CRANIOSPINAL-IRRADIATION: INDICATION, PHYSICS & CLINICAL ASPECTS

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ROADMAP

- INSERT A ROADMAP WITH FOLLOWING POINTS
- History
- Rationale
- Indications and physics
- Problems and solutions in delivering
- Newer modalities

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

Series or parallel organs

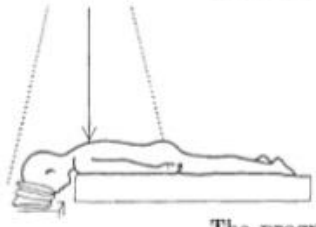
History

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*



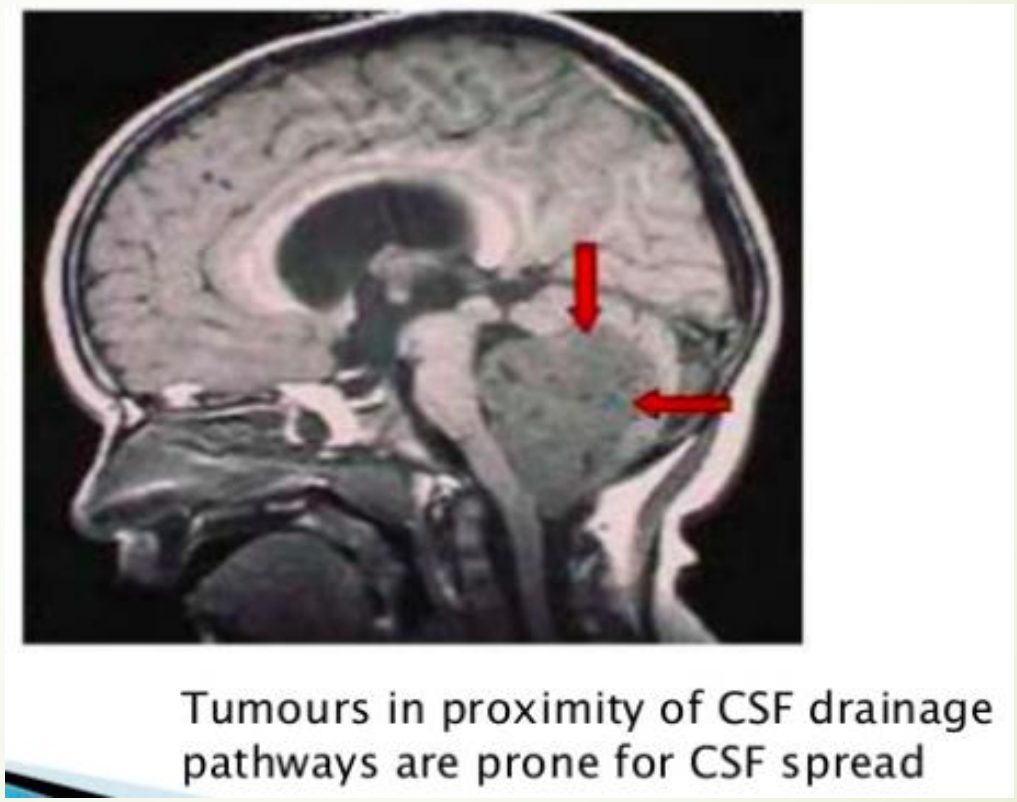
Introduction

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;

INDICATIONS

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

TUMORS PRONE FOR CNS DRAINAGE



Tumours in proximity of CSF drainage pathways are prone for CSF spread

RATIONALE

- Medulloblastoma forms the most common indication for CSI

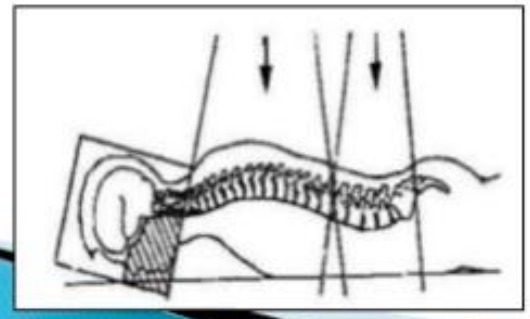
- In medulloblastoma , CSF Dissemination is known in 20 – 30 % of cases, producing a risk of metastases along the neuraxis.

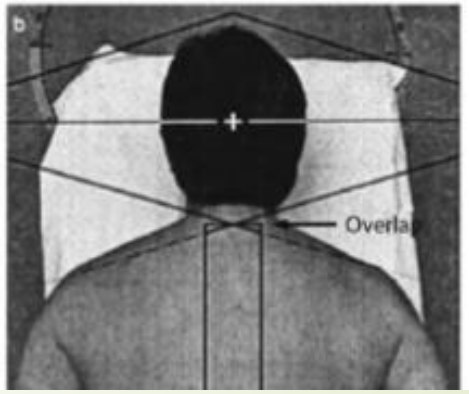
- Posterior fossa, spinal cord, ventricular walls & supratentorial region including the cribriform plate form the main sites of relapse

- Being a radiosensitive tumour, RT is curative in upto 70 % of average risk patients

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.





WHAT SHOULD BE OUR AIM

Proper immobilisation

Dose homogeneity in the planning target volume

Reducing the dose to organs at risk.

- Evaluating the integral dose (ID) received by normal tissue.
- Reduce the planning time and waiting time for patients to start their radiotherapy course.

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)

CSI (Phase I)

- 30 - 36 Gy in 18 - 21 fr over 4 weeks to the cranium @ 1.5- 1.8 Gy/fr

(36 Gy in 20# over 4 weeks to the cranium @ 1.8 Gy per #)

- 30 - 36 Gy in 18 - 21 fr over 4 weeks to the spine @ 1.5 -1.8 Gy/fr

(36 Gy in 20# over 4 weeks to the spine @ 1.8 Gy per #)

Posterior fossa boost (Phase II)

- 18-20 Gy in 10-11 fr over 2 weeks to the posterior fossa

(18 Gy in 10# over 2 weeks to the posterior fossa @ 1.8Gy/#)

OTHER TRIALS

Critical Normal Structures (OAR)

- Pituitary
- Eyes / Lens
- Cochlea / Inner ear
- Parotid
- Oral cavity
- Mandible
- Thyroid
- Larynx
- Heart
- Lungs
- Oesophagus
- Liver
- Kidneys
- Gonads (Testes / Ovaries)
- Breasts
- Whole Pelvis(marrow)

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.

Supine

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

BUT

- · Direct visualisation of spinal field is not possible

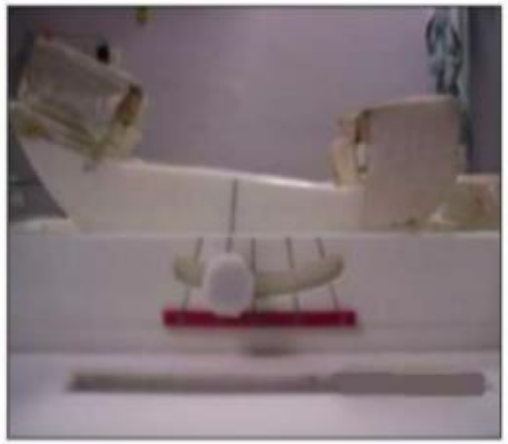
IMMOBILISATION

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)

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

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

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.

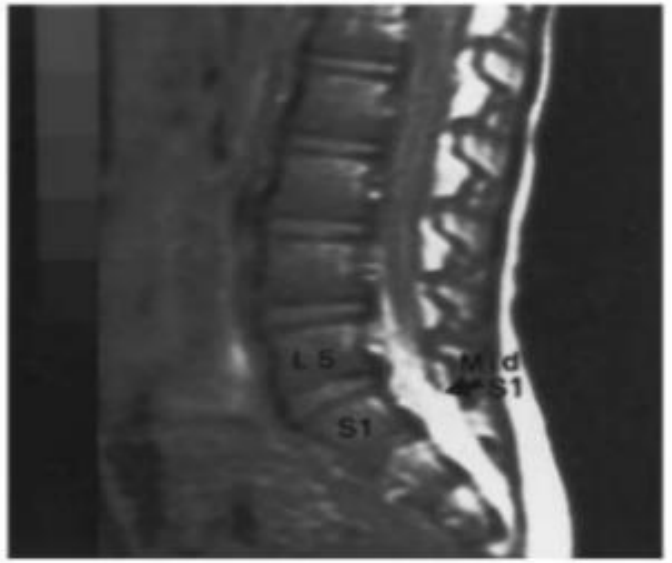


Fig. 1. Magnetic resonance imaging (MRI) of the spine showing thecal sac termination (arrow) at the mid-S1 vertebral level.

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

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 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

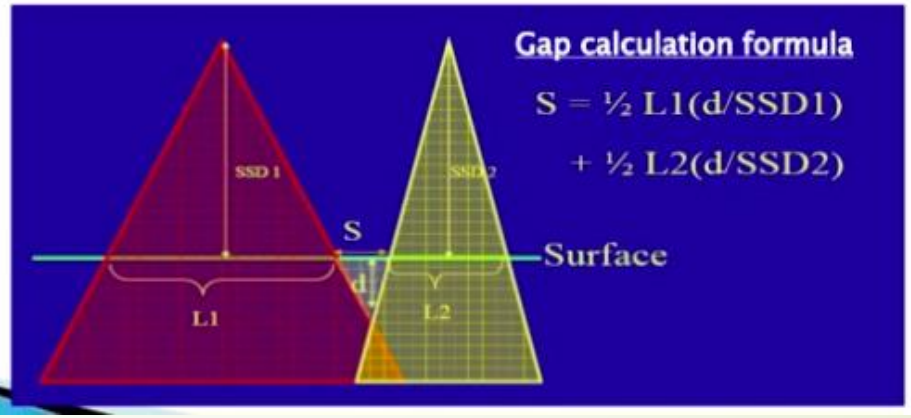
Are moving junctions in craniospinal irradiation for medulloblastoma really necessary?

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

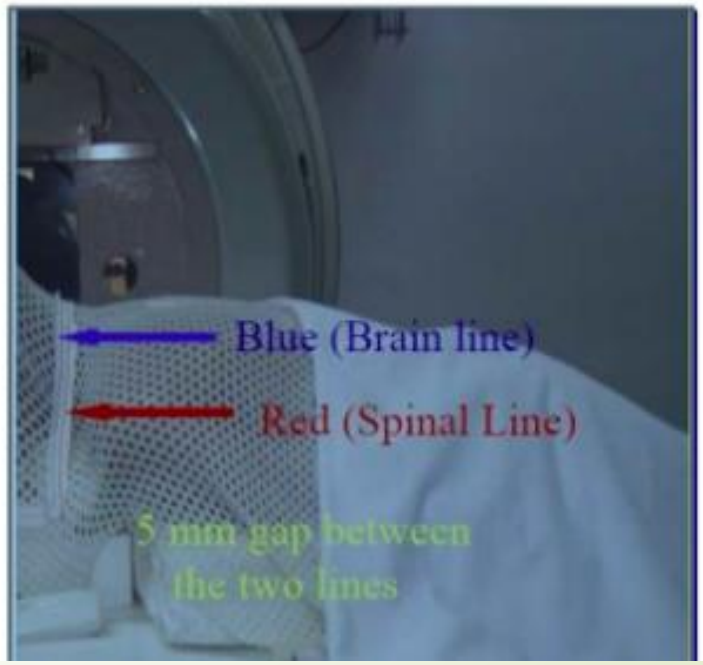
Gap: Fixed or Calculated

- 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



- 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



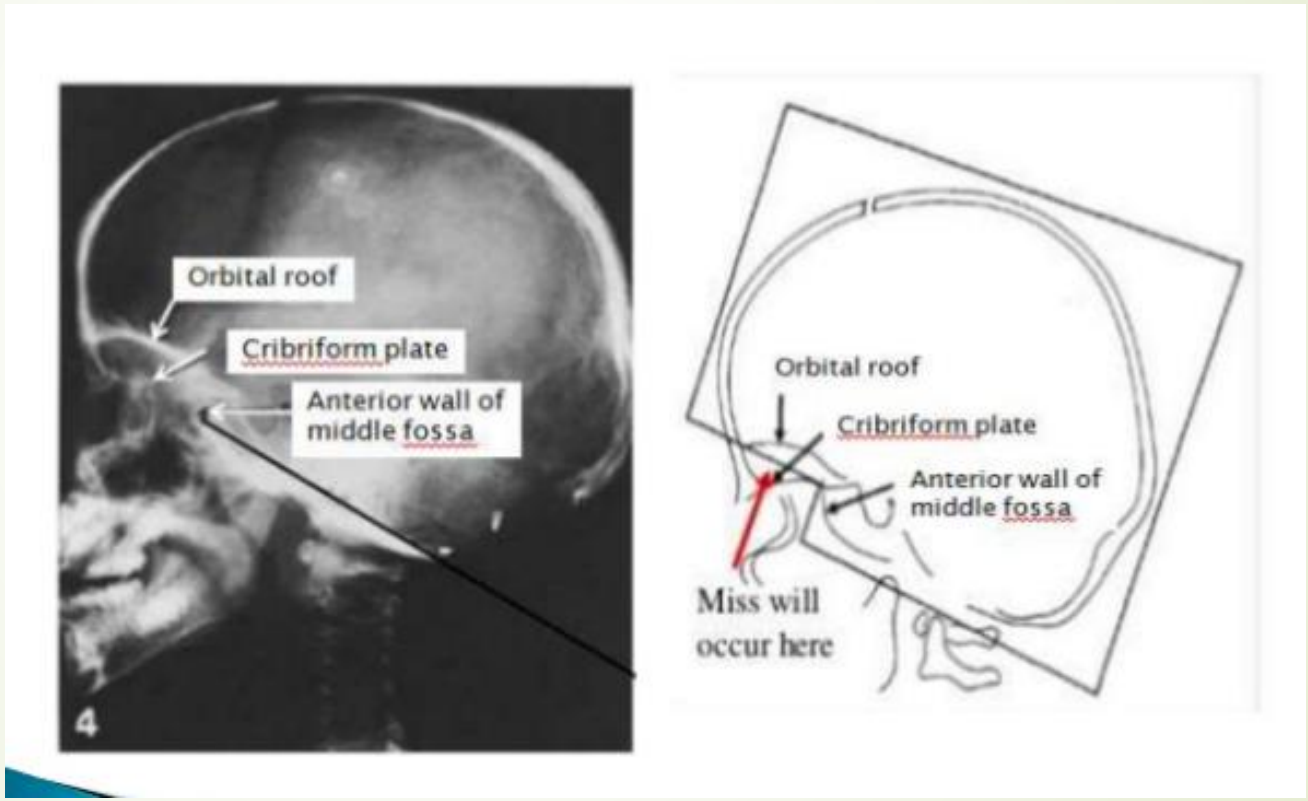
- Width - vertebral body + 1 cm to include the intervertebral foramina; usual width 5 - 7 cm.

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.


Orbital roof
Cribriform plate
Anterior wall of middle fossa
4
Orbital roof
Cribriform plate
Anterior wall of middle fossa
Miss will occur here

Shielding

- Most important is what not to shield

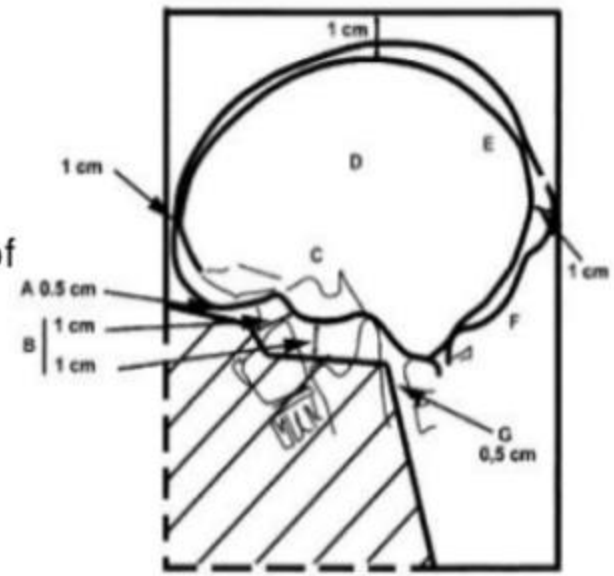
- ·Frontal (cribriform plate)
- ·Temporal region

- 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.

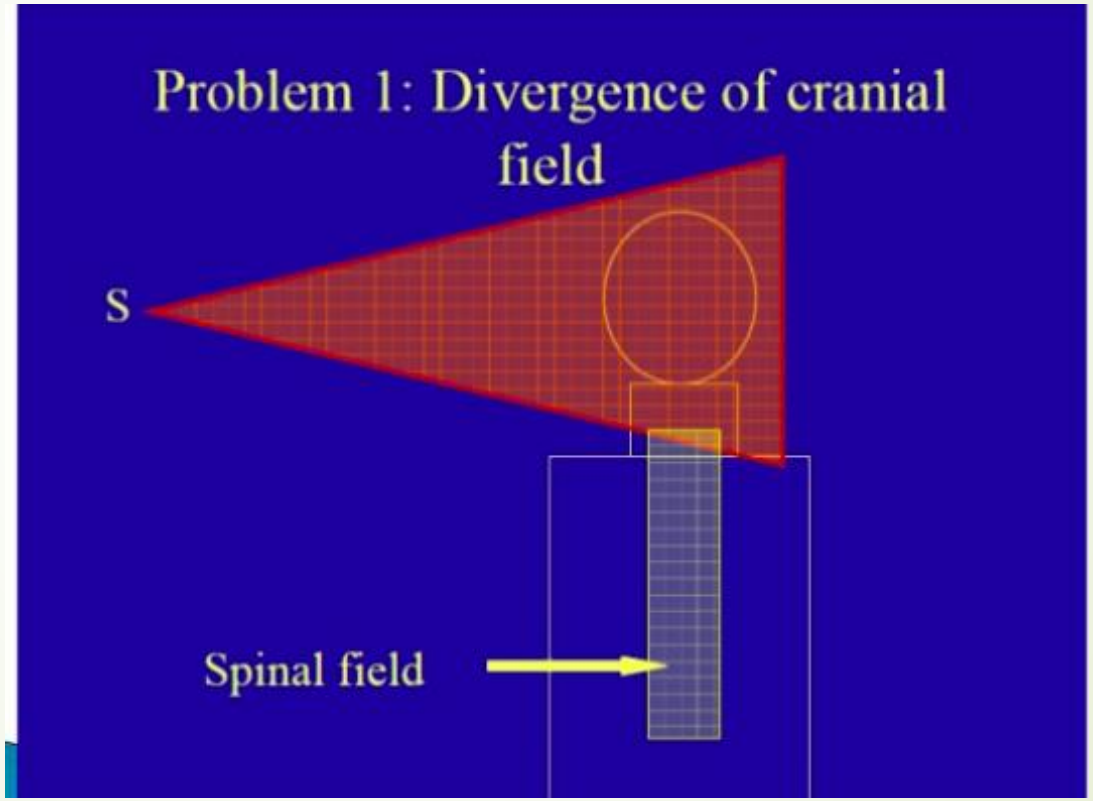
SFOP (French society Paediatric Oncology) Guideline- The recommended placement of block is

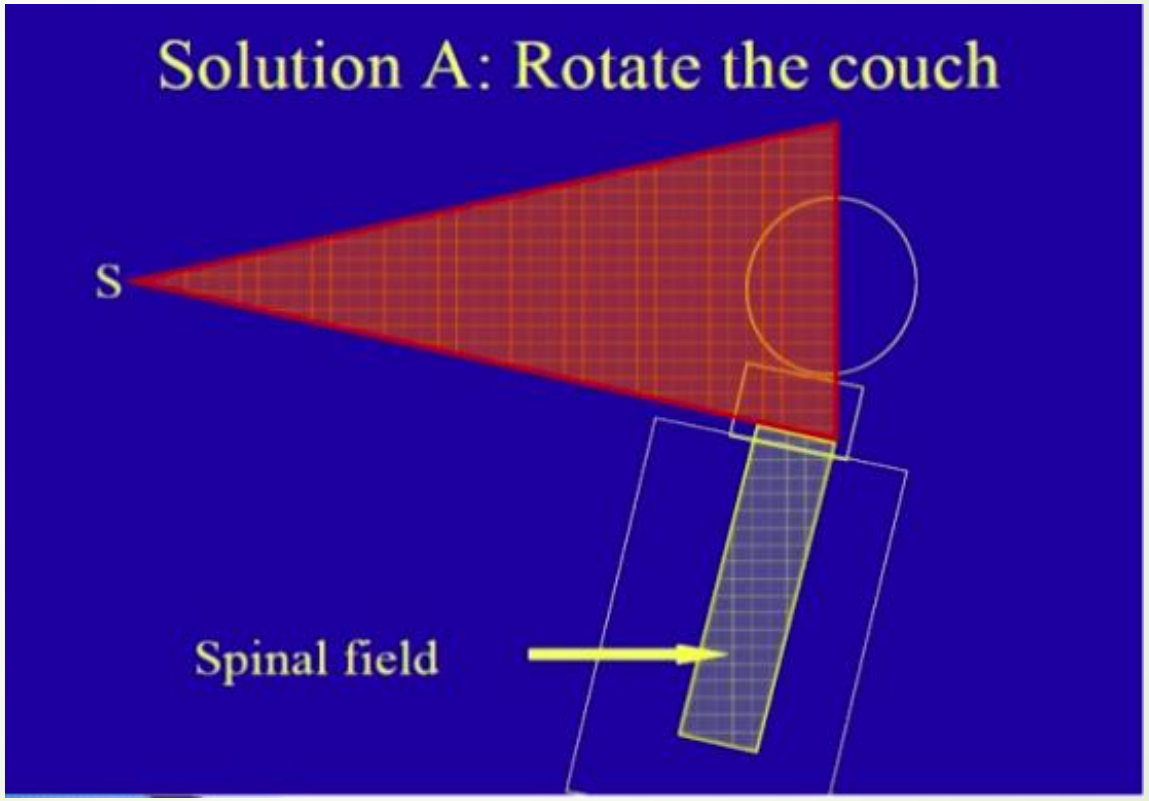
0.5cm below orbital roof

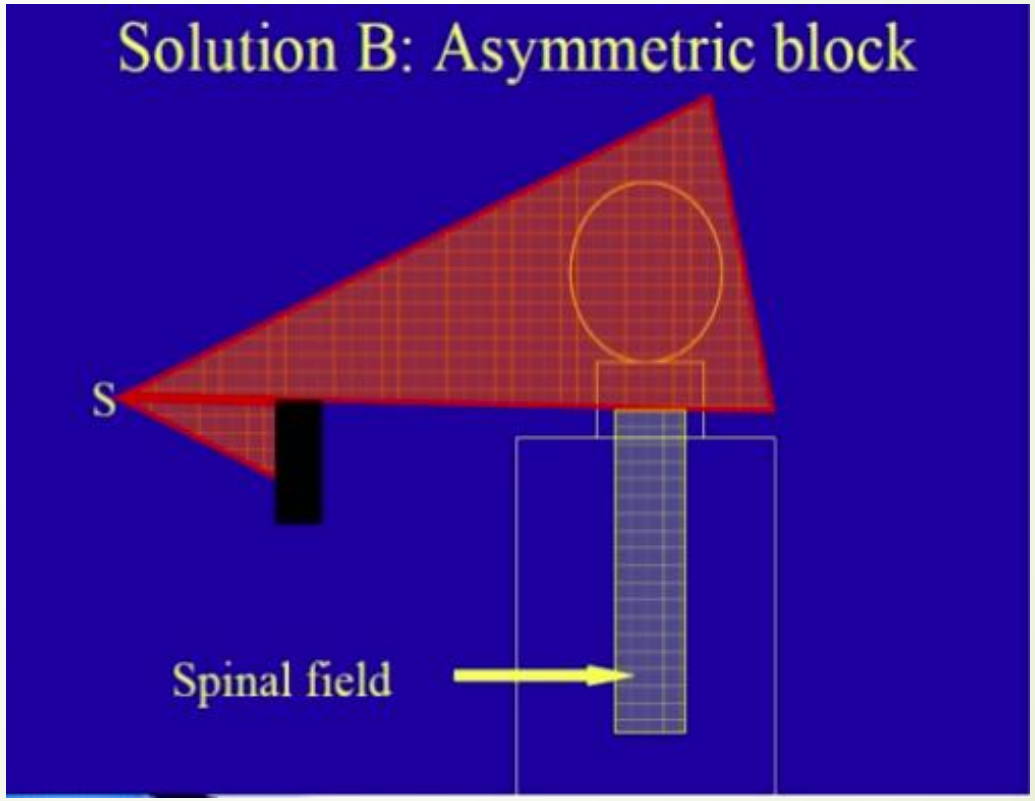
1cm below and 1cm in front of the lower most portion of the temporal fossa

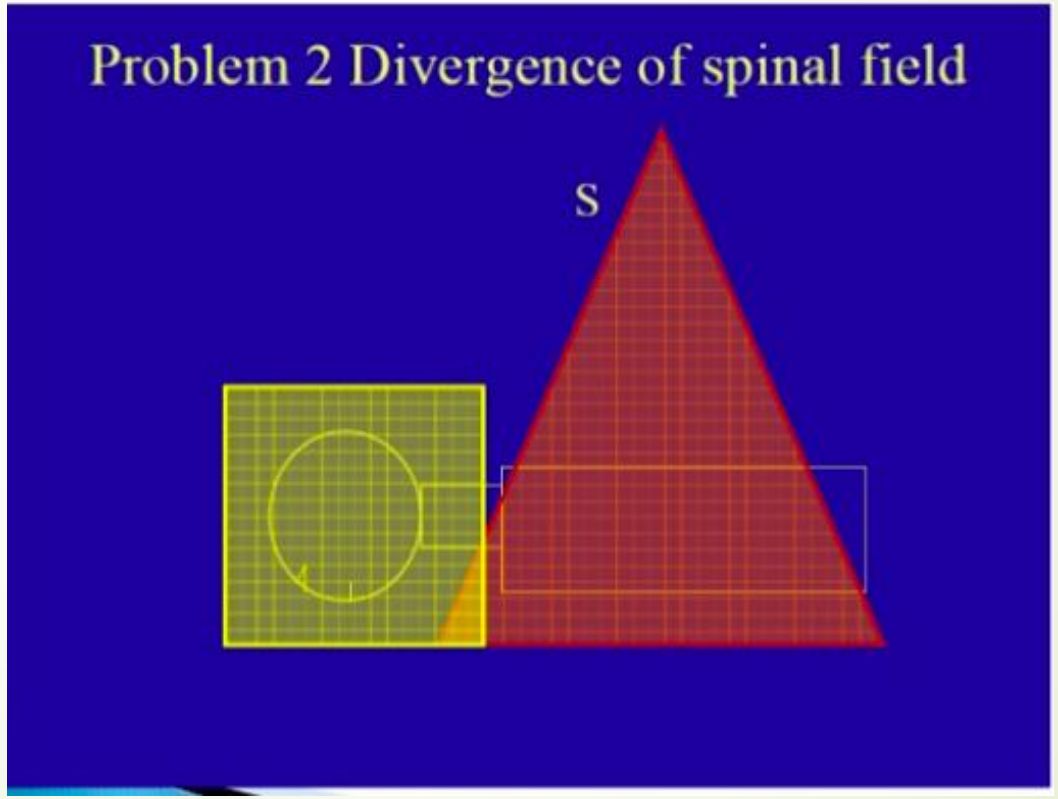


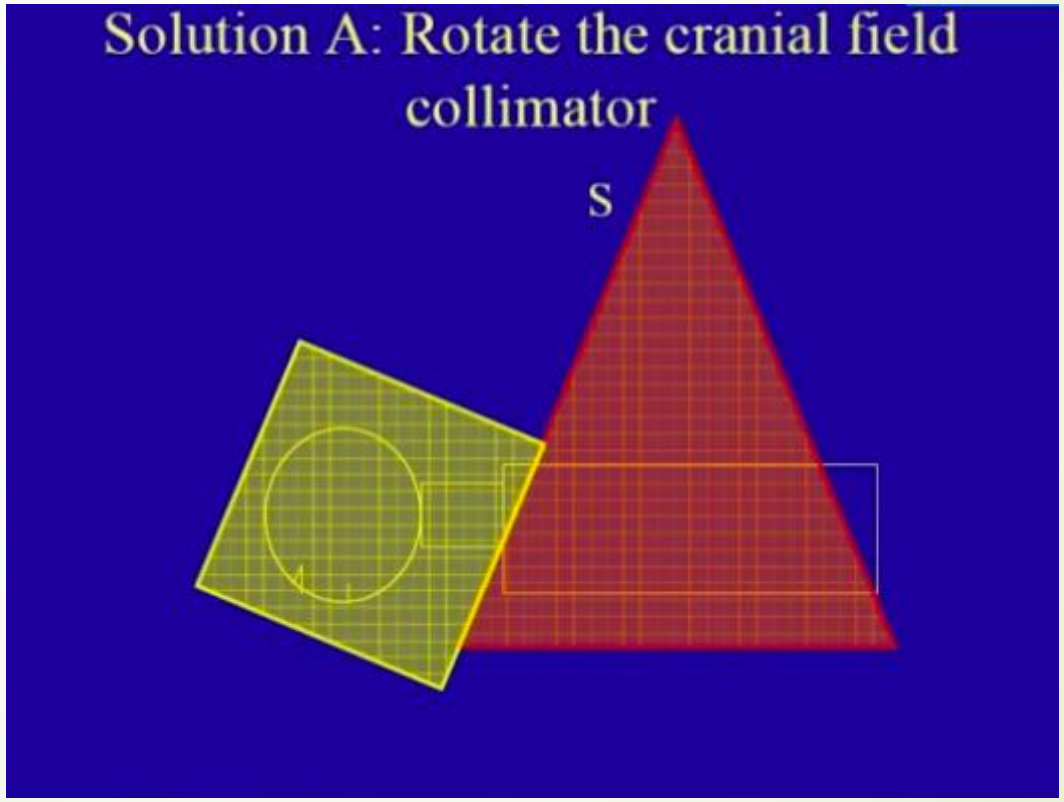
How to match cranio spinal junction

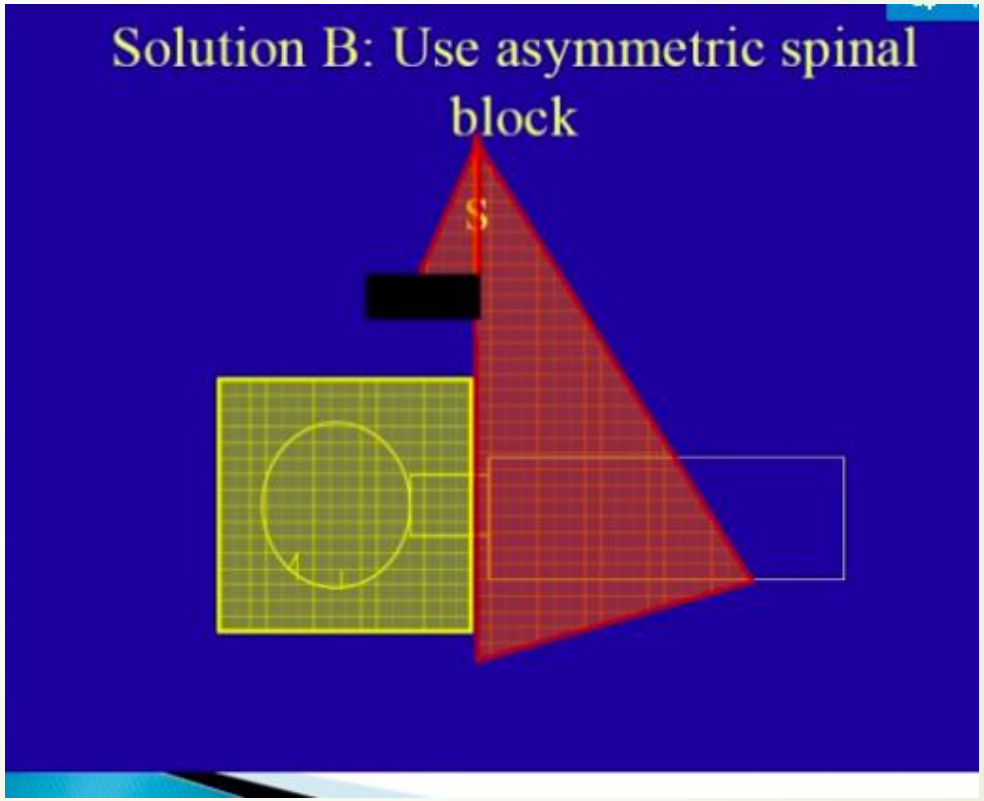

Problem 1: Divergence of cranial field
S
Spinal field


Solution A: Rotate the couch
S
Spinal field


Solution B: Asymmetric block
S
Spinal field

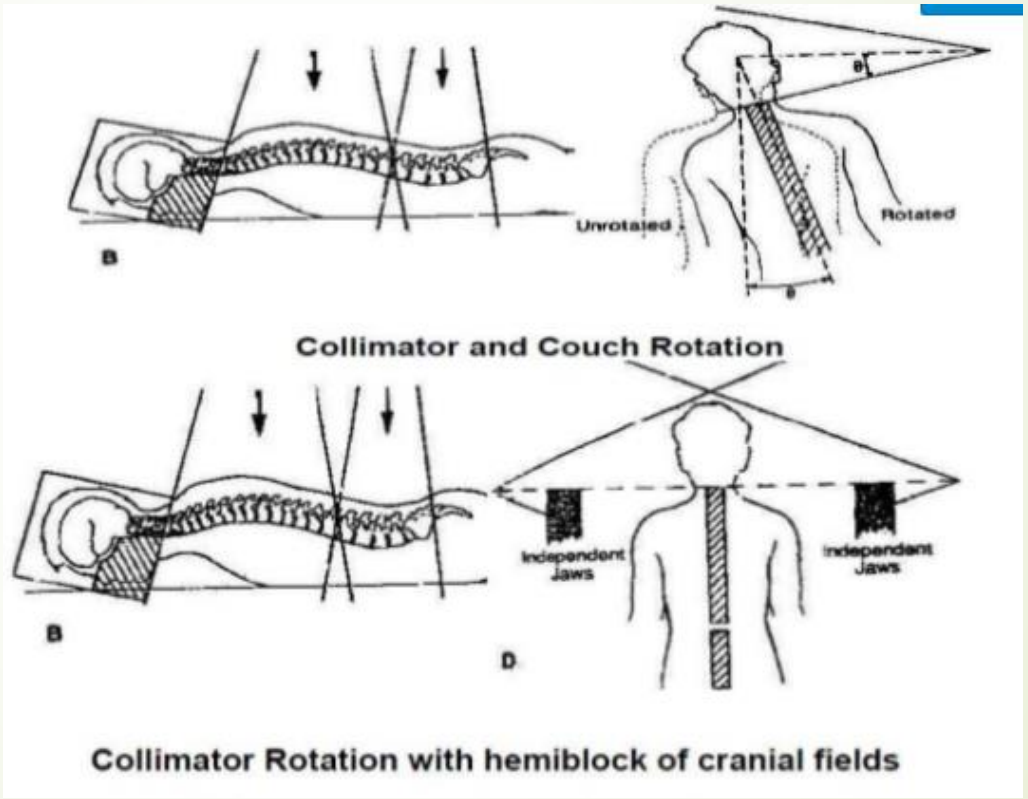

Problem 2 Divergence of spinal field
S

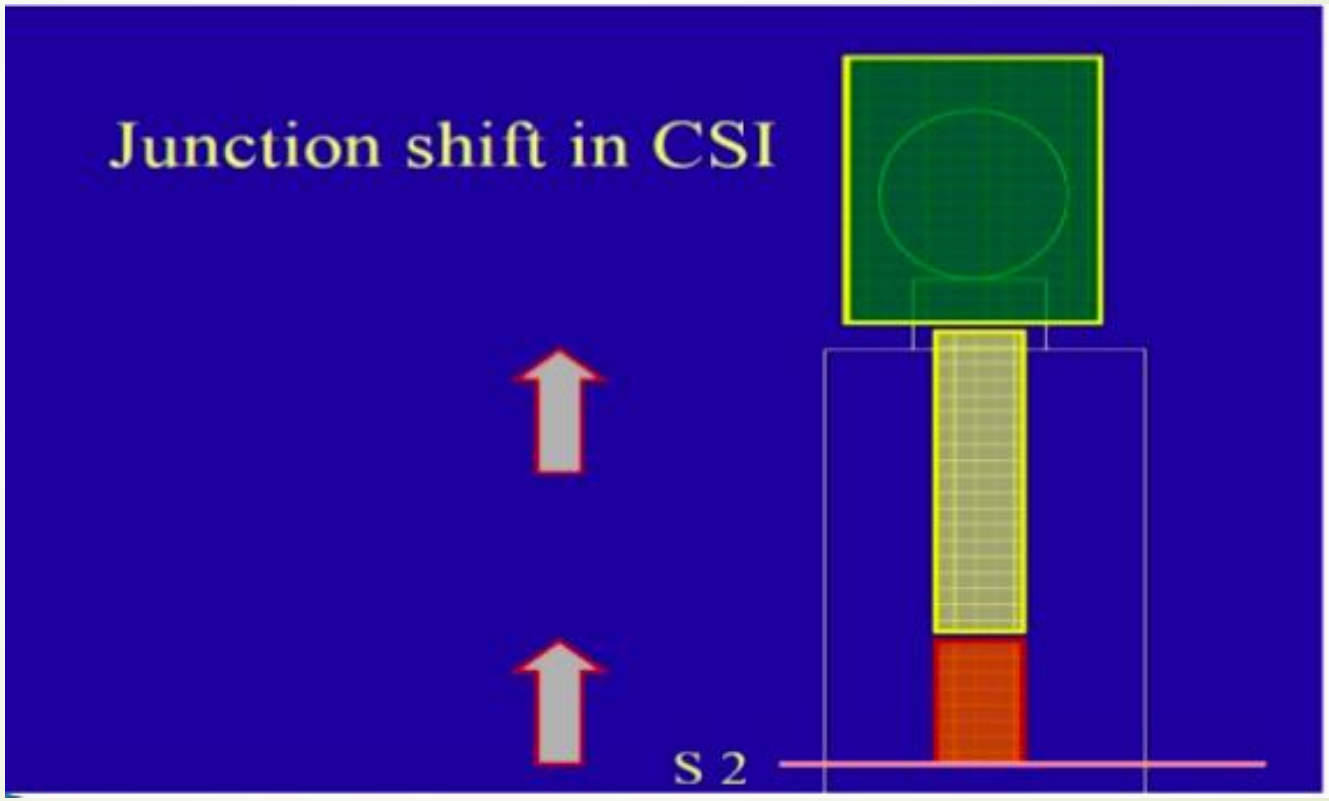

Solution A: Rotate the cranial field collimator
S

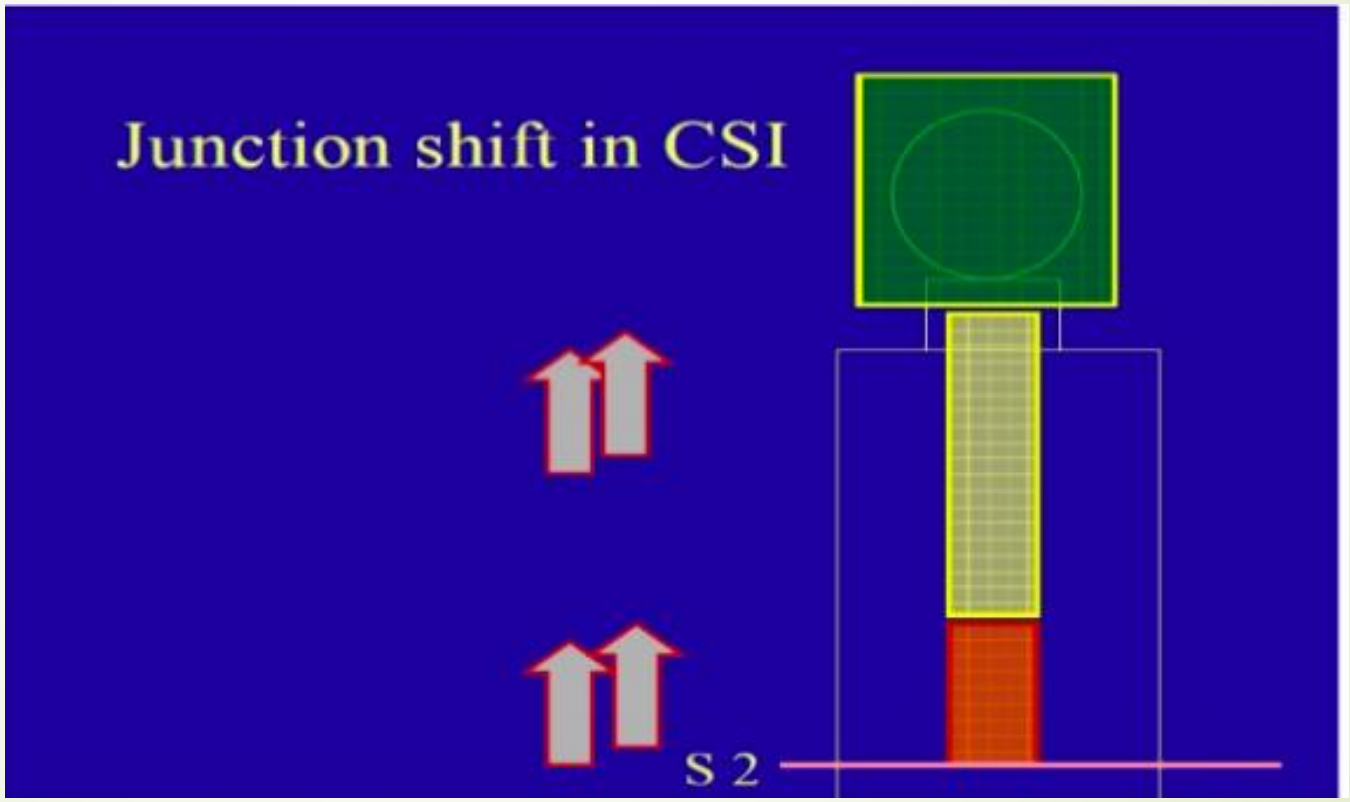

Solution B: Use asymmetric spinal block
S

Collimator-Couch rotation

- Classically described technique.
- Divergence of *spinal field* into the cranial field is overcome with collimator rotation.
- Divergence of *cranial field* into spinal fields is overcome with couch rotation(rotated so that the foot end moves towards the gantry).
- Both rotations are performed during irrediation of the cranial fields.


B
Unrotated
Rotated
θ
θ
Collimator and Couch Rotation
B
Independent Jaws
Independent Jaws
D
Collimator Rotation with hemiblock of cranial fields


Junction shift in CSI
S 2


Junction shift in CSI
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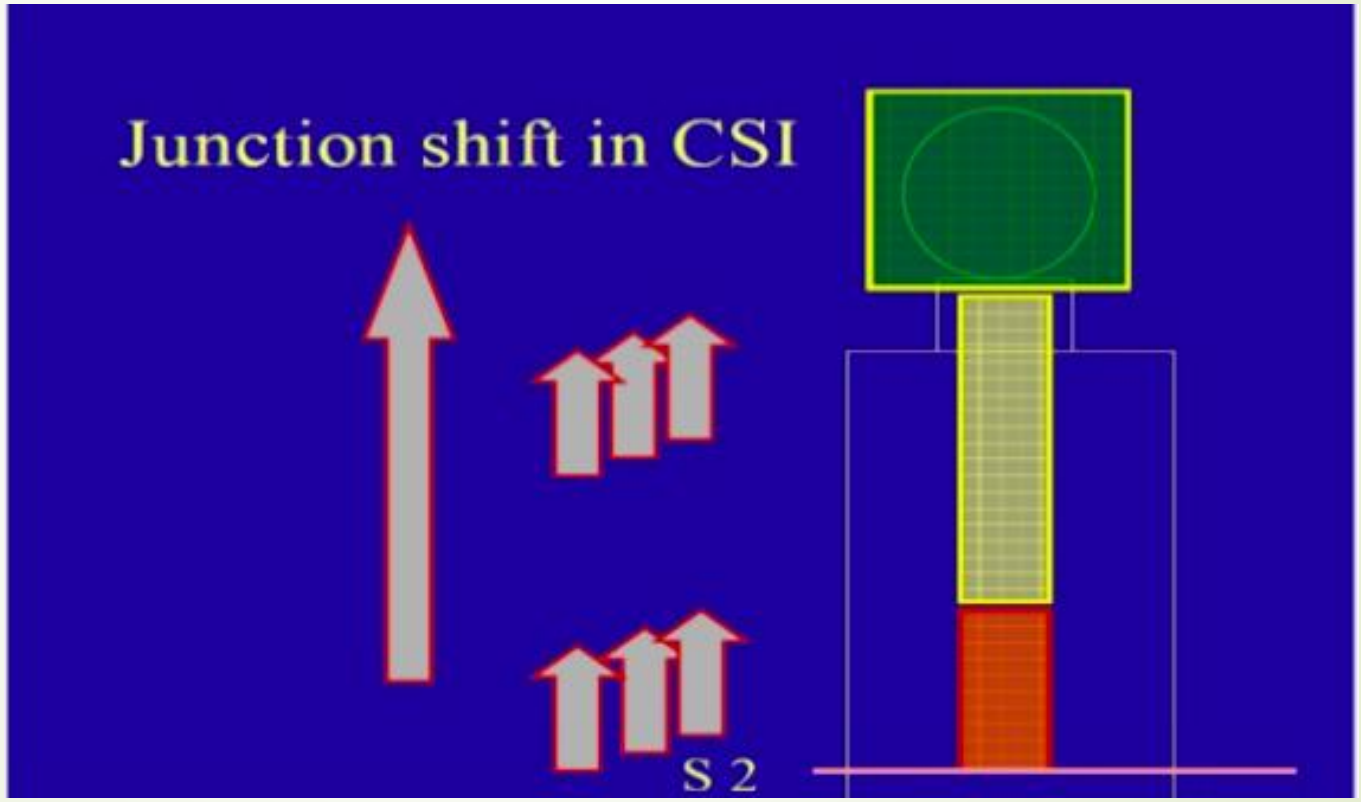

Junction shift in CSI
S 2

Extended SSD technique

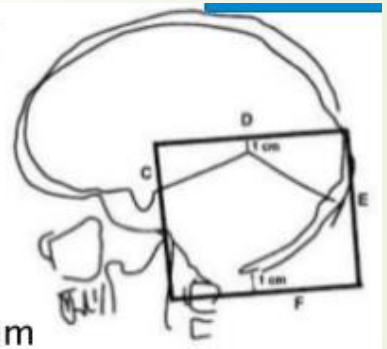
Advantage

- Single spinal field and circumventing the issue of junction between two spinal fields

Disadvantage

- Higher percentage depth dose and greater penumbra results in higher mean doses to all anterior normal structures,(mandible, esophagus, liver, lungs, heart, gonads and thyroid gland)

Posterior fossa boost

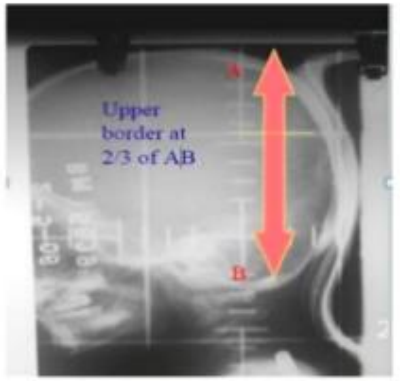


Borders

- ·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

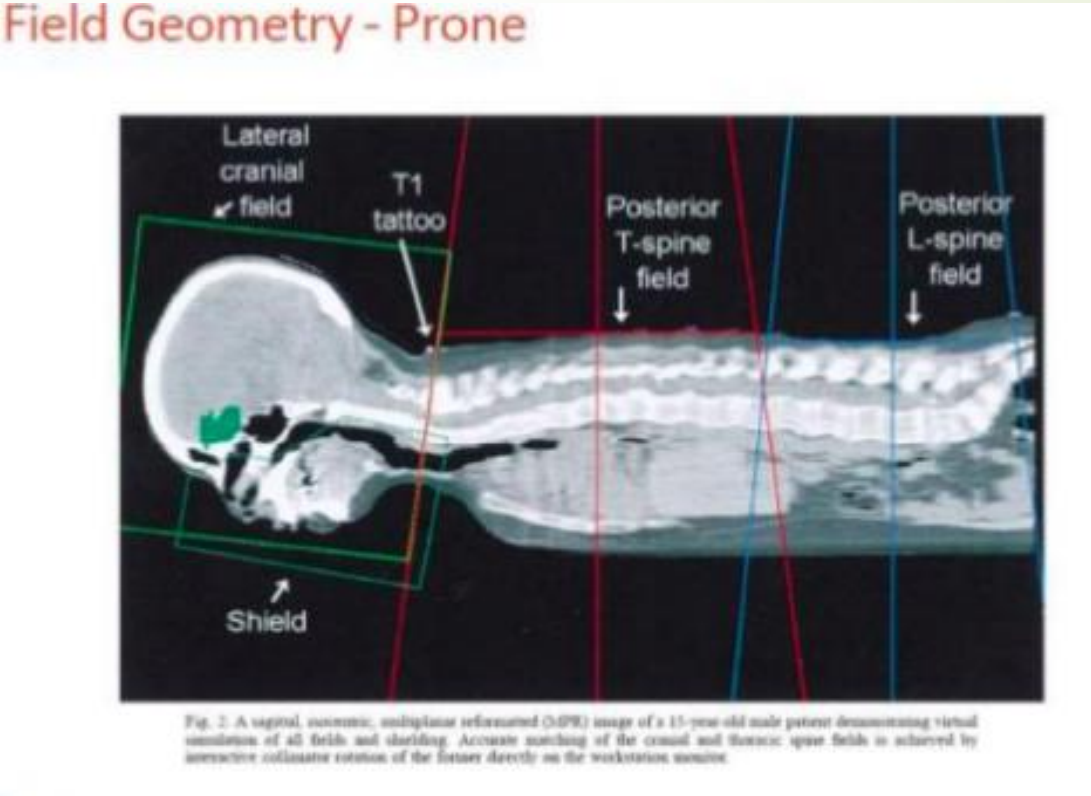
·Two lateral opposing fields.

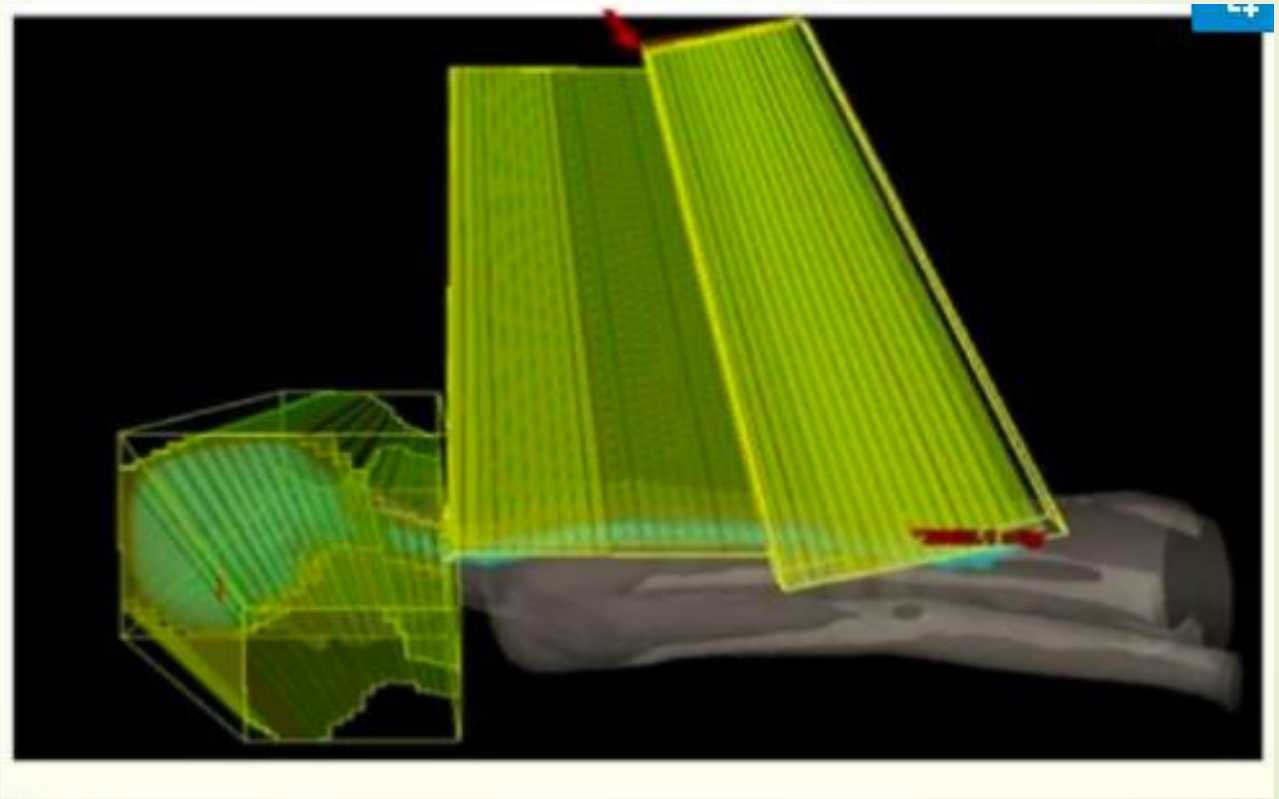


CT SIMULATION

- Patient positioned using all ancillary devices and the spinal columns aligned with the sagittal external laser.
- Three-fiducial reference marks placed on the mask in a transverse plane at the center of the head with the aid of the external laser.
- Spiral CT images of 5 mm from the vault of skull – bottom of sacrum, with 3mm slices through the primary tumor/bed are acquired.
- Target volumes and organs at risk are contoured on images.
- Co-registered MRI and CT data sets are used for target volume delineation.

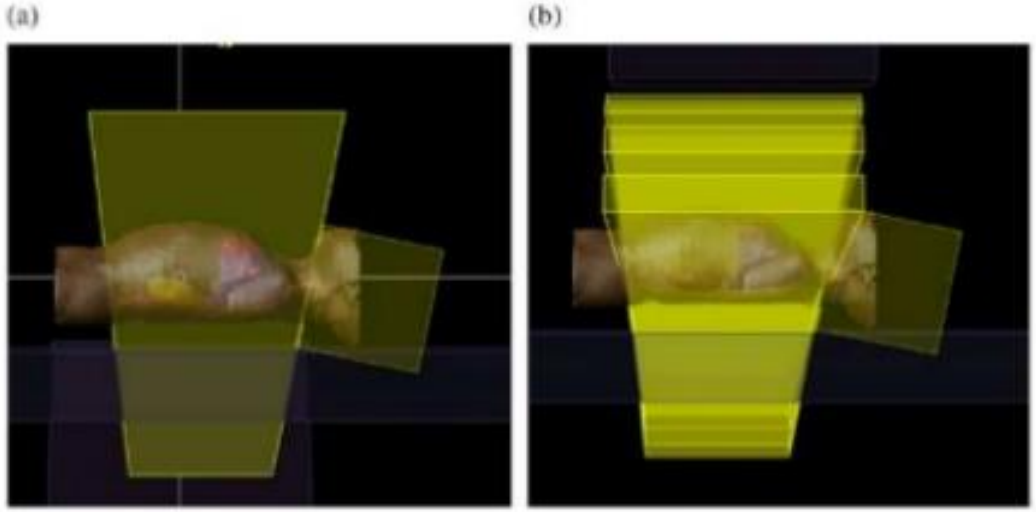
CSI BY 3DCRT


Field Geometry - Prone
Lateral cranial field
T1 tattoo
Posterior T-spine field
Posterior L-spine field
Shield



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

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.

CSI RELATED TOXICITIES

Acute Toxicity

- Within first few weeks
- Hair loss, skin reaction, sore throat, dysphagia, nausea and vomiting, fatigue
- Bone marrow suppression
- CNS toxicity
  - Acute radiation encephalopathy
  - Early cerebral necrosis

Late Toxicity

- After four weeks
- Bone marrow suppression
- CNS toxicity
  - Delayed cerebral necrosis
  - Delayed cranial nerve damage
  - Delayed radiation myelopathy
  - Delayed motor-neuron syndrome

SUMMARY

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

Medulloblastoma forms the most common indication for CSI.

There are ongoing trials for alternative dose of CSI to reduce toxicity- like reduced dosing schiduled with chemotherapy and HFRT.

In standard risk meduloblastoma, dose can be reduced to 23.4Gy along with chemotherapy but in high risk meduloblastoma dose reduction is not recommended.

Not to shield cribriform plate and Temporal region, as these are main site of recurrence due to overzealous shielding.

Craniospinal and two spinal fields are matched using different methods otherwise there may be over dose to spine and devastrating result will occur.

Feathering-Usually shifted by 1 to 2 cm at each shift, Done every 5# to 7#, Either in cranially or caudal direction.

IMRT, VMAT, IGRT, Tomotherapy, Proton therapy are now more homogenous treatment plans, where target is receiving required dose and OARs are having less dose.