22	3428.57	1.24	1.28	1.43	97.58%
Outer Shell	1091.80	1908.25	2710.53	n/a	n/a	n/a	n/a
REye	126.34	133.60	156.06	n/a	n/a	n/a	n/a
Outer_shell2	370.14	1045.27	1771.02	n/a	n/a	n/a	n/a
LEye	117.61	133.72	154.65	n/a	n/a	n/a	n/a
BRAINSTEM	162.60	316.43	1044.61	n/a	n/a	n/a	n/a

X:256 Y:256 Z:68 Value:1019

45 yrs/f, recurrent pituitary adenoma

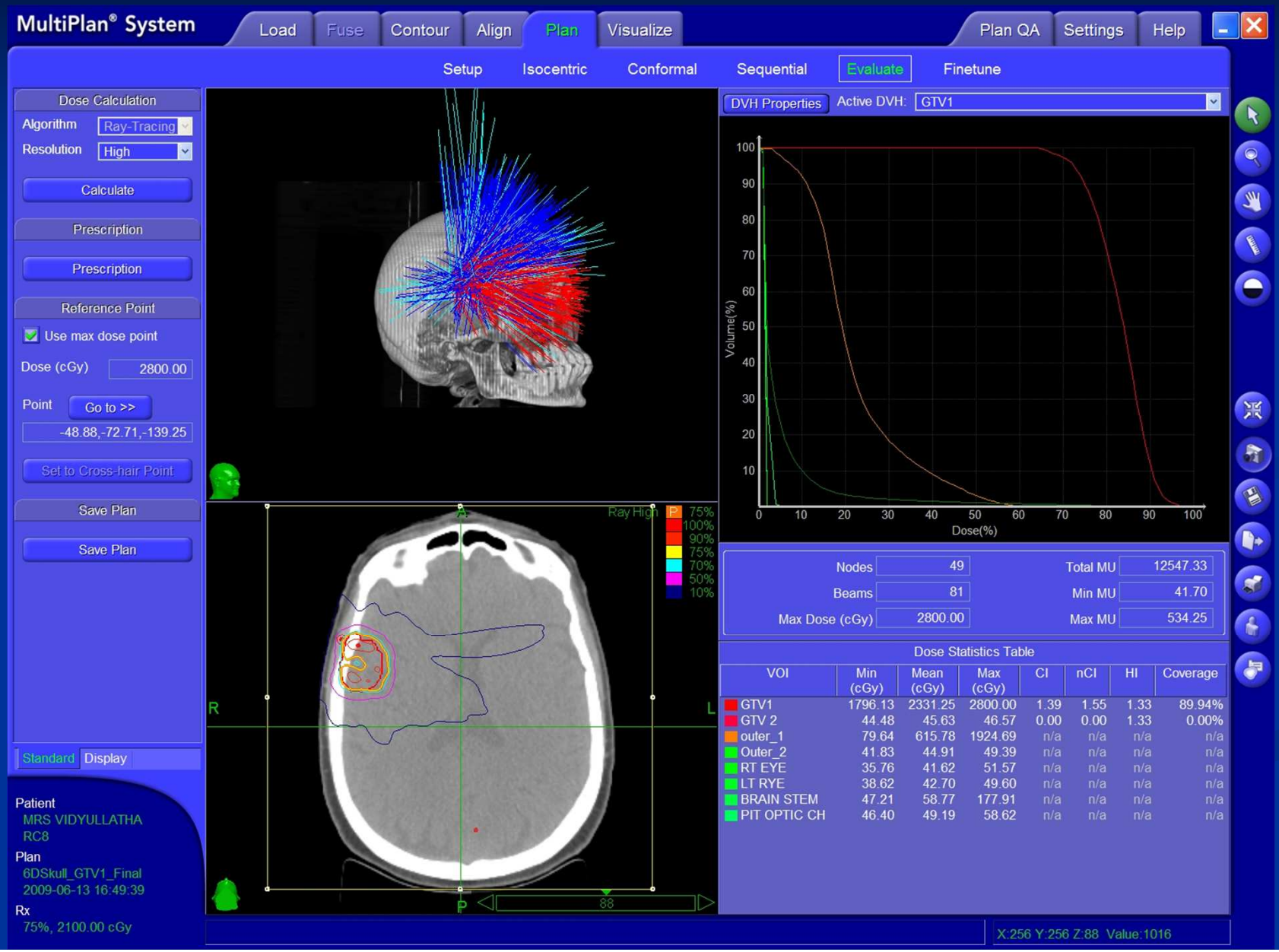


Pituitary adenoma



adding life to years

69Yrs/F/Ca Lung with Brain mets

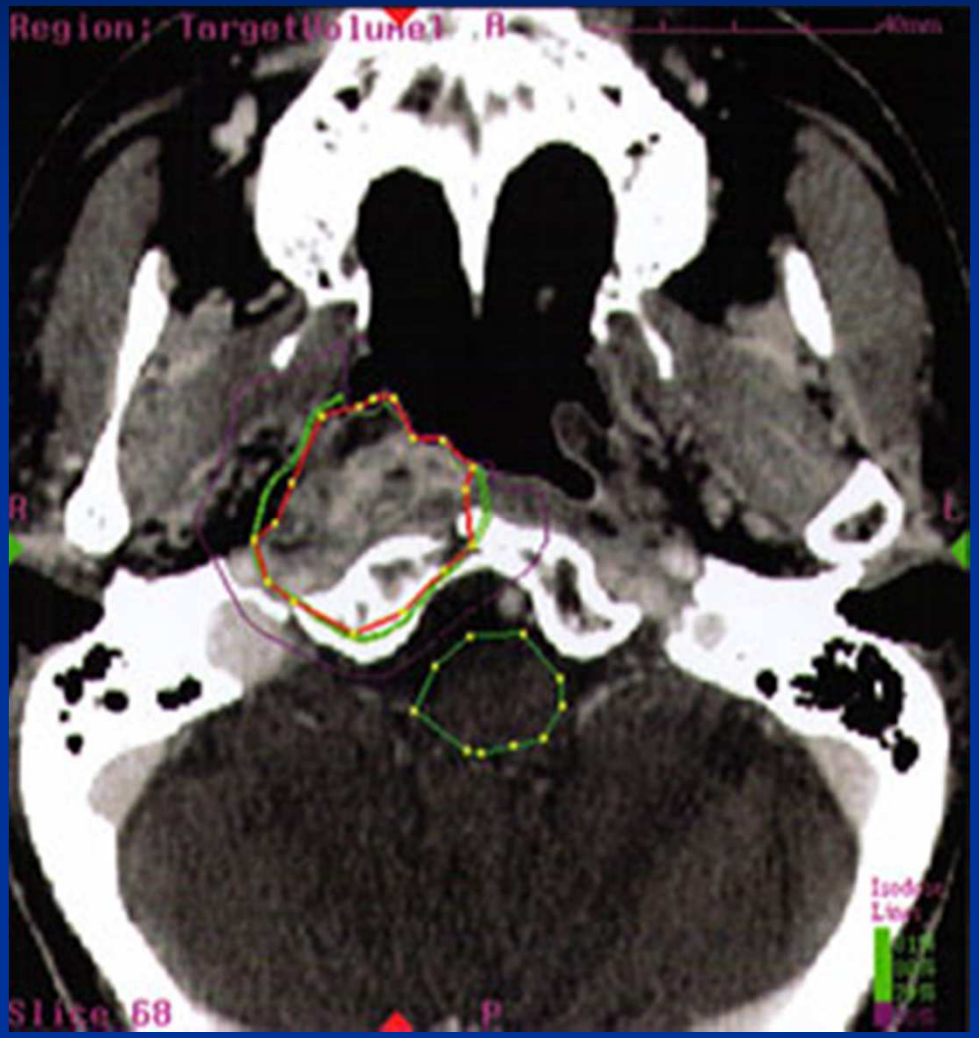


CK Indications Head/Neck

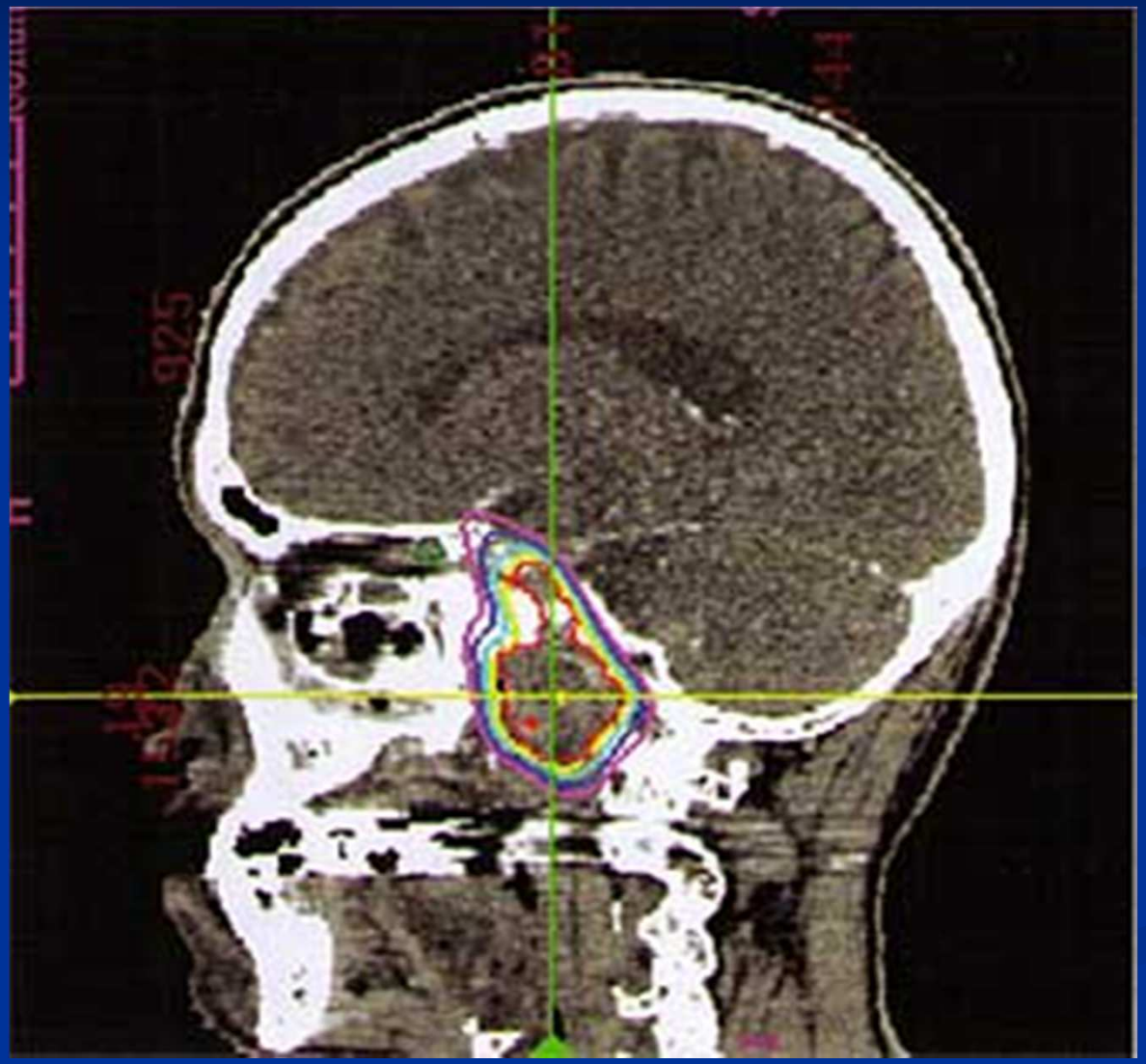
- Head and Neck

  Nasopharyngeal tumor
  Primary and metastatic cancer
  Glomus jugular tumor,
  Chondrosarcoma
  Ocular melanoma

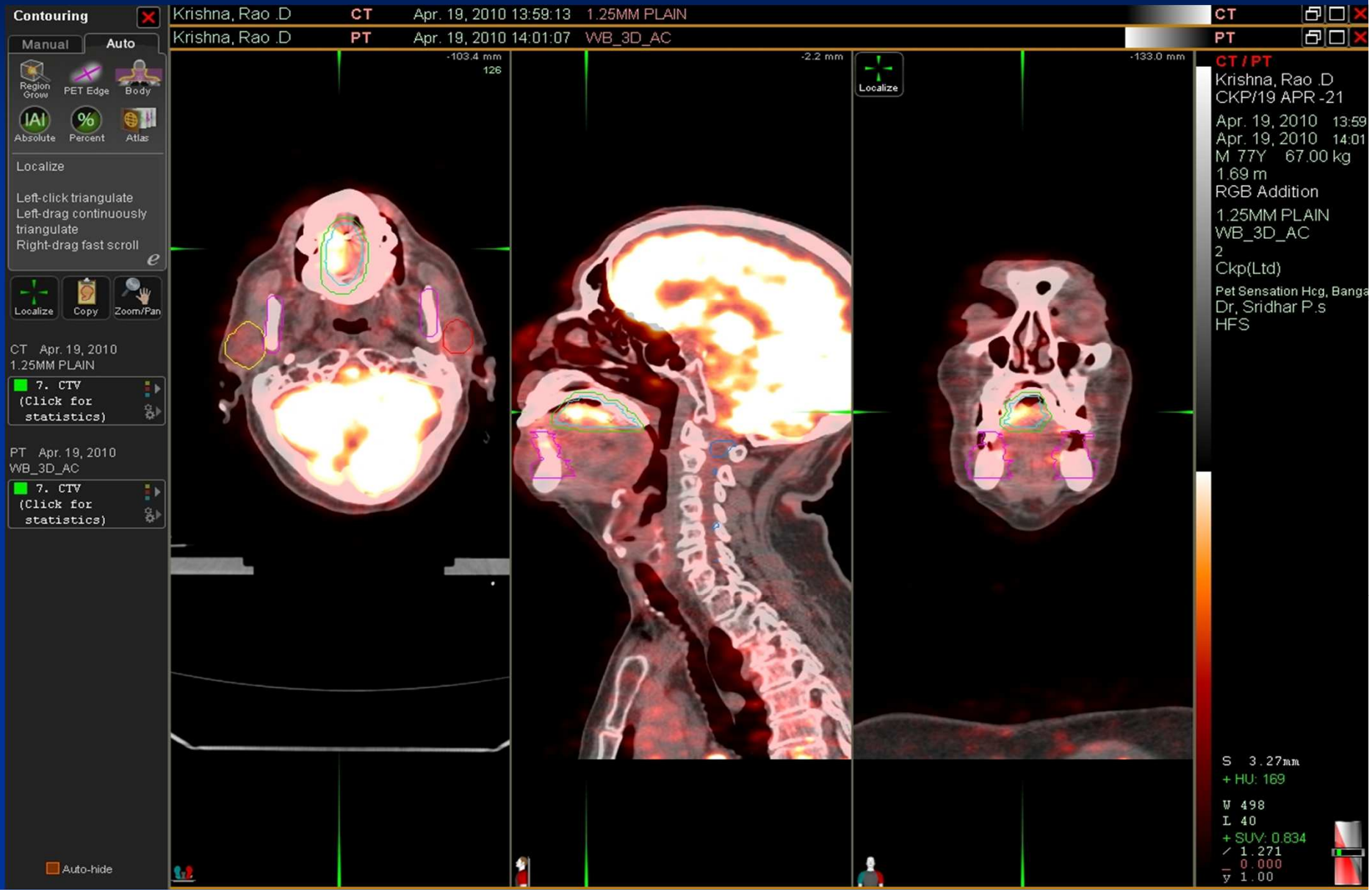
Nasopharynx

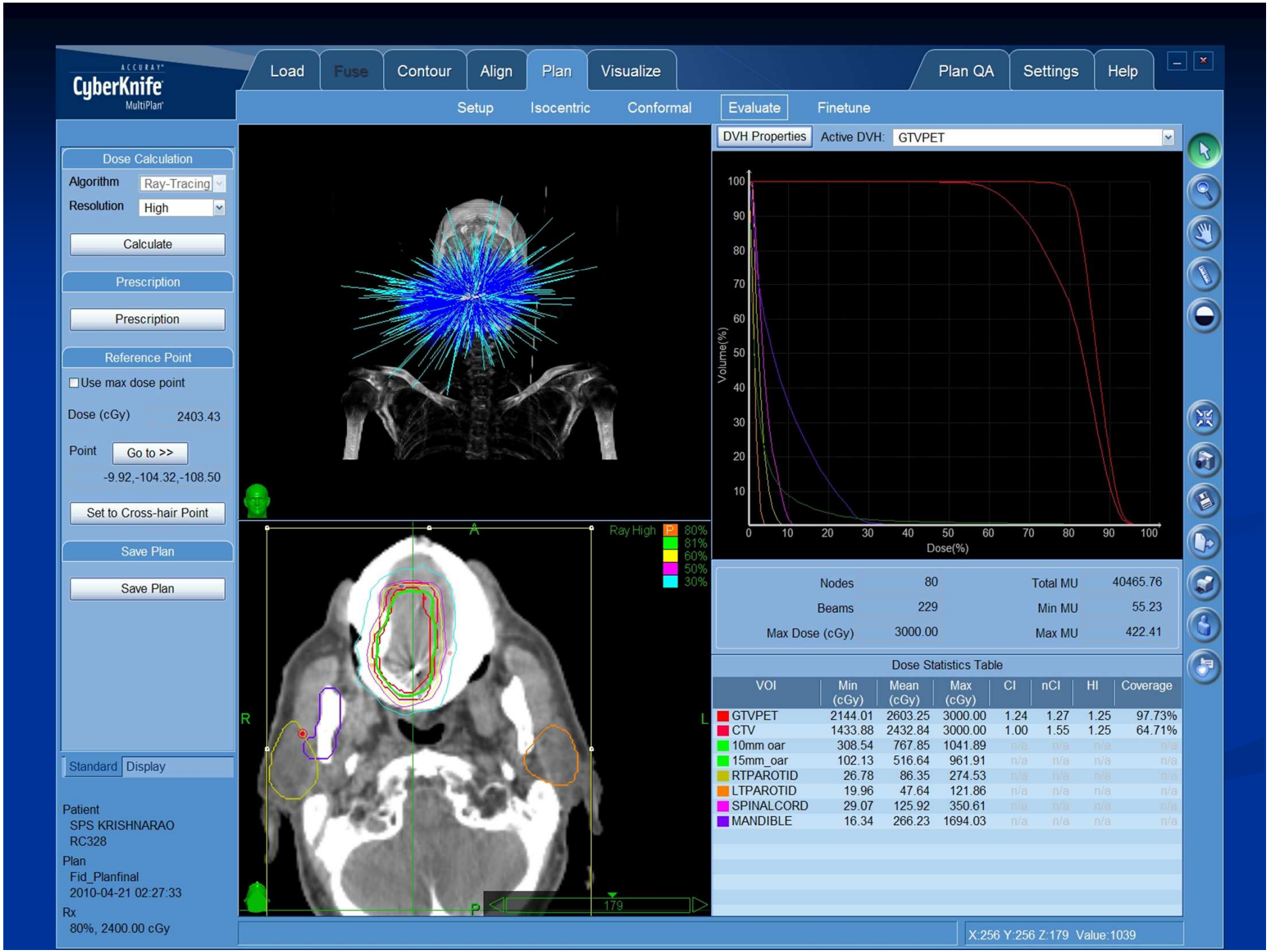


Nasopharynx

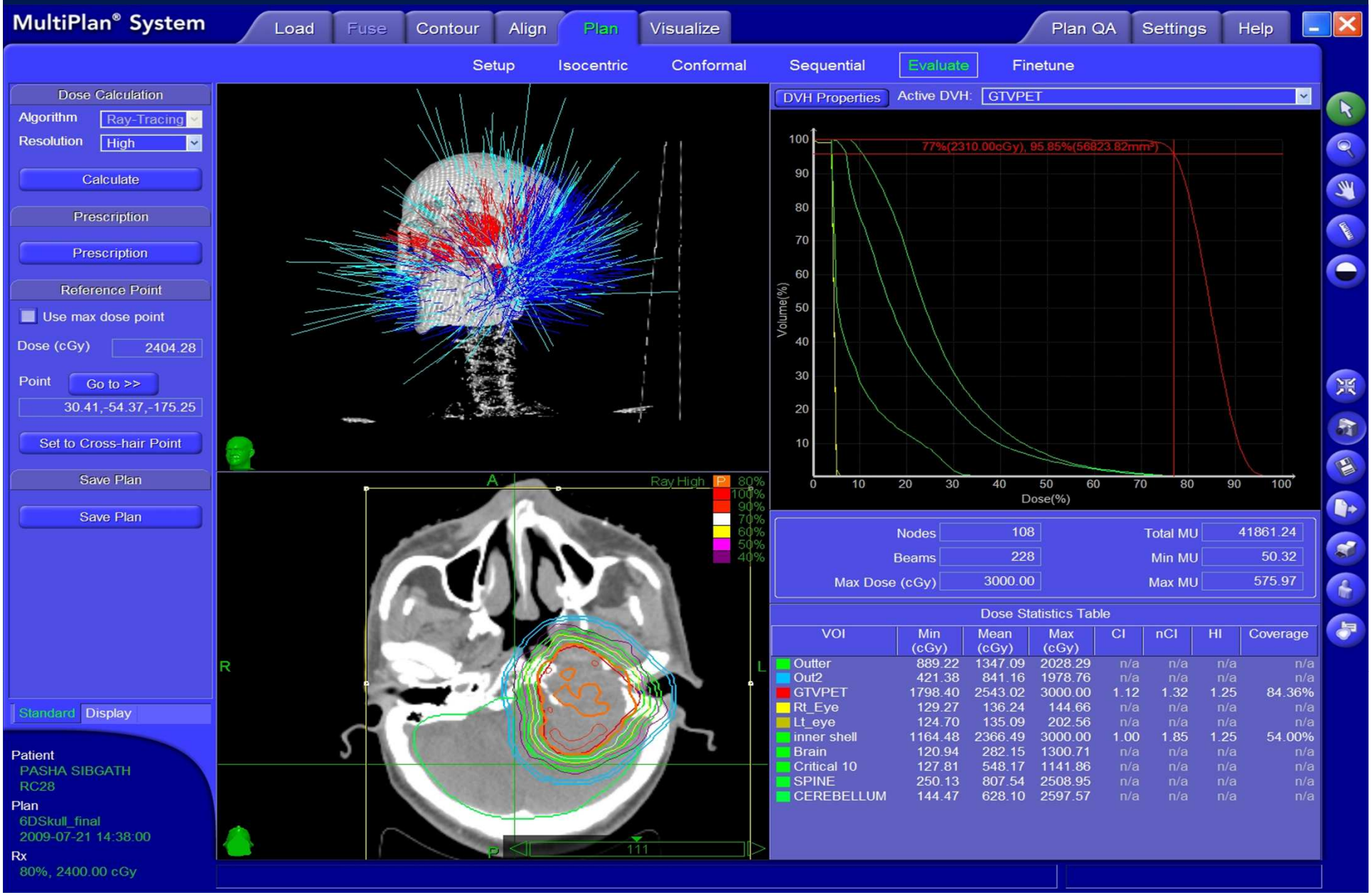


85yrs/M/Ca tongue T2N0



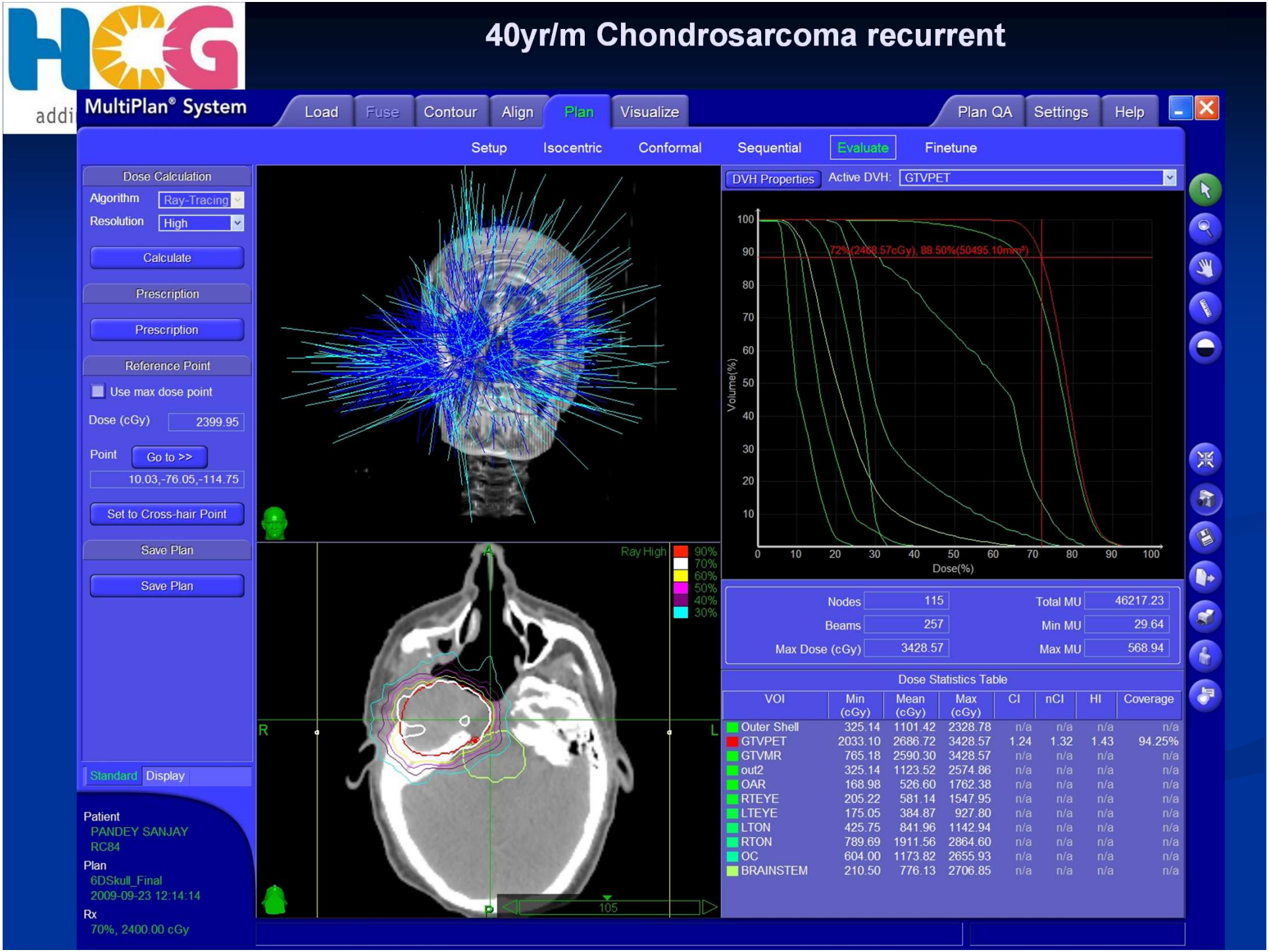

ACCURAY
CyberKnife
MultiPlan
Load
Fuse
Contour
Align
Plan
Visualize
Plan QA
Settings
Help
Setup
Isocentric
Conformal
Evaluate
Finetune
Dose Calculation
Algorithm
Ray-Tracing
Resolution
High
Calculate
Prescription
Prescription
Reference Point
Use max dose point
Dose (cGy)
2403.43
Point
Go to >>
-9.92,-104.32,-108.50
Set to Cross-hair Point
Save Plan
Save Plan
Standard
Display
Patient
SPS KRISHNARAO
RC328
Plan
Fid_Planfinal
2010-04-21 02:27:33
Rx
80%, 2400.00 cGy
Ray High
80%
81%
60%
50%
30%
A
R
L
P
179
DVH Properties
Active DVH:
GTVPET
Volume(%)
Dose(%)
Nodes
80
Total MU
40465.76
Beams
229
Min MU
55.23
Max Dose (cGy)
3000.00
Max MU
422.41
Dose Statistics Table
VOI
Min (cGy)
Mean (cGy)
Max (cGy)
CI
nCI
HI
Coverage
GTVPET 2144.01 2603.25 3000.00 1.24 1.27 1.25 97.73%
CTV 1433.88 2432.84 3000.00 1.00 1.55 1.25 64.71%
10mm oar 308.54 767.85 1041.89 n/a n/a n/a n/a
15mm_oar 102.13 516.64 961.91 n/a n/a n/a n/a
RTPAROTID 26.78 86.35 274.53 n/a n/a n/a n/a
LTPAROTID 19.96 47.64 121.86 n/a n/a n/a n/a
SPINALCORD 29.07 125.92 350.61 n/a n/a n/a n/a
MANDIBLE 16.34 266.23 1694.03 n/a n/a n/a n/a
X:256 Y:256 Z:179 Value:1039

35yrs/M/Recurrent Lt middle ear SCC



VOI	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage
Outter	889.22	1347.09	2028.29	n/a	n/a	n/a	n/a
Out2	421.38	841.16	1978.76	n/a	n/a	n/a	n/a
GTVPET	1798.40	2543.02	3000.00	1.12	1.32	1.25	84.36%
Rt_Eye	129.27	136.24	144.66	n/a	n/a	n/a	n/a
Lt_eye	124.70	135.09	202.56	n/a	n/a	n/a	n/a
inner shell	1164.48	2366.49	3000.00	1.00	1.85	1.25	54.00%
Brain	120.94	282.15	1300.71	n/a	n/a	n/a	n/a
Critical 10	127.81	548.17	1141.86	n/a	n/a	n/a	n/a
SPINE	250.13	807.54	2508.95	n/a	n/a	n/a	n/a
CEREBELLUM	144.47	628.10	2597.57	n/a	n/a	n/a	n/a

40yr/m Chondrosarcoma recurrent



VOI	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage
Outer Shell	325.14	1101.42	2328.78	n/a	n/a	n/a	n/a
GTVPET	2033.10	2686.72	3428.57	1.24	1.32	1.43	94.25%
GTVMR	765.18	2590.30	3428.57	n/a	n/a	n/a	n/a
out2	325.14	1123.52	2574.86	n/a	n/a	n/a	n/a
OAR	168.98	526.60	1762.38	n/a	n/a	n/a	n/a
RTEYE	205.22	581.14	1547.95	n/a	n/a	n/a	n/a
LTEYE	175.05	384.87	927.80	n/a	n/a	n/a	n/a
LTON	425.75	841.96	1142.94	n/a	n/a	n/a	n/a
RTON	789.69	1911.56	2864.60	n/a	n/a	n/a	n/a
OC	604.00	1173.82	2655.93	n/a	n/a	n/a	n/a
BRAINSTEM	210.50	776.13	2706.85	n/a	n/a	n/a	n/a

adding life to years

Cyberknife Stereotactic Radiosurgery for Disease of the Spine

adding life to years

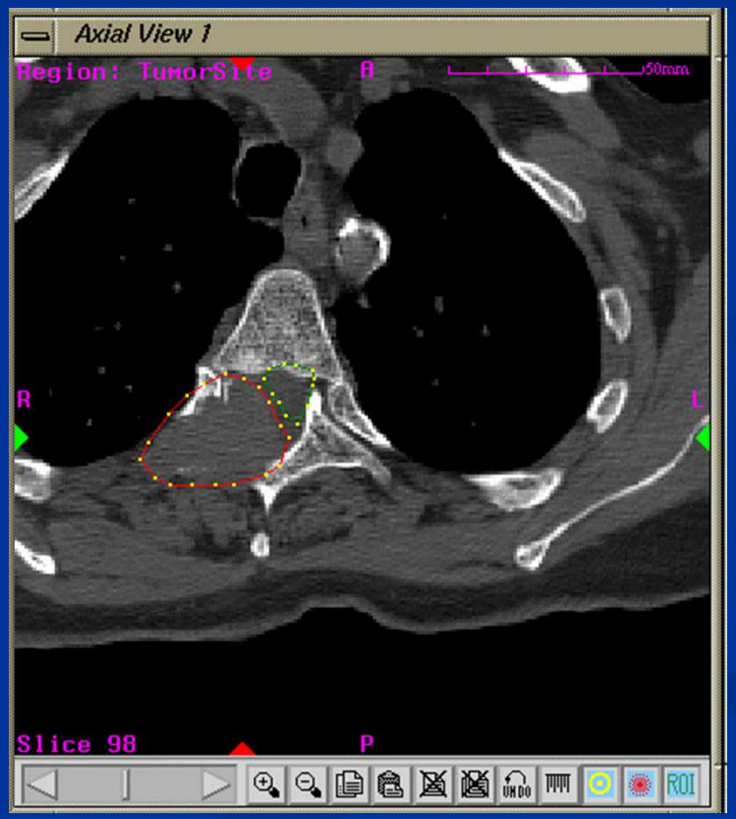
- Metastatic
- Benign lesions
- Post irradiated
- Sacral sarcoma
- Pediatric tumors

Indications for Spinal Radiosurgery

- *Spinal Lesions*
  - Metastases which recurred after conventional radiation (renal, colon, lung) or surgery
  - Patients with isolated lesions, potentially long life expectancy and the likelihood of re-treatment in the same area (solitary plasmacytoma, renal, breast)

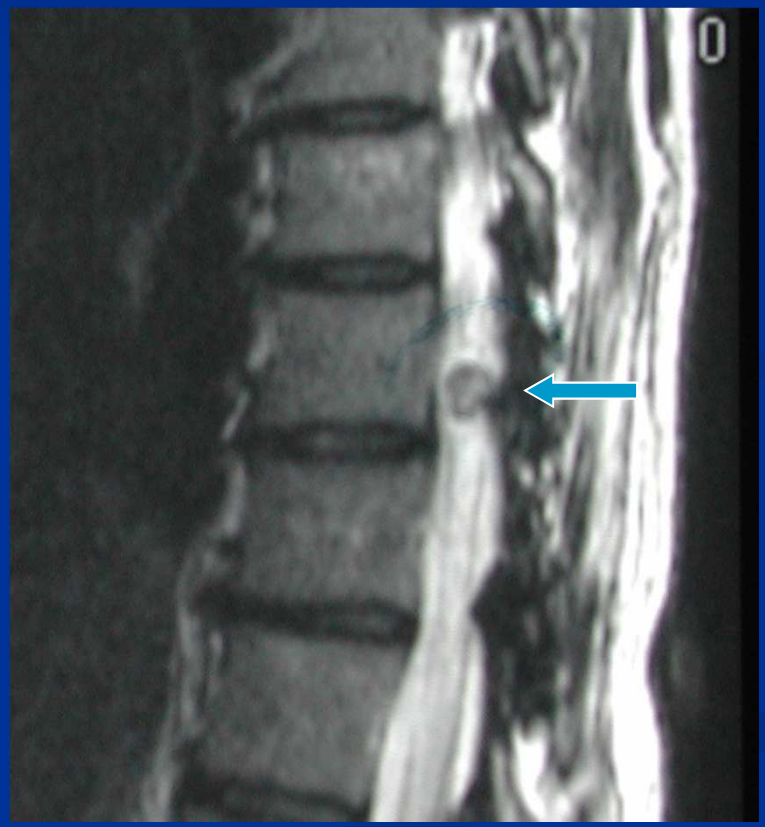
Indications for Spinal Radiosurgery

- *Spinal Lesions*
  - Cancers which are not sensitive to radiation in doses tolerated by the spinal cord (renal, sarcoma, melanoma)
  - Patients in whom shortening the duration of treatment would be advantageous
  - Patient with a short life expectancy or significant co-morbidity



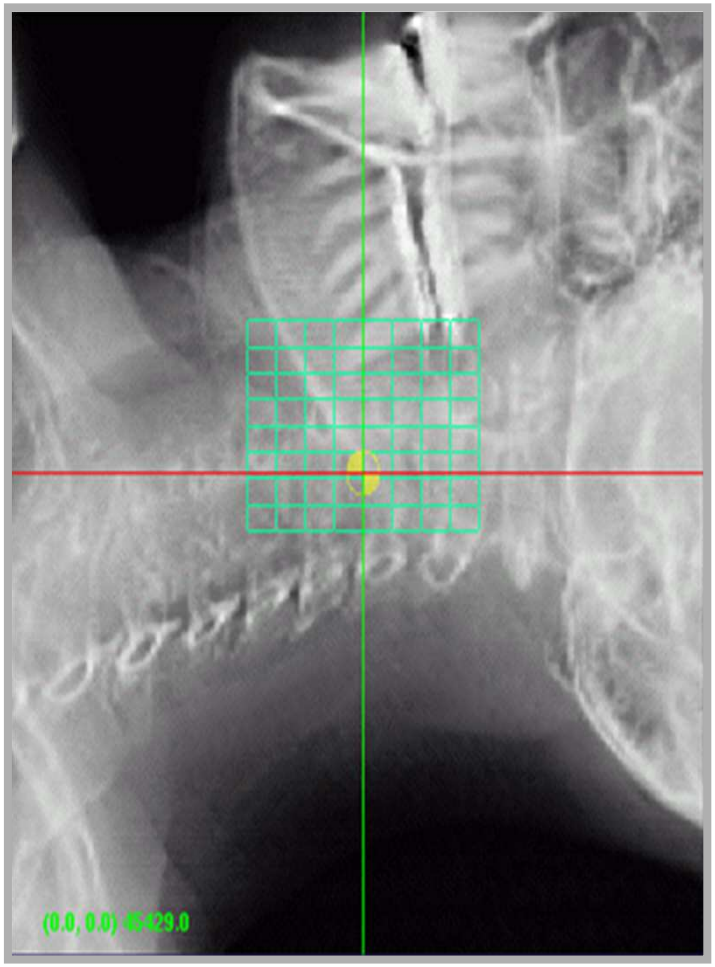
Indications for Spinal Radiosurgery

- *Spinal Lesions*
  - Definitive treatment of primary spinal tumors in patients in whom definitive surgery would not be tolerated
  - Any tumor but especially benign tumors which would require extensive surgery or a difficult approach for treatment (hemangioma, schwannoma, meningioma, desmoplastic fibroma)



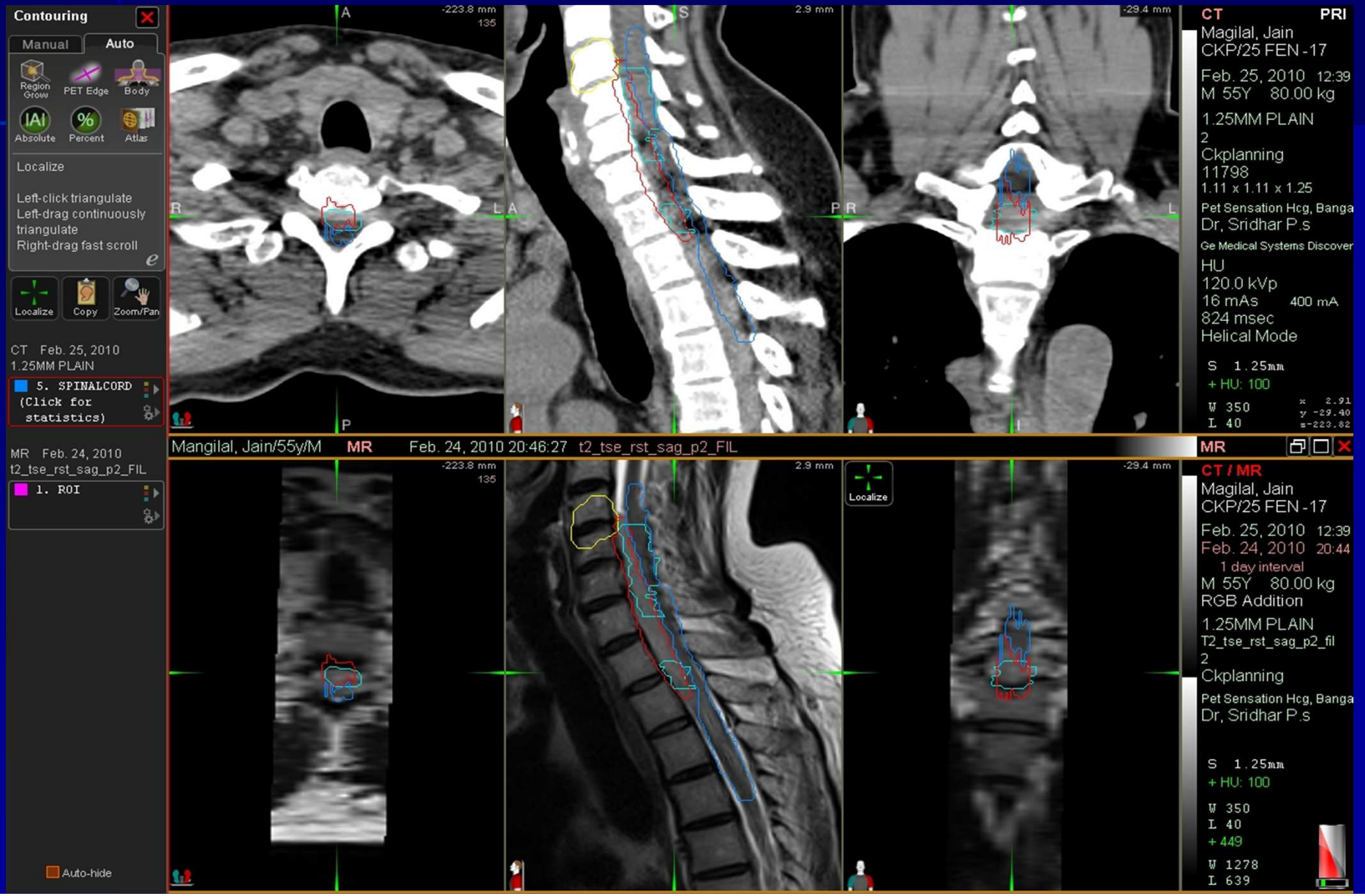
Xsight™ Spine Tracking System

- An alternative that eliminates risk for patients
- Sub-millimeter accuracy with non-rigid registration
- Utilizes the bony anatomy of the spine:
  - Cervical
  - Thoracic
  - Lumbar
  - Sacrum



ACCURAY

65yr/M/Rec spinal ependymoma

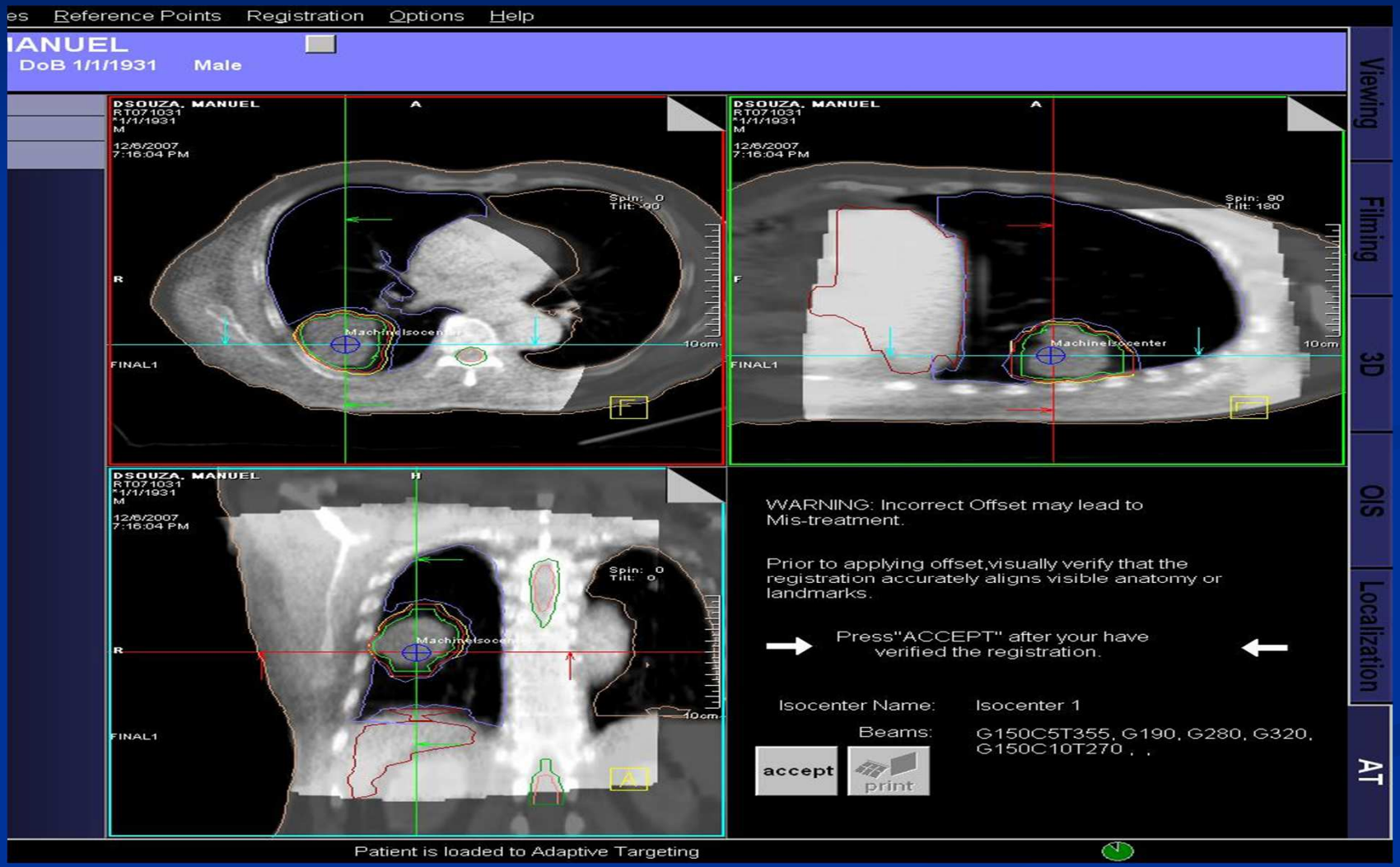


65yr/M/Rec spinal ependymoma


HCG
30.10.2009 20:31

Stereotactic Radiation Surgery: Lung

- Patient of carcinoma lung T1(or T2) N0 MO, <5 cm in size, peripherally located, medically inoperable/ surgery not feasible


es Reference Points Registration Options Help
IANUEL
DoB 1/1/1931 Male
DSOUZA, MANUEL
RT071031
*1/1/1931
M
12/6/2007
7:16:04 PM
A
Spin: 0
Tilt: -90
R
MachineIsocenter
10cm
FINAL1
DSOUZA, MANUEL
RT071031
*1/1/1931
M
12/6/2007
7:16:04 PM
A
Spin: 90
Tilt: 180
F
MachineIsocenter
10cm
FINAL1
DSOUZA, MANUEL
RT071031
*1/1/1931
M
12/6/2007
7:16:04 PM
H
Spin: 0
Tilt: 0
R
MachineIsocenter
10cm
FINAL1
WARNING: Incorrect Offset may lead to Mis-treatment.
Prior to applying offset,visually verify that the registration accurately aligns visible anatomy or landmarks.
Press"ACCEPT" after your have verified the registration.
Isocenter Name: Isocenter 1
Beams: G150C5T355, G190, G280, G320, G150C10T270 , ,
accept
print
Viewing
Filming
3D
OIS
Localization
AT
Patient is loaded to Adaptive Targeting

Synchrony™ Respiratory Tracking System

- Synchrony camera
- Synchrony tracking markers
- Fiber optic sensing technology
- Tracks patient's respiratory motion

ACCURAY

CyberKnife® Treatment with Synchrony

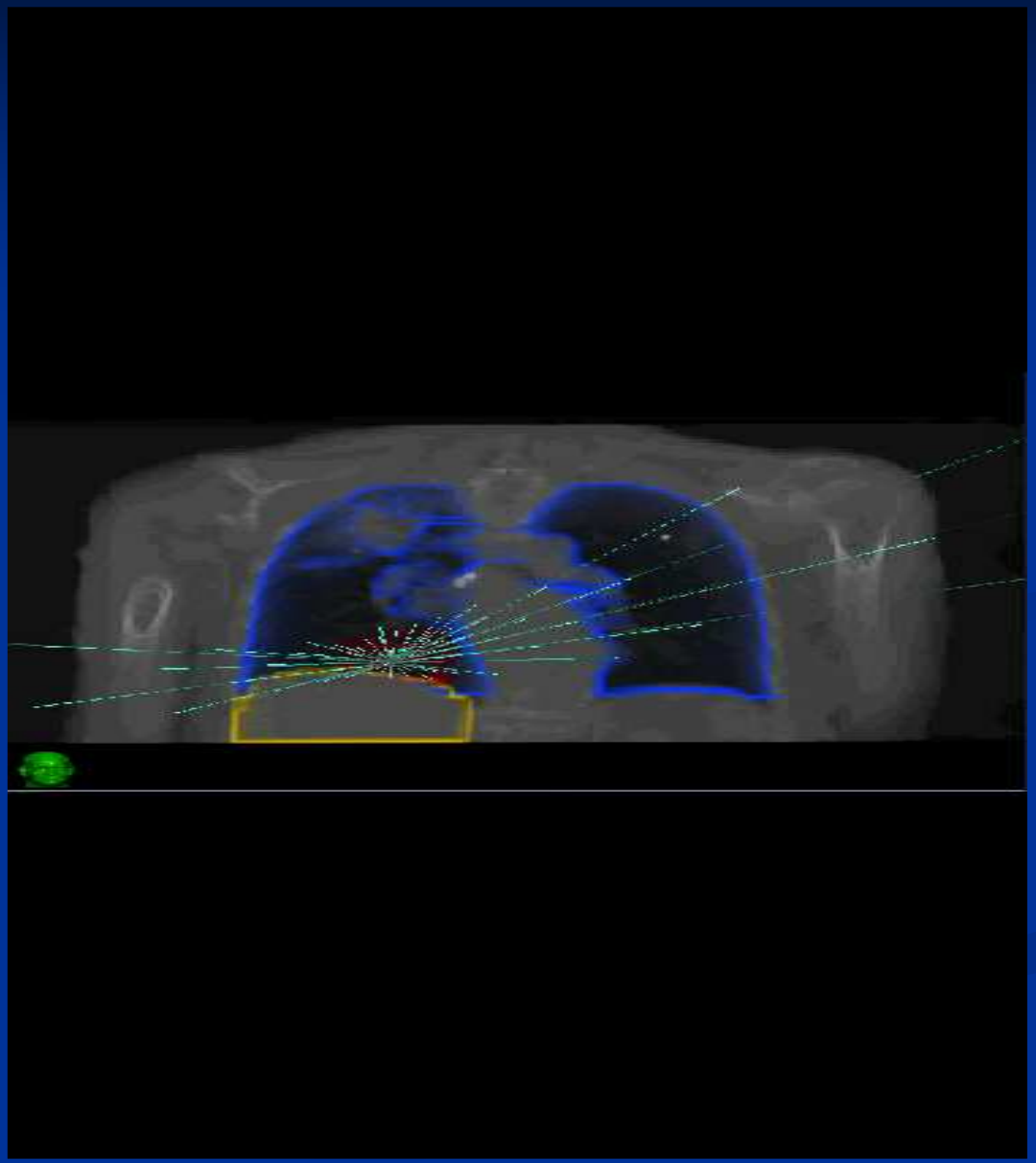
Synchrony's Benefits:

- Patient breathes normally
- Lesion tracked throughout treatment
- Sub-millimeter tracking accuracy*
- Minimal irradiation of healthy tissue

*Reference: Dieterich S, Taylor D, Chuang C, Wong K, Tang J, Kilby W, Main W. The CyberKnife Synchrony Respiratory Tracking System: Evaluation of Systematic Targeting Uncertainty

Respiratory Tracking System

- Delivers radiation throughout the respiratory cycle without gating or breath-holding
- Instantly adapts to variations in breathing patterns



Stereotactic Radiation Surgery: Lung

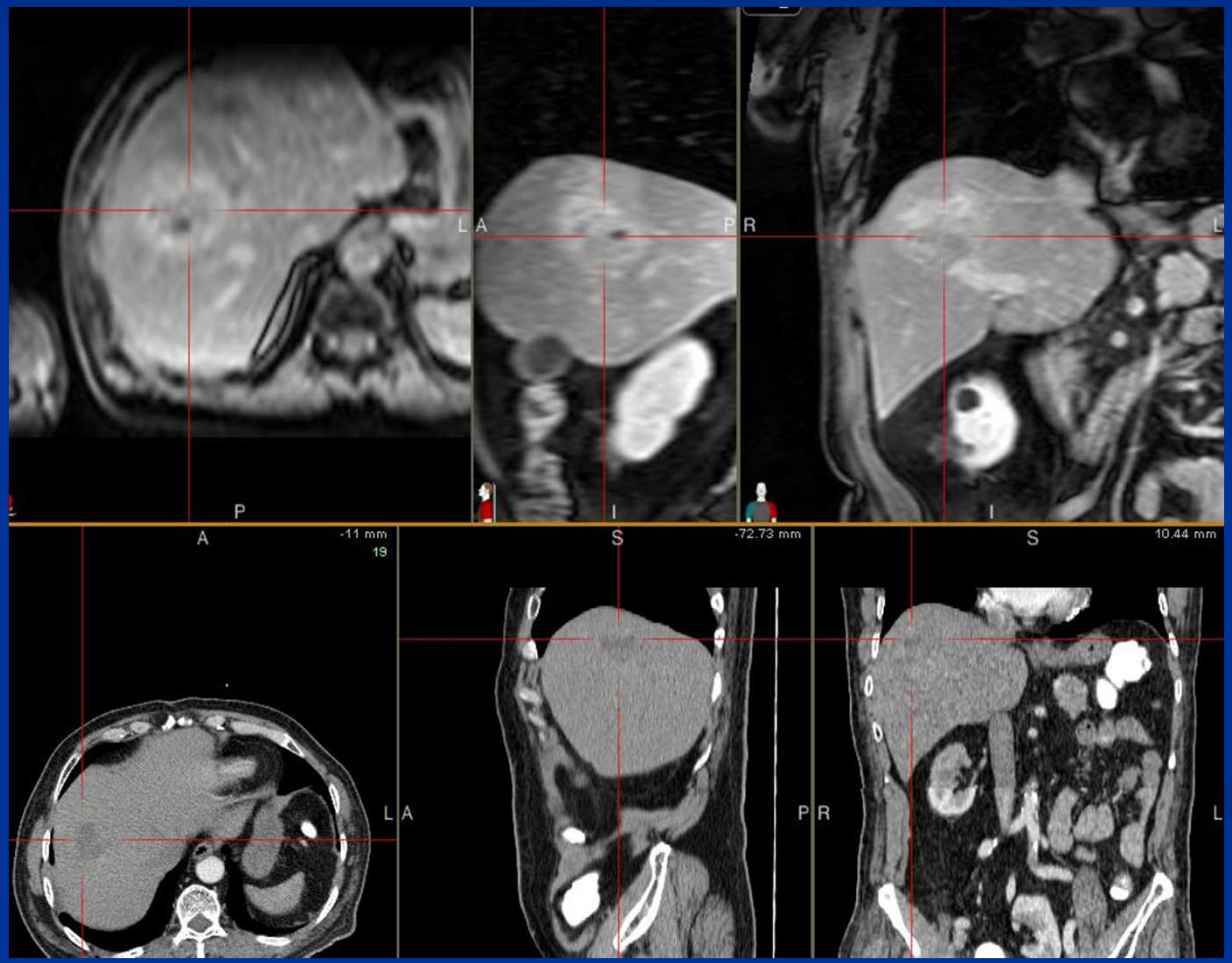
- Hoopes DJ et al, 2007 24 to 72Gy/ 3 f Stage I NSCL
  - LC – 74.8%. Nodal rec. 10%. 3 YOSR – 48.9% **PET activity may persist for 2 Y**
- Aoki M et al, 2007, early lung cancer 54 Gy/9 f (11 to 22 days)
  - LC - 95%, Survival 9.4-39.5 (median 17.7) mo. 2YSR- 89.5%
- Ongoing RTOG trial 20 Gy x 3 f
- Present option: Radiation surgery 16 Gy x 3 fr

[>5 cm lesions cyberknife 7 Gy X 5 f/ Artiste IGRT]

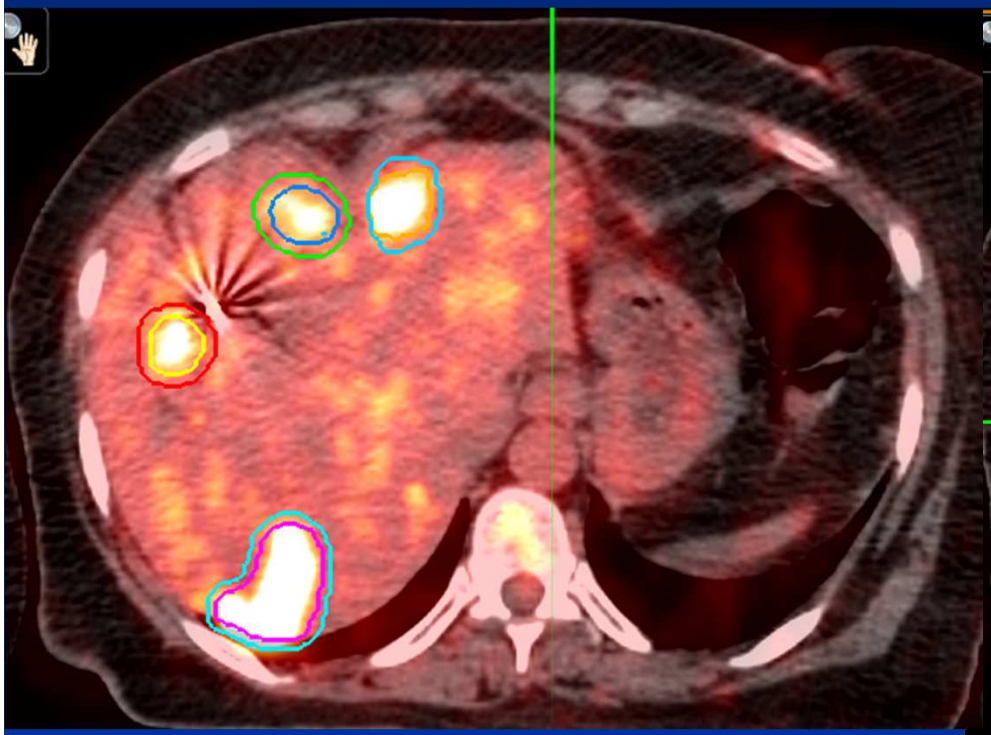
GI Cancers

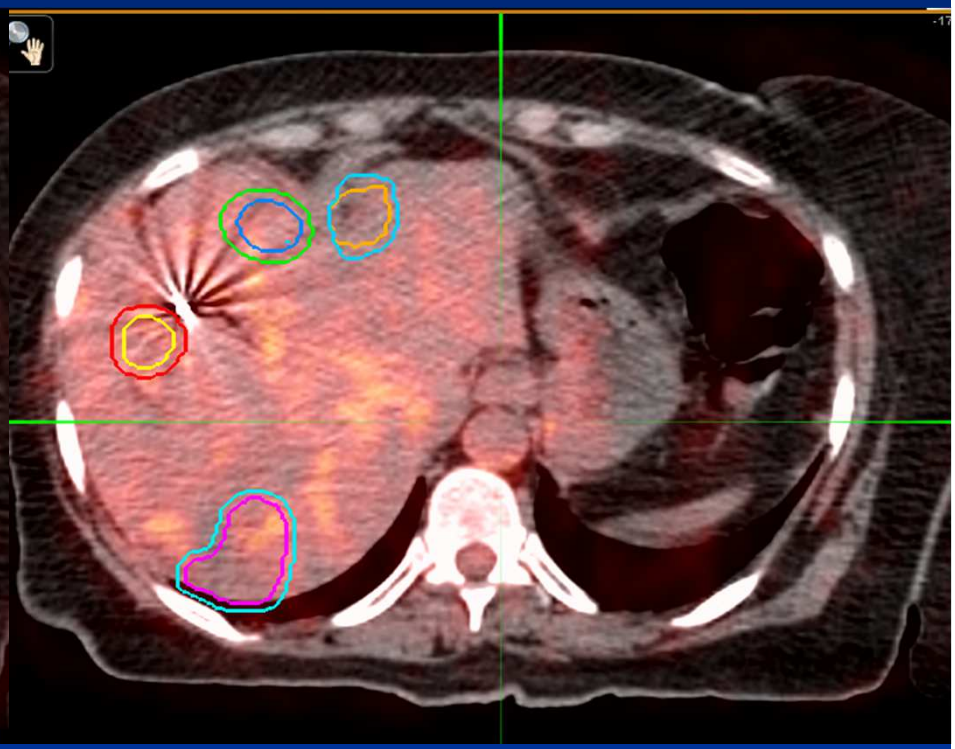
Hepato-Cellular Carcinoma

- Not Suitable for surgery
- Not Suitable for RFA (close to vessel)



CARCINOMA BREAST, 4 MTASTASES LIVER
→ complete response after CK at 6 months





Before

6 months later

Amazing precision

adding life to years

CK Inoperable
Carcinoma Pancreas

Stereotactic Radiation Surgery: Pancreas

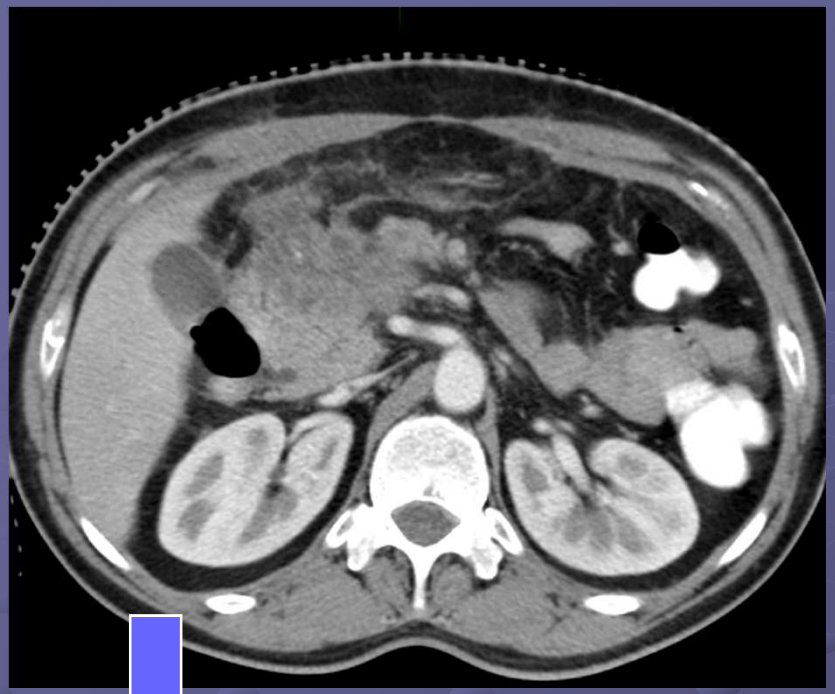
- Patient of Carcinoma Pancreas with local infiltration-Inoperable/surgery not feasible

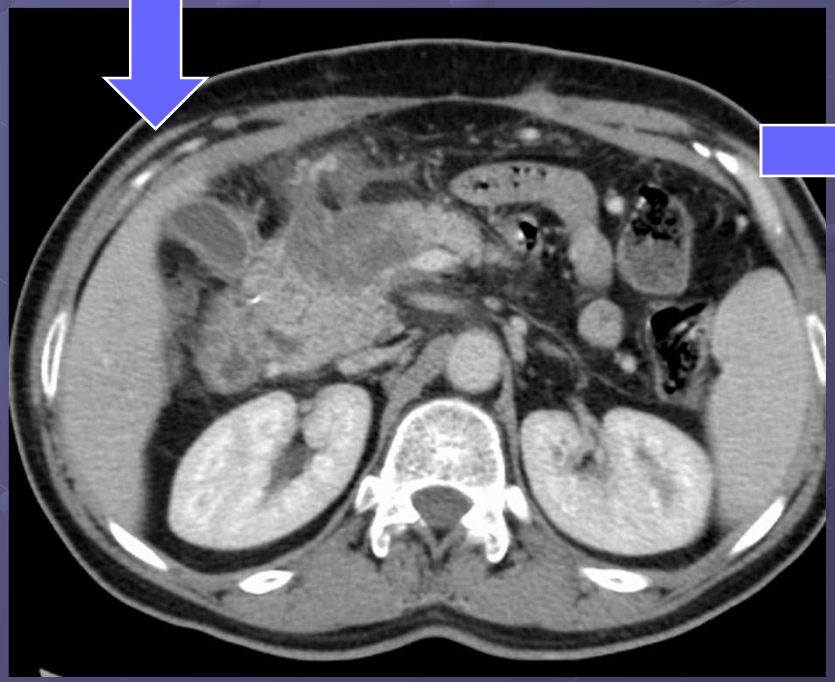
- Conventional option:
  - Radio-Chemotherapy
  - Clinical trial
  - Poor GC – Best supportive care

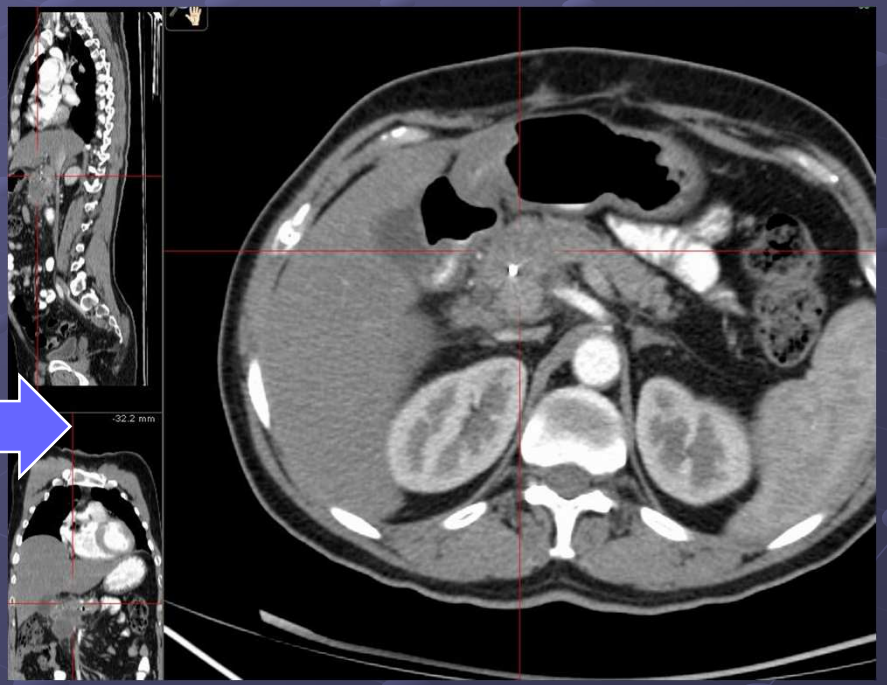
Internal fiducial gold seeds or Coils (Viscicoil©)

Fiducial gold seed markers with applicators

VOI	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage
GTV1	1266.71	2829.85	3858.60	1.06	1.43	1.54	74.51%
GTV0	1773.06	3079.15	3858.60	1.53	1.64	1.54	93.20%
tun	147.90	234.30	511.71	n/a	n/a	n/a	n/a
liver	93.32	408.28	2593.83	n/a	n/a	n/a	n/a
rt kidney	111.28	350.41	838.84	n/a	n/a	n/a	n/a
lt kidney	155.91	277.39	489.93	n/a	n/a	n/a	n/a
duodinum	181.17	975.79	2746.68	n/a	n/a	n/a	n/a
stomuch	99.27	503.39	2254.28	n/a	n/a	n/a	n/a
INTESTINE	105.57	309.15	1462.60	n/a	n/a	n/a	n/a
0 cm	218.62	795.91	2252.63	n/a	n/a	n/a	n/a
Body	85.08	585.53	3858.60	n/a	n/a	n/a	n/a







Before, 3 mo., 6 mo.
AFTER CK

Stereotactic Radiation Surgery: Pancreas

- Chang ST et al, 2007

  Treated with cyberKnife radiosurgery, 25 Gy in single fraction

  – local control of 90%

Present option (even with poor GC) :

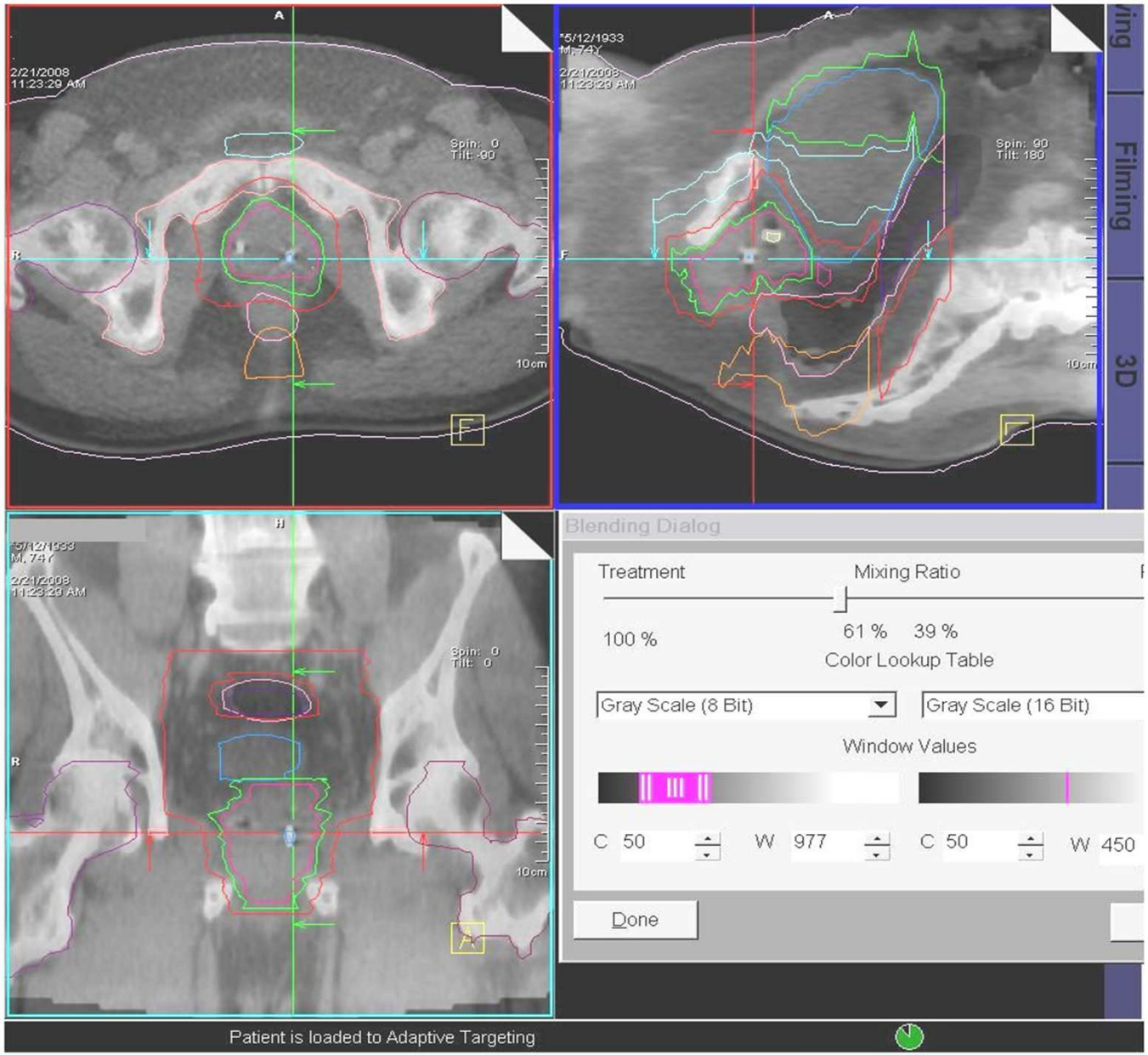
Cyberknife +/- Chemotherapy

[larger lesions cyberKnife therapy with 35 Gy/ 5 fractions]

GU Cancers

Prostate – Low & intermediate risk

- Surgery not feasible
- Is also an option instead of surgery


2/21/2008
11:23:29 AM
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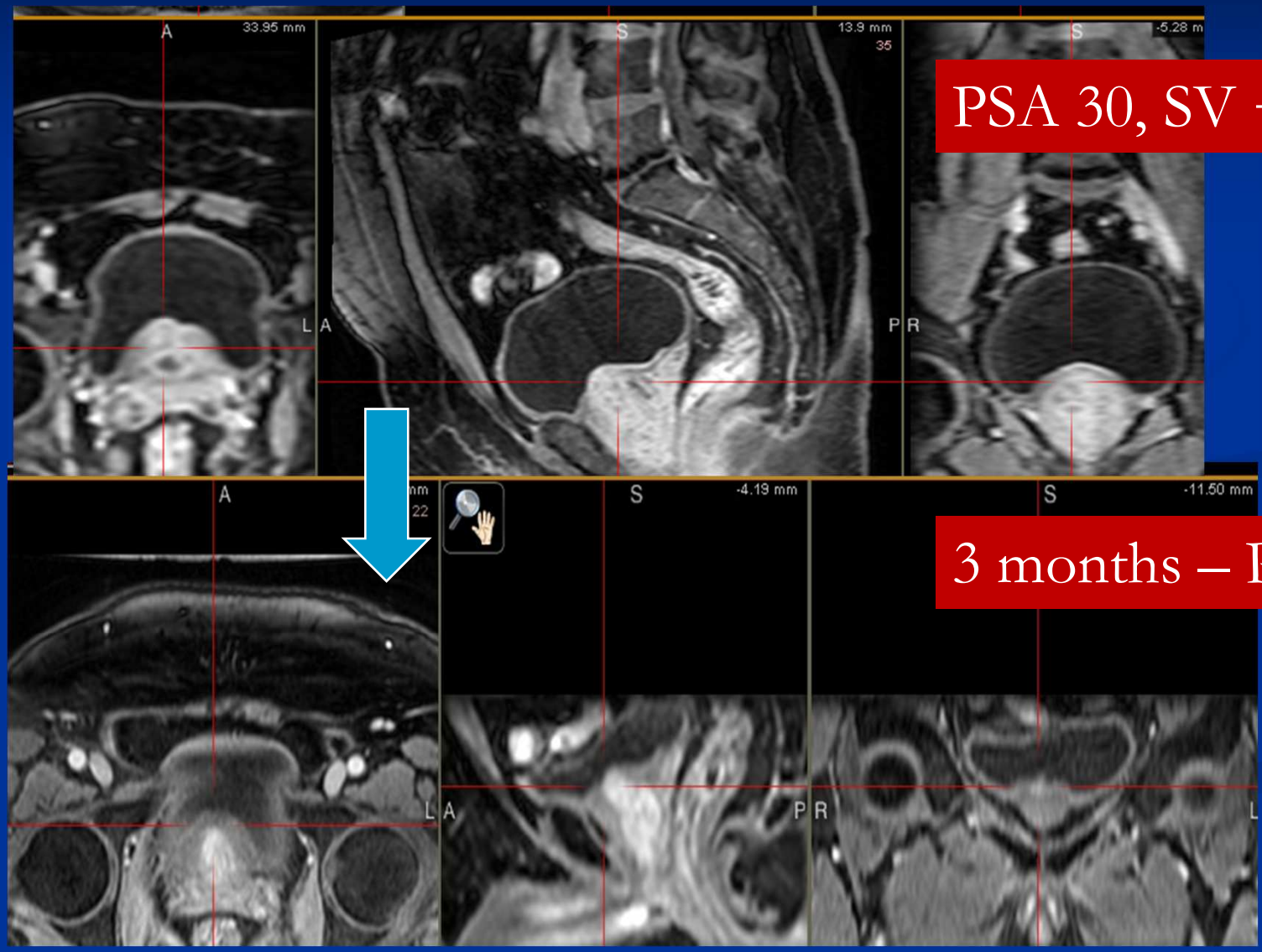
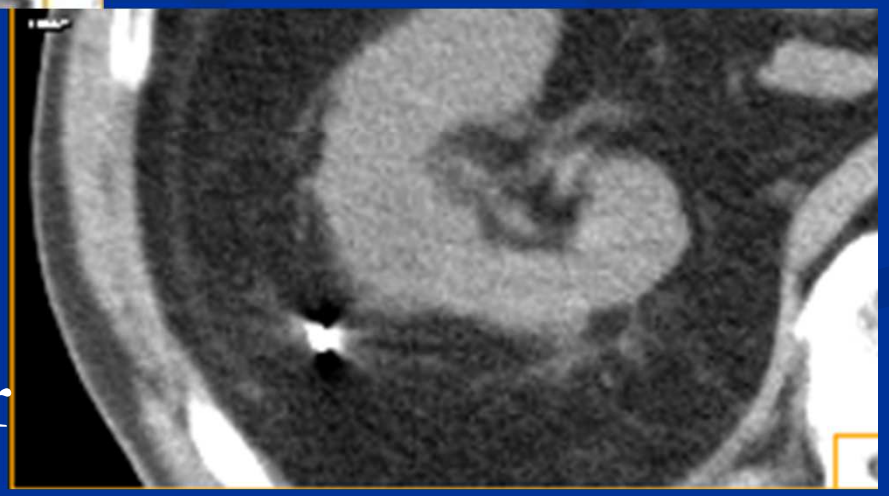
Tilt: -90
10cm
Spin: 90
Tilt: 180
Spin: 0
Tilt: 0
Filming
3D
Blending Dialog
Treatment
Mixing Ratio
100 %
61 %
39 %
Color Lookup Table
Gray Scale (8 Bit)
Gray Scale (16 Bit)
Window Values
C 50
W 977
C 50
W 450
Done
Patient is loaded to Adaptive Targeting

Locally advanced Ca Prostate – High risk
IGRT + CyberKNife + HT



Renal Cell Carcinoma – inoperable - Bilateral

PRE



3 months Later

Clinical Benefits

- Staged/Fractionated Radiosurgery
  - 1-5 fractions/stages
  - Larger lesions
  - Lesions next to critical structures/organs at risk
- Improved Patient Quality of Life
  - Short treatment course: 1-5 days CyberKnife vs. 6-8 wks Radiotherapy
    - Optimal for patients
    - Optimal for patients with limited life expectancy
    - Increased convenience
  - No infection risk
  - No general anesthesia
  - Minimal to no recovery time, as compared to open surgery

ACCURAY

Limitations

- Availability/Cost
- Treatment time

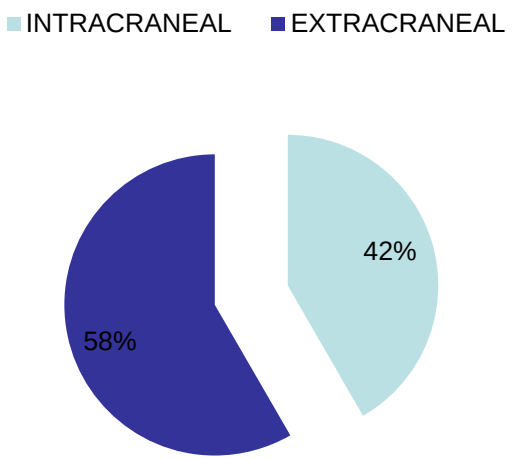
Future

- Movable Collimation
- Increased dose rate
- Robotic couch movement

ACCURAY

CYBERKNIFE-1YR

- 30/05/09-13/08/10
- Total – 395
- Extracranial-224
- Intracranial-171



INTRACRANIAL

METS	50
GLIOMA	65
PITUITARY	7
PINEAL	3
SCHWANNOMA	13
MENINGIOMA	20
EPENDYMOMA	5
AVM	3
CHORDOMA	3
VASCULAR	2

EXTRACRANIAL

LUNG	34
PANCREAS	27
LIVER	38
HEAD AND NECK	40
GYNECOLOGY	16
CHOLANGIOCARCINOMA	4
COLORECTAL	12
STS	15
NEUROENDOCRINE	7
VASCULAR	3
RCC	3
PROSTATE	23
LYMPHOMAS	2