Radiotherapy techniques in brain tumors (2D, 3D CRT, IMRT) including craniospinal irradiation

Dr Anusheel Munshi
Additional Director, Radiation Oncology,
Fortis Memorial Research Institute, Gurgaon

anusheel.munshi@fortishealthcare.com

Evolution of RT

- Conventional 2 dimensional approaches
- 3 dimensional conformal radiotherapy (3DCRT)
- Intensity modulated radiotherapy(IMRT)
- Image guided radiotherapy (IGRT)

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Planning steps

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

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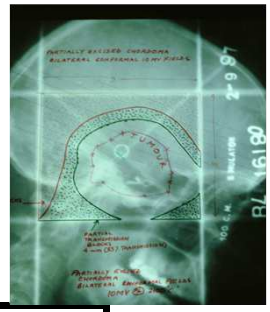

CT simulator		Conventional Simulator	
Step	Time	Step	Time
Positioning/orfit	10 min	Positioning/orfit	10 min
CT Cuts	10 min	-	-
Contouring	20 min	-	-
Virtual simulation	40 min	Simulation	25 min
Extrapolating lasers	5 min	-	-
Verification by EPID/Con sim	10 min	-	-
Total	95 min	Total	35 min

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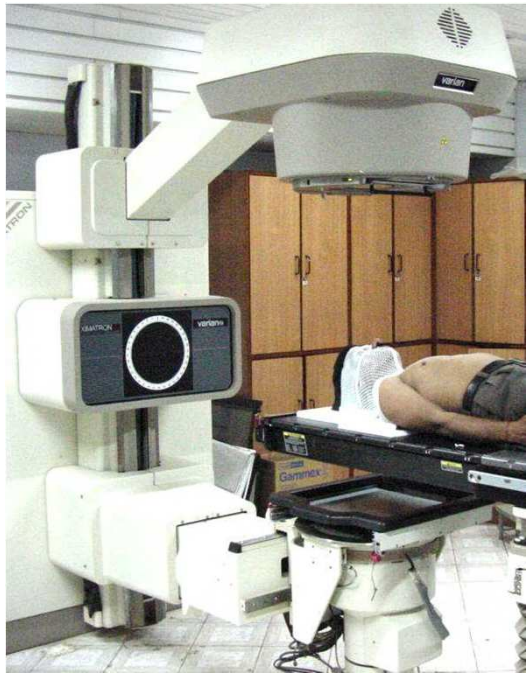
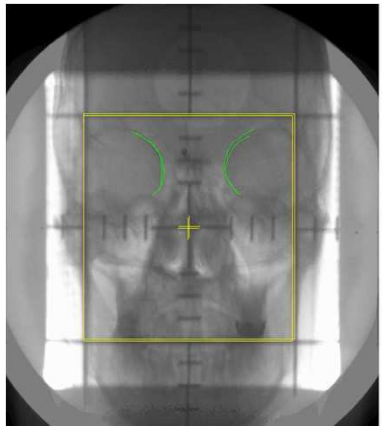
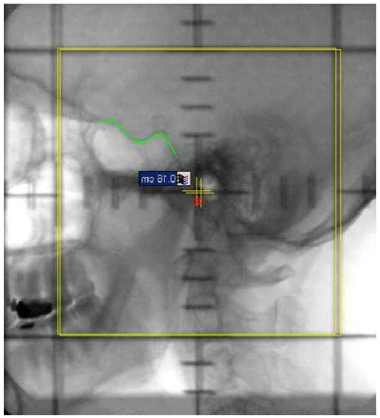
Conventional Radiotherapy planning



Simulator





- Based primarily on 2D planar radiographs
- Usually done with the aid of a Simulator
- Planned Treatment Portals by collimating rectangular fields that circumscribed the presumed tumor location on the basis of bony landmarks
- 2 to 3 beams are arrange in a standard geometry
-

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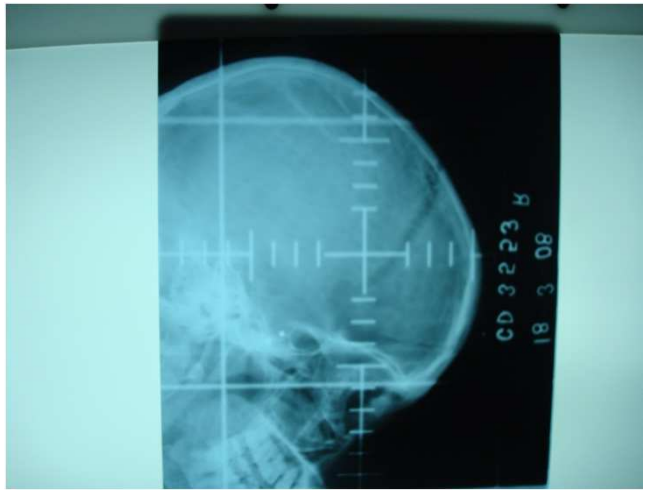
2 D SIMULATION

- **Steps**
- Turn gantry to right (270)
- Set up TSD 95 conventionally

- Define field on patient with the help of recon images Scans, bony landmark
- Get width & length of field



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Head Position

- Neutral Position-
- Flexion- Sellar/Suprasellar tumors
  Temporal lobe tumors
  Pineal region Tumors
  All sites where field borders likely to extend to lower Temporal region

- Head flexion –
  NNR+4+3
  Blue Thermocol – Posterior field
  Air equivalent NNR+4+3

SIMULATION

- Immobilization
- Head POSITION
  - -Prone, neutral, flexed
- Imaging modality-
  - CT
  - MRI

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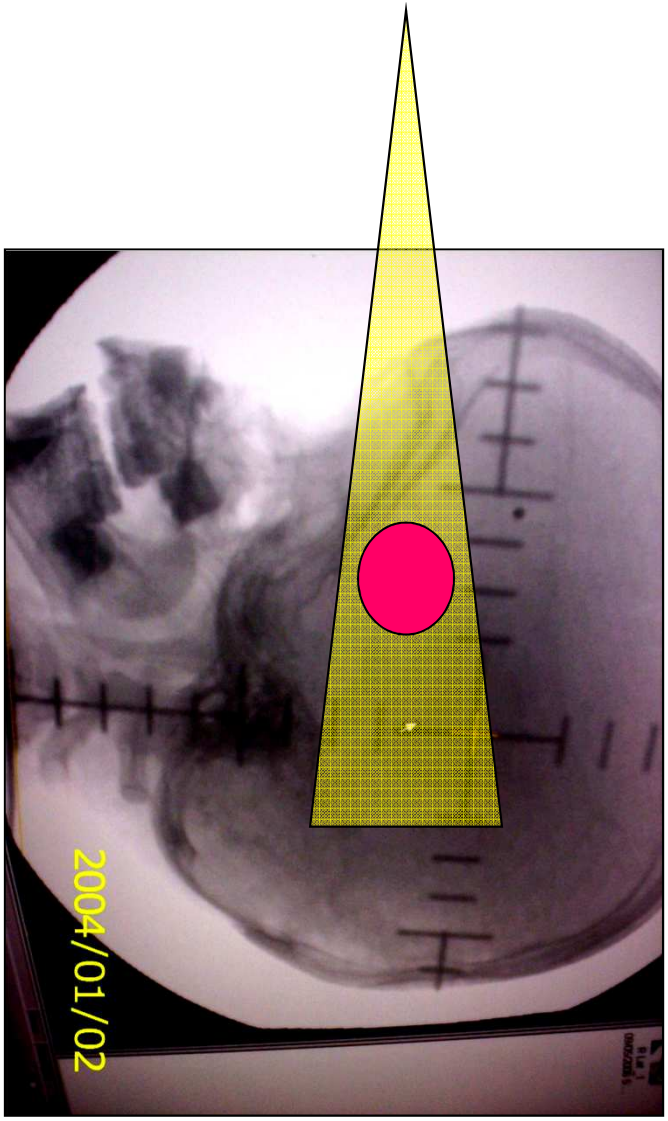
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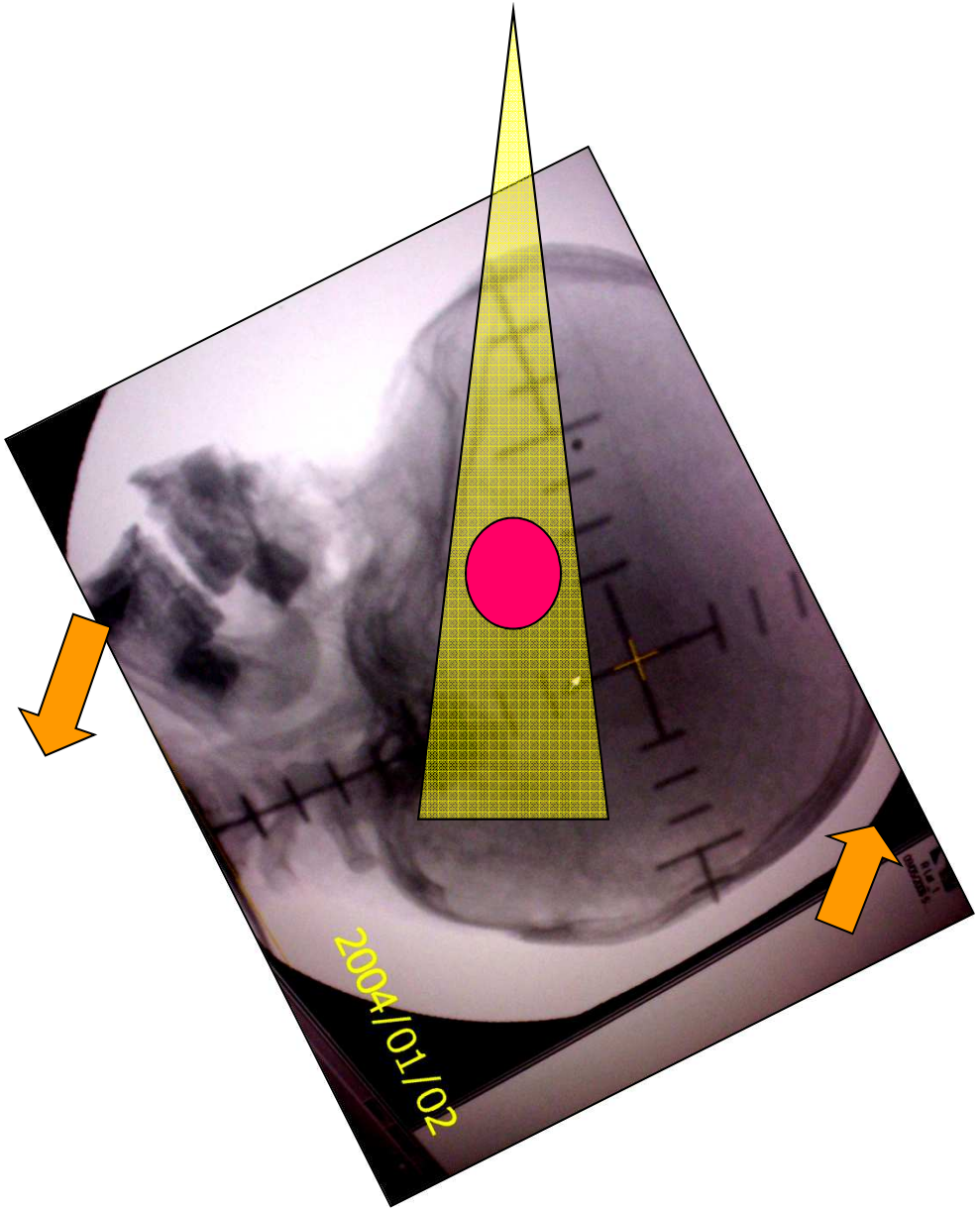
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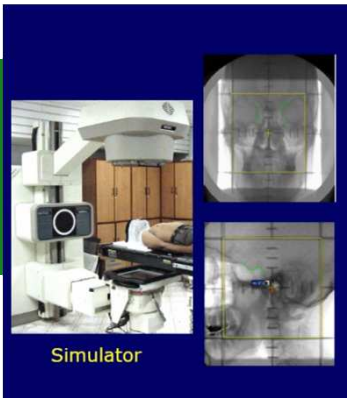
Conventional planning



Advantages

- Time
- High grade tumour
- Survival
- General condition
- Simulator
- 2D radiographic portal films
- Presumed tumour location on the basis of bony landmarks
- Blocks- Standard/ Custom

Disadvantages

- Irradiation of large volumes of brain with normal tissue also
- Higher toxicity and side effects
- Lack of 3D visualization of tumour
- 2D planning of 3D tumour

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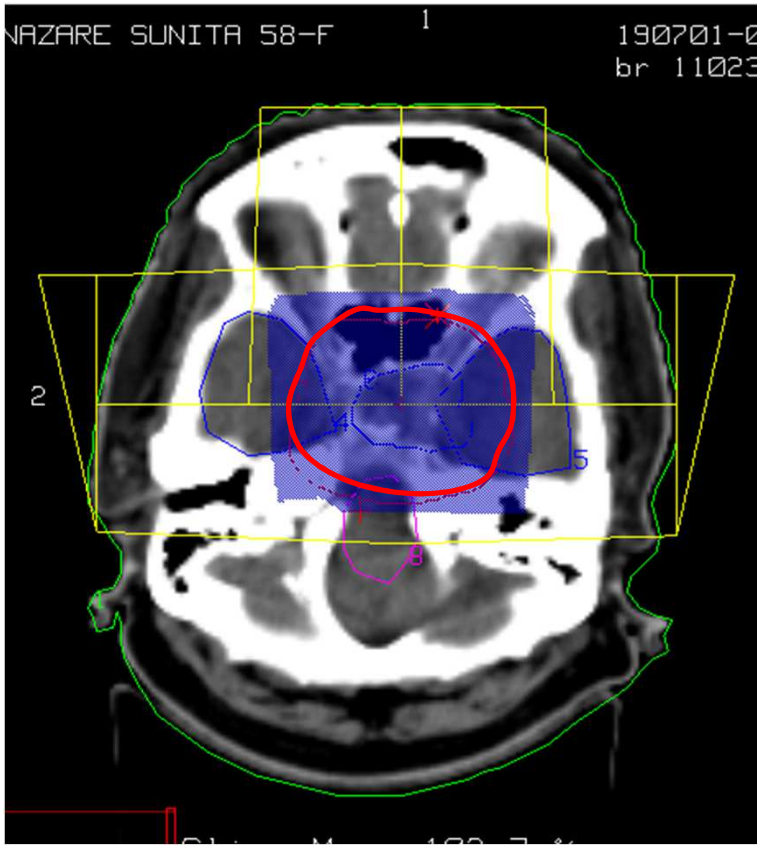
Shortcoming of conventional planning

- Lack of 3D appreciations of tumor volume and its location with respect to sensitive organs
- 2D beam planning of a 3D tumor
- Dose computation perform on a single transverse plane
- Dose computation does not take in to account of scatter contribution from adjacent body tissue



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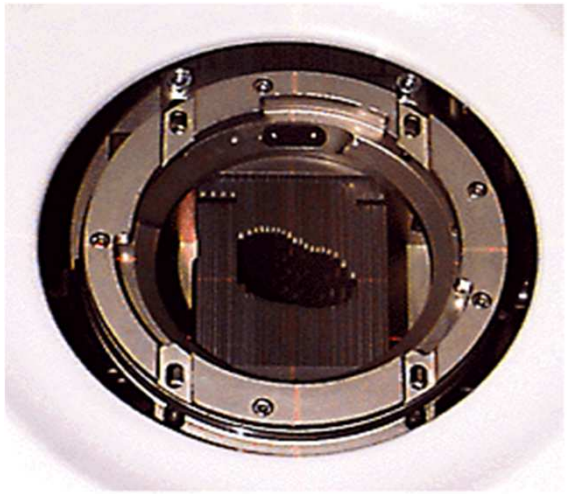
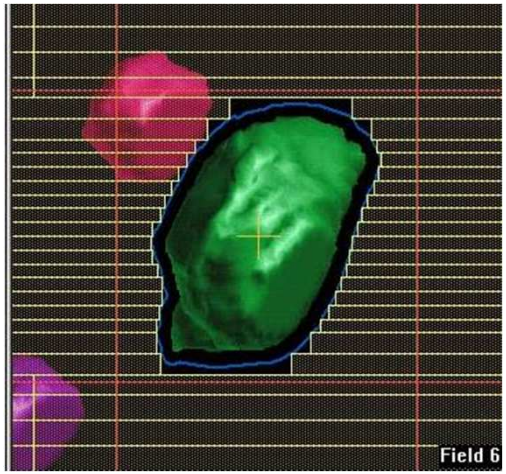
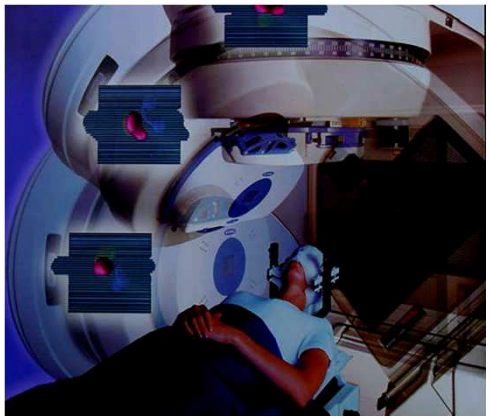


3D Conformal radiotherapy
individualised conformation





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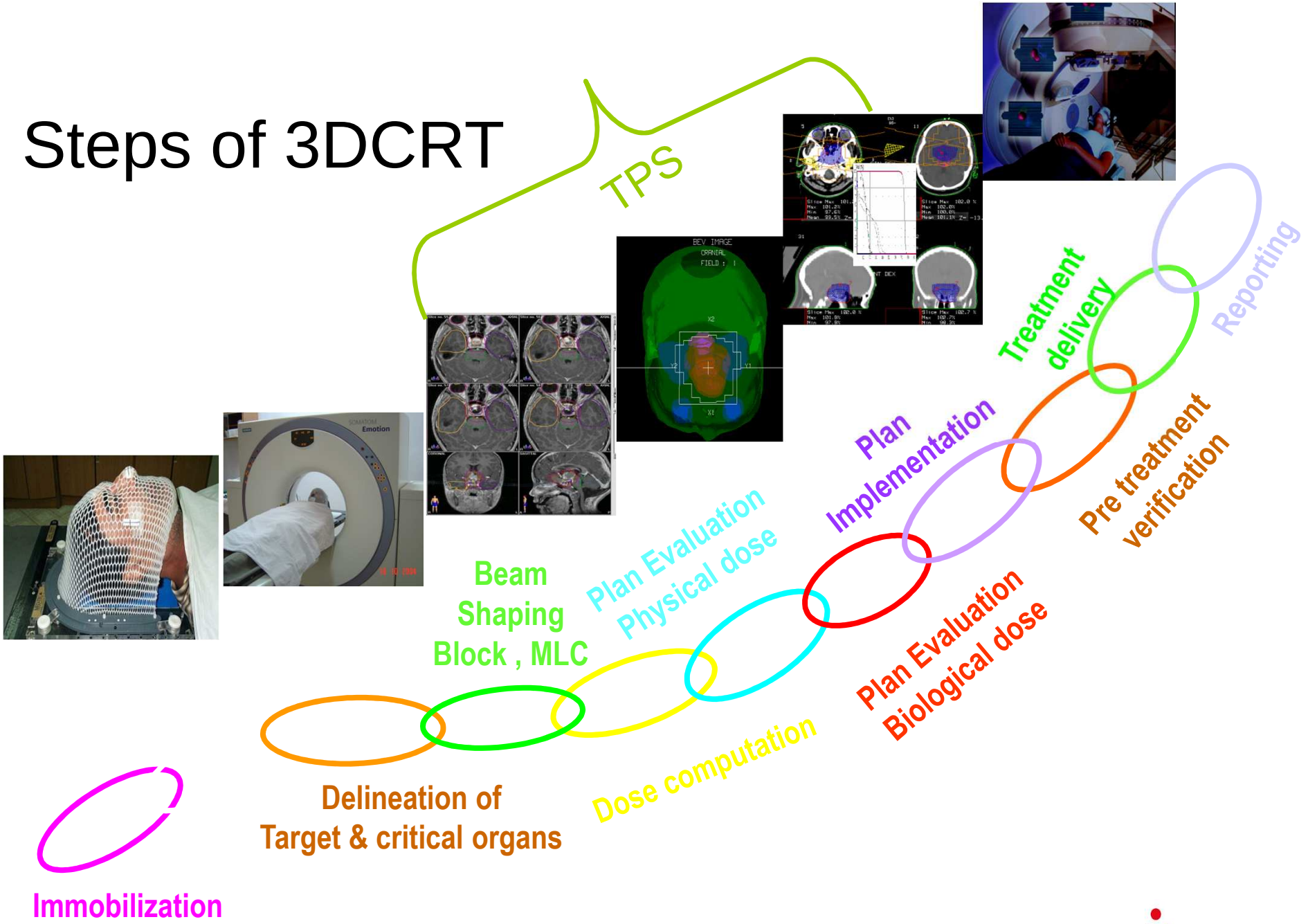
Steps of 3DCRT



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Planning CT cuts in CNS radiotherapy

Aim for taking a planning CT in neurooncology

To obtain a stack of images which

can be used

- For 3DCRT, IMRT, SRT, SRS(have to be exported to planning station. Plan implementation in conventional simulator/treatment machine)
- For doing virtual simulation(exported to V sim station. Isocenter exported back to CT simulator by moving lasers)

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Taking planning CT slices in neurooncology

The commandments:

- Different from diagnostic imaging
- Know your machine/system well !
- Use appropriate immobilisation device
- Image the patient in treatment position
- No gantry tilt please

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Planning MRI

- Position

  Ideally in treatment position with orfit & base plate

  Problems with head / body coil

  Fiducial markers Vit.E cap. Platinum, etc.

- 3D- FSPGR

  T1 contrast axial cuts

  Matrix resolution 256 x 256

  Slice thickness 2mm with no gap

- Transfer images to contouring stations

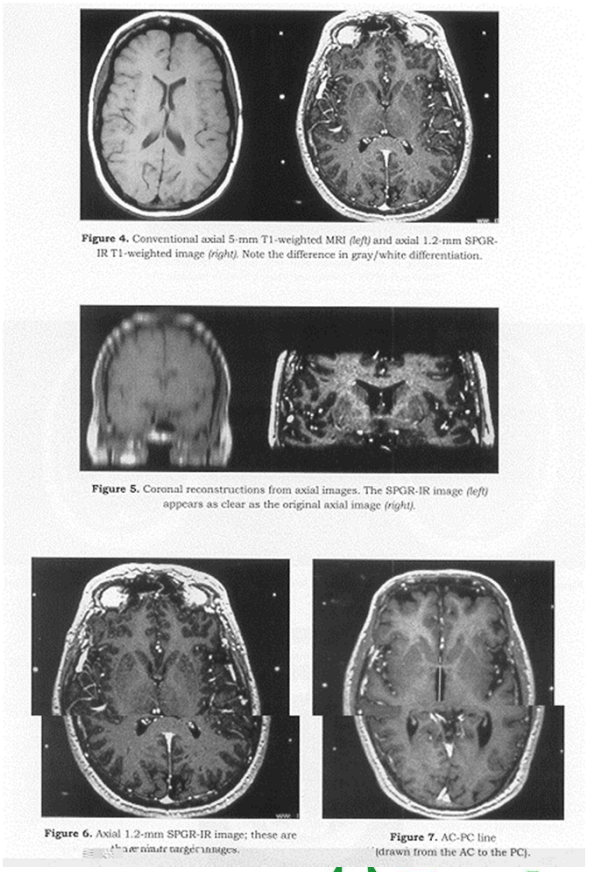

Figure 4. Conventional axial 5-mm T1-weighted MRI *(left)* and axial 1.2-mm SPGR-IR T1-weighted image *(right)*. Note the difference in gray/white differentiation.

Figure 5. Coronal reconstructions from axial images. The SPGR-IR image *(left)* appears as clear as the original axial image *(right)*.

Figure 6. Axial 1.2-mm SPGR-IR image; these are

Figure 7. AC-PC line (drawn from the AC to the PC).

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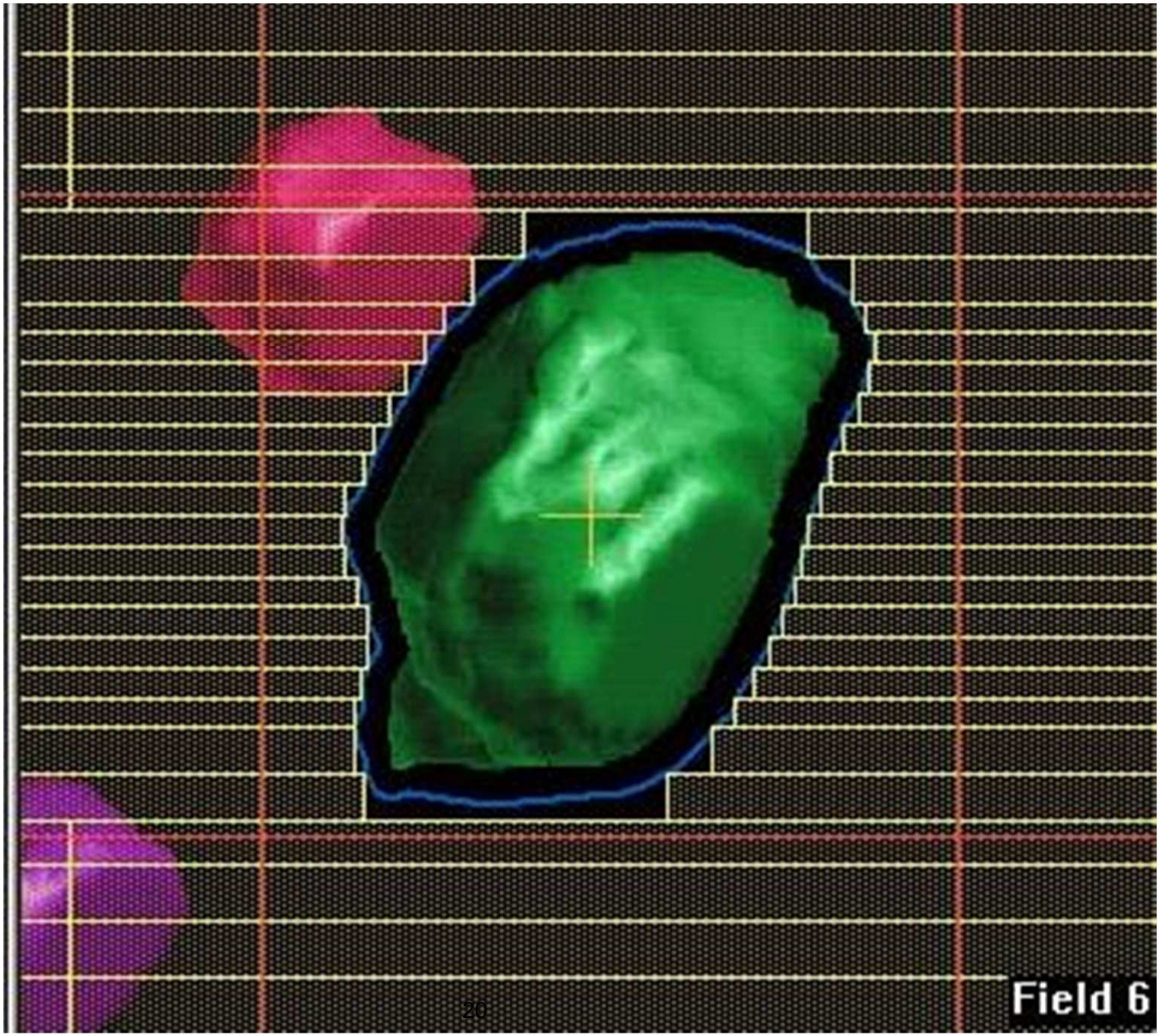
Tumour	GTV	CTV	Dose Gy/#
GBM/AA	T1 post contrast/ CECT	2-3	60/30
GR II	T2 Flair abn.	1.5-2 cm	54/30
Pilocytic	enhancing	1.5-2cm	54/30
Meningioma	enhancing	1-2cm	Benign 54/30 Malig. 60/30
Pit. adenoma	enhancing	0.5-1cm	45/25

Medullo initial	Brain +spine	1-2cm	35/21
boost	enhancing	1-2cm	19.8/11
Ependymoma	Hypo CT/ HyperT2	2 cm	54/30
spinal	T2Flair	2-3	50.4/28
Craniopharyngioma	enhancing	1-2cm	54/30

Multileaf collimators (MLC)



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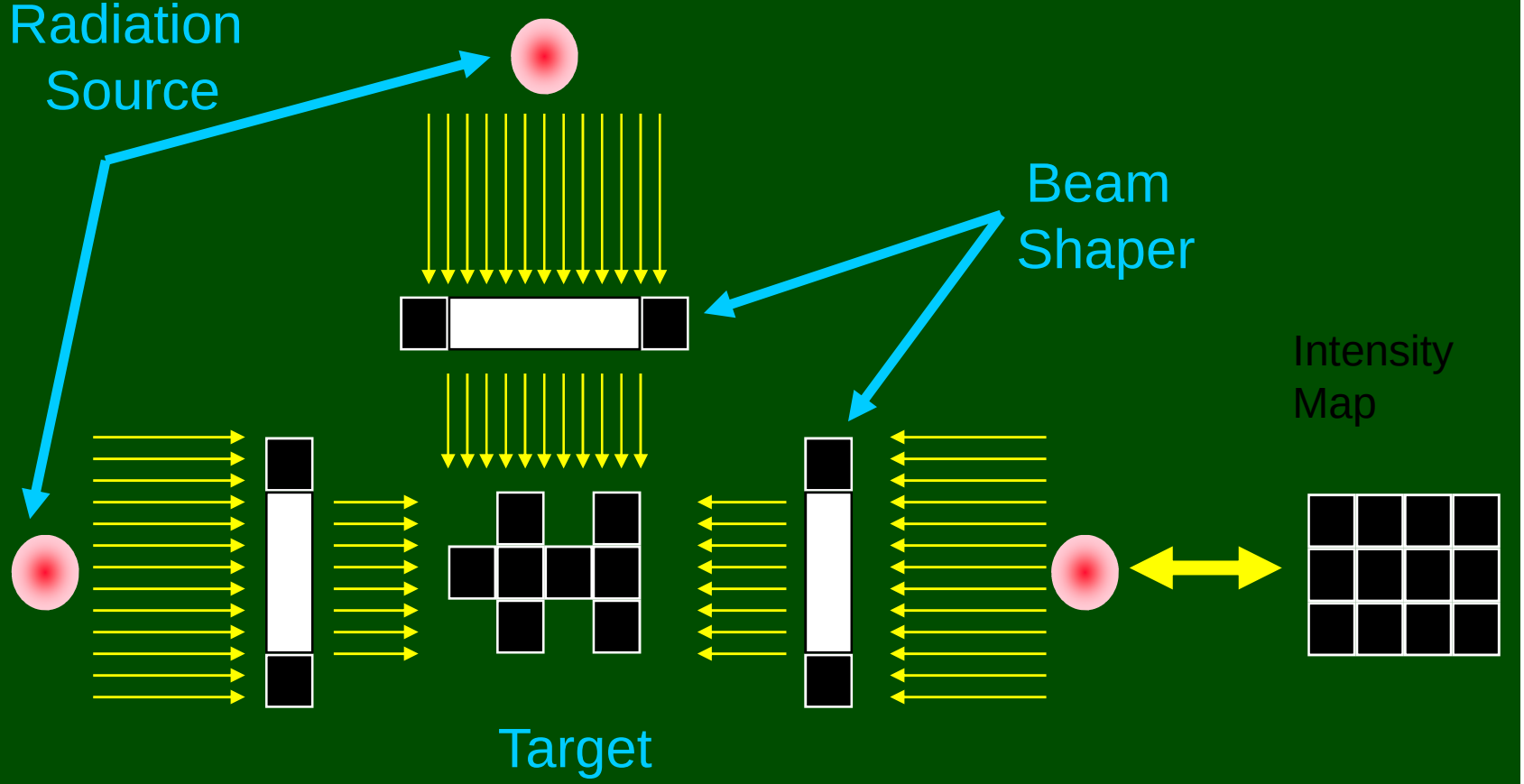
Conventional 3D Treatment



3-D PLANNING

- **Advantages**
  - Ideal for all
  - Conformal
  - Max. sparing of normal tissue
  - Lower toxicity
- **Disadvantages**
  - Time consuming
  - Cost
  - Technical support

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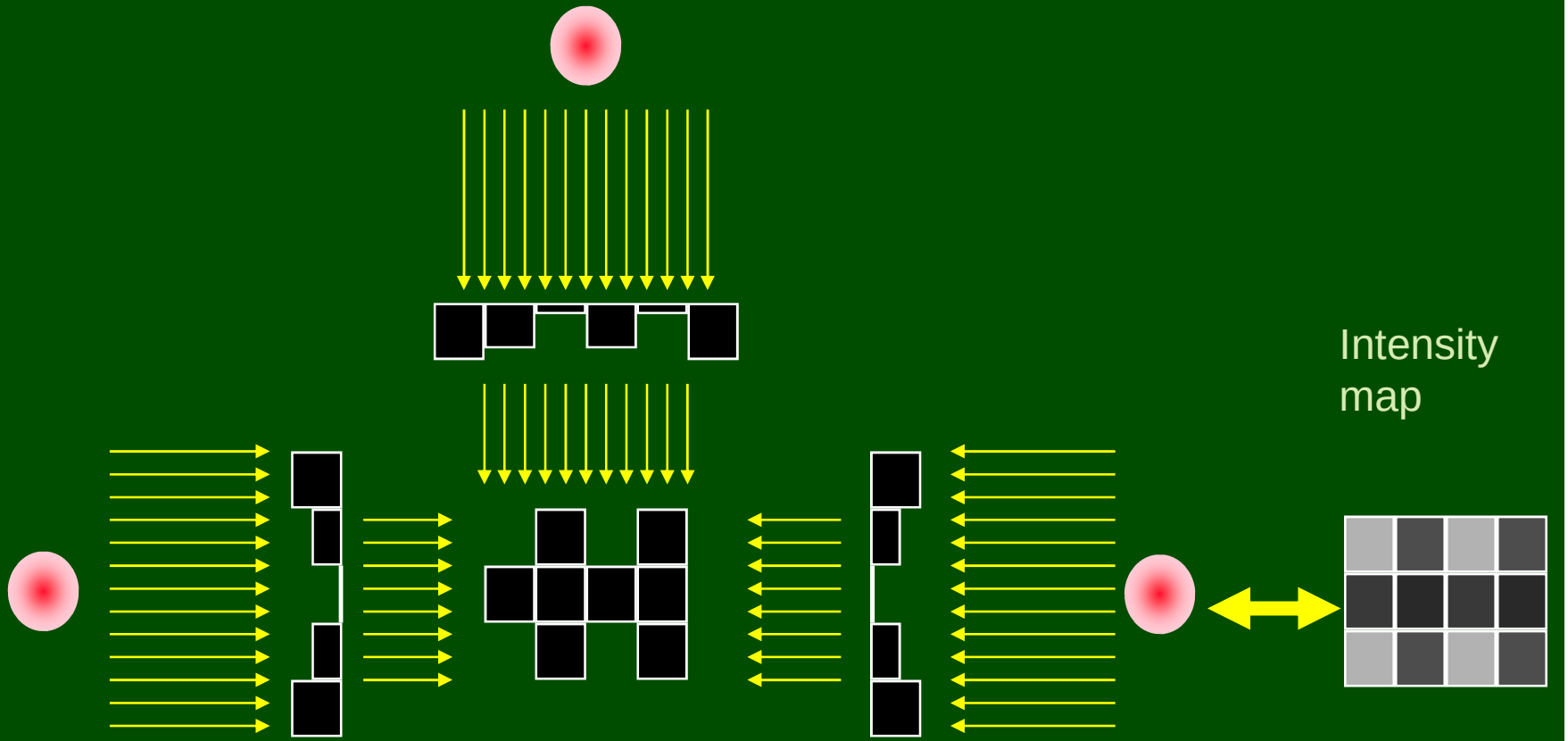
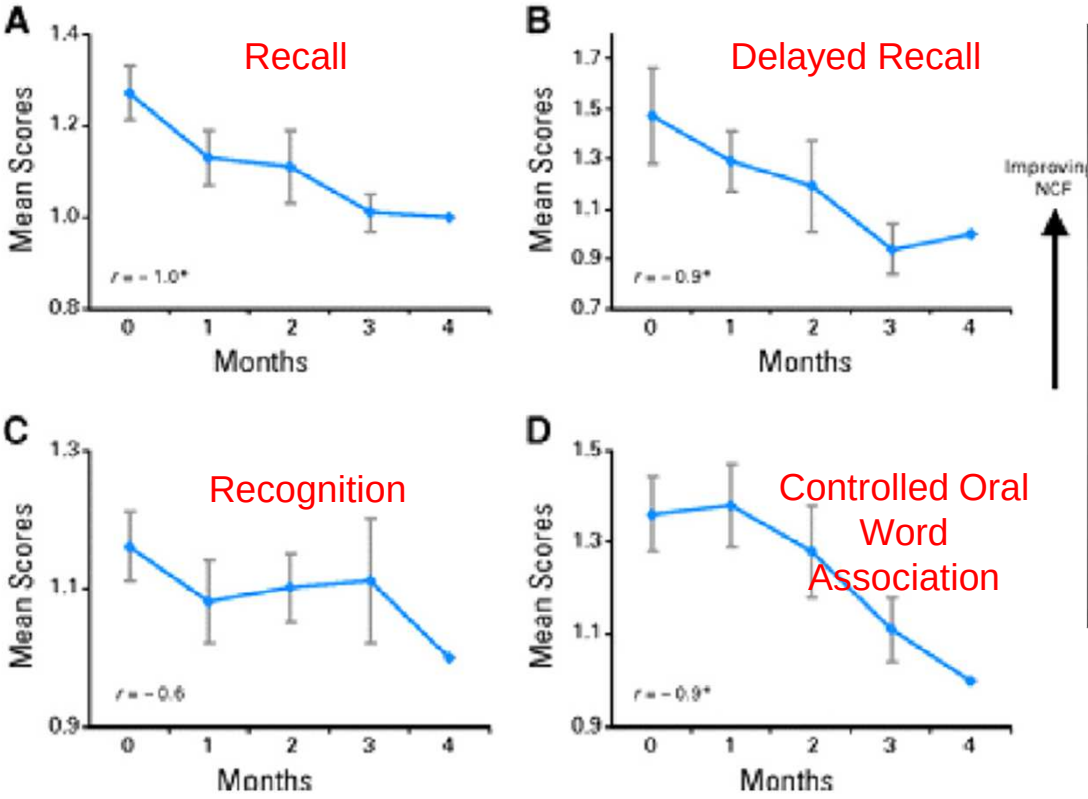
IMRT Treatment



Neurocognitive decline post Radiotherapy



ASCO 2008

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Suggested optimal candidates for IMRT

Clinical

- Patients with better prognosis
- (lower age, favorable histology, better PS)

Dosimetric

- FP or TP lesions considering their close proximity to optic pathways
- Lesions close to brainstem

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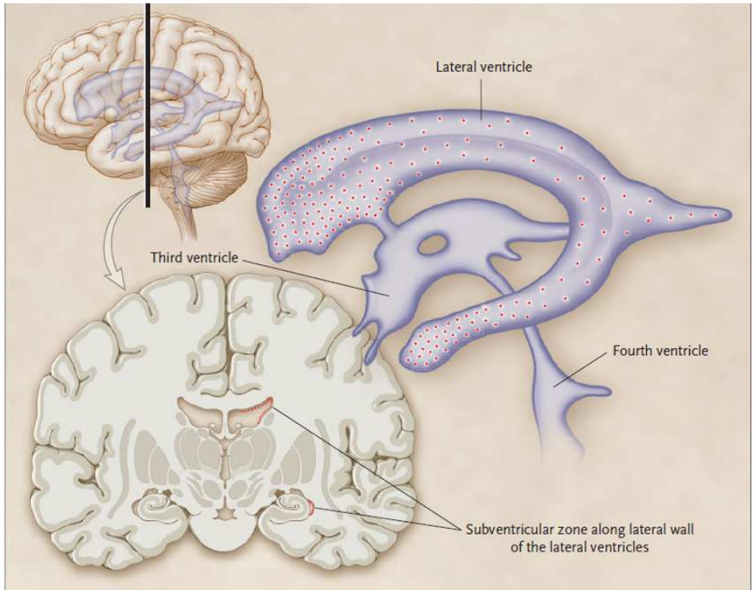

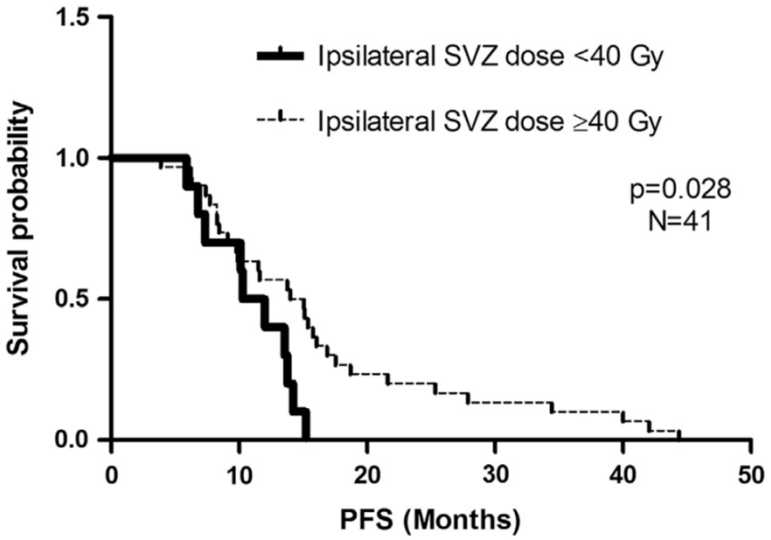

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Editorial

The Subventricular Zone Neural Progenitor Cell Hypothesis in Glioblastoma: Epiphany, Trojan Horse, or Cheshire Fact?

Iris C. Gibbs, MD,* Daphne Haas-Kogan, MD,† Stephanie Terezakis, MD,‡ and Brian D. Kavanagh, MD, MPH§

*Departments of Radiation Oncology, *Stanford University, Palo Alto, California; †University of California, San Francisco; ‡Johns Hopkins University, Baltimore, Maryland; and §University of Colorado, Aurora, Colorado*

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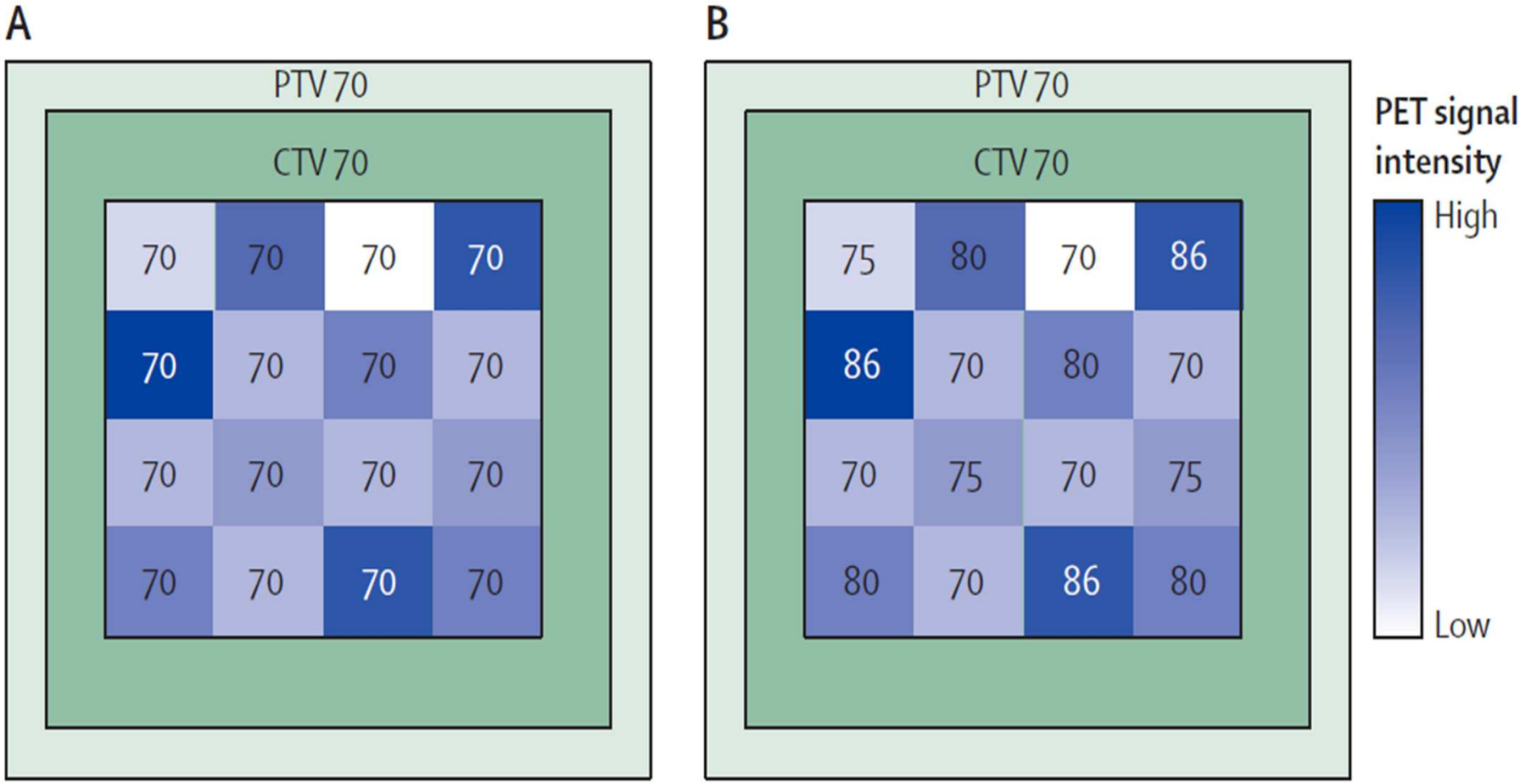
Biological Adaptive RT



Gregoire V , Lancet Oncol 2012

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3 D CRT vs IMRT

	3 D CRT	IMRT
Conformality	Less (may be preferable for a moving target!)	More
Dose reduction to OAR	Less efficacious	More efficacious
MU effficacy/ Quickness of delivery	Better	Worse
Dose sculpting	Less efficacious	Highly efficacious

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3 D CRT vs IMRT

- 3D-CRT and IMRT techniques provide similar results in terms of target coverage;
- IMRT more efficient in reducing the maximum dose to the OAR(extent varies)
- IMRT better in terms of dose conformity and sparing of the healthy brain at medium to low doses
- IMRT can be worse with respect to very low dose areas.

Challenges in planning CSI

- Immobilization & positioning of a large target area
- Large & irregular shape of the clinical target volume (CTV)
- Multiplicity of fields
- Inhomogeneity at the junctions between the brain and spinal fields
- Large number of critical normal structures having direct bearing on the late effects in these pediatric long term survivors.

Positioning

PRONE:

- It provides direct visualization of the field junctions on the patient.
- Good alignment of the spine.

SUPINE

- Comfortable.
- Useful in anesthesia(in < 7yr age gp)

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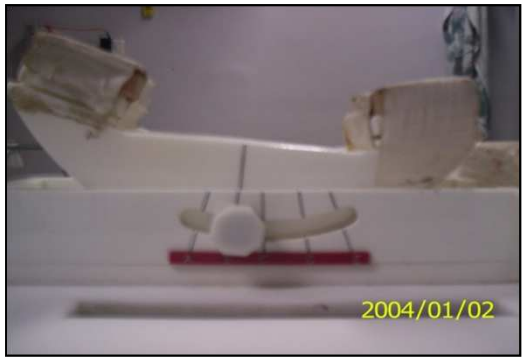
Immobilization

- Prone position of patient
- Arms by the side on a CSI board CSI board(shoulders in low position if possible)
- Lucite base plate with a sliding semicircular Lucite structure for head-rest & chin-rest.
- Slots from A to E to

  allow various degrees

  of extension of neck



- Alignment of the thoracic & lumbar spine parallel to the couch (to confirm under fluoroscopy)

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Radiotherapy Planning

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 issues in CSI fields

- Concern 1

Divergence of the upper border of the spinal field in case of single spinal field(and interdivergence of spinal fields in case of 2 spinal fields)

- Concern 2

Divergence of both cranial fields

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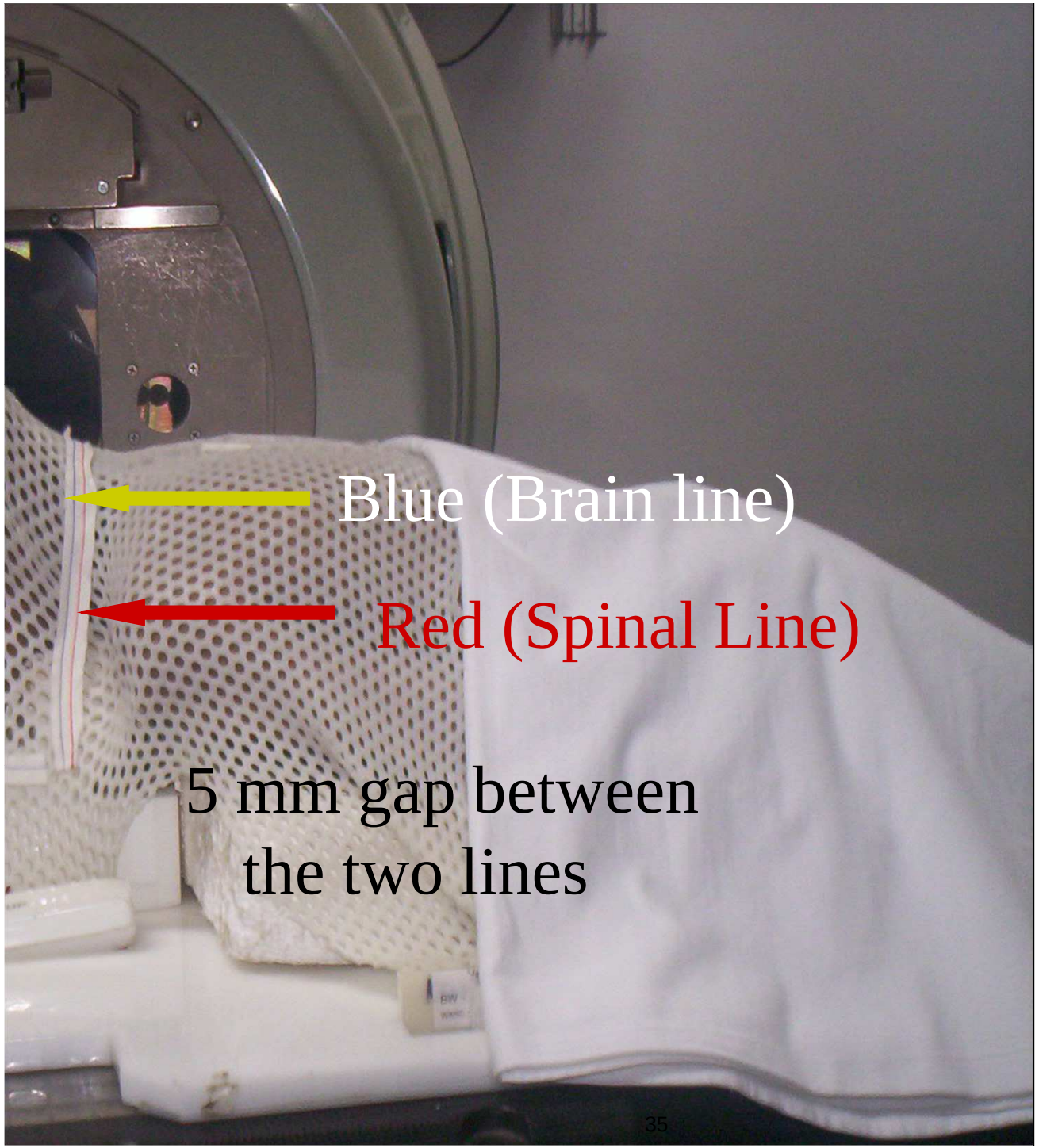

Spinal field

(Upper border)

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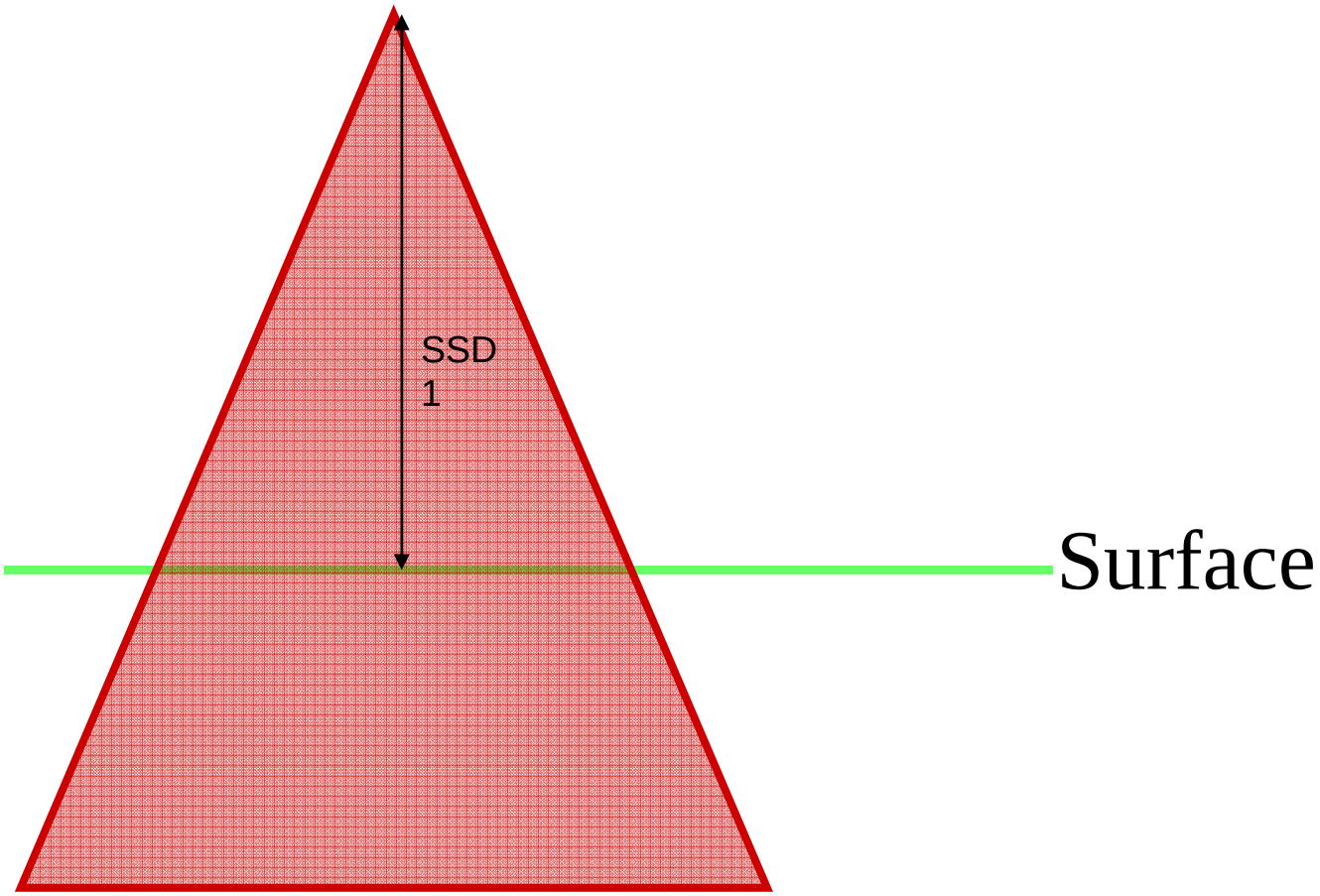
Gap calculation-formula



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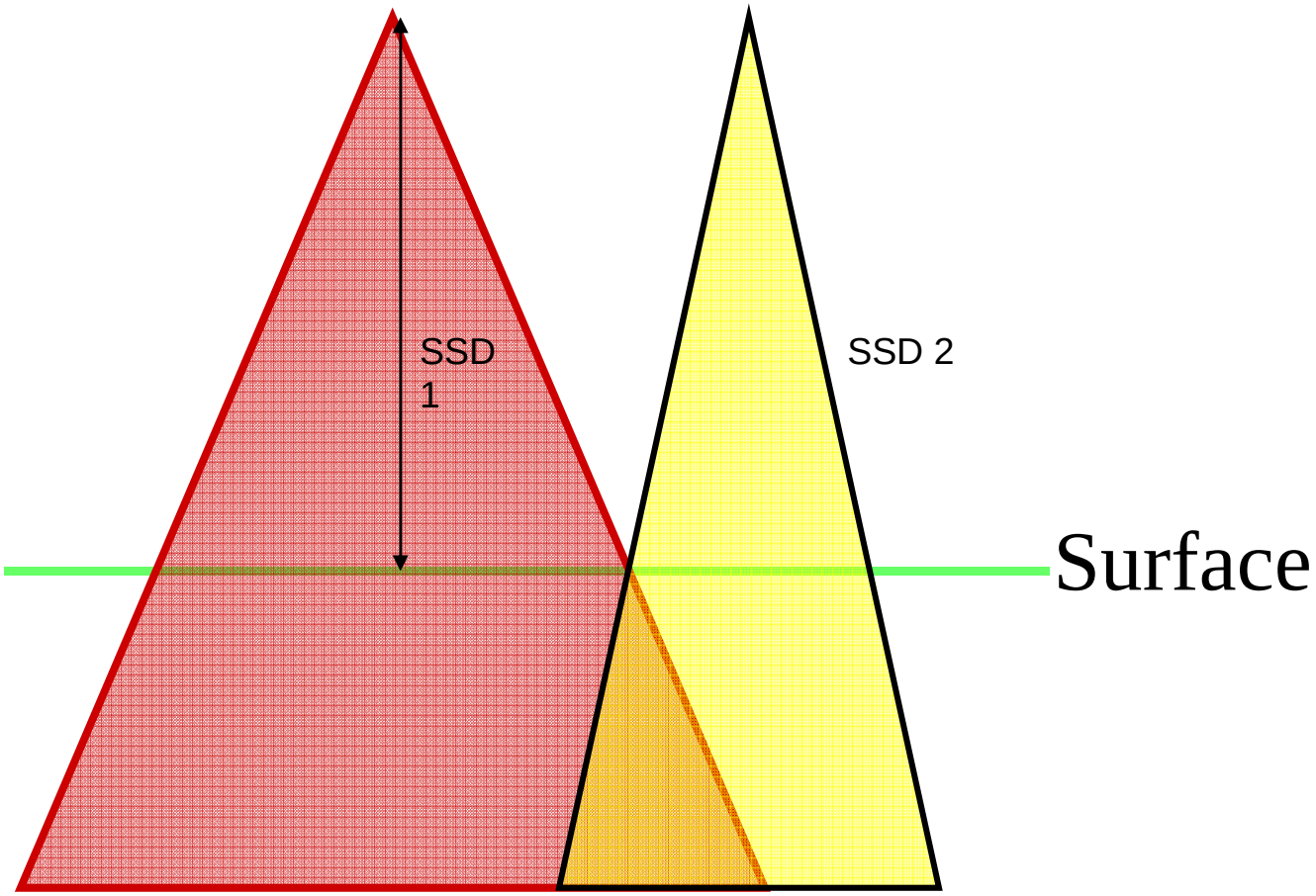

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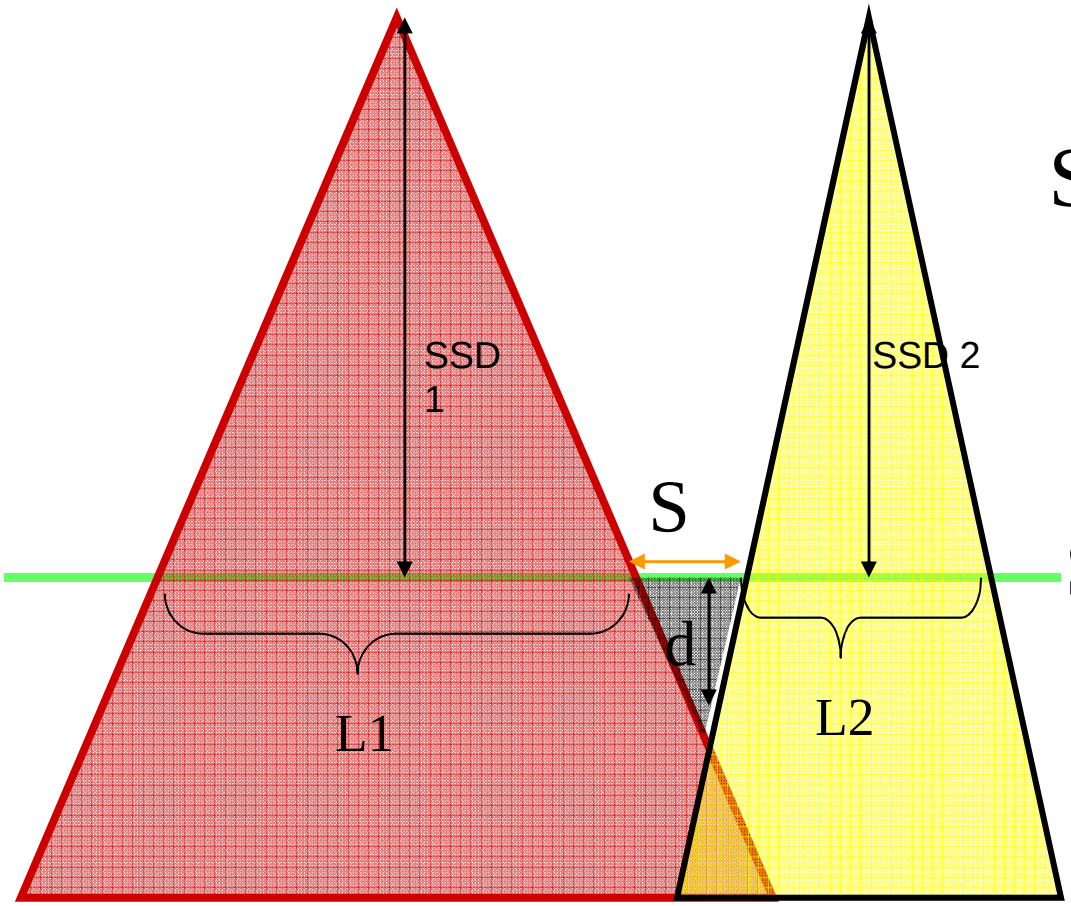

$$S = \tfrac{1}{2} L1(d/SSD1)$$

$$+ \tfrac{1}{2} L2(d/SSD2)$$

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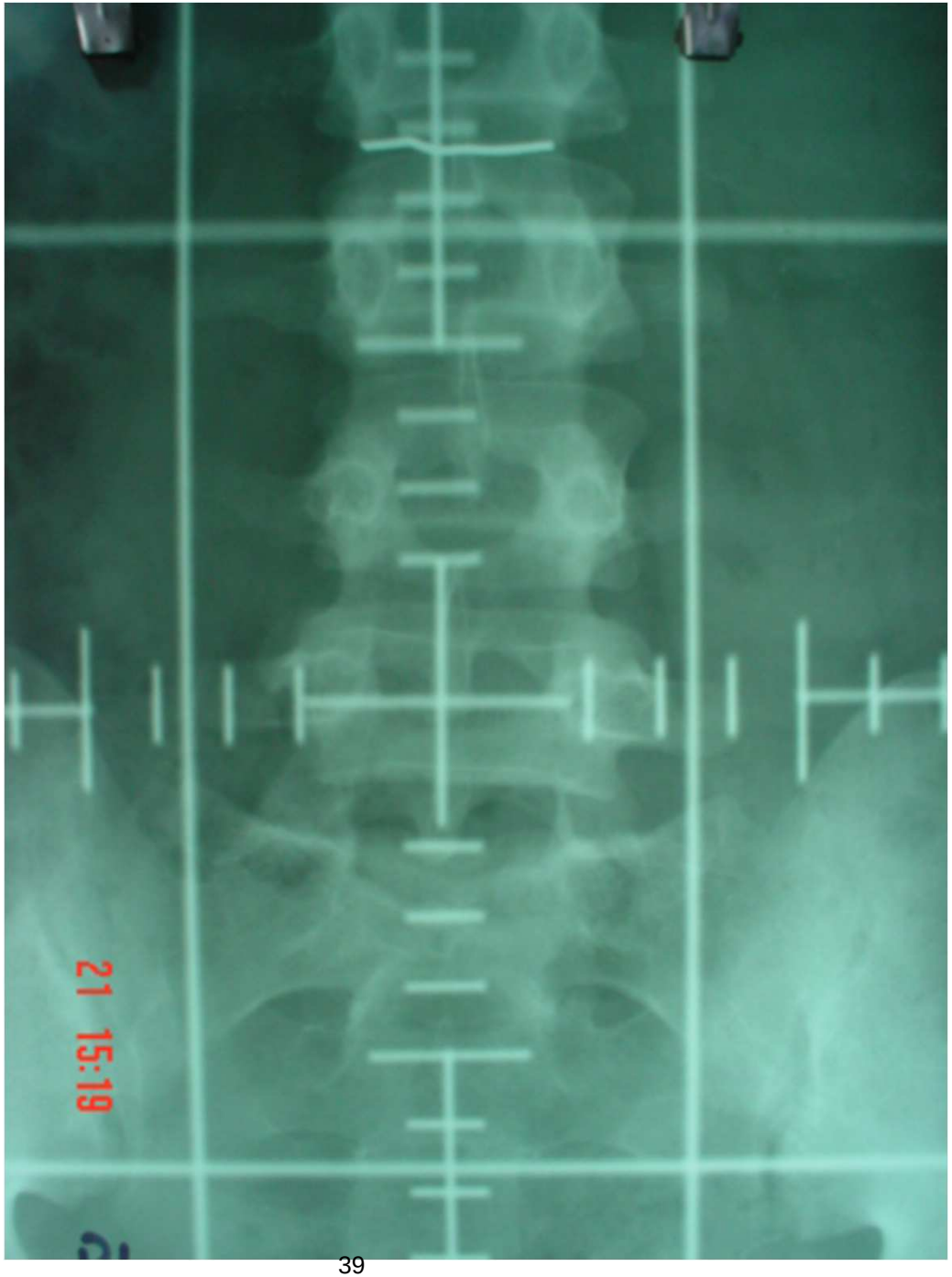
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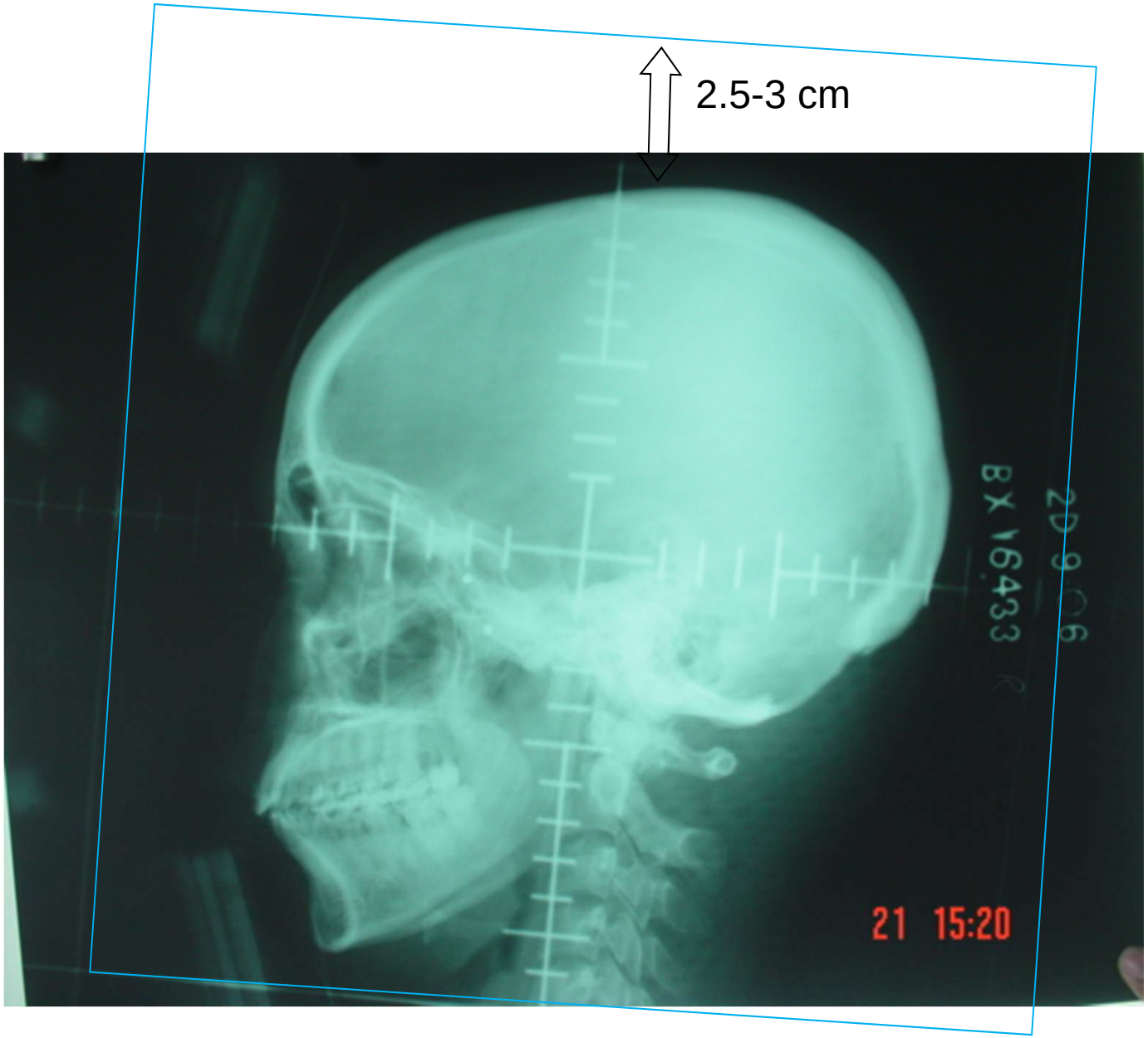
2.5-3 cm
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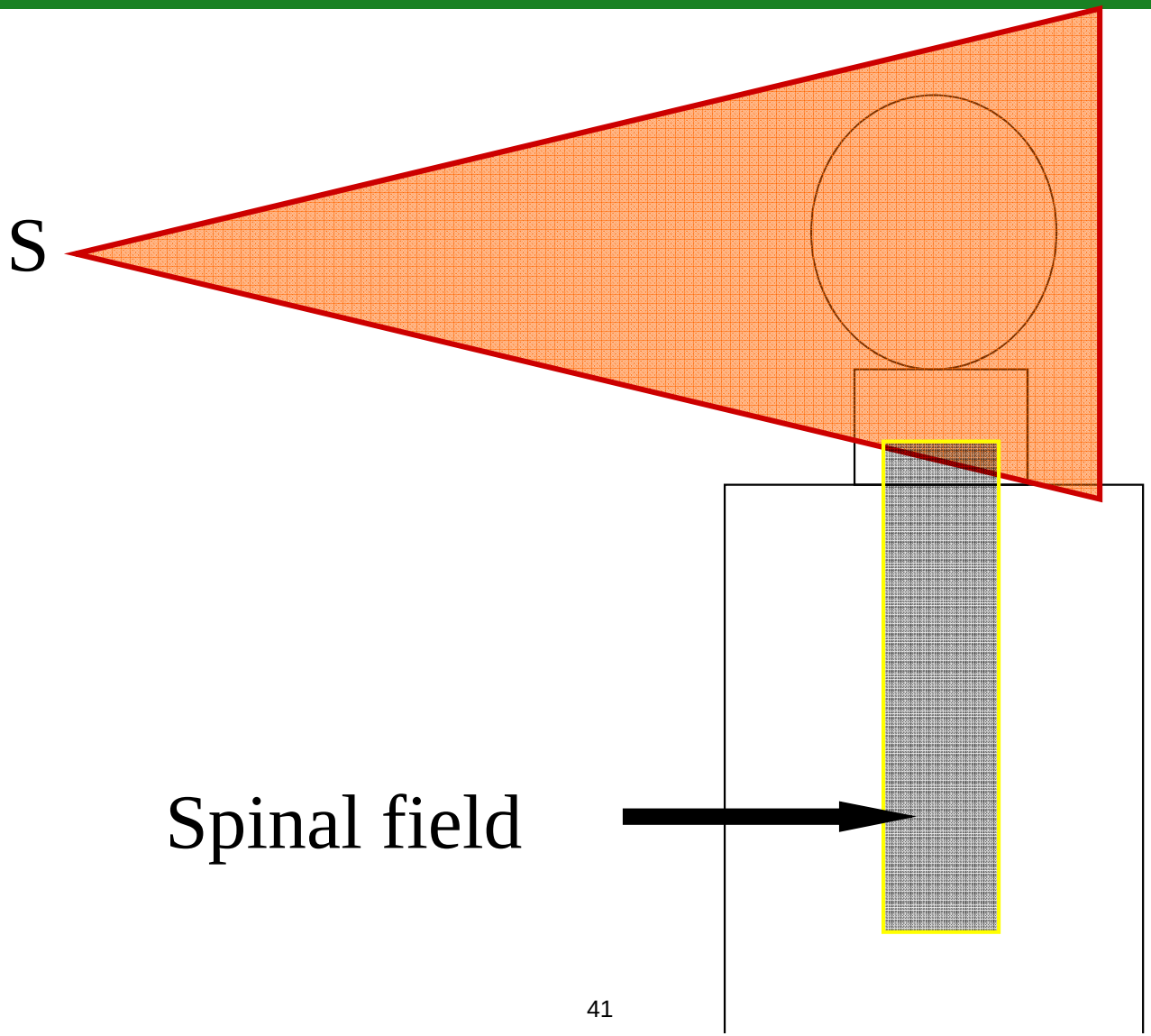
Problem 1: Divergence of cranial field



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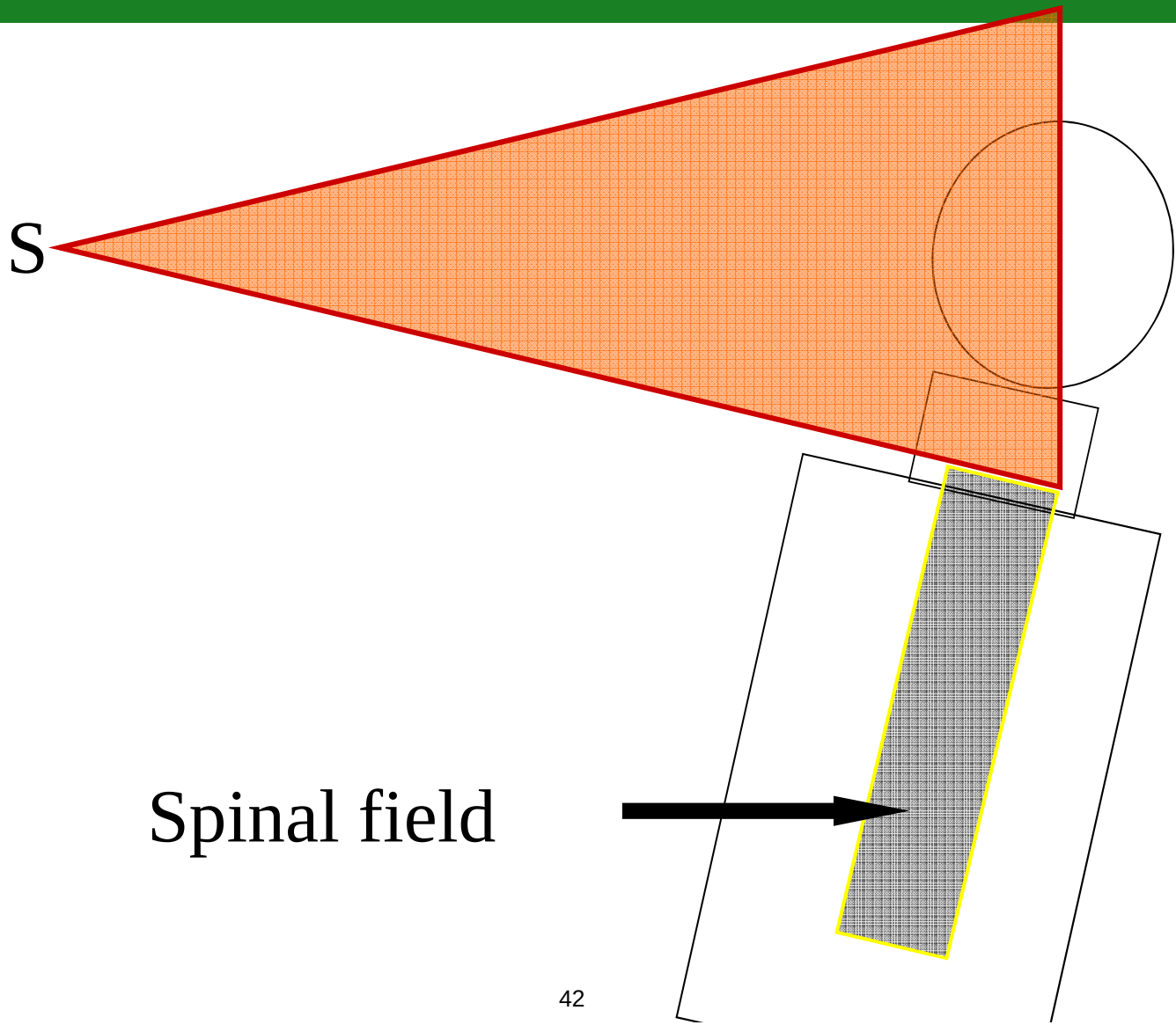
Solution A: Rotate the couch



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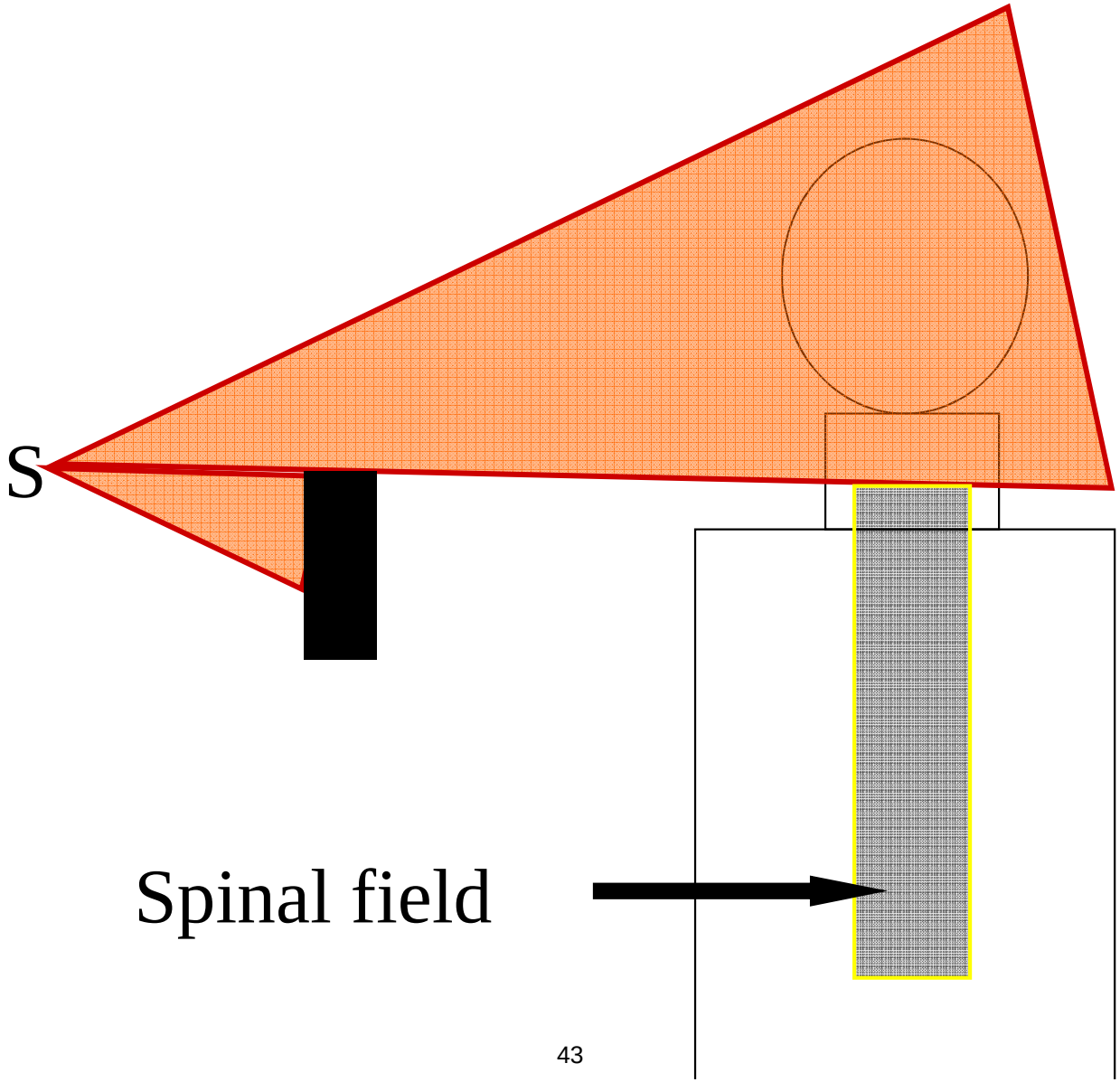
Solution B: Asymmetric block



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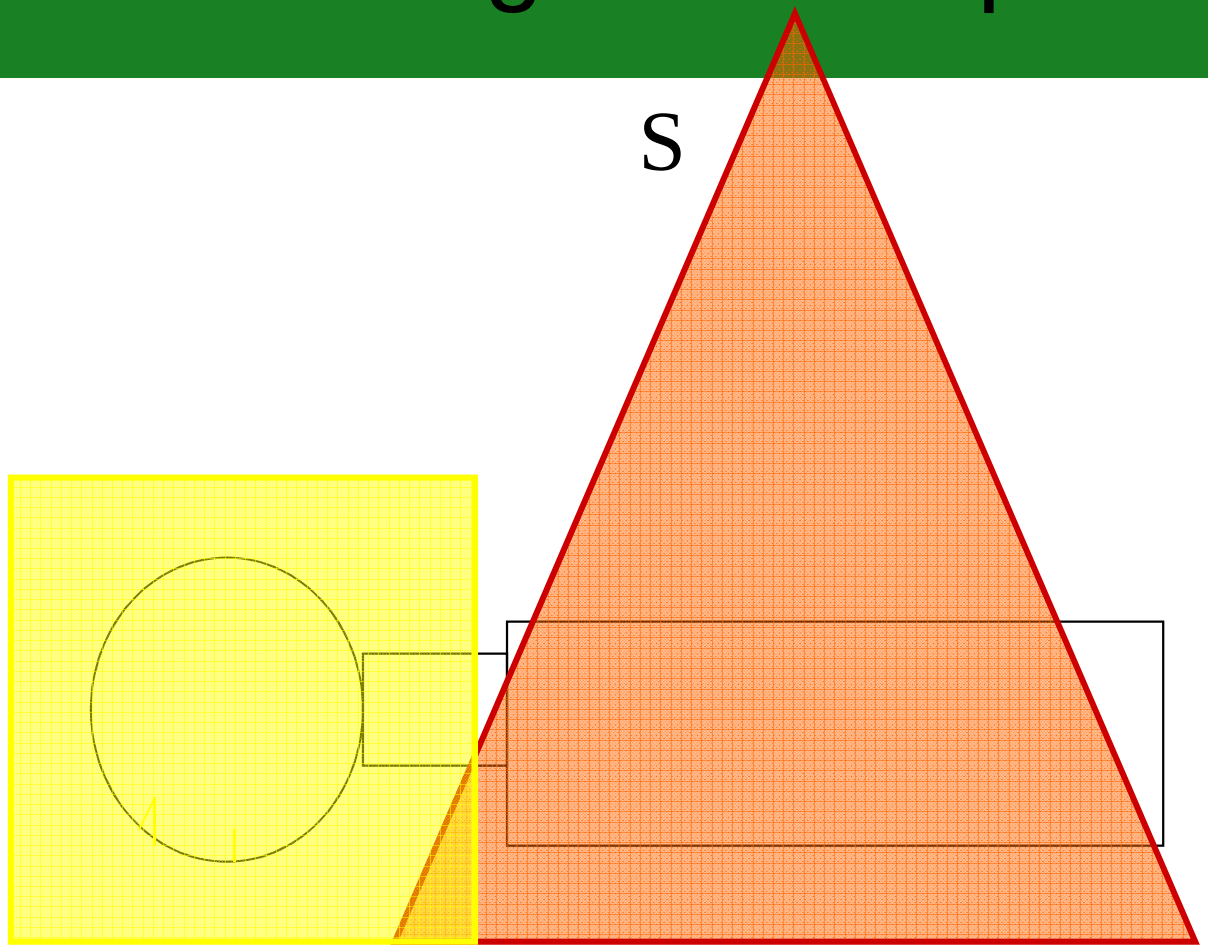
Problem 2 Divergence of spinal field



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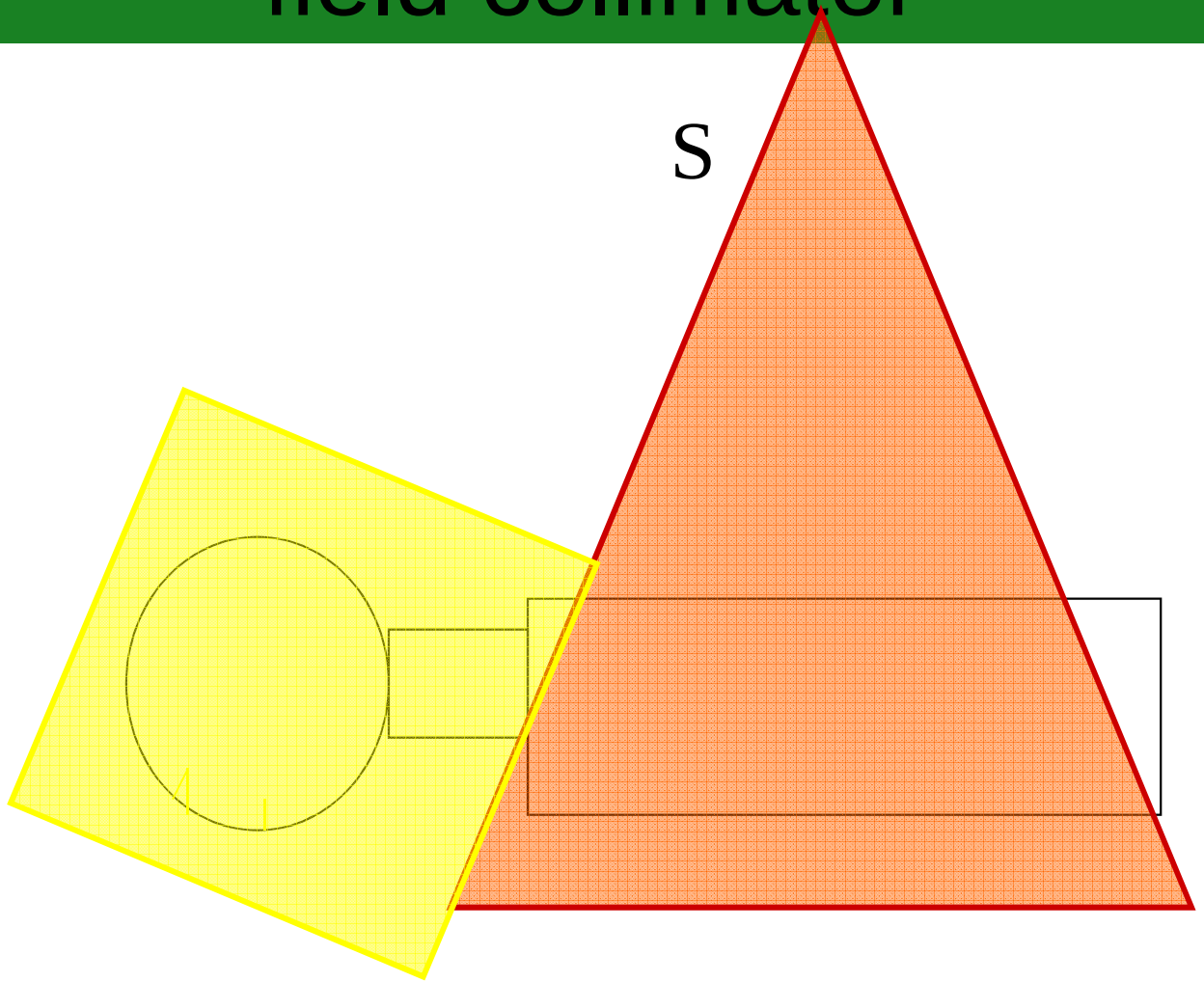
Solution A: Rotate the cranial field collimator



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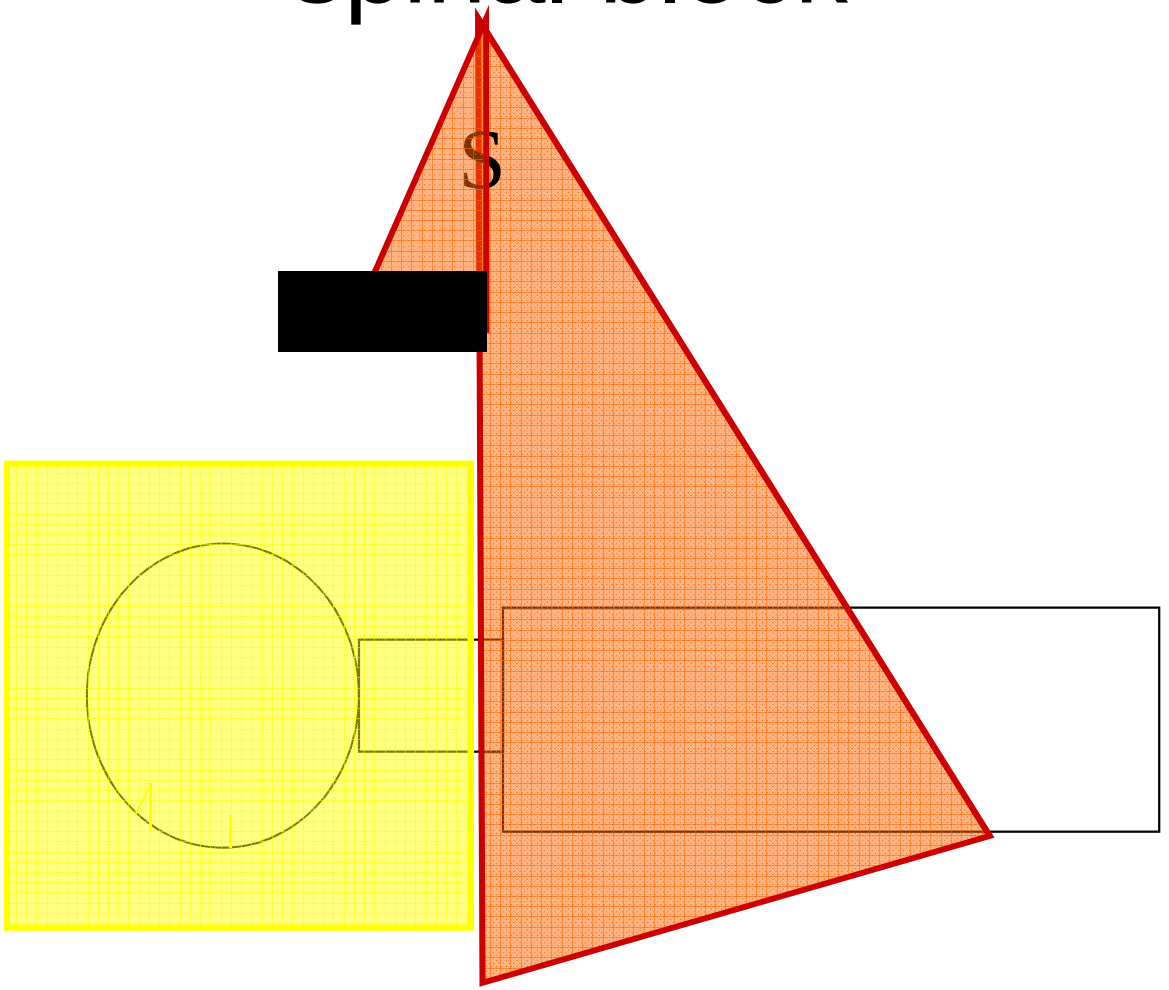
Solution B: Use asymmetric spinal block



Simulation-cranial field

- In practice 5 mm gap left in the cranial and spinal fields.
- Cranial field Collimator angle = $\tan^{-1}\{ ½ L_1/SSD\}$ L_1 is spinal field length.
- Couch angle = $\tan^{-1}\{ ½ L_2/SAD\}$

  L_2 is cranial field length.
- Use of asymmetric collimator jaws precludes the need of couch rotation.

Shielding

More important is what not to shield !

DO NOT SHIELD

- Frontal (cribriform plate)
- Temporal region

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Moving Junction in CSI

- 5mm overlap at 4mv photons → 30 to 40% overdose(14Gy for 36Gy prescribed dose) which may exceed cord tolerance

  (Hopulka, 1993, IJROBP).

- Systematic error during radiotherapy delivery could further lead to an overlap or gap.

- Feathering after every 5 to 7 fraction smoothesout any overdose or underdose over a longer segment of cord

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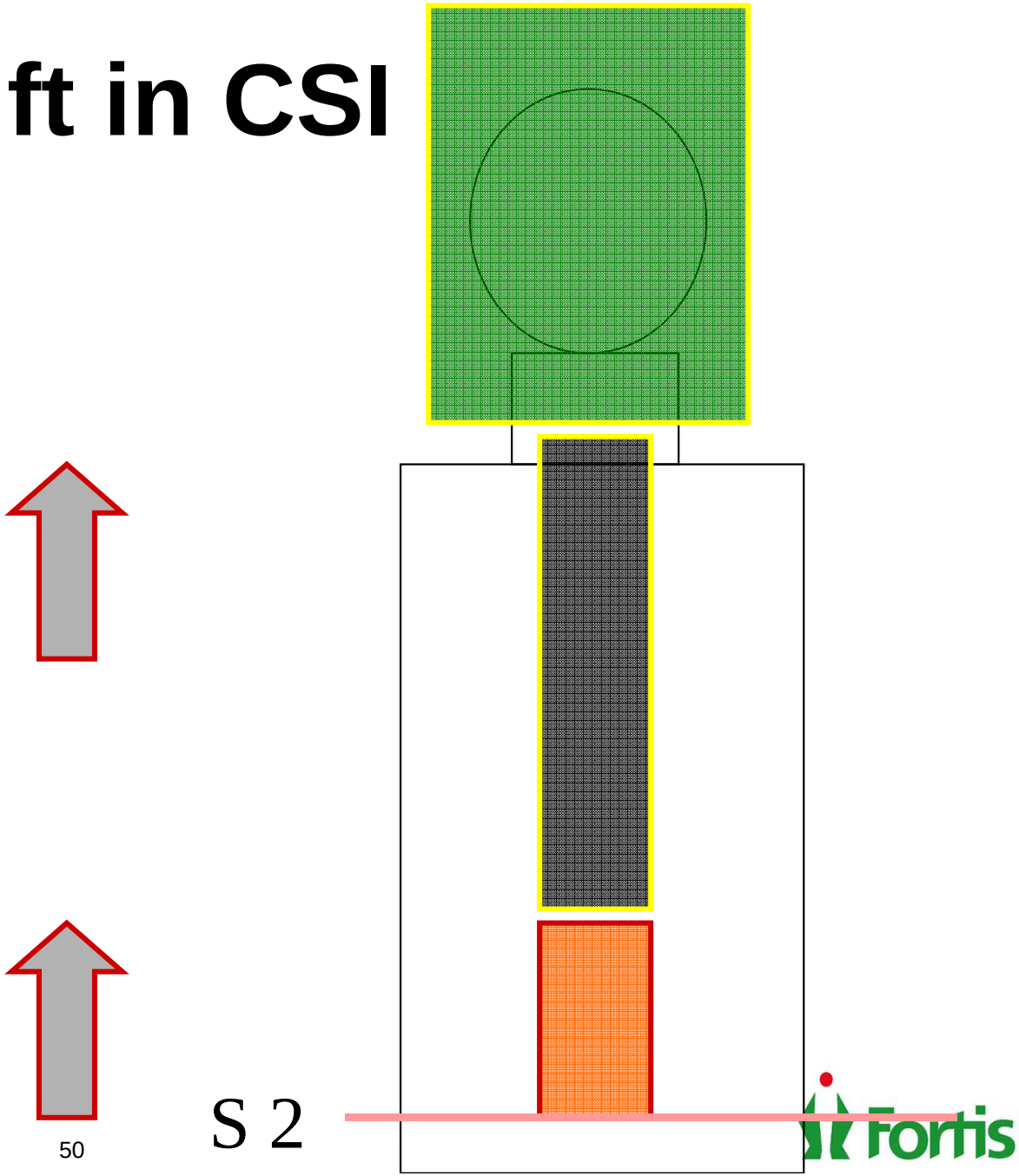
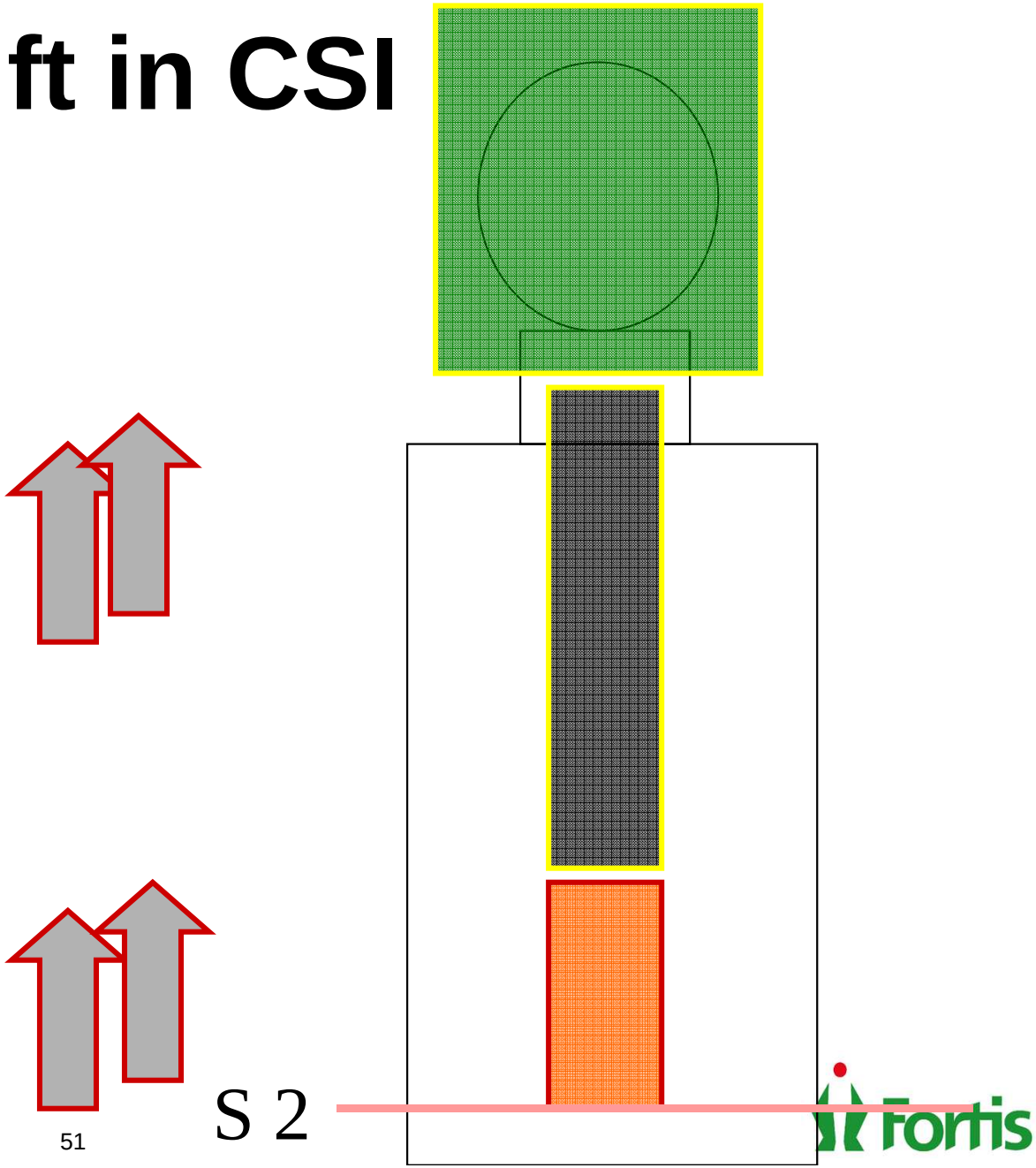
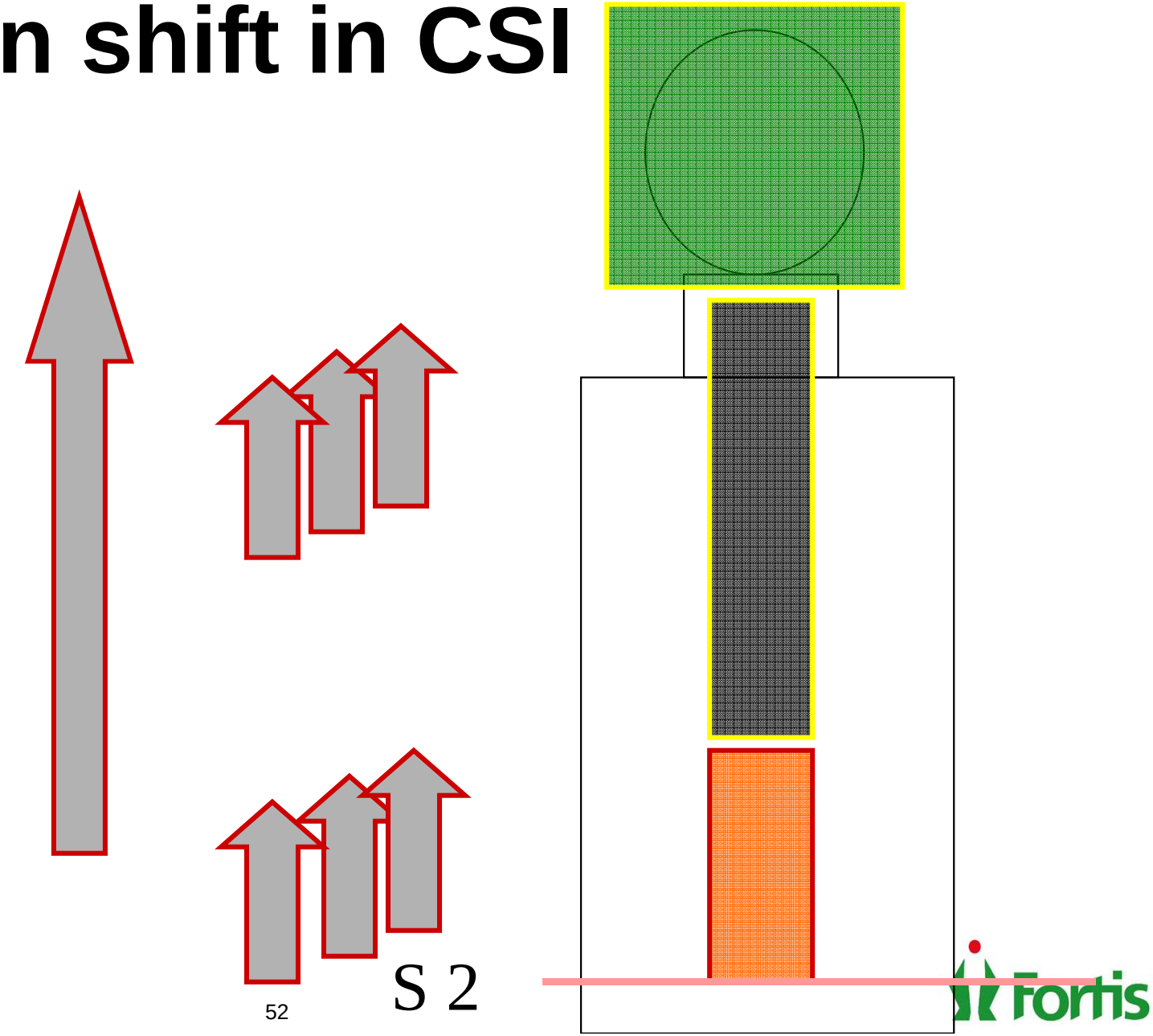
Junction shift in CSI



Junction shift in CSI



Junction shift in CSI



Posterior fossa boost

Borders

- Anterior: Posterior clinoid process.
- Posterior: Internal occipital protuberance.
- Inferior: C2-C3 interspace.
- Superior: Midpoint of foramen magnum & vertex or 1 cm above the tentorium (as seen on MRI).

Field arrangement

- Two lateral opposing fields.
- 3DCRT boost to the preop tumor bed with appropriate margins

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Steps in CT simulation

- Patient positioned using all ancillary devices and the spinal columns aligned with the sagittal external laser.
- Three-point reference marks drawn on the mask in a transverse plane at the center of the head with the aid of the external lasers.
- Two or three reference marks were placed on the posterior skin surface along the spinal column
- Spiral CT images of 3-5 mm thickness are acquired.
- Following image acquisition, all spinal reference marks are tattooed and the patient permitted to leave.
- A total of 130–170 images are reconstructed depending on the patient's height.

Supine CSI planning

CT based

Individualized CT planning

- Method analogous to conventional simulation but with use of asymmetric collimator jaws for matching beam divergence.
- Field junctions can be visually verified.
- The distance between the two isocenters (three if two spine fields are required) can be calculated once the beams have been set.
- This distance can then be used as the digital longitudinal table distance shift.

Supine CSI by conventional simulation

ELSEVIER

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0958-3947/07/$–see front matter

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A SIMPLE TECHNIQUE OF SUPINE CRANIOSPINAL IRRADIATION

ANUSHEEL MUNSHI
Department of Radiation Oncology, Tata Memorial Hospital, Mumbai, Maharashtra, India

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Abstract—We describe a simple procedure of craniospinal irradiation in supine position. The procedure was carried out with a 100-cm isocenter linear accelerator and compatible simulator. Treatment was with a 1 or 2 posteroanterior (PA)-directed spinal fields abutting lateral-directed cranial fields. Abutment of the fields was established by placement of markers on the neck of the patient, which provided a measure of the divergence of the spinal field. The precision and reproducibility of this technique, including the placement of junctions, appeared to be as good as for treatment in the prone position. The same could be verified with port films. We conclude that this new technique of supine craniospinal treatment is a simple and convenient alternative to traditional treatment in the prone position. © 2007 American Association of Medical Dosimetrists.

Key Words: ●●●.

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Supine CSI planning - conventional

Positioning:

- Supine on NNR with arms by the side of body.
- Check spinal column alignment on fluoroscopy.
- Neck in near neutral position but slightly extended.

Immobilisation:

- Thermoplastic mold for immobilization of face & neck.
- Close fit at the nasion.
- Any constraint for the jaw is removed to facilitate anaesthetic maneuvers.

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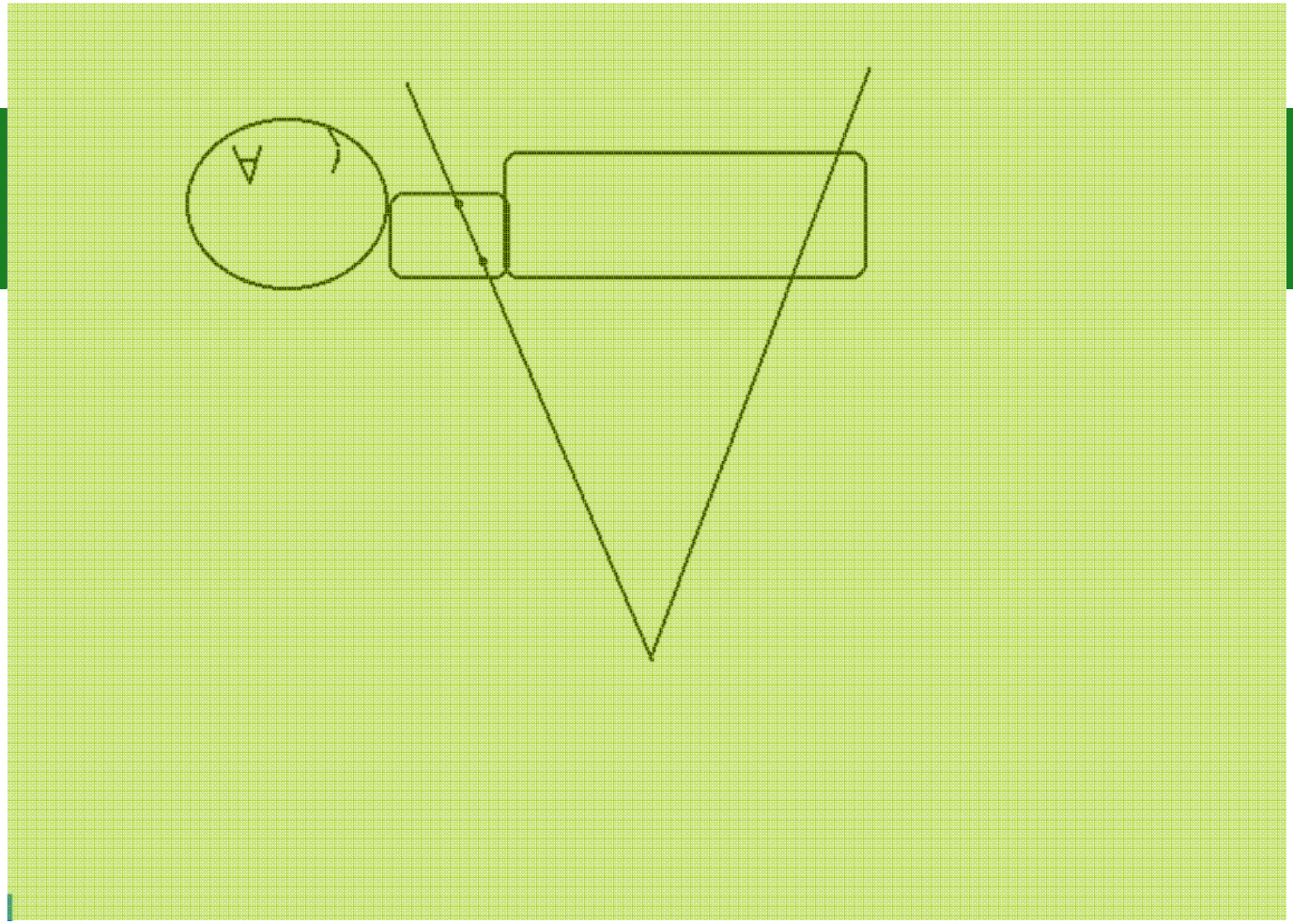
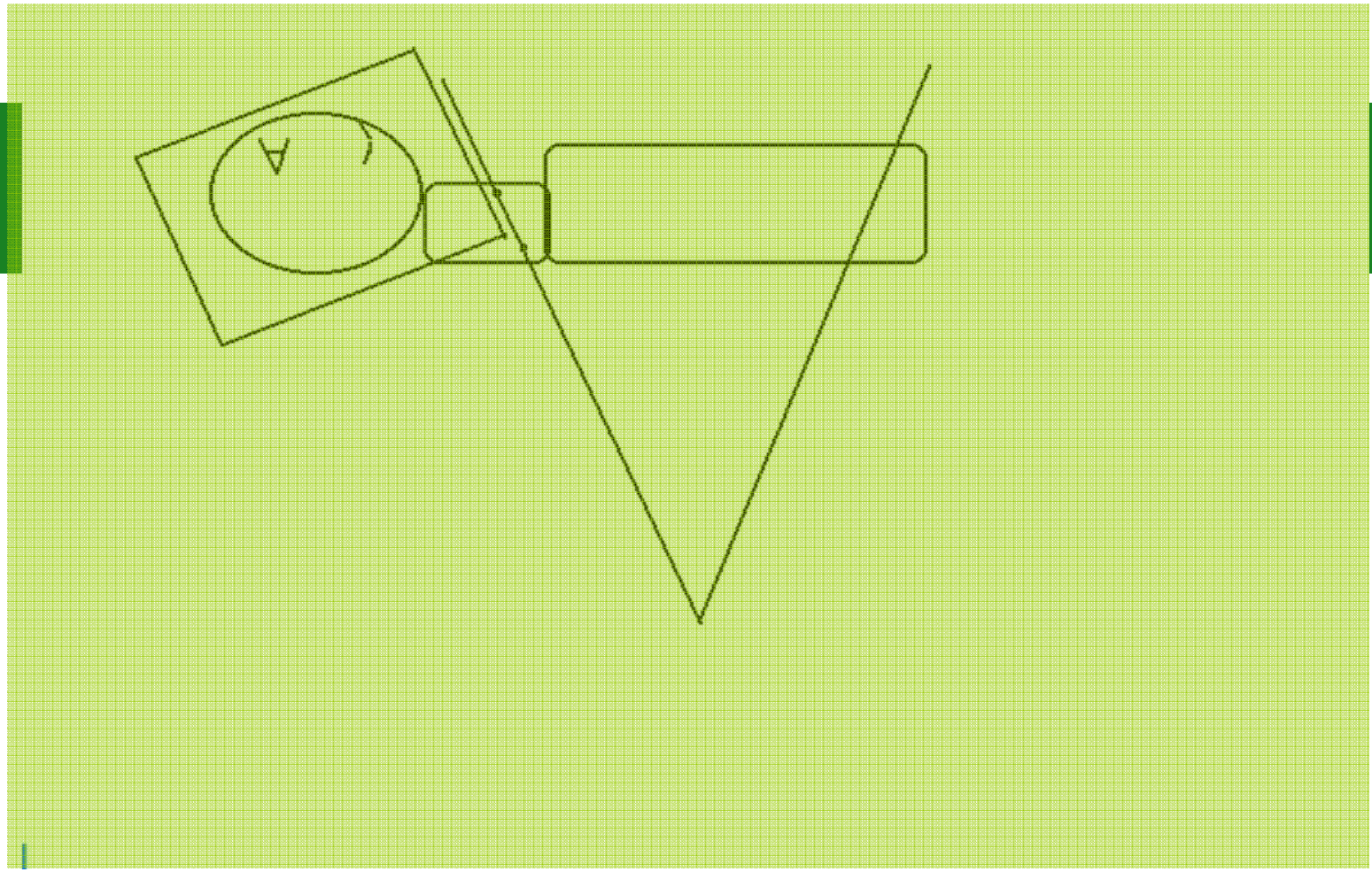


Step a : Gantry taken through table and the upper border of spinal field matched with the markers.

Step b: Two additional markers placed in the line of upper border



Step C: Collimation of the cranial field adjusted according to the line joining the two markers on one side of the neck(which is the divergence of the spinal field)

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