CRANIOSPINAL-IRRADIATION: INDICATION, PHYSICS & CLINICAL ASPECTS

DR SAPNA MARCUS BHATTY

MD DNBR

ASSOCIATE PROFESSOR & INCHARGE

ADVANCED CANCER INSTITUTE

BATHINDA. PUNJAB

OVERVIEW

- Indications
- Challenges
- Planning
- Critical issues
- Controversies
- Toxicities

DEFINITION

Craniospinal irradiation (CSI) is a technique used in radiation therapy to deliver a prescribed amount of radiation to the entire cranial–spinal axis to achieve curative measures in the treatment of intracranial tumors.

Craniospinal Irradiation – Treats anywhere CSF flows – Treatment fields typically include the brain to the thecal sac

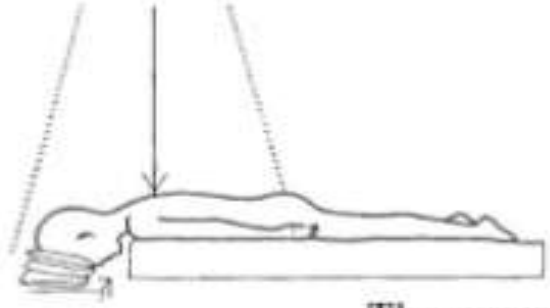
History: EDITH PATERSON

FROM THE CHRISTIE HOSPITAL AND HOLT RADIUM INSTITUTE (DIRECTOR: RALSTON PATERSON), MANCHESTER, ENGLAND

CEREBELLAR MEDULLOBLASTOMA: TREATMENT BY IRRADIATION OF THE WHOLE CENTRAL NERVOUS SYSTEM

by

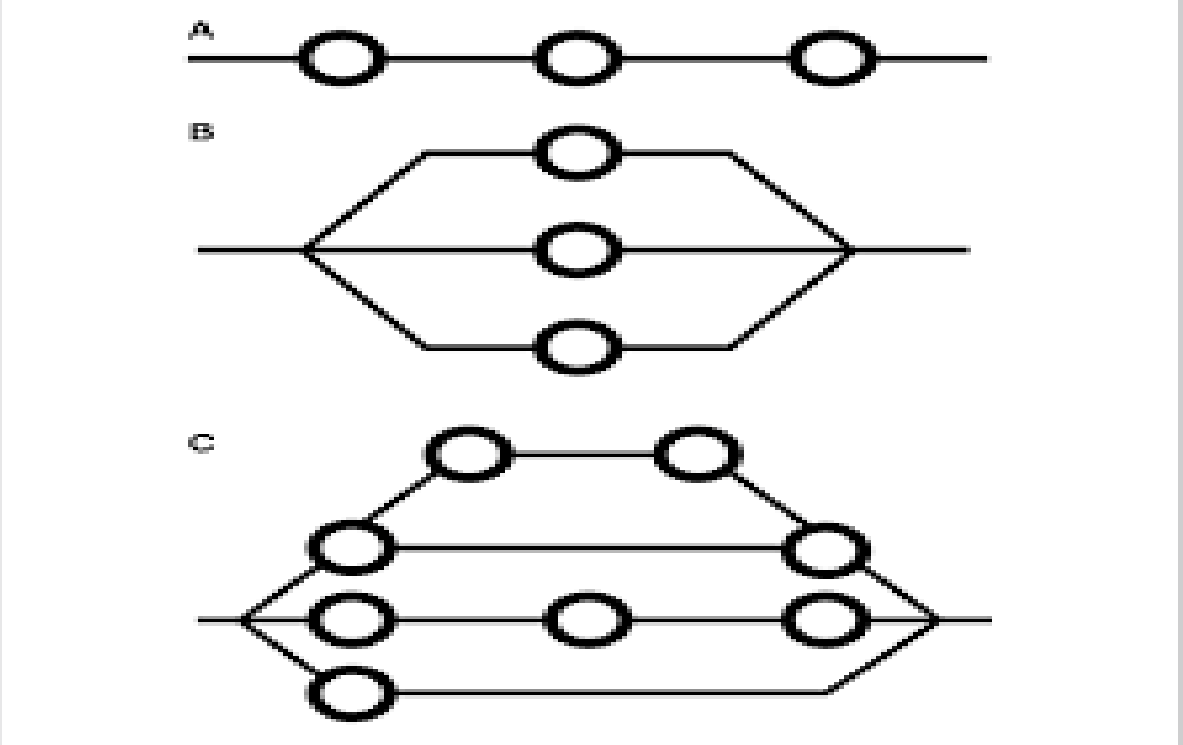
Edith Paterson and *R. F. Farr*



Introduction

The prognosis in cases of medulloblastoma of the cerebellum has for many years been regarded as fairly hopeless. This viewpoint is expressed by DARGEON (1948) where he states that "medulloblastomas . . . have a consistently unfavourable prognosis". In their excellent book, "Intracranial tumours of infancy and childhood", BAILEY, BUCHANAN and BUCY come to the same conclusion. There are, however, a few authenticated cases reported with a long survival following treatment, cases which are almost historical in their rarity (PENFIELD and FEINDEL 1947;

TYPE OF ORGAN



INDICATIONS

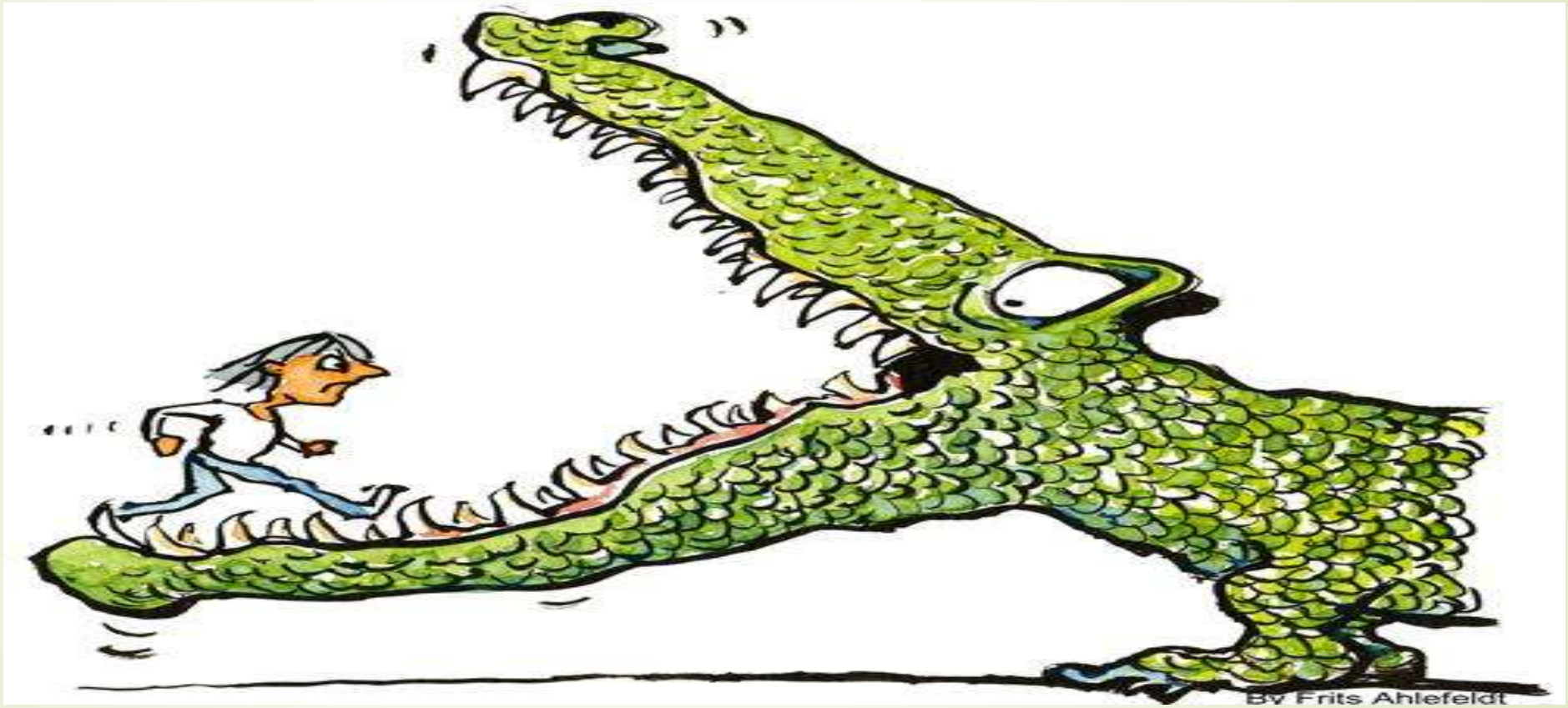
Medulloblastoma
Pinealoblastoma
Ependymoblastoma
Intracranial Germ cell tumor(germinoma)
Leukemia/lymphoma(with CNS axis mets)
Supratentorial PNET

- **LEARN NMR**
  - **L**ymphoma
  - **E**wing's
  - **A**cute lymphoblastic leukemia
  - **R**habdomyosarcoma
  - **N**euroblastoma
  - **N**euroepithelioma
  - **M**edulloblastoma
  - **R**etinoblastoma

HISTOLOGIC VARIANTS OF MB

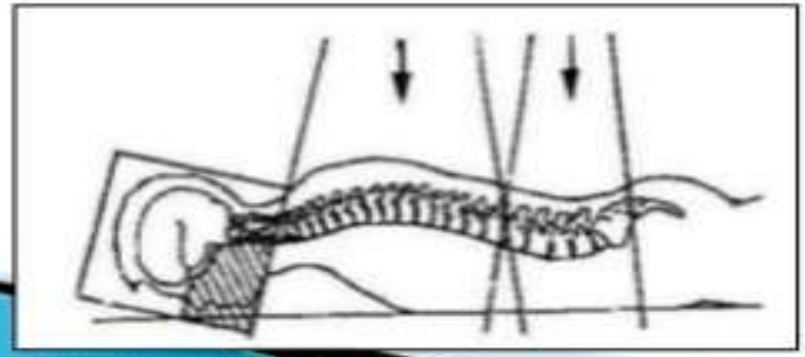
- Classic
- Nodular / Desmoplastic
- Large cell / Anaplastic

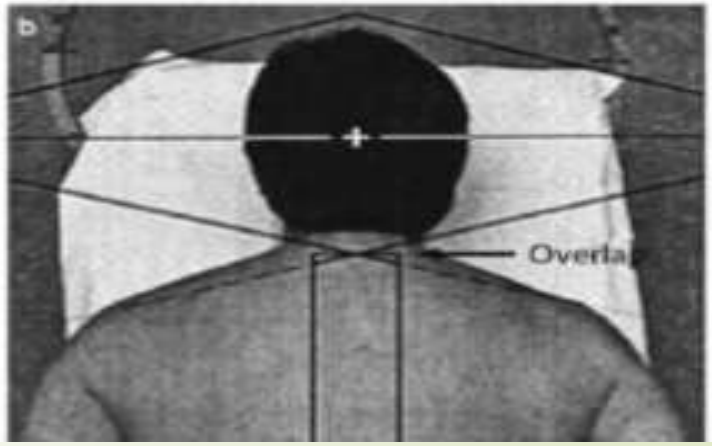
WHY IS RT SO CHALLENGING IN CSI



WHY IS IT SO CHALLENGING

- Patient positioning and immobilization difficult, especially in paediatric cases (may require anaesthesia).
- Large, irregular target volume.
- Critical structures, with special importance to paediatric cases, who are potential long term survivors.
- Problems of matching junctions between the divergent brain and spinal cord fields.






Radiotherapy
George sang along to the tune, wondering what the big deal was about Radiotherapy

PRINCIPLES OF RADIOTHERAPY

- Goals: Achieve uniform dose throughout the subarachnoid space
- Spine field(s) delivered with PA beam
- Cranial fields delivered with opposed laterals
- Cranial and spine fields must be matched
  - The collimator and couch must be rotated during delivery of cranial fields in order to account for beam divergence
- Moving junction (i.e. gap and feather) is often used between fields to minimize areas of potential underdose/overdose

RADIOTHERAPY PLAN

- Phase I : Craniospinal radiotherapy (two parallel opposed lateral cranial fields orthogonally matched with the posterior spinal field to cover the entire length of the spinal cord)

- Phase II : Posterior fossa boost (whole posterior fossa irradiation or conformal boost to tumour bed)

PRE RT EVALUATION

- · Detailed history & operative notes.
- · General physical & complete neurologic examination (ophthalmoscopy included)
- · Gadolinium enhanced pre-op MRI of the brain & spine.
- · Immediate post-op MRI brain for residual disease status.
- · Post-op MRI of the spine (if pre-op scans not done).
- · CSF cytology
- Anesthetic evaluation before RT .

Target Volume:-

- · Entire brain and its meningeal coverings with the CSF
- · Spinal cord and the leptomeninges with CSF
- · Posterior fossa – boost

Energy:-

- · 4–6 MV linac or Co60

Portals:-

- · Whole Brain: Two parallel opposed lateral field.
- · Spine: Direct Posterior field

Scheduling of radiotherapy:-

- · Starting time : within 28 to 30 days following surgery (perez)
- · Duration of treatment : 45 to 47 days

AIM OF RADIOTHERAPY PLANNING

Aimed at maximum tumor control with minimized normal tissue toxicity

Positioning
Immobilization
Simulation
Target and OAR Delineation
Treatment Planning
Junction shift

POSITIONING

Prone Position:

Advantages :

- · Direct visualization of the field junctions.
- · Good alignment of the spine

Disadvantages :

- · Uncomfortable, and larger scope for patient movement
- · Technically difficult to reproduce.
- · Difficult anesthetic maneuvers.

PRONE POSITION

- Sim and place spine fields first:
  - SSD setup (cranial fields will be SAD)
  - Borders
    - Superior: C4-C7 (while avoiding exit dose through oral cavity)
    - Inferior: establish termination of thecal sac as determined by MRI (~S2) and cover 1-2 cm inferiorly.
    - Lateral: cover the recesses of the entire vertebral bodies with at least 1 cm margin on either side. Must cover the sacral foramina (“spade” shape)

Supine

- · More comfortable.
- · Better reproducibility
- · Safer for general anaesthesia

BUT

- · Direct visualisation of spinal field is not possible

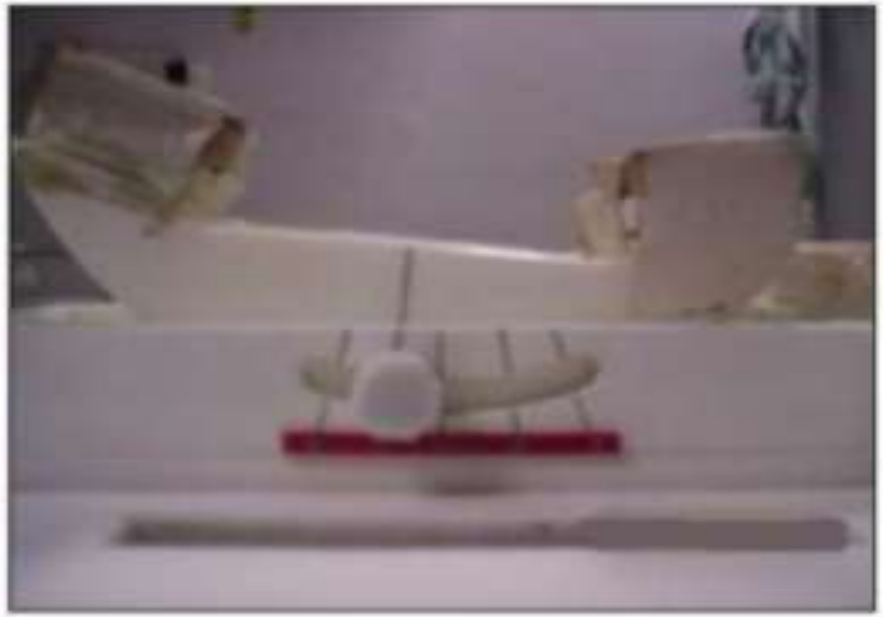
IMMOBILISATION

1. Orfit (Thermoplastic devices) for immobilization of the head, cervical spine & shoulder

2. Small children- inverted full body plaster cast with facial area open for access for anesthesia

5.CSI board: Lucite(polymethyl methacrylate) base plate fitted on which is a sliding semicircular lucite structure for head-rest & chin-rest.

Slots from A to E to allow various degrees of extension.



Thermocol wedge for supporting the chest wall

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

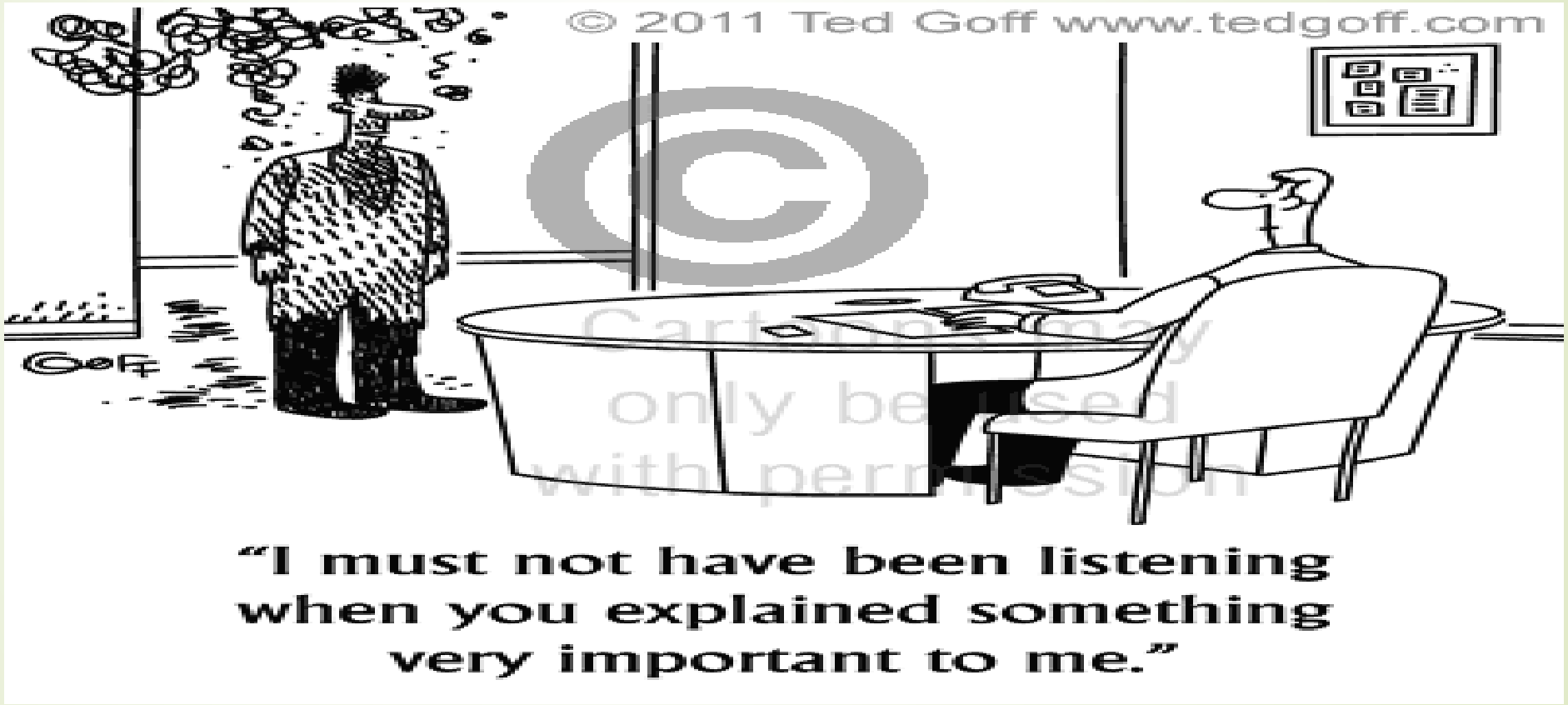
Lateral cranial fields

Anterior posterior width includes entire skull with 2cm clearance.

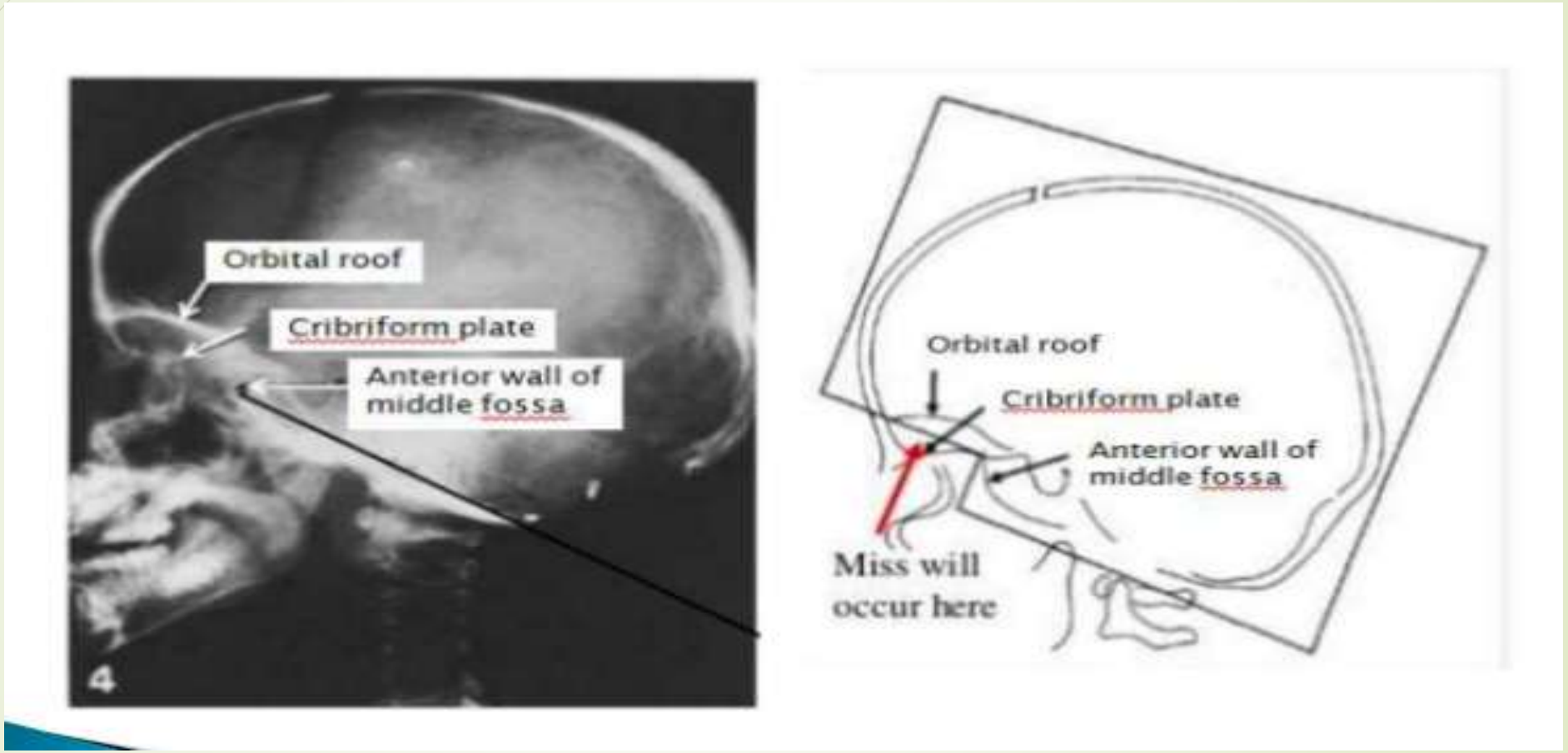
Superiorly, clearance to allow for symmetric field reduction while doing junction shift.

Inferiorly, the border is matched with superior border of spinal field.

The most important……field borders



Cranial fields ….(2ND TO MARK)



Shielding

- Most important is what not to shield

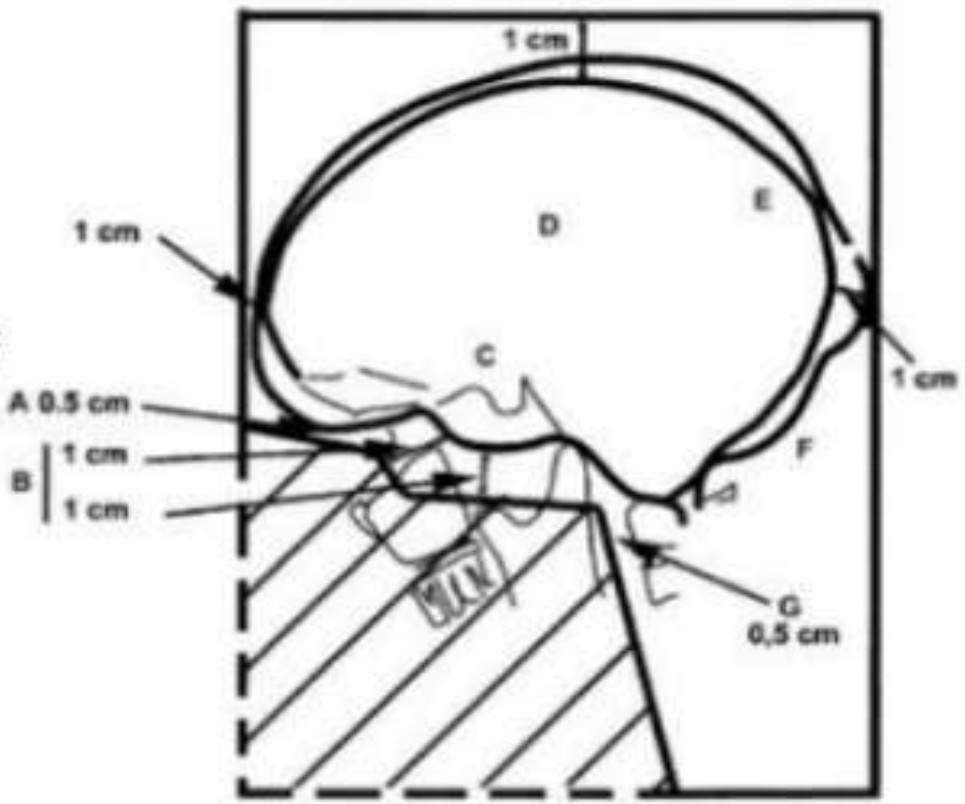
- ·Frontal (cribriform plate)
- ·Temporal region

- In meduloblastoma nearly 15-20% of recurrences occur at cribriform plate site which is attributed to overzealous shielding, because of its proximity to ocular structure it often get shielded.

SFOP (French society Paediatric Oncology) Guideline- The recommended placement of block is

0.5cm below orbital roof

1cm below and 1cm in front of the lower most portion of the temporal fossa



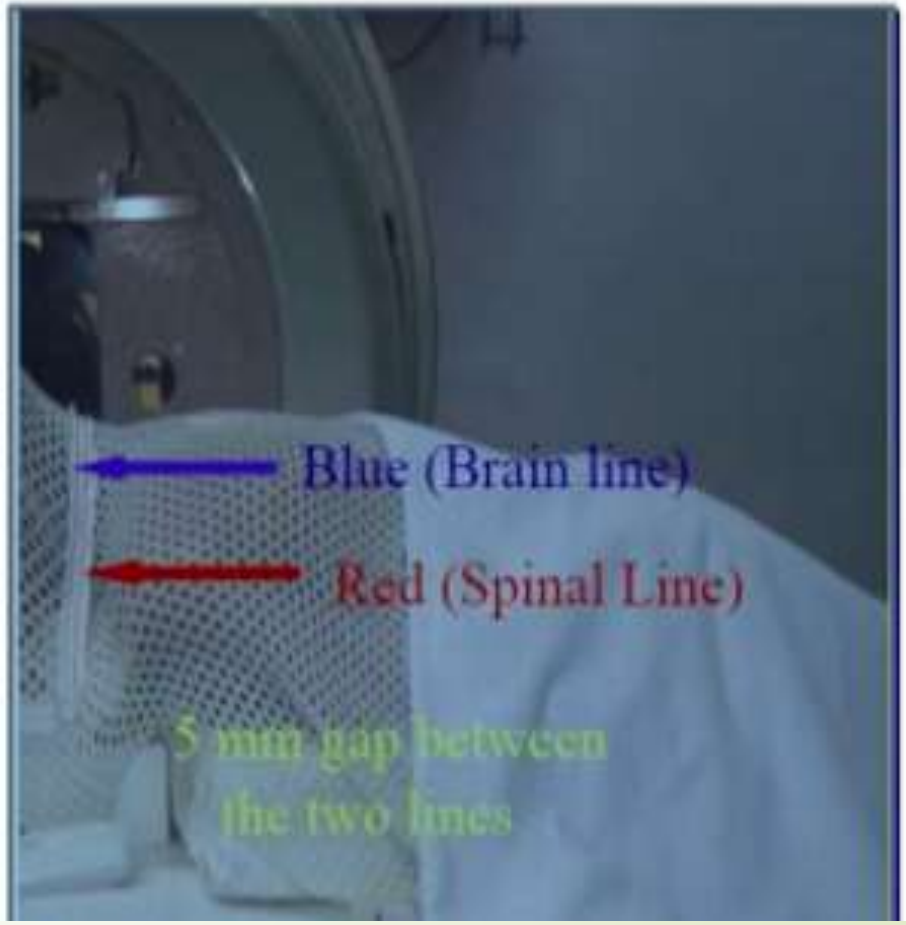
Spinal fields…..(1st to mark)

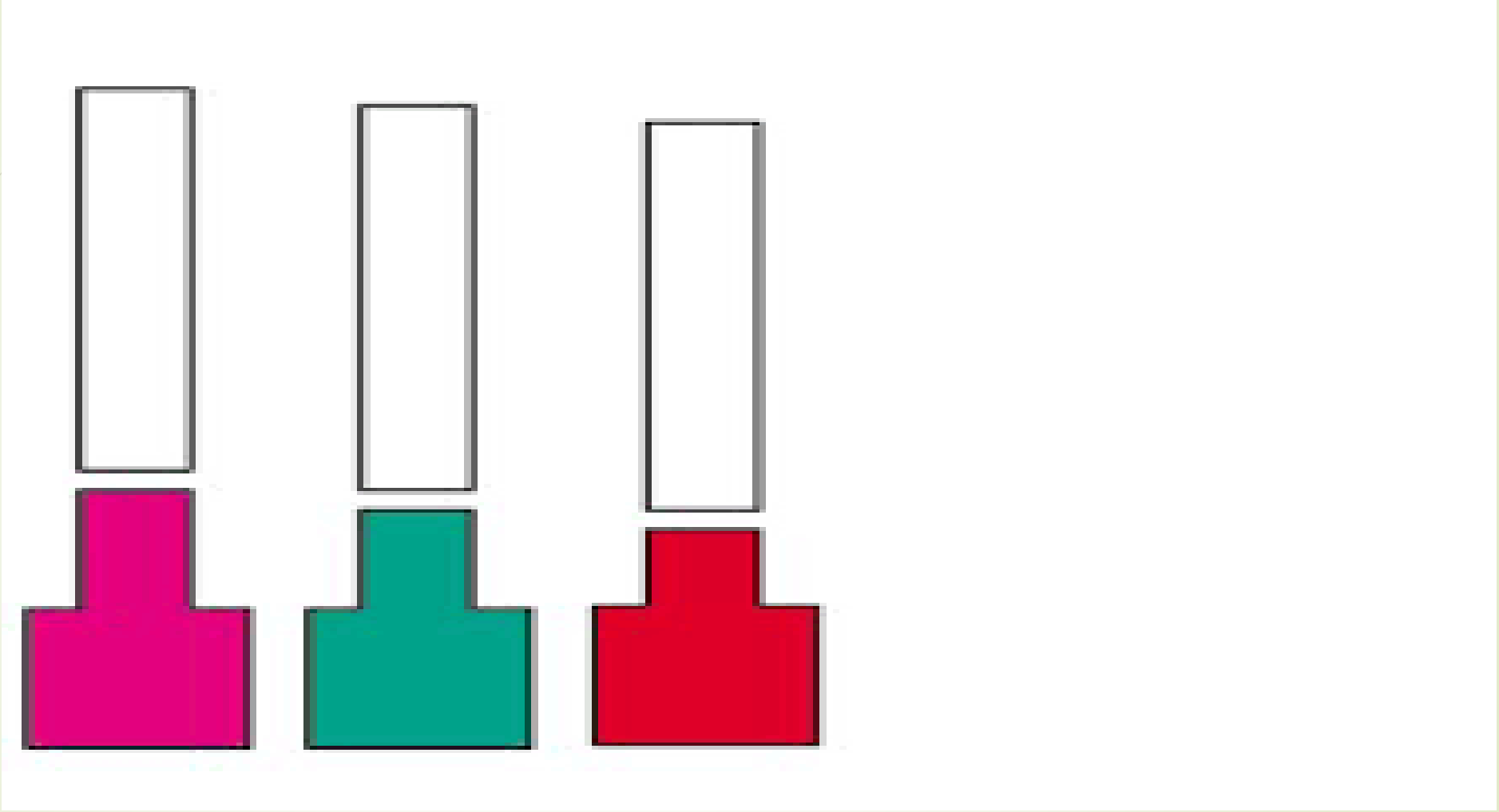
- Width - vertebral body + 1 cm to include the intervertebral foramina; usual width 5 - 7 cm.

- Spinal field- superior boarder at C3 – C4 junction such that field is not exiting through oral cavity.

Mark the divergent boundary of the superior margin of spinal field (red line) on lateral aspect of neck to provide a match line for the lateral cranial field(blue line).

Open length of field to a maximum length and mark inferior border or





THE THECAL SAC…..

Traditional recommendation for lower border of spinal field is inferior edge of S2 (myelogram & autopsy studies).

8.7% patients have termination below S2-S3 interspace.

MRI accurately determines the level of termination of the thecal sac & the extent of neuraxial disease if present.

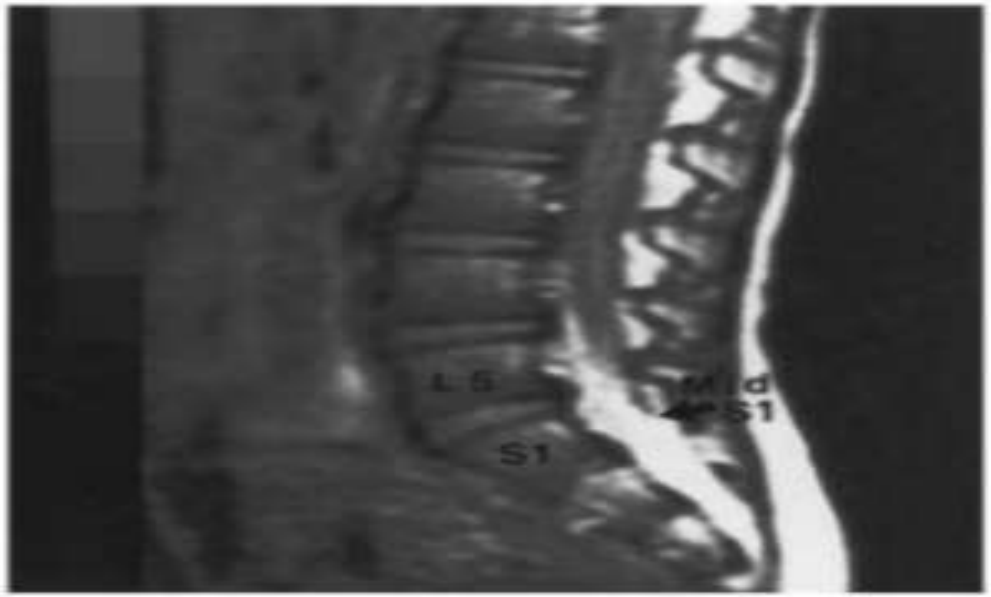


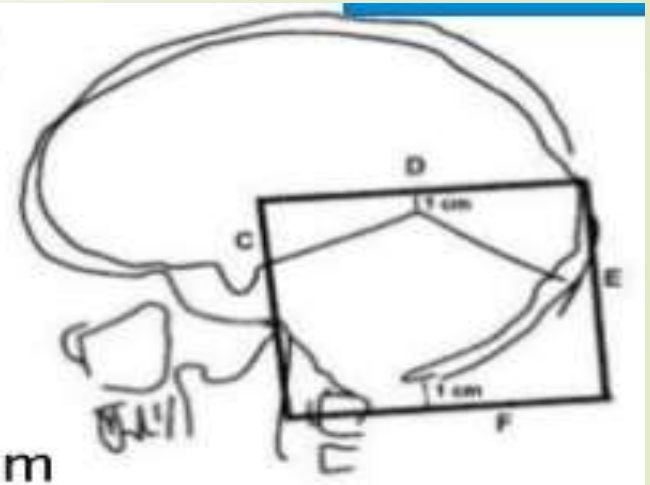
Fig. 1. Magnetic resonance imaging (MRI) of the spine showing thecal sac termination (arrow) at the mid-S1 vertebral level.

Int J Radiat Oncol Biol Phys. 1998 Jun 1;41(3):621–4, scharf et.al.

STANDARD RISK: TUMOR BED VS. POSTERIOR FOSSA BOOST

- Current COG protocol (ACNS 0331) is comparing posterior fossa boost vs. tumor bed boost in standard risk patients
- However, there is evidence available to support limiting the boost volume to the tumor bed
  - Failure rates within posterior fossa after tumor bed boost are comparable to historical experience with treating entire posterior fossa
    - Wolden et al., JCO, 2003 (PMID: 12915597)
    - Merchant et al., IJROBP, 2008 (PMID: 17892918)

Posterior fossa boost

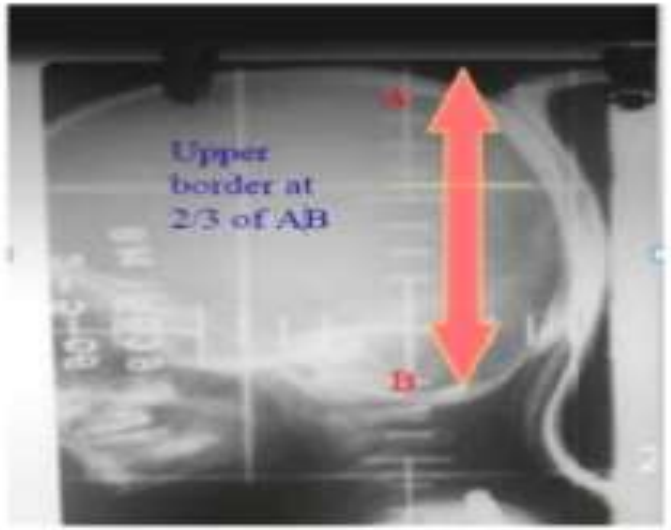


Borders

- ·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.



CTV = entire posterior fossa, including brainstem

PTV = CTV + 3-5 mm (exclude pituitary unless involved)

Bony Landmarks

- Superior: 1 cm above the midpoint of a line drawn between the foramen magnum and the vertex
- Anterior: posterior clinoids and anterior C1 (the pituitary should be blocked unless involved)
- Inferior: C1-C2 junction
- Posterior: internal occipital protuberance

So question is how much can we boost????

COG ACNS03332-

- Boost intracranial mets to 50.4Gys
- Focal spinal mets below the cord terminus to 50.4 Gys
- Focal spinal mets above the cord terminus to 45 Gys
- Diffuse spinal disease to 39.6 Gys.

Does entire PF needs to be boosted to > 50 Gys???

- Retrospective evidence- failures occur in the PF outside the tumor bed (<5%)
- Fukunaga-Johnson et al (IJROBP-1998)
- Wolden et al (JCO-2003)
- Final answer: COG protocol 0331

Benefits of Hyperfractionation

- CSI – 1 Gy bd to 36 Gy to tumor bed followed by 1Gy bid to 68 Gy boost
- 6 yrs OS was 78%
- EFS was 75%
- IQ decrease was less pronounced.

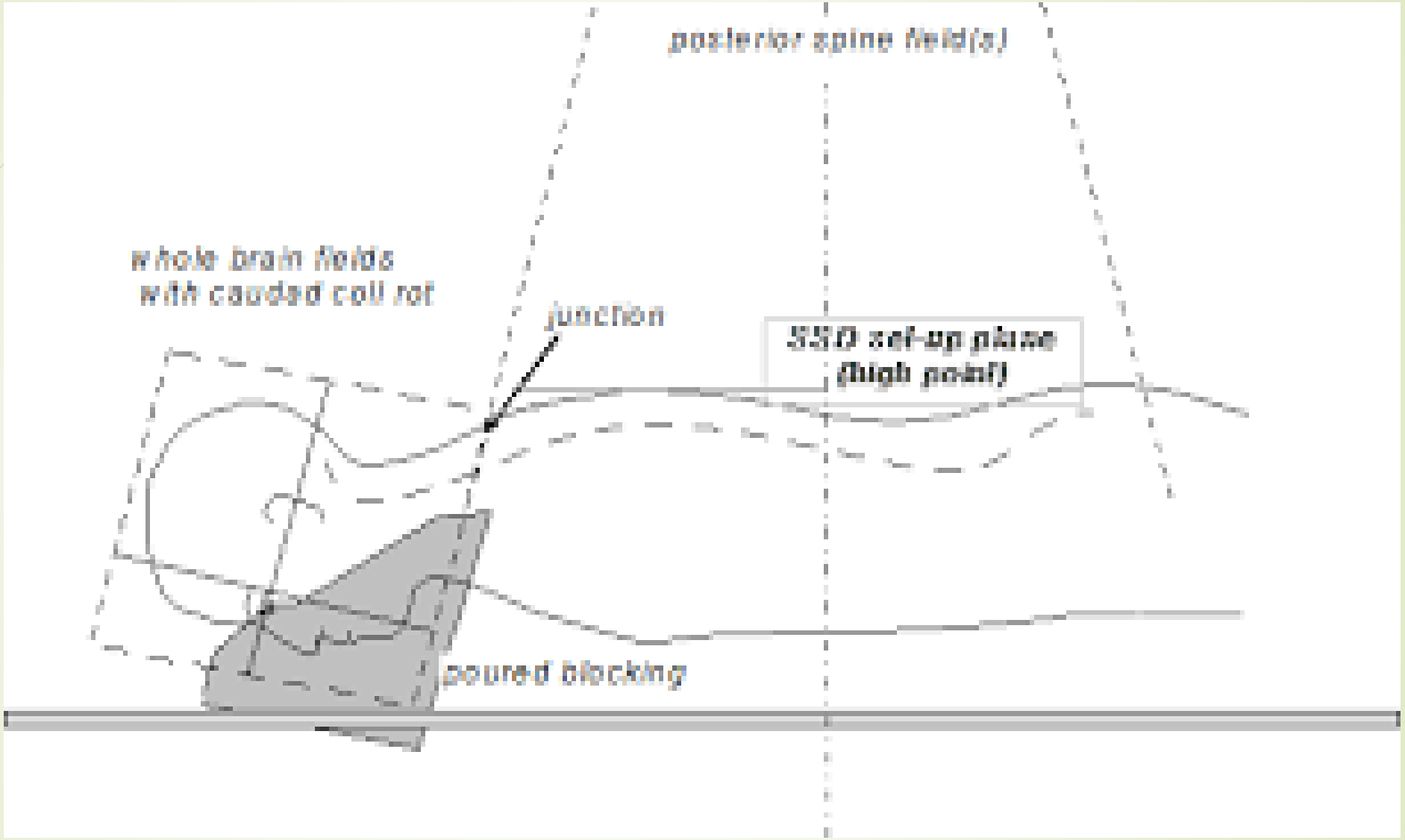
CRITICAL ISSUES IN CSI

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


posterior spine field(s)
whole brain fields
with caudad coll rot
junction
SSD set-up plane
(high point)
poured blocking

THE SOLUTION…

- Spinal field simulated first (get to know the divergence of the spinal field)
- SSD technique
- 2 spinal fields if the length is > 36 cm
- Upper border at low neck
- Lower border at termination of thecal sac or S2 whichever is lower
- In case of 2 spinal fields , junction at L2/L3

Field matching at both the junctions critical

- 1. Cranio-spinal junction : various techniques; described subsequently
- 2. Spinal-spinal junction *: no gap / fixed gap / calculated gap* can be employed for matching as central axes of both the beams are parallel

GAP AND FEATHERING TECHNIQUE

Rather than rotating the couch to match divergence of cranial beam, a gap of 0.5 cm is placed between the brain and spine field each day (collimator is still rotated).

Feathering "spreads out" the cold spot at the gap between the brain and spine fields, as well as any cold spots in the cord due to skin gap when more than one spine field is required.

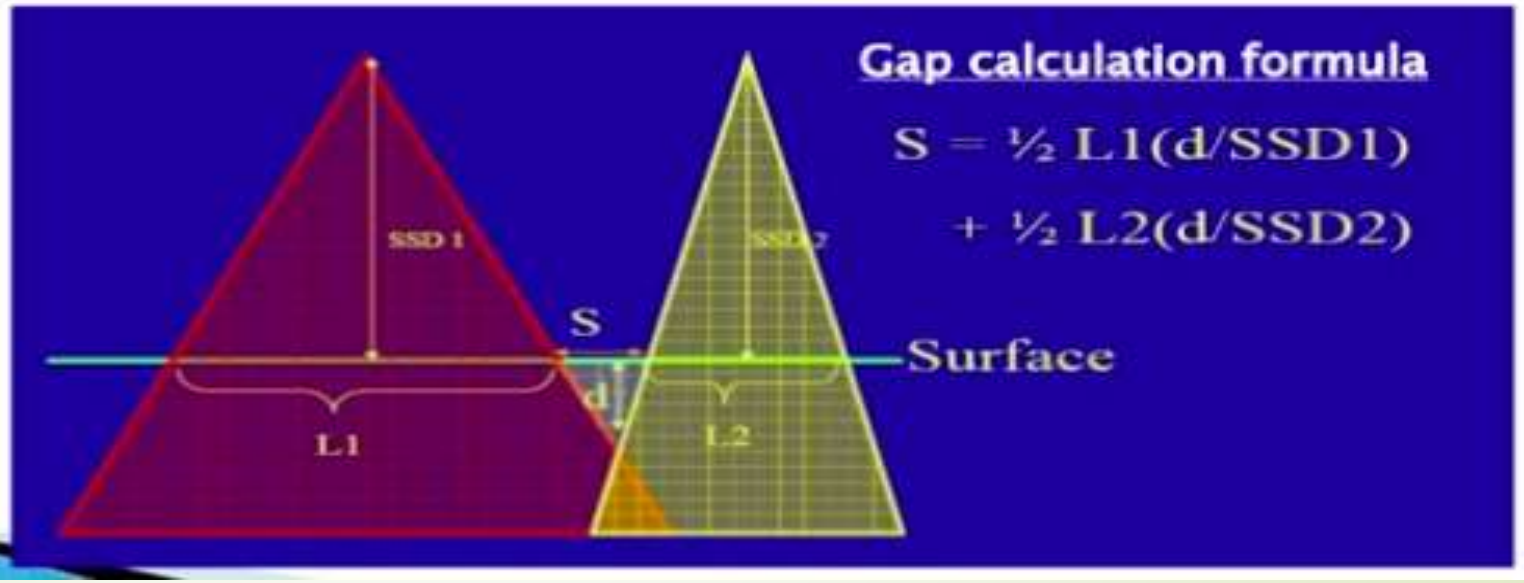
Feathering is accomplished with the use of asymmetric jaws.

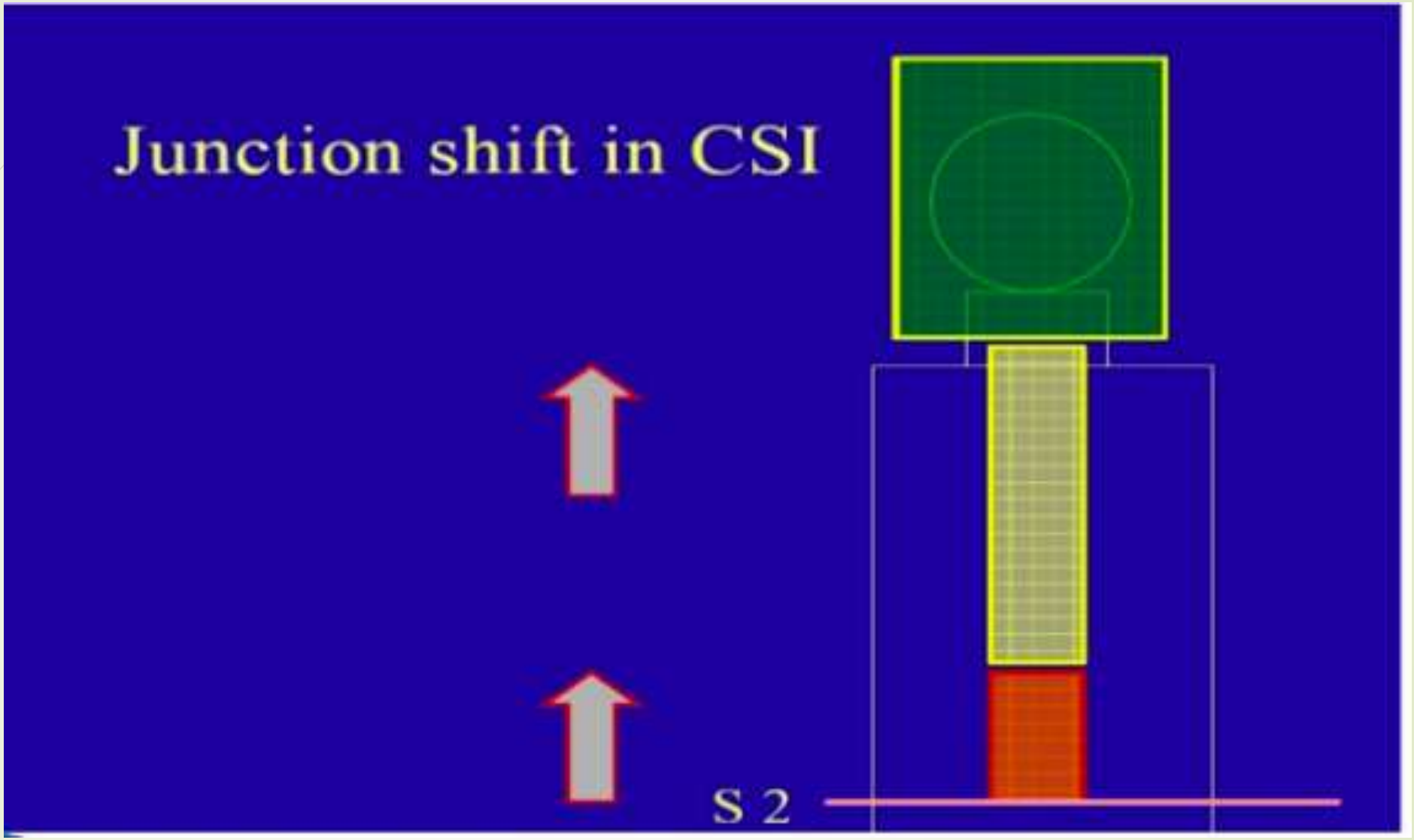
- For cranial fields: open caudal border of cranial field by 1cm each day, cycle every 3 days.
- For spine fields: shift isocenter(s) caudally by 1cm for each day; adjust blocks for each day accordingly.

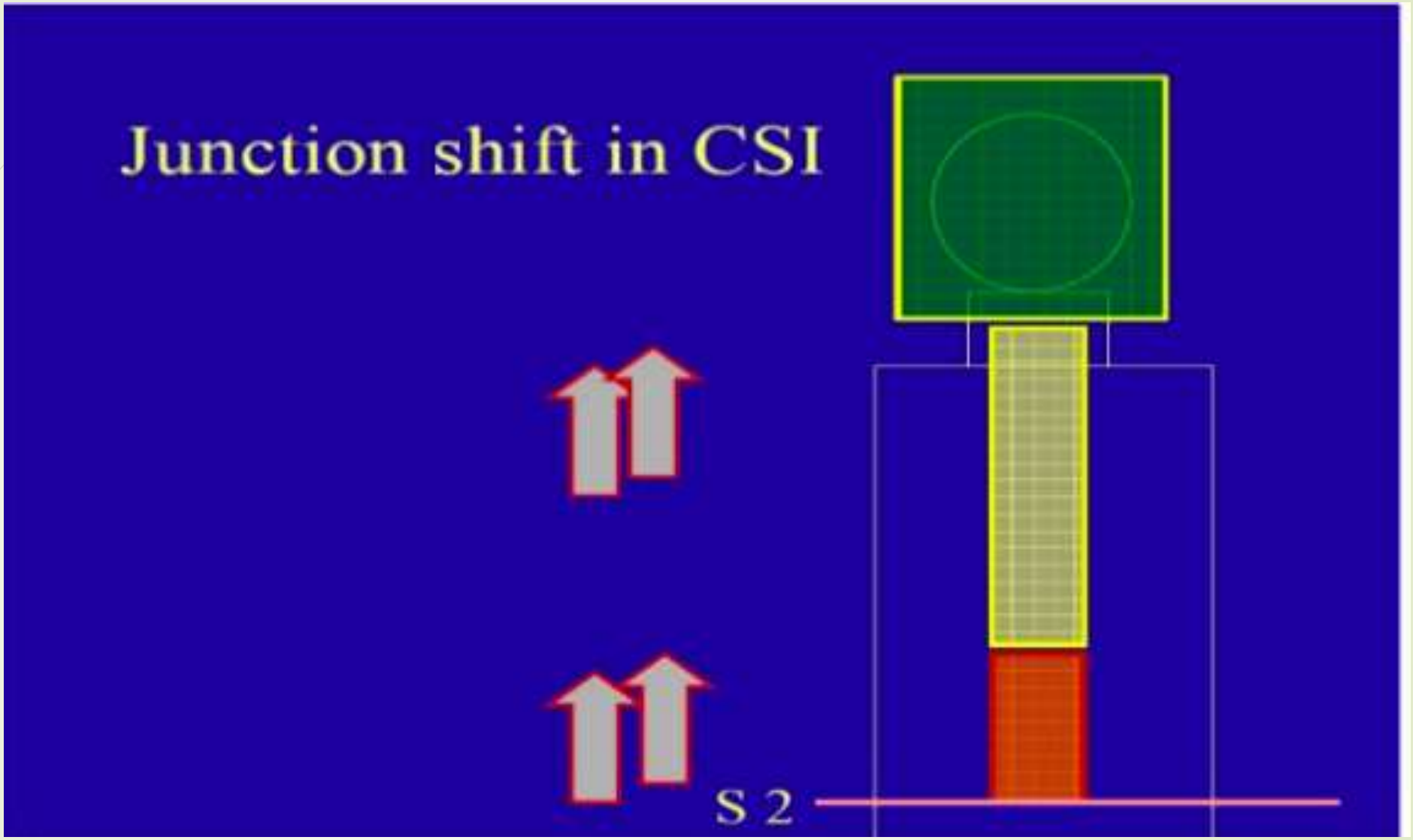
Gap: Fixed or Calculated

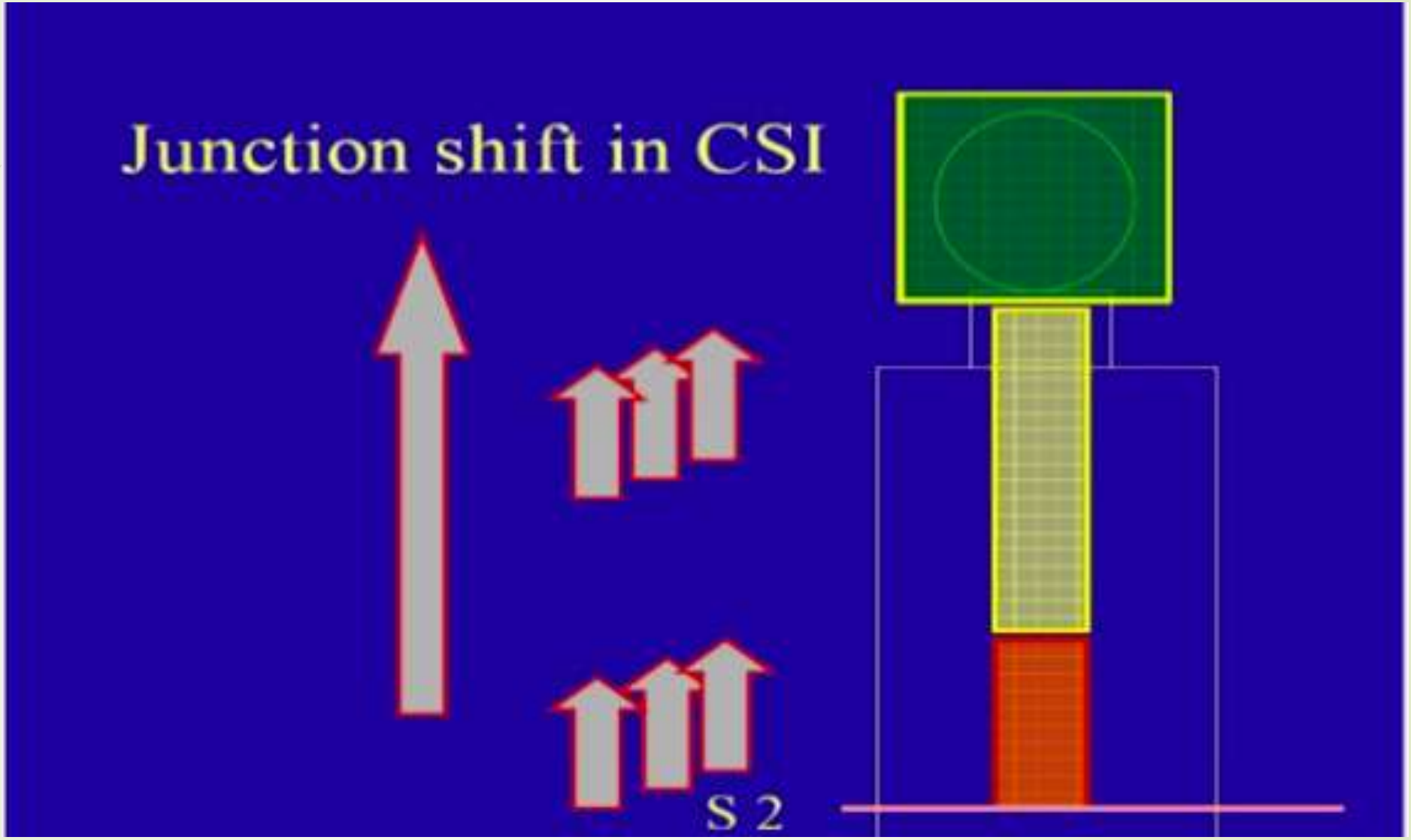
- Many institutes use a fixed gap ranging from <5 mm - 10 mm

- A customized gap calculated for each patient depending on field length & depth of prescription, is more appropriate




Junction shift in CSI
S 2


Junction shift in CSI
S 2


Junction shift in CSI
S 2

Gap vs Nogap ?

- Proponents of *no gap* argue that as medulloblastoma is radiosensitive tumor, small reduction in dose per fraction or total dose to part of Target Volume, owing to a gap, may produce significant difference in cell kill over a fractionated course of CSI, seen as local recurrences.

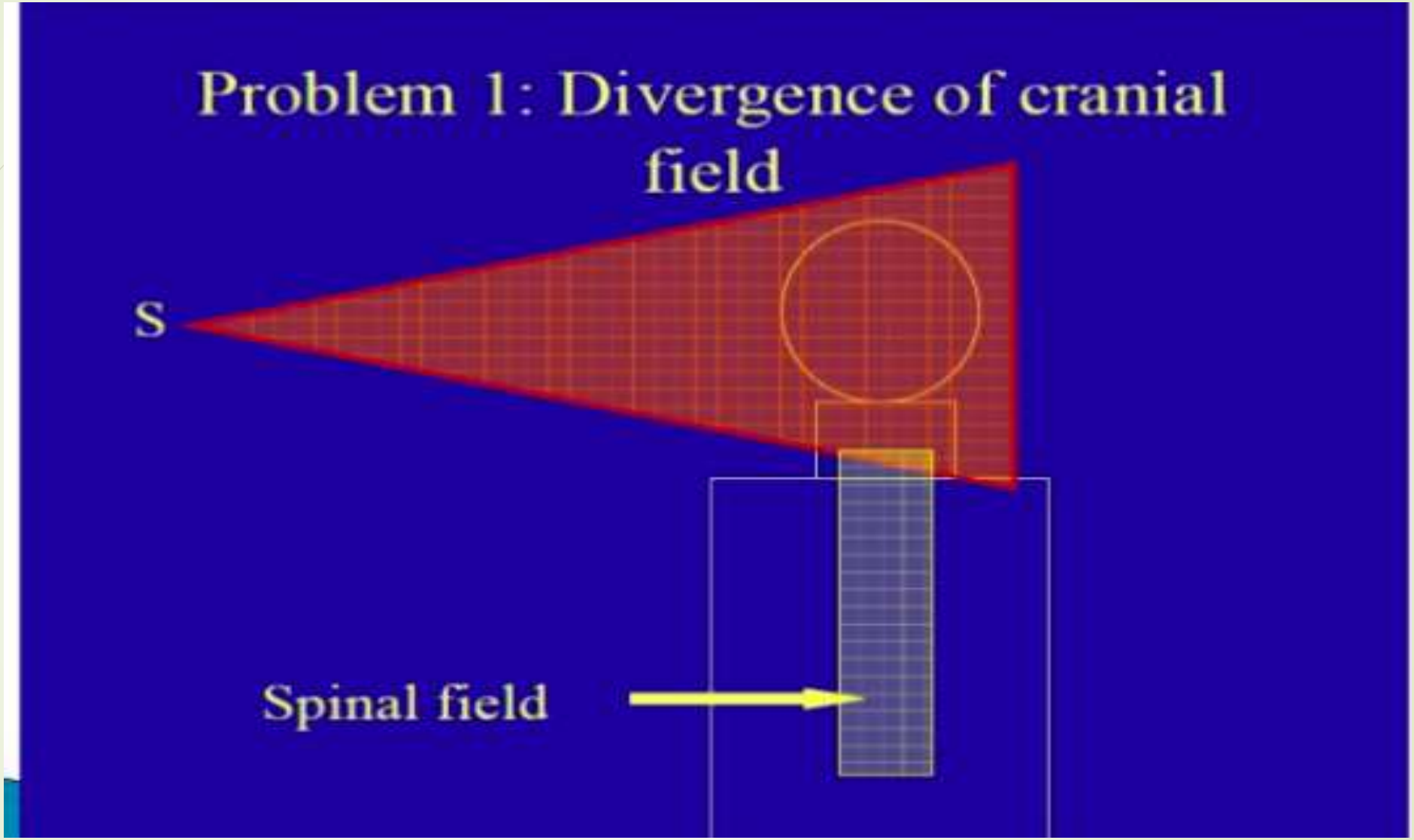

1995, *The British Journal of Radiology*, 68, 736–739

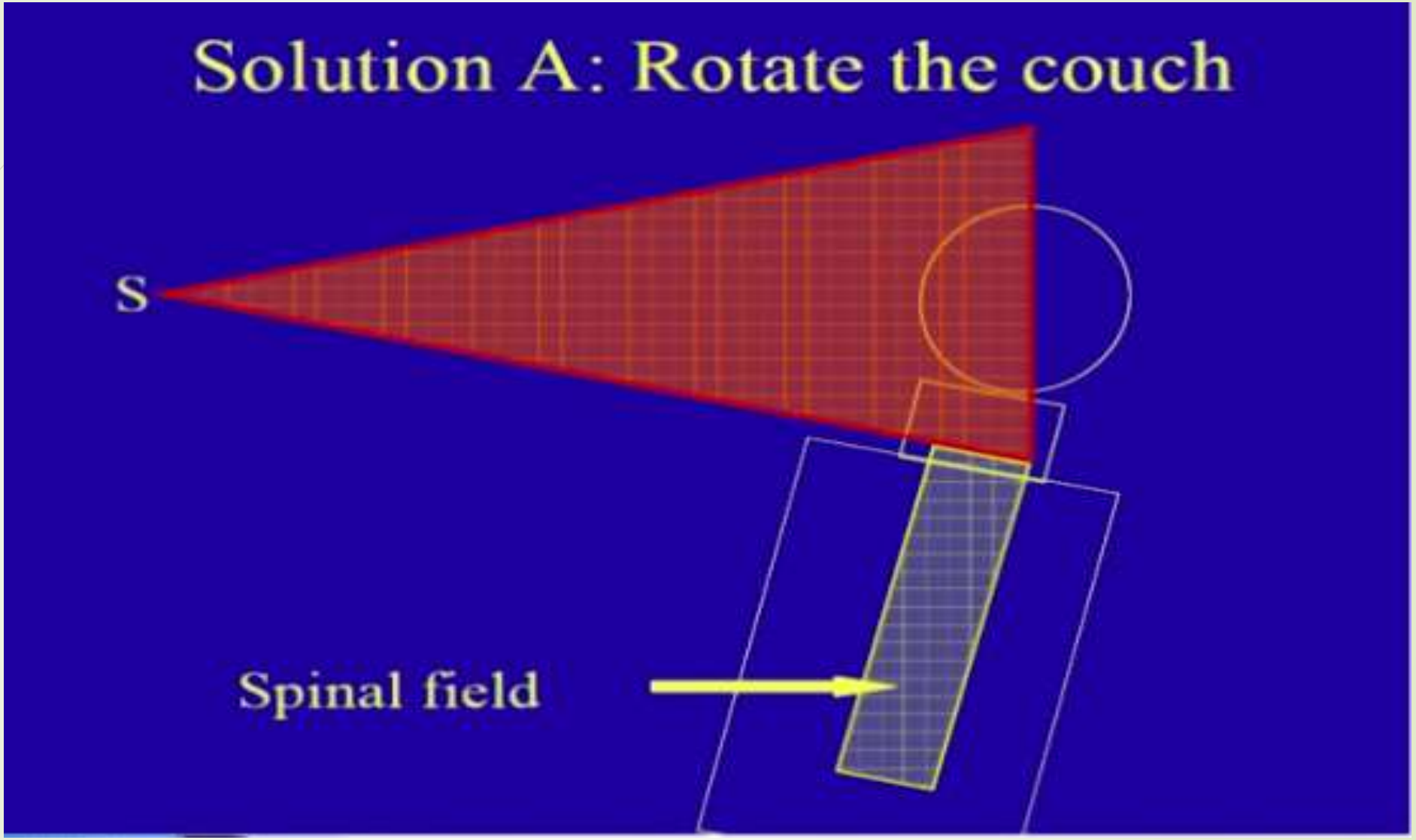
Are moving junctions in craniospinal irradiation for medulloblastoma really necessary?

S D TINKLER, MRCP, FRCR and H H LUCRAFT, FRCP, FRCR

- Proponents of *gap* argue that no gap risks overdose at the junction & cervical spine & may result in disabling late toxicity

How to match cranio spinal junction


Problem 1: Divergence of cranial field
S
Spinal field


Solution A: Rotate the couch
S
Spinal field

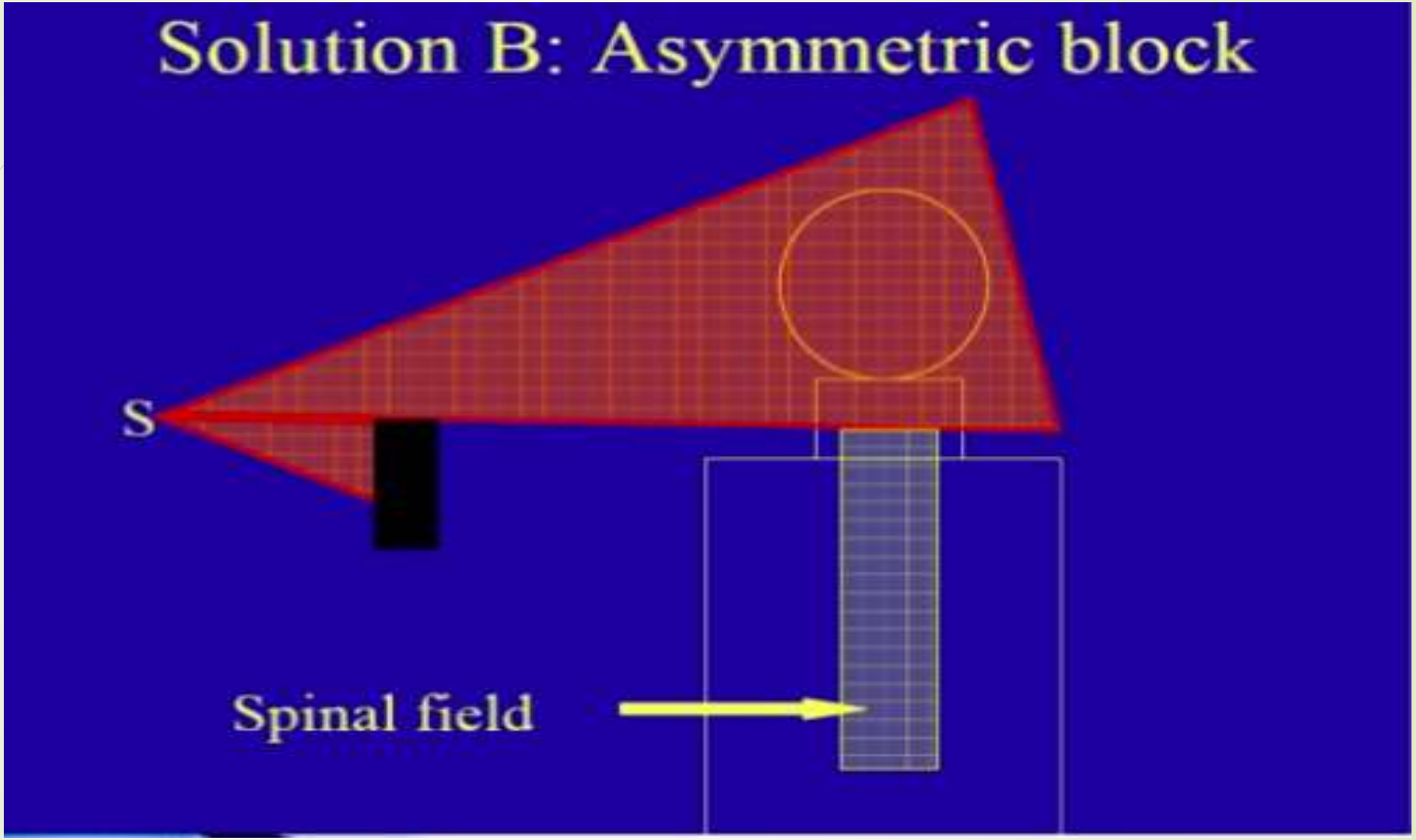
Technique for matching brain and spine field:

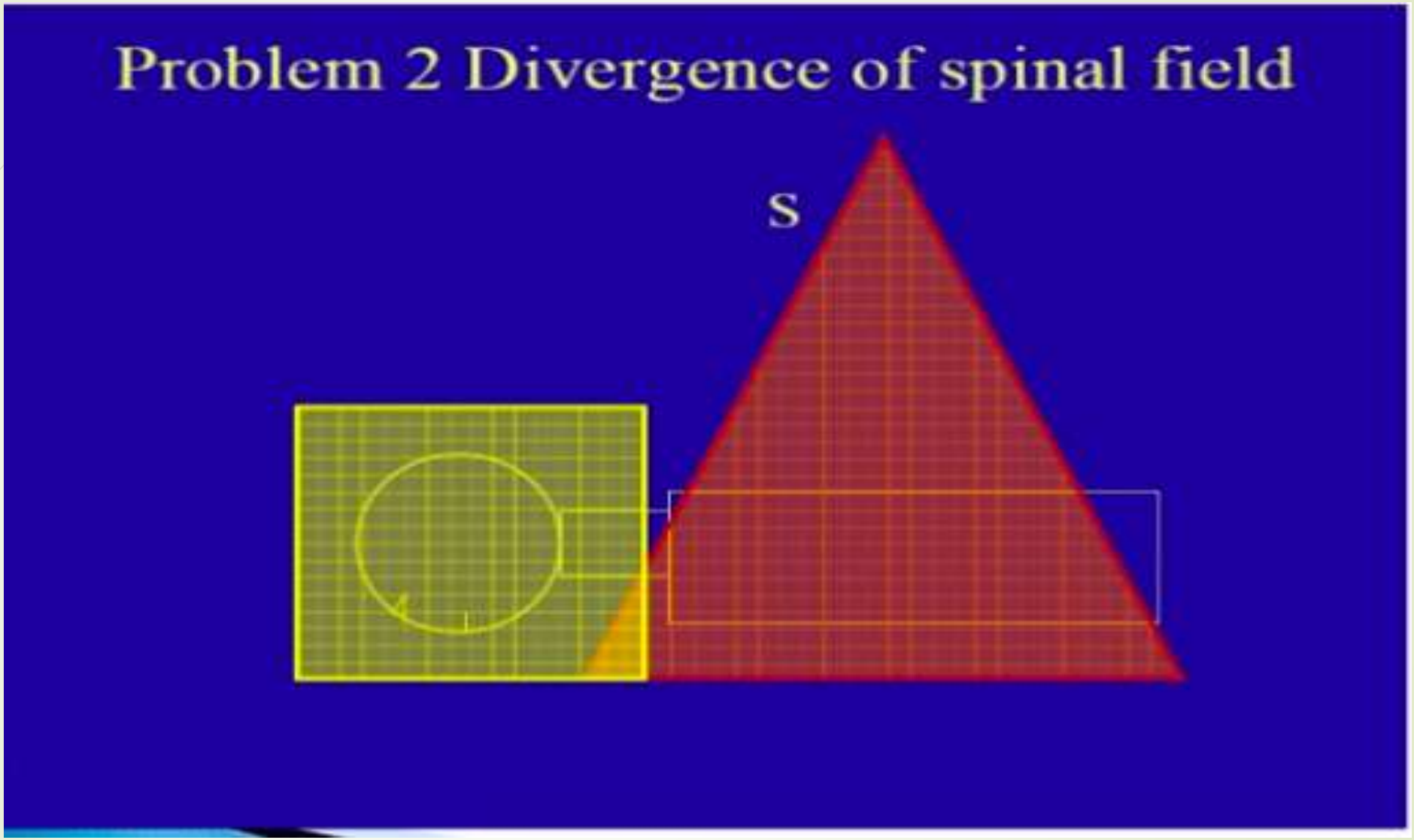
- In order for the spine field to match diverging cranial fields, couch must rotate **toward the gantry**
- Angle of "couch kick" can be calculated with the following equation:

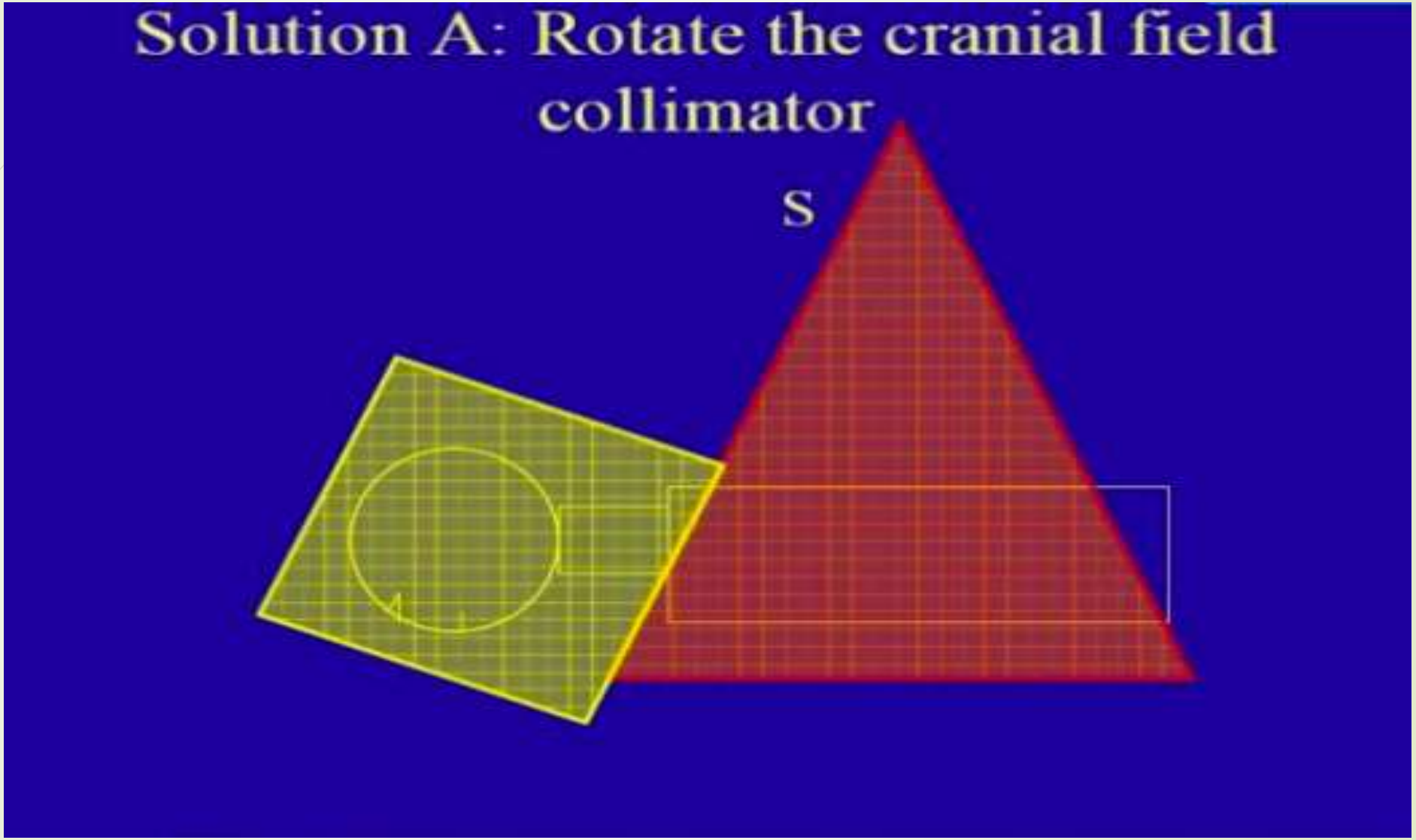
$$\theta_{couch} = \arctan\left(L_2/2*SAD\right)$$

L_2= length of lateral cranial field

SAD = source to axis distance of lateral cranial field


Solution B: Asymmetric block
S
Spinal field


Problem 2 Divergence of spinal field
S


Solution A: Rotate the cranial field collimator
S

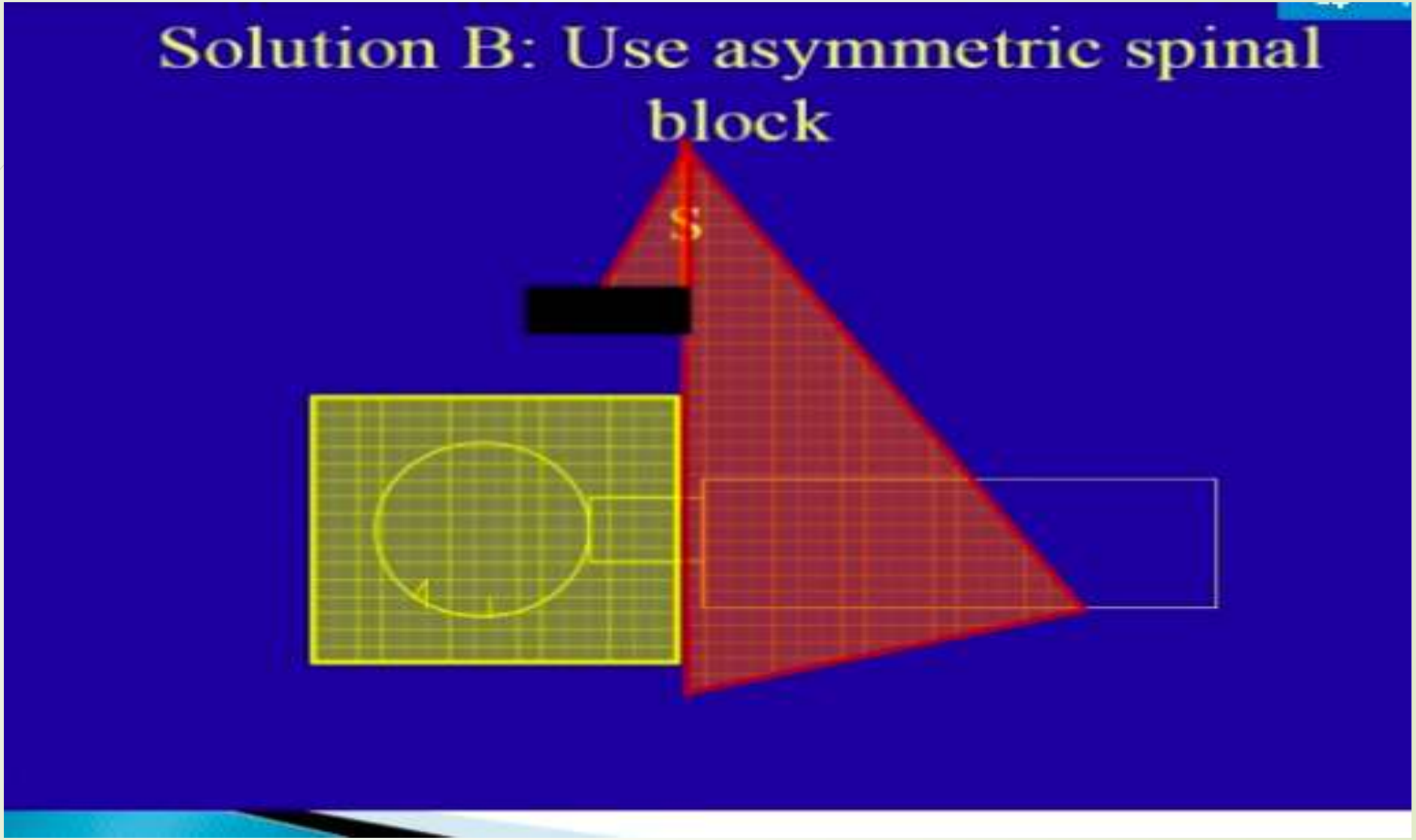
Technique for matching brain and spine field:

- In order for the cranial field to match diverging spine fields, the collimator must rotate
- Angle of collimator rotation can be calculated with the following equation:

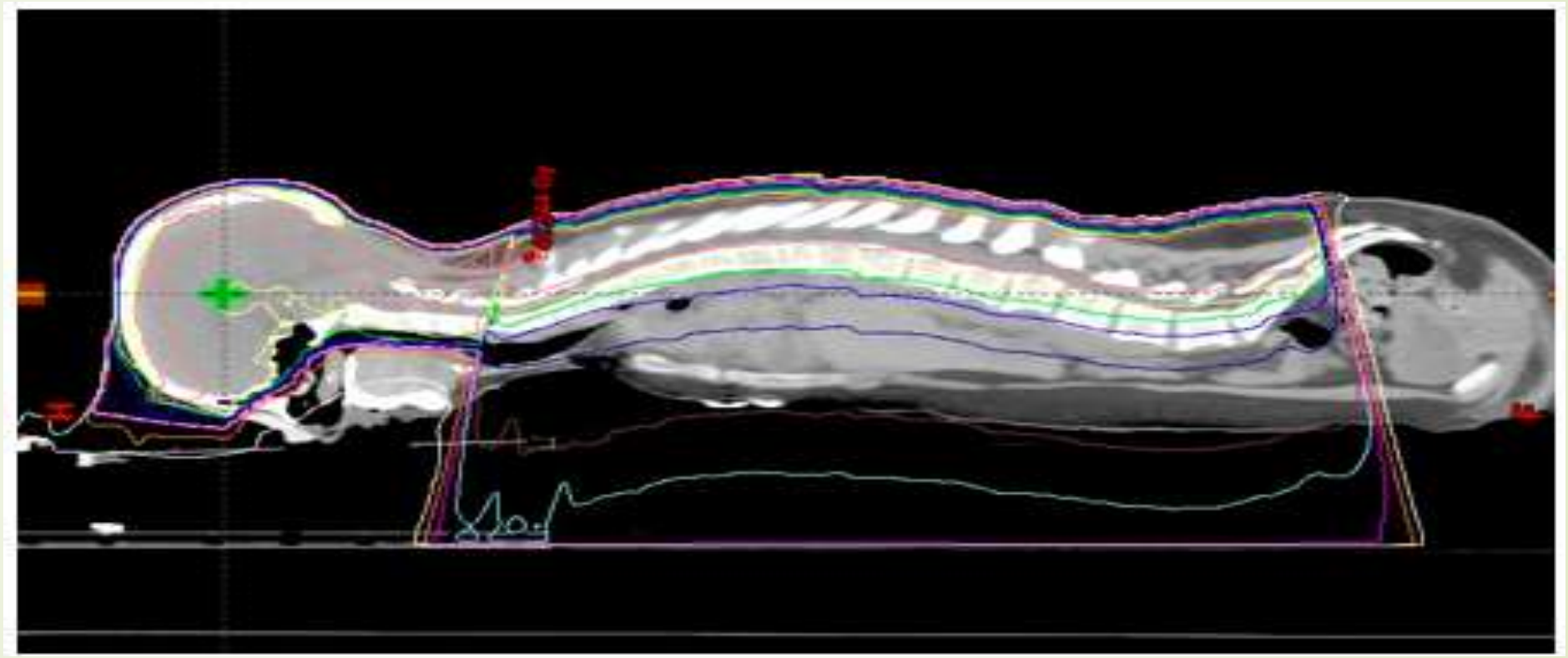
$$\theta_{coll} = \arctan\left(L_1/2*SSD\right)$$

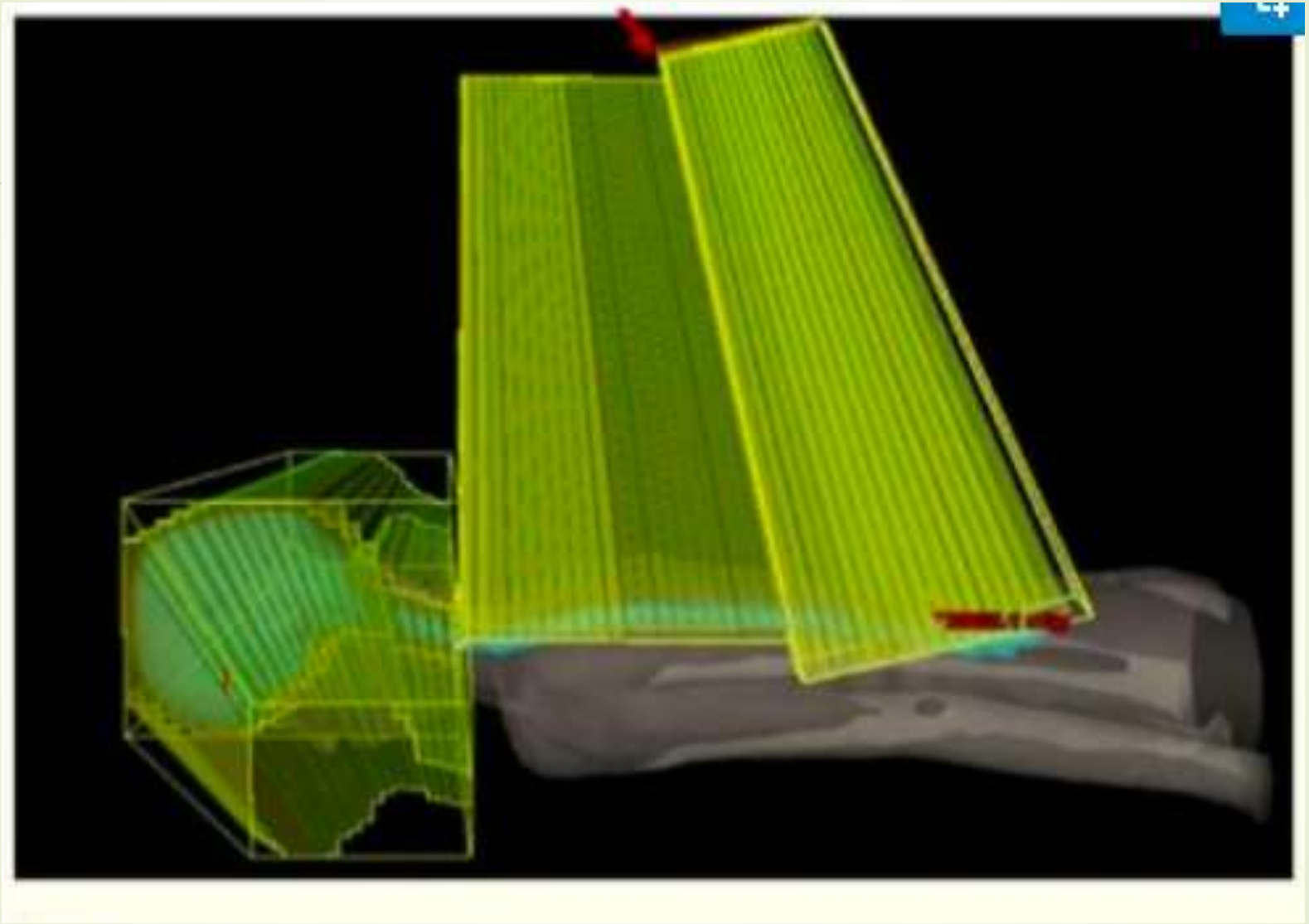
L_1= length of posterior spine field

SSD = source to surface distance of posterior spine field


Solution B: Use asymmetric spinal block
S

CSI BY 3DCRT



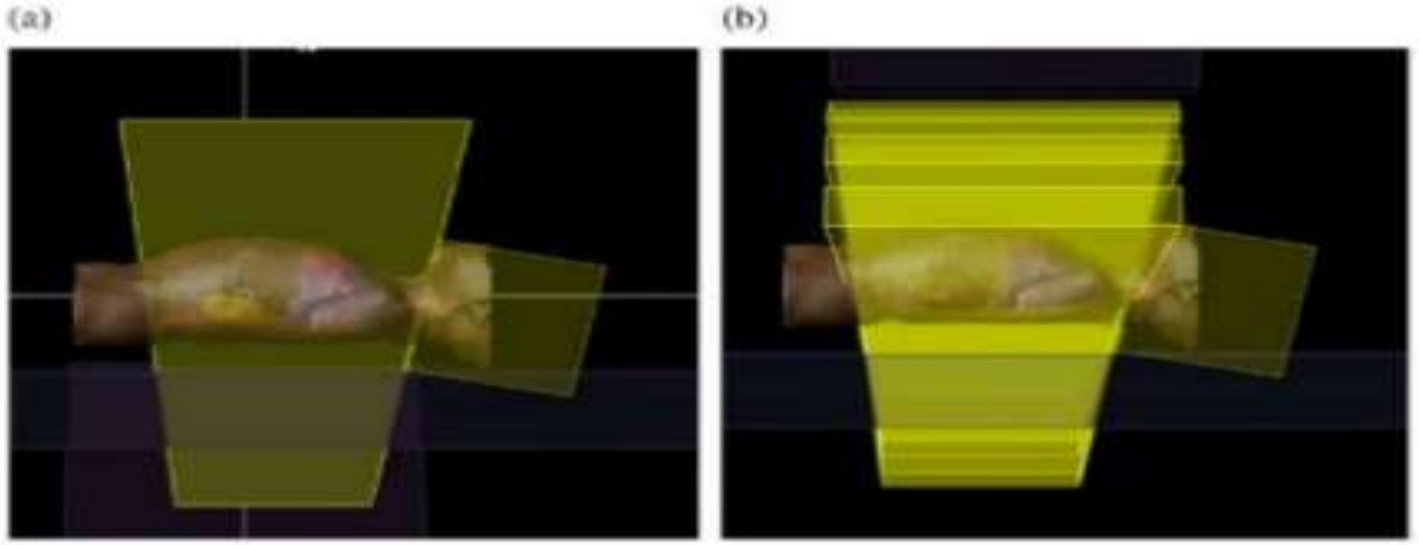


After CSI to 23.4 Gy, patient received limited target boost to tumor bed with IMRT photons to a total dose of 54 Gy

- GTV:
  - tumor bed + gross residual disease, including T1 signal abnormality with and without contrast
  - Do not include surgical defects visible on post-op MRI that did not contain disease on pre-op MRI
- CTV:
  - GTV + 1 – 1.5 cm
  - excluding bone, tentorium, and entirety of brainstem (however, brain stem immediately adjacent to tumor bed should be included as this is an area of potential microscropic disease)
- PTV:
  - CTV + 3 – 5 mm

CSI BY IMRT

- IMRT plans provided better healthy tissue sparing than either the 2D or the 3D plans.
- IMRT results in better sparing of OARs without a significant increase in integral dose.



CSI BY VMAT

Target volumes:

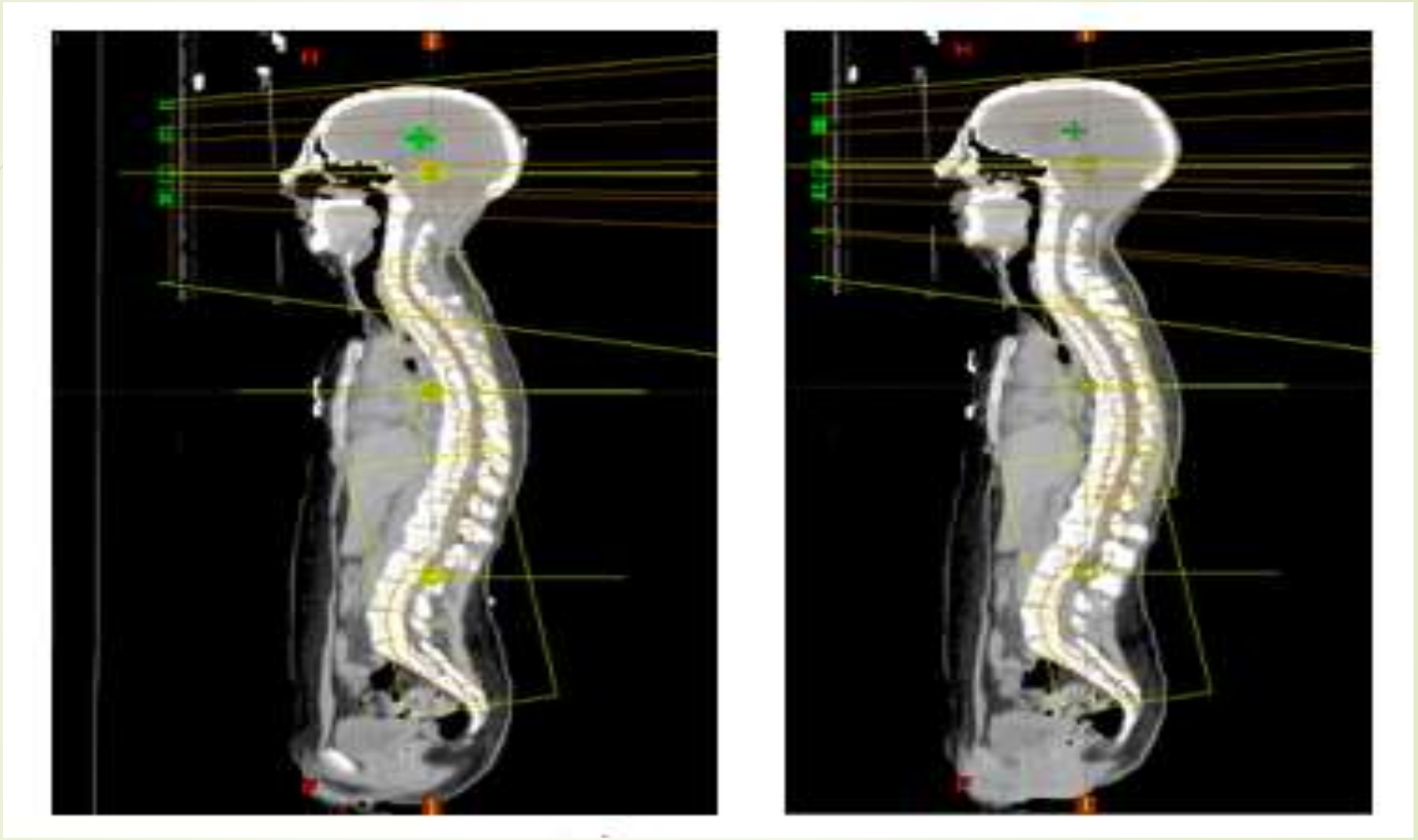
- PTVBrain = CTV Brain + 3mm (incl. Optic Nerves)
- PTVSpine C1-L2 = Spinal Canal + 0.5cm Margin
- PTVSpine L3-S3 = Spinal Canal + 0.8cm Margin

Isocentres:

- Typically 3 (Brain, SUP Spine and INF Spine)
- Placed mid plane and optimally at ANT/POST level that can be maintained for other isocentres
- Spinal levels T6, L3 (similar field lengths)

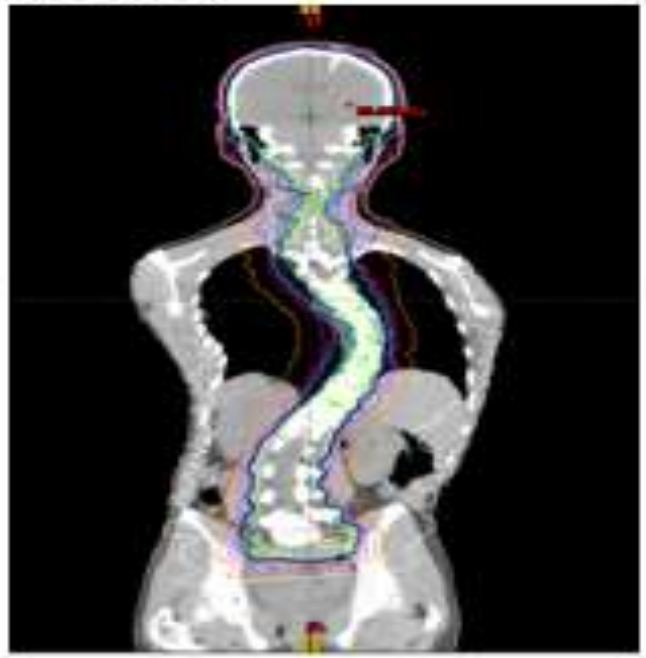
Fields:

- Brain iso treated with 2 full arcs
- Spine iso's treated with posterior arcs (Prone) or full arcs with avoidance sectors for arms (Supine)
- One arc of each Isocentre overlapping
- 6-8cm overlap



3DCRT VS. VMAT

- Advantages VMAT
  - More homogenous and conformal dose distribution
  - Patient comfort
  - Decreased dose to certain OARs
  - Unique cases
- Disadvantages VMAT
  - Integral dose
  - Treatment and planning time
  - Amount of imaging required



CSI BY VMAT

Int. J. Radiation Oncology Biol. Phys., Vol. 82, No. 2, pp. 1006–1012, 2012

0360-3016/$ – see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2010.12.033

PHYSICS CONTRIBUTION

DEVELOPMENT AND EVALUATION OF MULTIPLE ISOCENTRIC VOLUMETRIC MODULATED ARC THERAPY TECHNIQUE FOR CRANIOSPINAL AXIS RADIOTHERAPY PLANNING

YOUNG K. LEE, PH.D.,* CORRINNE J. BROOKS, B.SC.,* JAMES L. BEDFORD, PH.D.,*
ALAN P. WARRINGTON, M.SC.,* AND FRANK H. SARAN, M.D., F.R.C.R.†

- A reduction of late sequelae and thus improved quality of life may be achieved by the use of VMAT.
- A VMAT planning solution for different lengths of craniospinal axis has been developed, with significant reductions in dose to the OAR around the brain, neck, and thoracic regions.
- HOWEVER there may be a risk of second malignancy due to increase of integral dose.

LATE EFFECTS OF RADIOTHERAPY

Decreased IQ

Decreased growth

Ototoxicity

Hypopituitarism

Secondary malignancy

IQ OUTPPUT

- Keeps deteriorating for >5yrs after treatment.
- Greater decline if:

Age < 7yrs

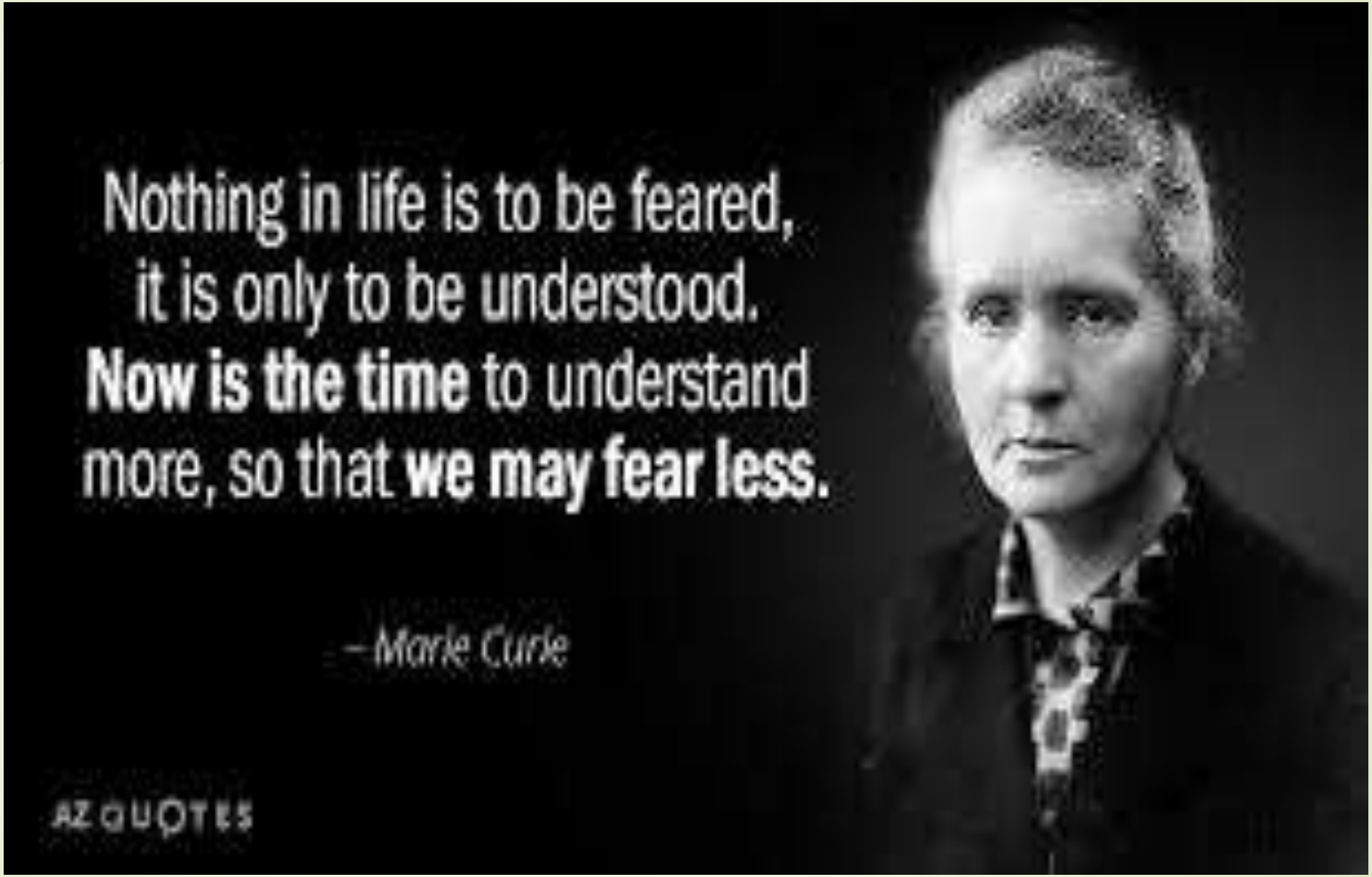
Higher dose

Higher IQ at initiation of treatment

Female gender

TAKE HOME MESSAGE

- Physics along with clinical anatomy should be very clear.
- Immobilization needs further improvisation.
- Ongoing trials about different dose-fractionation are awaited.
- Feathering or gap needs to be answered carefully during treatment
- IMRT, VMAT are replacing conventional mode but still need expertise.
- Move towards Particle Therapy.


Nothing in life is to be feared,
it is only to be understood.
Now is the time to understand
more, so that we may fear less.
—Marie Curie
AZ QUOTES