Cranio-spinal Irradiation

ICRO course:
26 Apr
2014,Shimla

Prof.Bidhu K Mohanti
FORTIS Memorial Research Institute,Gurgaon
<bk.mohanti@fortishealthcare.com>

Fortis

Cranio-spinal axis radiation therapy

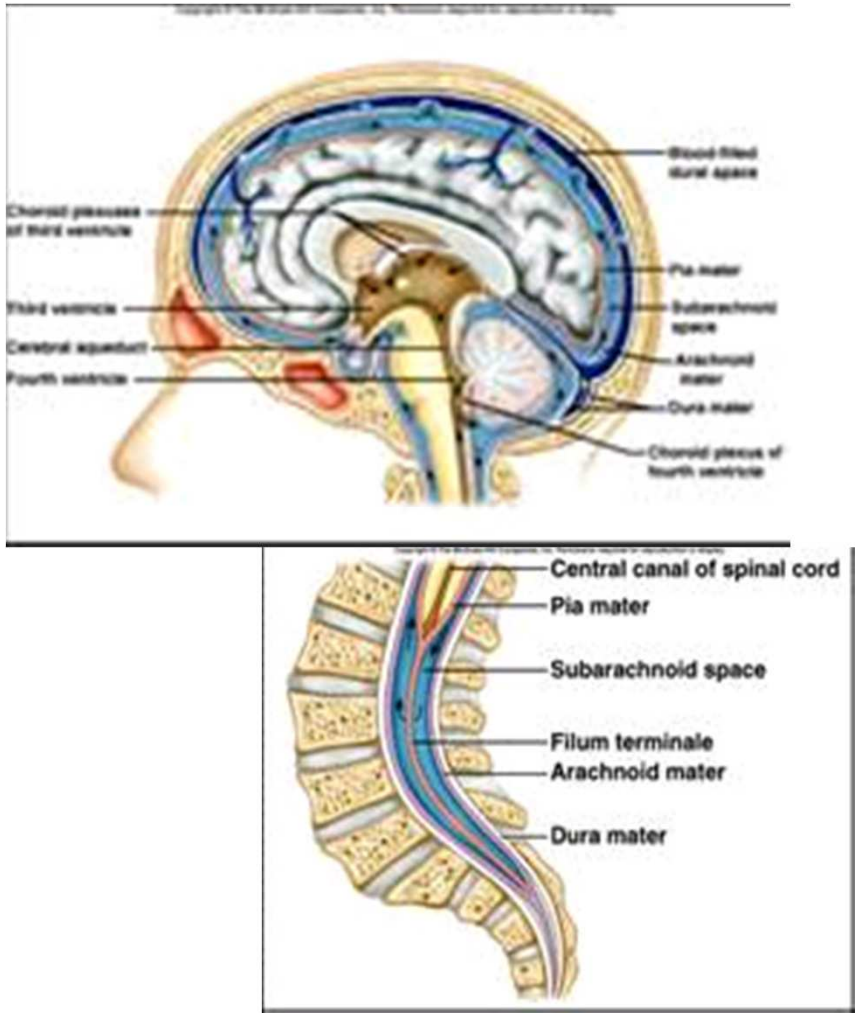
- Medulloblastoma
- Pinealoblastoma
- Ependymoblastoma
- Intracranial Germ cell tumor(germinoma)
- Central neurocytoma
- Glioneuronal tumor
- Choroid plexus carcinoma
- Leukemia/lymphoma(with CNS axis mets)

Perez and Brady. Radiation oncology 5th Ed. P1822-1836

CSF seeding: Cerebrospinal fluid

secreted by choroid plexus

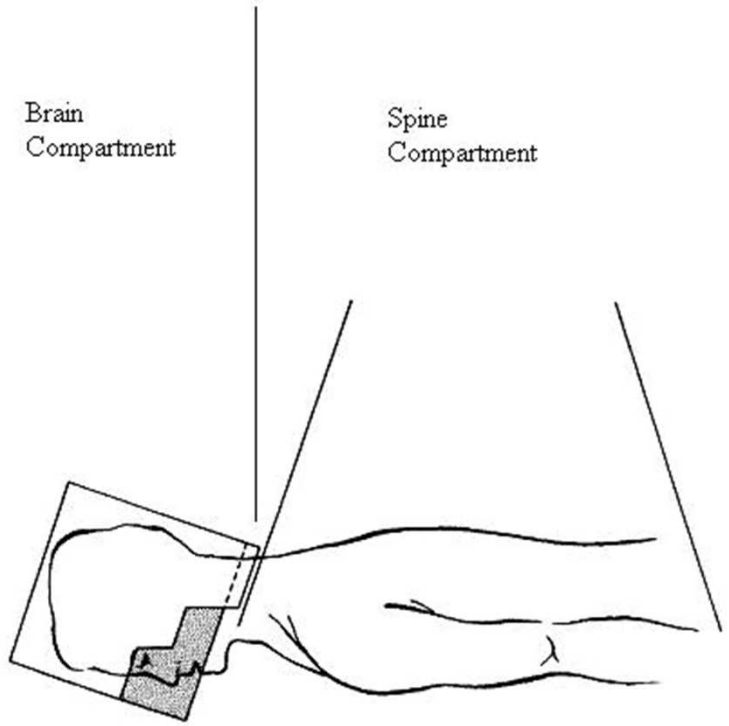
- circulates in ventricles, central canal of spinal cord, and subarachnoid space
- completely surrounds brain and spinal cord
- clear liquid
- nutritive and protective
- helps maintain stable ion concentrations in CNS



Meyer JJ et al.Radiation Oncol 2006;1:48

Craniospinal Irradiation(CSI) volume

- To treat the entire CNS axis, because tumor cells from the brain parenchyma ,for certain neoplasms, have direct access to the subarachnoid space and hence to the CSF.



A two compartment kinetic model, brain parenchyma & the CSF fluid, which are interconnected .

- PTV_brain
- PTV_spine

Dose needed for tumor control

Two compartments:

- brain(solid tumor)
- spine(fluid)

require different total dose,fractions,schedule

PTV_brain: ≤ 54 Gy

PTV_spine: 24-35 Gy

Site	Whole	Boost
Brain	23-35 Gy	Posterior fossa=54 Gy
Spine	23-35 Gy	Seeding = 36-42 Gy

Before we deliver CSI

- We should realize,the cranio-spinal irradiation is going to treat a large and complex volume of body.

Leading to:

-acute morbidities

-long-term late effects

CSI: Acute morbidities

- Multiple acute toxicities take place during therapy course , because of the exposure of a large portion of the normal tissues,including bone marrow, head and neck, thorax,abdomen,and pelvis:

-nausea,vomiting

-esophagitis

-diarrhoea

-myelosuppression

-fatigue,weight loss

CSI: long-term effects

- Endocrine dysfunction
- Hypothyroidism
- Impaired fertility
- Neurocognitive decline
- Growth retardation
- Hearing/visual impairment
- Cardiomyopathy
- Nephropathy
- Second malignancies

CSI: Reducing Morbidities

- All our techniques and dose regimens for CSI should aim to reduce:

1. the acute morbidities for better tolerance and compliance
2. the late effects which diminish the QOL in the cured children(as they achieve adulthood)

- *All efforts should be made to monitor closely during RT course , and subsequently maintain a follow-up strategy to identify the long-term effects.*

CSI: the evolving techniques

- 2-D
- 3-D CRT
- IMRT
- Adaptive IGRT
- VMAT
- Tomotherapy
- Proton therapy

•Paterson E, Farr RF. Acta radiol 1953;39:323
•Chojnacka M etal. Paediatr Blood Cancer 2004;42:155
•Taylor RE etal. PNET-3 study. IJROBP 2004;58:1184
•Wang Z et al . Radiation Oncology 2013;8:217

Planning steps

- Positioning
- Immobilization
- Simulation
- Verification
- Treatment
- Junction shift

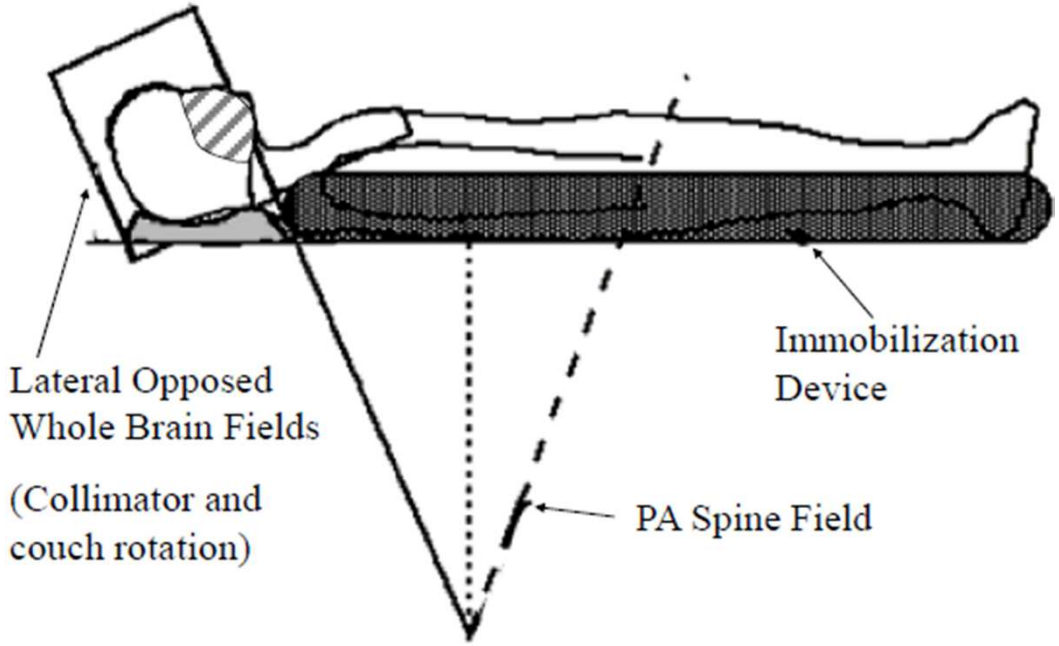
Fortis

Difficulties in classic irradiation techniques

- Divergences of bilateral brain fields and the upper spine field are in different directions
  - Matching inf. border of cranial fields & sup. border of spine field
- Spine fields are not geometrically matched
  - How to avoid/reduce high dose region?
- Varying depth of spinal cord along its length
- Patient is in prone position – difficult position to reproduce

Craniospinal irradiation: 2-D

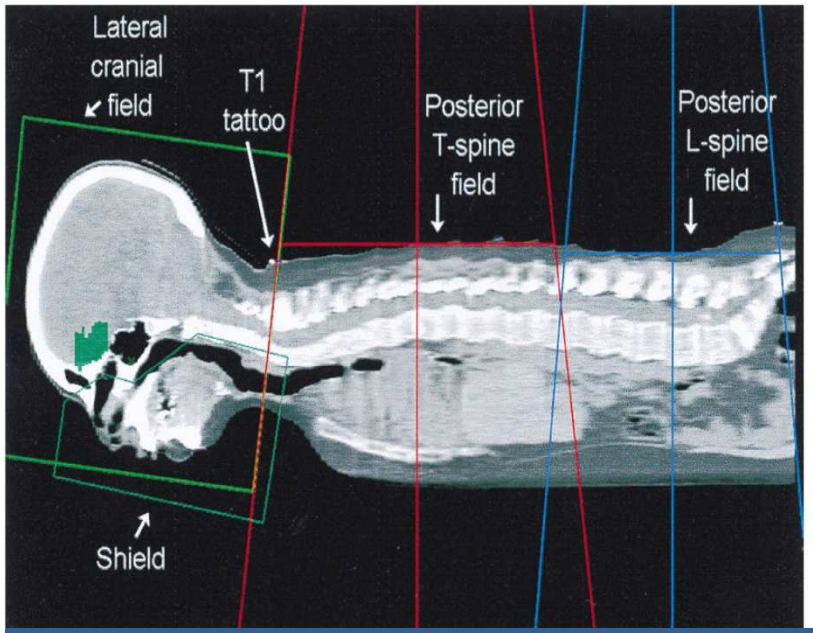
- Goal: To irradiate the entire neuraxis
- Classical setup
  - Two lateral brain fields
  - Abutted to one or two PA spine fields



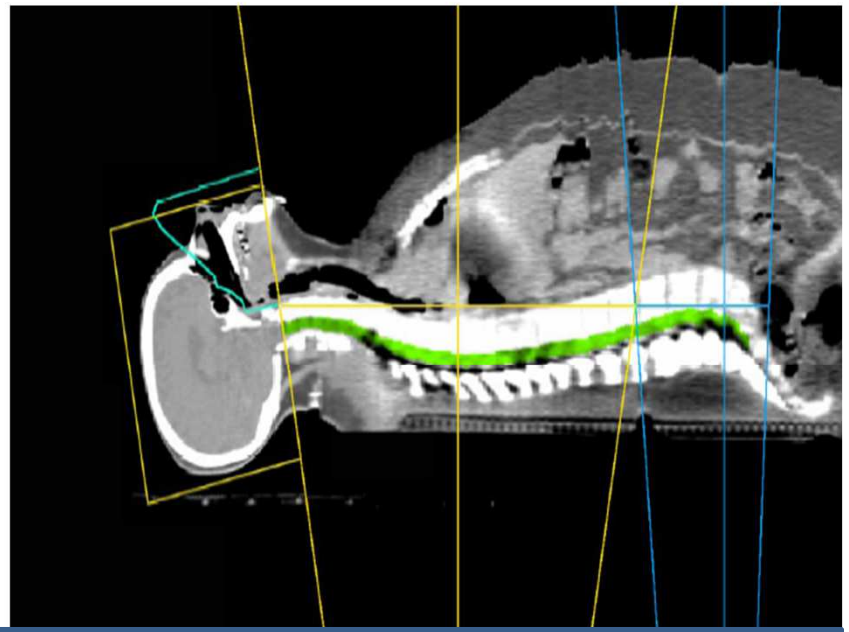
Fortis

CSI:positioning

Prone



Supine



In standard care, prone positioning is preferred.
Supine positioning is required for anesthesia.

Radiotherapy Planning: 2-D

Phase I

- Two lateral cranial fields
- 1 or 2 spinal fields

Phase II: Posterior fossa boost

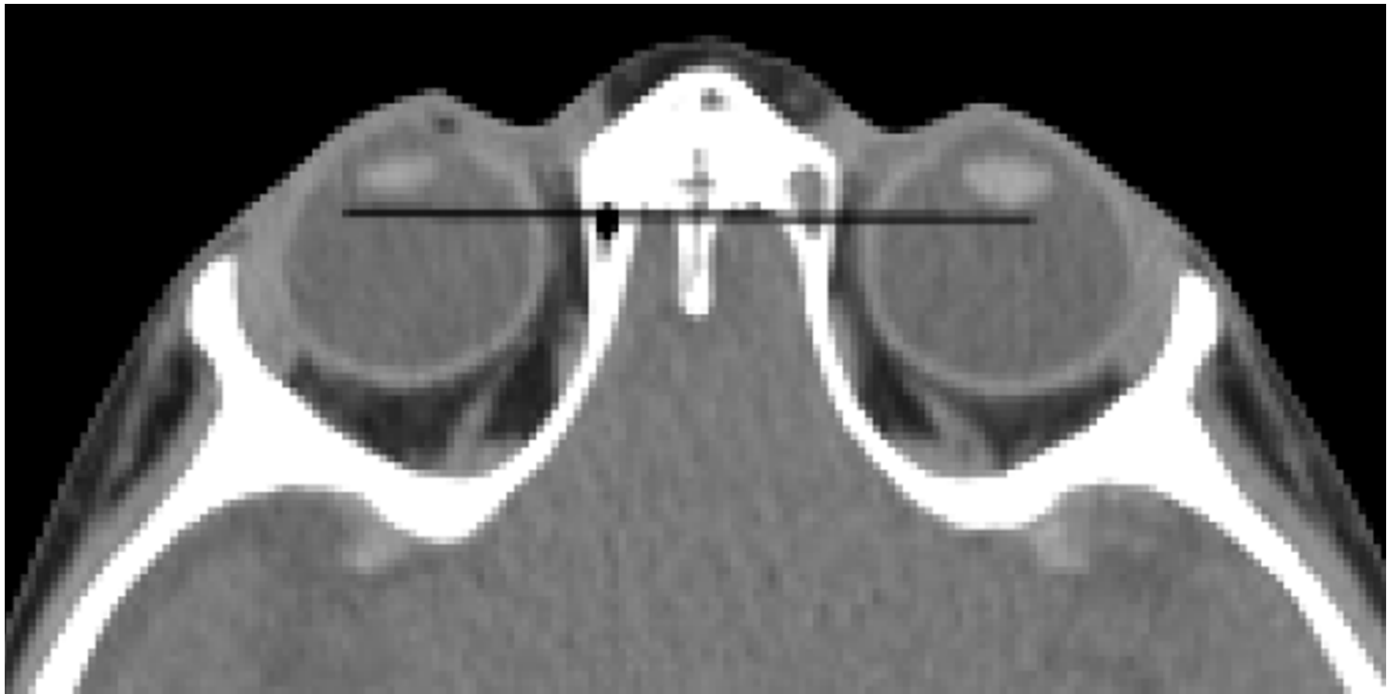
- Two lateral cranial fields
- Conformal technique in low risk cases.

Critical organs are too many

- Eye lens, optic apparatus,
- Lungs, heart, breast tissue, kidneys
- Exit dose is an issue

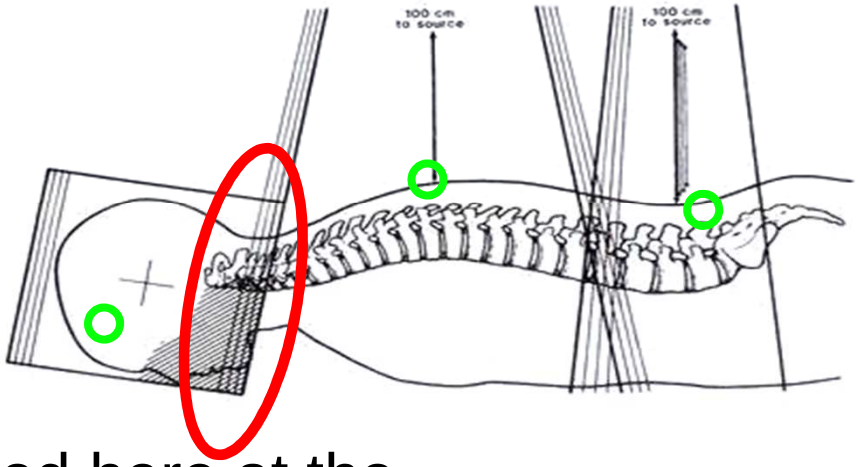
Fortis

Spare lenses, but cover cribriform plate region

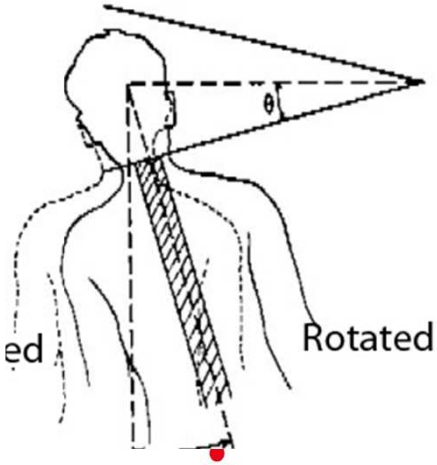


Fortis

All symmetric fields

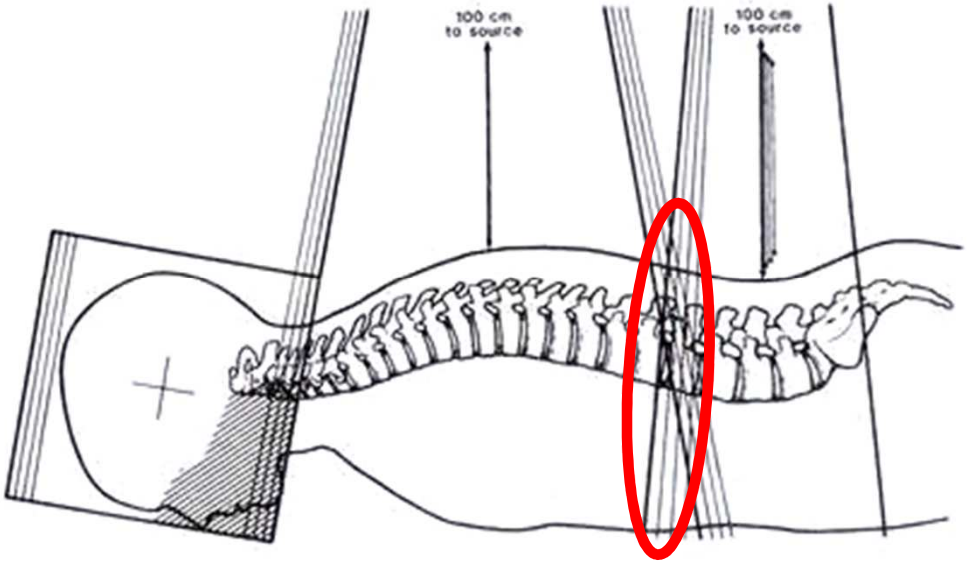


- A. **Fully divergent skull fields and a divergent upper spine field**
  - Two divergences are involved here at the **junction of cranio-spinal fields**
    - Skull fields diverge in the RT – LT direction
    - Upper spine field diverge in the PA direction
- Collimator rotation required to match the skull fields with the divergence of upper spine field
- Additionally, couch rotation *(couch kick)* required to match the divergence of the skull fields



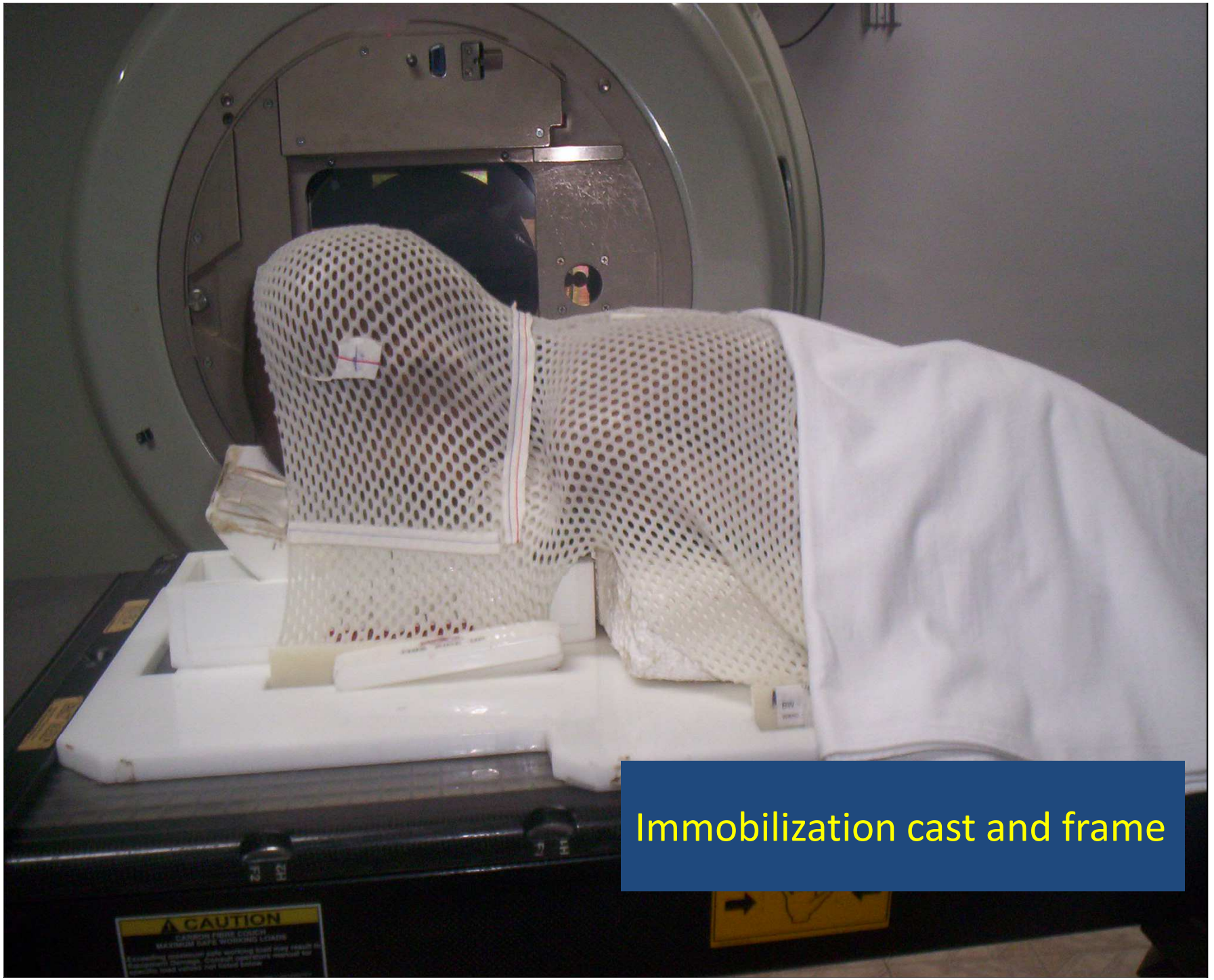
Fortis

All symmetric fields



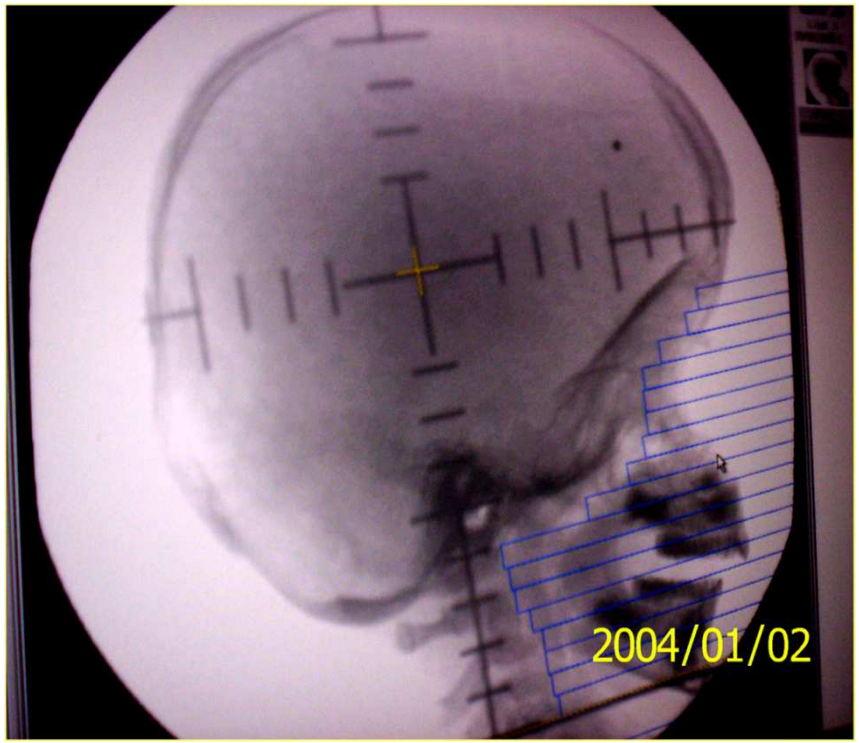
- Is that all?
- No, there are two spine fields – **another junction**
- This junction ***cannot*** be matched
  - There will be a gap
  - There will be a overlap

Fortis

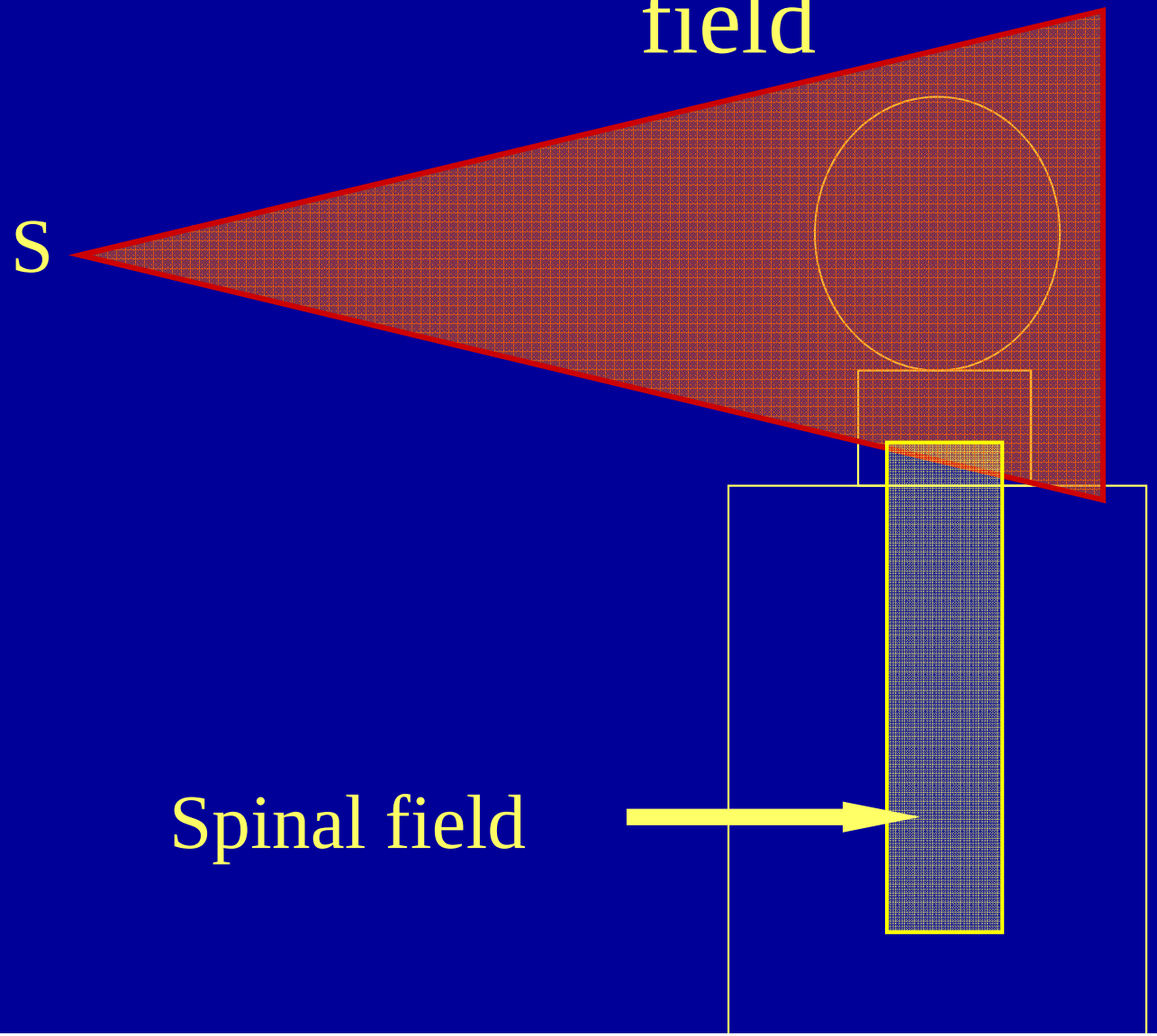


Immobilization cast and frame

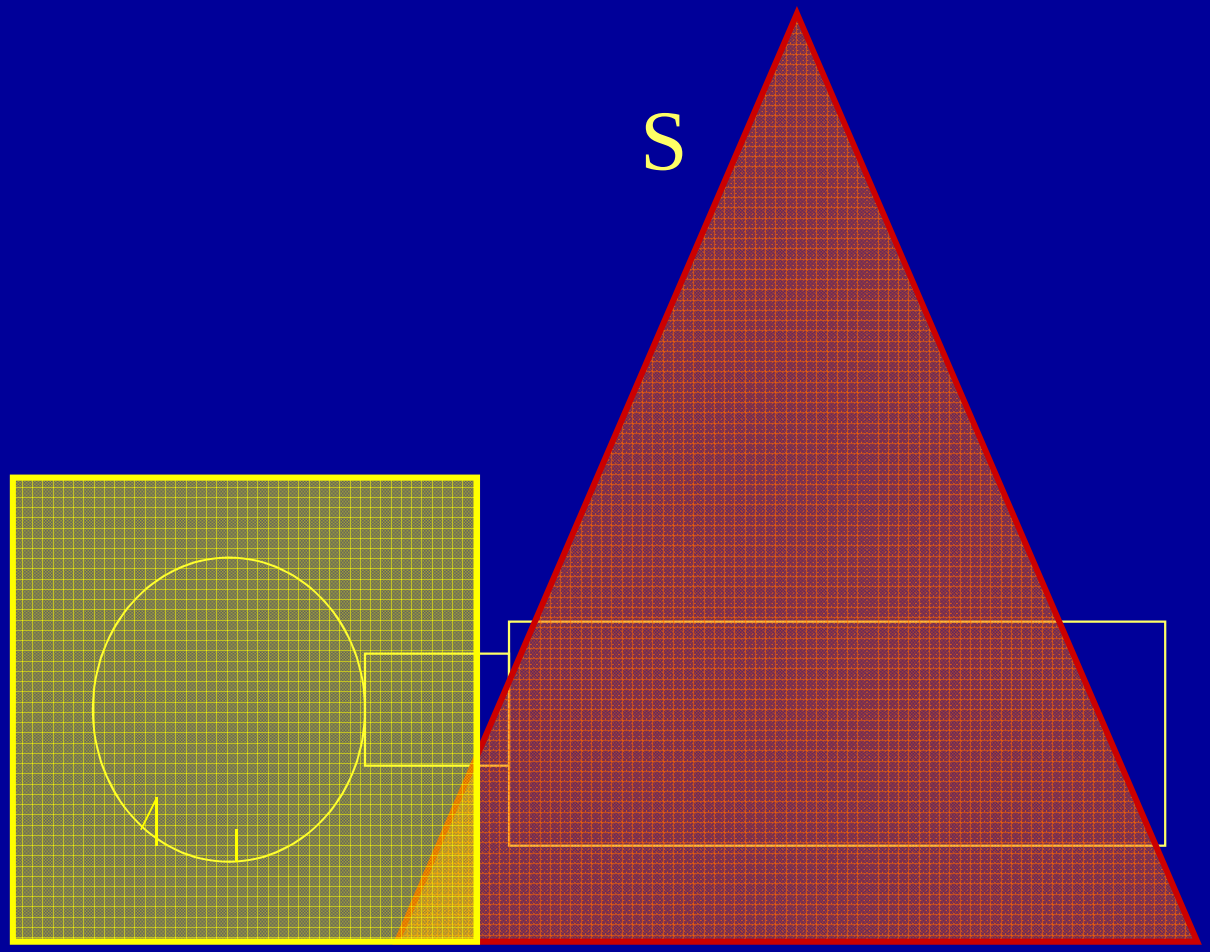
CSI: 2-D Simulator settings



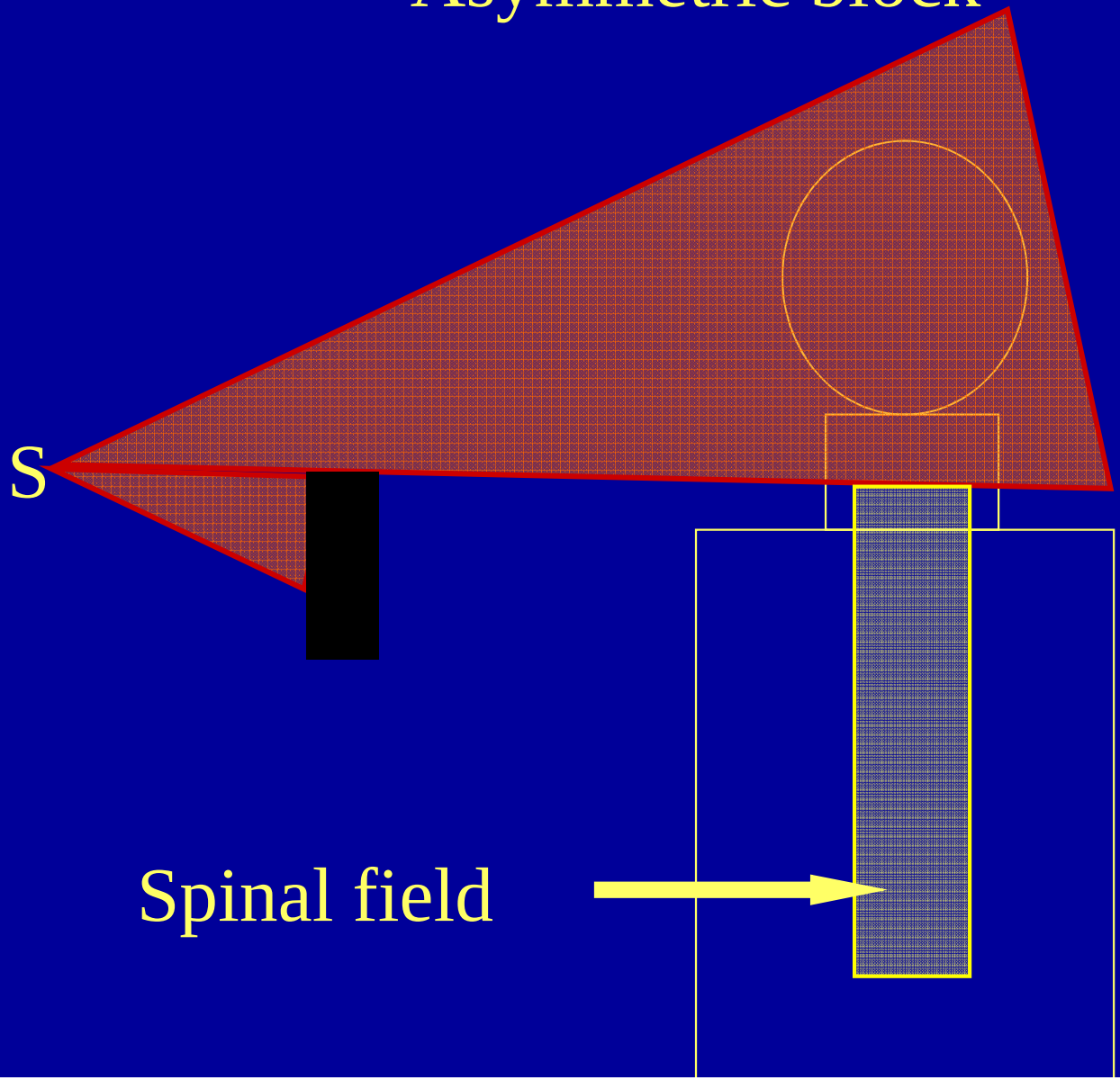
Problem 1: Divergence of cranial field



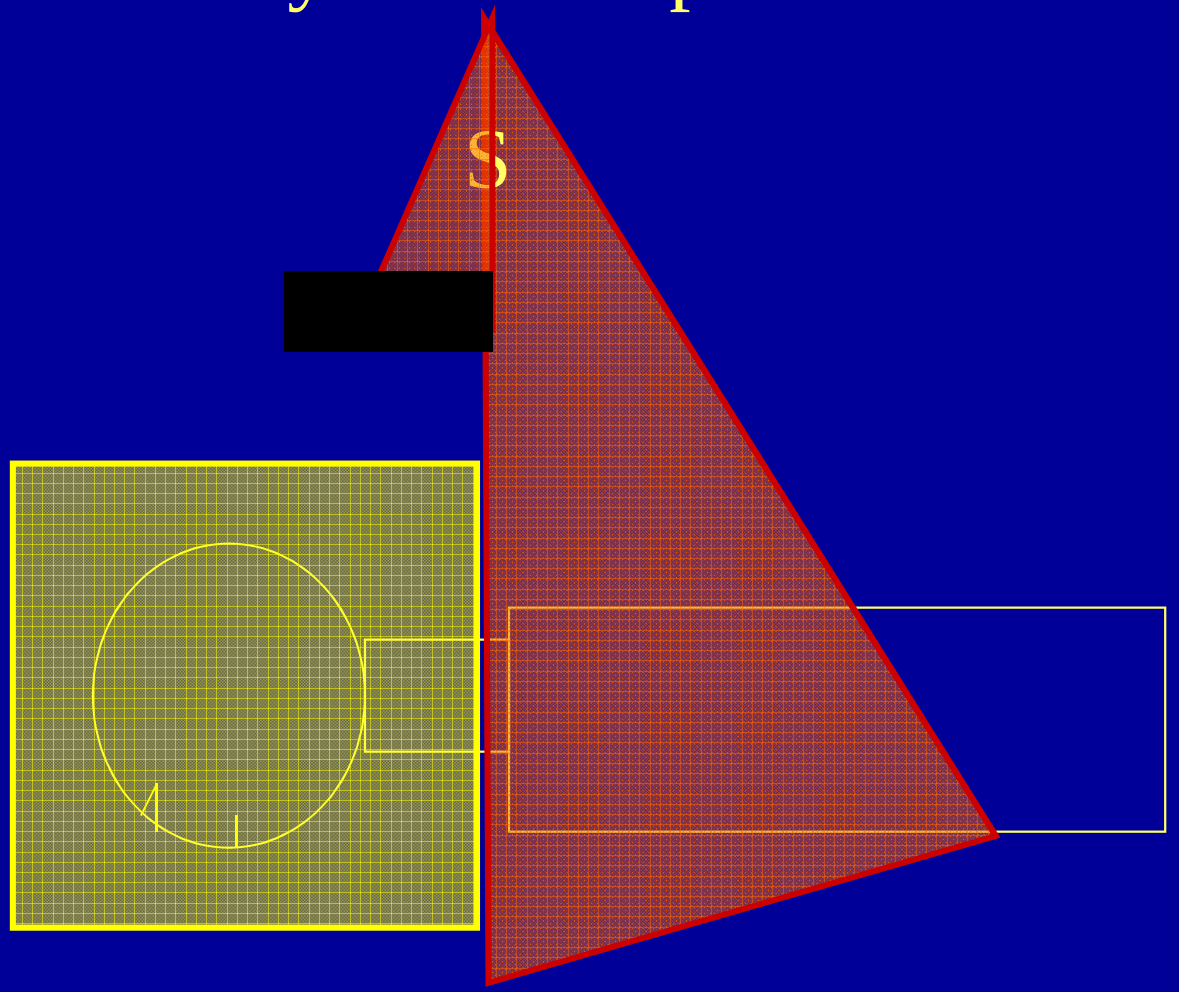
Problem 2 Divergence of spinal field



Solution to Problem 1: Asymmetric block

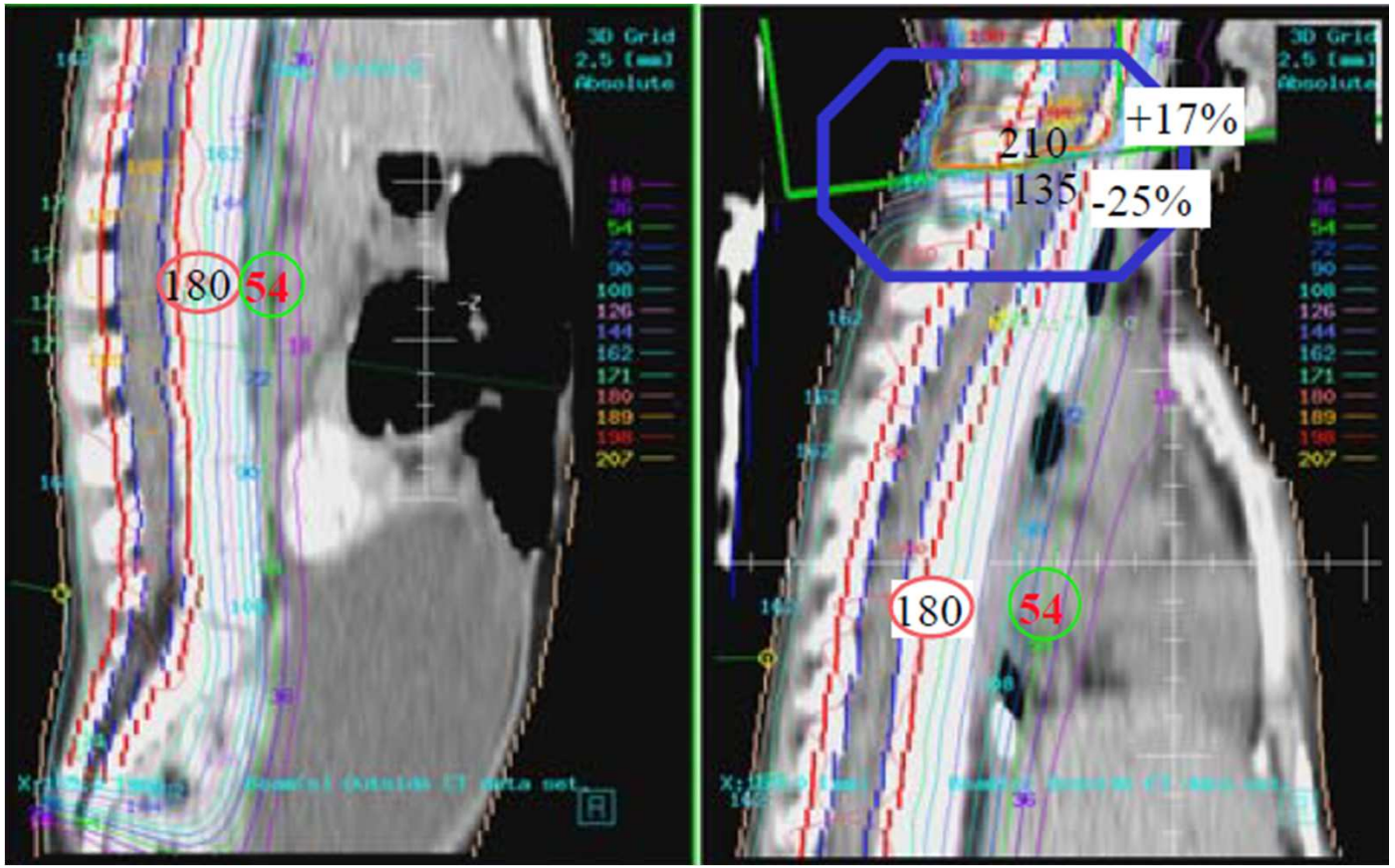


Solution to Problem 2:
Use asymmetric spinal block



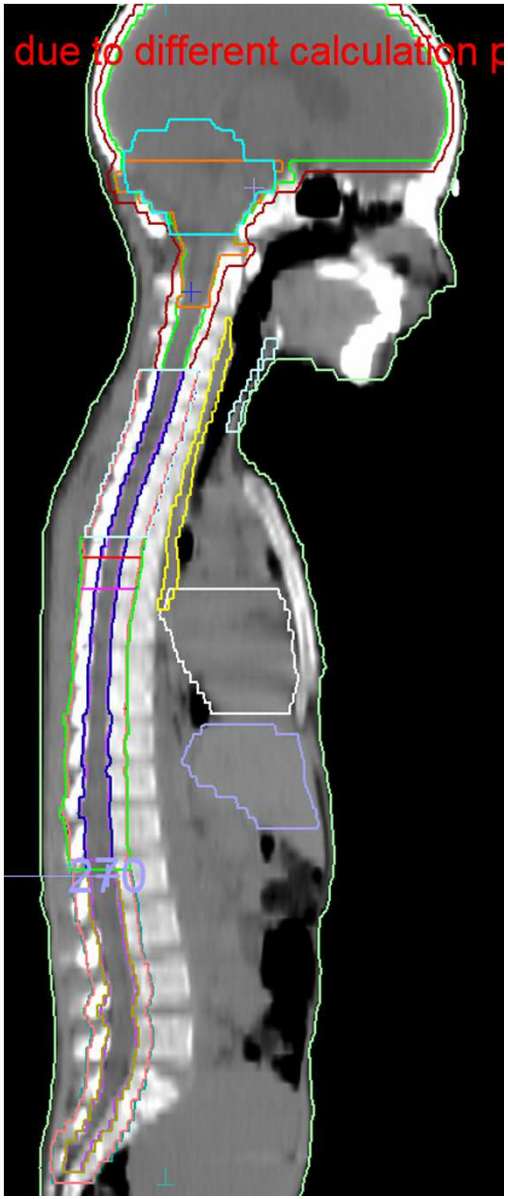
2-D:What are the other techniques? Electron Field(s)

- 16 MeV PA electron beam spine field



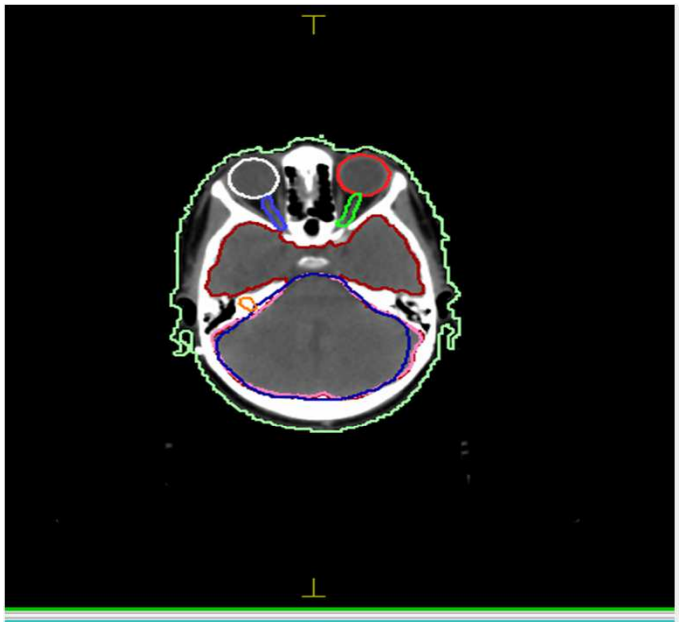
Fortis

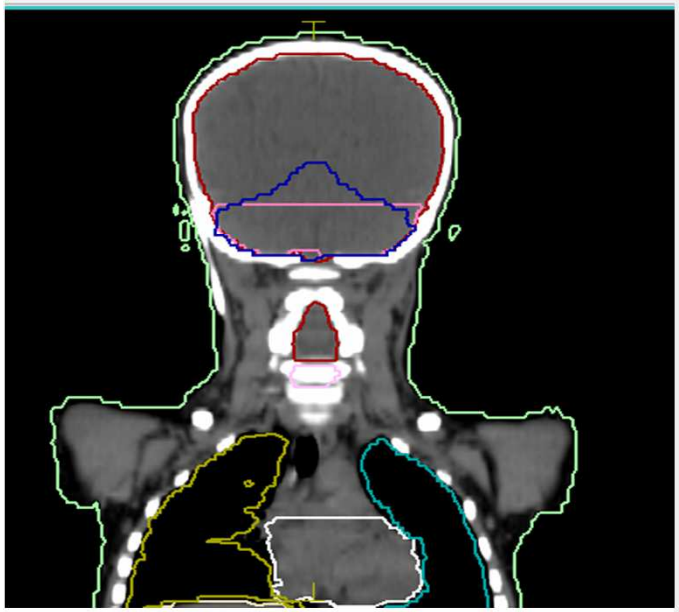
3-D image-based :Contouring



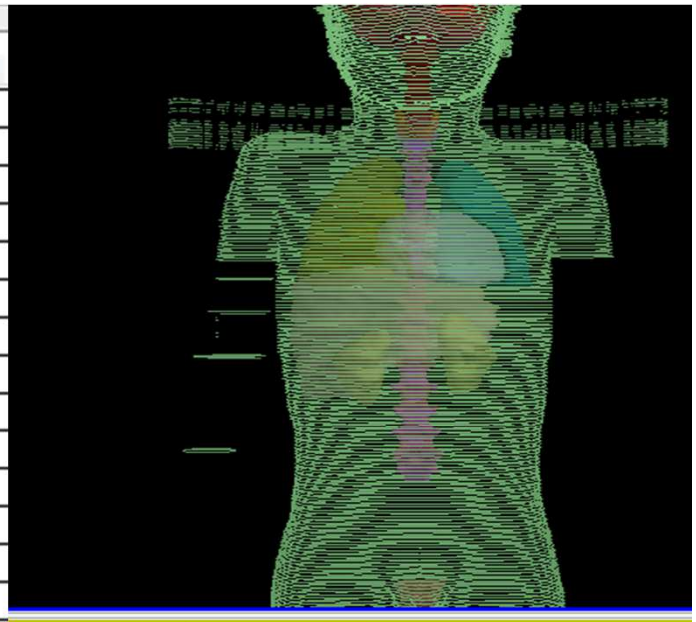
Structure	2D T
BRAIN	
BRAIN NEW	
CHIASMA	
CTV BOOST	
HEART	
HPA	
L COCHLEA	
L KIDNEY	
L OPTIC NV	
L. EYE	
LIVER	
POST FOSSA	
PRV L COCHLEA	
PRV R COCHLEA	
PTV BRAIN NEW	
PTV SPINE NEW	
R COCHLEA	
R EYE	
R KIDNEY	
R OPTIC NV	
SPARE	
SPINE	
SPINE BOOST	
SPINE NEW	
THYROID	
l lung	
patient	
r lung	
residual	
target vol. 3	
testis	

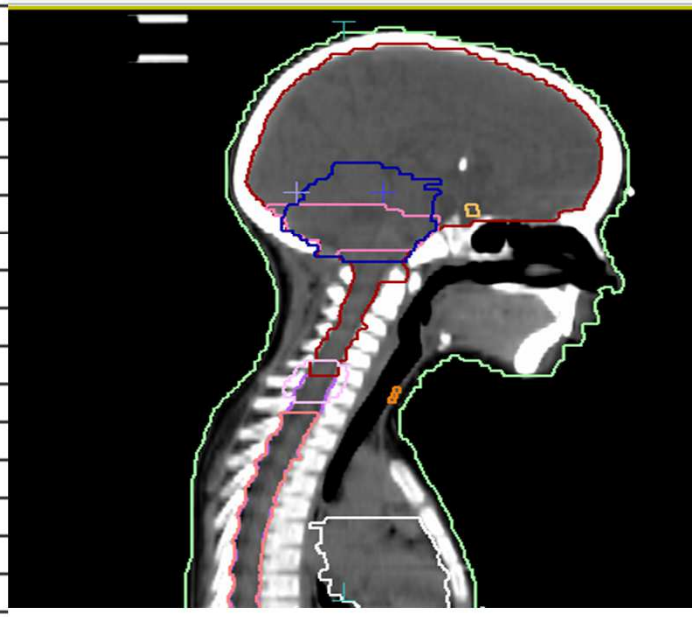
3-D:Contouring all planes



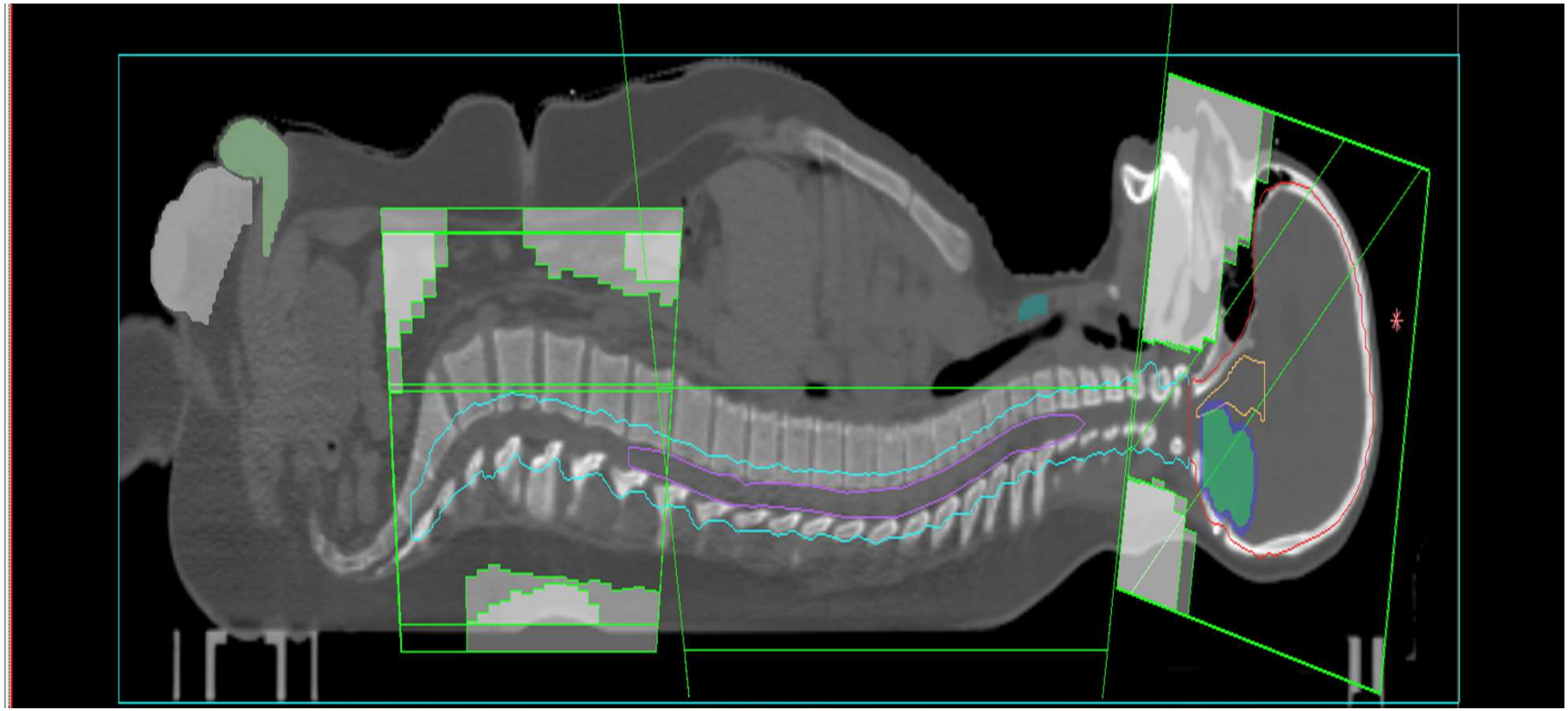


Structure	2D T
BRAIN	
BRAIN NEW	
CHIASMA	
CTV BOOST	
HEART	
HPA	
L COCHLEA	
L KIDNEY	
L OPTIC NV	
L. EYE	
LIVER	
POST FOSSA	
PRV L COCHLEA	
PRV R COCHLEA	
PTV BRAIN NEW	
PTV SPINE NEW	
R COCHLEA	
R EYE	
R KIDNEY	
R OPTIC NV	
SPARE	
SPINE	
SPINE BOOST	
SPINE NEW	
THYROID	
l lung	
patient	
r lung	
residual	
target vol. 3	
testis	



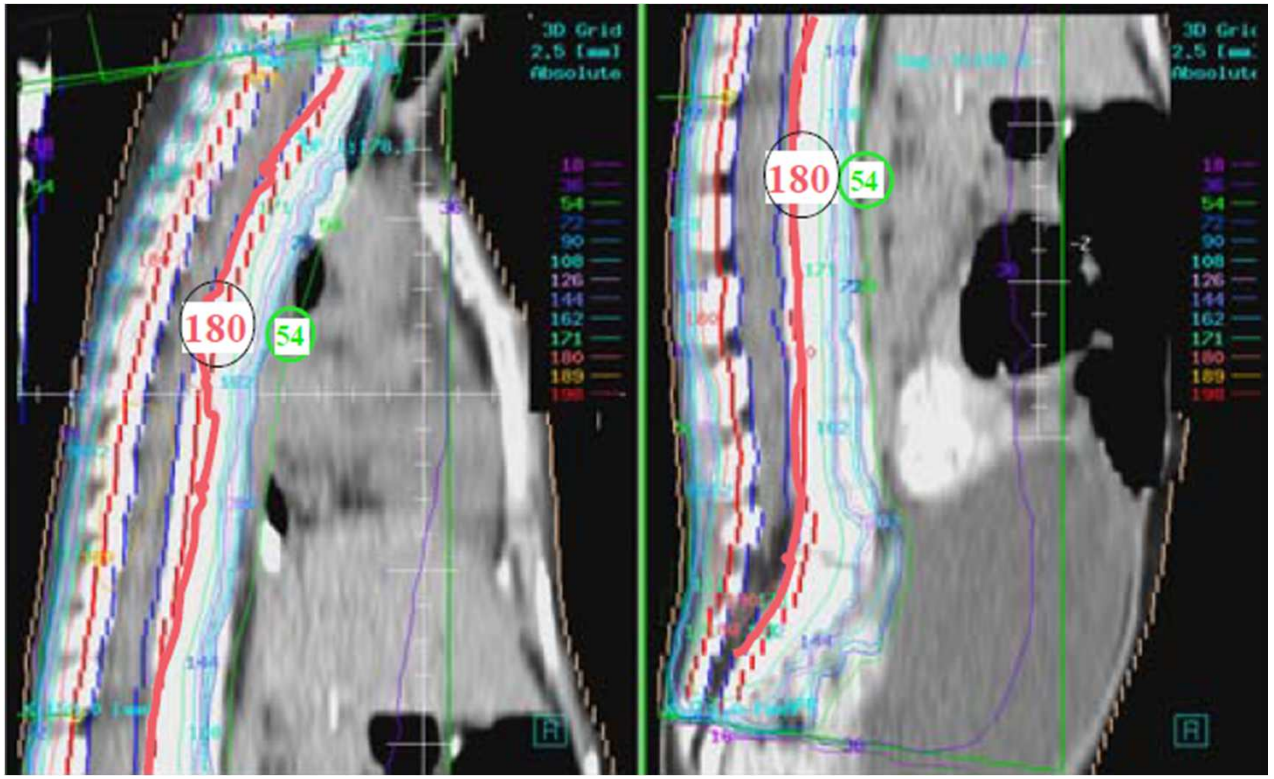


CSI:Beam arrangement- 3D-CRT



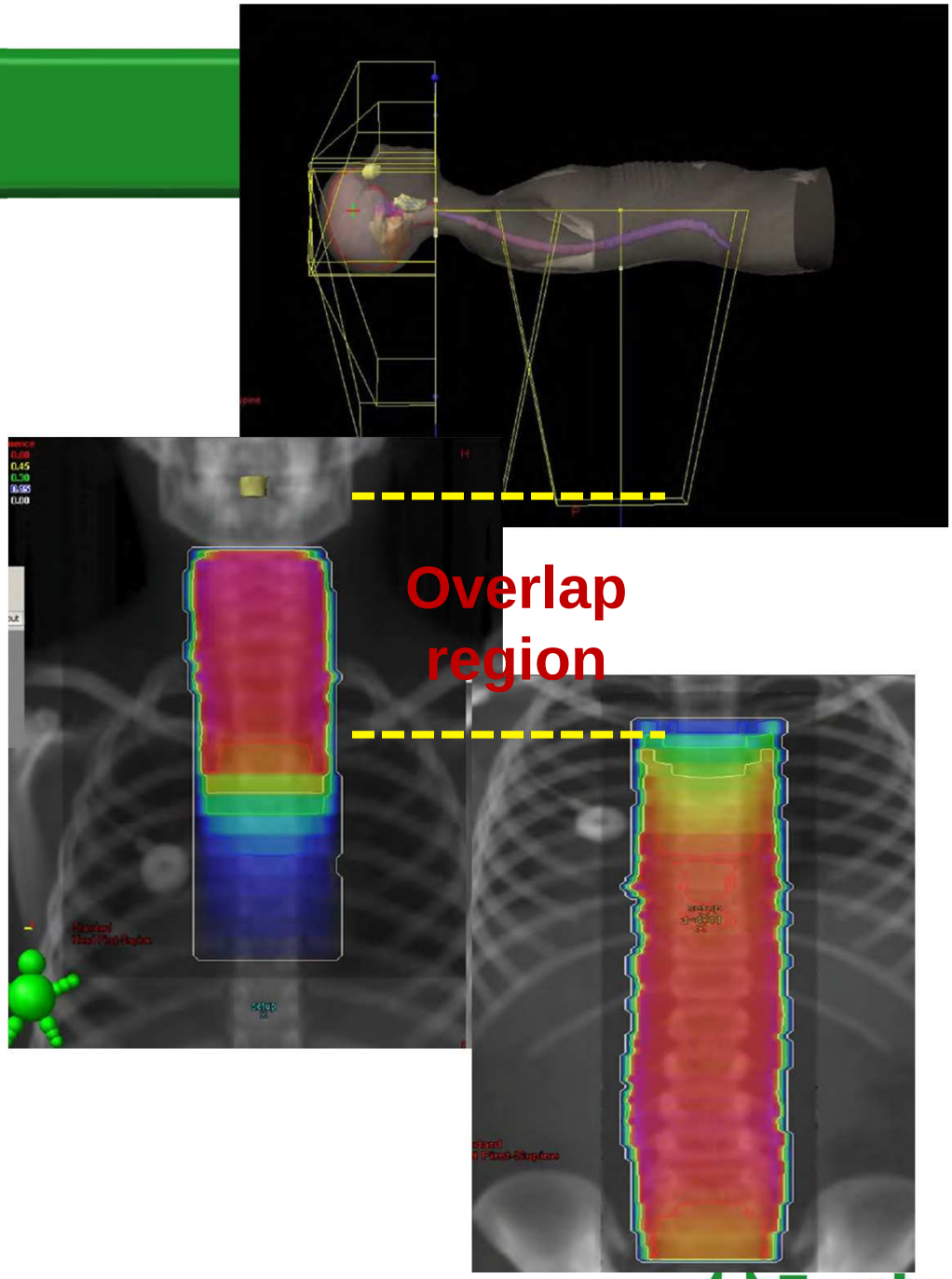
3-D planning:What are the other techniques?

- Spine treated by **PA, RPO & LPO**
- Decreased dose to gut, heart, trachea, esophagus and kidneys for 3-field technique



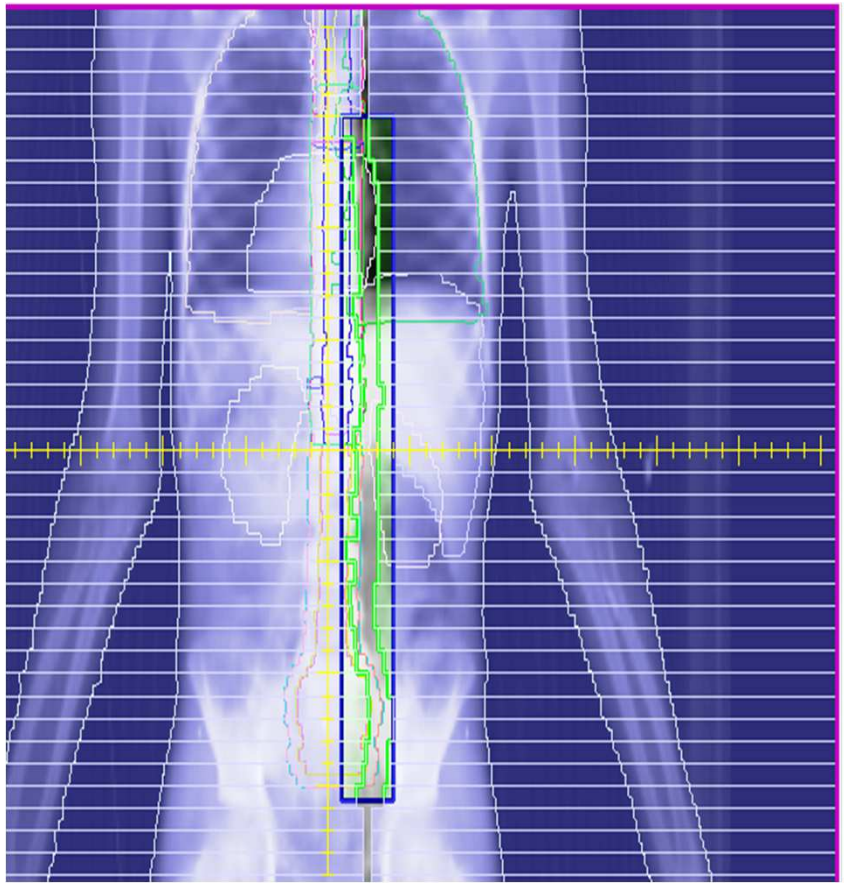
CS:IMRT techniques?

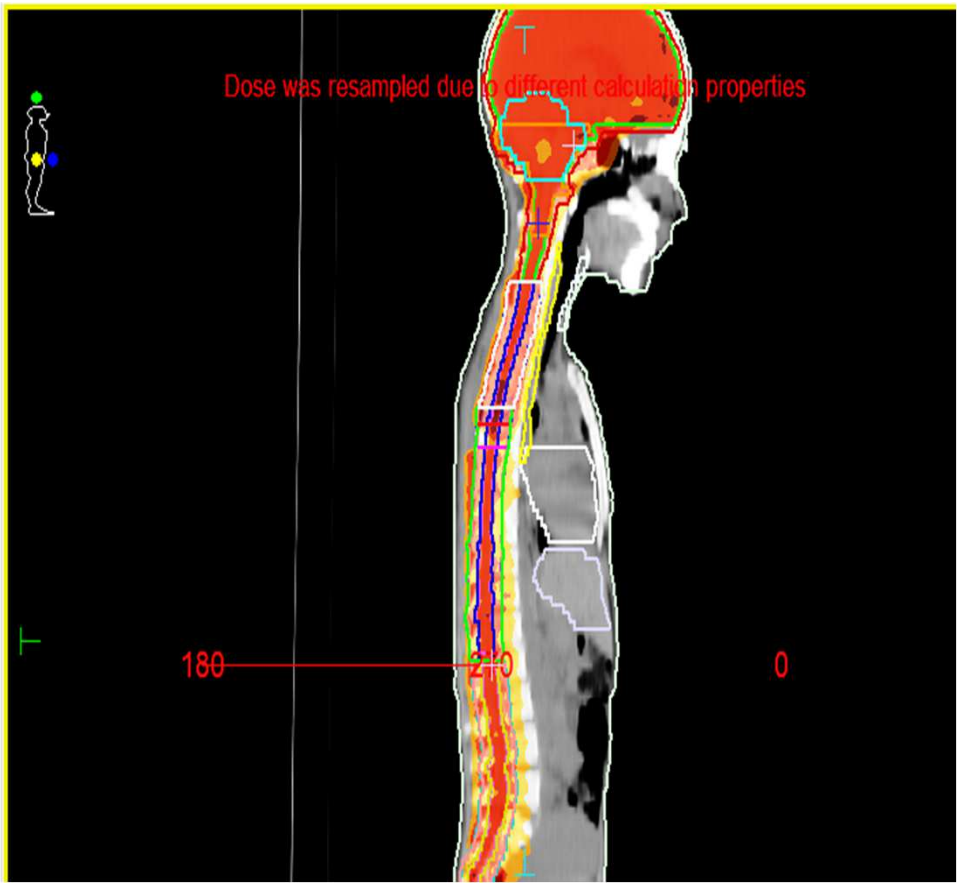
- IMRT
  - Better dose distribution
  - Less dose to parotid and lenses
  - Easy to setup
  - No need to shift junctions
  - Upper & lower spine fields have a long overlap
    - Intensity modulated region
  - Cranial and spinal fields are optimized as a single plan



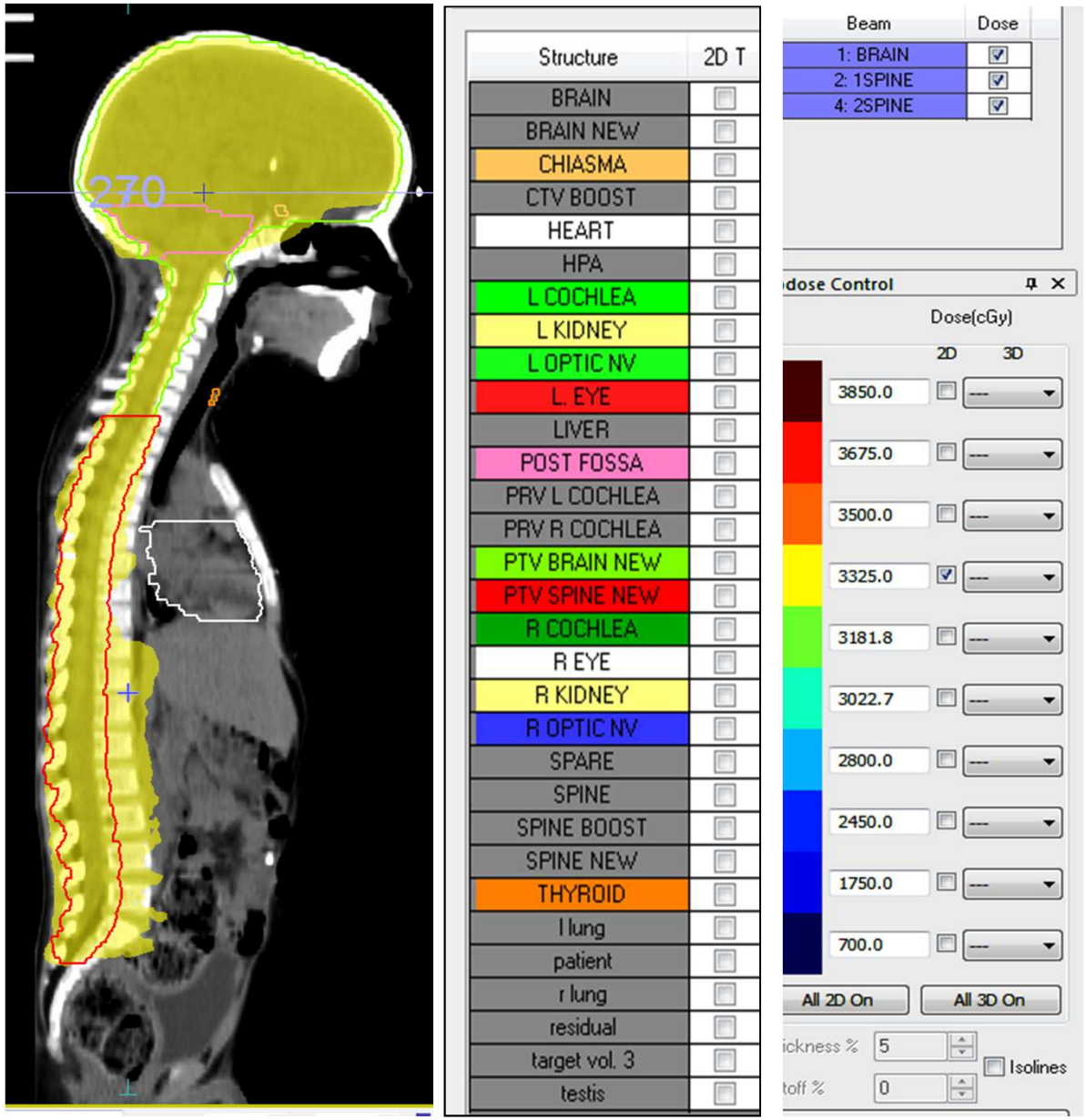
Fortis

CSI-VMAT (no Junction shift: dose tapering)





VMAT :Complete dose distribution

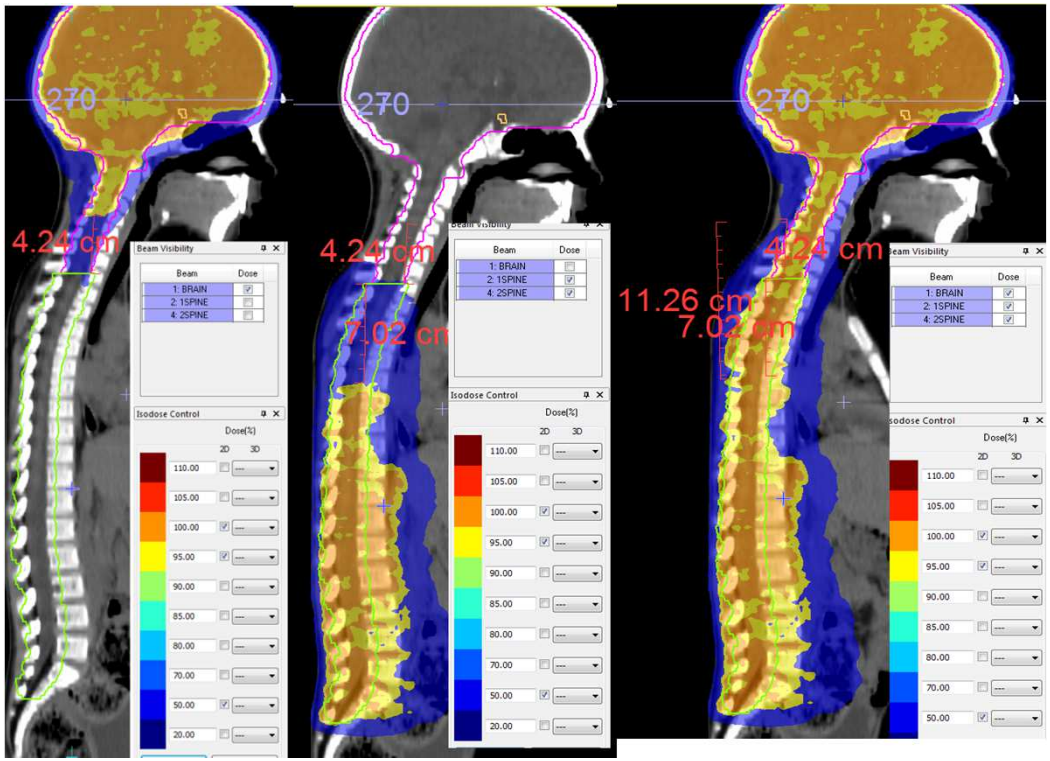


A novel VMAT technique for CSI developed at FMRI, Gurgaon

- **IMRT Techniques:**

Better dose distribution,Less dose to parotid and lenses,Easy to setup,No need to shift junctions.Cranial and spinal fields are optimized as a single plan

- **We extended this IMRT protocol to VMAT at FMRI, Gurgaon**

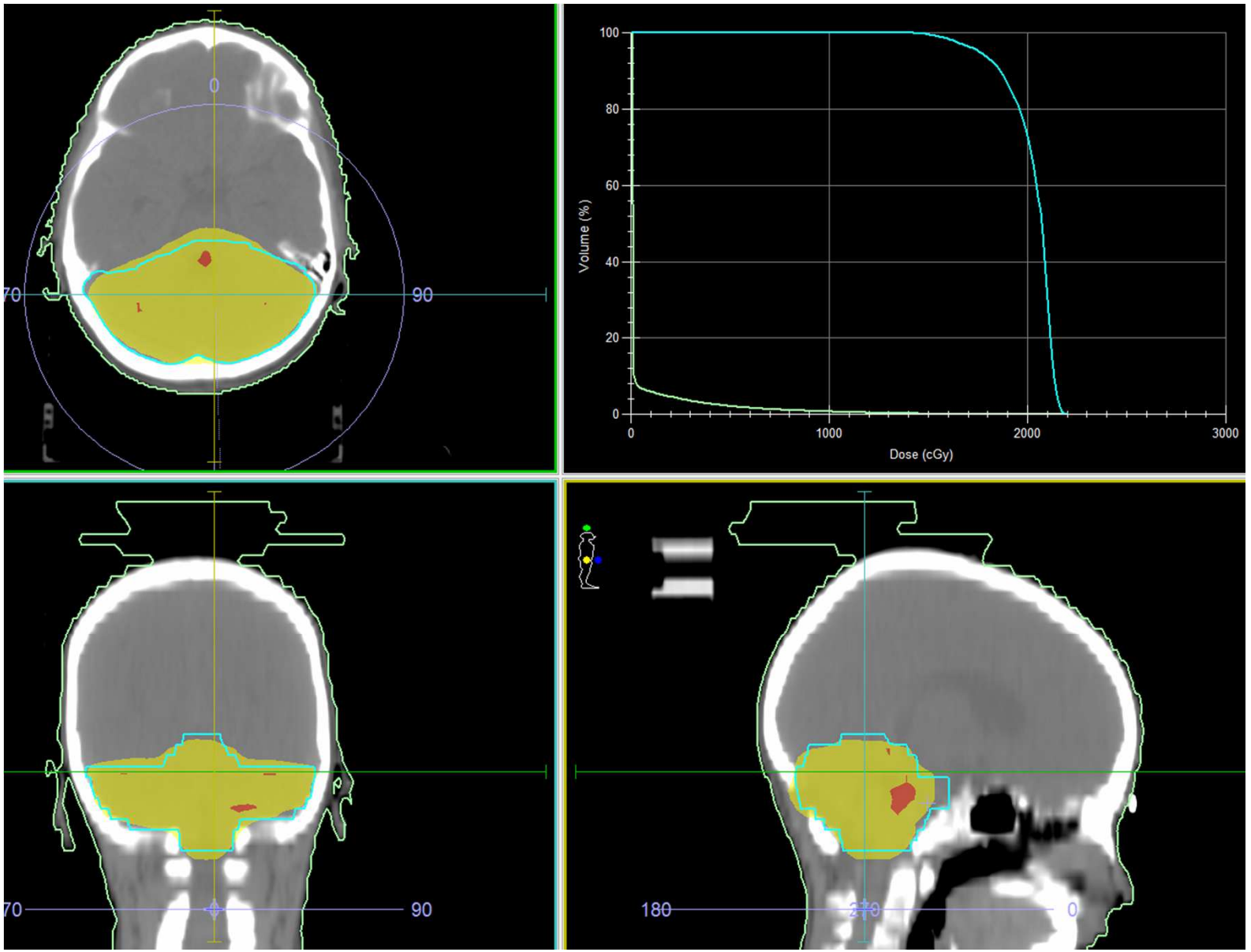


Junction free craniospinal irradiation in linear accelerator using volumetric modulated arc therapy : A novel technique using dose tapering.

Sarkar B et.al., accepted at AAPM, 2014

Fortis

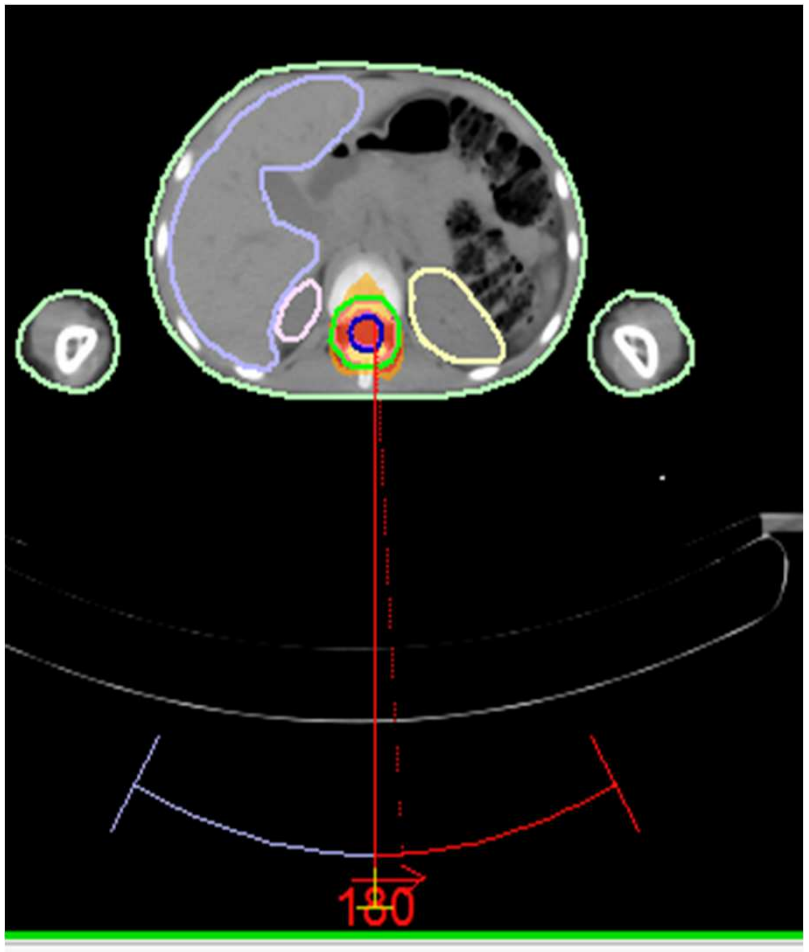
Post fossa boost: dose distribution



Comparison of VMAT and 3DCRT dose distribution

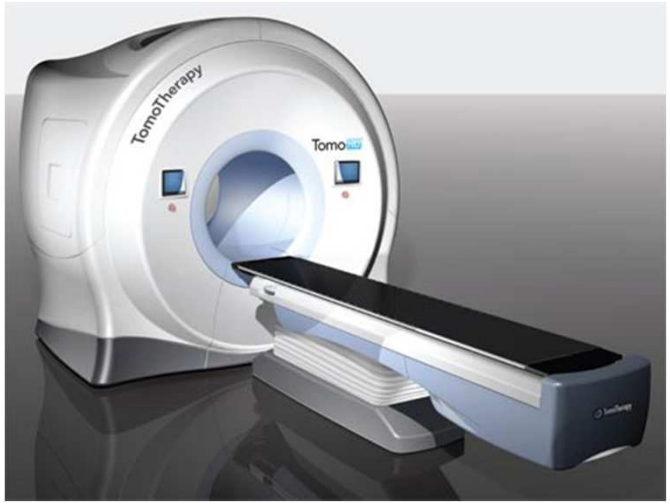
3DCRT dose distribution

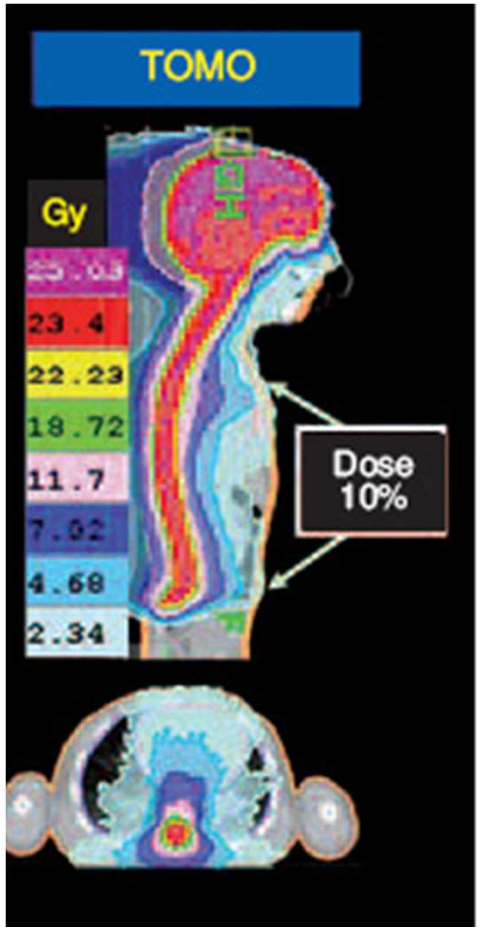
VMAT dose distribution



CSI:Tomotherapy

- Helical Tomotherapy
- Tomo eliminates junctions
  - In one long couch movement, the entire volume is treated without any need for junctions
    - Biggest advantage
  - However a large volume receives small dose



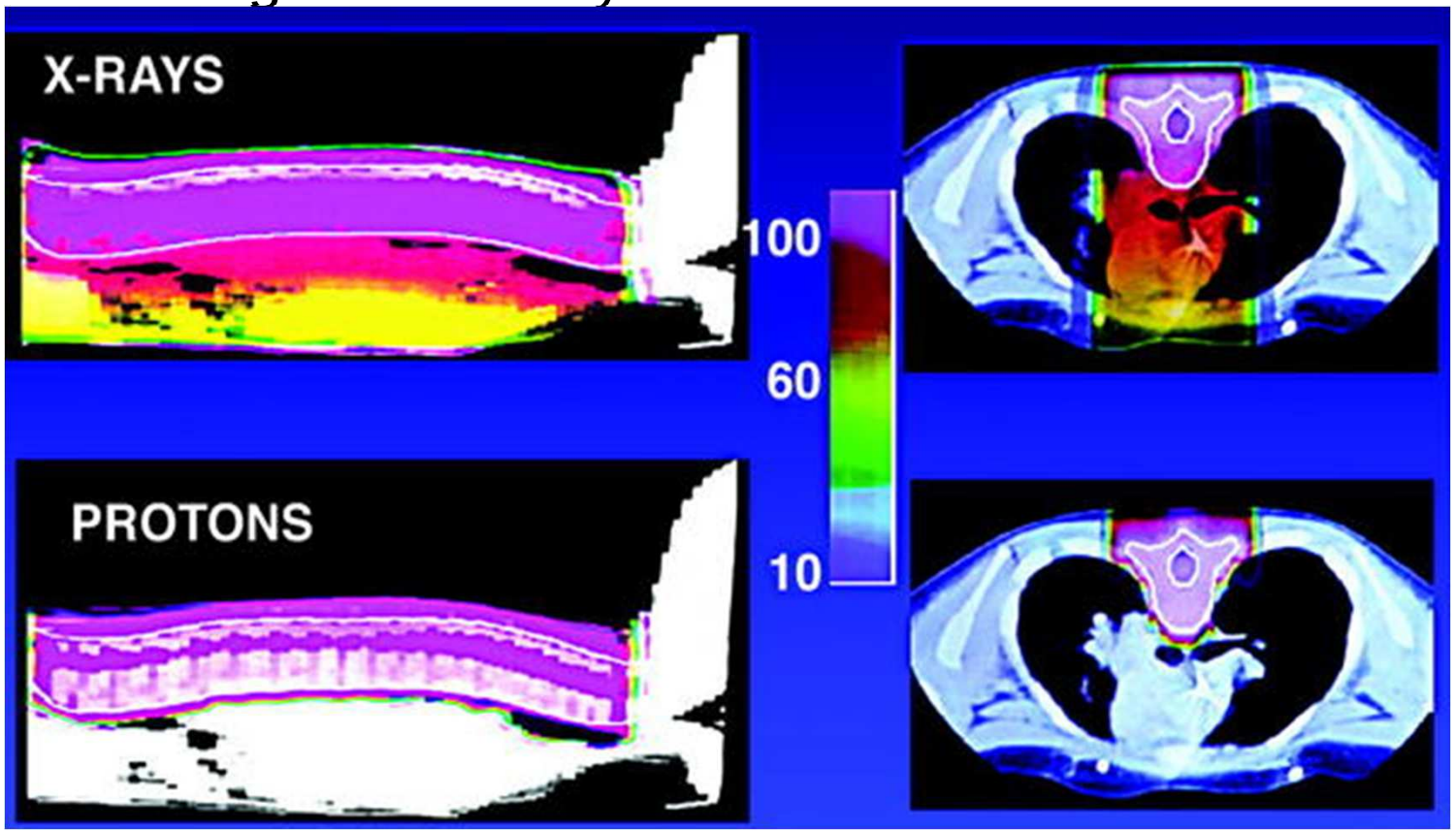


Sharma DS et al. BJR 2009:82:1000-09

Fortis

CSI:Proton Therapy

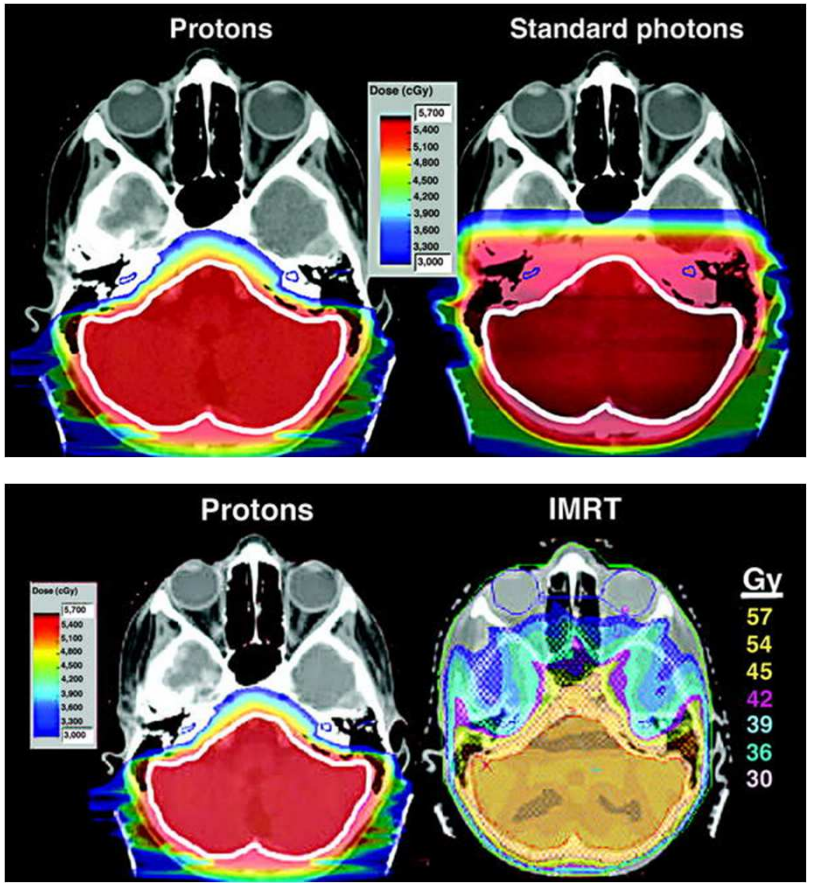
- Protons!
- Advantages are many!



Fortis

Proton therapy

- Perfect dose painting
- No exit dose whatsoever
- All critical organs saved



Mailhot Vega RB et al.
Cancer 2013;119:4299

Fortis

CSI: treatment results

Long term disease control and survival have consistently improved in last 20 years.

- Medulloblastoma:50% to 80% survival at 5 years or more
- Other neoplasms:35% to 80% survival at 5 years or more

Perez and Brady 5th Ed. 1836-42.
Packer RJ et al. JCO 2006;24:4202

Patient Treated with Craniospinal irradiation in FMRI, Gurgaon(n=8;Average RT course=40 days)

	Dose				Boost			
	Brain		Spine		Post fossa		Spine	
Plan	Dose In Gy	No of #	Dose In Gy	No of #	Dose In Gy	No of #	Dose In Gy	No of #
IMRT	35	21	35	21	19.8	11	x	x
IMRT	23	13	23	13	30.6	17	x	x
IMRT	35	21	35	21	19.8	11	x	x
IMRT	35	21	35	21	19.8	11	16	8
3-D CRT	30.6	17	30.6	17	28.8	16	x	x
VMAT	35	21	35	21	19.8	11	x	x
VMAT	35	21	35	21	19.8	11	x	x
VMAT	35	21	35	21	19.8	11	5.4	3
Mean Value	**33**	**19**	**33**	**19**	**22**	**12**		

Thank you