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Stereotactic Radiosurgery

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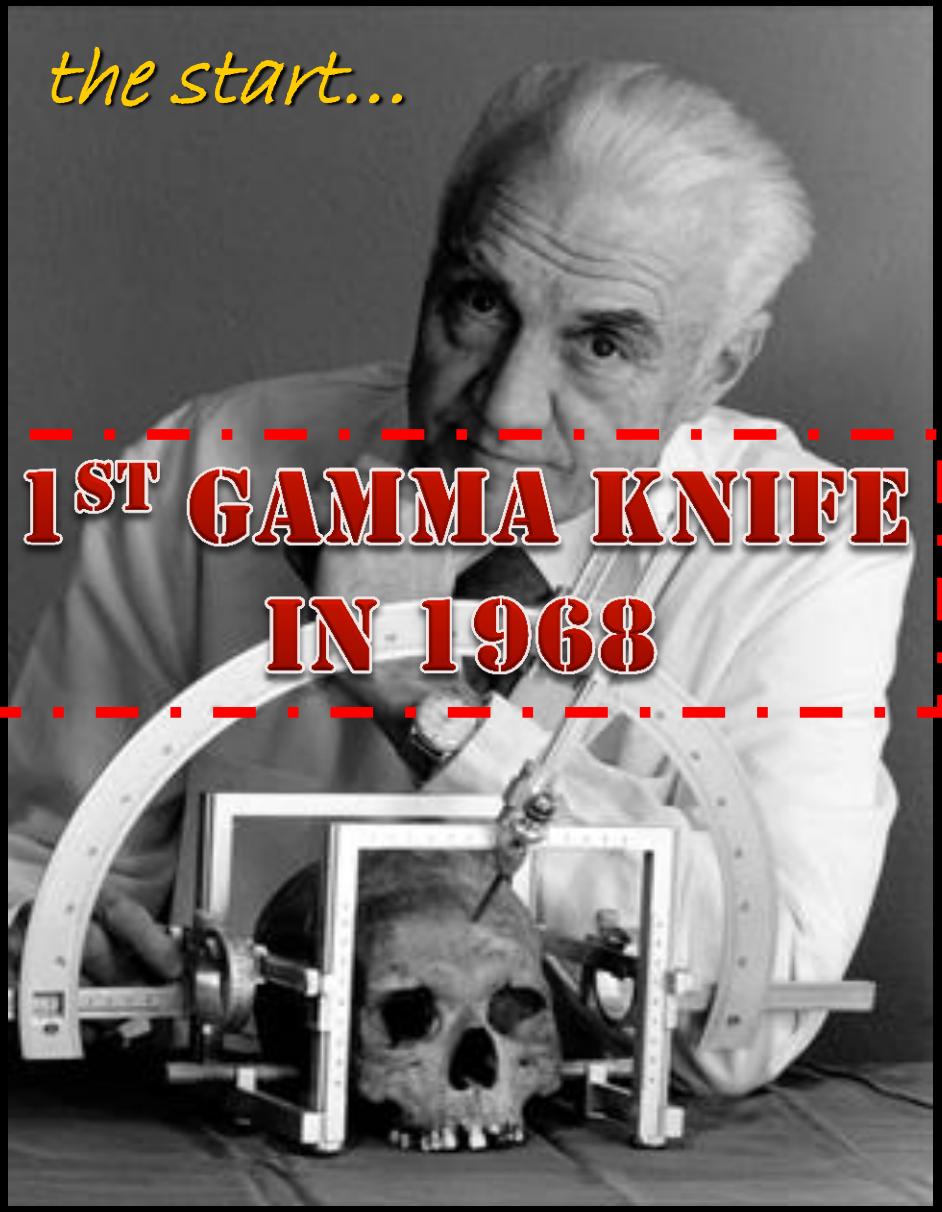
SRS

- Introduction
- Stereotactic techniques
  - Frame based
  - Frameless, Image Guided
- Indications
- Quality of life

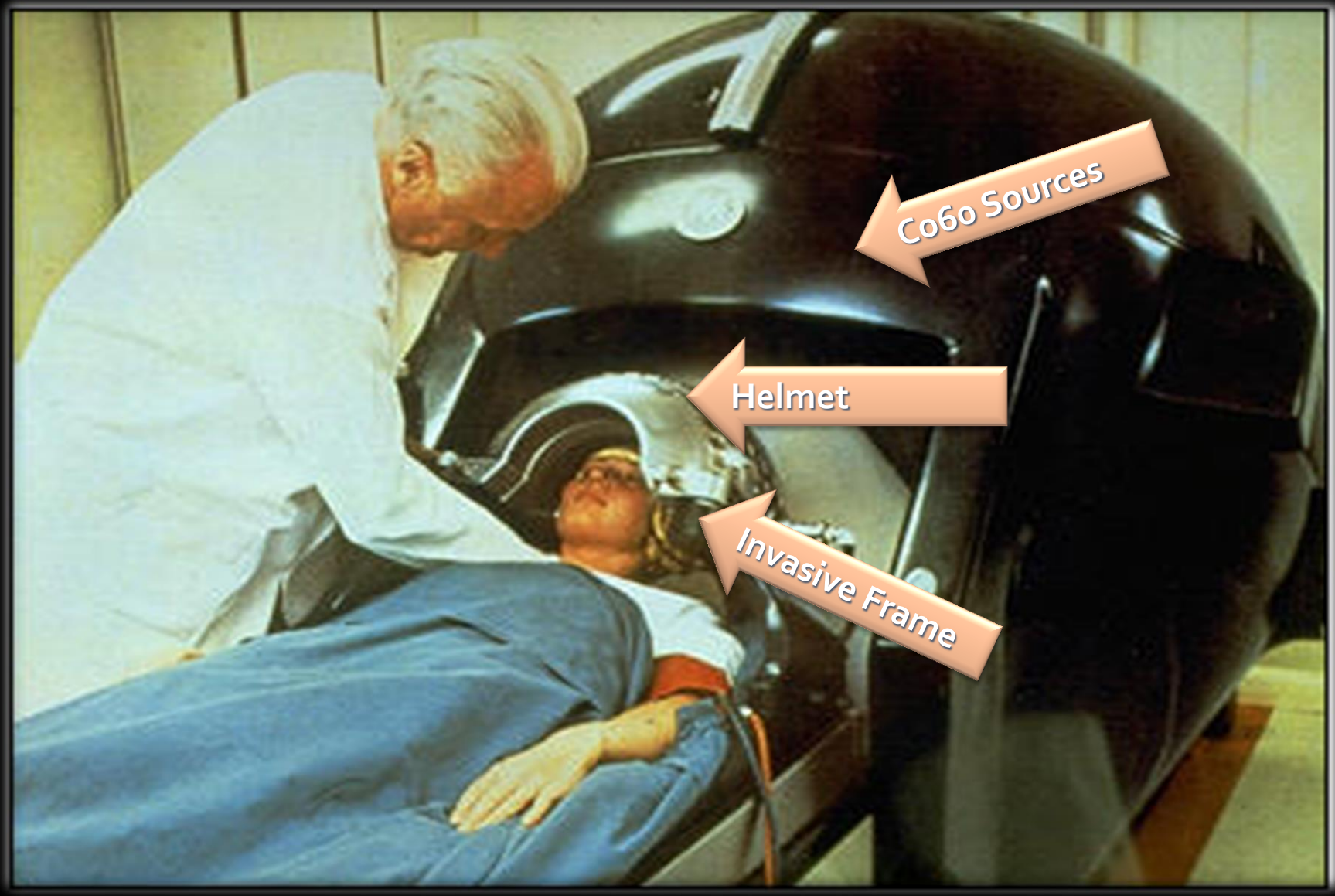
Introduction

- **Stereotaxy**
  - Precise three-dimensional mapping technique to guide a procedure
- **SRS**
  - Stereotactically guided conformal irradiation of a target in a single session

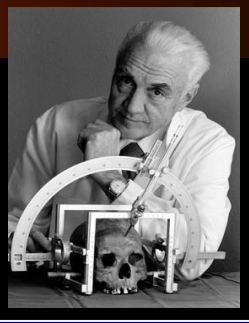


Prof. Lars Leksell

Prof Lars Leksell with first Gamma Knife in 1968



the development…



1951	Concept of Radiosurgery by Prof Leksell
1968	1st Gamma Knife in Stockholm, Sweden
1988	Linac-based Radiosurgery, Univ of Florida
1997	3mm Micro MLC M3 by BrainLab
2006	Frameless Radiosurgery by BrainLab

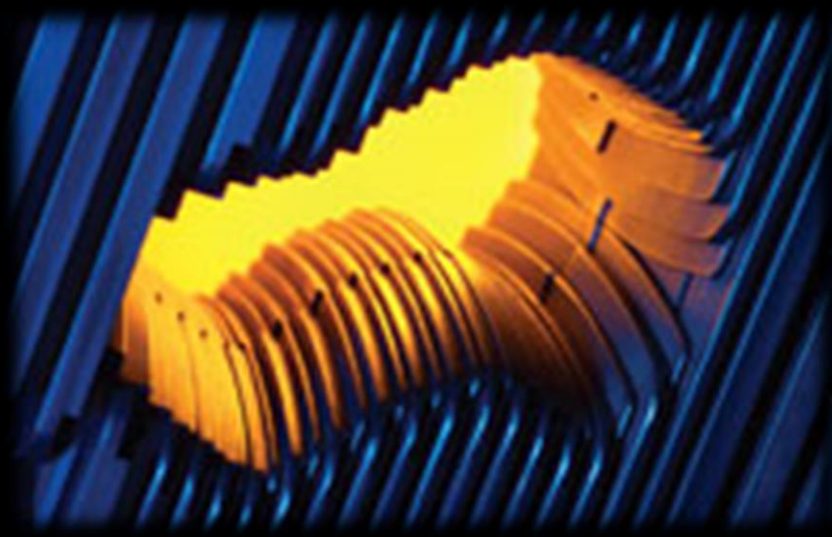
SRS: Gamma Knife vs. LinAc

Gamma knife (**Cobalt60**)	• Dedicated • High cost of source replacement • Fractionation not possible • More rigid	Linac (**X rays**)	• Versatile • No recurrent cost • More suitable for irregular targets • Fractionation possible • Less rigid

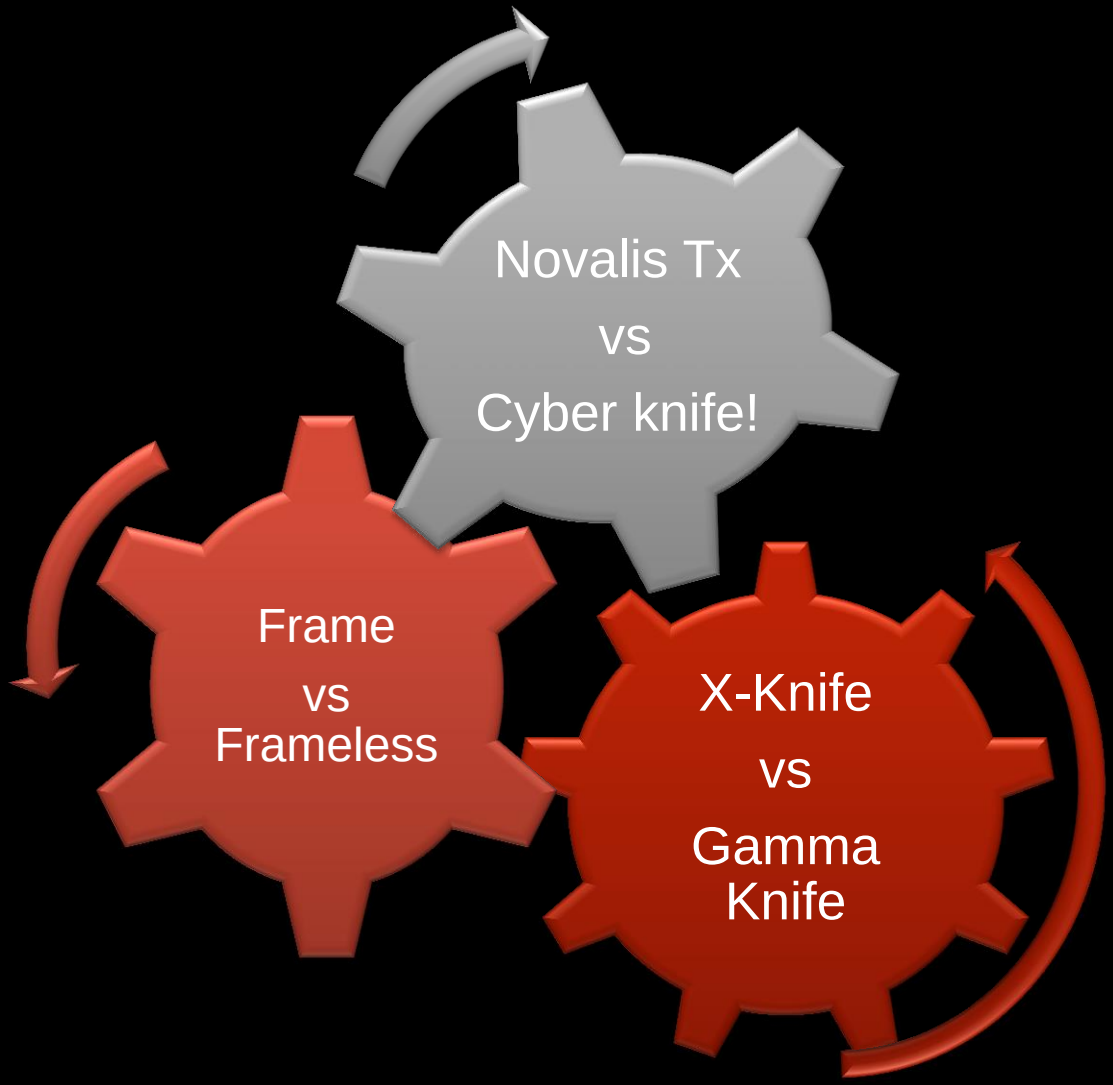
LinAc Radiosurgery:1988

Localisation: Frame or Image Guided

Beam shaping: MLC or Cone



Spoilt for Choice!



LinAc Based Stereotactic..

- X Knife
- NovalisTX
- Cyberknife
- Tomotherapy

Cyber Knife

Image guided frameless

NovalisTx - Versatile + Accurate

Novalis TX *Versatile + Accurate*

- Hi Def mMLC 2.5 mm
- OBI: KV imaging & CBCT
- 6D Robotic Couch
- Adaptive and RPM Gating
- ExacTrac positioning, Verification
- iPlan SRS Planning System

Workflow

SRS

- Joint clinical decision (Neuro+RT)
- Imaging- MRI
- Frame/Mask fixation
- Imaging- Angiogram / CT scan
- Localization of reference markers
- Image fusion
- Target Delineation
- Planning
- QA
- Patient positioning & Treatment

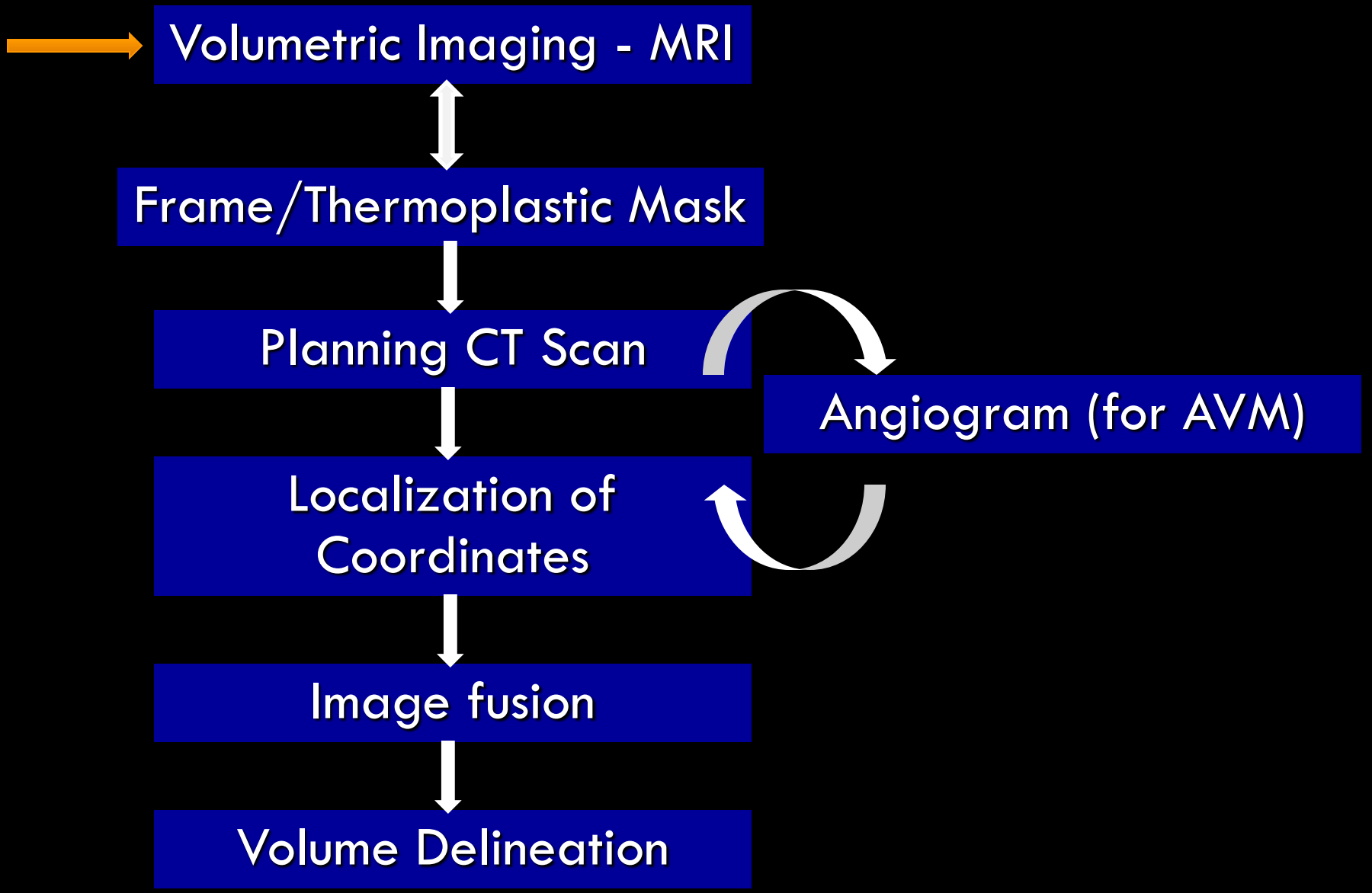
Workflow

Joint Clinical Decision

Frame or Frameless

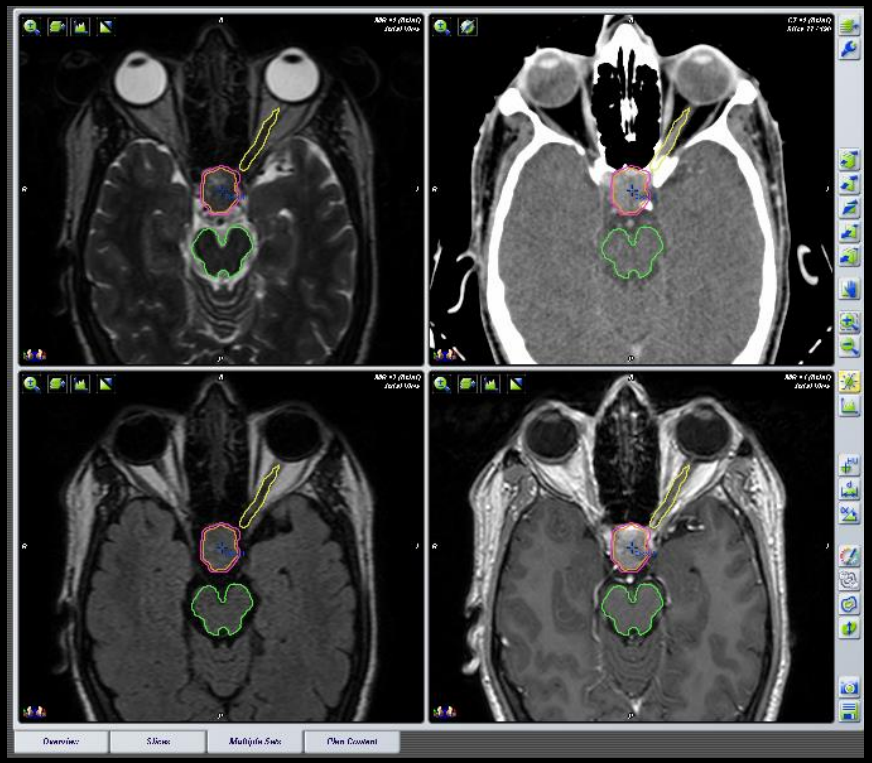
Dose Fractionation

the workflow …



Procedure of Radiosurgery

3D-multimodality imaging…



MRI

- T1 Plain & Contrast
- T2
- Flair
- 3D Volumetric Study

- 1.5mm
- True Axial
- 512 x 512 matrix DICOM RT compatible

the workflow …

Volumetric Imaging - MRI

Frame/ Thermoplastic Mask

Planning CT Scan

Angiogram (for AVM)

Localization of Coordinates

Image fusion

Volume Delineation

the procedure...

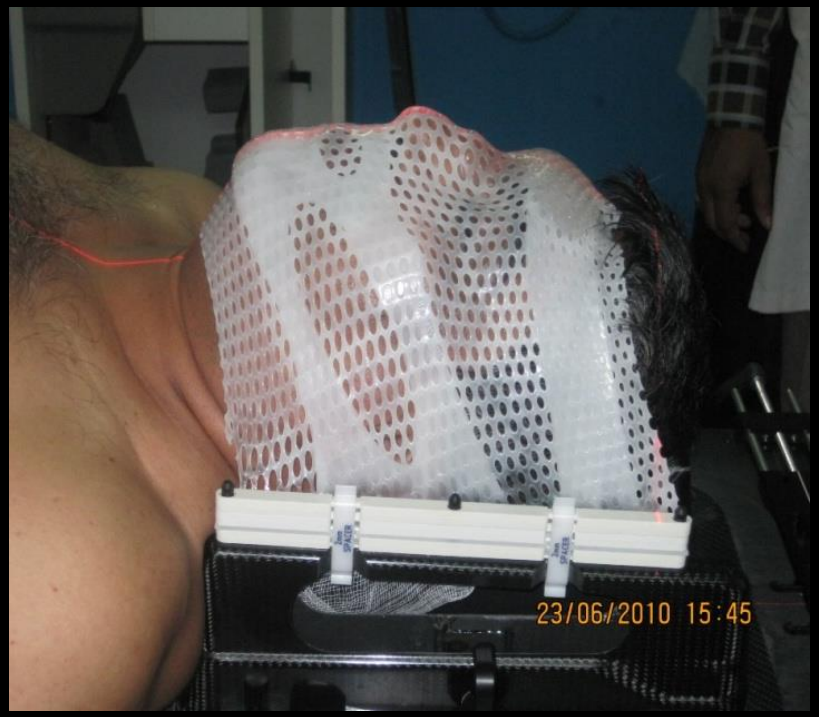
Frame

Frameless

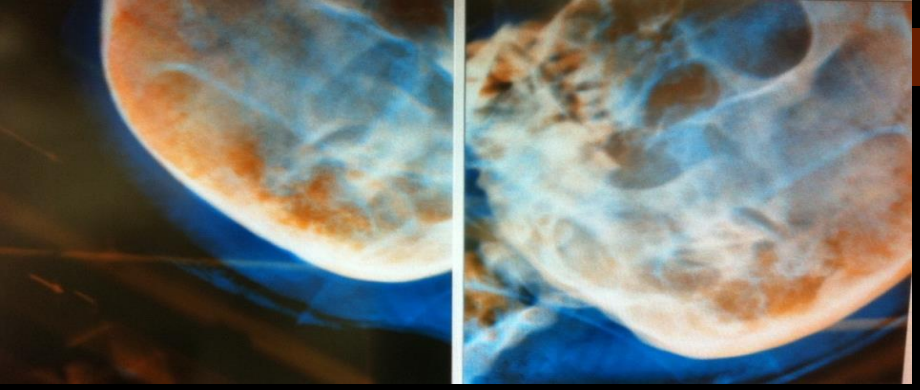
... why not painless non invasive?

Frame based

Frameless, mask based



... why not painless non invasive?

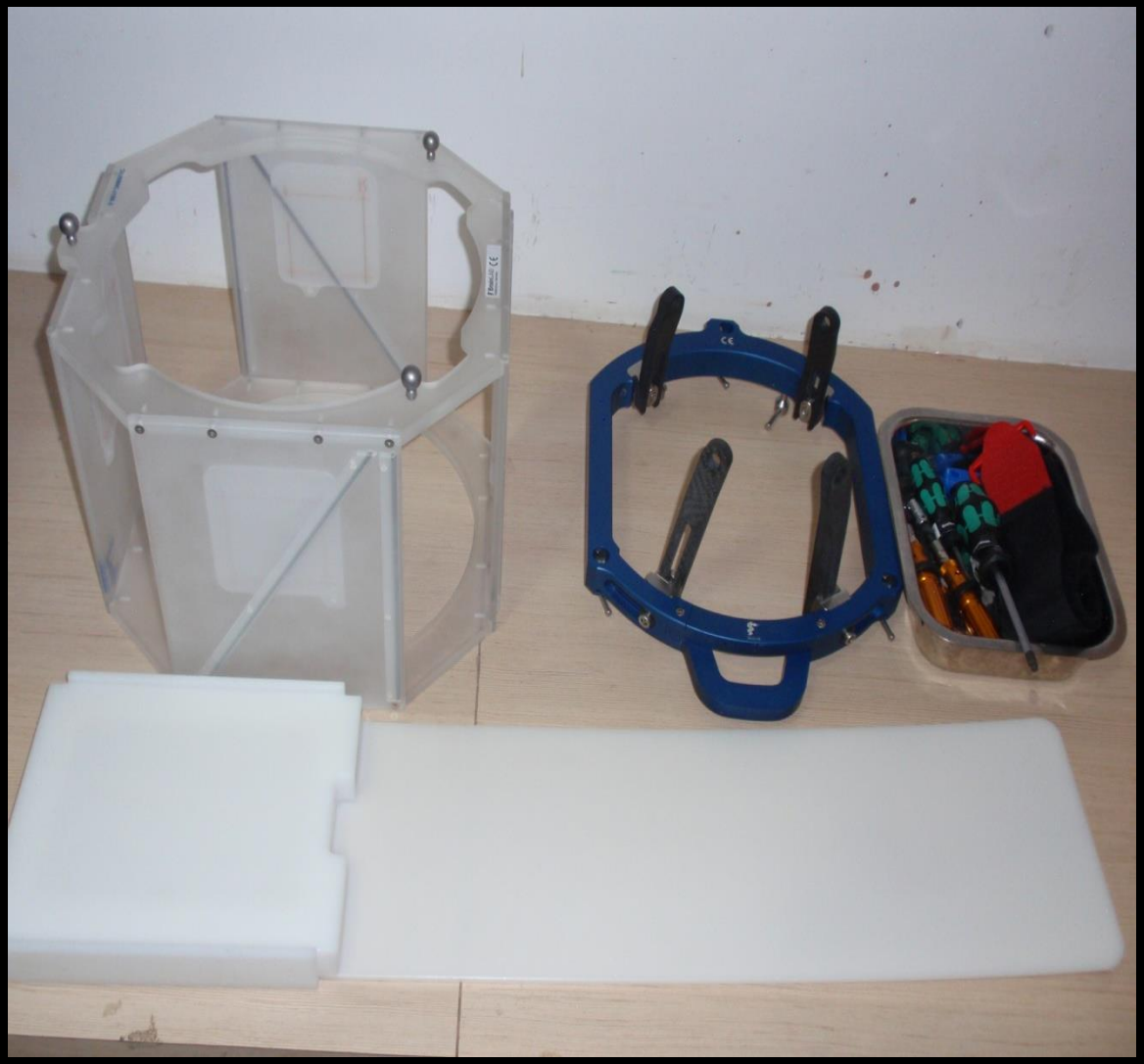


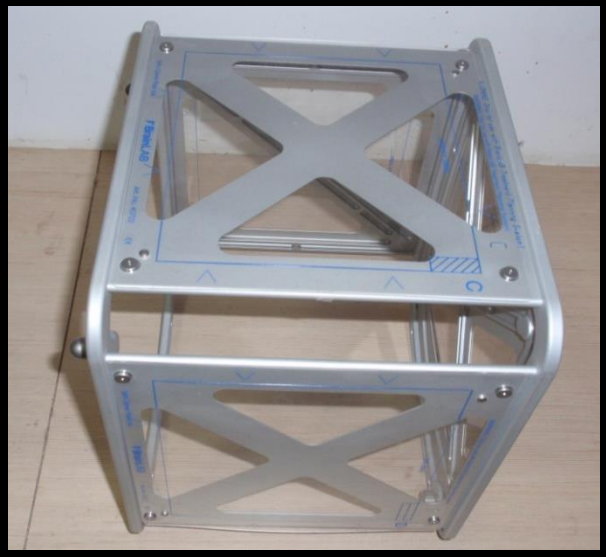
Frameless ExacTrac System

Conclusions / Advantages

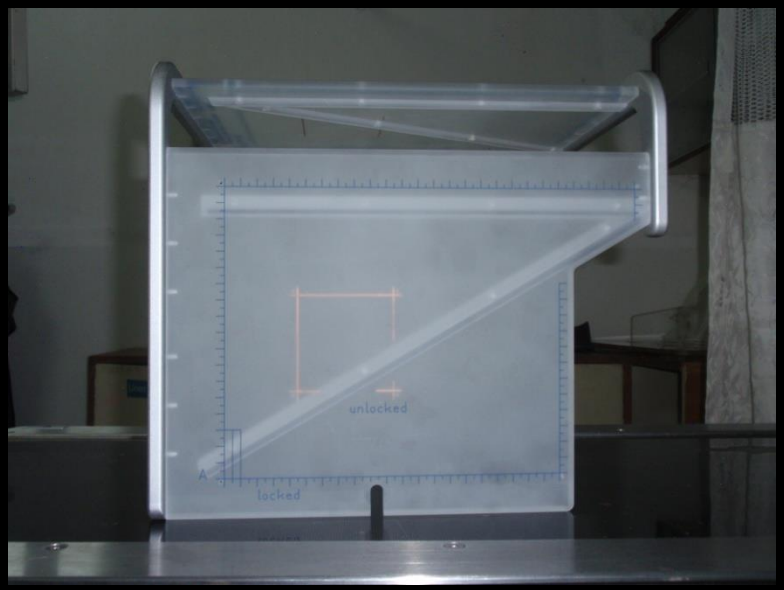
- Easier on the patient
- Easier on the Physician
- Flexible
- Faster
- Accurate
- Check possible in all couch / treatment positions
- Can be fractionated if necessary

Frame : BrainLab CT Localizer



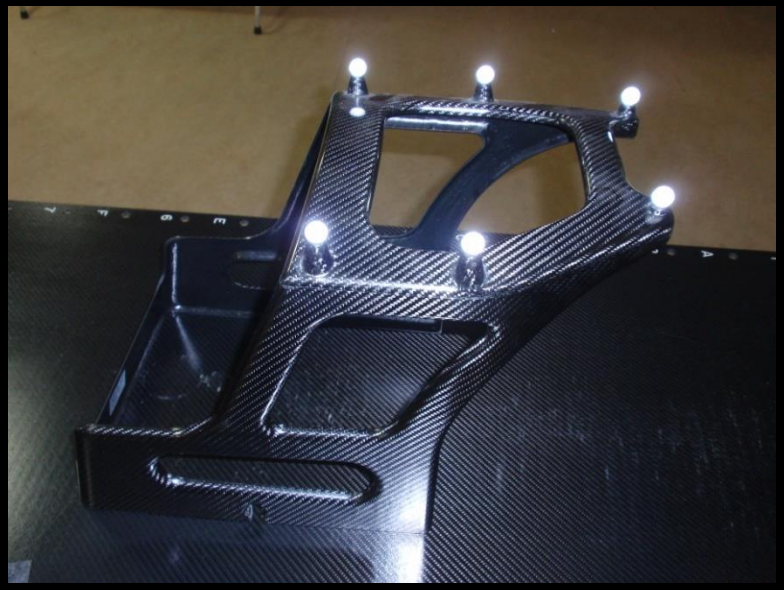


Frameless : Localization

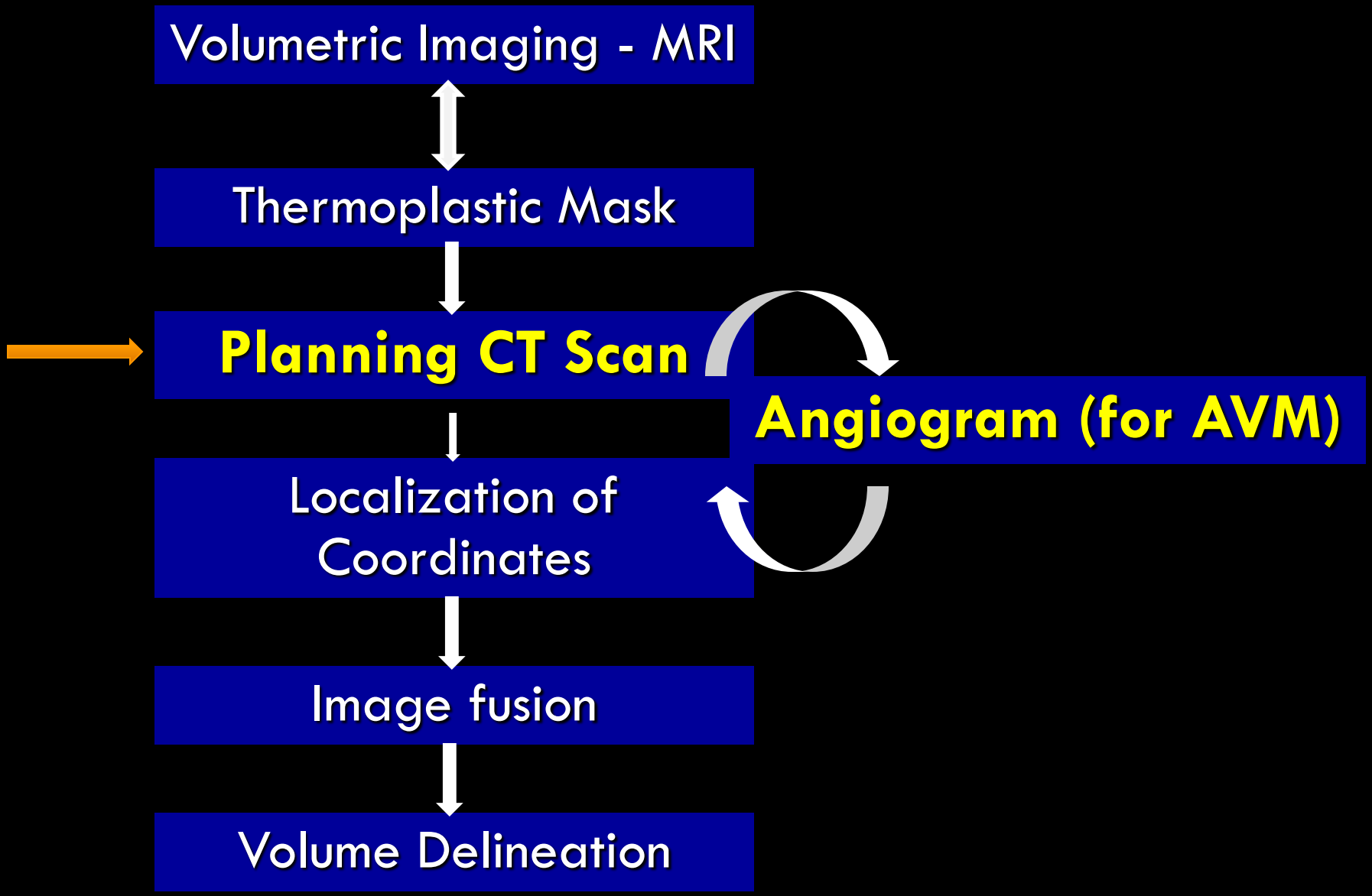


- H&N Localizer Box used during CT/ ANGIO
- Supports all lesions down to T1 spine
- Attached to CARBON BASE PLATE of H&N mask

- Frameless Radiosurgery position array used during treatment
- Helps in tracking pt position during treatment



the workflow …



Procedure of Radiosurgery

3D-multimodality imaging…

CT Scan

1.5 mm true axial cuts

Contrast administration – 1 to 1.5ml/kg

FOV must cover entire localizer box

In treatment position, with the mask & localization box

Procedure of Radiosurgery

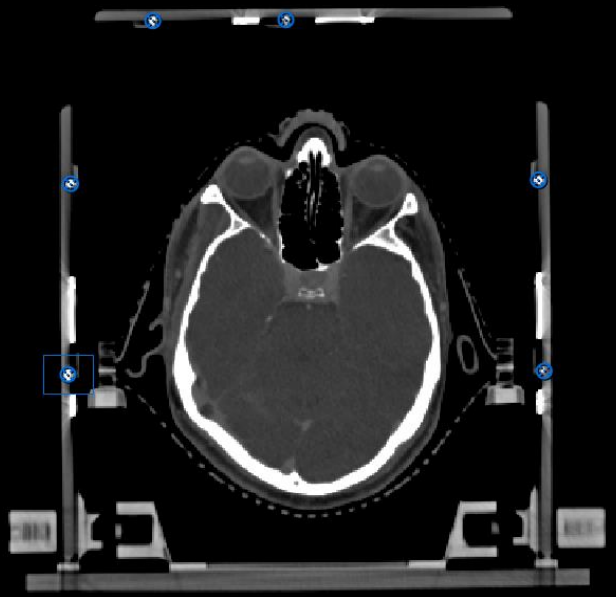
3D-multimodality imaging…

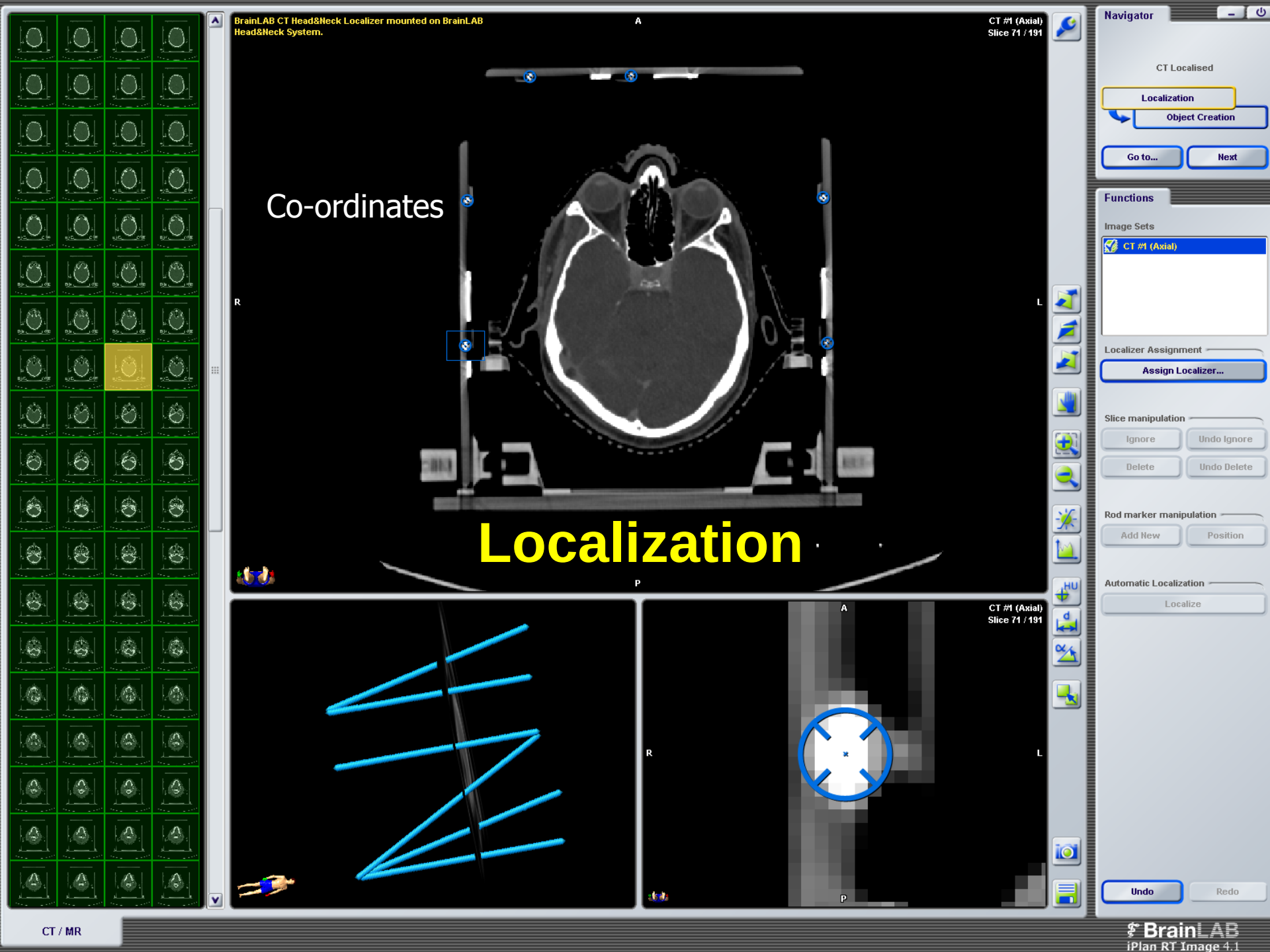
Angiography (AVM)

- With the localizer box in situ
- Orthogonal Images
- DICOM RT compatible
- Early Arterial Phase
- Main Feeding Vessel

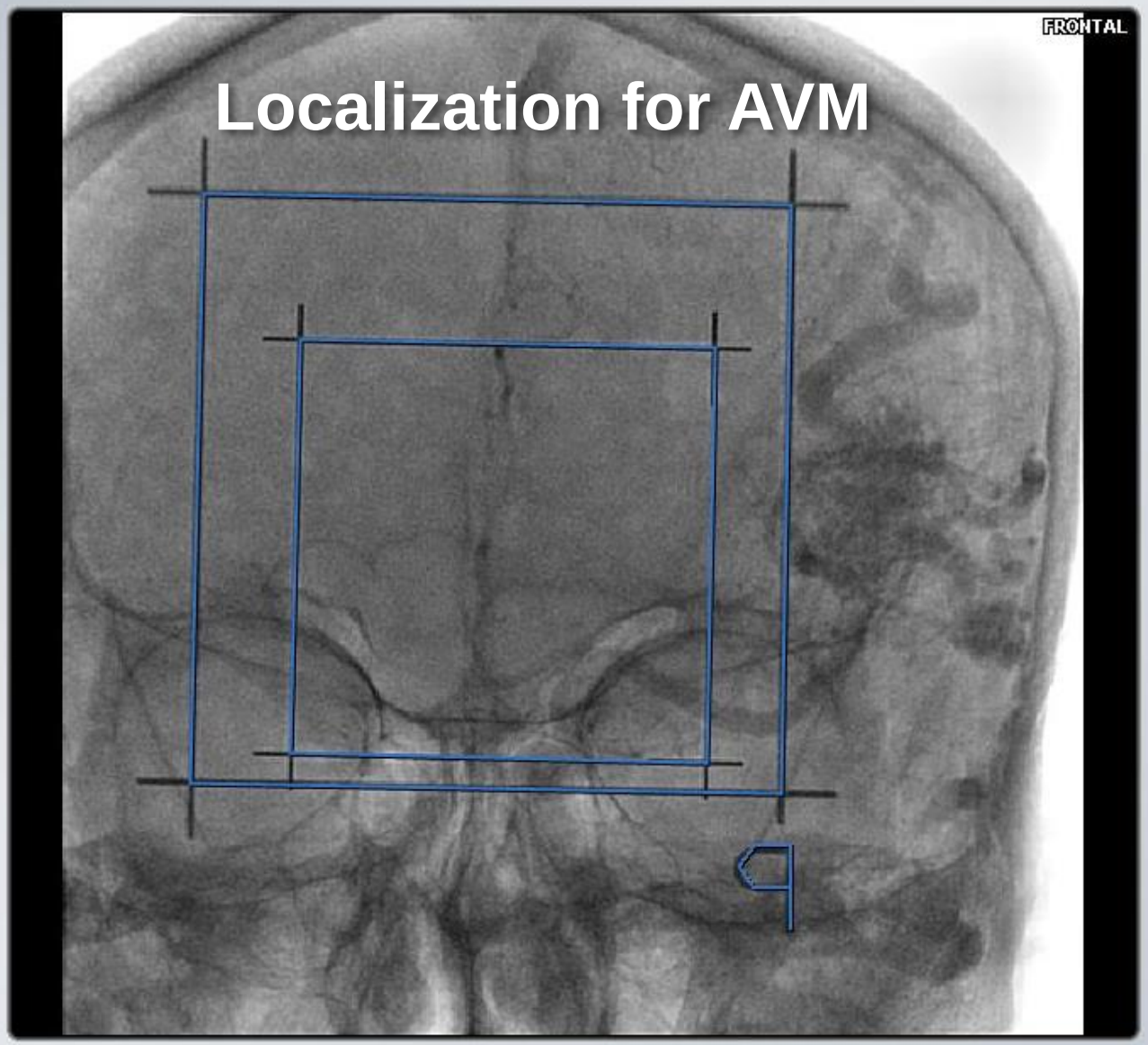
the workflow …

- Thermoplastic Mask
- Planning CT Scan
- **Localization of Coordinates**
- Image fusion
- Volume Delineation




BrainLAB CT Head&Neck Localizer mounted on BrainLAB Head&Neck System.
A
CT #1 (Axial)
Slice 71 / 191
Co-ordinates
R
L
P
Localization
CT #1 (Axial)
Slice 71 / 191
A
R
L
P
Navigator
CT Localised
Localization
Object Creation
Go to...
Next
Functions
Image Sets
CT #1 (Axial)
Localizer Assignment
Assign Localizer...
Slice manipulation
Ignore
Undo Ignore
Delete
Undo Delete
Rod marker manipulation
Add New
Position
Automatic Localization
Localize
Undo
Redo
CT / MR
BrainLAB
iPlan RT Image 4.1

Frontal



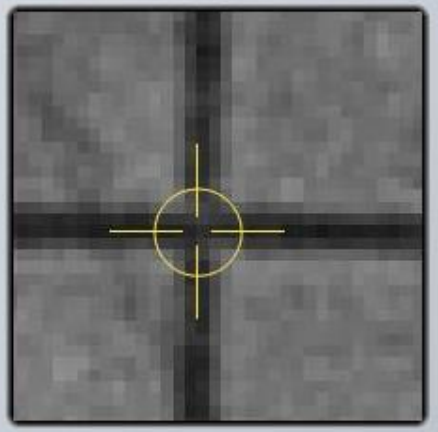
Assigned Localizer

BrainLAB CT/X-Ray Head&Neck Localizer mounted on BrainLAB Head&Neck System

Select View Orientation

Mirror Image

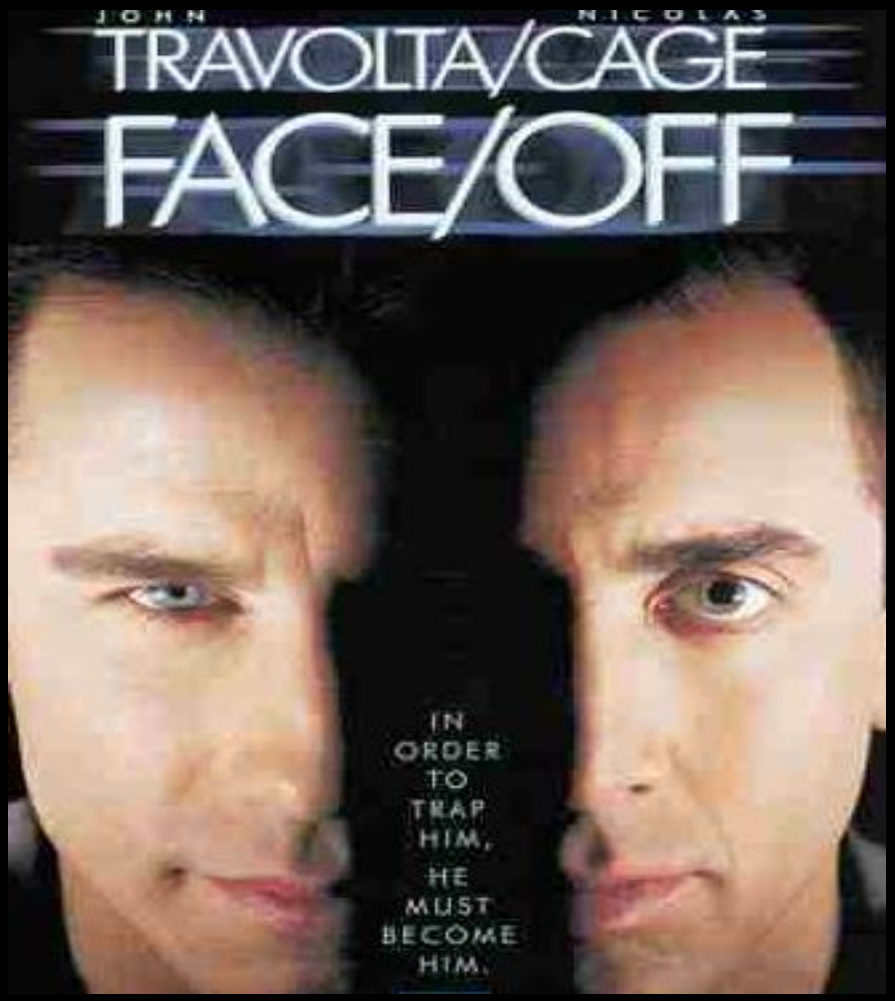
Magnifier

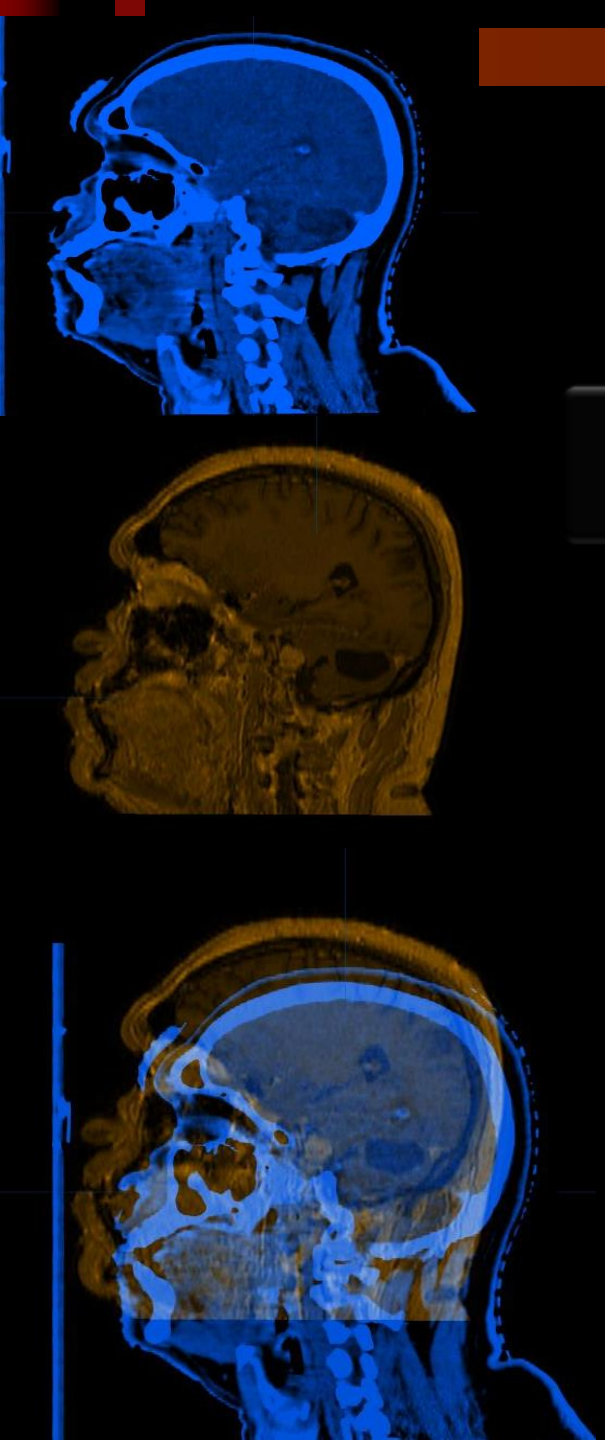


Back | Next | Cancel

the workflow …

- Thermoplastic Mask
- Planning CT Scan
- Localization of Coordinates
- **Image fusion**
- Volume Delineation



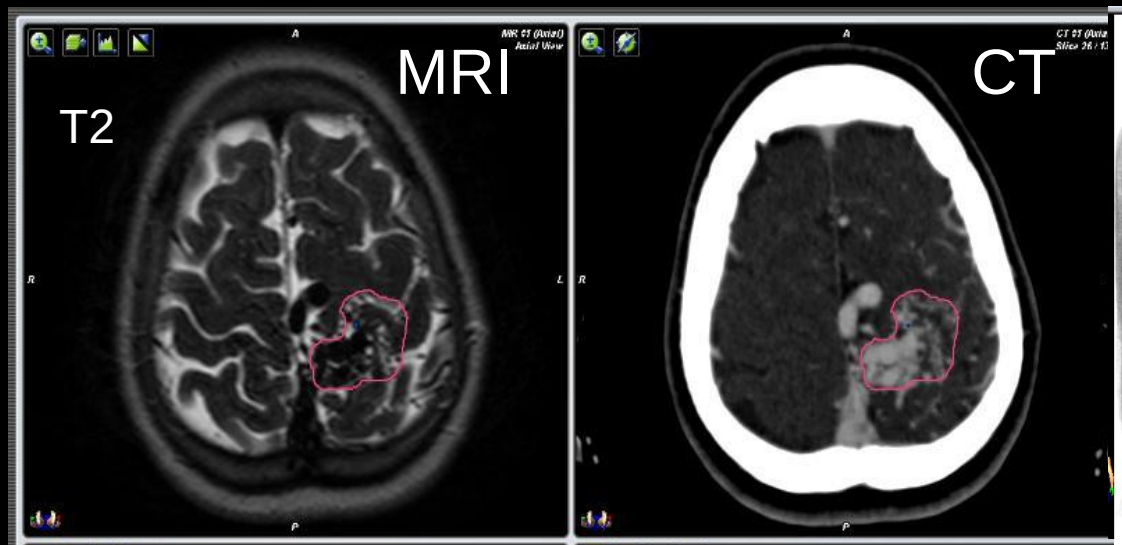


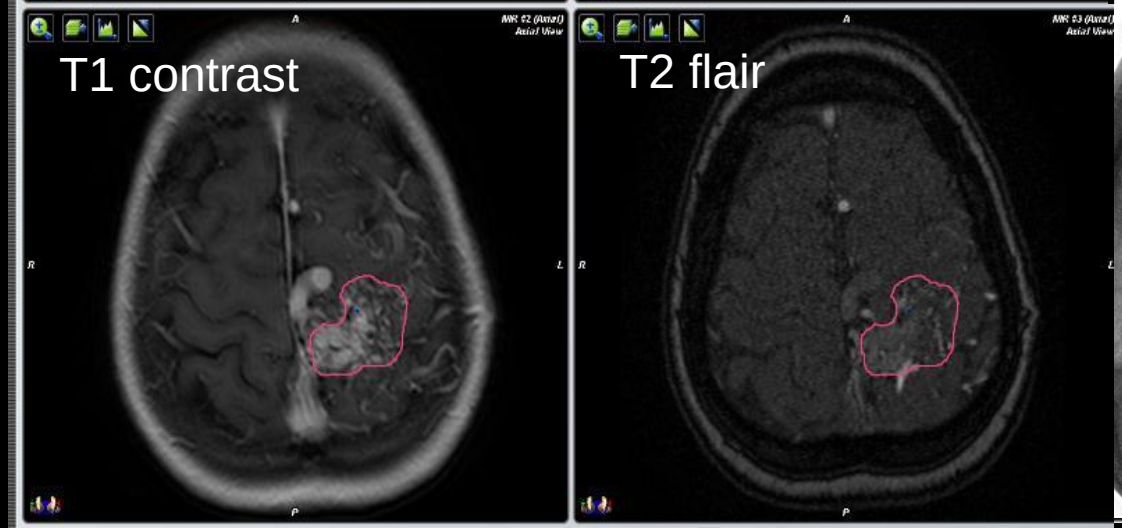
Workflow

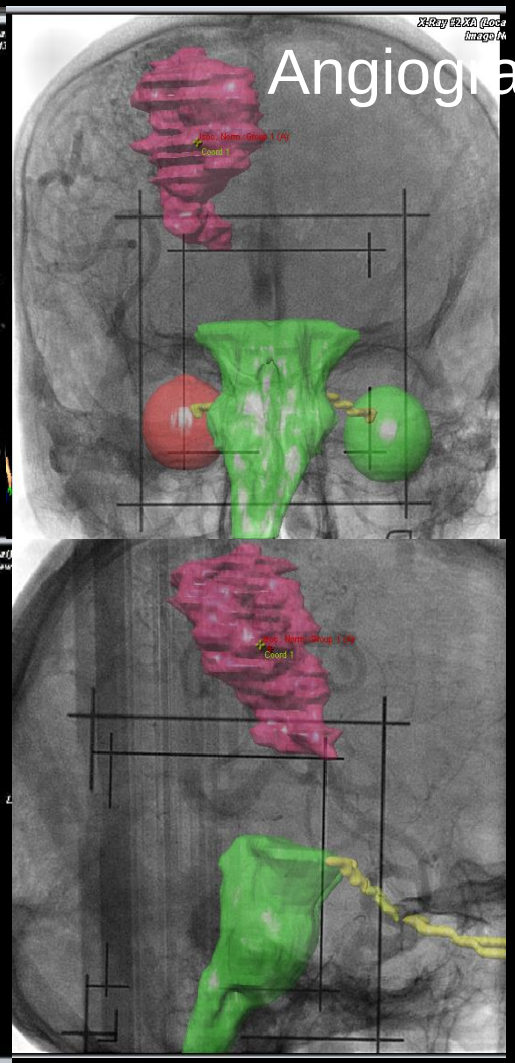
Image Fusion

- iPlan Planning System
- Automatic vs Manual
- Clinically relevant area
- Creating fusion pair of all series

Target Delineation





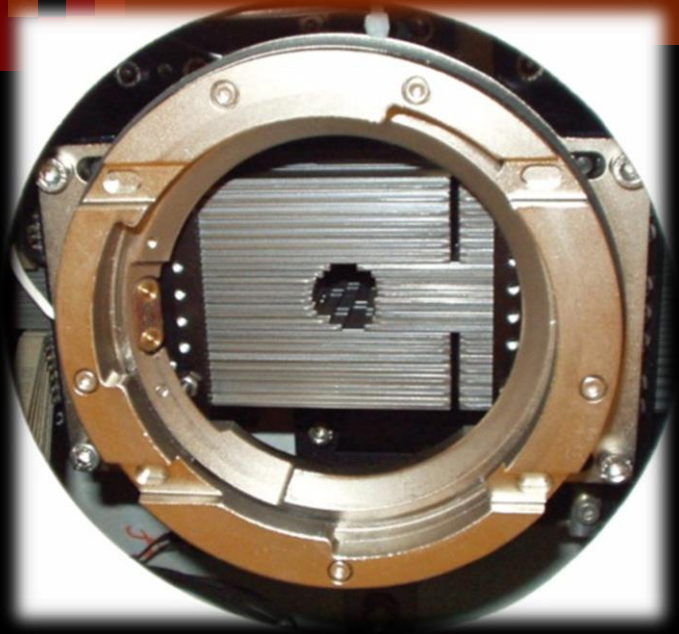


Radiation dose Constraints …

Normal Structures

- Brainstem, Eyes,
- Optic N, Chiasm, Optic Tract,
- Temporal Lobe, PHA
- Cochlea, internal ear
- Spinal cord

Work flow… Planning



mMLC

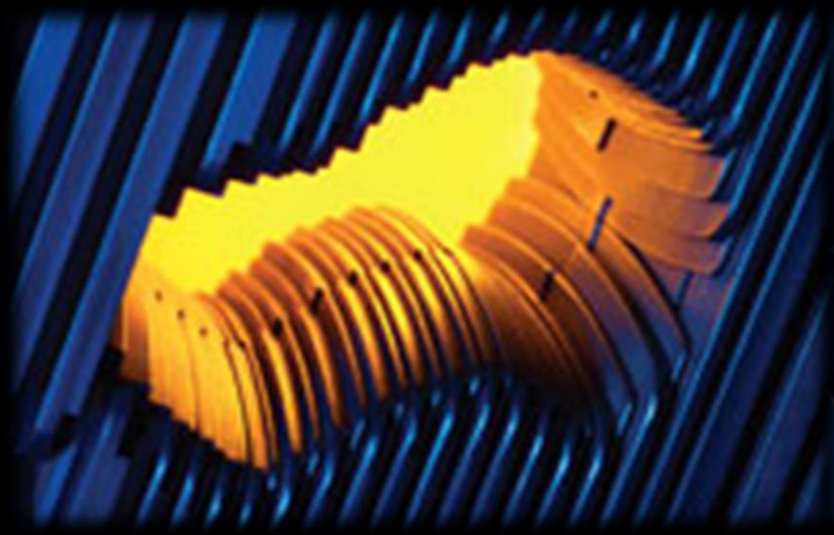
Cone

IMRS, Dynamic Arc, Static Conformal

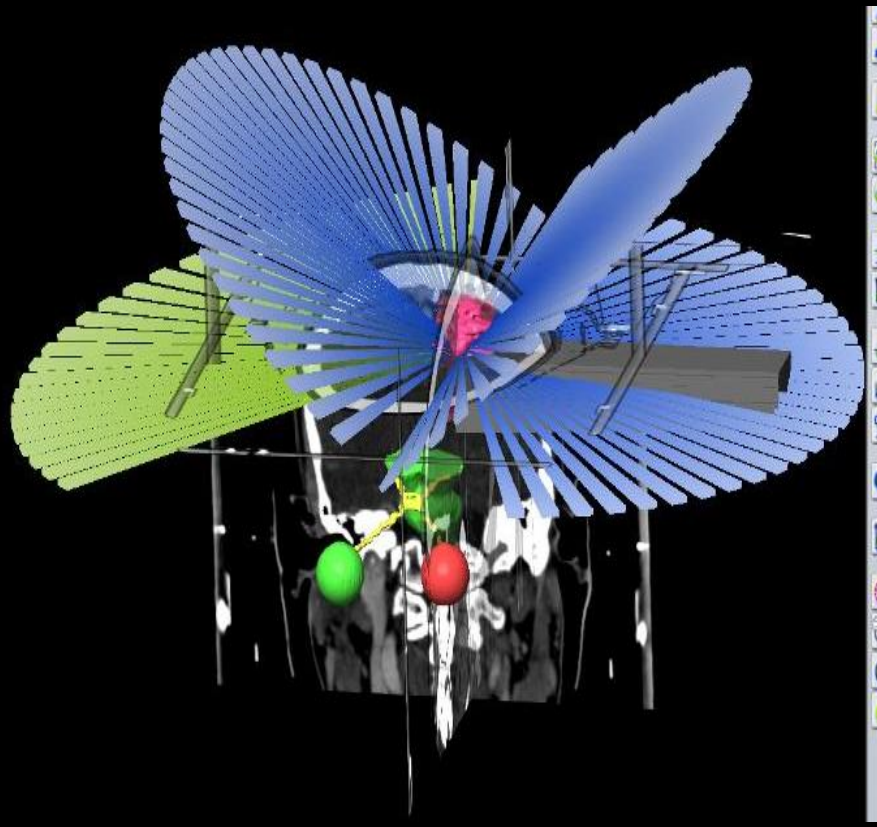
LinAc Radiosurgery:1988

Localisation: Frame or Image Guided

Beam shaping: MLC or Cone

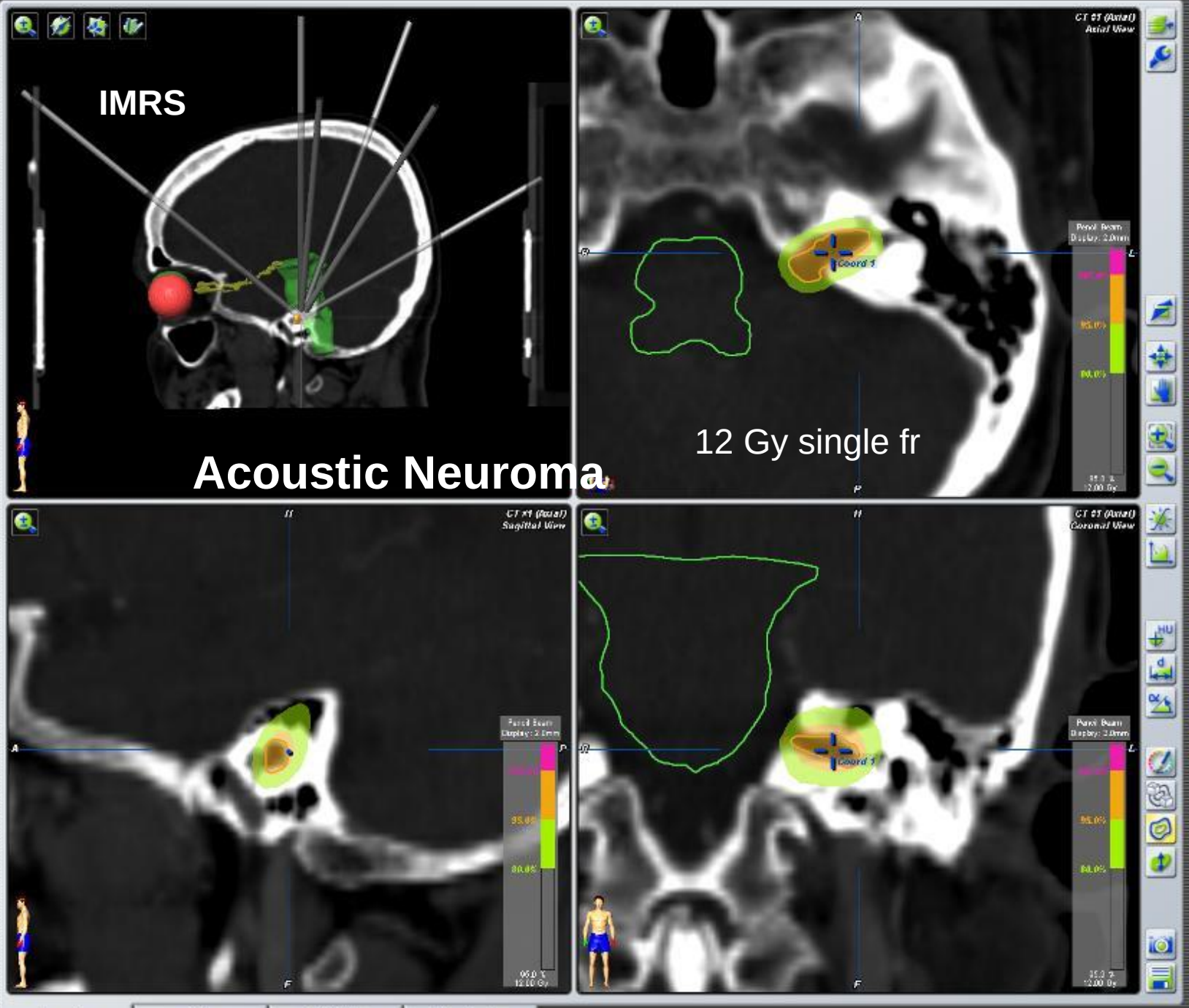


Computer Planning… *I plan*

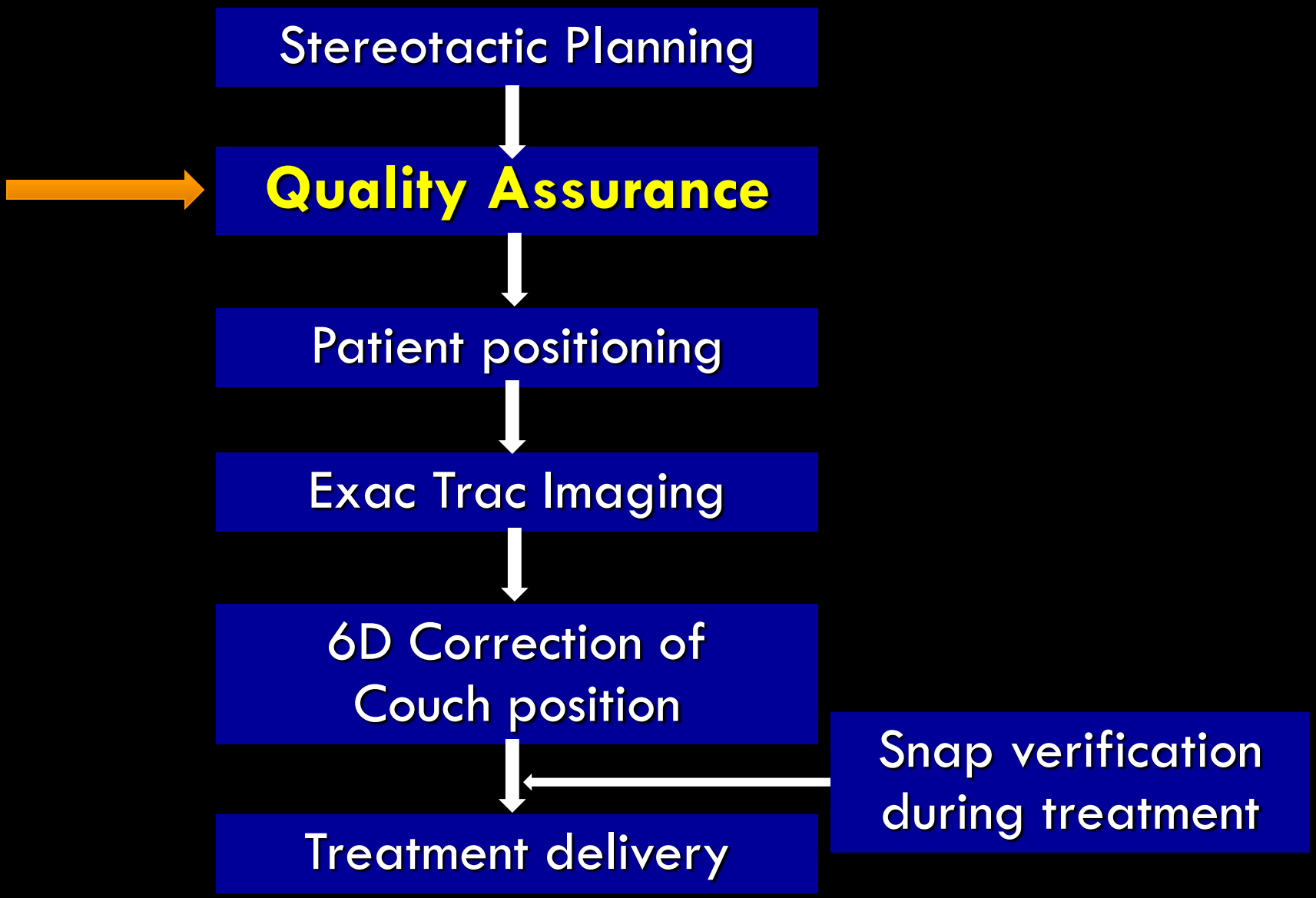


IMRS, Conformal beam, Dynamic Arc, Cone based

Co-planar, Non co-planar, Multiple arcs


IMRS
12 Gy single fr
Acoustic Neuroma
Navigator
Object
Object Creation
Treatment Planning
Go to...
Next
New...
Remove
Auto Segmentation...
Draw Sphere
SmartShaper...
Advanced Manipulation...
Role Reassignment...
Undo
Overview
Slices
Multiple Sets
Plan Content
BrainLAB
iPlan RT Dose 4.1

The workflow …

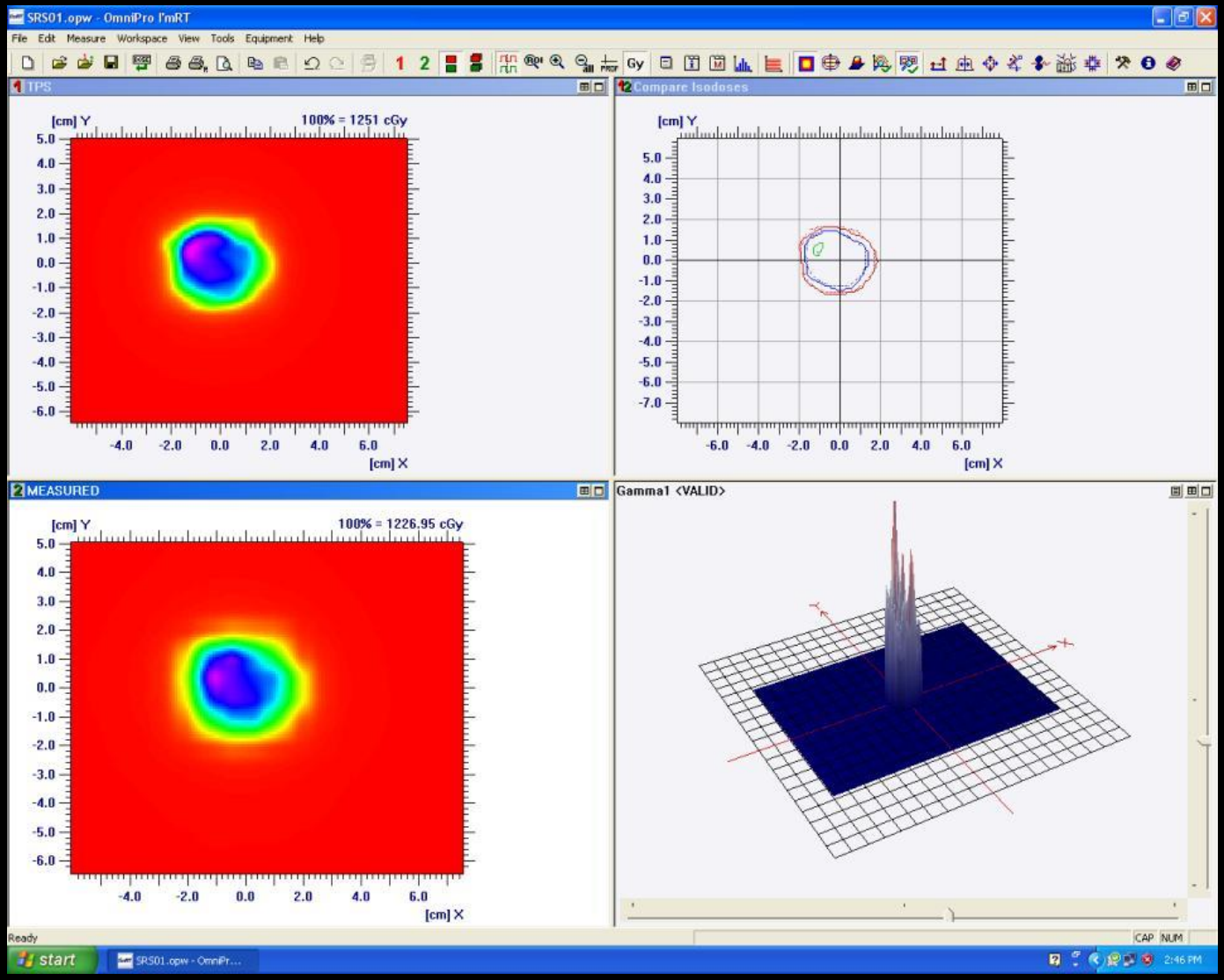


QA Protocols

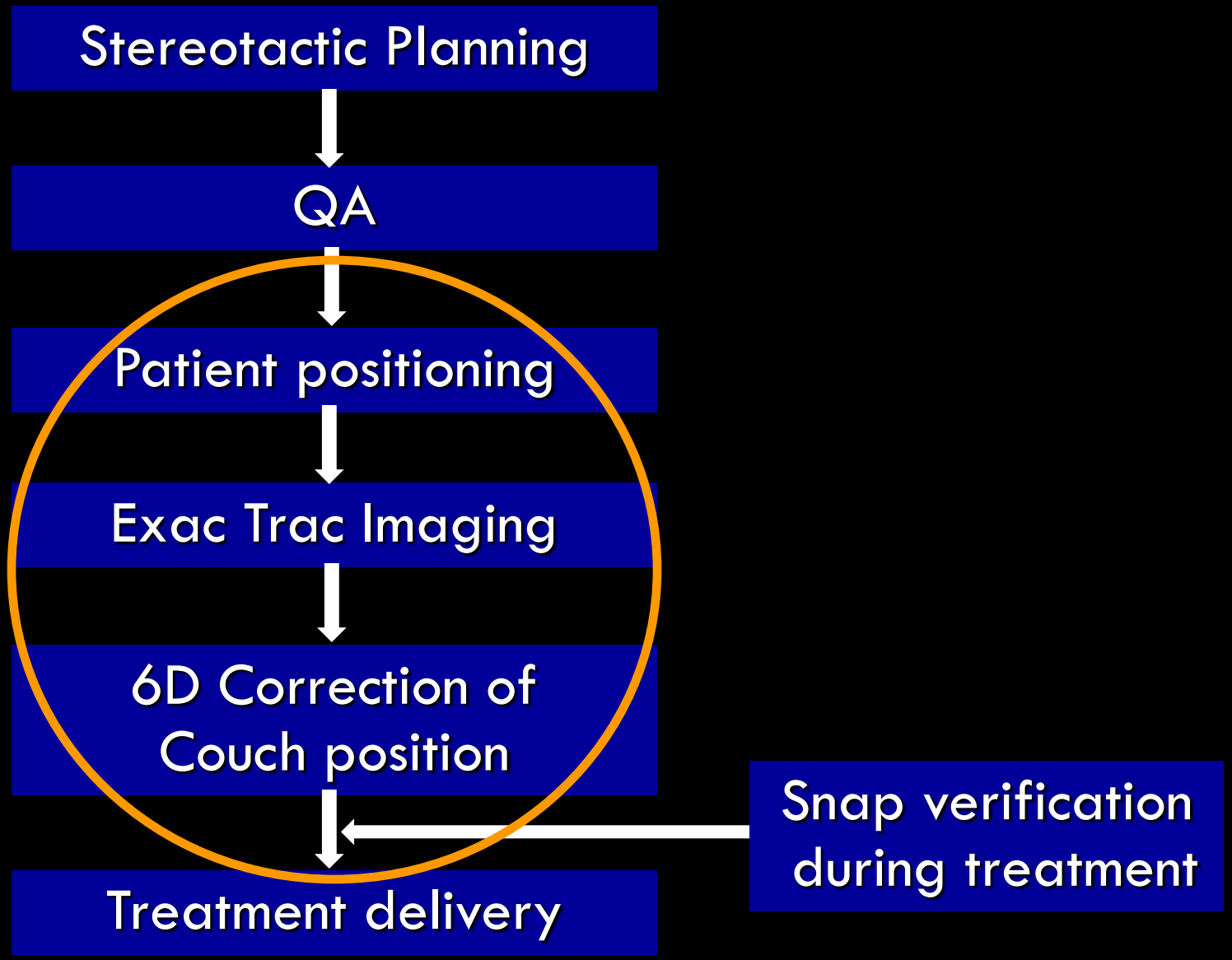
QA Protocols for SRS fall into 3 categories

- The basic QA protocols
  - performance of the equipment,
  - proper immobilization,
  - planning and radio-surgical dose delivery
- The treatment QA protocol
  - Calibration &
  - preparation of the equipment prior to SRS/SRT
- Patient Specific Treatment QA
  - Protocol dealing with patient Specific QA.

The Quality Assurance! …



the workflow ...



Patient Positioning

the components …

- Isocenter verification WL pointer
- Perfect Immobilization
- IR-based Stereotactic Positioning
- Automatic Patient Monitoring
- X-ray Correction with Exact trac
- 6D Robotics Angle Correction
- Auto/Manual Couch Rotation
- X-ray Snap Verification

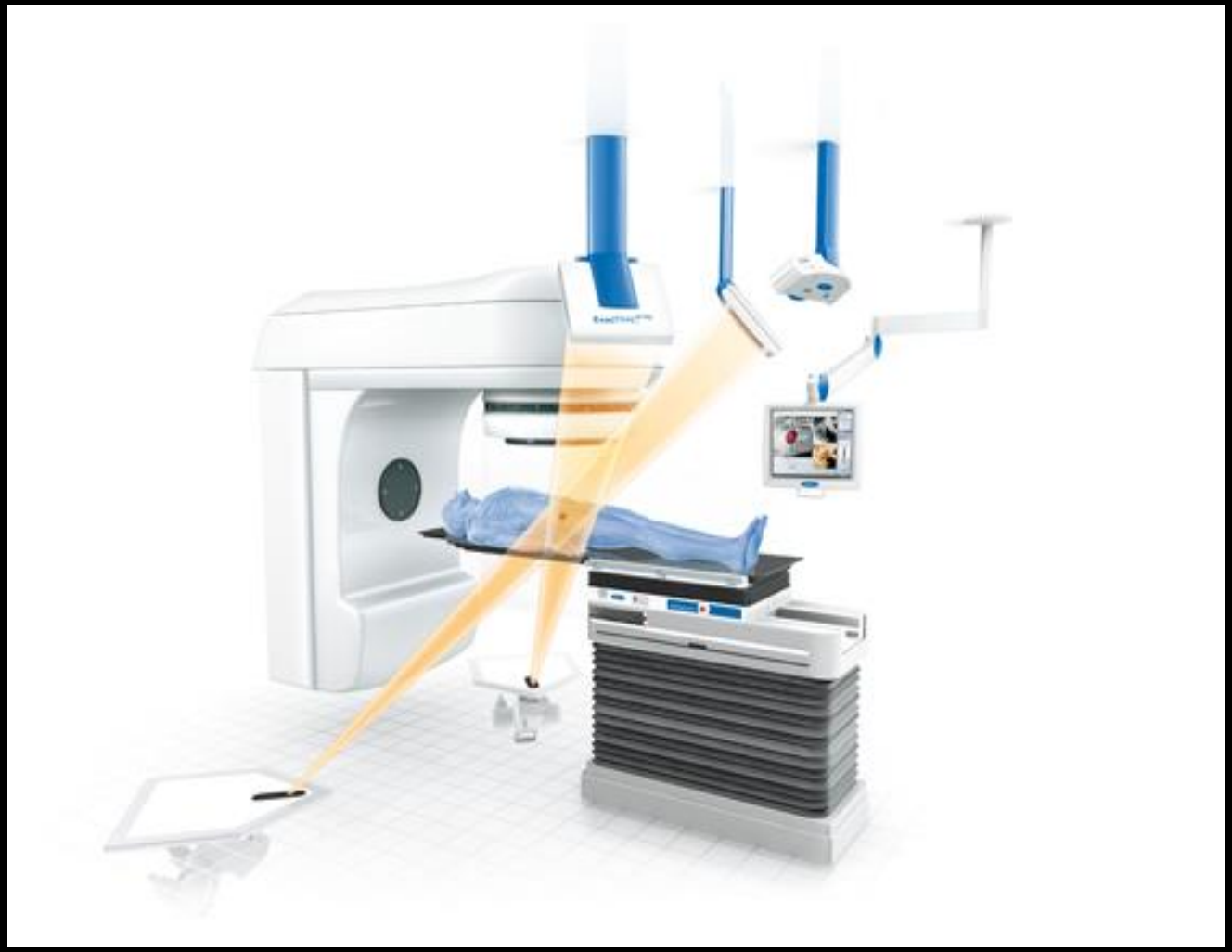
treatment should be delivered only after verification of position in each couch angle by 2 X-rays resulting in correction error ZERO

the mask...

... the localizer box

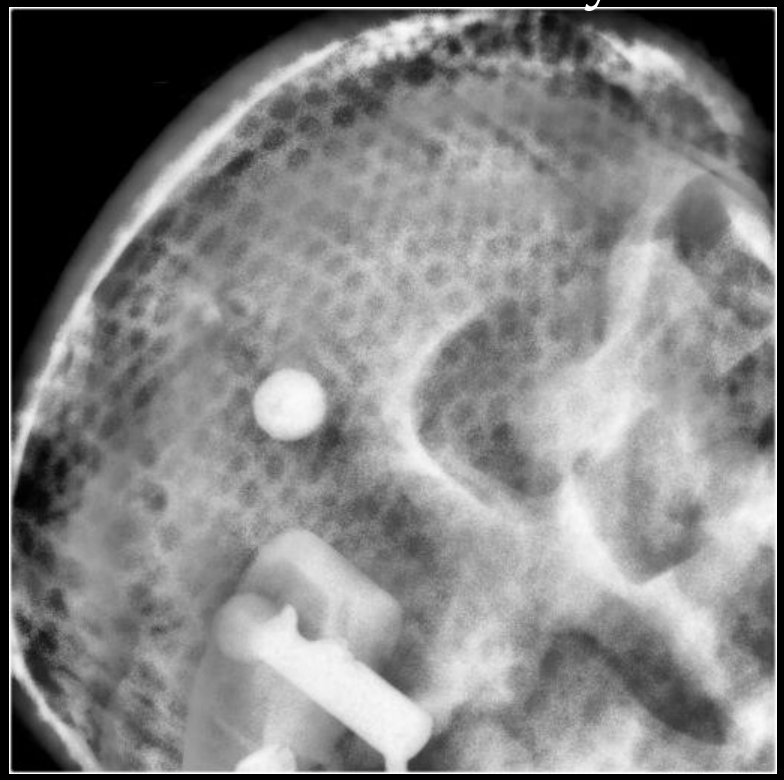
ExacTrac

takes two oblique stereoscopic X-ray images

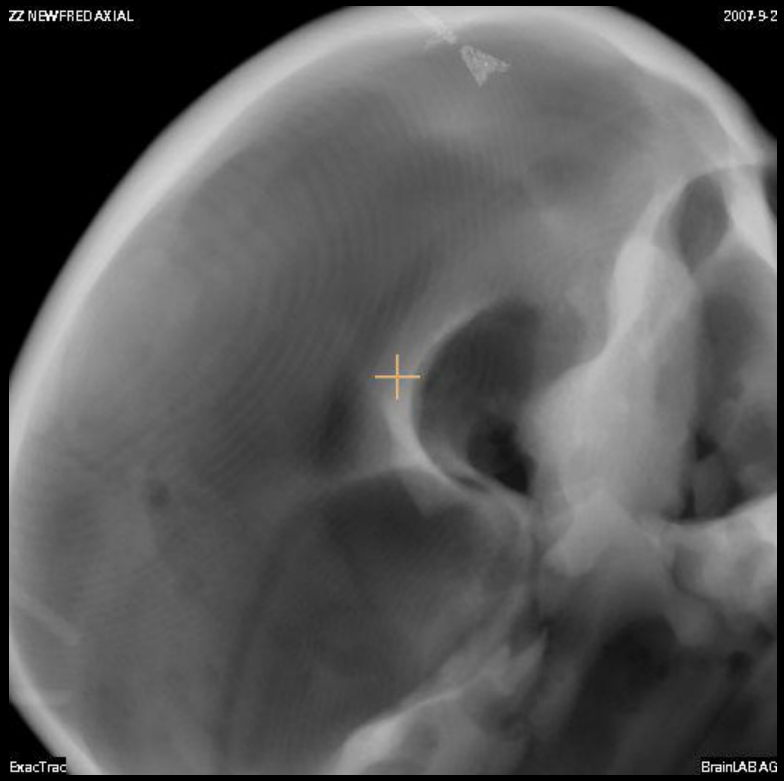


Fusion with Oblique X Rays

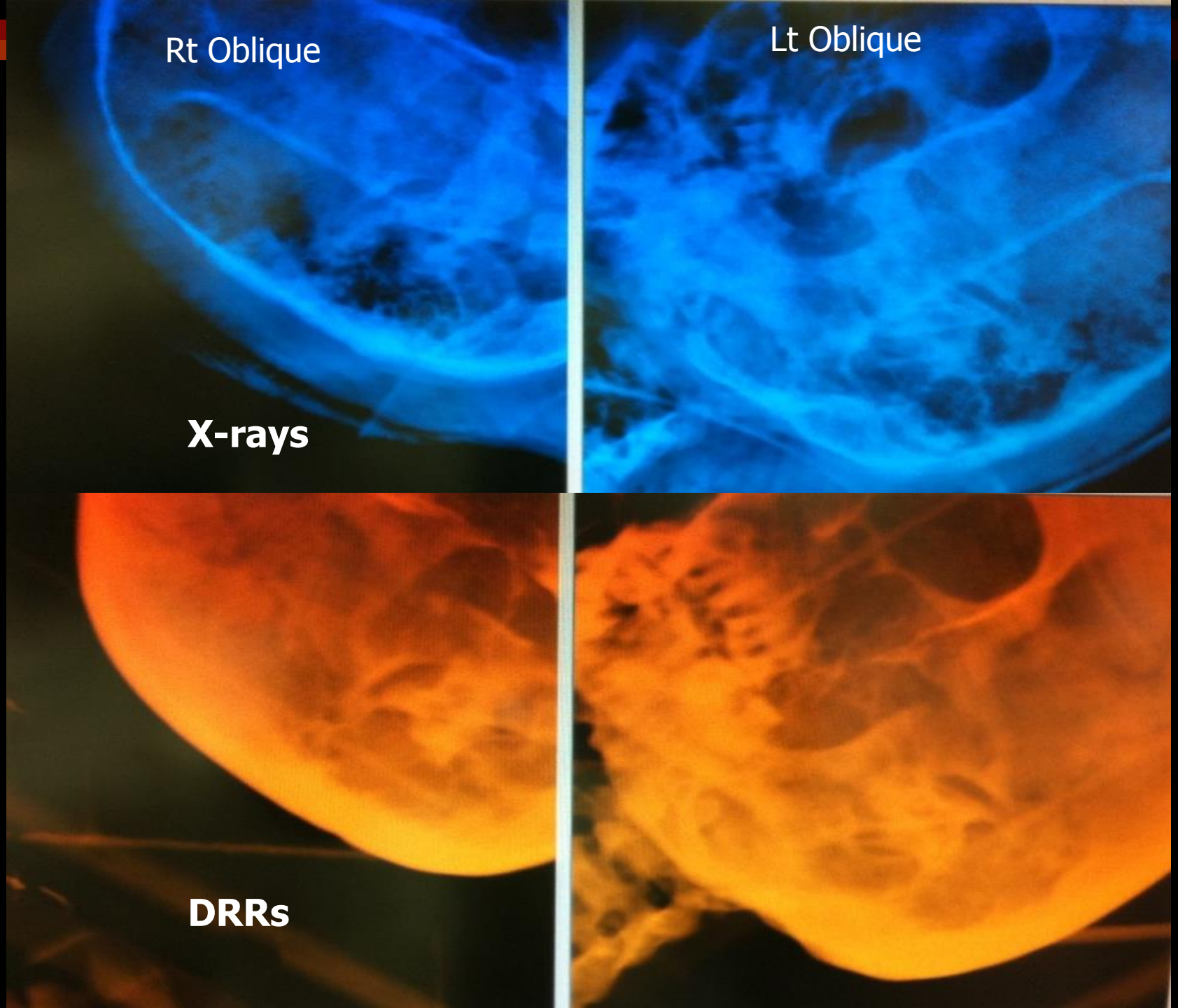
Exactrac X Ray

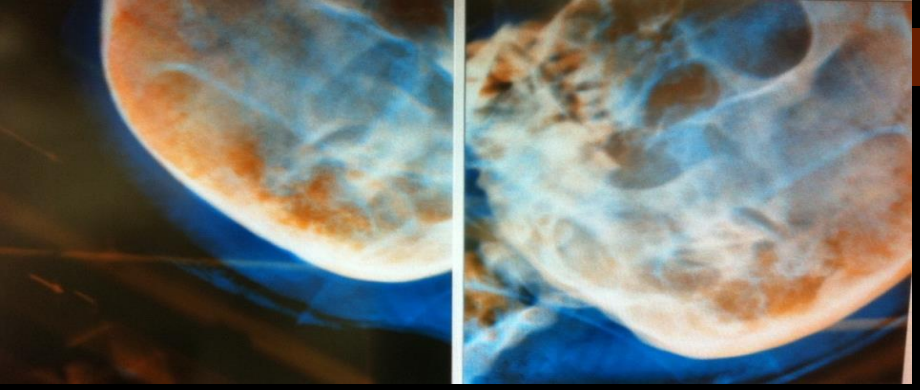


DRR



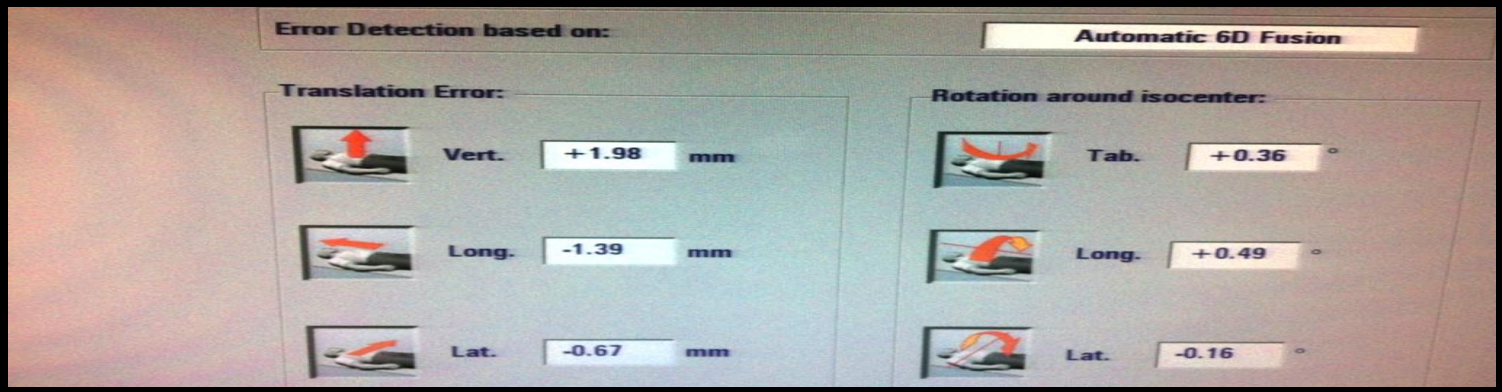
Exactrac X ray images are fused to the digitally reconstructed radiograph from the treatment planning CT scan.


Rt Oblique
Lt Oblique
X-rays
DRRs



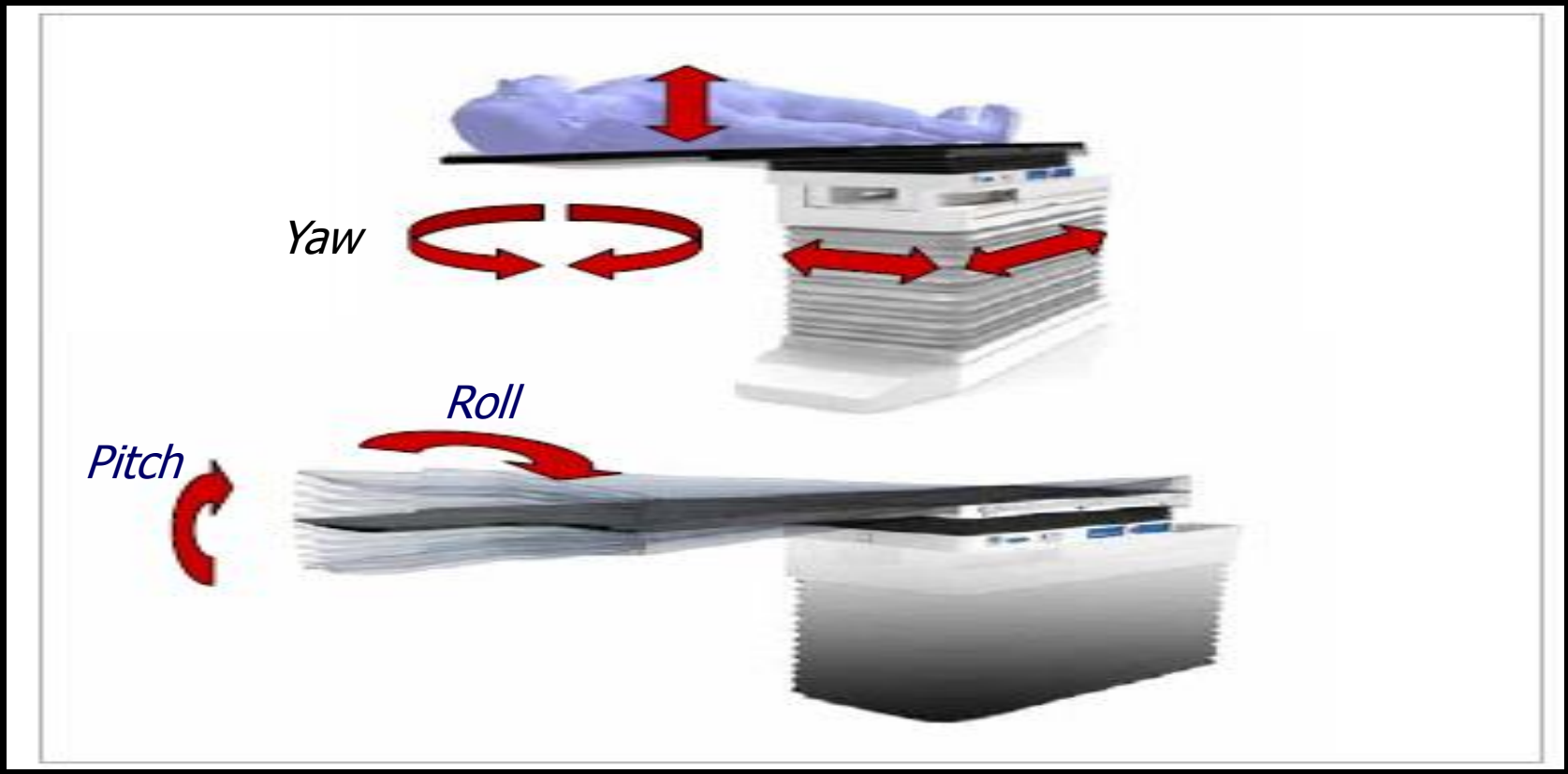
ExacTrac System

- The deviation between the patient's previous and current position is calculated,
- and the patient is automatically re-positioned without having to move
- The whole couch can move with 6º of freedom to attain the correct position.



6D Correction values with Exactrac

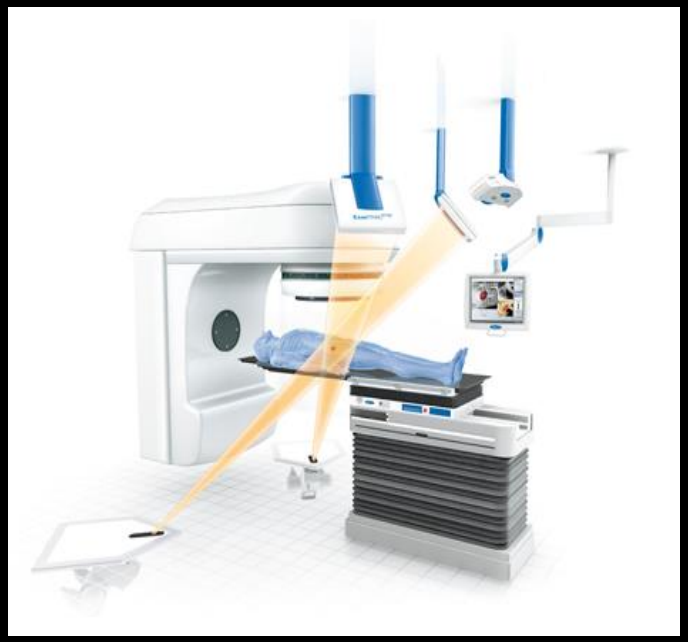
6D Correction with Exactrac



The whole couch can move with 6º of freedom to attain the correct position.

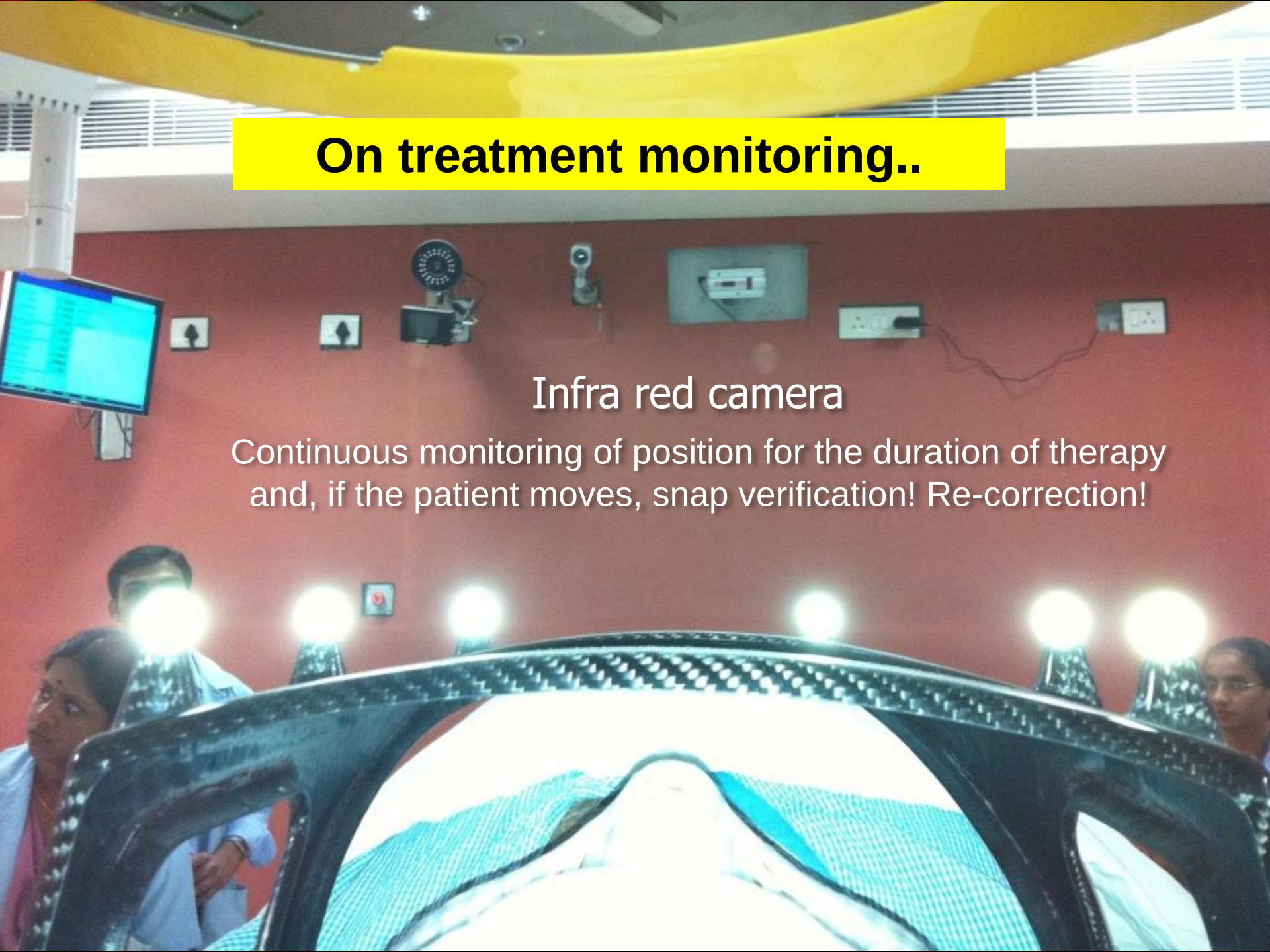
after correction - Snap Verification

Positioning, Verification, Correction, Snap verification & Treatment delivery



- Positioning with mask ✓
- Infrared positioning ✓
- X Ray Verification with ExacTrac ✓
- Correction with 6D Robotic Couch ✓
- Snap Verification (at every couch angle)
- Beam On

The ExacTrac system setup accuracy is within 0.6mm


On treatment monitoring..
Infra red camera
Continuous monitoring of position for the duration of therapy
and, if the patient moves, snap verification! Re-correction!

Current indications…

- **Benign Tumors**
  - Vestibular Schwannomas, Meningiomas
  - Pitutary Adenomas, Craniopharyngiomas, Pineal tumors
- **Arteriovenous malformations (AVM)**
- **Functional**
  - Trigeminal neuralgia.
- **Malignant Tumors**
  - Brain Metastasis
  - Spine Metastasis
  - Lung Primary & metastasis
  - Liver Primary & metastasis

Current indications…

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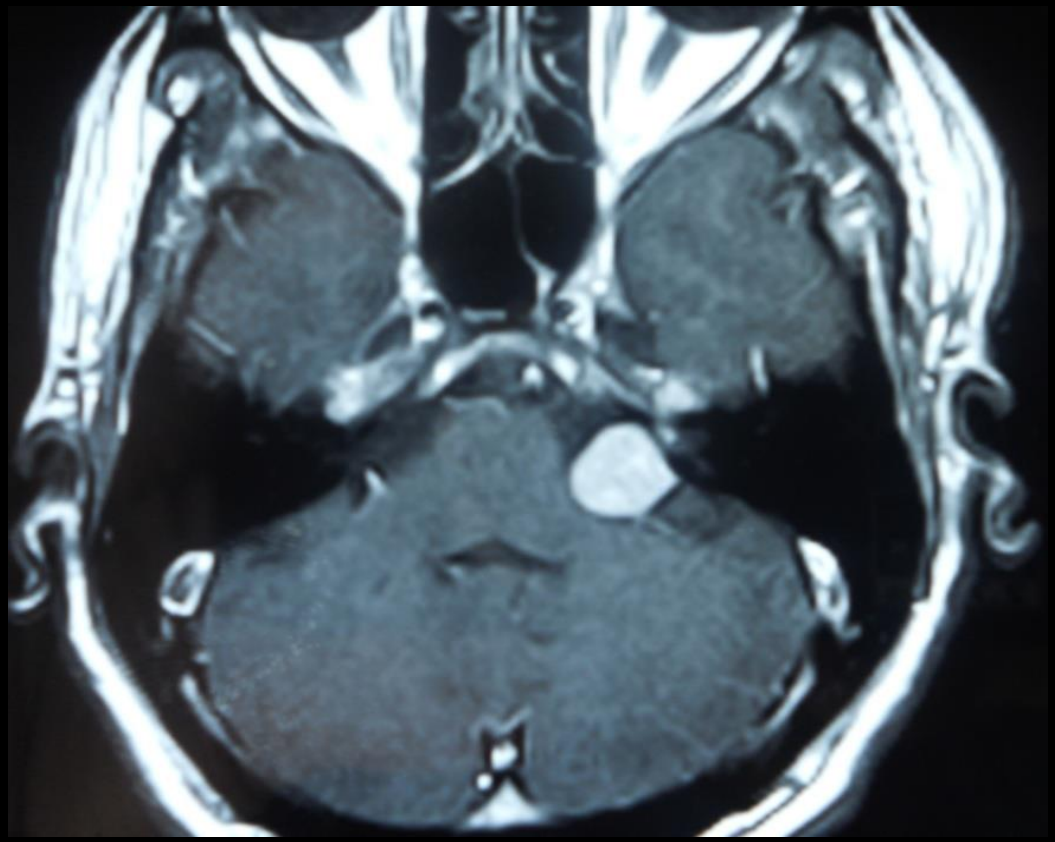
SRS - Acoustic Neuroma



Acoustic Neuroma

- **Treatment Options**

  Observation,

  Surgery,

  Radiotherapy (SRS, fractionated SRT)

- **Local control > 95% following SRS**

- **Doses 12-13Gy using CT-based tx planning**
  - **1% incidence of facial nerve dysfunction**
  - **4% incidence of trigeminal nerve dysfunction**
  - **70% hearing-level preservation**

Flickinger JC, IJROBP 2004

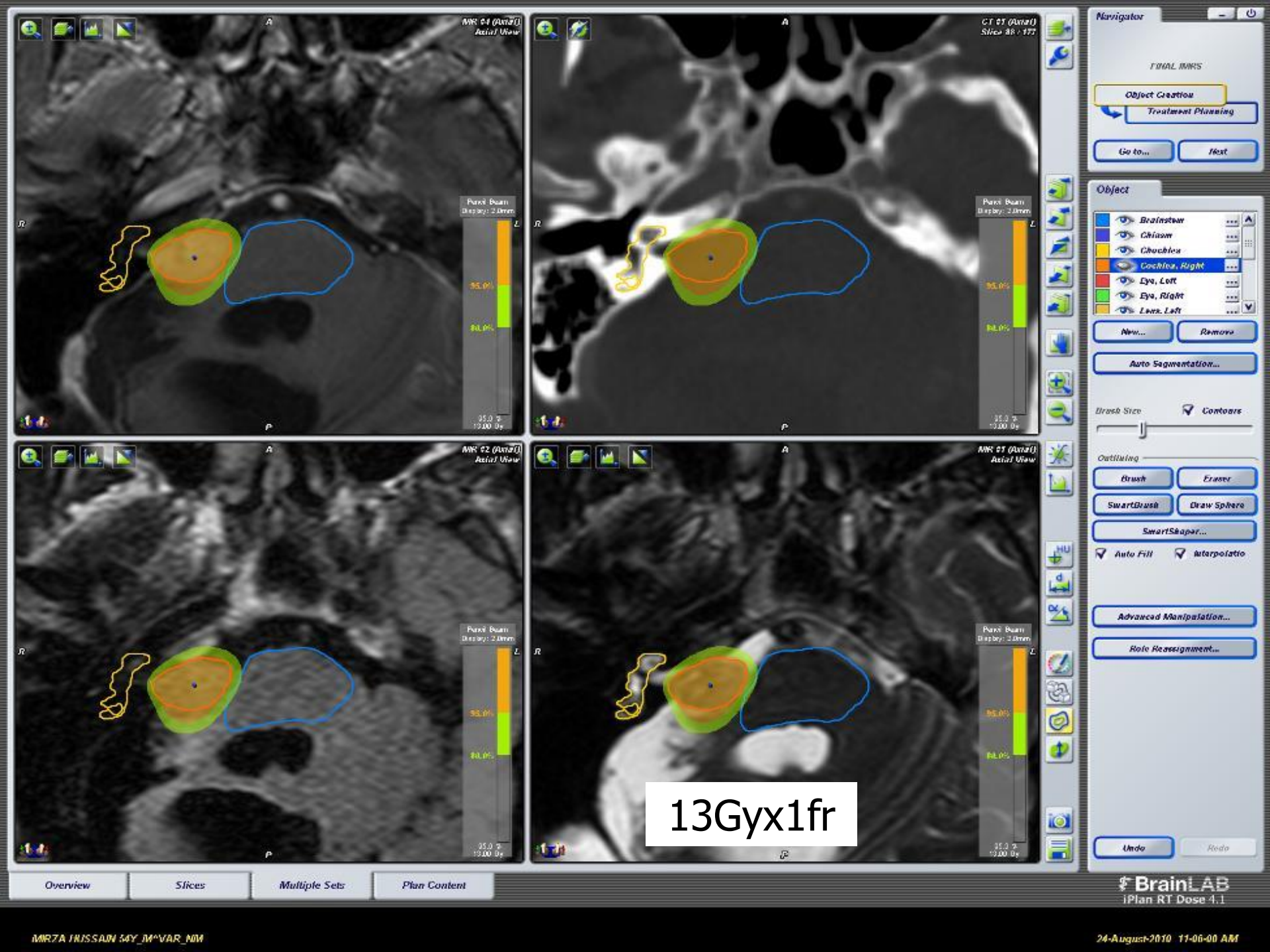
SRS - Schwanomas

Dose Schedule

Single fraction – 12-13 Gy

Cochlear dose should be <4.5Gy (Dmax)

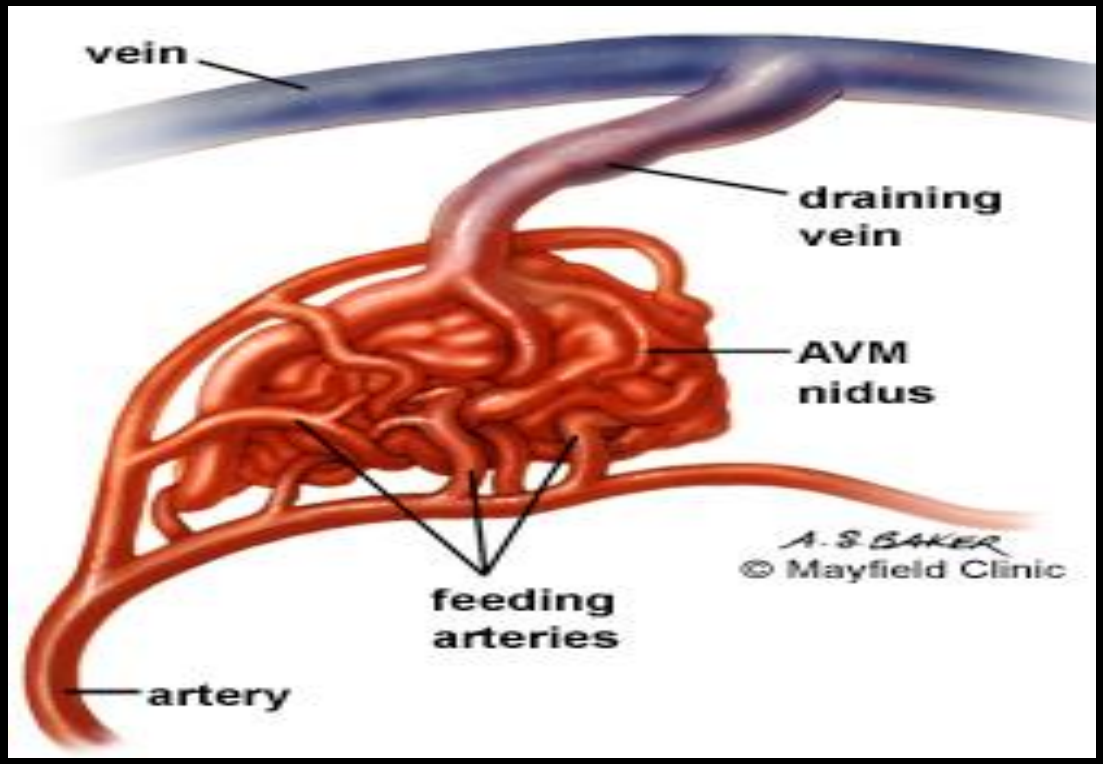
Multi- fraction – 5Gy x 5 fractions


Navigator
Object Creation
Treatment Planning
Go to...
Next
Object
Brainstem
Chiasm
Cochlea
Cochlea, Right
Eye, Left
Eye, Right
Lens, Left
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolatio
Advanced Manipulation...
Role Reassignment...
Undo
Redo
13Gyx1fr
Overview
Slices
Multiple Sets
Plan Content
BrainLAB
iPlan RT Dose 4.1
24-August-2010 11:06:00 AM

Acoustic Neuroma

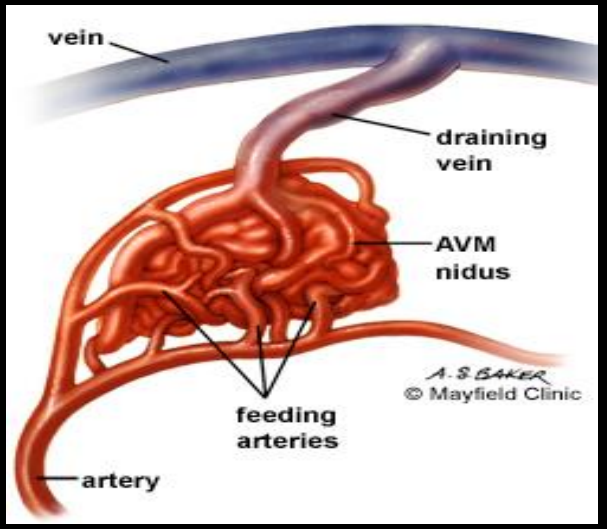
Complete Response one yr post SRS

SRS - AVMs


vein
draining vein
AVM nidus
feeding arteries
artery
A. S. BAKER
© Mayfield Clinic

SRS for AVMs

- Surgery preferred if can be accomplished safely
- SRS causes Damage to endothelial and sub-endothelial cells leads to proliferation and eventual occlusion
- Obliteration rates 70-80%
- Often takes 1 – 2 years



Potential Side-Effects

Acute (hours)

- Nausea/vomiting
- Seizure
- Fatigue
- Hair loss

Late (months-years)

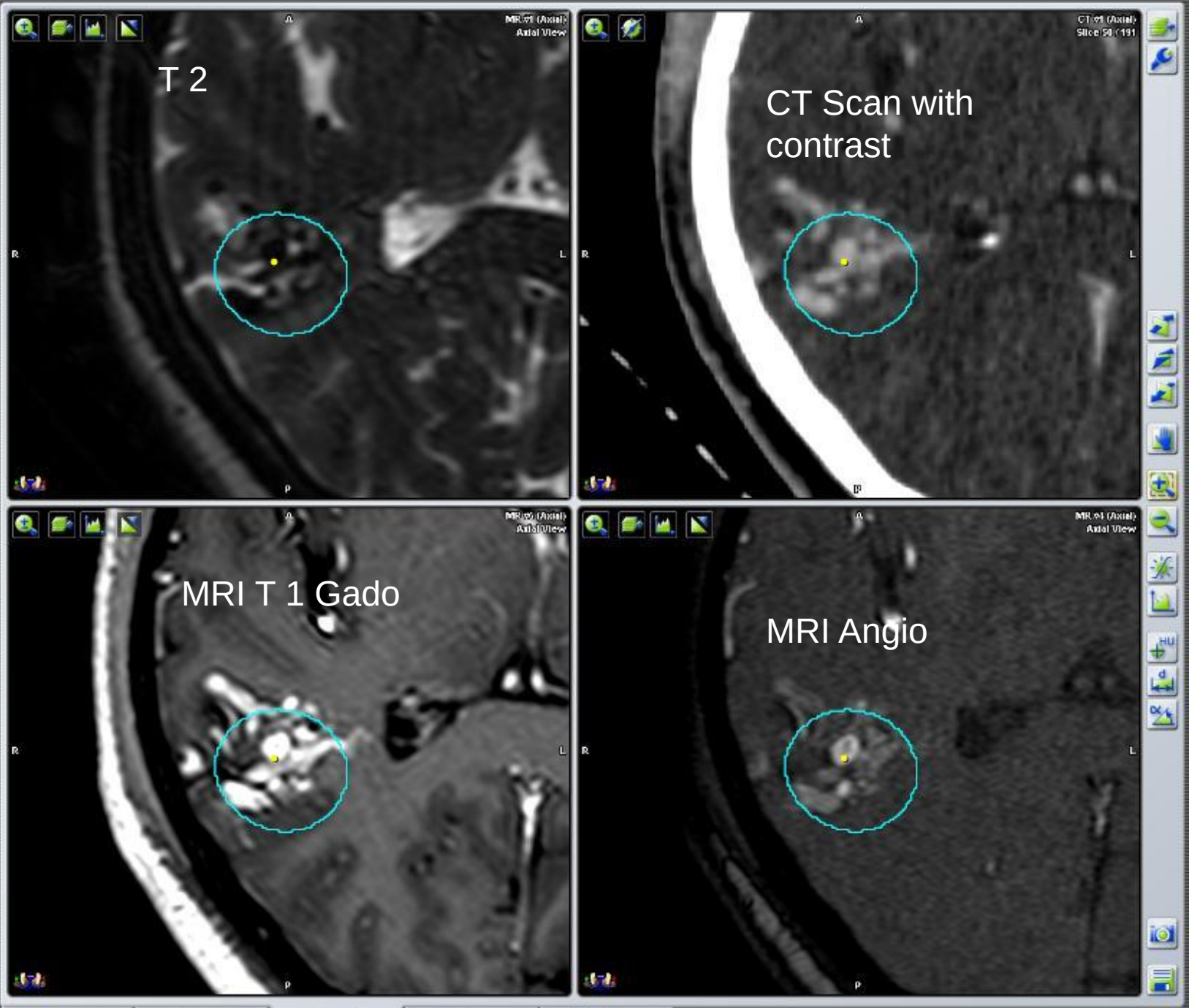
- **Edema requiring steroids and/or surgery**
- **Brain necrosis**
- **Blindness**
- **Cranial neuropathies**
- **Radiation-associated malignancies**

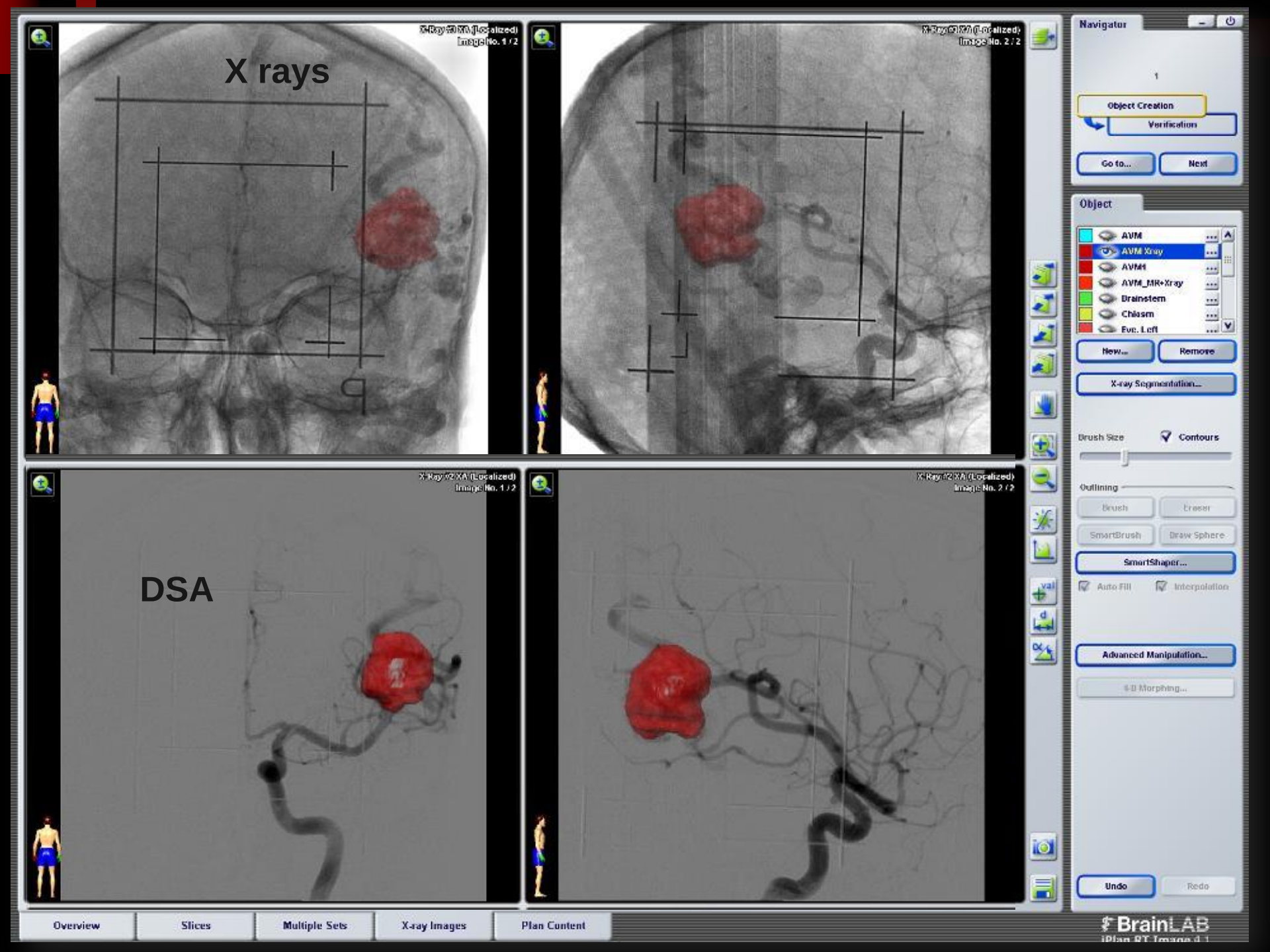
SRS- Arteriovenous Malformation

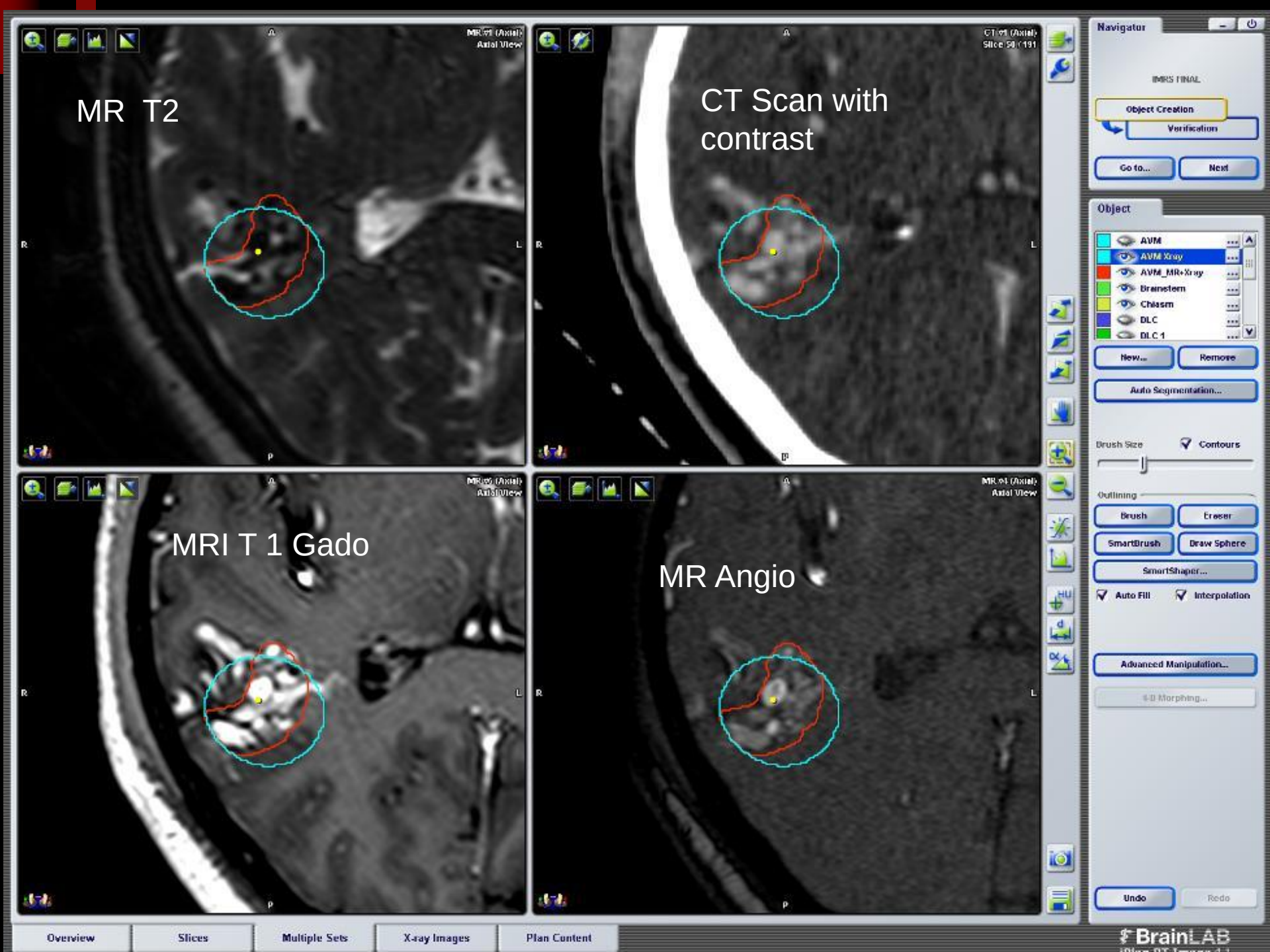
Dose

Single fraction – 17 to 24 Gy

12 Gy Volume of normal brain should be < 5-10cc

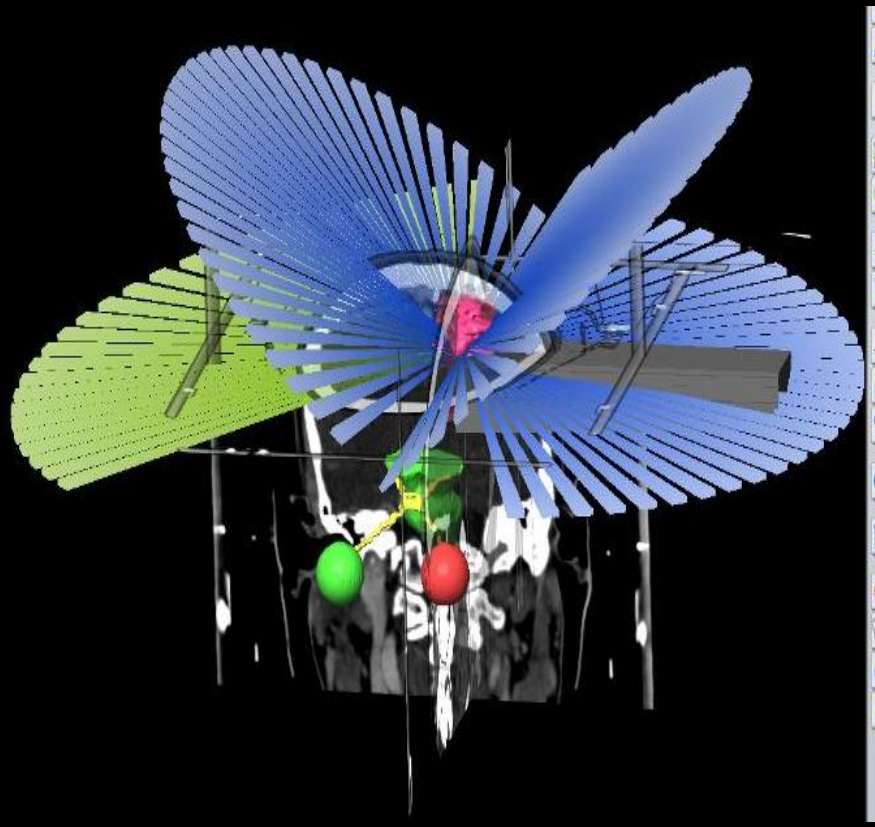

T 2
CT Scan with contrast
MRI T 1 Gado
MRI Angio
Navigator
IMRS FINAL
Object Creation
Verification
Go to...
Next
Object
AVM
AVM Xray
AVM_MR+Xray
Brainstem
Chiasm
DLC
DLC 1
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolation
Advanced Manipulation...
4-D Morphing...
Undo
Redo
Overview
Slices
Multiple Sets
X-ray Images
Plan Content
BrainLAB
iPlan RT Image 4.1


X rays
DSA
Navigator
Object Creation
Verification
Go to...
Next
Object
AVM
AVM Xray
AVM1
AVM_MR+Xray
Brainstem
Chiasm
Eye, Left
New...
Remove
X-ray Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolation
Advanced Manipulation...
4-D Morphing...
Undo
Redo
Overview
Slices
Multiple Sets
X-ray Images
Plan Content
BrainLAB


MR T2
CT Scan with contrast
MRI T 1 Gado
MR Angio
Navigator
Object Creation
Verification
Go to...
Next
Object
AVM
AVM Xray
AVM_MR+Xray
Brainstem
Chiasm
DLC
DLC 1
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolation
Advanced Manipulation...
Undo
Redo
Overview
Slices
Multiple Sets
X-ray Images
Plan Content
BrainLAB

Procedure of Radiosurgery

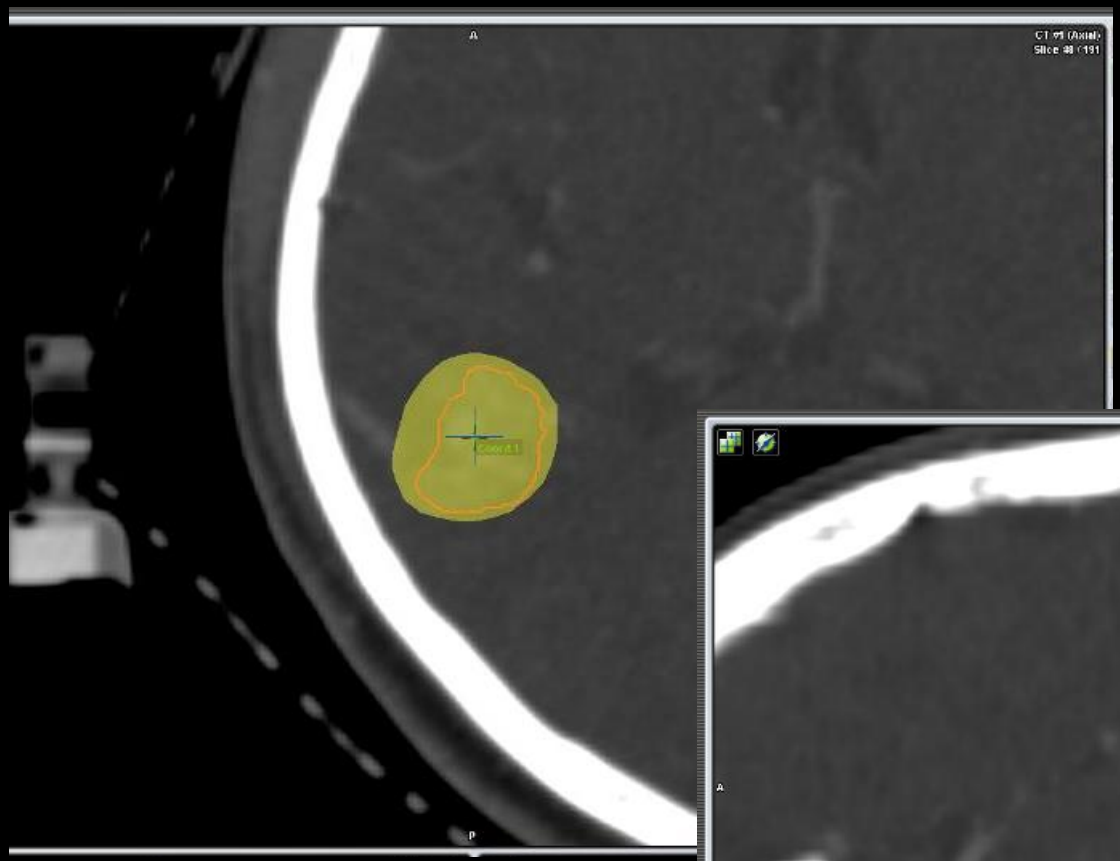
Computer Planning… *I plan*



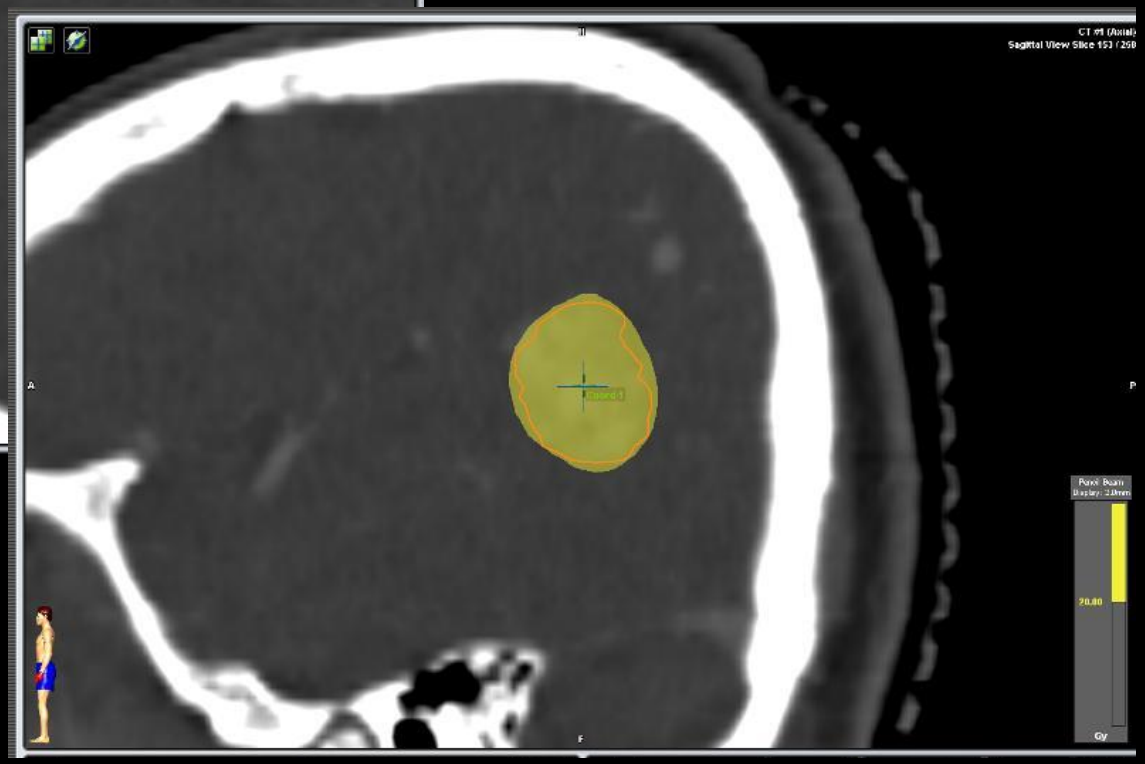
IMRS, Conformal beam, Dynamic Arc, Cone based

Co-planar, Non co-planar, Multiple arcs

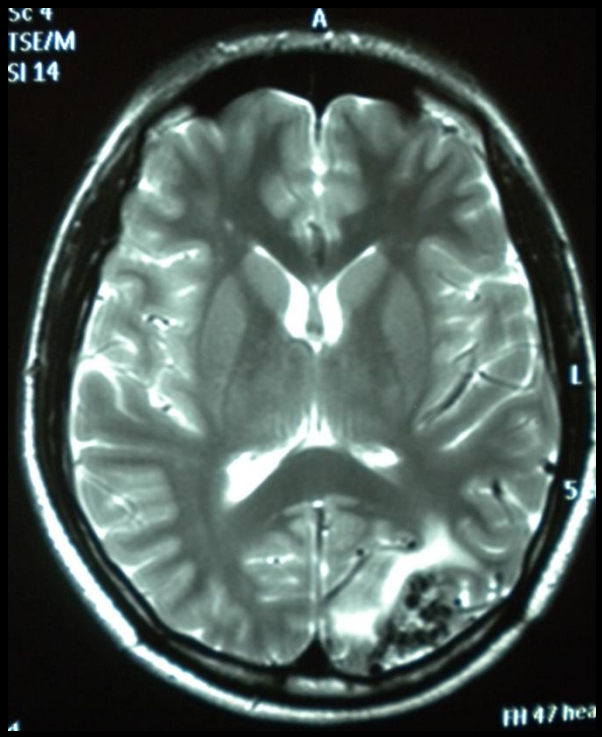
SRS Planning – Dose prescription



18Gy in 1 fraction
at 90% isodose line
covering nidus

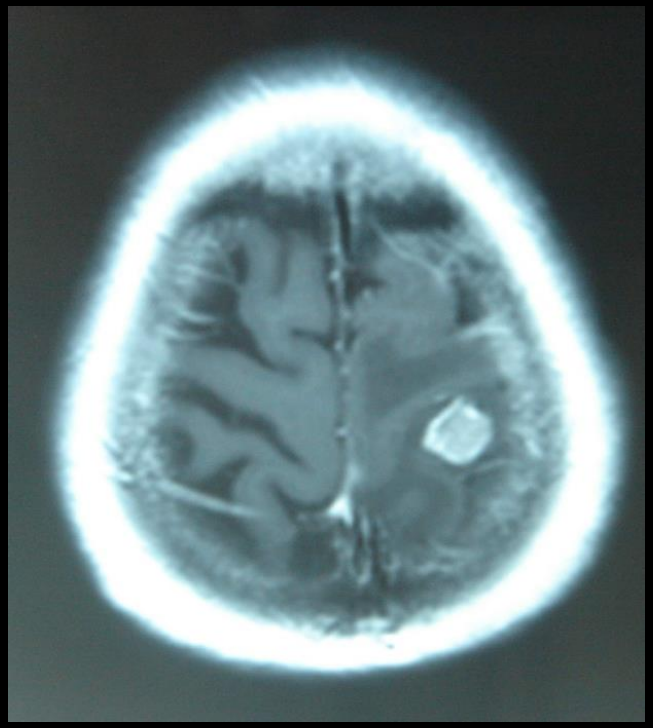


AVM



Six mths post SRS

Radio-surgery in Brain Metastases



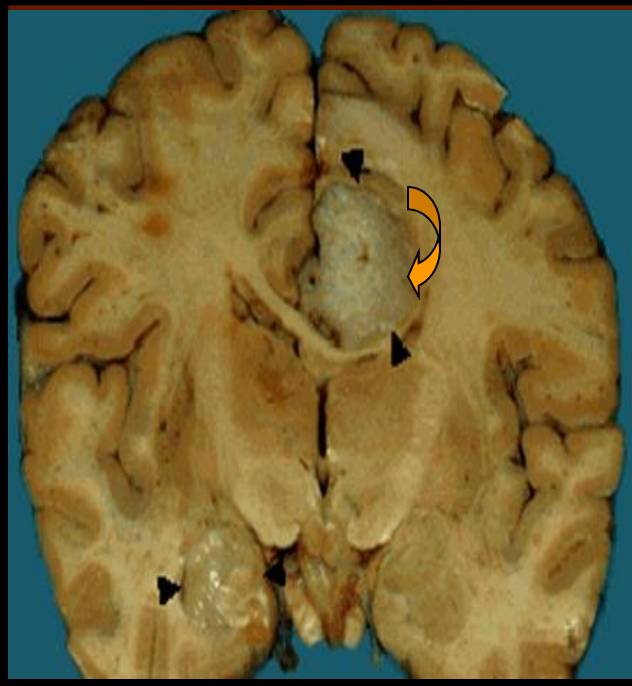
Whole Brain RT

- Poor survival outcome
- Toxicities –
  - **Acute:** hair loss, vomiting, fatigue, erythema
  - **Late :** progressive dementia, ataxia, impaired neurocognition

Brain Metastases

Ideal Target for Radiosurgery

- **Often spherical**
- **Usually <3cm in diameter**
- **Radiologically distinct margins**
- **Displace adjacent brain parenchyma**



SRS for Brain Metastases

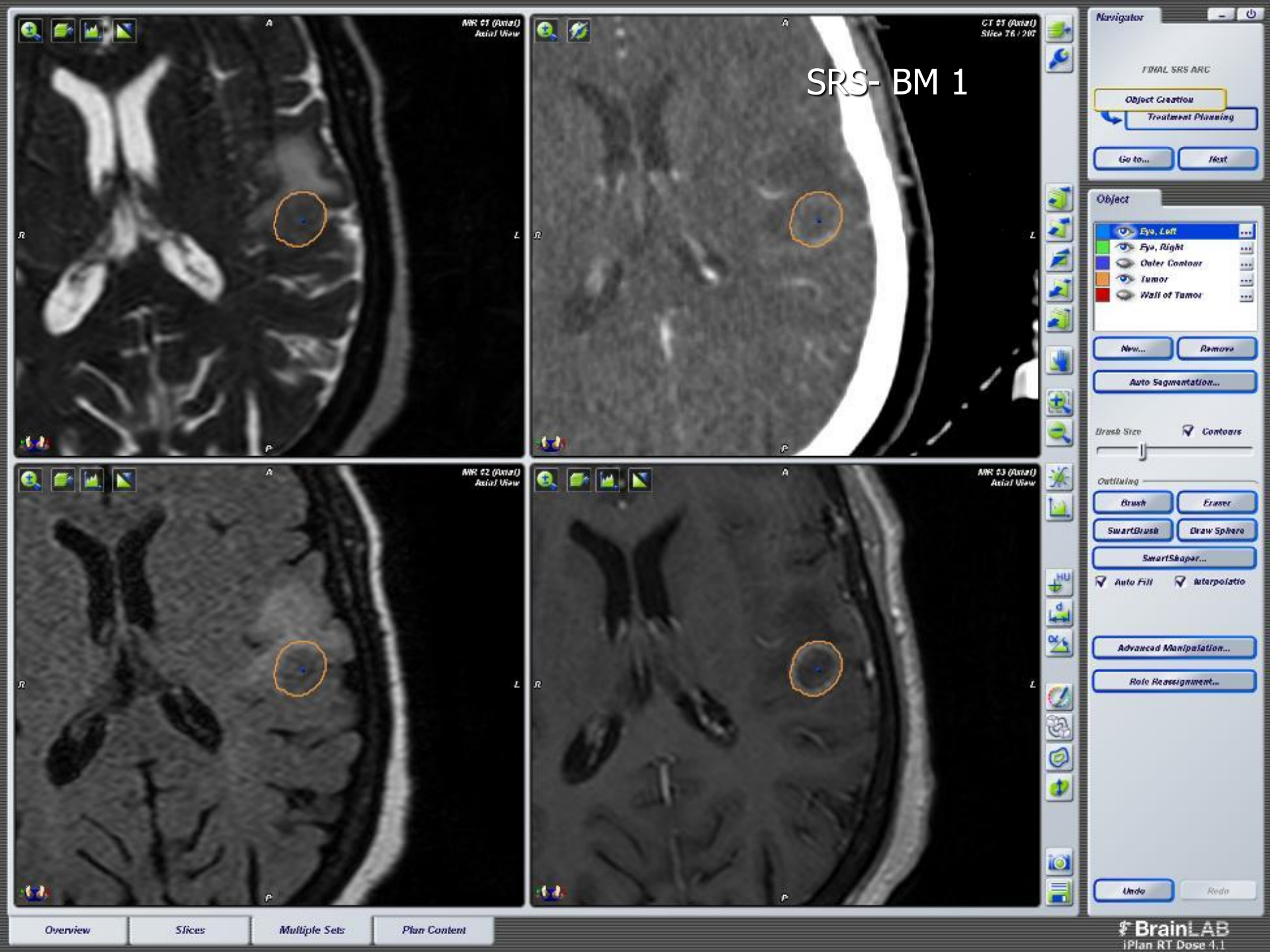
- 80-90% local control
- Doses range from 15-24 Gy
- Better neurocognitive functions after SRS
- No difference in overall survival

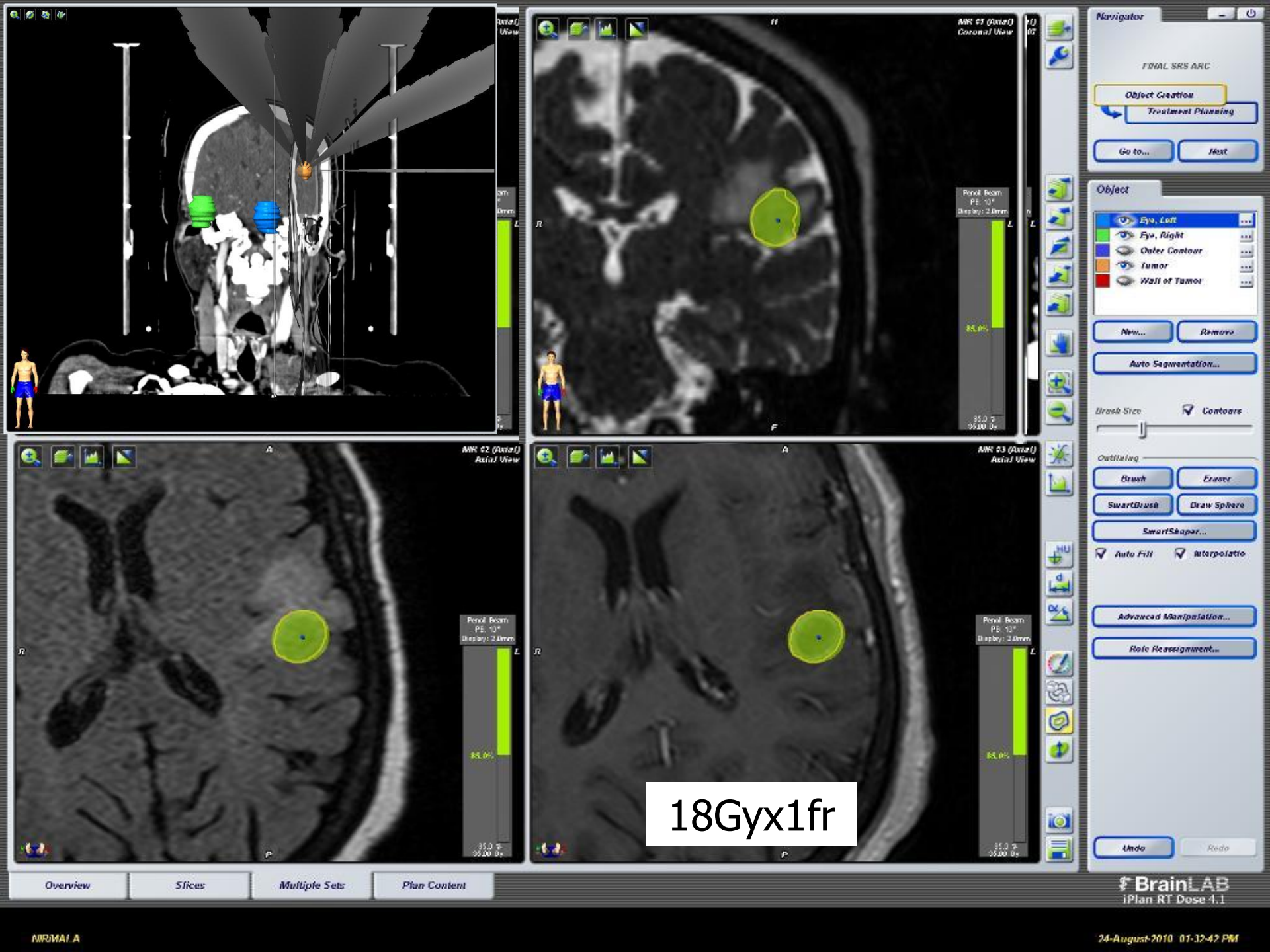
Kocher M et al, JCO 2011 (epub),
Aoyama H et al, JROSG 99-1. JAMA 2006
Shehata MK, IJROBP 2004; Chidel MA, IJROBP 2000;
Chang E, Lancet Oncol 2009

SRS - Brain Metastases

Dose Schedule

Single fraction – 16 to 20 Gy


SRS- BM 1
Navigator
FINAL SRS ARC
Object Creation
Treatment Planning
Go to...
Next
Object
Eye, Left
Eye, Right
Outer Contour
Tumor
Wall of Tumor
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolatio
Advanced Manipulation...
Role Reassignment...
Undo
Redo
Overview
Slices
Multiple Sets
Plan Content
BrainLAB
iPlan RT Dose 4.1


Navigator
FINAL SRS ARC
Object Creation
Treatment Planning
Go to...
Next
Object
Eye, Left
Eye, Right
Outer Contour
Tumor
Wall of Tumor
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolatio
Advanced Manipulation...
Role Reassignment...
Undo
Redo
MR #1 (Axial)
Coronal View
MR #2 (Axial)
Axial View
MR #3 (Axial)
Axial View
Pencil Beam
18Gyx1fr
Overview
Slices
Multiple Sets
Plan Content
BrainLAB
iPlan RT Dose 4.1
MRMAI A
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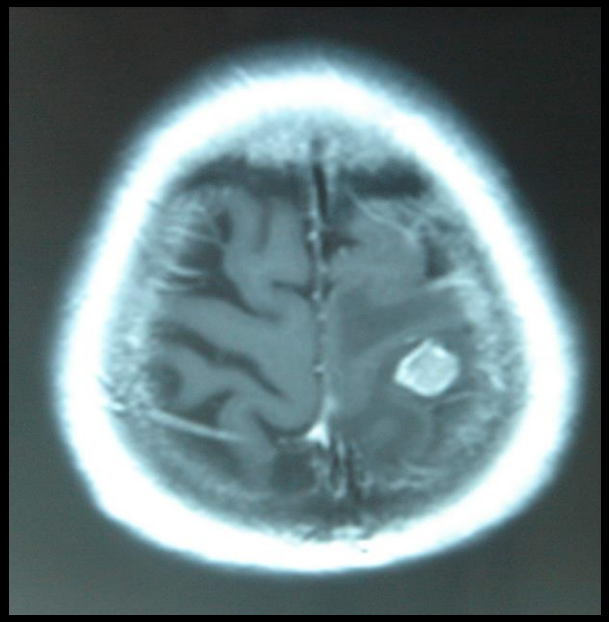
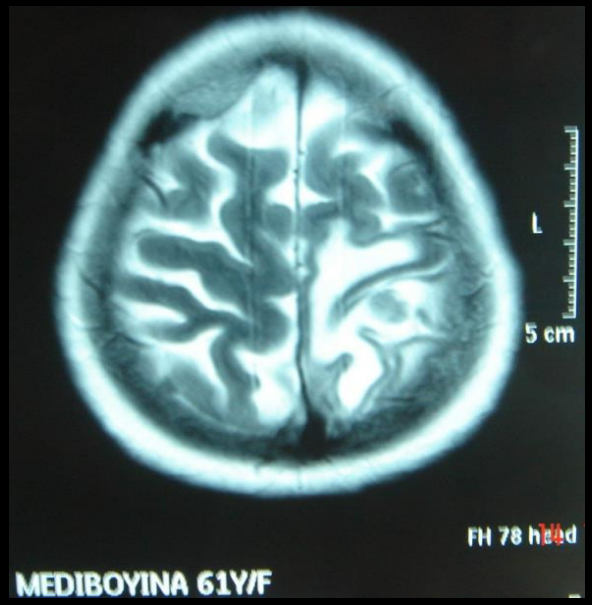
Brain Metastases





One year post SRS

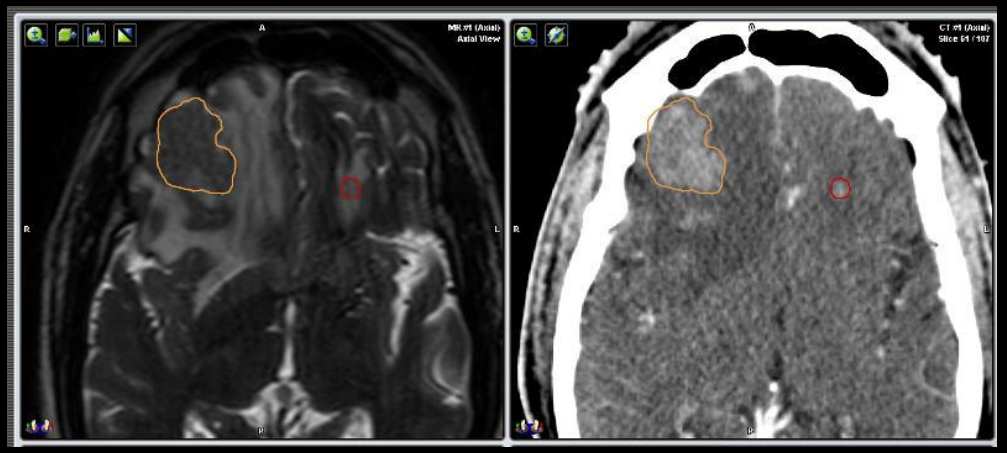
Brain Metastases

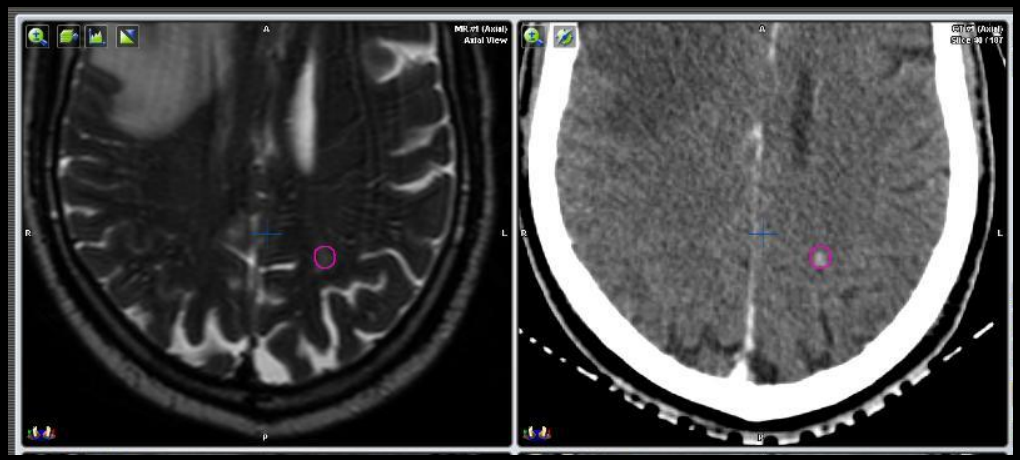
53 y, Male

NSCLC with brain and bone mets diagnosed in Aug 2010

Brain – 1 lesion Rt Frontal

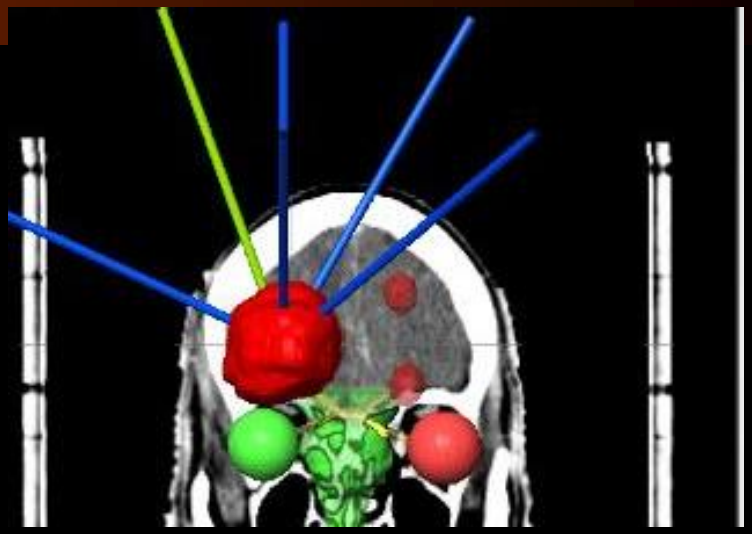
2 small lesions in Lt frontal and occipital lobes





Rt Frontal
SRT – 40Gy/10fr

Lt Frontal & Occipital
SRS - 20Gy/1fr

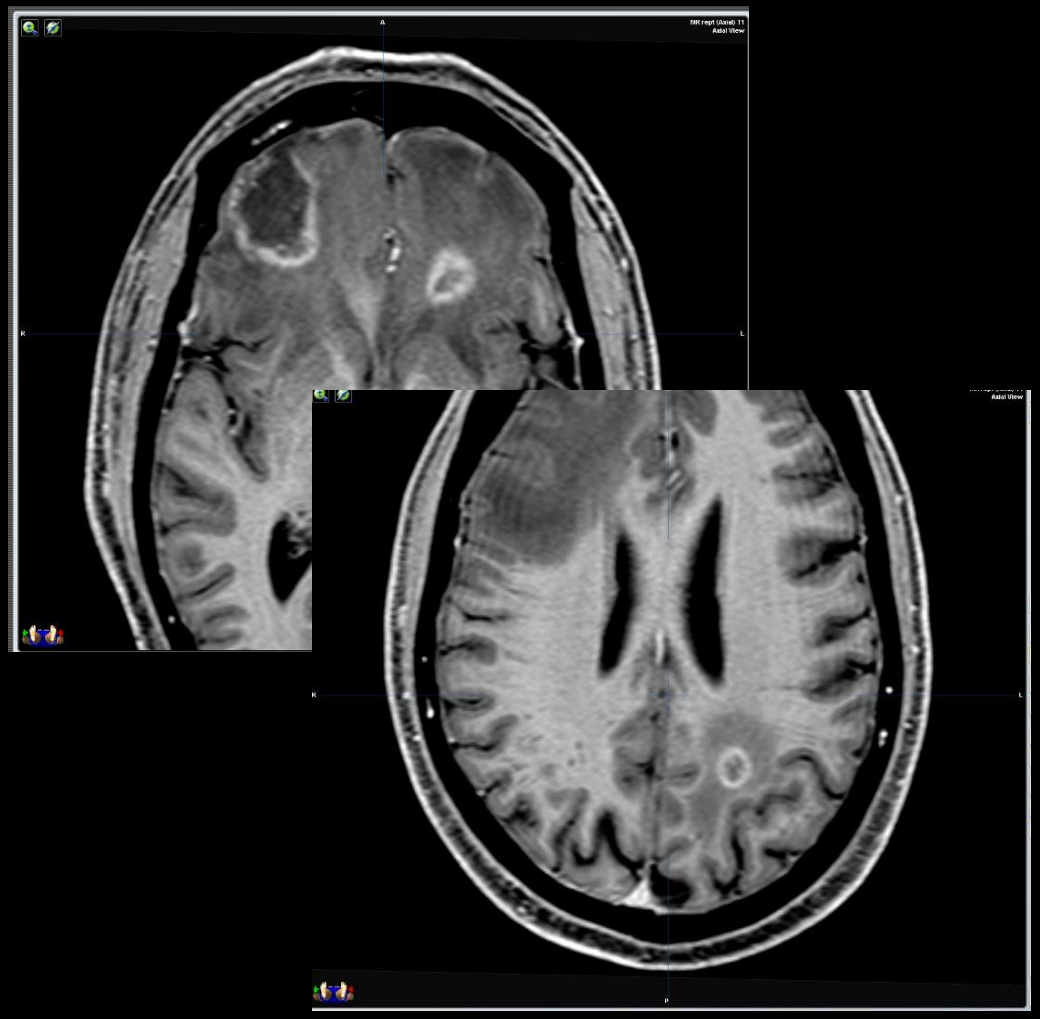


Systemic Rx – Erlotinib

F/u MRI at 1 year

Rt-Frontal lesion – Necrosis on Sx

Lt Frontal and Occipital lesions – Pseudoprogression, stable on f/u



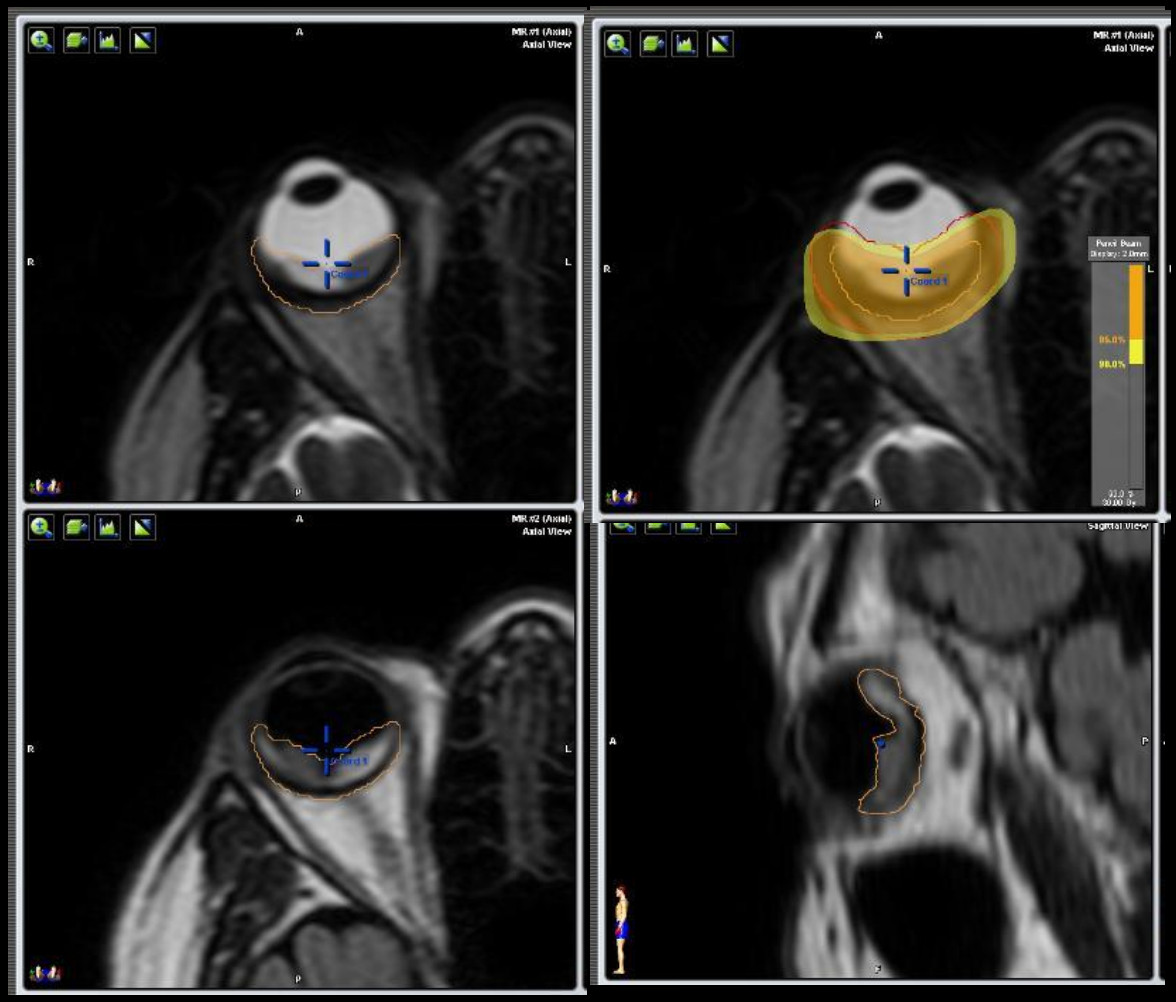
Choroidal Mets

56 Yr, Female

2006 – MBC (Bone Mets) on HT

2011, Sep – Choroidal Mets RE

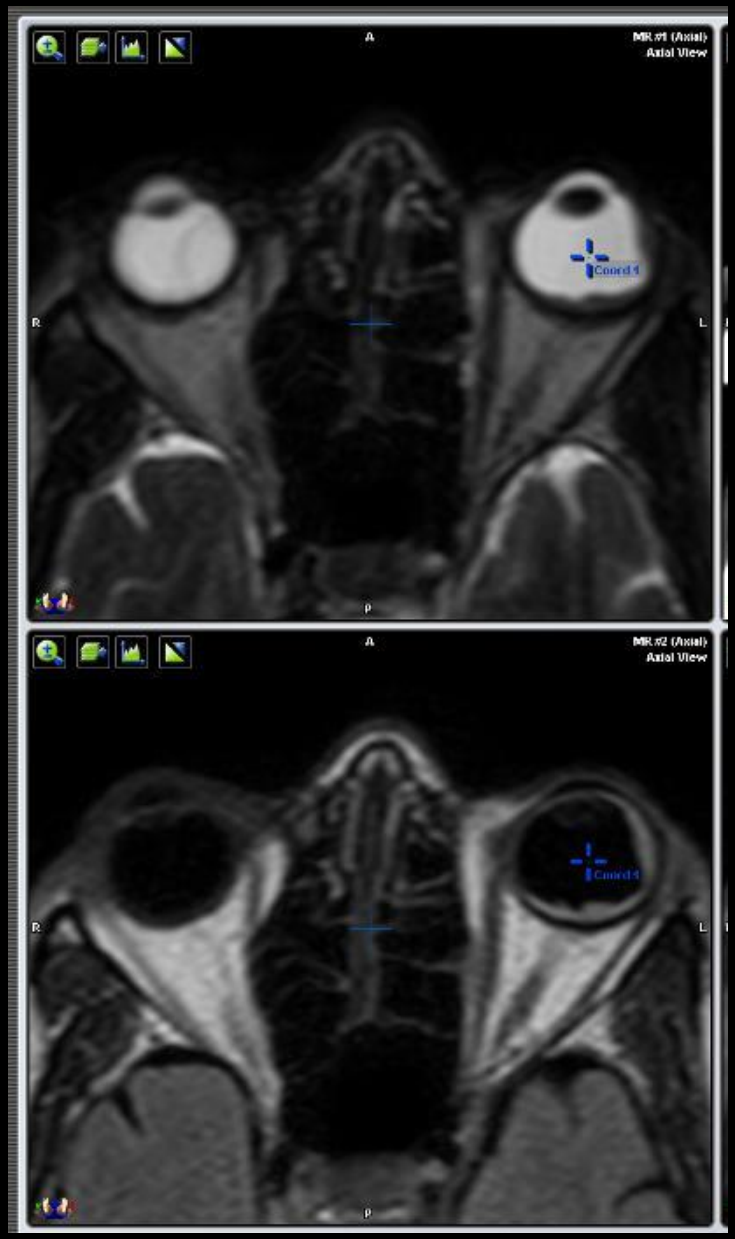
SRS – 30Gy/5fr

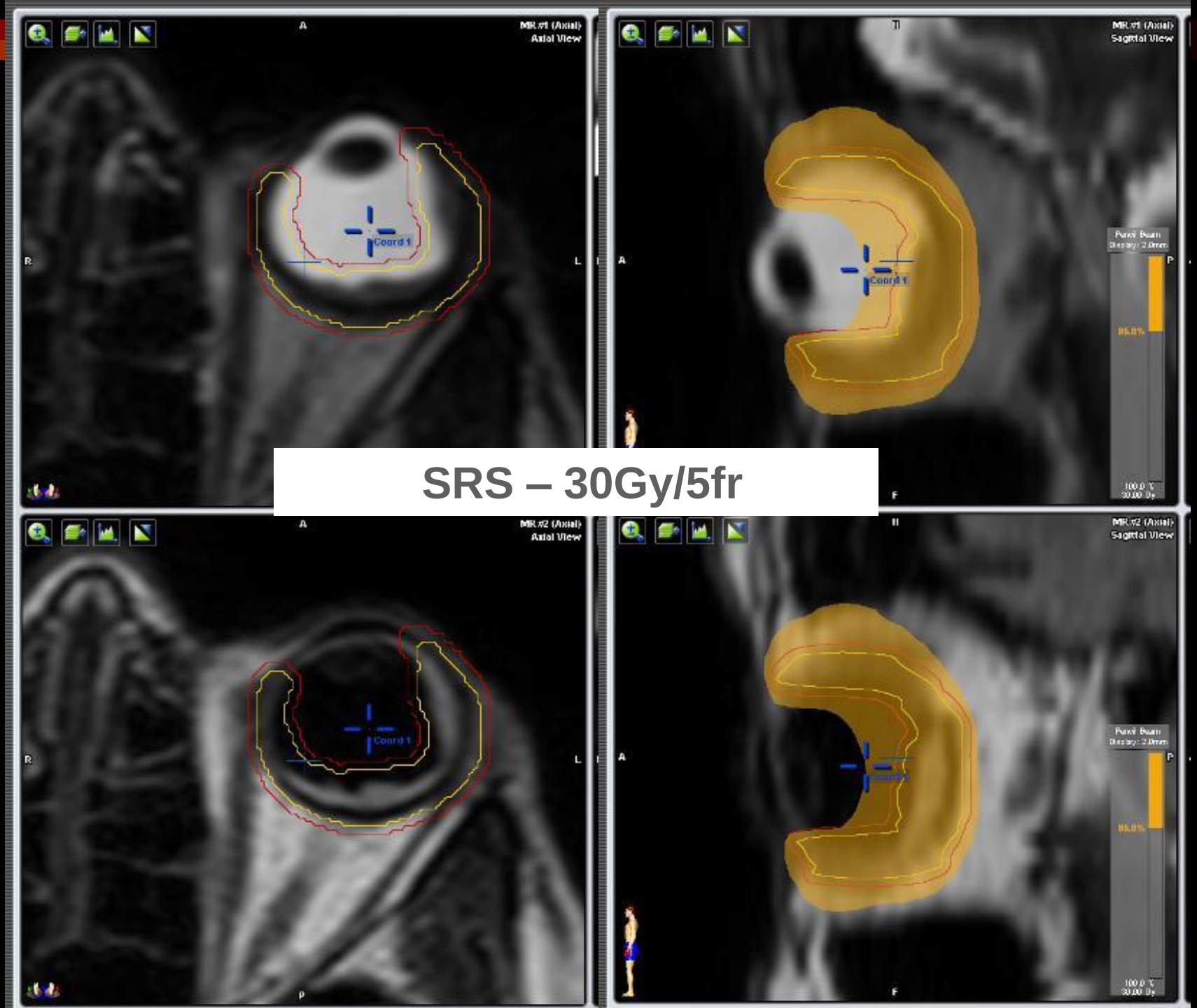


2012, April

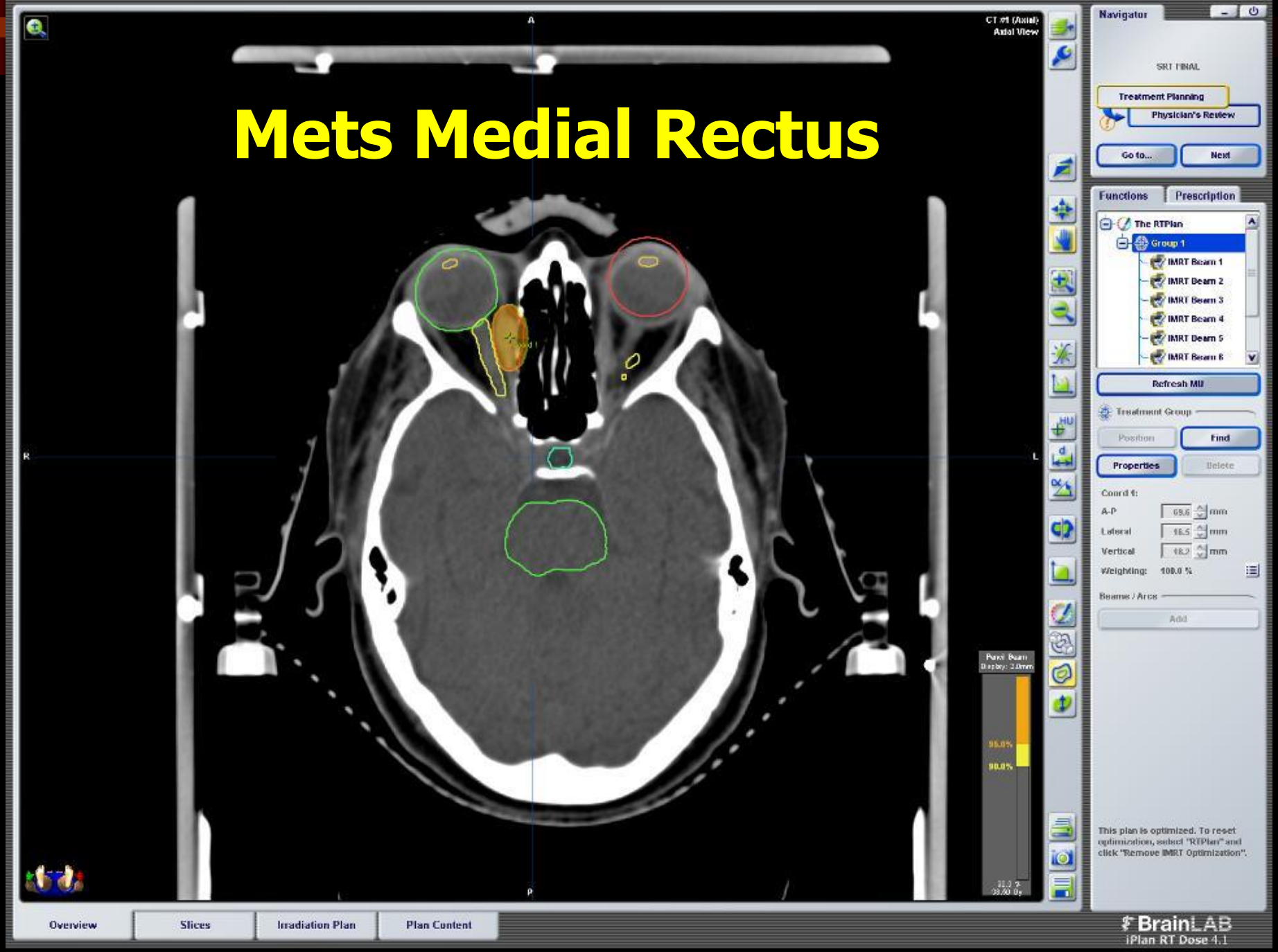
Choroidal Mets LE

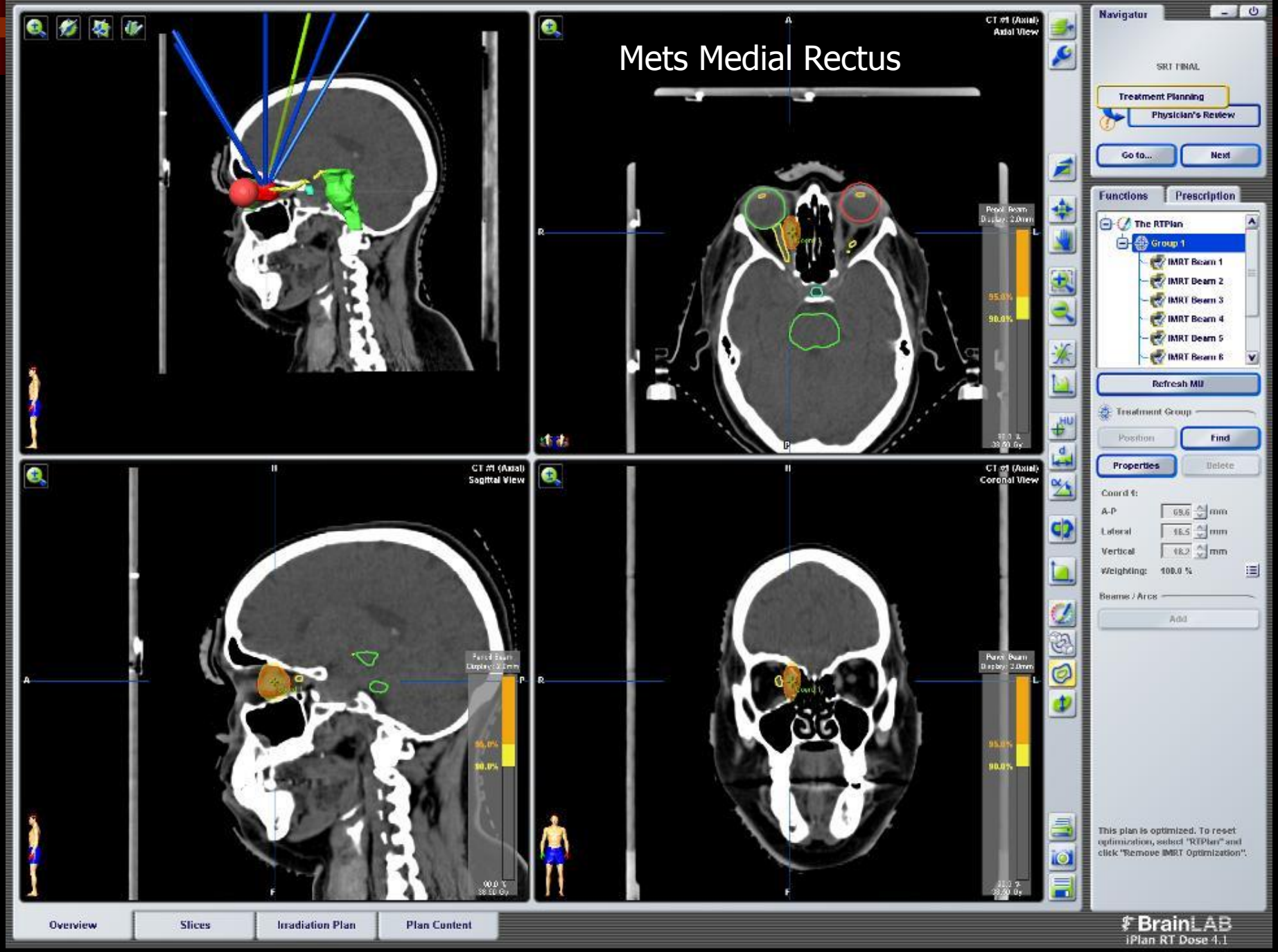
Complete regression of Mets in RE with improvement of vision




MR.#1 (Axial)
Axial View
Coord 1
MR.#1 (Axial)
Sagittal View
Coord 1
Pencil Beam
MR.#2 (Axial)
Axial View
Coord 1
MR.#2 (Axial)
Sagittal View
Pencil Beam

SRS – 30Gy/5fr


Mets Medial Rectus
Navigator
SRT FINAL
Treatment Planning
Physician's Review
Go to...
Next
Functions
Prescription
The RTPlan
Group 1
IMRT Beam 1
IMRT Beam 2
IMRT Beam 3
IMRT Beam 4
IMRT Beam 5
IMRT Beam 6
Refresh MU
Treatment Group
Position
Find
Properties
Delete
Coord 1:
A-P
Lateral
Vertical
Weighting:
100.0 %
Beams / Arcs
Add
This plan is optimized. To reset optimization, select "RTPlan" and click "Remove IMRT Optimization".
Overview
Slices
Irradiation Plan
Plan Content
BrainLAB
iPlan RT Dose 4.1
SEEMA AGARWAL ^VAR,NM
30-November-2010 01:42:26 PM



SEEMA AGARWAL ^VAR,NM

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Radiosurgery
in
Spine tumors

Indications

- **Metastases:**
  - **Bone, Soft tissue**
- **Primary bone tumors**
  - Osteoclastoma
  - AVMs
  - Hemangiomas

Spine Metastases

Indications

- Pain
- Impending Fracture
- Neurological compromise

Pain Relief

Rationale for SRS:

- More efficient 95% vs 65%
- Longer duration 14mo vs 5 mo
- More rapid onset 3days vs 2wks
- Re-treatments 30% vs 10%

Pain Relief
Conventional vs. SRS

	Conventional RT (8 Gy)	SRS (10-25 Gy)
Pain Relief	55-70%	95%
Duration	2.5-5 months	13 months
Onset	3 weeks	14 days
Retreatment	25–30%	0-15%

SRS - Spine Metastases

Dose Schedule

Single fraction – 16-20Gy

Spinal Cord dose limit – 10%Vol < 10Gy

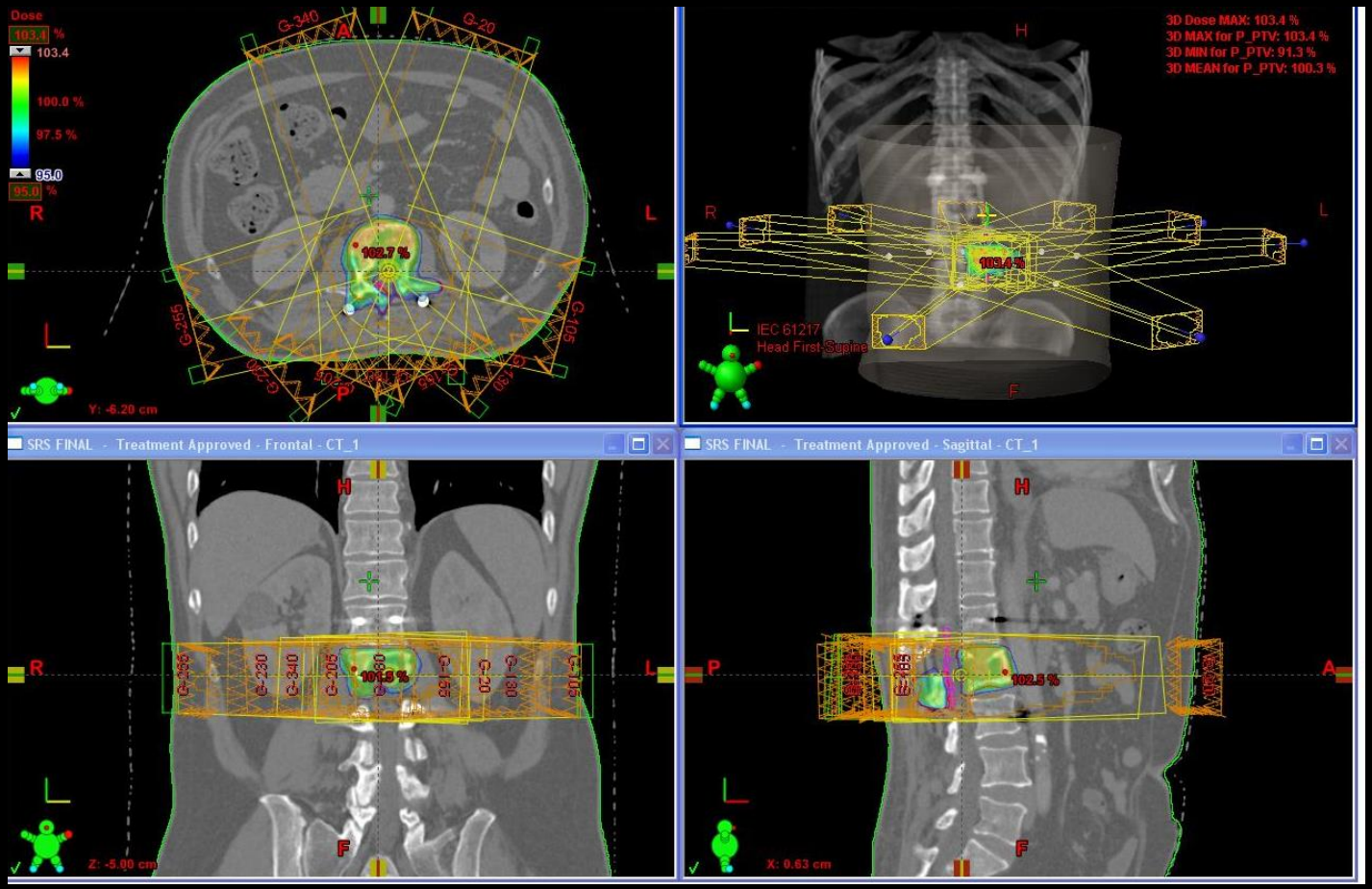
Dmax – 12-14Gy

Multi- fraction – 6Gy x 5 fr

7Gy x 4 fr

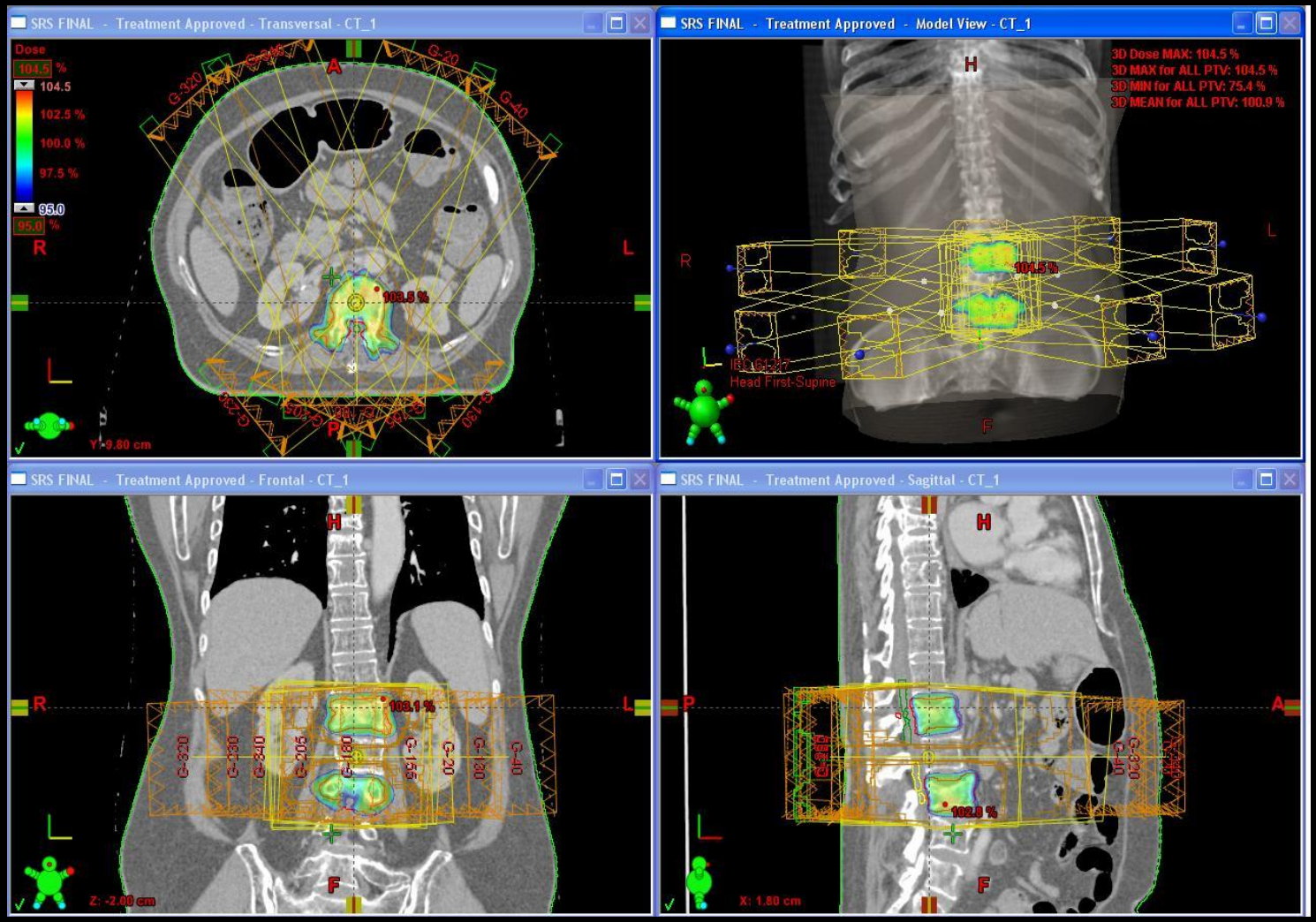
8Gy x 3 fr

Spine Metastases

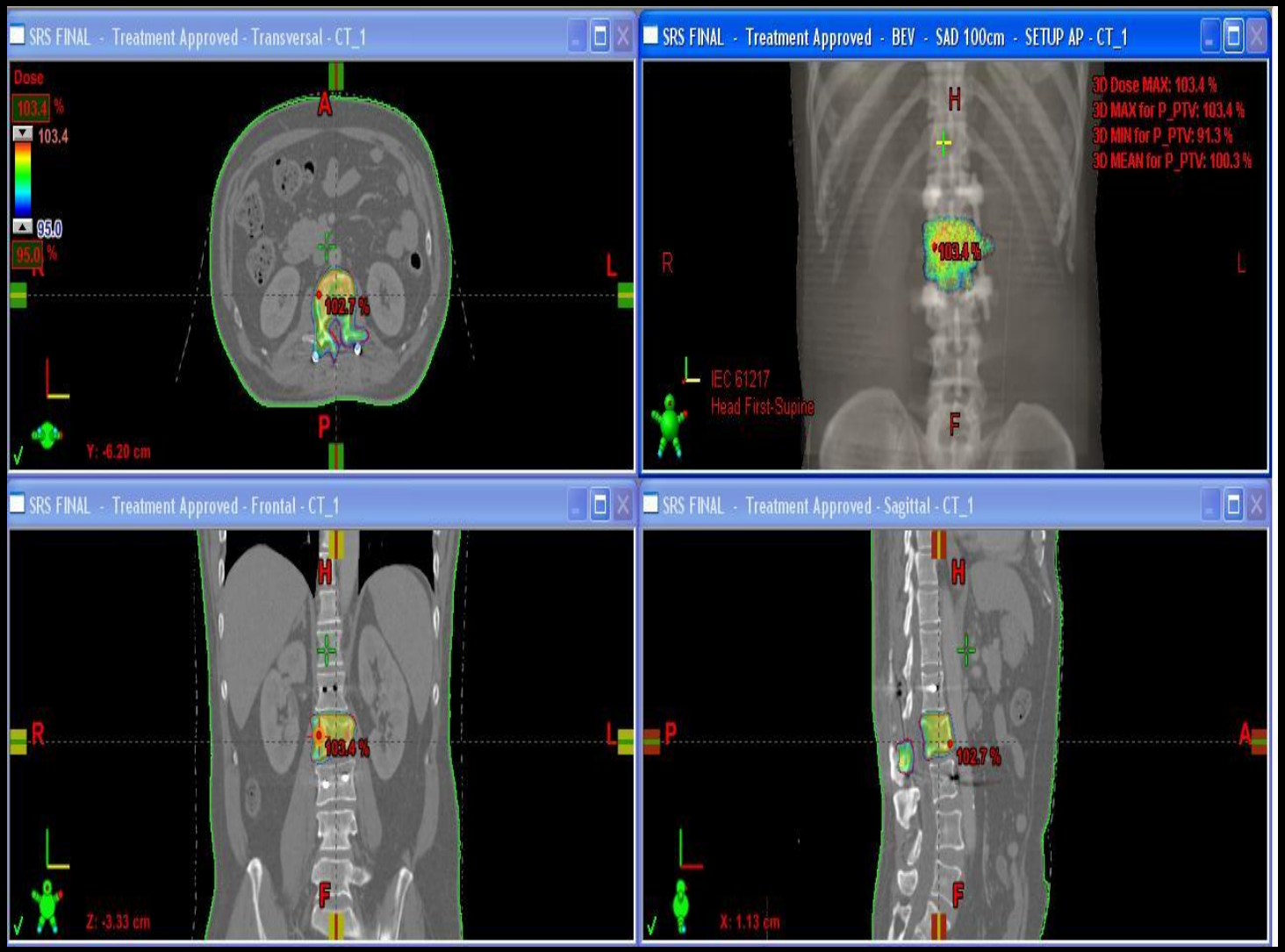


L2 Spine SRS, 6Gyx5frs
8 beams, sparing cauda

Spine Metastases

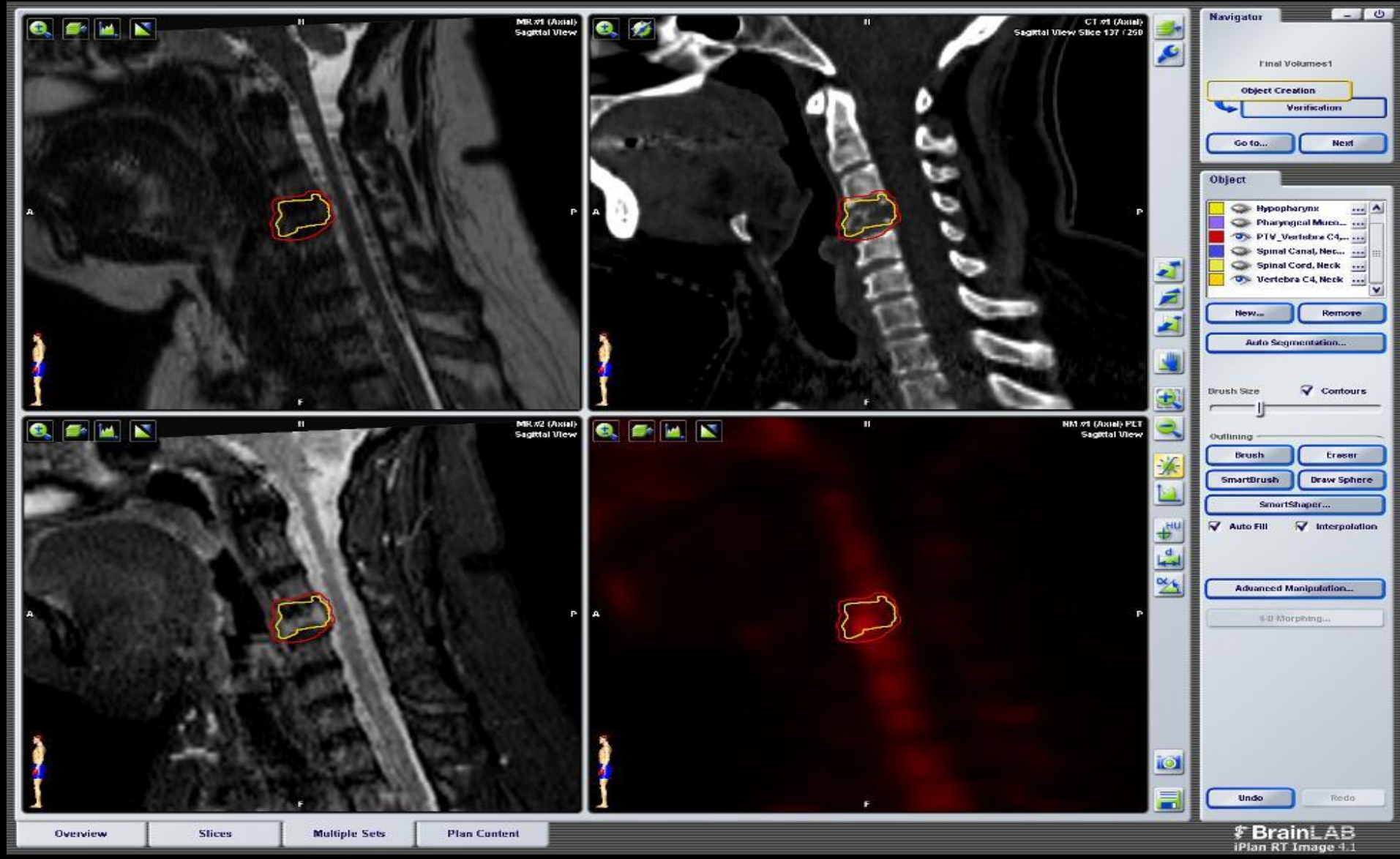


Spine Metastases



High Dose Envelope around PTV
Conformal Avoidance of OARs

47/F Ca Breast, C4 Mets




MM 01 (Axial) PET
Sagittal View
CT 01 (Axial)
Sagittal View Slice 136 / 258
MR 01 (Axial)
Sagittal View
MR 02 (Axial)
Sagittal View
Point Beam
30 Gy / 5 fr
Navigator
FINAL SMART
Object Creation
Treatment Planning
Go to...
Next
Object
Enlarged Vertebr...
Hypopharynx
Outer Contour
Pharyngeal Muc...
PTV_Vertebra C4...
Spinal Canal, Ne...
Spinal Cord, Neck
New...
Remove
Auto Segmentation...
Brush Size
Contours
Outlining
Brush
Eraser
SmartBrush
Draw Sphere
SmartShaper...
Auto Fill
Interpolatio
Advanced Manipulation...
Role Reassignment...
Undo
Redo
Overview
Slices
Multiple Sets
Plan Content
BrainLAB
iPlan RT Dose 4.1

47/F Ca Breast, C4 Mets

Summary

- Excellent treatment approach for a number of tumors
- Non invasive
- Single treatment requiring a short hospital stay
- Few if any side effects
- Patient Selection and Expertise