Craniospinal Irradiation- from 2 D to Conformal RT

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- CSI has been the main stay of treatment for MB since 1970s….
- Red J Publication 1982

Int. J. Radiation Oncology Biol. Phys., Vol. 8, pp. 2023–2027
0360-3016/82/112023-05$03.00/0

● *Editorial*

MEDULLOBLASTOMA IN CHILDREN: INCREASING SURVIVAL RATES AND FURTHER PROSPECTS

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Over the past decade greater survival rates for children with medulloblastoma have been reported from a number of treatment centers following the use of improved cerebro-spinal axis megavoltage radiotherapy techniques and of higher doses of irradiation, particularly to the posterior fossa.[4,24,29,32–34] On the other hand, some very poor results have also been experienced,[14,22,23,26] presumably when those principles of treatment, based on the natural history of the disease, have not been applied.

In a previous editorial on this subject in 1977, I suggested that, since limitations are necessarily imposed on the extent of surgery and also on the dose of radiother-

histological type (non-desmoplastic), and especially evidence of brain-stem involvement at operation, may all adversely effect outcome.[2,8] Results of treatment should be considered in high and also low risk categories of patients. Attention must also be given to treatment factors such as the extent of surgical resection, the presence or absence of a shunt, and radiotherapy technique and dose. Furthermore, in somer large series with case-entry spanning 20 or more years, treatment techniques have varied; results in the earlier period are often inferior to those obtained in the same series in more recent years.

Silverman and Simpson[41] and also Berry *et al.*[1] have

Radiotherapy Volume

	SURVIVAL ACCORDING TO RT VOLUME		
	Posterior Fossa only	Posterior fossa + spine	Craniospinal
University of Lund	5%	25%	53%
University of Toronto	0%		53%
Strong Memorial Hospital	No RT: 0% Whole brain RT: 20%		50%

What are the challenges in CSI?

- Long and complex shaped target volume
- Can not be covered in one field and needs multiple fields
- Orthogonal fields
- Divergence of fields
- Junctions are always a/w dose inhomogeneity– which bring worries about under dosing/over dosing. Junctions fall on spinal cord.
- Geometric matching
- Positioning- Supine /prone
- Early and late side effects

Summary of evolution of techniques of CSI

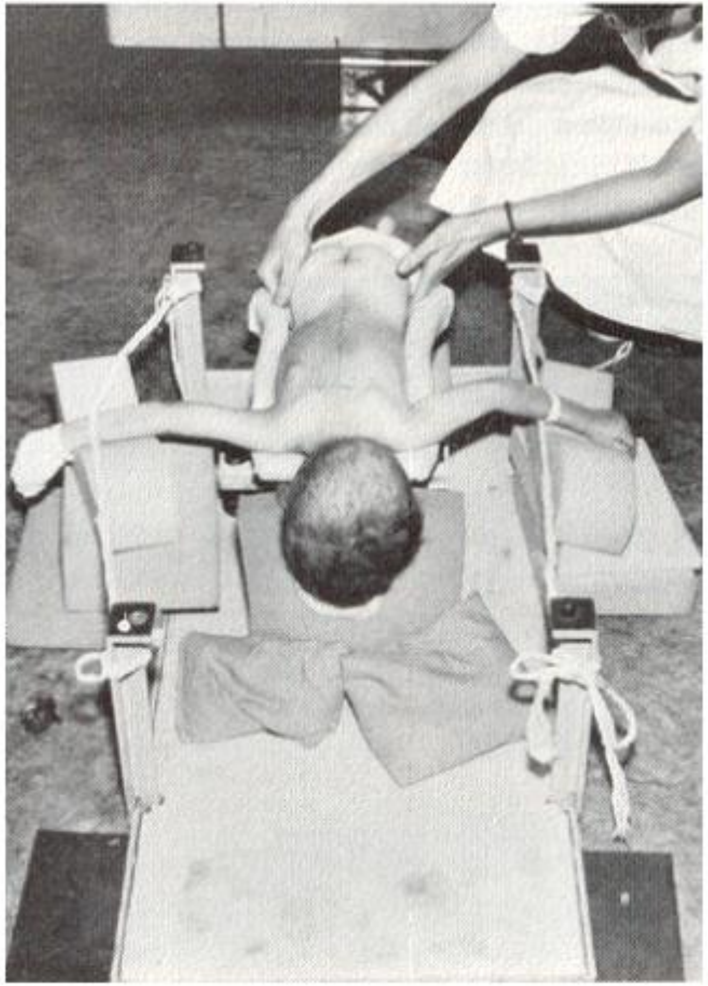
- 2 D RT with Fluoroscopy/Conventional simulators using Posterior spinal fields and bilateral cranial fields with appropriate blocks- prone position
- 3 D RT with Conventional/CT simulators using Posterior spinal fields and bilateral cranial fields with appropriate blocks/MLC- prone position
- 3 D RT in supine position
- IMRT – Step and shoot/Dynamic/Arc/Tomotherapy (helical)
- IMPT

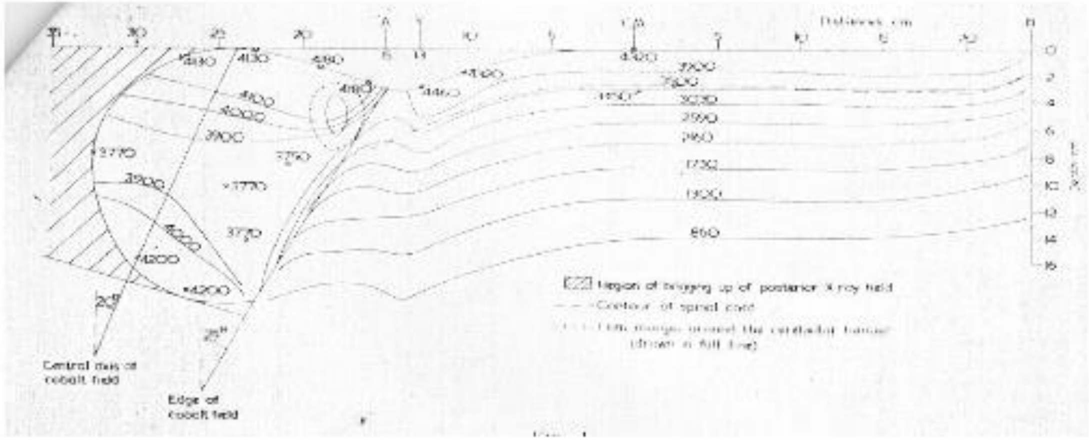
The more you know about the past, the better prepared you are for the future.

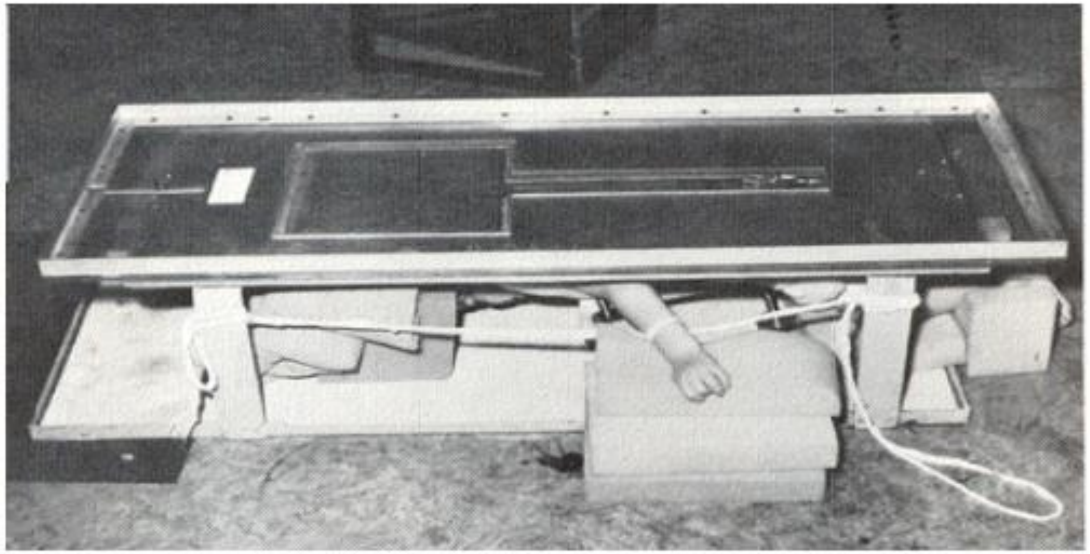
~Theodore Roosevelt

2 D CSI

Craniospinal Radiotherapy- London Hospital Technique

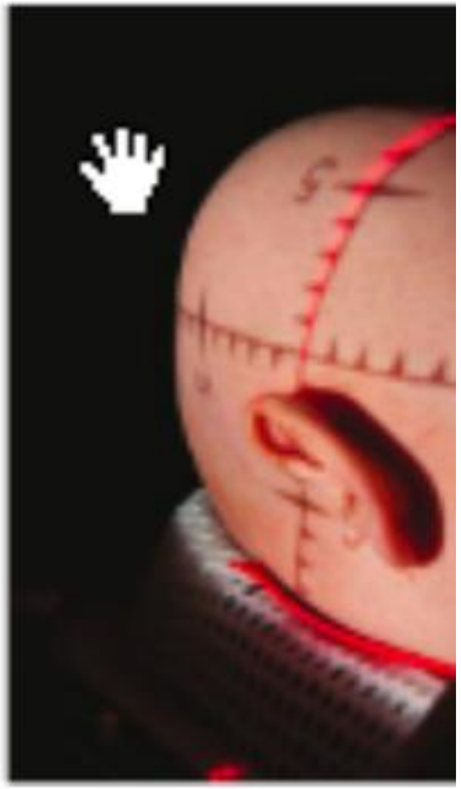






Bottrill et al, 1965, BJR 38 122-130

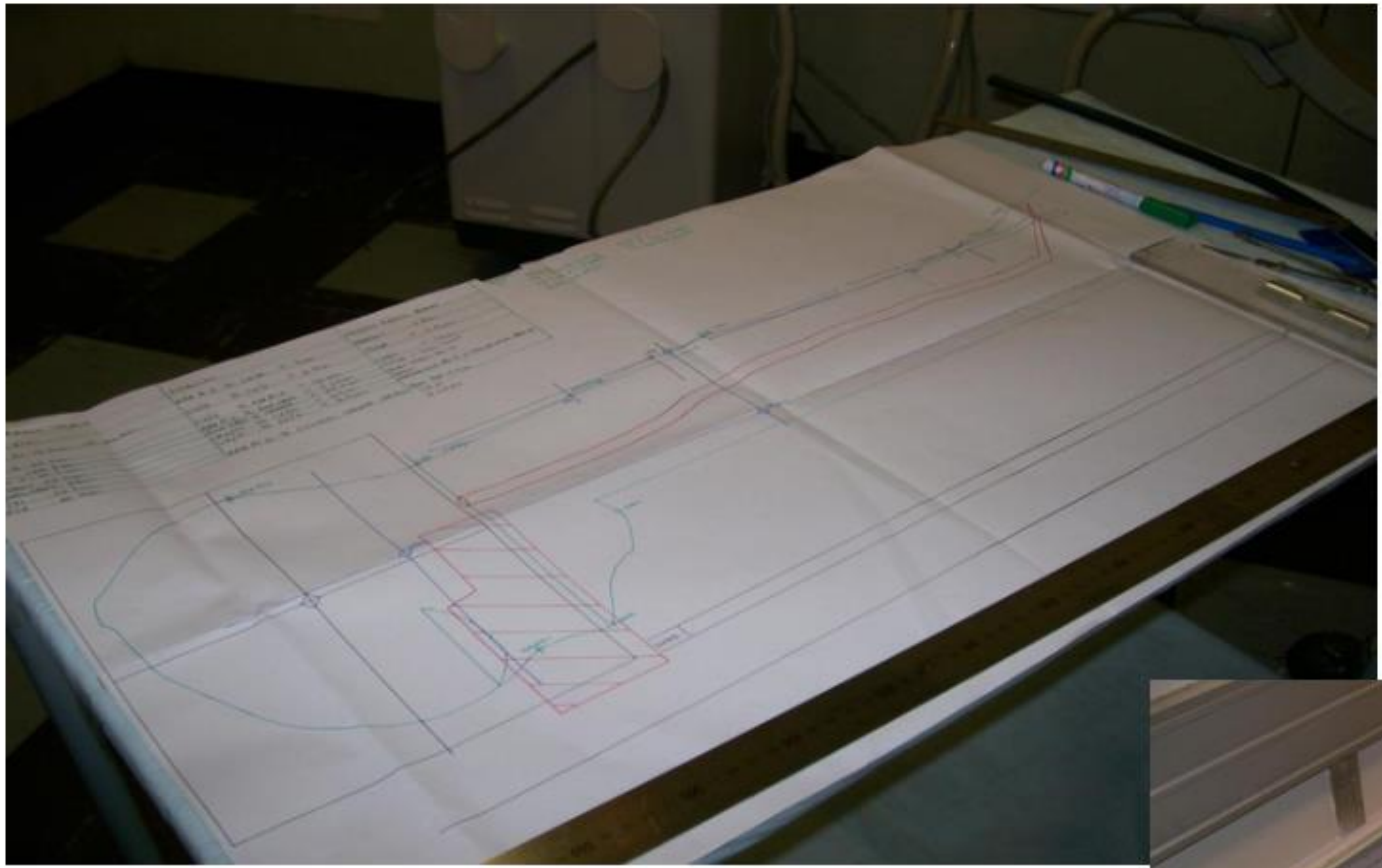
Craniospinal radiotherapy.. immobilisation



Localisation using image intensifier!

In the old days!

Sagittal 2-D drawing and planning



3 D CSI

Craniospinal RT- 3D RT- Prone

- Two lateral fields for brain and single/two PA fields for spine- planned on Xray/CT simulator
- Junction of Cranial and Spine field generally at C4-5
- Avoid higher junction to

✓ Avoid junction close to ds/brain stem

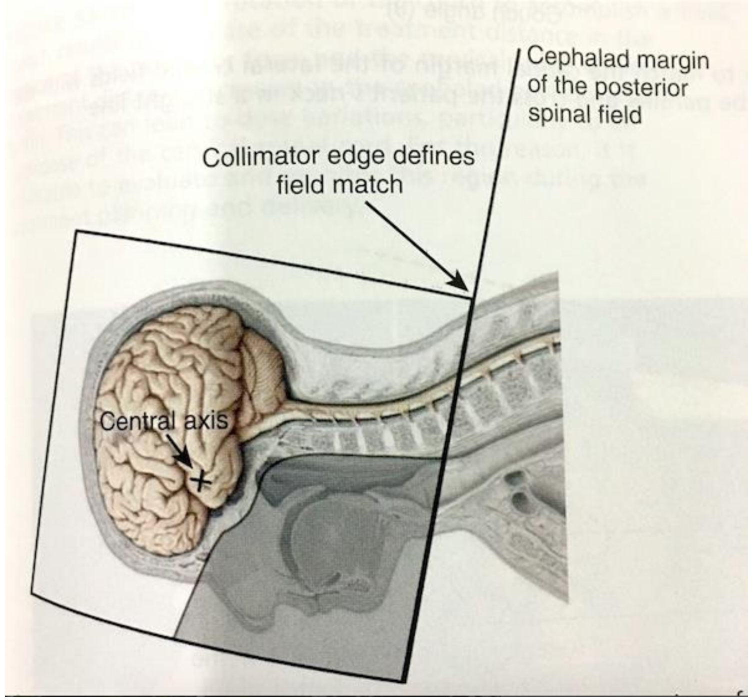
✓ Avoid high dose to mandible/Oral cavity/ thyroid etc. through post spine field

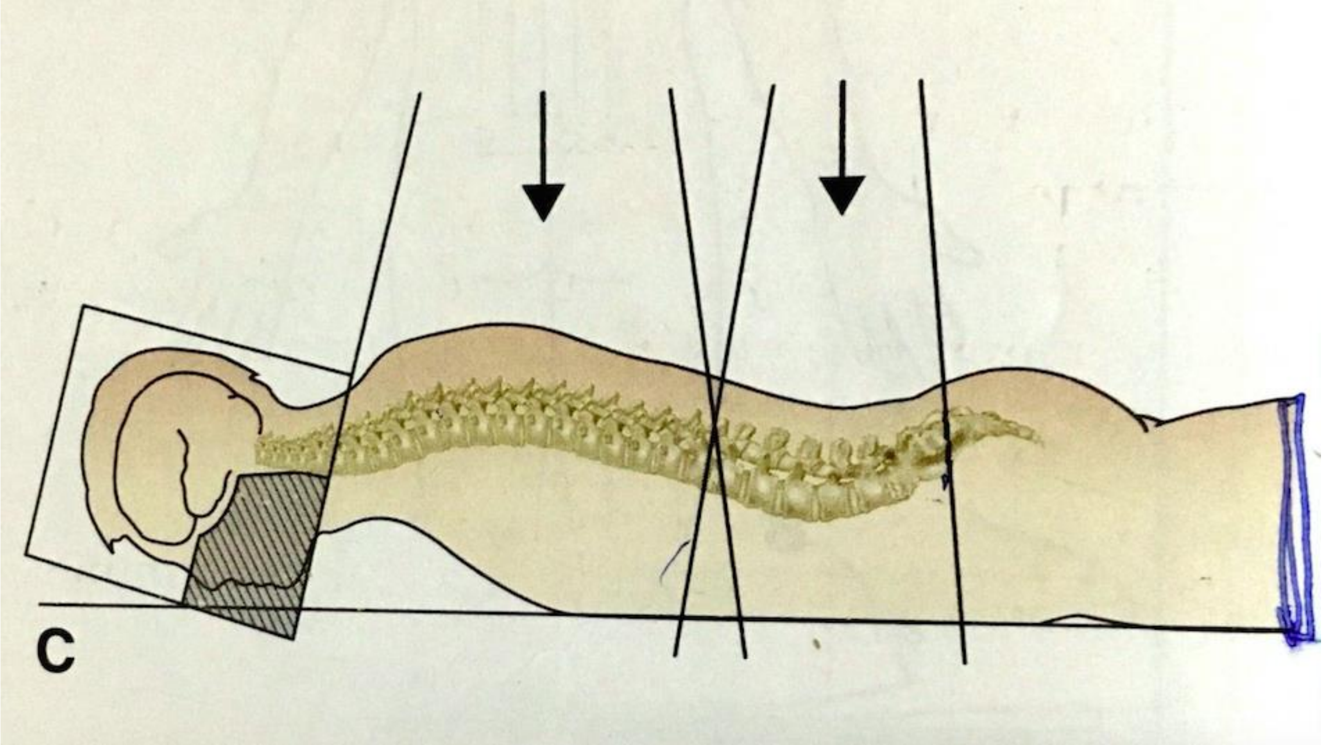
- Avoid low junctions- shoulders come in way of lateral cranial fields

- Position patient on prone HR and make thermoplastic shell
- Apply fiducial at lateral canthus to facilitate design of eye blocks for brain RT
- Align patient using sagittal laser
- Set up Posterior spinal field
- Find out depth of cord from CT/MRI or take lateral Xray with lead wire on skin
- As field junction is moved twice during RT, initial spinal field length must be such that it can be increased by 4-6cm without exceeding max field length

Challenges– Matching divergence of spinal- spinal fields and cranio-spinal fields

Geometric Matching





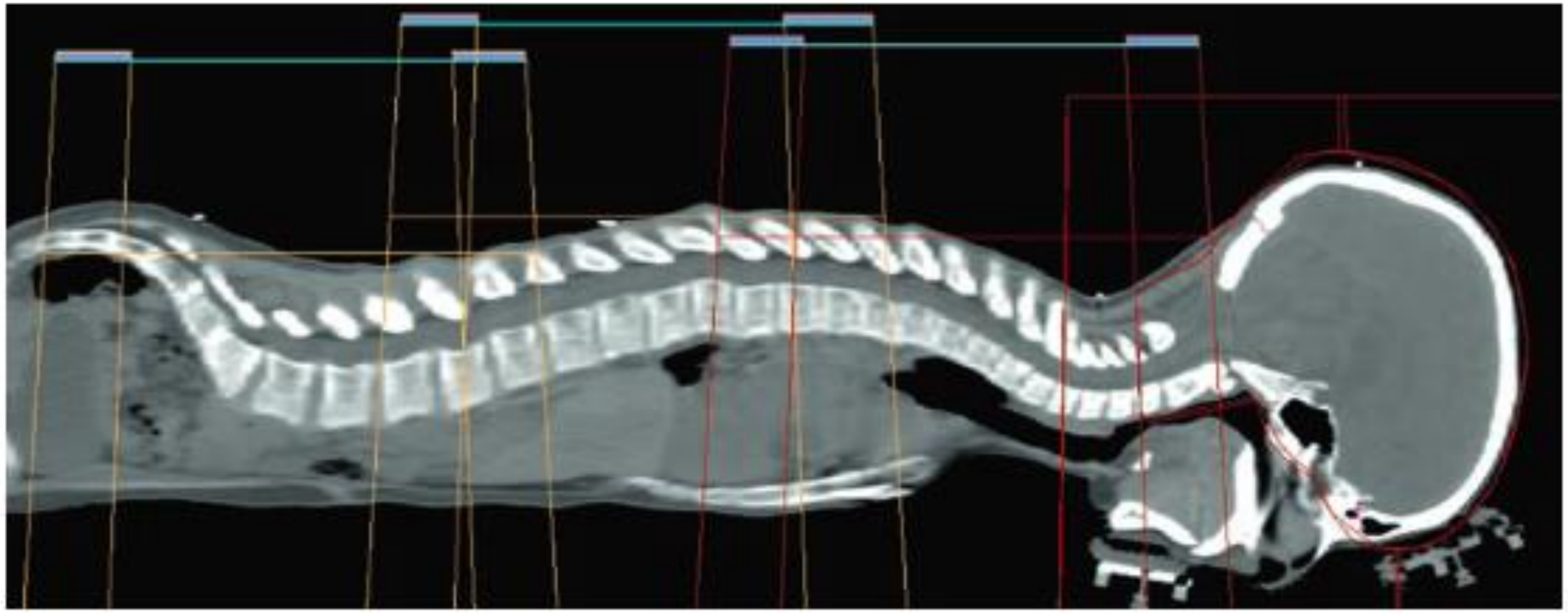
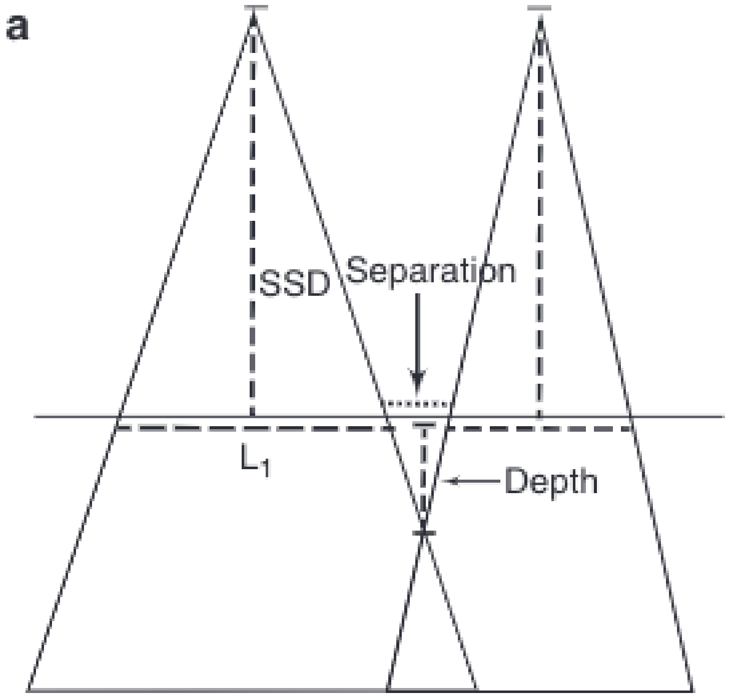


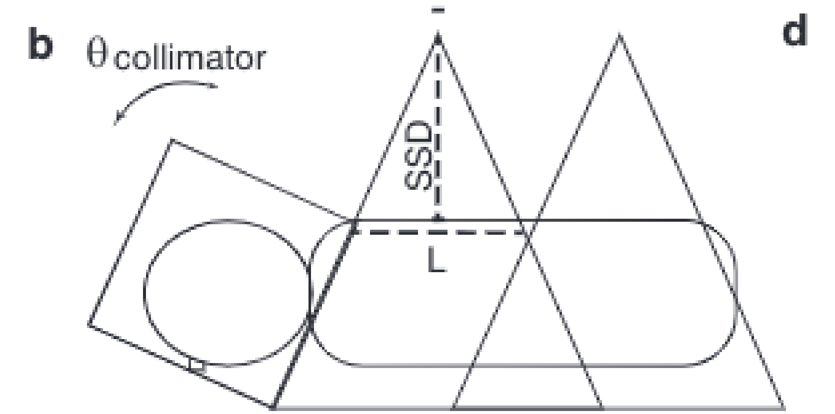
Fig. 27.2 Picture of craniospinal field matching where the divergence from the upper and lower spine fields is matched at the anterior spinal canal

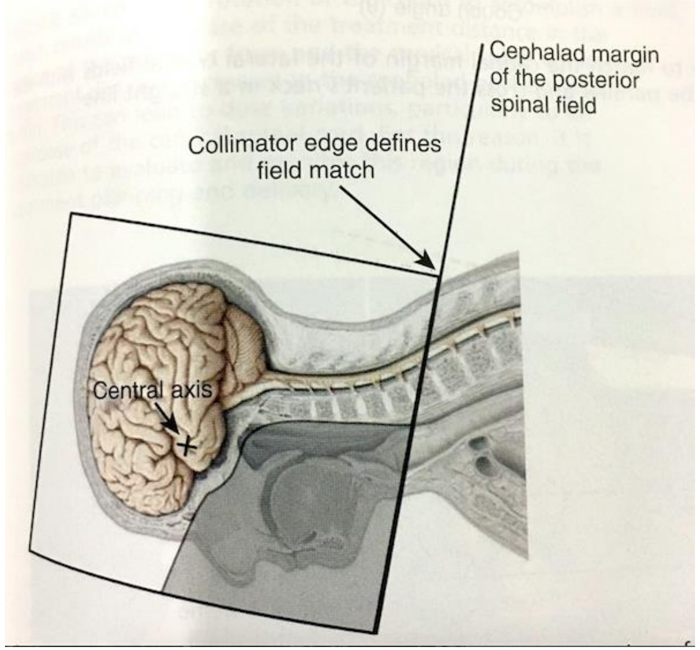


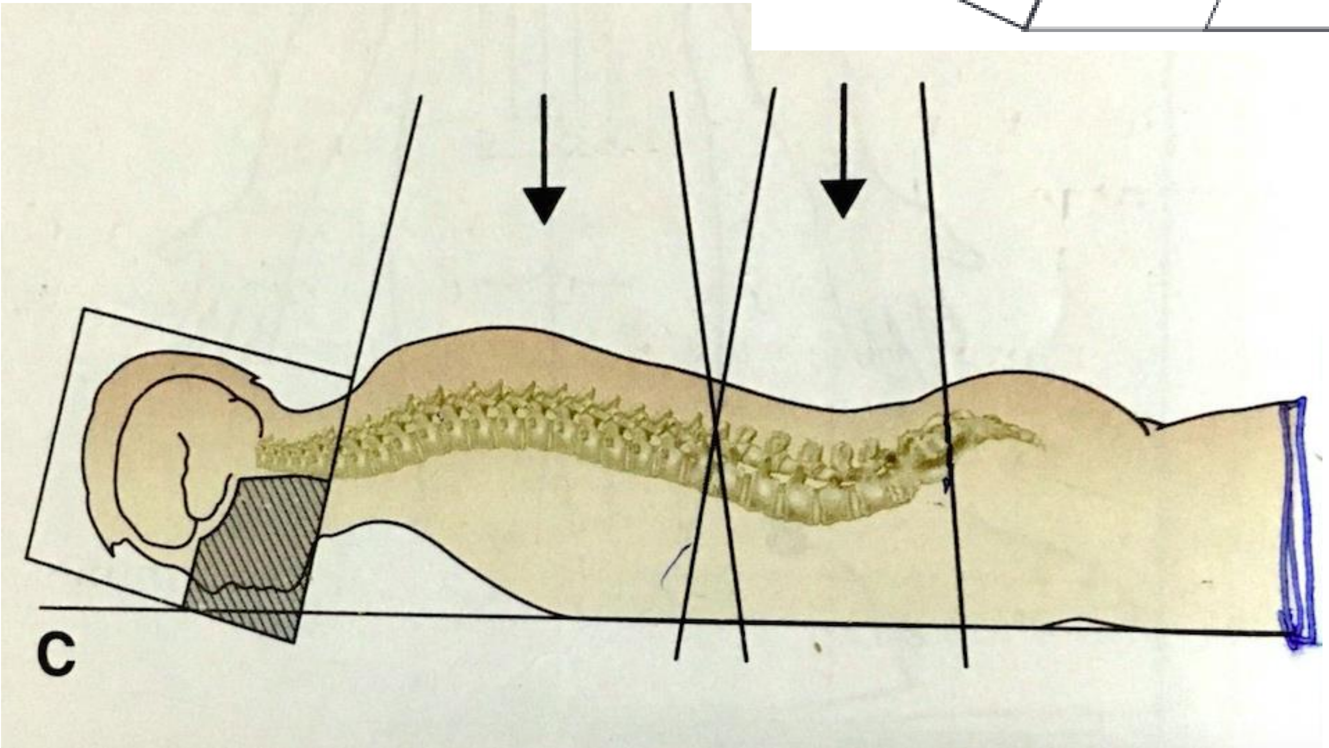
$$Gap = S_{(\text{field1})} + S_{(\text{field2})} = \frac{1}{2}\left(\frac{L_1 \times \text{Depth}_1}{SSD_1}\right) + \frac{1}{2}\left(\frac{L_2 \times \text{Depth}_2}{SSD_2}\right)$$

Rotate collimator for cranial field to match caudal margin of cranial field with diverging posterior spinal field

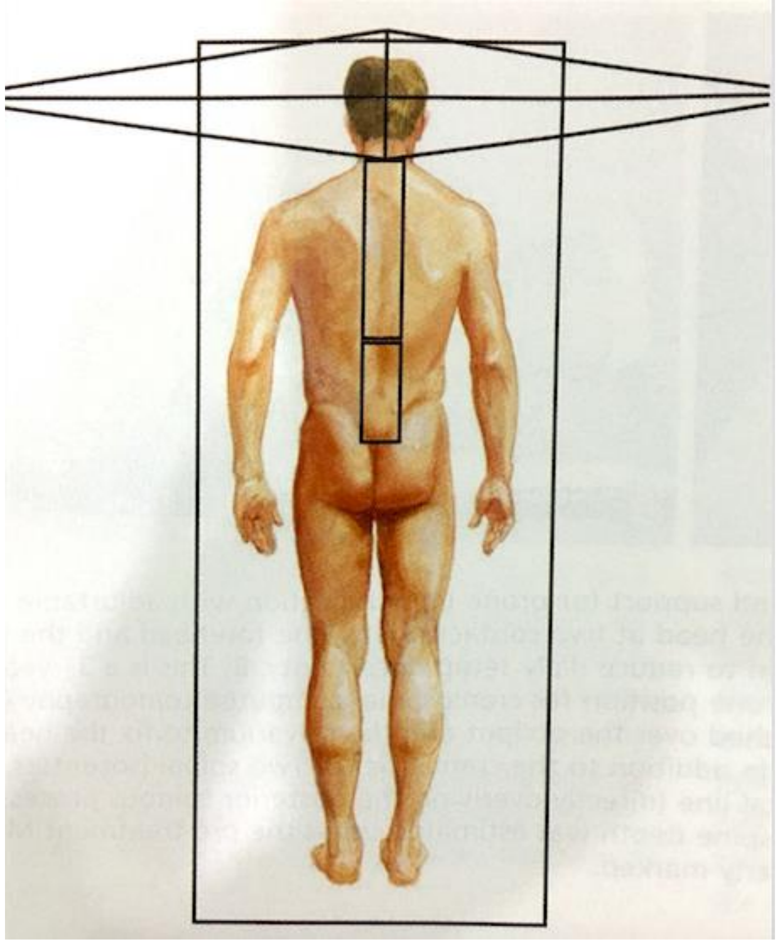
$$\theta_{collimator} = \tan^{-1}\left(\frac{1}{2} \times \frac{L}{SSD}\right)$$

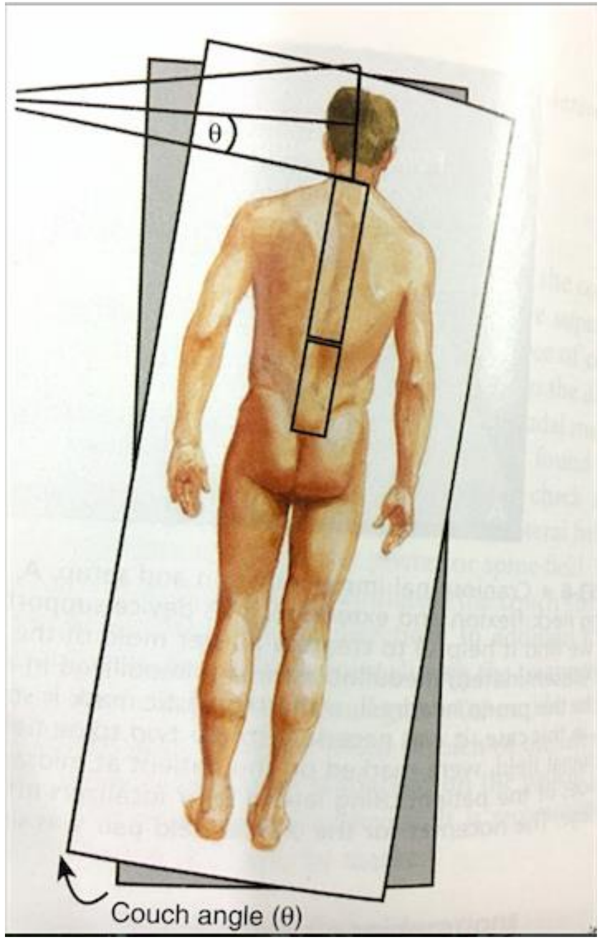




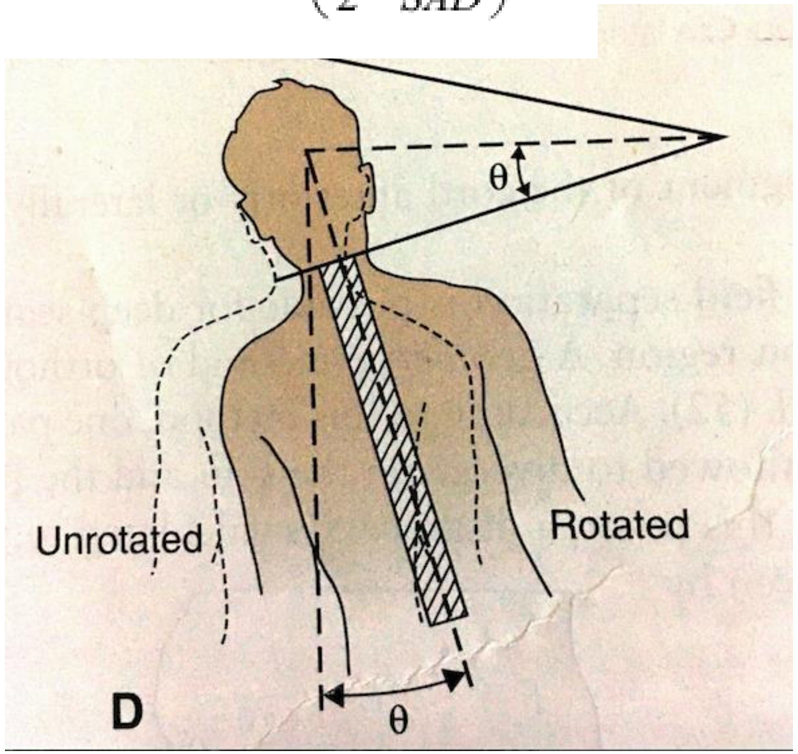


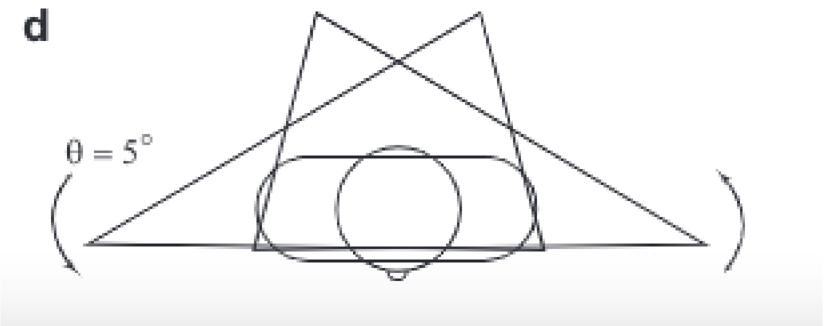
- Rotate couch towards gantry head to prevent lateral cranial field from diverging into posterior spinal field





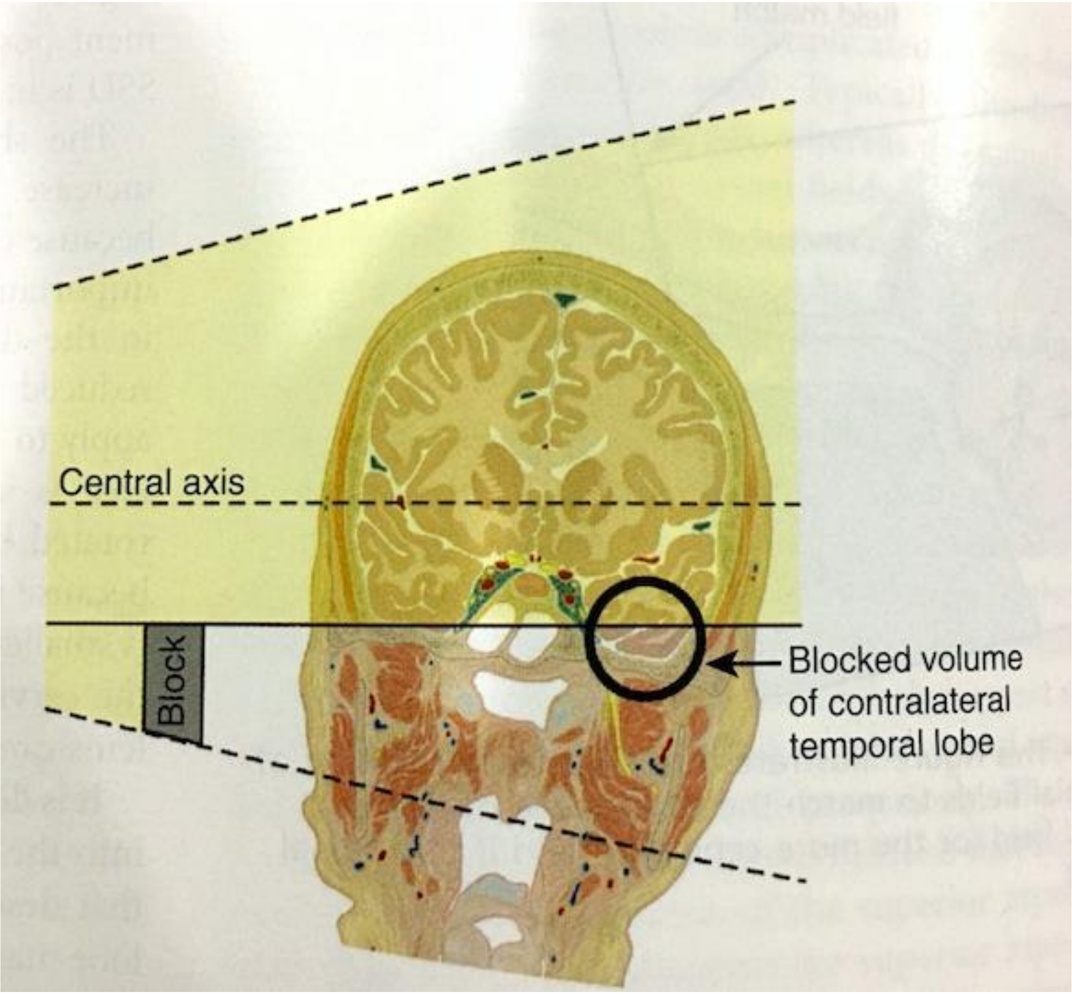
$$^{\theta}\text{couch} = \tan^{-1}\left(\frac{1}{2}\times\frac{L}{SAD}\right)$$



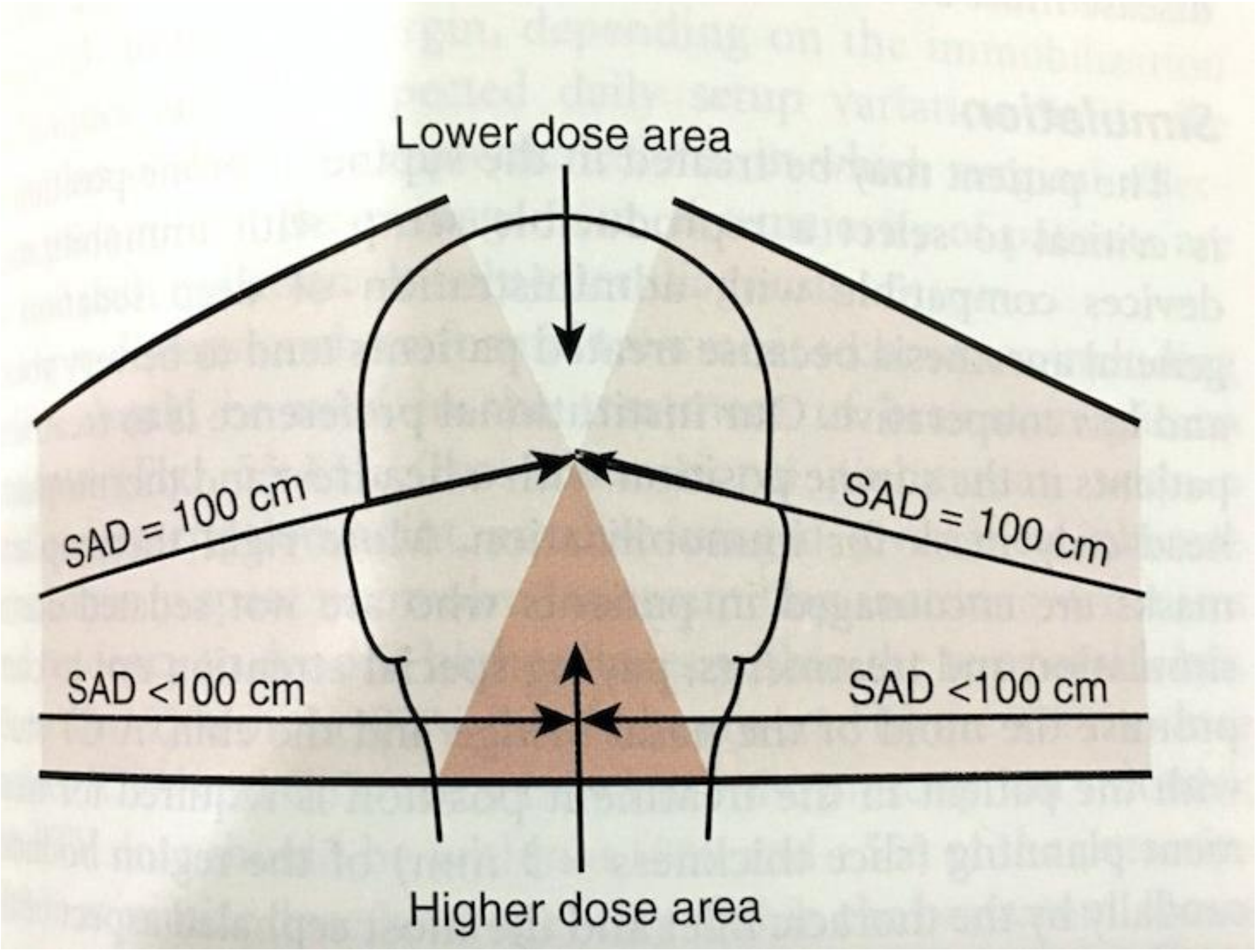


Gantry of cranial field rotated by 5 degrees to create slight posterior field to avoid divergence of cranial field through contralateral lens

In addition to junction shift; keep gap of 0.5 cm b/w cranial and spinal fields



Potential for underdosing of contralateral temporal lobe due to collimator rotation



Some inhomogeneity gets introduced in cranial fields due to Couch rotation

Positioning

- Traditionally CSI is delivered in prone position with lateral opposed cranial field and posterior direct spinal field– allowed direct visualization of junctions and easier for technologist to set up patient by palpating spine

- Supine positioning was explored

- More patient comfort
- Ease of immobilization
- Set up reproducibility
- Direct access of airway if anesthesia is required

- Supine CSI became feasible due to

- 1. Asymmetric jaws
- 2. Isocentric gantry mounting
- 3.Digital indexing of treatment tables/couches
- 4. In room imaging/OBI

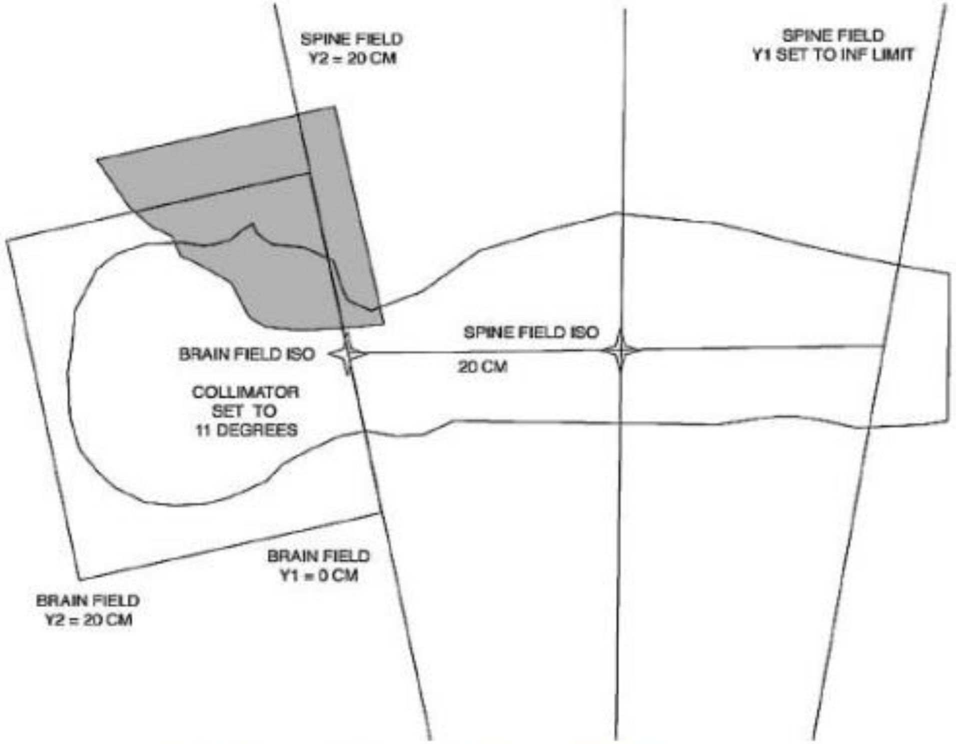


Fig. 1. Schematic diagram of the CSI technique as applied to a supine patient.

Medical Dosimetry, Vol. 28, No. 1, pp. 35–38, 2003

0958-3947/03/$–see front matter
doi:10.1016/S0958-3947(02)00239-X

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CRANIOSPINAL TREATMENT WITH THE PATIENT SUPINE

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Medical Physics, University of Wisconsin, Madison, WI

Pediatr Blood Cancer 2010;54:322–325

BRIEF REPORT
Feasibility and Early Outcomes of Supine-Position Craniospinal Irradiation

Fleur Huang, MD,[1] **William Parker,** MSc,[2] **and Carolyn R. Freeman,** MBBS[1]*

Medical Dosimetry, Vol. 33, No. 1, pp. 1-5, 2008

0958-3947/08/$–see front matter
doi:10.1016/j.meddos.2007.03.004

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A SIMPLE TECHNIQUE OF SUPINE CRANIOSPINAL IRRADIATION

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

TMH technique of Supine CSI

Medical Dosimetry, Vol. 33, No. 1, pp. 1-5, 2008

0958-3947/08/$–see front matter
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doi:10.1016/j.meddos.2007.03.004

A SIMPLE TECHNIQUE OF SUPINE CRANIOSPINAL IRRADIATION

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- Supine position with arms by the side with suitable body vacloc
- Head and neck immobilized in a slightly extended position using a thermoplastic 4 clamp mask
- Radio Opaque fiducial marker placed at inferior and posterior end of neck on mask on each lateral side – along same line using LASERS

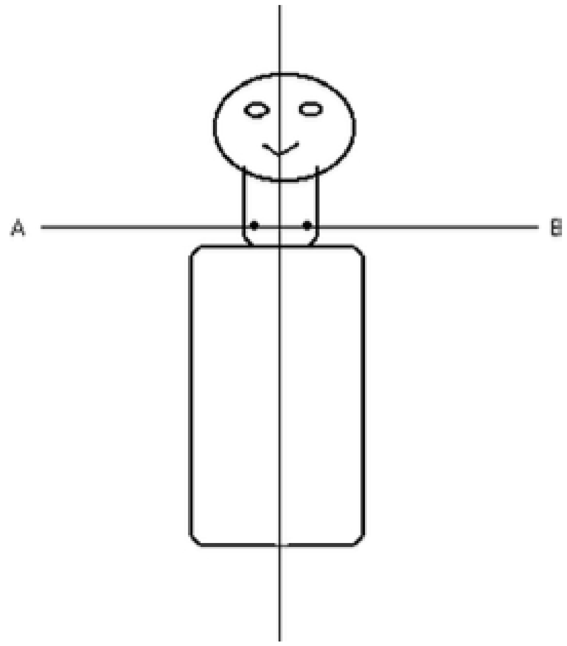


Fig. 1. Anterior view of the initial position of markers on 2 sides of the neck.

Set up Spinal field (Single field)

- Single spinal field is useful when field length is <34 cm
- Move gantry to 180 using couch set at LASER level to ensure SSD 100cm
- Open suitable width 5-7 cm
- Lower border kept at end of TS as per MRI or S2
- Upper border matched to fiducial markers placed at neck

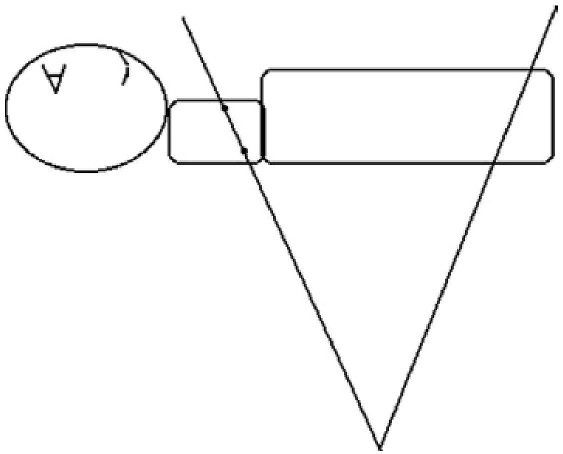


Fig. 2. The "through table" spinal field. The 2 markers on 1 side of the neck fall in the same line of divergence of the spinal field.

- Place 2 more markers on TP mould on neck – 1-2 cm across midline
- Collimator wire at upper border of spinal field should have all 4 markers
- This helps in defining divergence of spinal field
- Mov gantry anteriorly to 0 degree and mark centre of spinal filed on TP mould or tattoo on pt’s skin

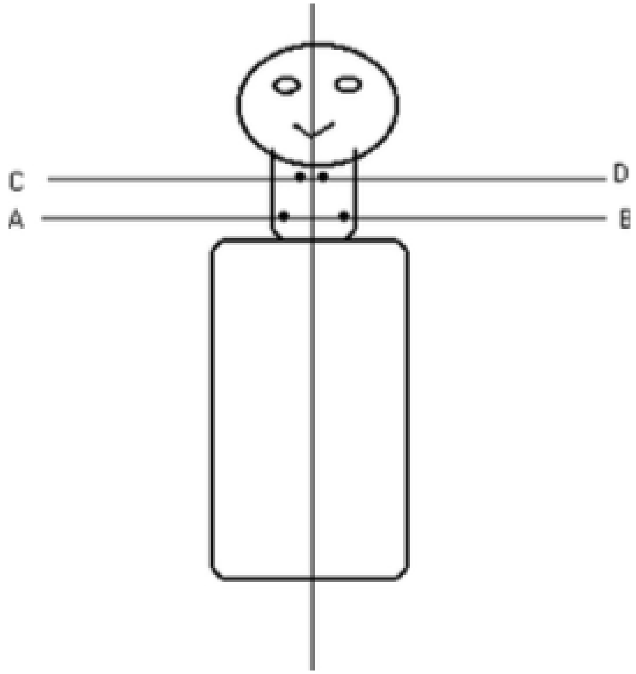


Fig. 3. Anterior view of the final position of the 4 markers on 2 sides of the neck.

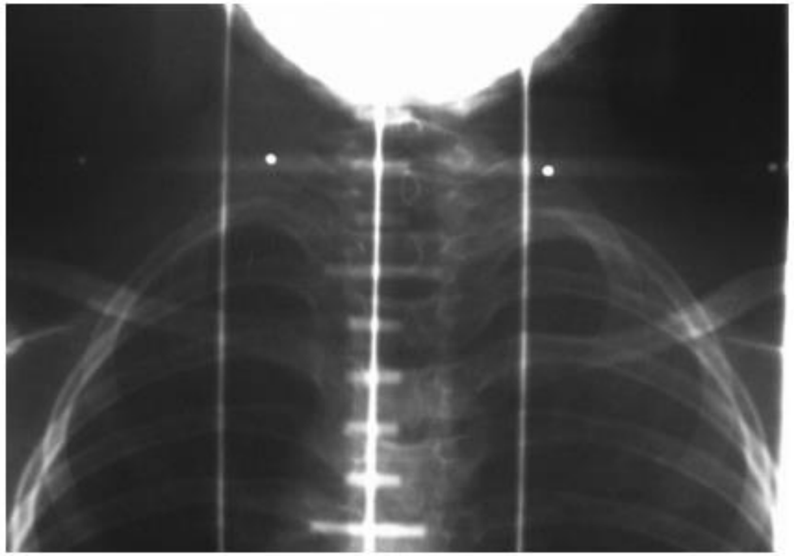


Fig. 4. X-ray showing all 4 markers (2 on either side of the neck) in a straight line at the superior border of the spinal field.

Fig. 6. X-ray of the cranial field. The markers are inferior to the caudal edge of the field because a gap of 5 mm has been kept at simulation.

Cranial Field

- Open appropriate field with 2-3 cm generous margin in air superiorly, anteriorly and posteriorly
- Set up field at SSD 100 cm
- Rotate collimator such that lower border of cranial field matches with line joining 2 markers on the same side of neck

Rotate couch by 6 degree (towards gantry) or calculate by using formula $\text{Tan } \Theta^{-1} = ½$
Field width of spinal field /SAD

As a policy at TMH a gap of 0.5 cm was kept between cranial and spinal field and hence couch needs to be moved out by 0.5 cm

Take fluoroscopy image and design either customized lead blocks or MLCs to block eyes /jaw (Orofacial Blocks)

Avoid overzealous blockage of critical regions- subfrontal/cribriform plate/temporal lobe meninges

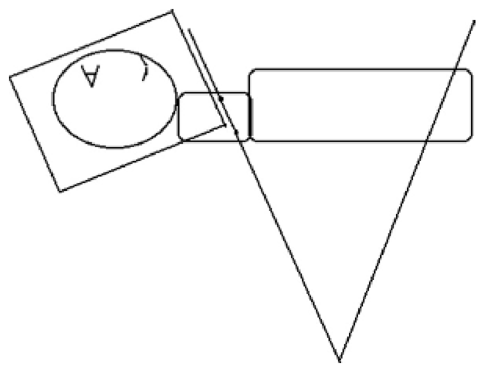
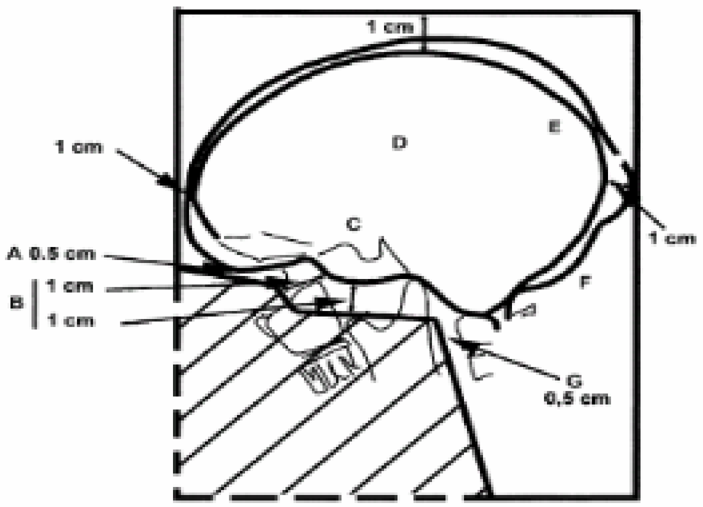
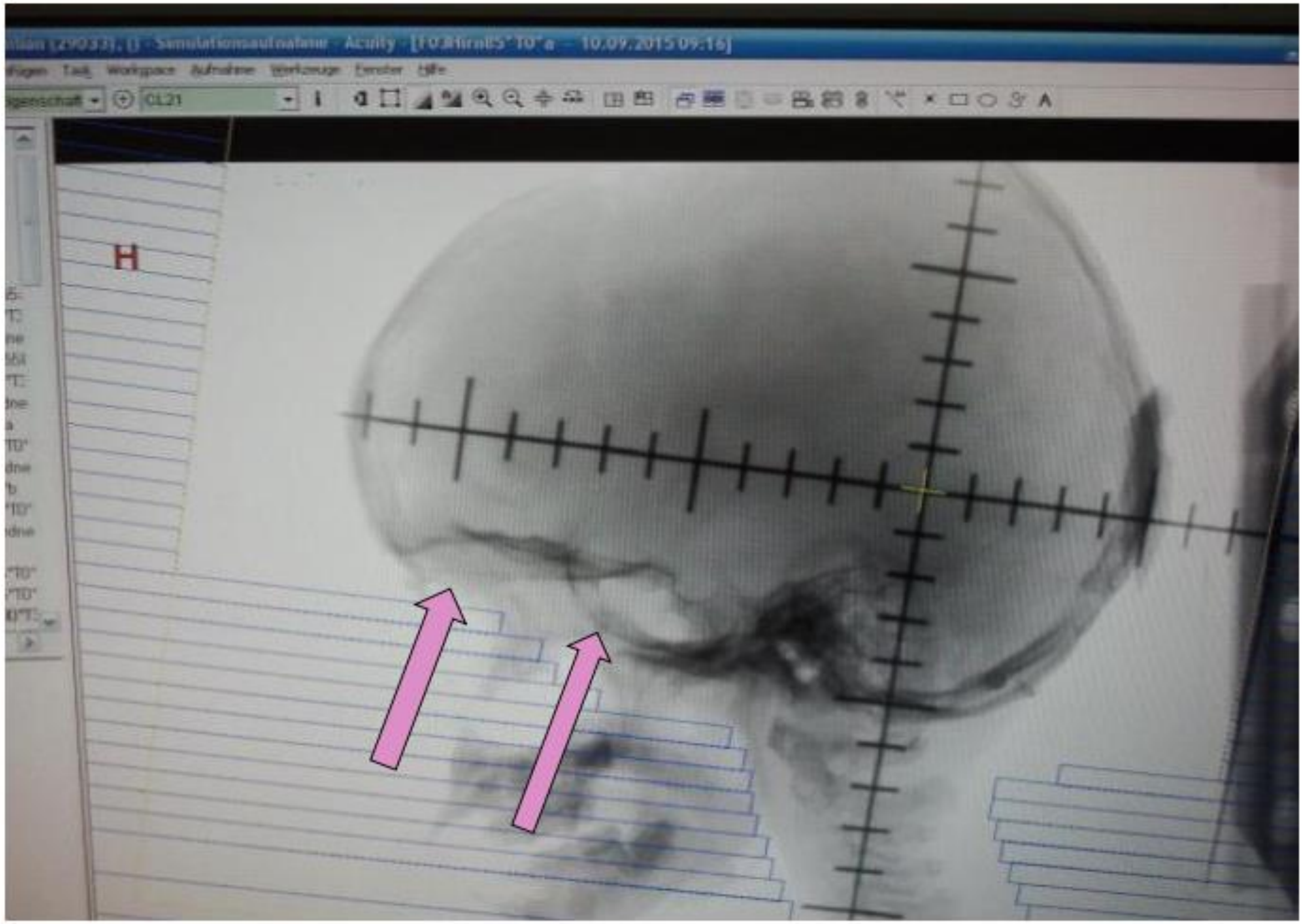


Fig. 7. Cranial field collimation based on the spinal field divergence, as suggested by the line joining the markers. The caudal edge can be abutted to the markers or kept with a gap of 5 mm, as shown in the figure.

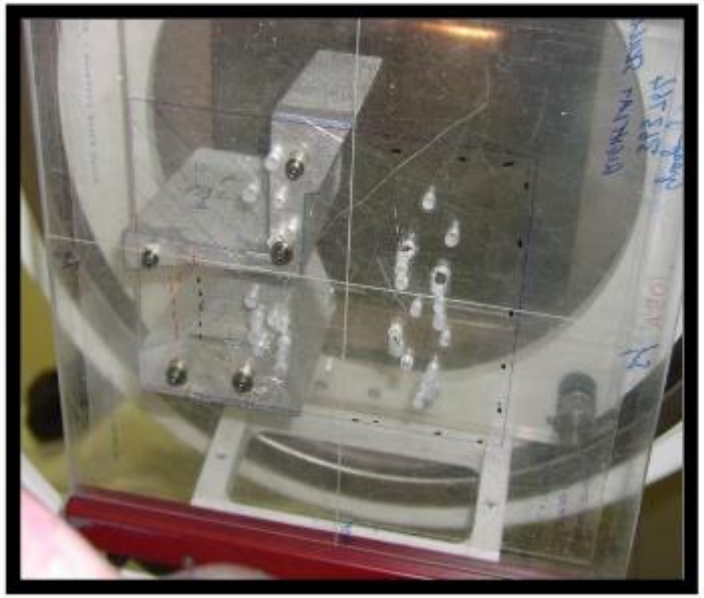


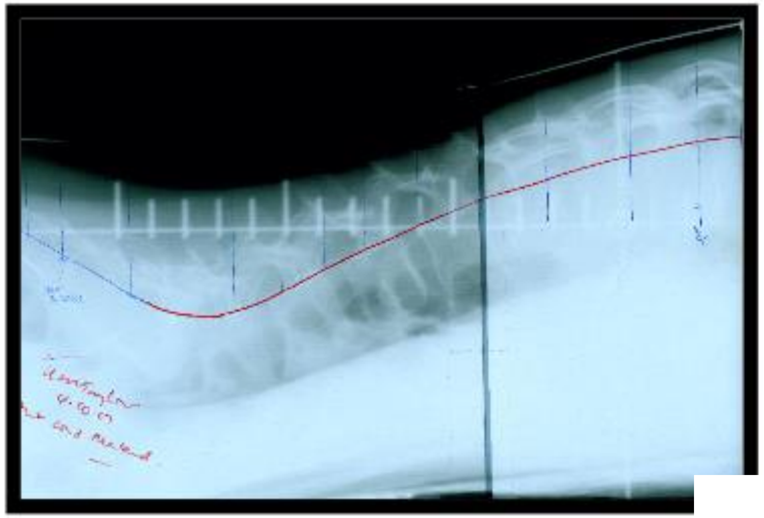
Screen Shot of Simulation



Simulator based planning

- Spinal compensator
- Lead alloy blocks
- Manual compensator and MU calculation



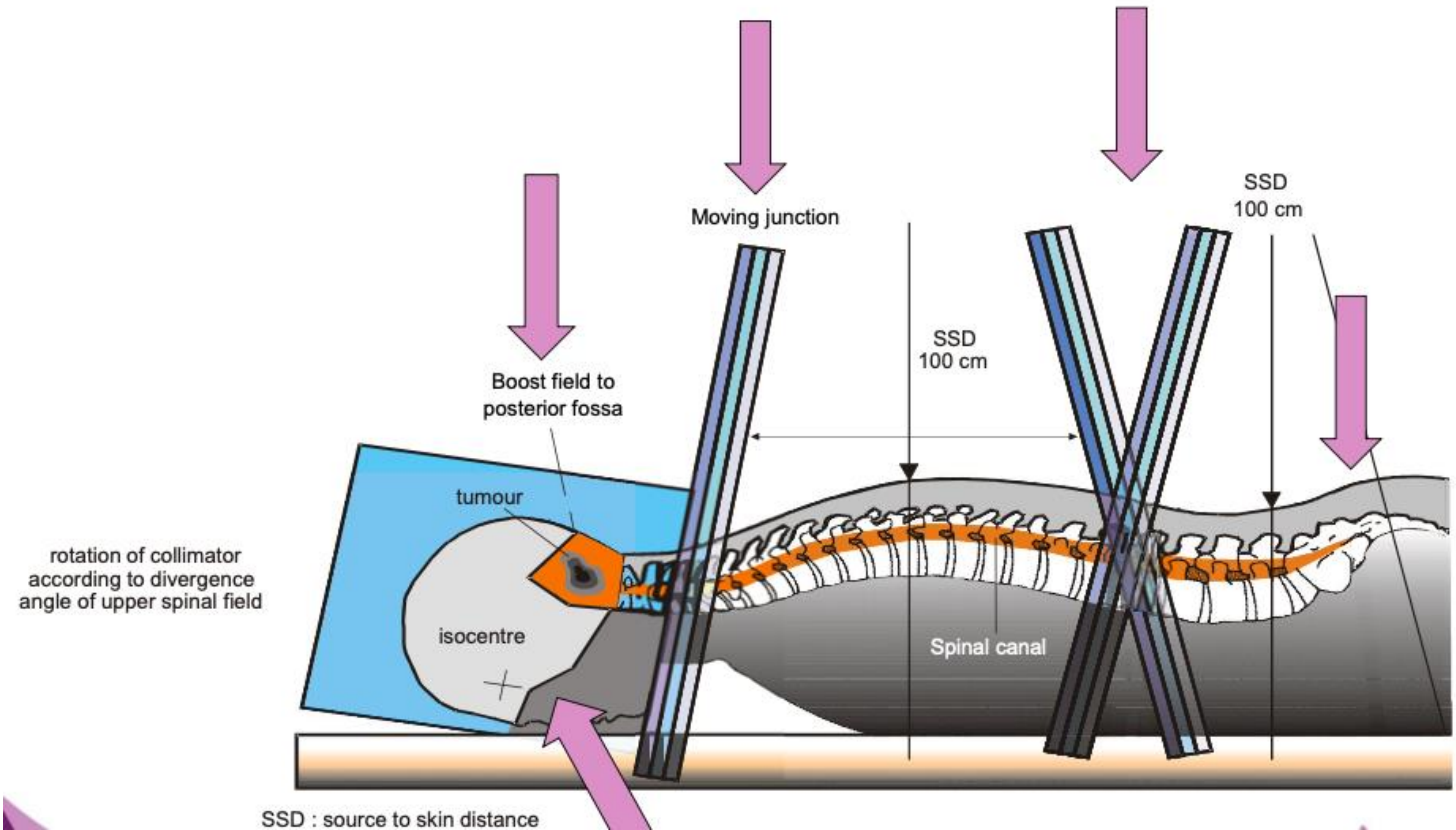


Junction shifting

- In all 2 D and 3 D technique – all junctions (Craniospinal as well as spinal- spinal) should be shifted periodically to feather dose across the junctions and minimize hot/cold spots

- Can be easily done decreasing spinal field superiorly and increasing cranial field inferiorly by 5 mm during each shift

- Low dose CSI 24.3Gy- one shift is enough and for high dose 35-40Gy – 2 shifts are desirable


Moving junction
SSD
100 cm
SSD
100 cm
Boost field to
posterior fossa
tumour
rotation of collimator
according to divergence
angle of upper spinal field
isocentre
Spinal canal
SSD : source to skin distance

Practical Radiation Oncology (2014) **xx**, xxx–xxx

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Original Report

Comparison of supine and prone craniospinal irradiation in children with medulloblastoma

Jonathan Verma MD [a], Ali Mazloom MD [a], Bin S. Teh MD [a], Michael South CMD [a], E. Brian Butler MD [a], Arnold C. Paulino MD [a, b,*]

[a] *Department of Radiation Oncology, The Methodist Hospital, Houston, Texas*

Retrospective study of 46 children – 23 treated prone and 23 treated supine

Rejection rate of port film for prone position was more 35% as compared to supine position 8% ($p < 0.0001$)

No difference in PFS or OS

There were no cases of junctional failures or radiation myelitis in either CSI position

IMRT CSI

Int J Radiat Oncol Biol Phys. 2007 August 1; 68(5): 1402–1409.

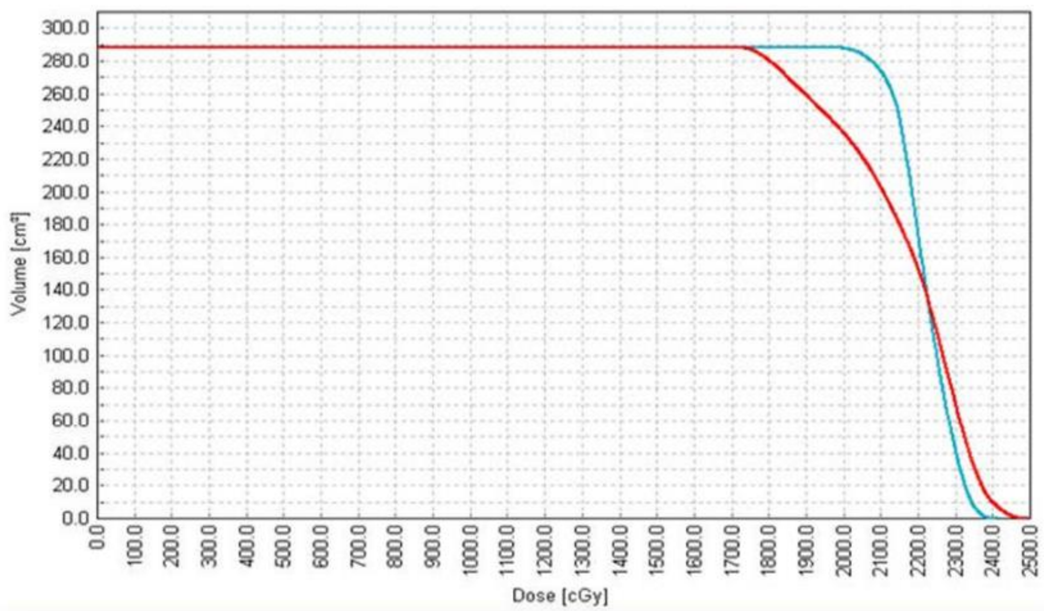
Craniospinal Irradiation with Spinal IMRT to Improve Target Homogeneity

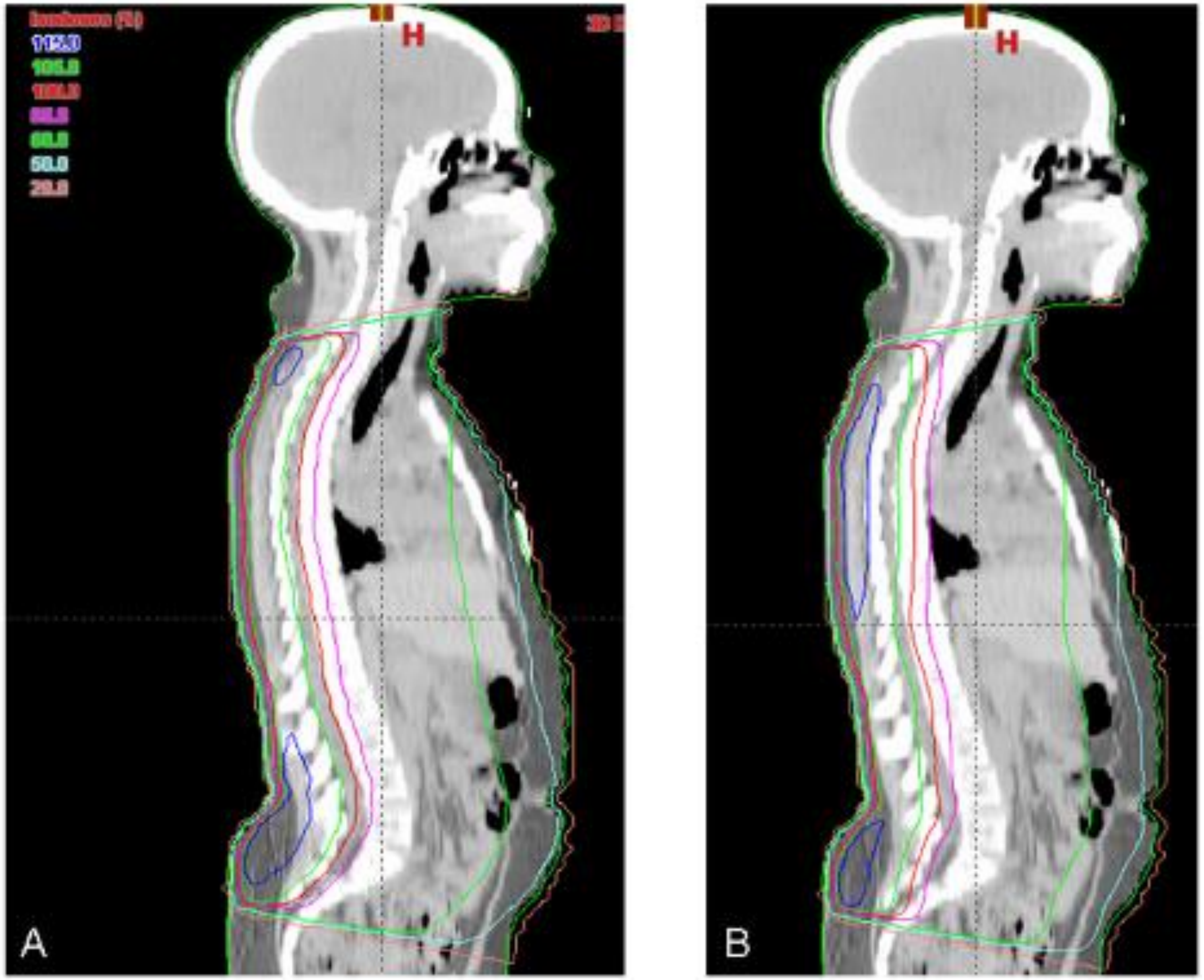
Atmaram Pai Panandiker, M.D.[1], **Holly Ning, Ph.D.**[1], **Anna Likhacheva, B.S.**[1], **Karen Ullman, B.A., R.T.T.**[1], **Barbara Arora, M.S.**[1], **John Ondos, C.M.D.**[1], **Shervin Karimpour, M.D.**[2], **Rc Packer, M.D.**[3], **Robert Miller, Ph.D.**[1], and **Deborah Citrin, M.D.**[1]

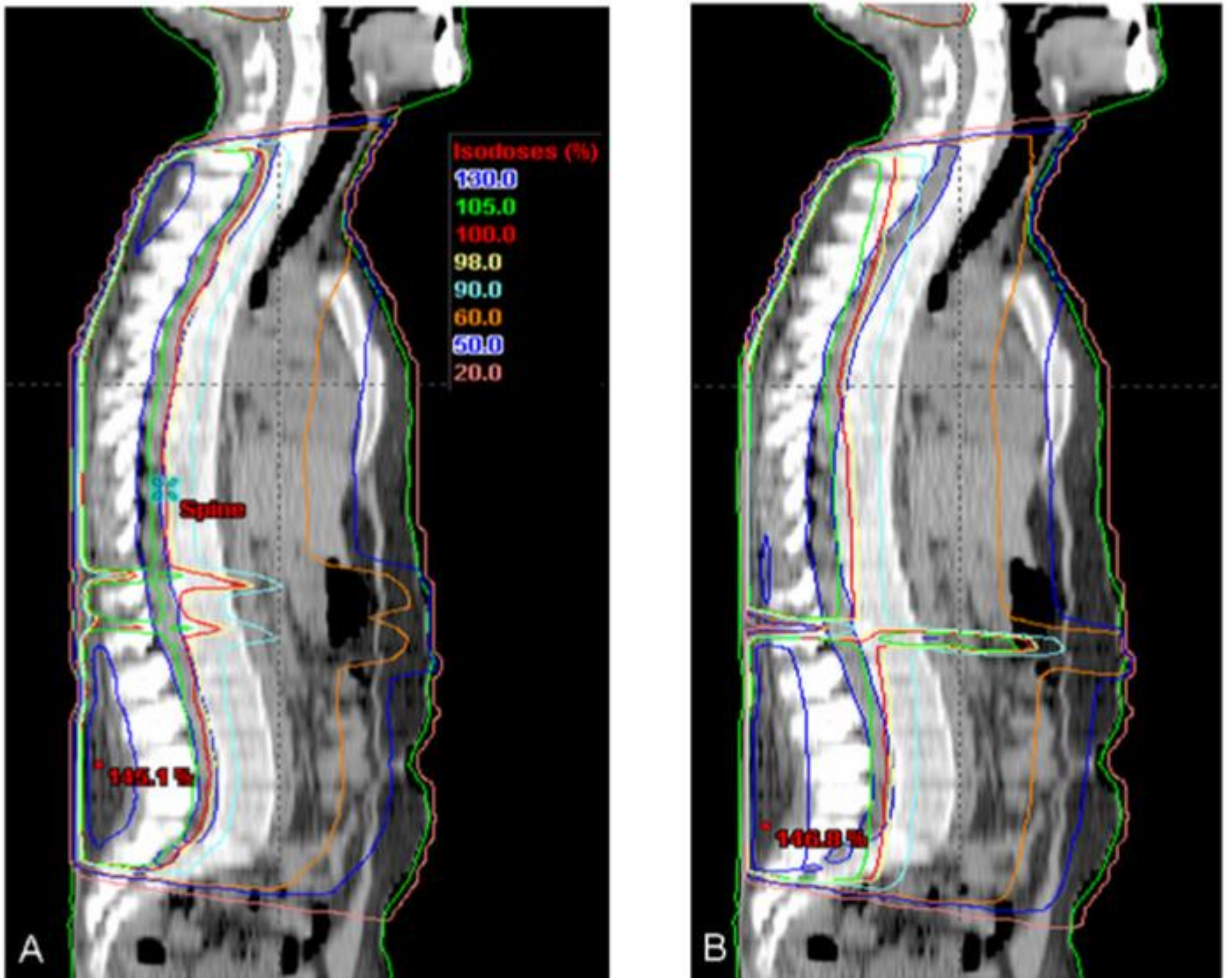
1Radiation Oncology Branch, National Cancer Institute, National Institutes of Health

IMRT- field

Conventional single PA






Isodoses (%)
130.0
105.0
100.0
98.0
90.0
60.0
50.0
20.0
Spine
A
B

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Int. J. Radiation Oncology Biol. Phys., Vol. 69, No. 1, pp. 251–257, 2007

0360-3016/07/$–see front matter

doi:10.1016/j.ijrobp.2007.04.052

PHYSICS CONTRIBUTION

INTENSITY-MODULATED RADIOTHERAPY FOR CRANIOSPINAL IRRADIATION: TARGET VOLUME CONSIDERATIONS, DOSE CONSTRAINTS, AND COMPETING RISKS

William Parker, M.Sc., F.C.C.P.M.,* Edith Filion, M.D.,† David Roberge, M.D.,† and Carolyn R. Freeman, M.D.†

Seminal paper which compared 2D, 3D and IMRT dosimetry

3 patients were chosen

Cranial RT was with bilateral fields

Spinal RT was delivered with 2D, 3D or IMRT approach

Spinal IMRT was with 5 posterior and posterior oblique fields

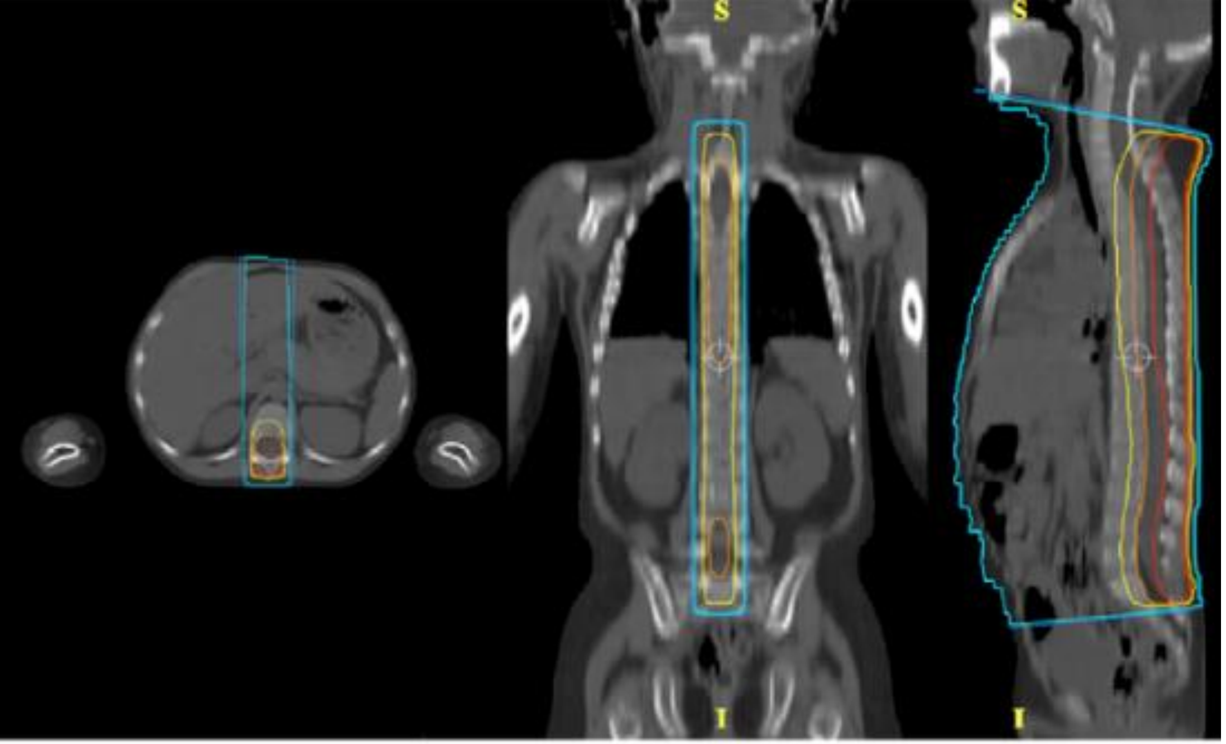
PTV coverage and dose homogeneity was superior with IMRT as compared to 2D and 3 D RT

Doses to OARS were better with IMRT particularly in terms of V10, V15 AND V20Gy

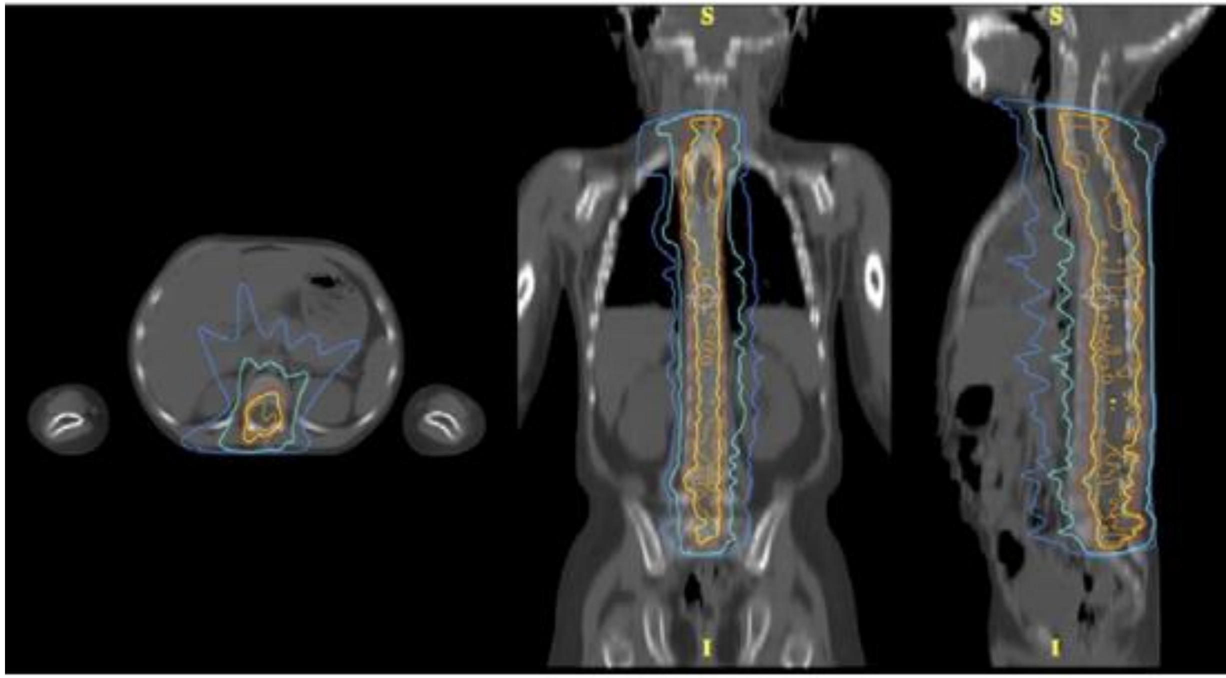
3 D plan was superior for V5Gy or below

Table 1. Evaluation parameters used to assess target dose coverage and homogeneity for the spinal axis

Parameter (%)	2D	3D	IMRT
R_x isodose line	85	84	88
$V_{95\%}$	98	96	100
$V_{107\%}$	37	38	3
D_{max}	118	119	114



Cyan-10Gy



Challenges with IMRT

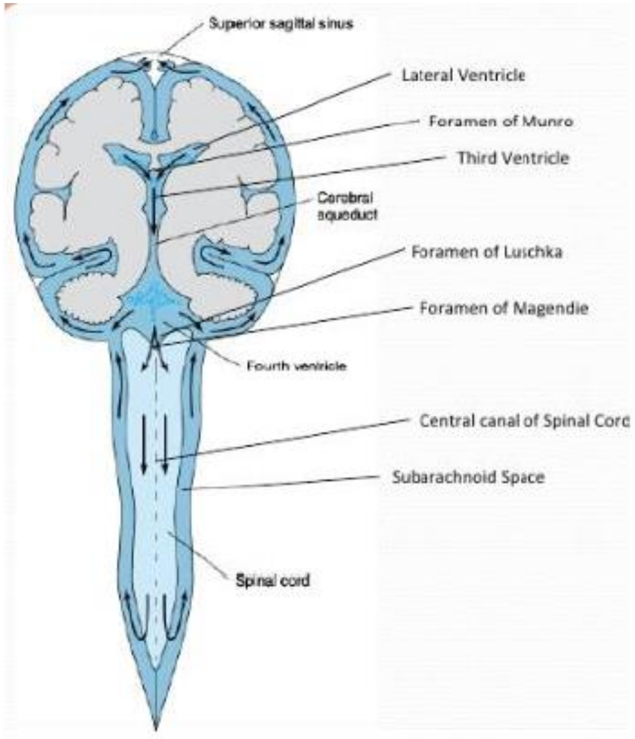
- Precise target volume definition

- Geometric uncertainties reduced
- Dose homogeneity and coverage improved
- OAR doses decreased

Target Volume

- Target Volume- Subarachnoid space-Whole brain, Spinal Cord down to caudal end of thecal sac and meninges

- Areas of potential marginal misses
- Cribriform plate
- Temporal lobes
- Inferior aspect of thecal sac
- Optic N/Base skull

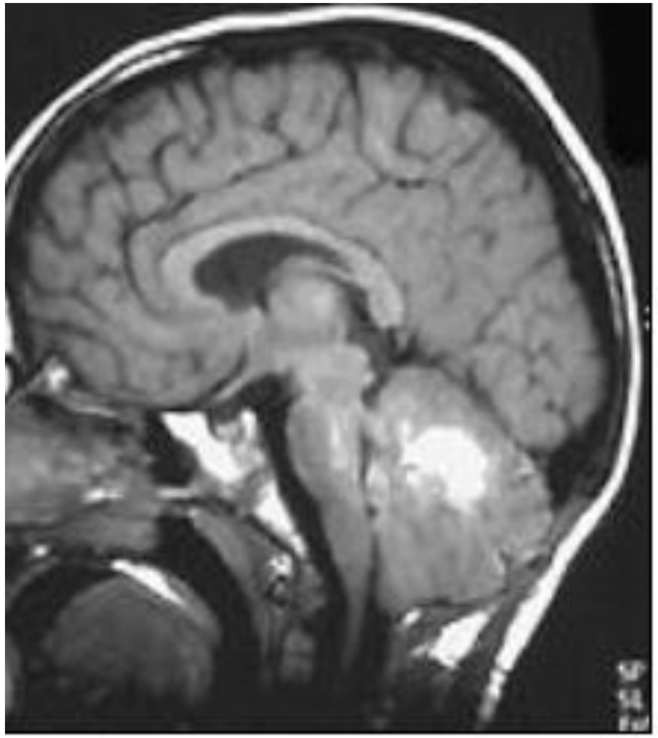


Basics are critical

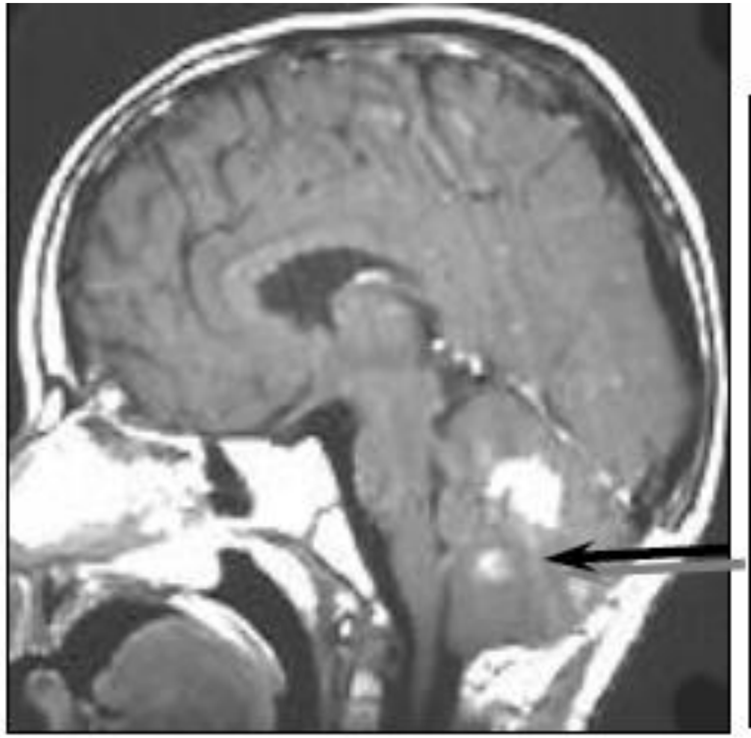
- Study Pre and post MRIs well and identify
- Initial extent of ds
- areas of residual ds/enhancement
- Leptomeningeal spread
- Lower limit of thecal sac

Spinal MRI – showing leptomeningeal enhancement

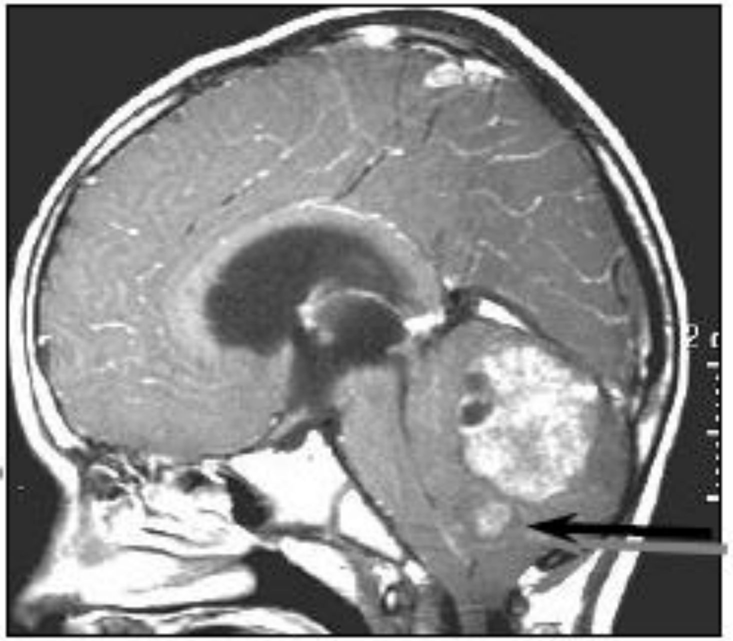
Post op Cranial MRI showing LM enhancement



post operative
T1



post operative
T1 + Gd



preoperative
T1 + Gd

Compare and correlate Pre and post op MRI to identify residual ds

Challenges in transition from 2 D to 3D- Optic N

- Optic N - whether meninges around optic N should be specifically targeted or not?
- Anecdotal case reports of recurrences around Optic N from 2 D& 3 D Taylor R - in a workshop on Children's cancer study group – advised " it is essential to avoid shielding meninges of optic nerves, cribriform plates, temporal fossa and base skull"
- Optic N are covered by meninges that extend anteriorly to lamina cribrosa.
- In pts with Leukemia, it's a standard practice to cover ON and posterior half of globe as leukemic cells can infiltrate ON

Taylor R Clin Oncol 2001; 13:58-64
Freeman C Radiotherapy and Oncology 97(2010)387-389

Table 2
Published cases of metastasis to the optic nerves from intracranial tumours.

Author	Diagnosis	Radiotherapy	Comments
Garrity et al. [8]	Medulloblastoma	WB 45.4 Gy, spinal cord 37.5 Gy, boost 55.4 Gy	Biopsy proven optic nerve metastasis
Hertle and Robb [9]	Pineoblastoma	WB 32 Gy (excluded orbits), boost 50 Gy	Cysternogram showed blocking to the entrance of contrast material into the optic nerve subarachnoid space
Manor et al. [10]	Germinoma	No RT before optic nerve metastasis	Optic nerve metastasis at initial diagnosis
Nakajima et al. [11]	Germinoma	WV 24 Gy (excluded orbits)	
	Germinoma	WV 24 Gy (excluded orbits)	
Glas et al. [12]	Medulloblastoma	WB 35.3 Gy, spinal cord 35.3 Gy, boost 56 Gy	Metastasis to intracranial portion of optic nerve

WB, whole brain; WV, whole ventricles; RT, radiotherapy.

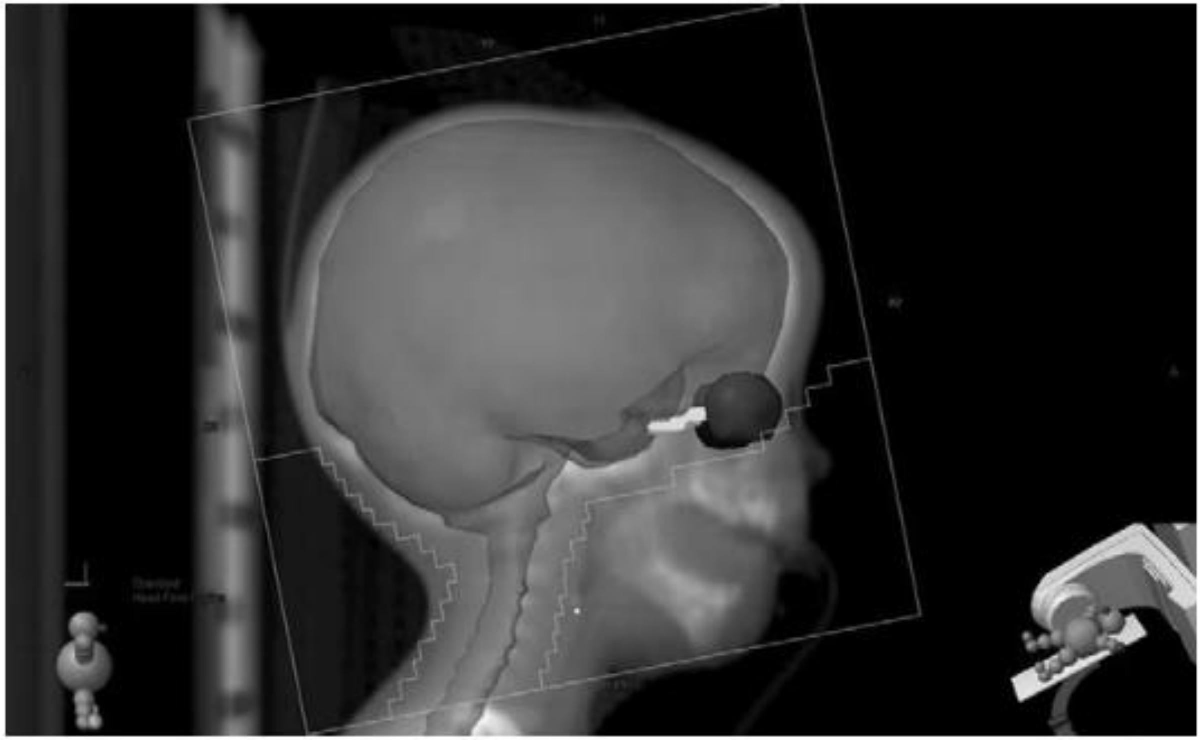


Fig. 2. "Beam-eye view" of a lateral field of a 3D conformal RT plan. Despite not intentionally targeting the optic nerves, both are well encompassed in the field.

There are dosimetric studies which have shown that anterior part of Optic N- gets under dosed in IMRT plans if its especially not contoured and targeted

However, its still a topic of controversy

Favour- Sub arachnoid space around ON

Against- Anecdotal case reports of recurrence around ON and impact on eye/lens doses

Radiotherapy and Oncology xxx (2018) xxx–xxx

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journal homepage: www.thegreenjournal.com

Original article

SIOPE – Brain tumor group consensus guideline on craniospinal target volume delineation for high-precision radiotherapy

Thankamma Ajithkumar [a,*], Gail Horan [a], Laetitia Padovani [b], Nicky Thorp [c], Beate Timmermann [d],

Atlas for Target Volume Delineation for Craniospinal Radiotherapy

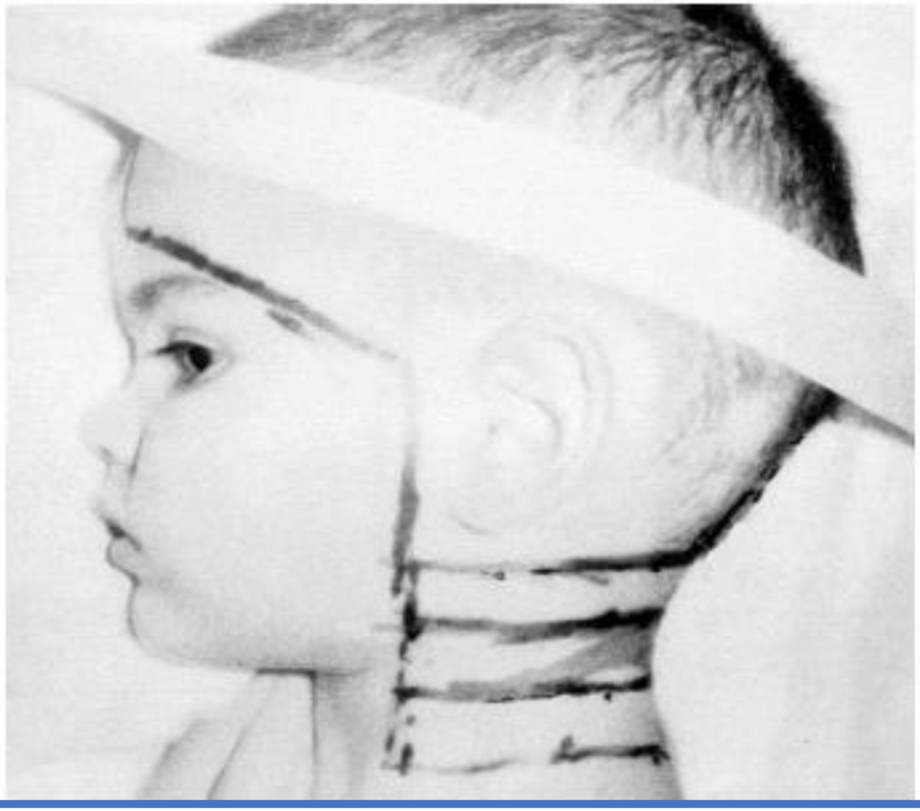
SIOPE Brain Tumour Group
Guide for Clinical Trial Protocols

CTV Cranial/Brain

- Contour whole brain within inner table of skull
- Bone window (suggested window levels are 1500-2000/300-350)
- Ensure coverage of cribriform plates
- Most inferior aspect of temporal lobes
- Whole pituitary fossa

Subfrontal/cribriform Recurrence

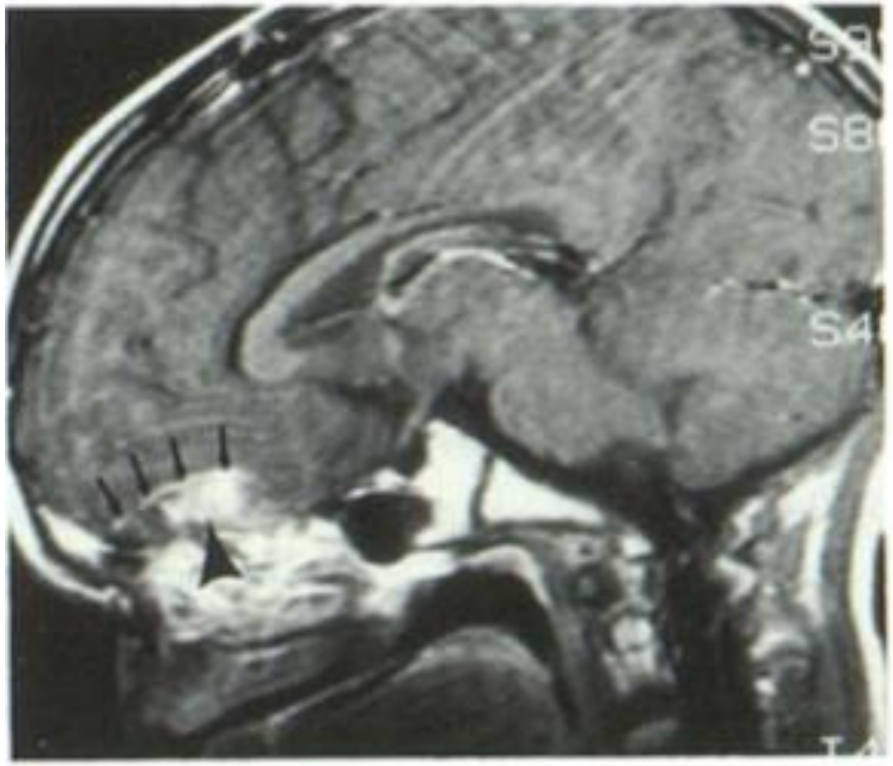
Helmet technique
(anterior cranial fossa shielded / relapse)
(C. Carrie et al, 1994)

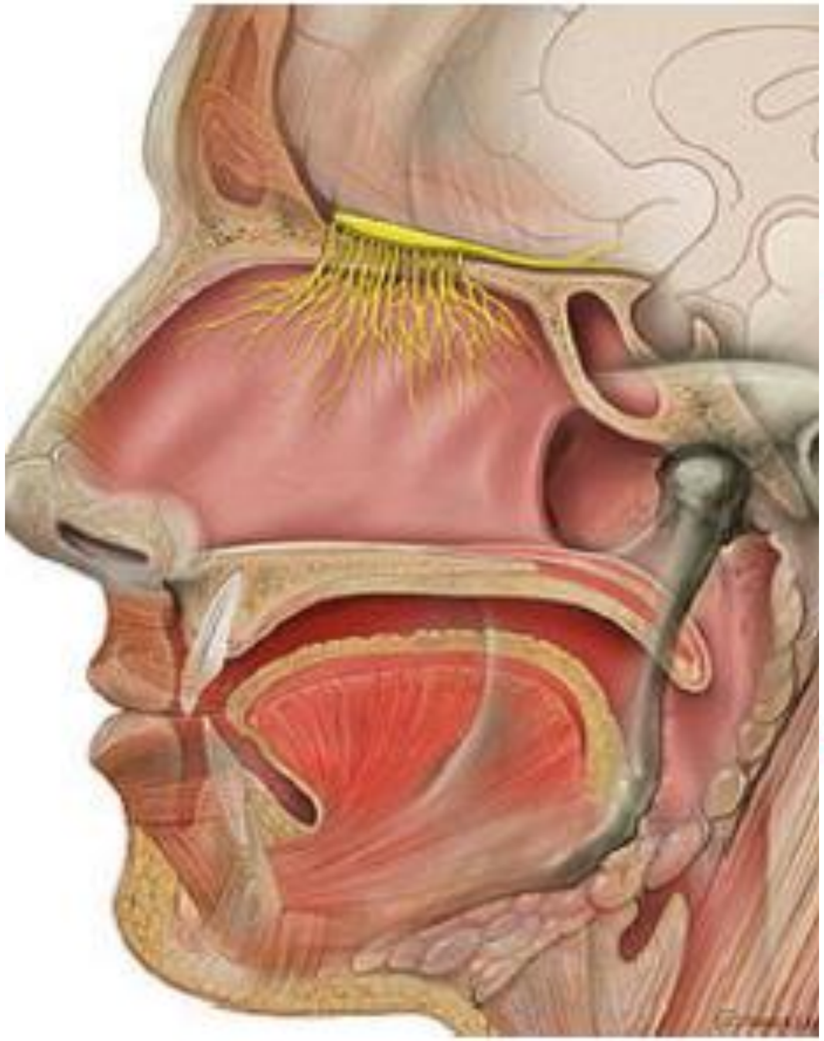


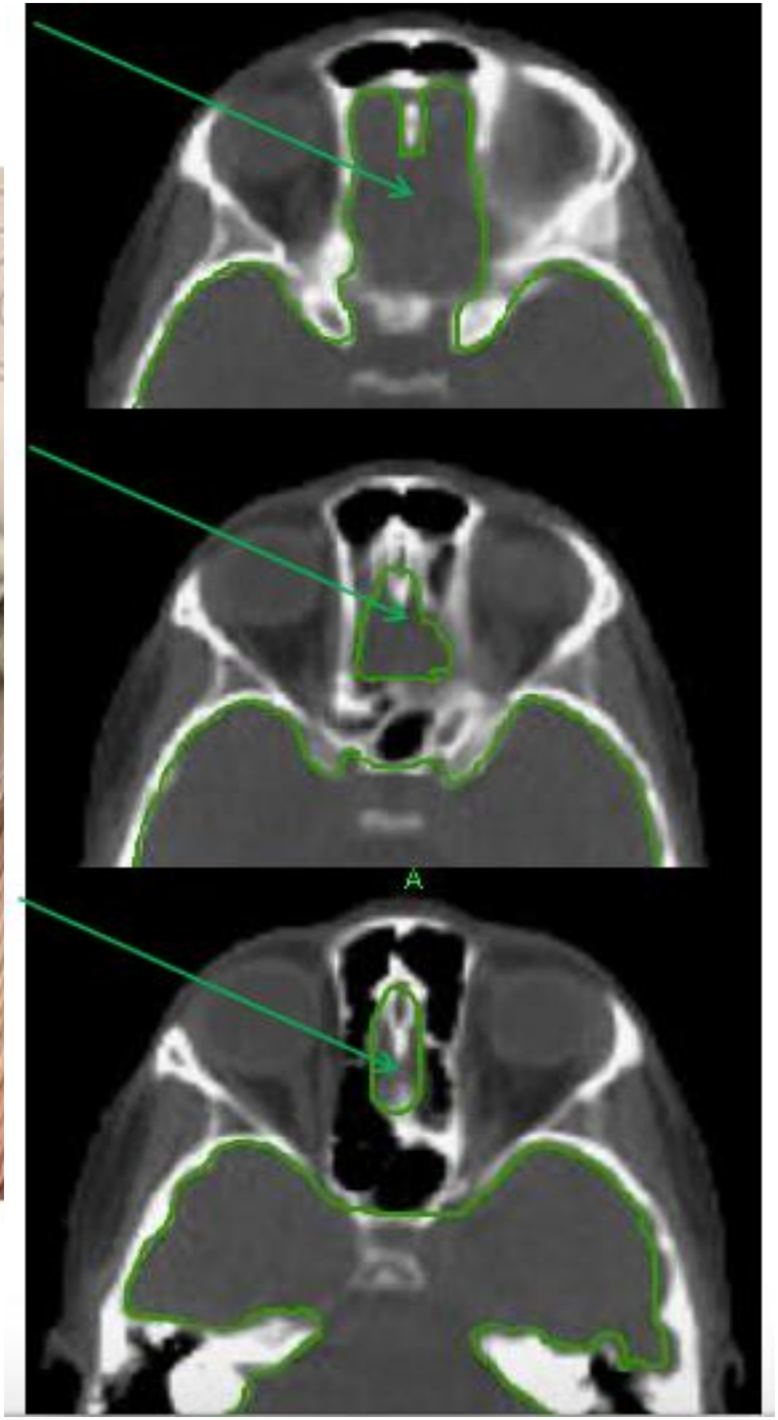
Possible reasons- Patients are operated in prone position- gravity –Cribriform recurrences; over zealous use of Eye Blocks

Subfrontal Recurrence of Medulloblastoma

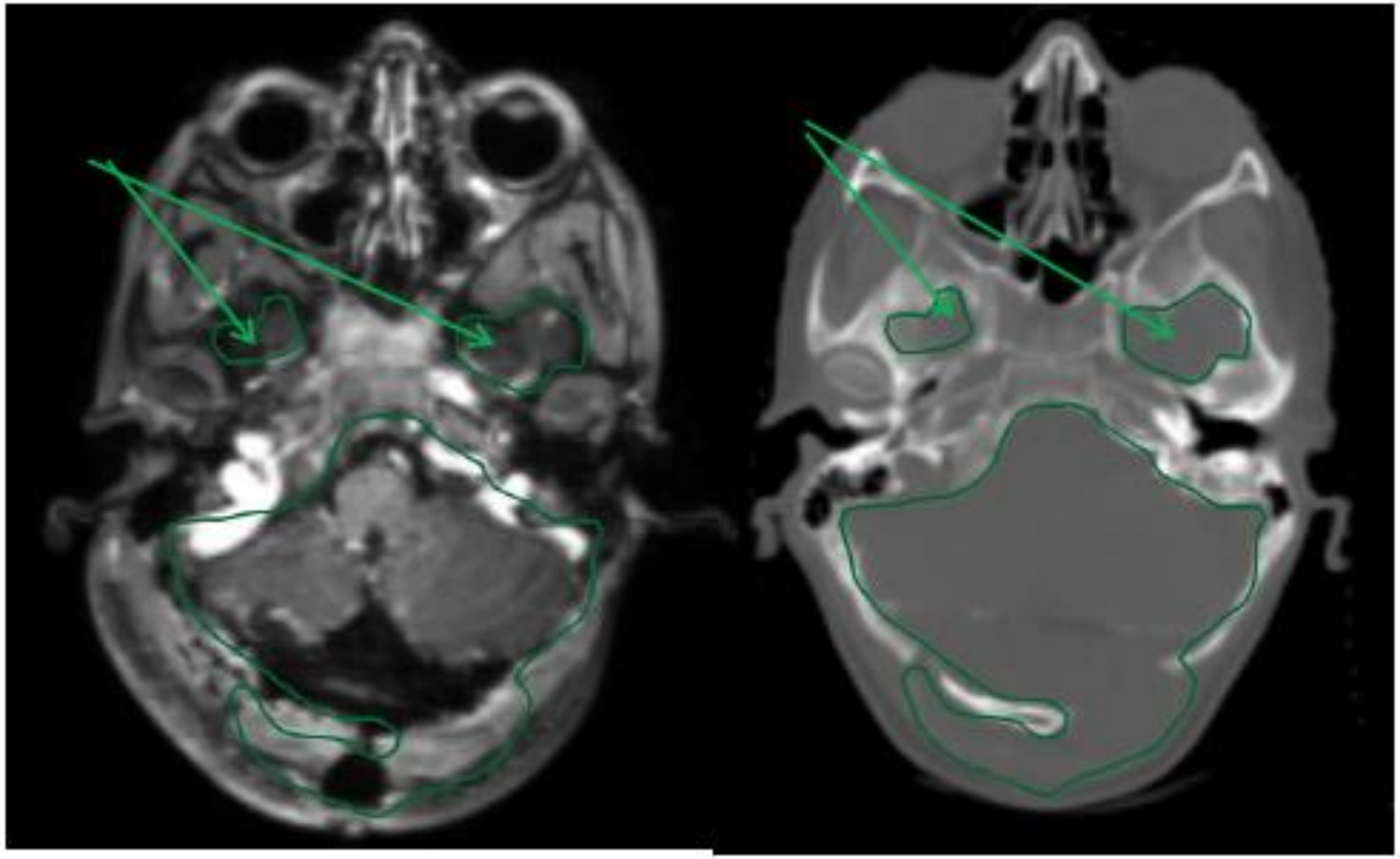
John Donnal,[4] Edward C. Halperin,[2] Henry S. Friedman,[3] and Orest B. Boyko[1]





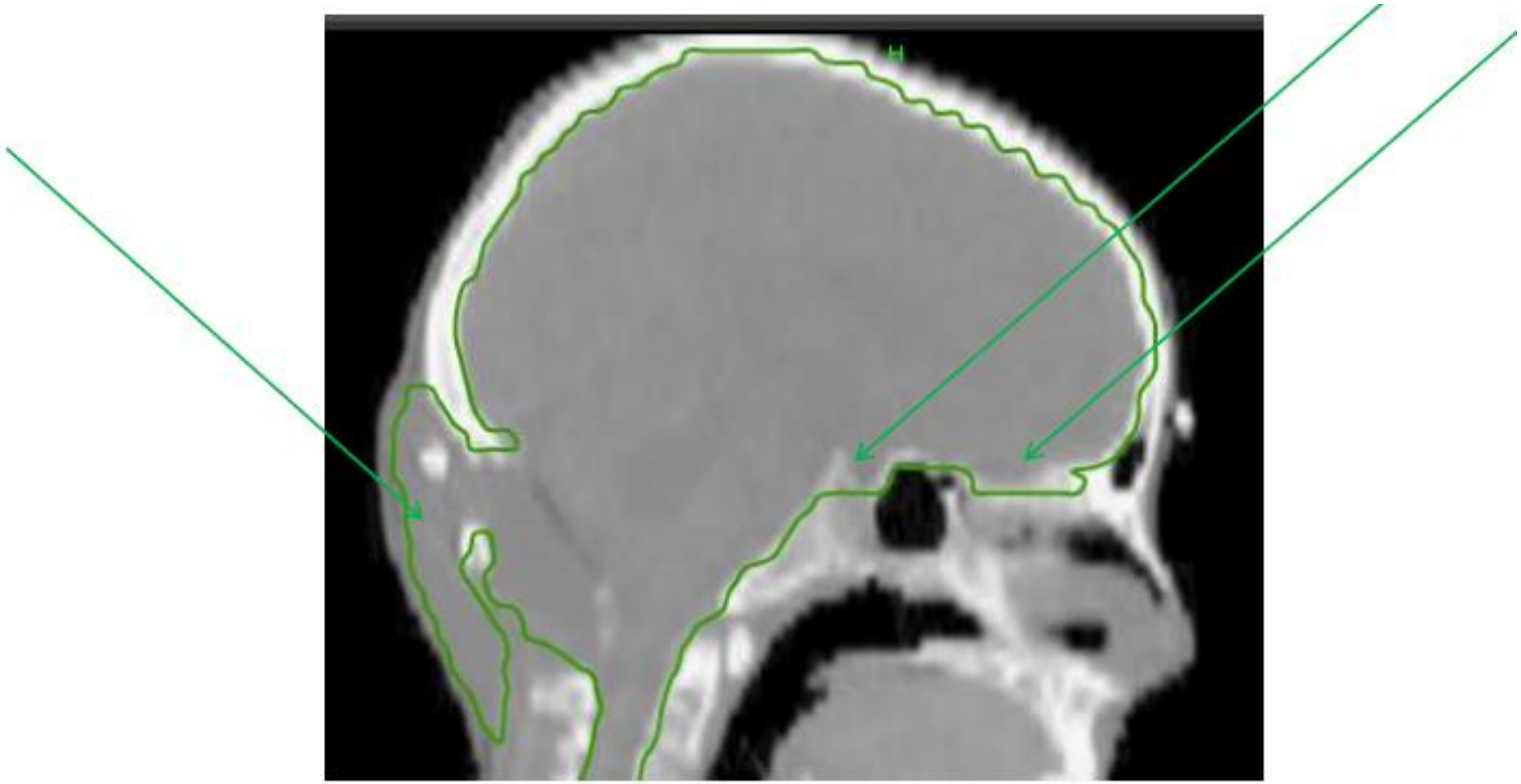


Cribriform Plate area contouring



Inferior portion of temporal lobes need extra attention- Bone window

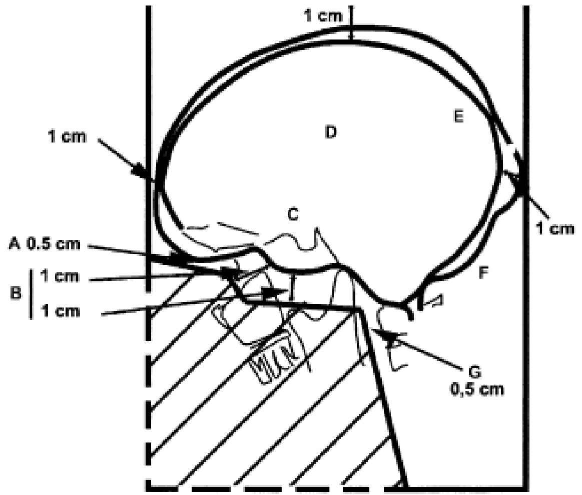
Any meningeal /parenchymal herniation should also be included well in CTV Cranium



Always Cross check CTV in sagittal view

Fast imaging employing steady-state acquisition (FIESTA) MRI to investigate cerebrospinal fluid (CSF) within dural reflections of posterior fossa cranial nerves

[1]DAVID J NOBLE, MSc, FRCR, [2]DANIEL SCOFFINGS, MBBS, FRCR, [1]THANKAMMA AJITHKUMAR, MD, FRCR,



- Majority of target contouring knowledge comes fro PoF studies
- Inclusion of base skull foraminas and CSF containing sheaths has come from Planning radiological study
- Cranial N were always covered in conventional planning

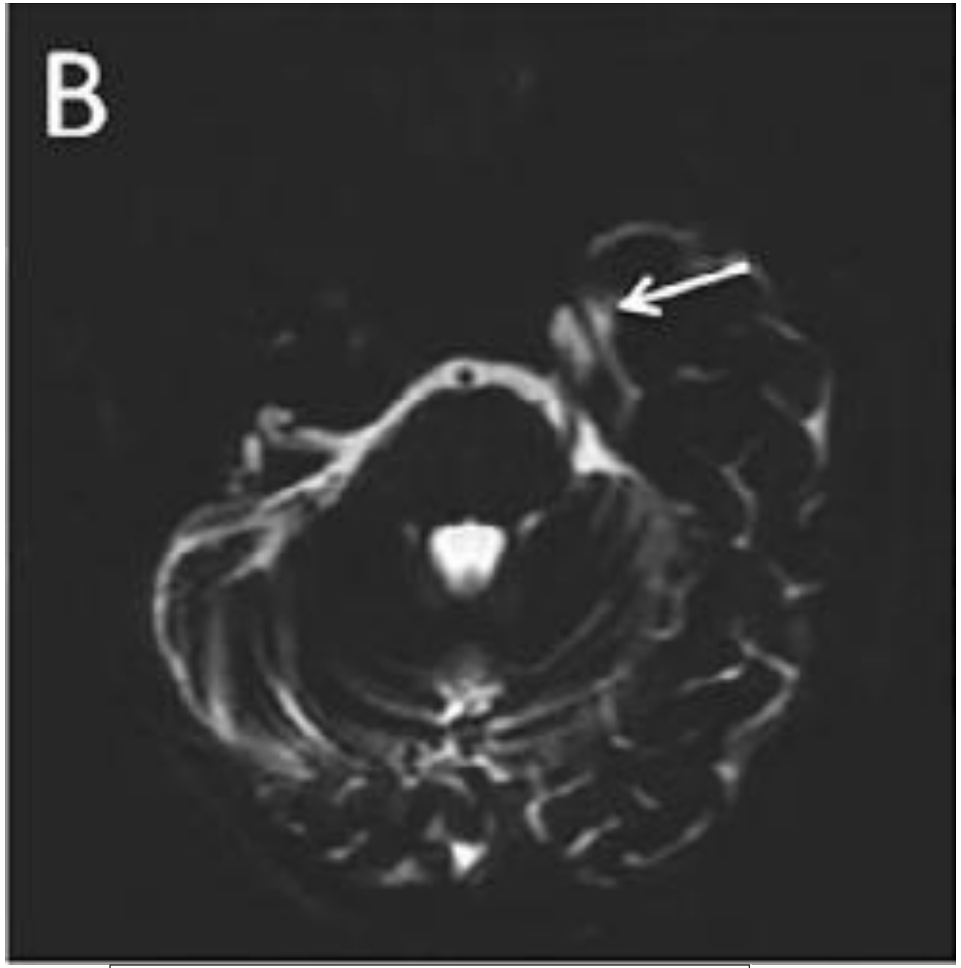
- 96 Posterior fossa FIESTA MRI sequences were reviewed
- CTV Cranial modified to include extension of CSF within dural sheath of cranial nerves- Cover dural cuffs containing CSF as they exit through skull base

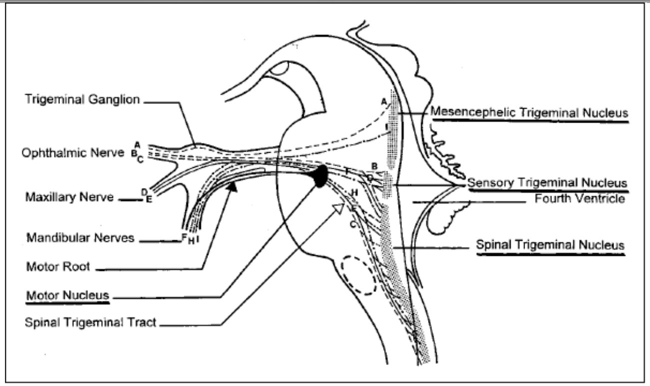
Olfactory Nerve

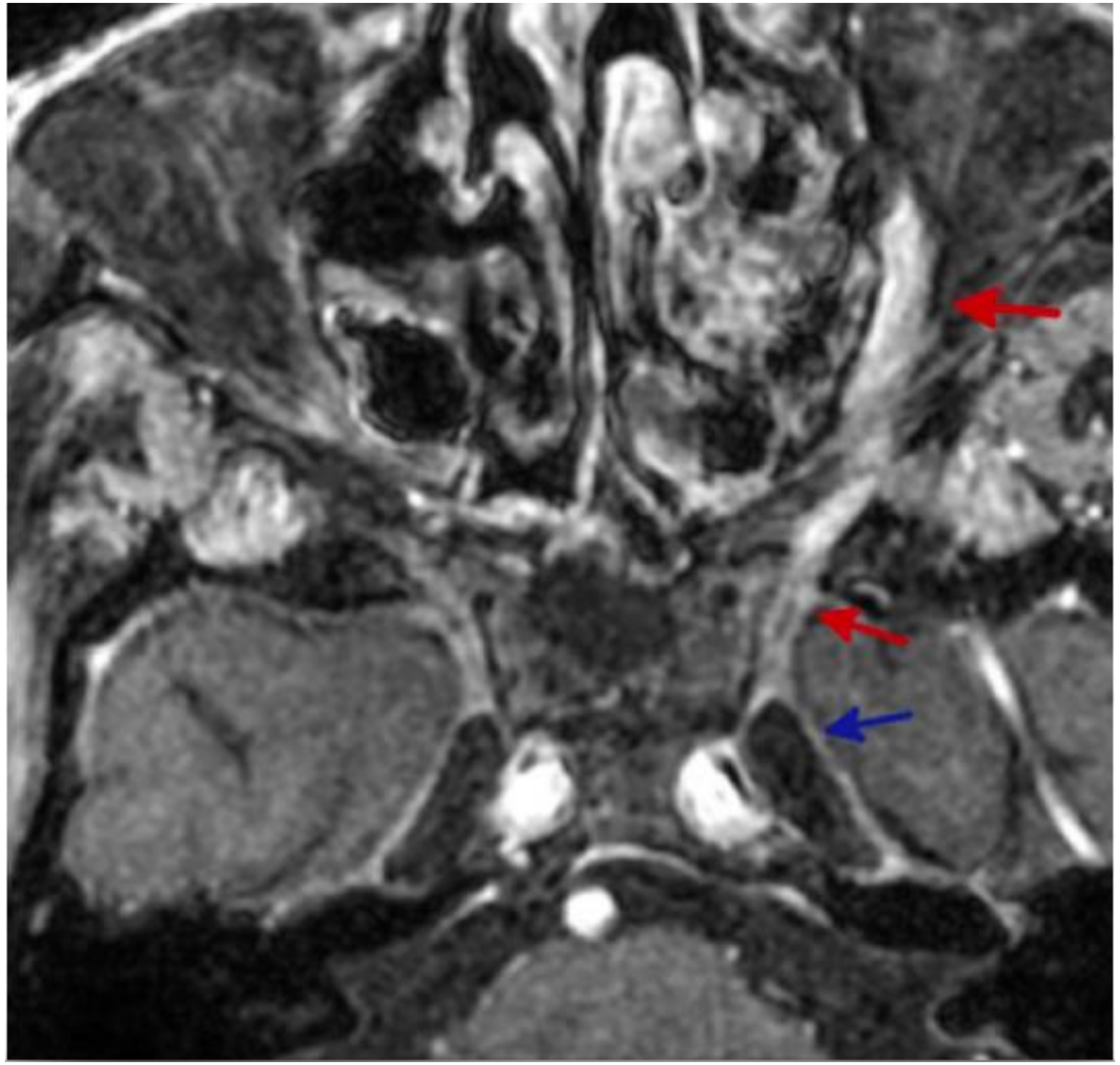
- Olfactory nerve fibres are encompassed in cribriform plate

- Oculomotor, Abducens and Trochlear N- thin nerves without a dural cuff and exit through superior orbital fissure

- Trigeminal Nerve- arises from ventral aspect of pons- forms Gasserian/Trigeminal ganglion within Meckel's cave- located lateral to cavernous sinus





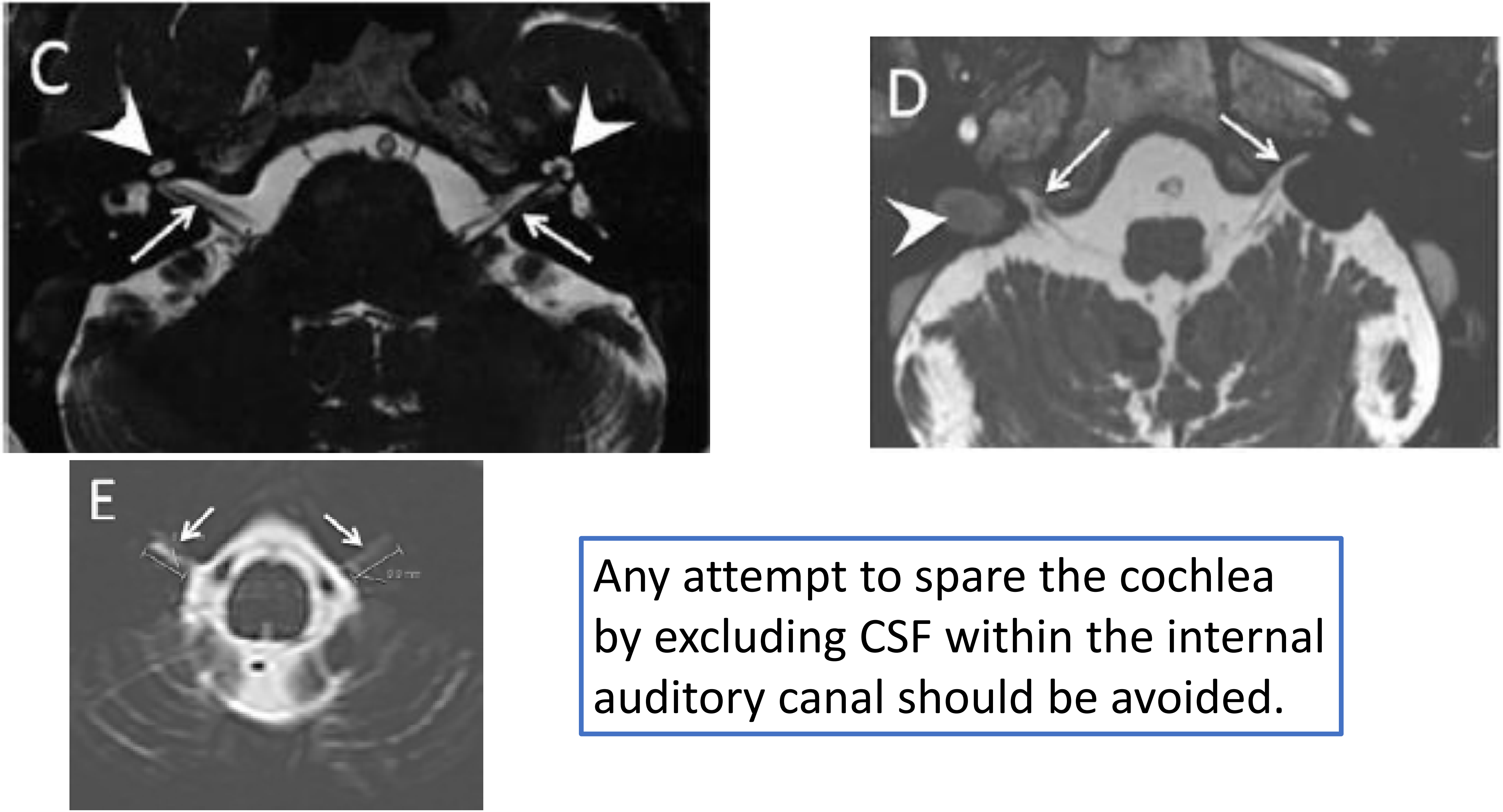


CSF within Meckel's cave gets covered in CTV Cranium

Three Branches-

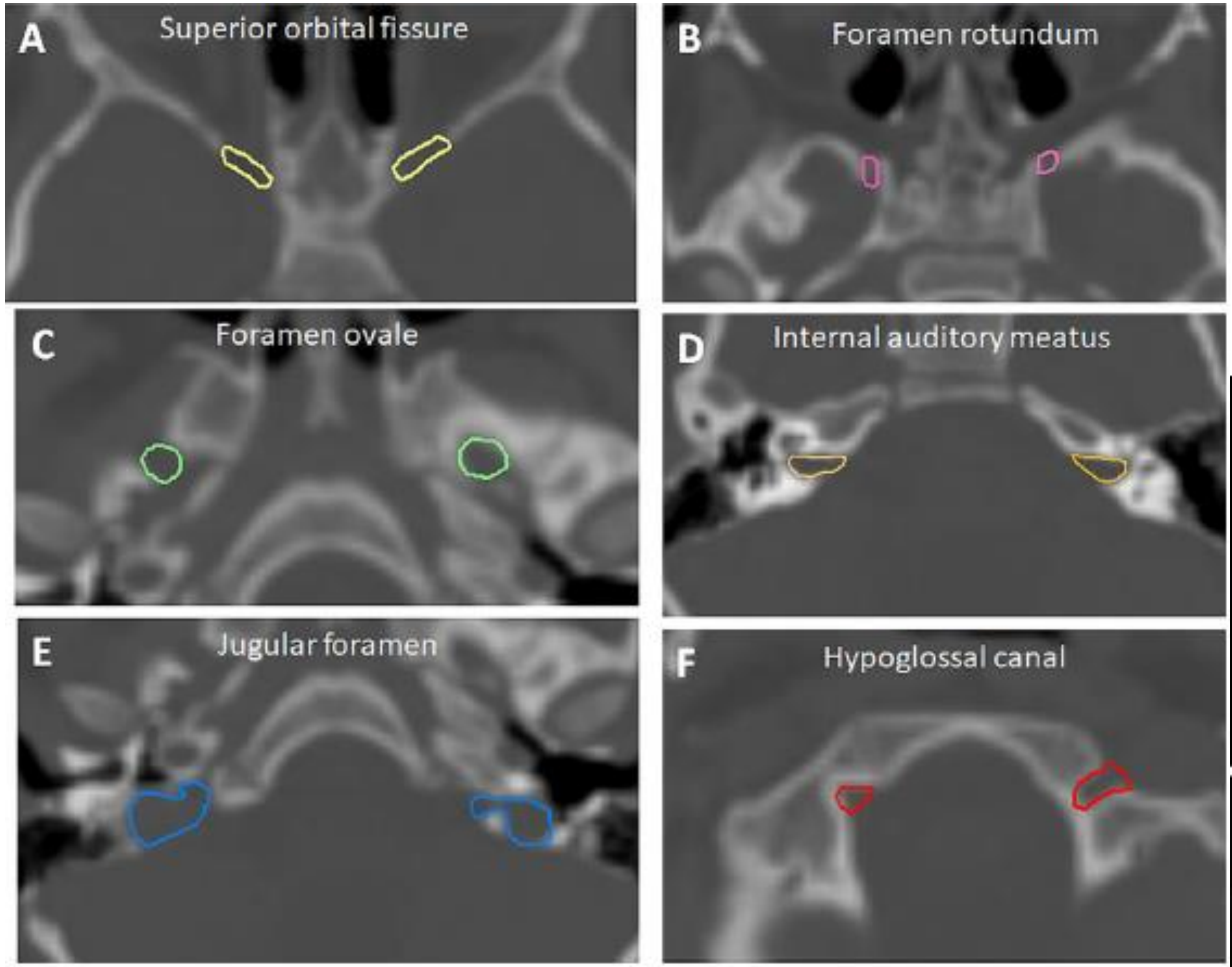
Ophthalmic Division- Superior Orbital Fissure
Maxillary- F Rotundum
Mandibular- F Ovale

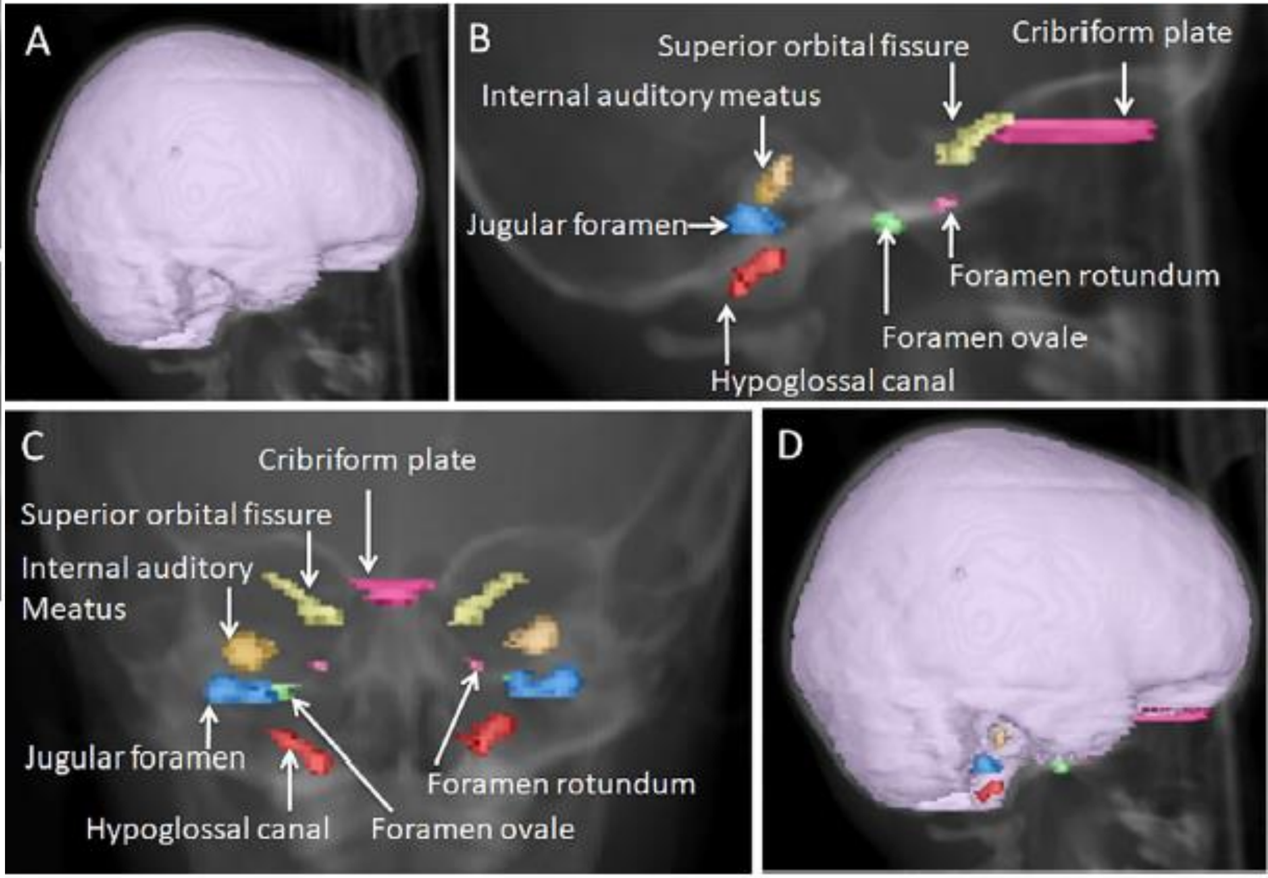
- Internal Auditory Meatus (IAM)- Facial and Vestibulocochlear N
- Juglar F (JF)- Glossopharyngeal, Vagus and Accessory
- Hypoglossal Canal- Hypoglossal N
- CSF flow within dural sheath in these cranial N has been shown up to 10-16 mm
- Correlative CT studies have shown that CSF space d/n extend beyond outer table



Any attempt to spare the cochlea by excluding CSF within the internal auditory canal should be avoided.

Skull base foramen/Canal	Cranial nerve(s)
Cribriform plate	Olfactory nerve
Optical canal of sphenoid	Optic nerve[**]
Superior orbital fissure	Oculomotor, trochlear, and first branch of trigeminal, and abducens nerves
Foramen rotundum	Second branch of trigeminal nerve
Foramen Ovale	Third branch of trigeminal nerve
Internal auditory meatus	Facial and vestibulo-cochlear nerves
Jugular foramen	Glossopharyngeal, vagus, and accessory nerves
Hypoglossal canal	Hypoglossal nerve


A
Superior orbital fissure
B
Foramen rotundum
C
Foramen ovale
D
Internal auditory meatus
E
Jugular foramen
F
Hypoglossal canal


A
B
Superior orbital fissure
Cribriform plate
Internal auditory meatus
Jugular foramen
Foramen rotundum
Foramen ovale
Hypoglossal canal
C
Cribriform plate
Superior orbital fissure
Internal auditory
Meatus
Jugular foramen
Hypoglossal canal
Foramen rotundum
Foramen ovale
D

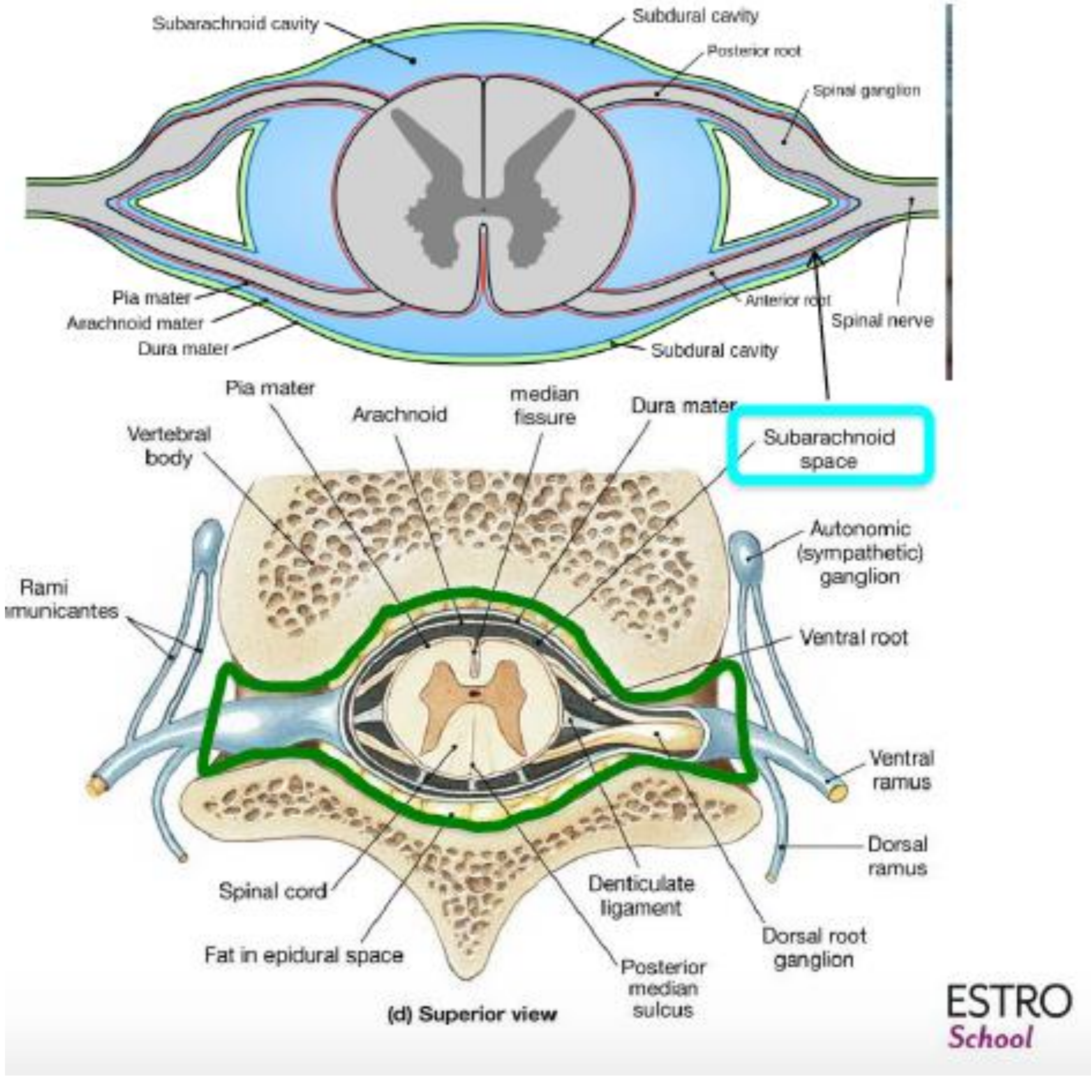
Target Delineation

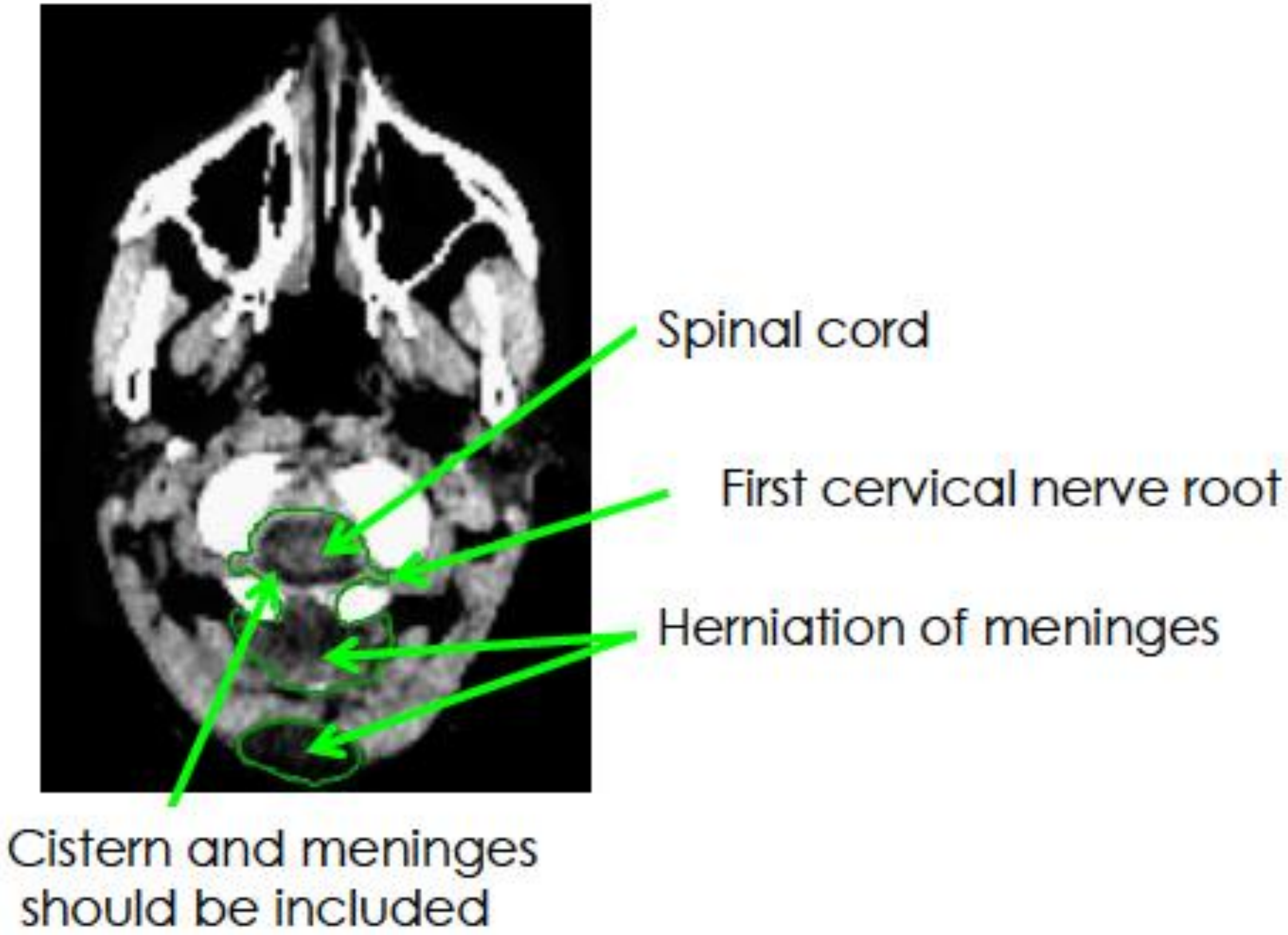
- Since the entire CSF space is at risk of disease dissemination, the entire sub arachnoid space is defined as the CTV.

CTV Cranial: 3 steps

1. Inner table of the skull is outlined using bony window settings (suggested CT Window/level: 1500–2000/300–350).
2. Cribriform plate (most inferior parts of the temporal lobes), and whole pituitary fossa (which contains CSF) are included.
3. CTV cranial is modified to include the extension of CSF within the dural sheath of cranial nerves.

CTV Spinal- Entire Subarachanoid Space including extension along nerve roots laterally

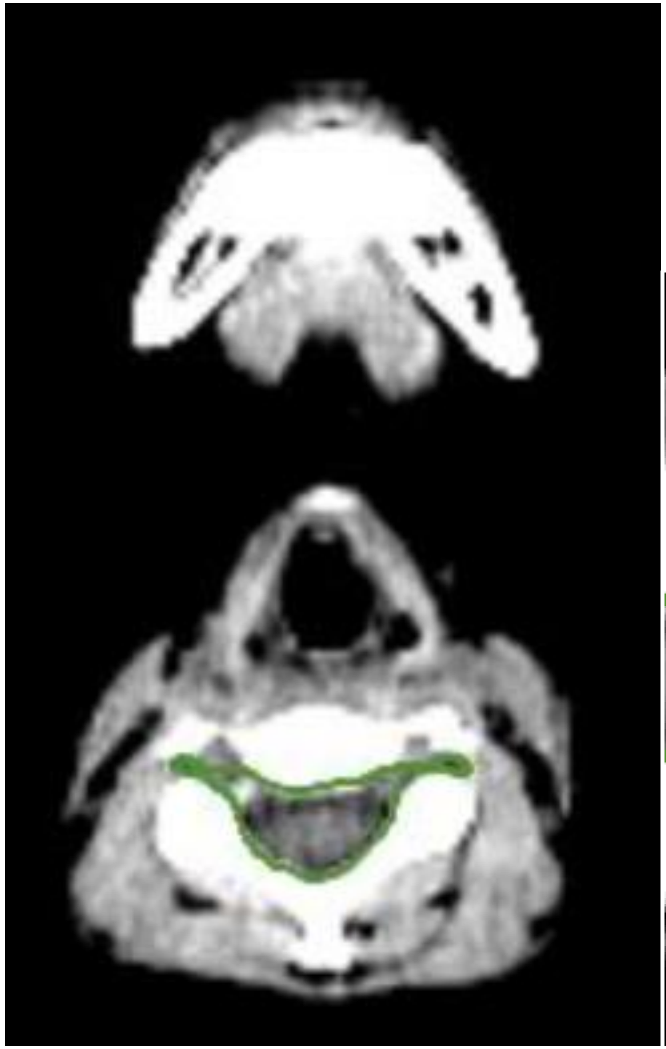


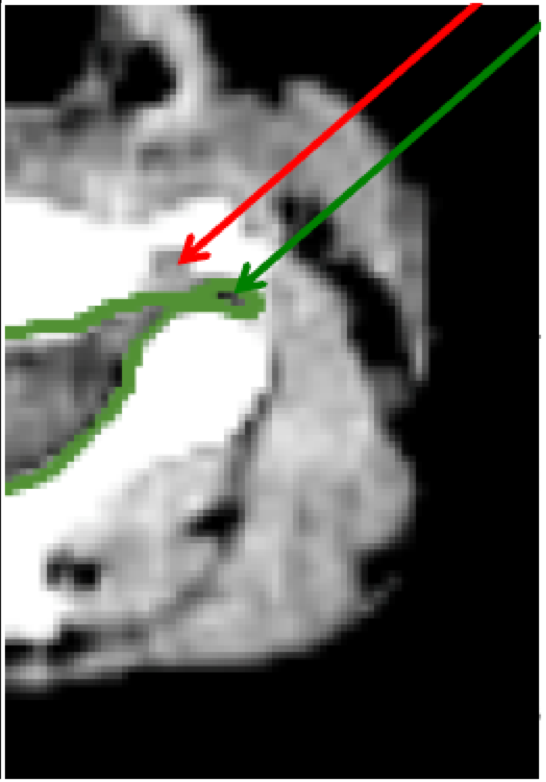


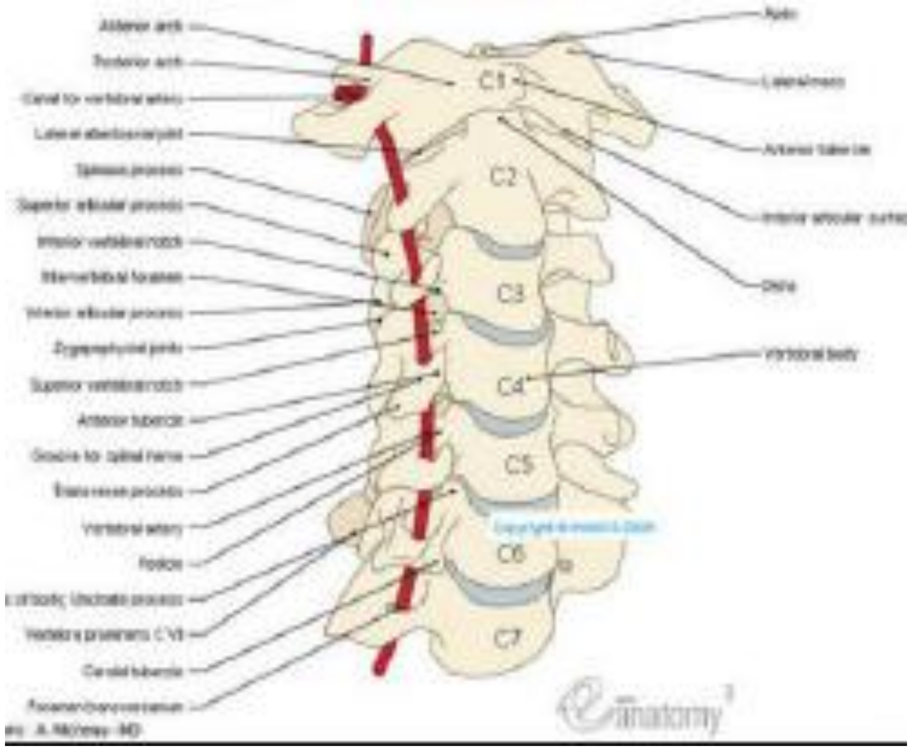
There are 7 cervical vertebrae and eight cervical Nerves

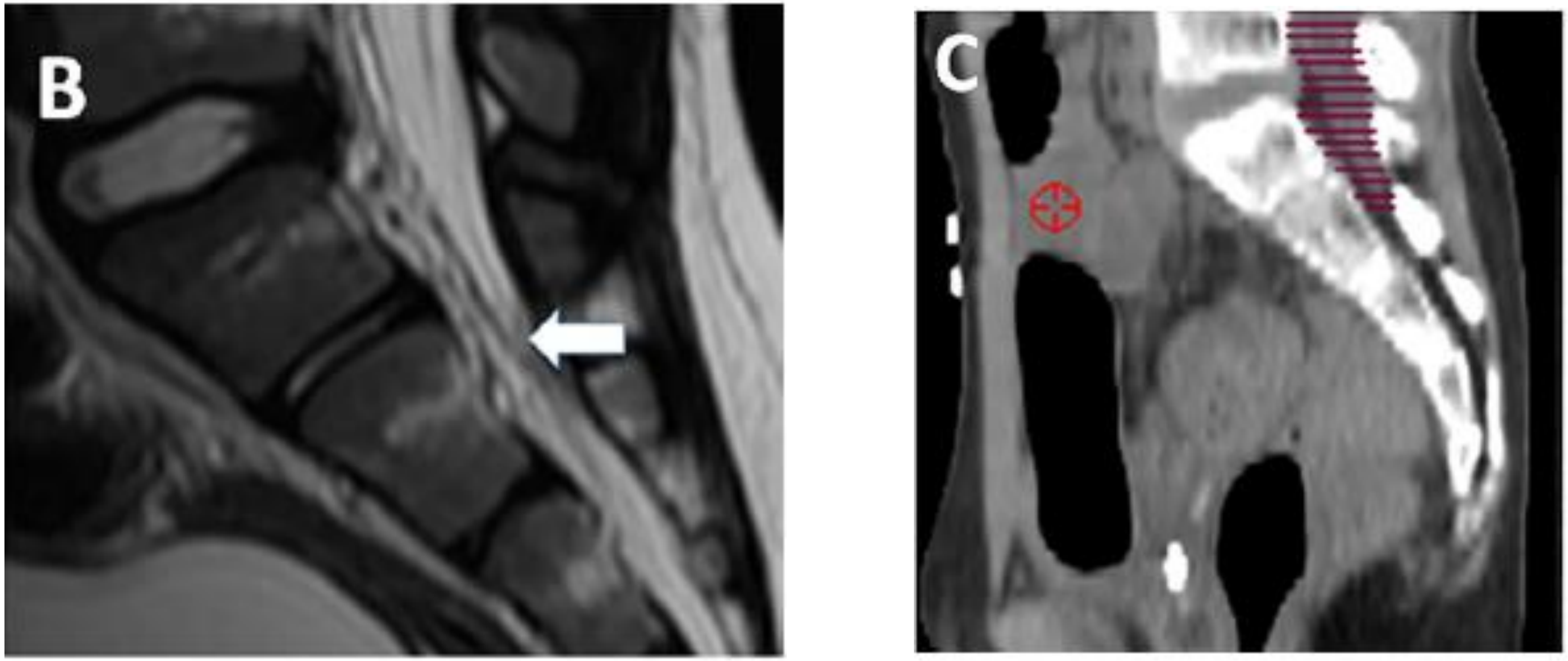
Make sure to include first cervical nerve which exits b/w occiput and Atlas vertebrae

Do Not include Vertebral A in CTV Spinal









- Inferior limit of CTV Spinal is lower limit of thecal sac which is best seen on MRI Spine
- Above L5/S1 <10% cases
- Bottom of S1-50% cases
- Bottom of S2 >90% cases

Int. J. Radiation Oncology Biol. Phys., Vol. 41, No. 3, pp. 621–624, 1998

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PII S0360-3016(97)00562-2

● *Clinical Investigation*

DETERMINATION OF THE INFERIOR BORDER OF THE THECAL SAC USING MAGNETIC RESONANCE IMAGING: IMPLICATIONS ON RADIATION THERAPY TREATMENT PLANNING

Carole B. Scharf, M.D.,* Arnold C. Paulino, M.D.* and Kenneth N. Goldberg, M.D.†

Traditional teaching is to give caudal border of spinal field at S2-3 interspace

Spine MRI of 23 children were studied

8.7% children had thecal sac termination below S2-3

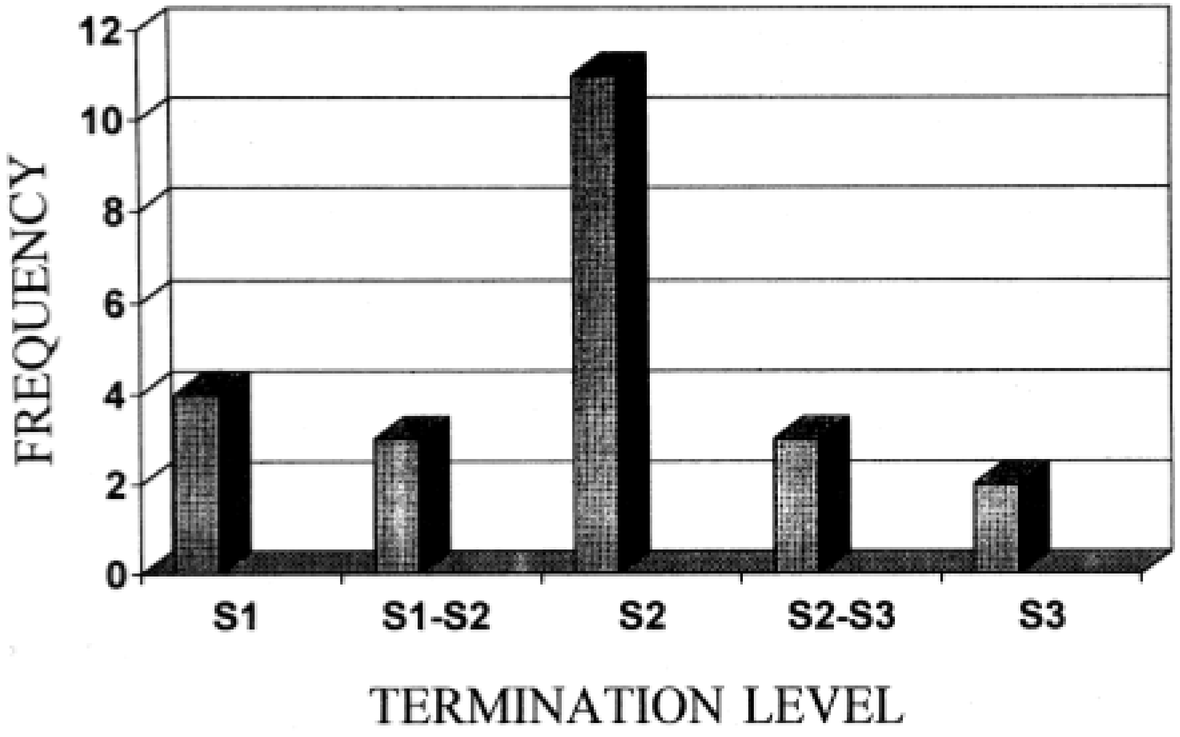


Fig. 2. Distribution of thecal sac termination levels in the 23 children who had spinal magnetic resonance imaging prior to the craniospinal irradiation.

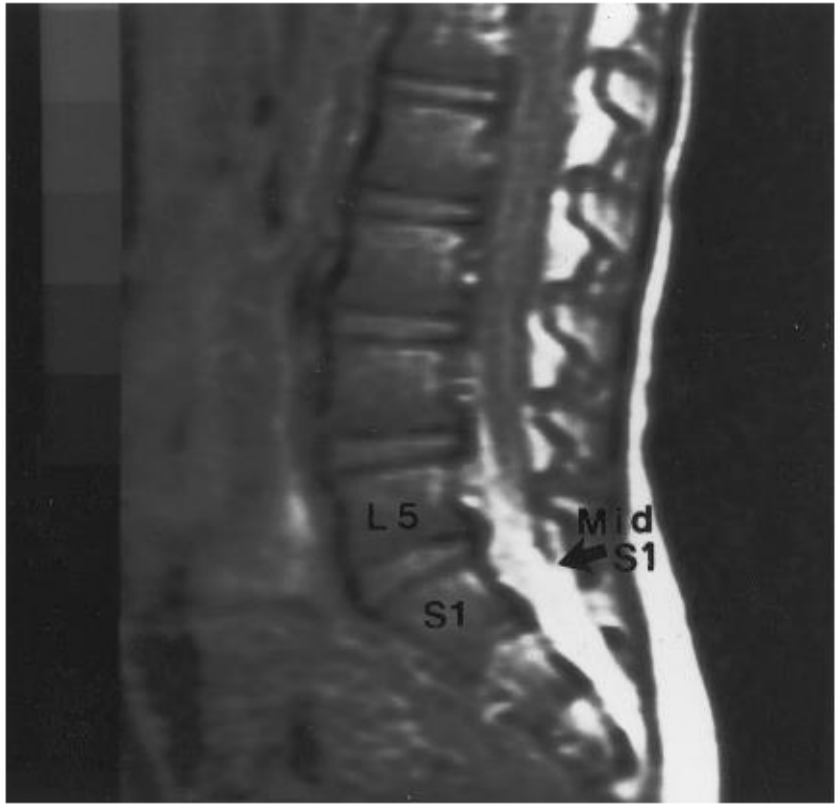
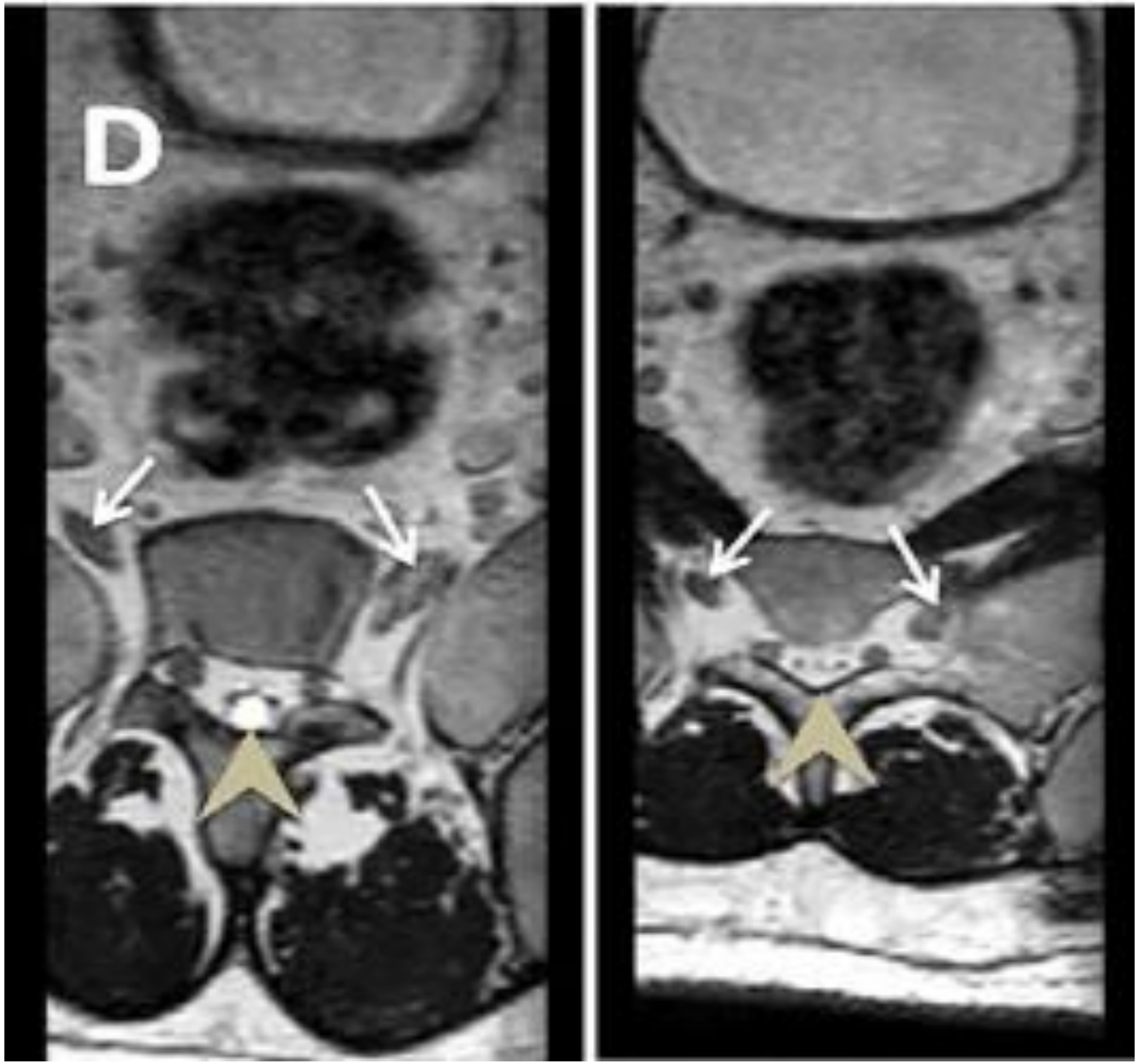


Fig. 1. Magnetic resonance imaging (MRI) of the spine showing thecal sac termination (arrow) at the mid-S1 vertebral level.



No need to cover sacral nerve roots as multiple studies have shown there is no CSF flow along sacral nerve roots

Scoliosis in Children Treated With Photon Craniospinal Irradiation for Medulloblastoma

Arnold C. Paulino, MD,*,† Hilary S. Suzawa, MD,† ZoAnn E. Dreyer, MD,†

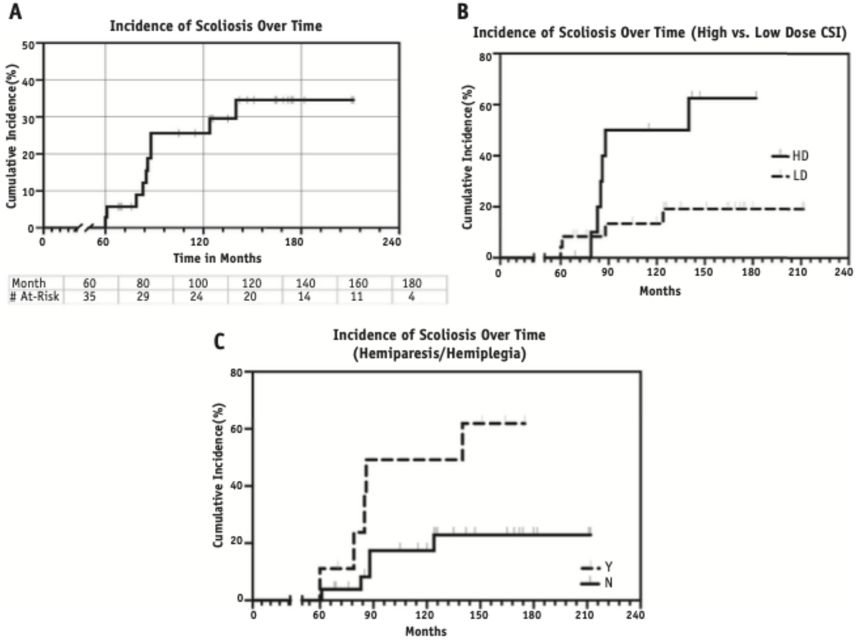


Fig. 3. Example of a case with moderate scoliosis after craniospinal irradiation (CSI) for medulloblastoma. The patient was 9 years of age at time of high-dose CSI (34.2 Gy). The x-ray was taken 10.3 years after CSI and showed a 10 degree to the right curvature from T4 to T8, 5-degree curvature from T9 to T11 convex to the left and 20-degree lumbar curve to the left from L2 to L5.

35 children with MB treated at MDACC from 1996-2006 – 3 DCRT
Age <12 years; median age 6.8 Y
Median FU 14.3 years (range 5.8-19.3Y)
15 Y cumulative incidence of scoliosis was 34.6%
Median time to develop scoliosis was 7.1 years
Treatment with high dose CSI (34.2-40 Gy) and presence of hemiparesis/hemiplegia were a/w scoliosis

Vertebral Body- How much to include?

Growing children, partial vertebral irradiation leads to spinal deformities.

- It is important to ensure uniform radiotherapy dose to the vertebrae in the region of the CTV spinal in growing children to avoid non-uniform growth cessation.

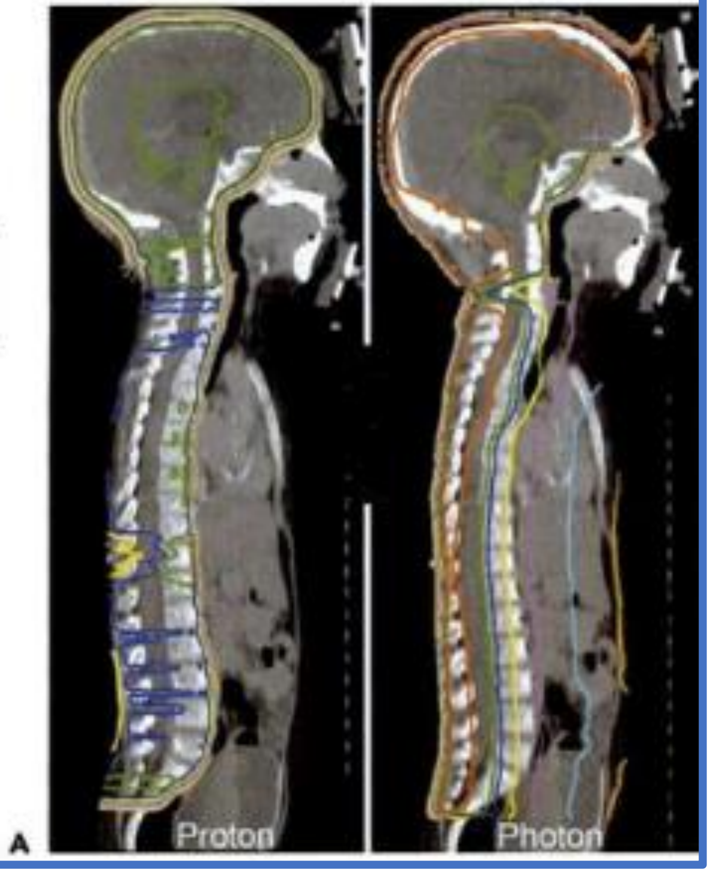
Parts of the vertebrae bearing growing plates (the body of the vertebra, the posterior element and facet joints; but not the lateral elements and transverse processes) should be enclosed to a uniform minimum dose (18–20 Gy).

DO WE HAVE TO INCLUDE in our PTV
THE ENTIRE VERTEBRAL BODY?

COMPLETED BONE GROWTH	NO

NOT COMPLETED BONE GROWTH

3DCRT	NO
VMAT/TOMO	MAYBE NO
PROTONS	YES

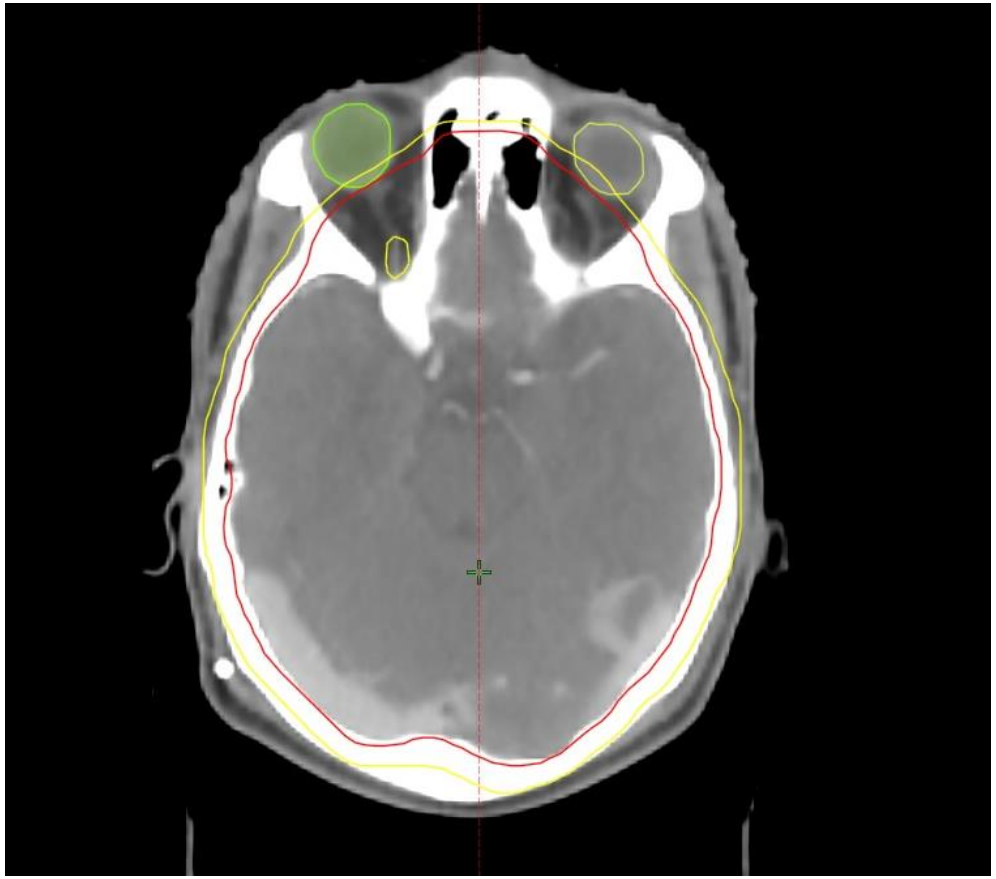


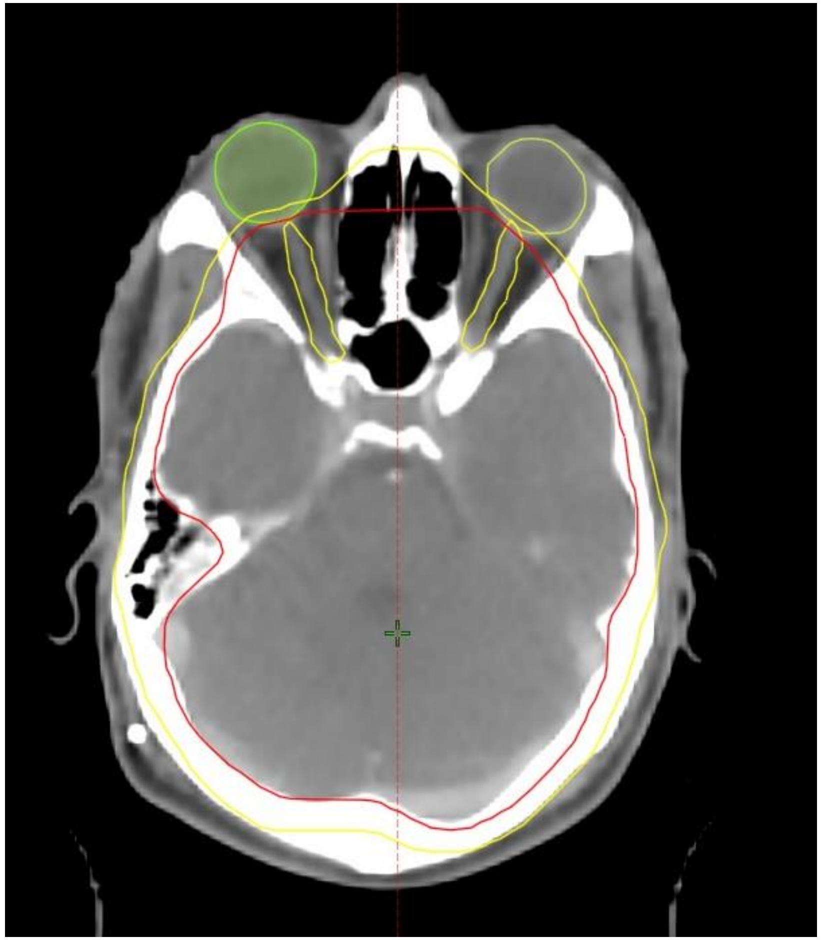
PTV

- PTV Cranial -3-5 mm
- PTV Spinal- 5-8 mm

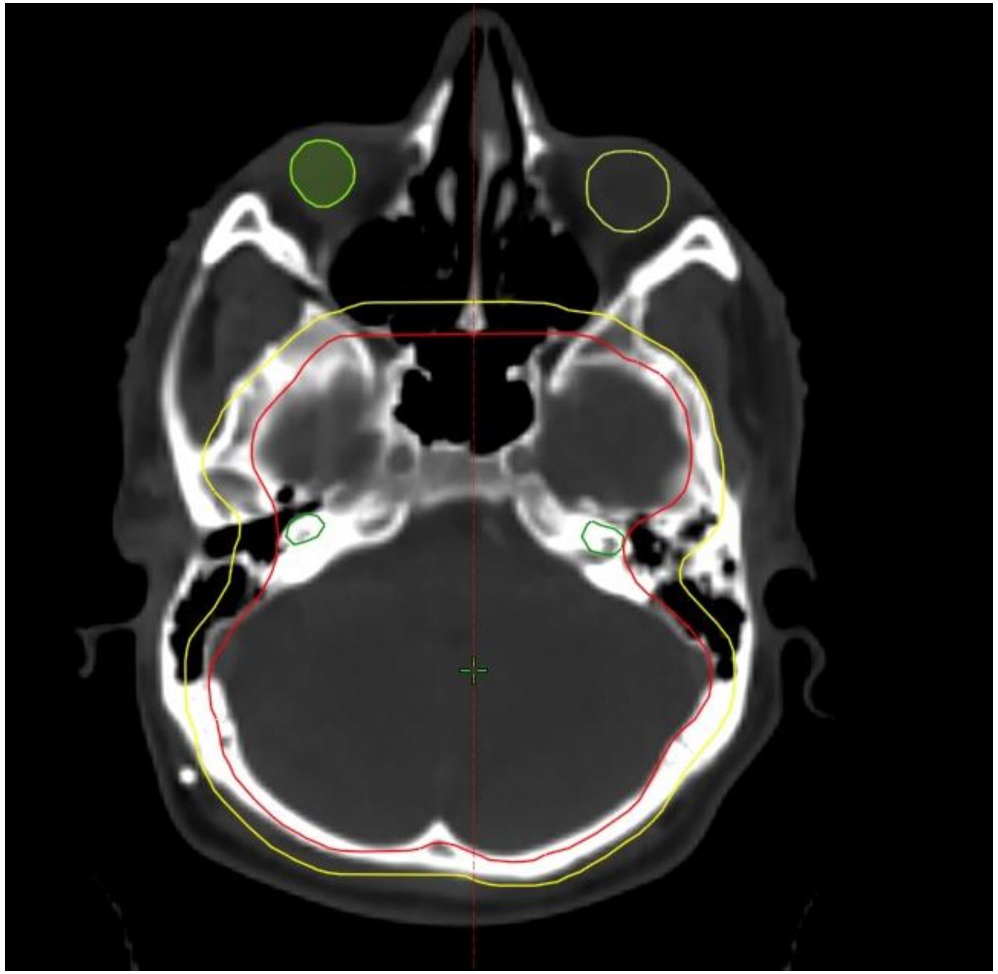
- Our Policy
- Brain- 5mm Isotropic
- Spine- 6 mm AA +10 mm CC

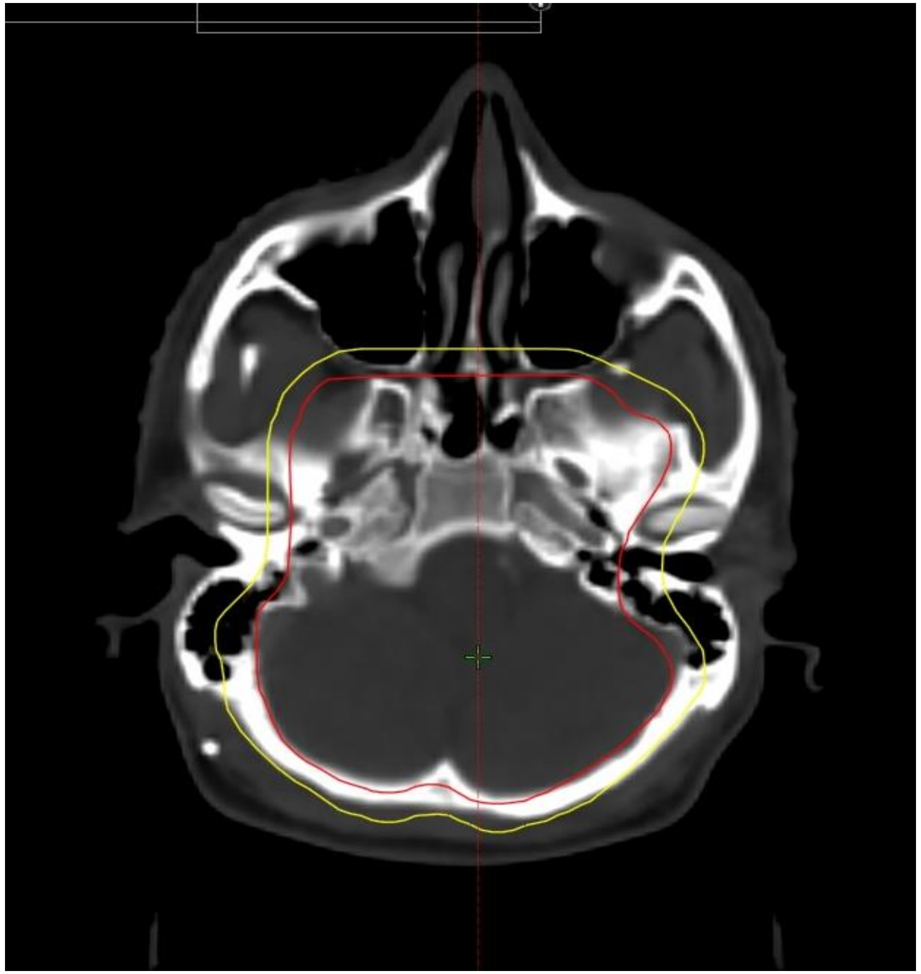
Contours from our patient- CTV includes Cribriform plates, Optic N up to eye balls, Pituitary fossa



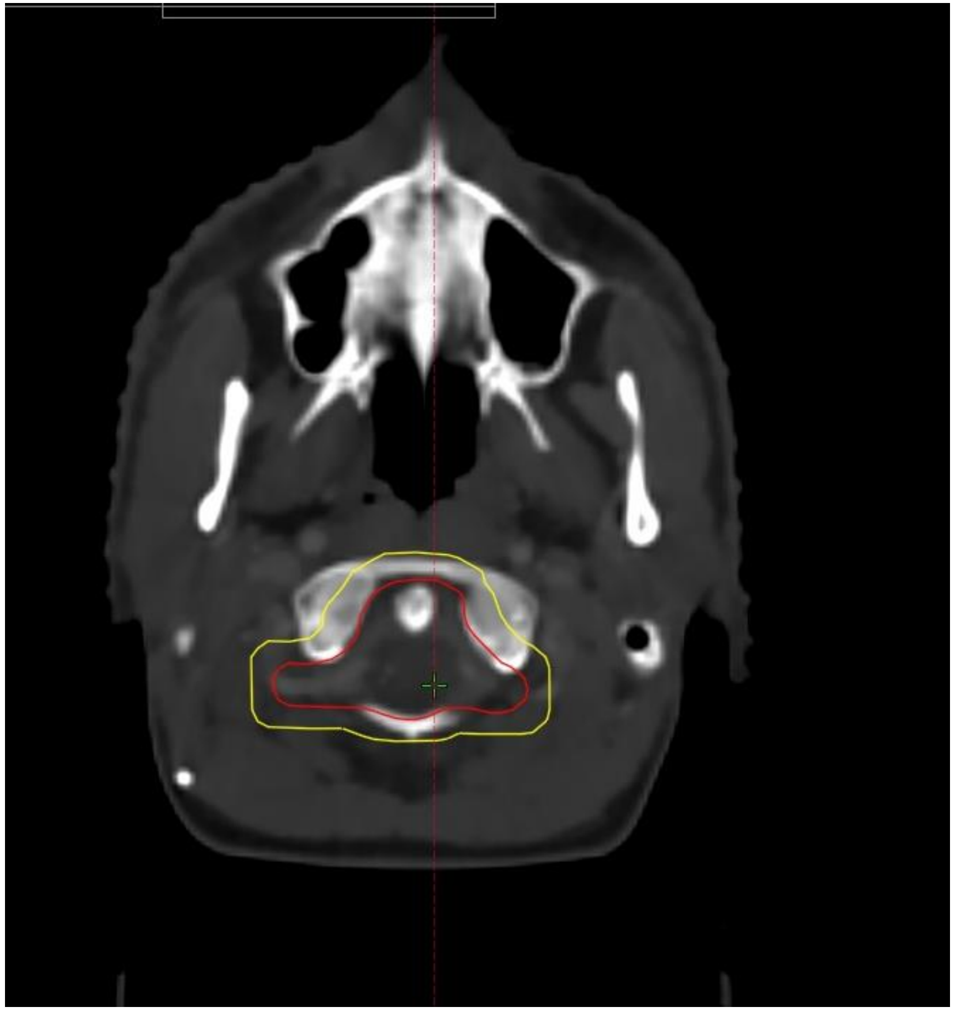


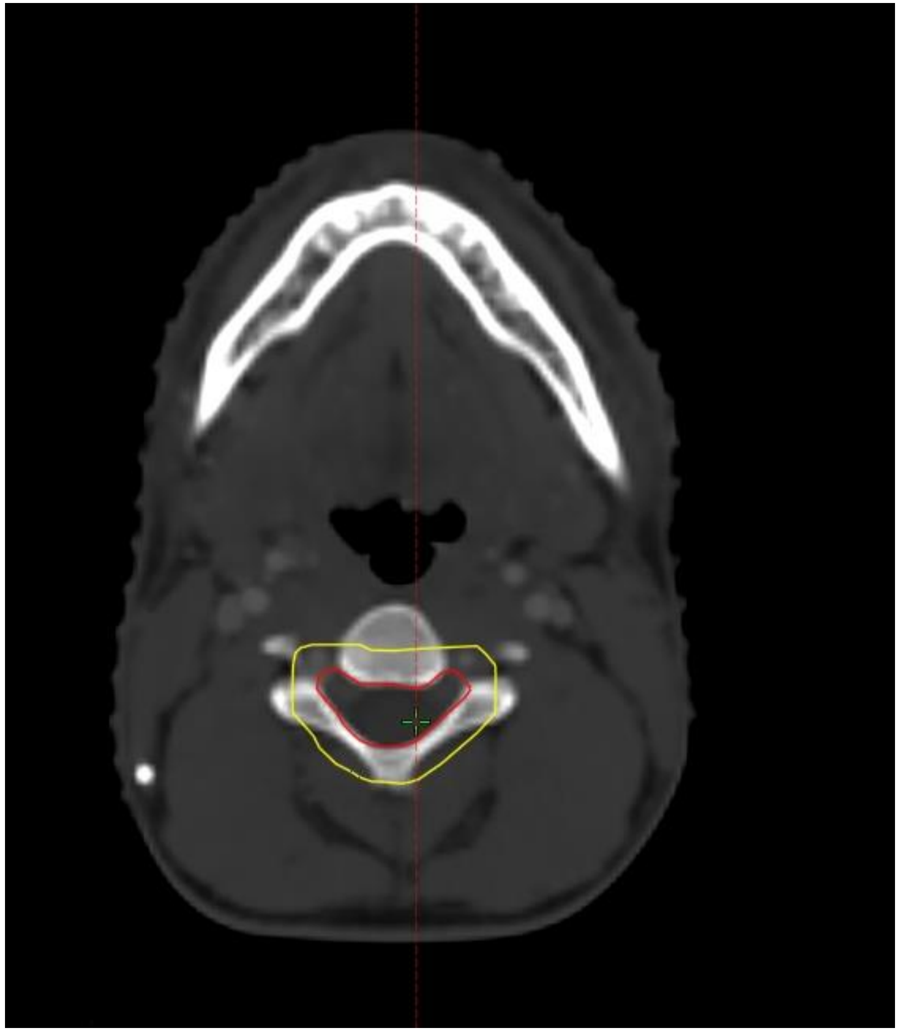
CTV – PTV along base skull in bone window– Cochlea and all formanias are covered in CTV

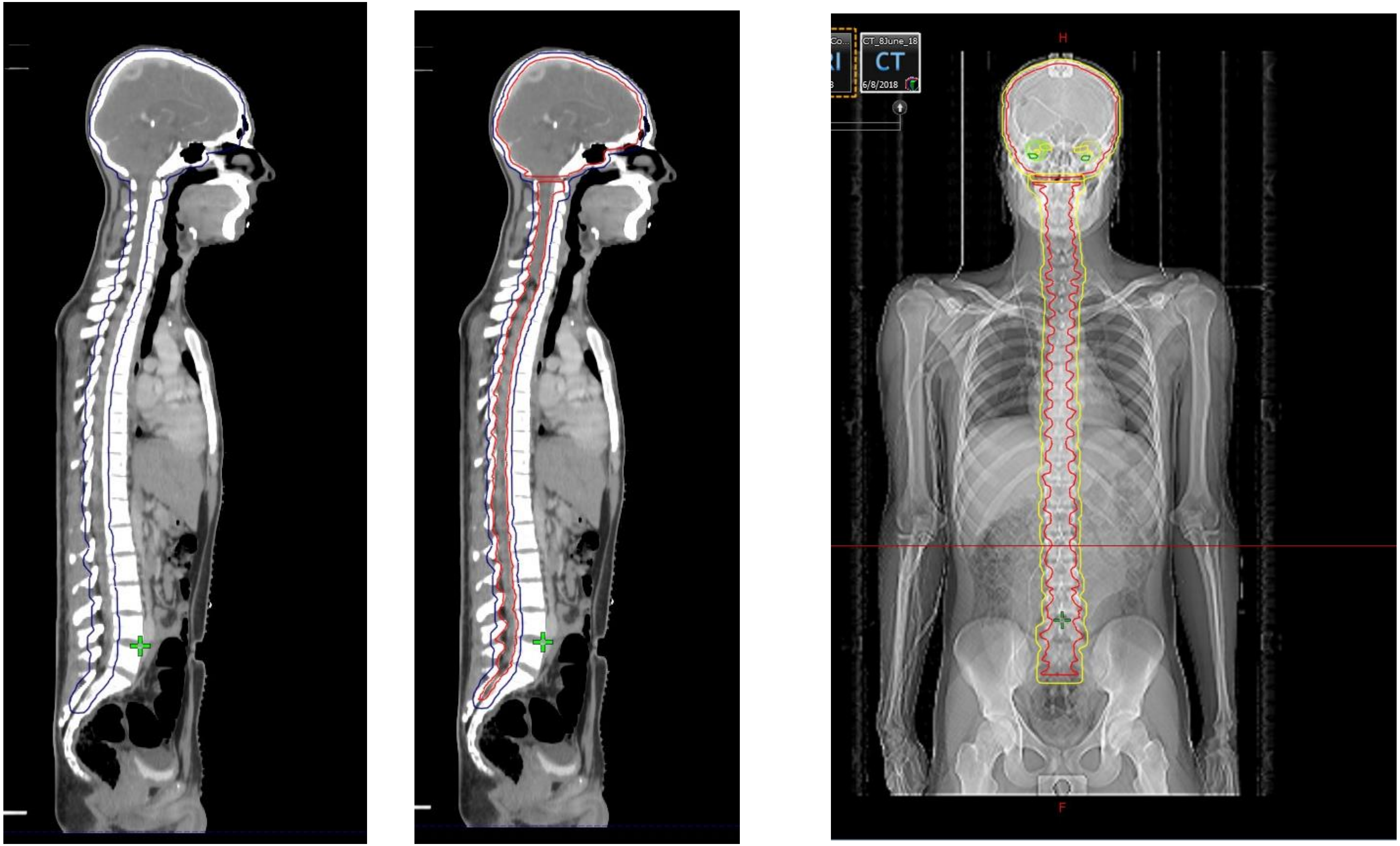




Spinal CTV including C1 Cervical N
CTV – PTV does not include entire vertebrae







Final Cranio Spinal CTV and PTV

OARS- Dose Recording and Assessment

Brain

- Eyes, lenses, Optic N, Optic Chiasm
- Cochlea
- Brain Stem
- Pituitary, Hypothalamus, Hippocampus

Head Neck

- Salivary glands
- Thyroid
- Mandible
- Oral Cavity &Larynx

Thorax

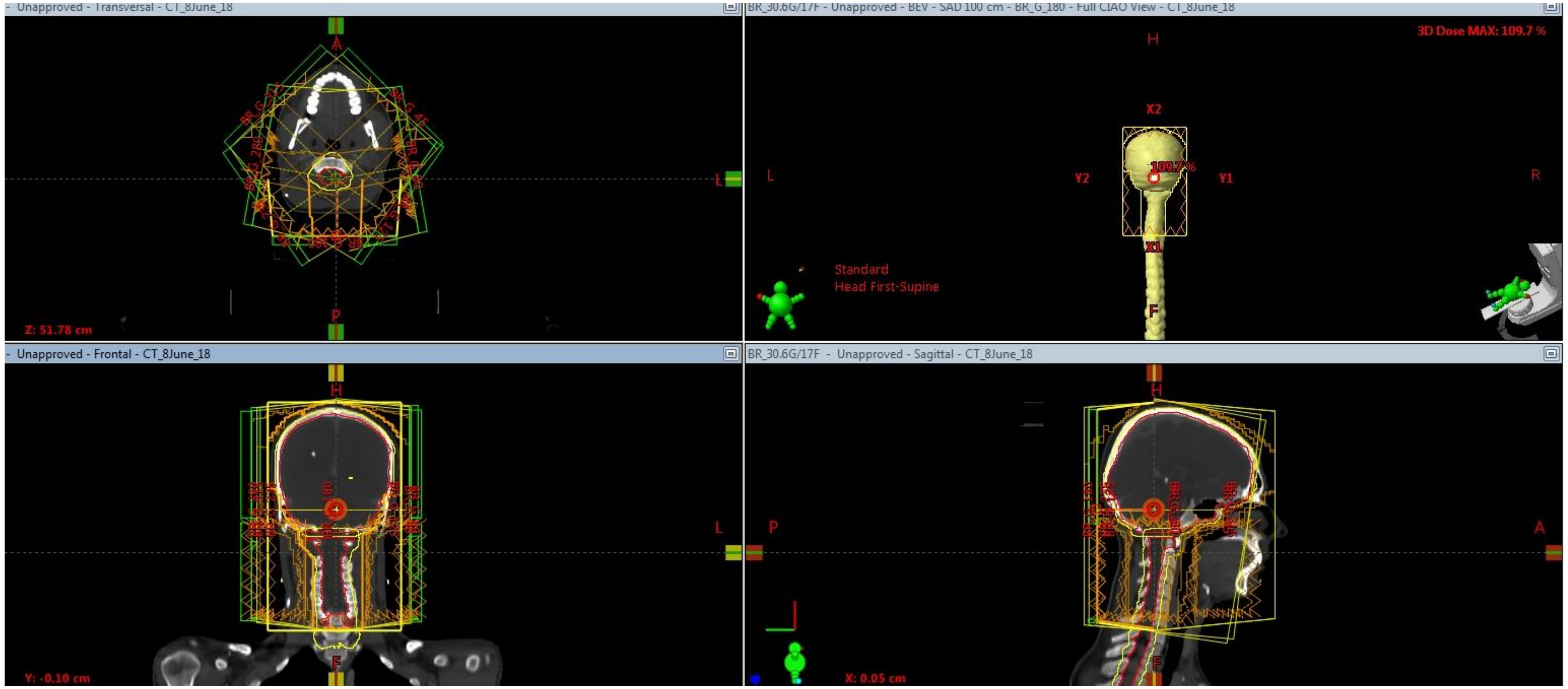
- Lungs
- Esophagus
- Heart
- Breast

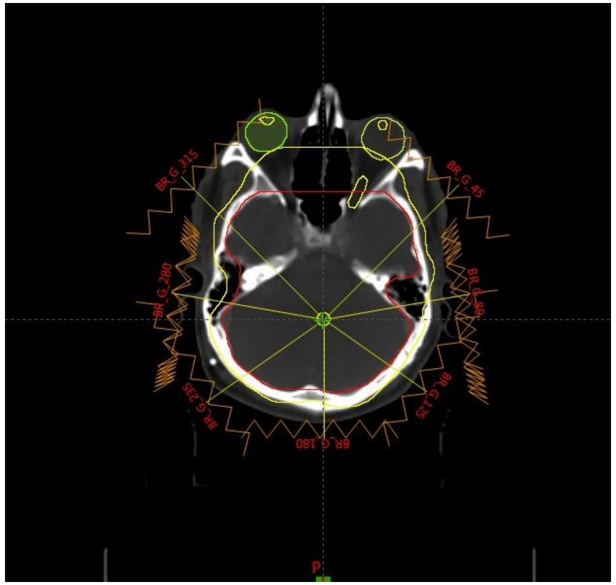
Abdomen

- Stomach, Bowel
- Liver, Kidneys
- Testis
- Uterus and Ovaries

Treatment Planning with IMRT

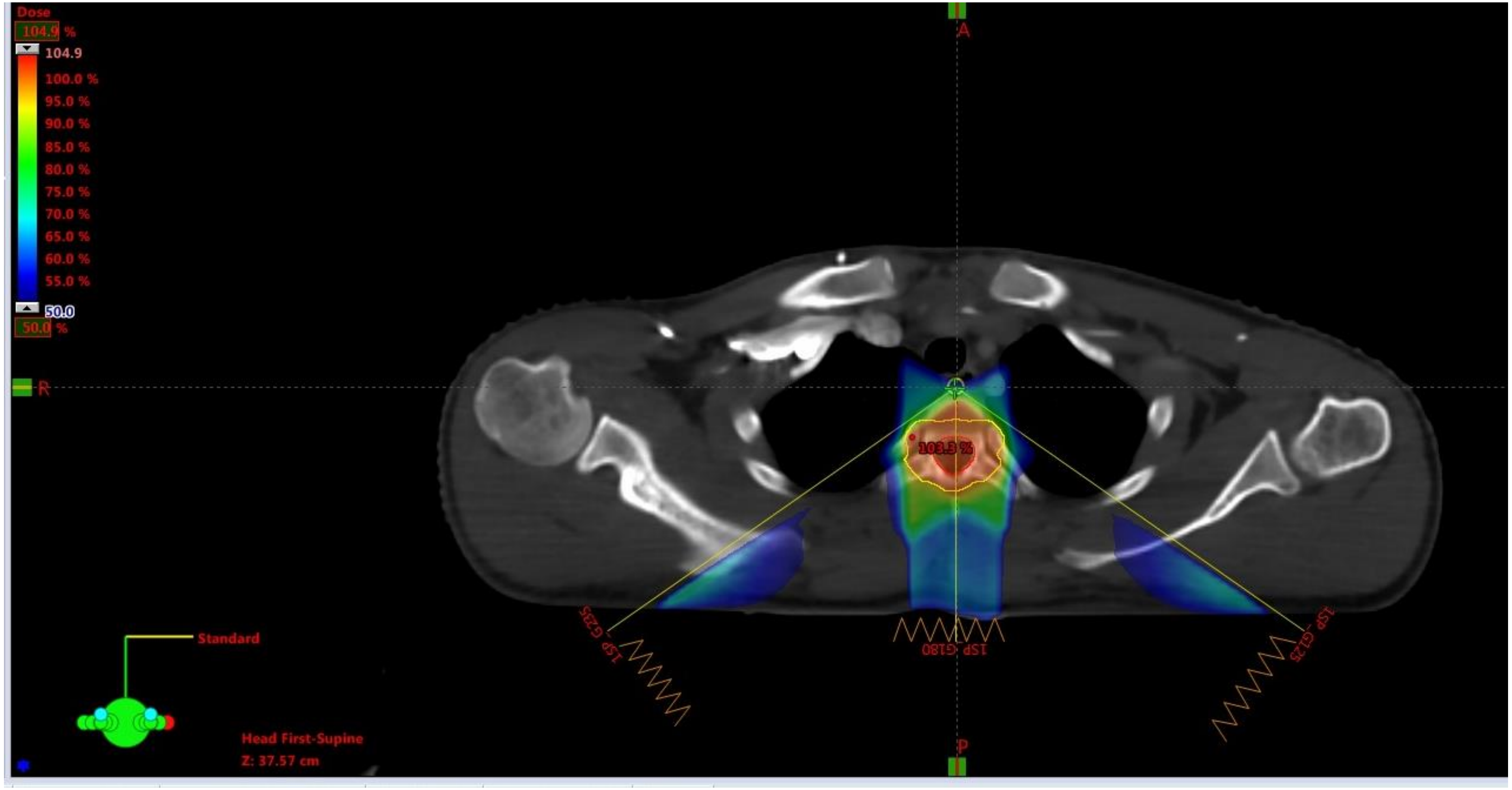
- Rotational (VMAT/Tomotherapy)
- Non Rotational /conventional/ Fixed Gantry Beams IMRT
- Hybrid- VMAT for Brain + Conventional for Spine
- Choose your comfort/ competence/ practice level



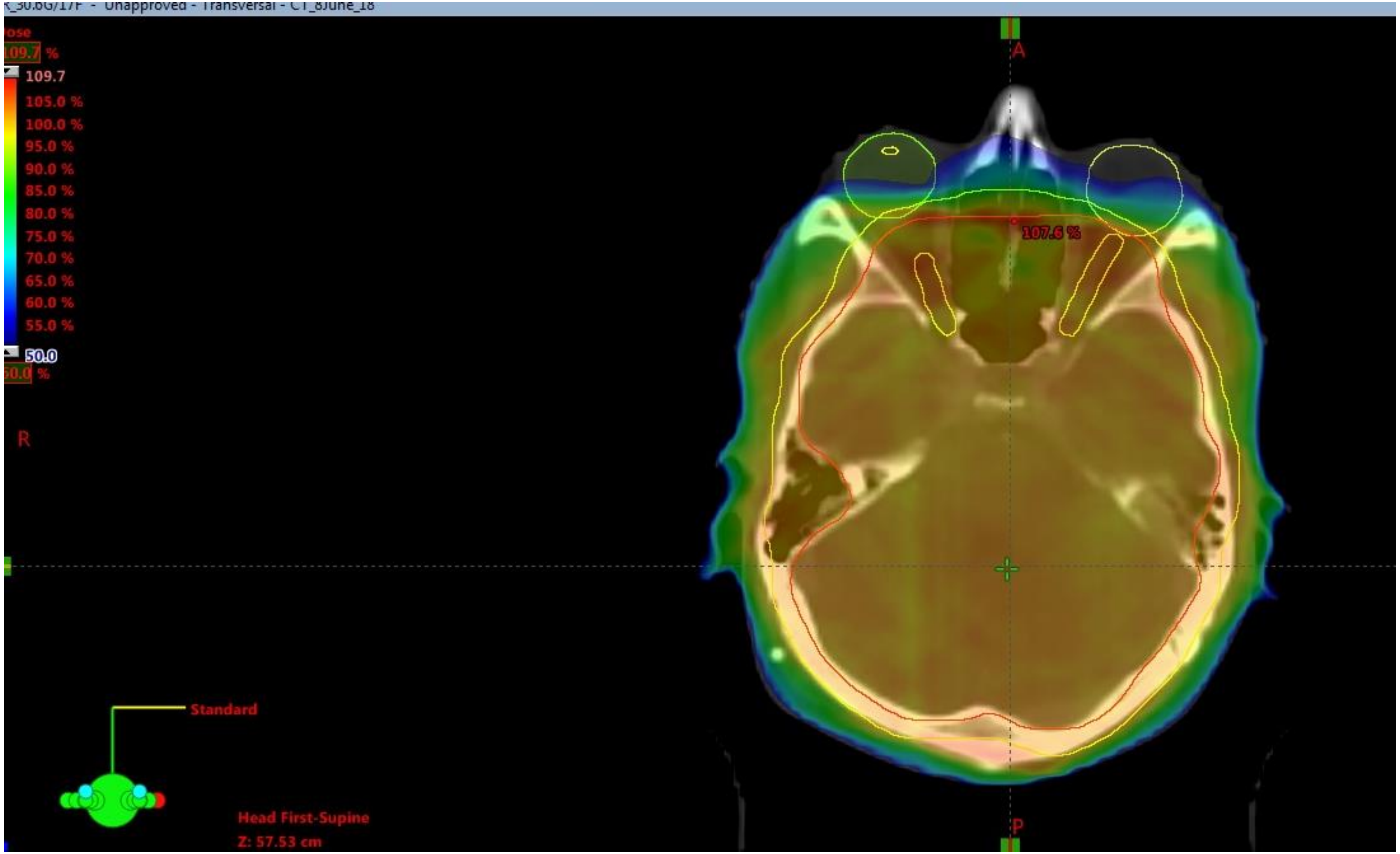


CSI Planning at our center

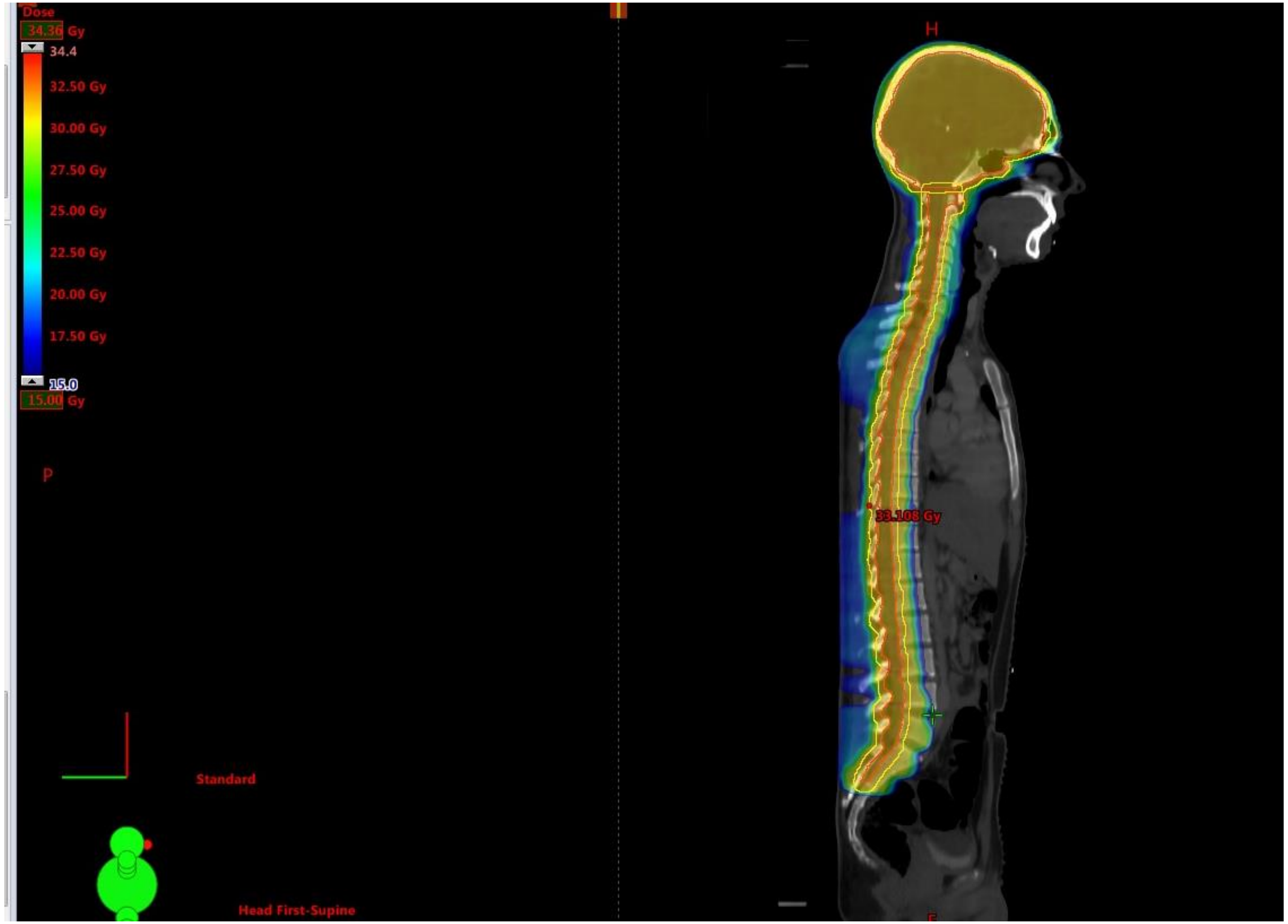
Cranial – Equispaced beams all around



Spine – 3 Fields



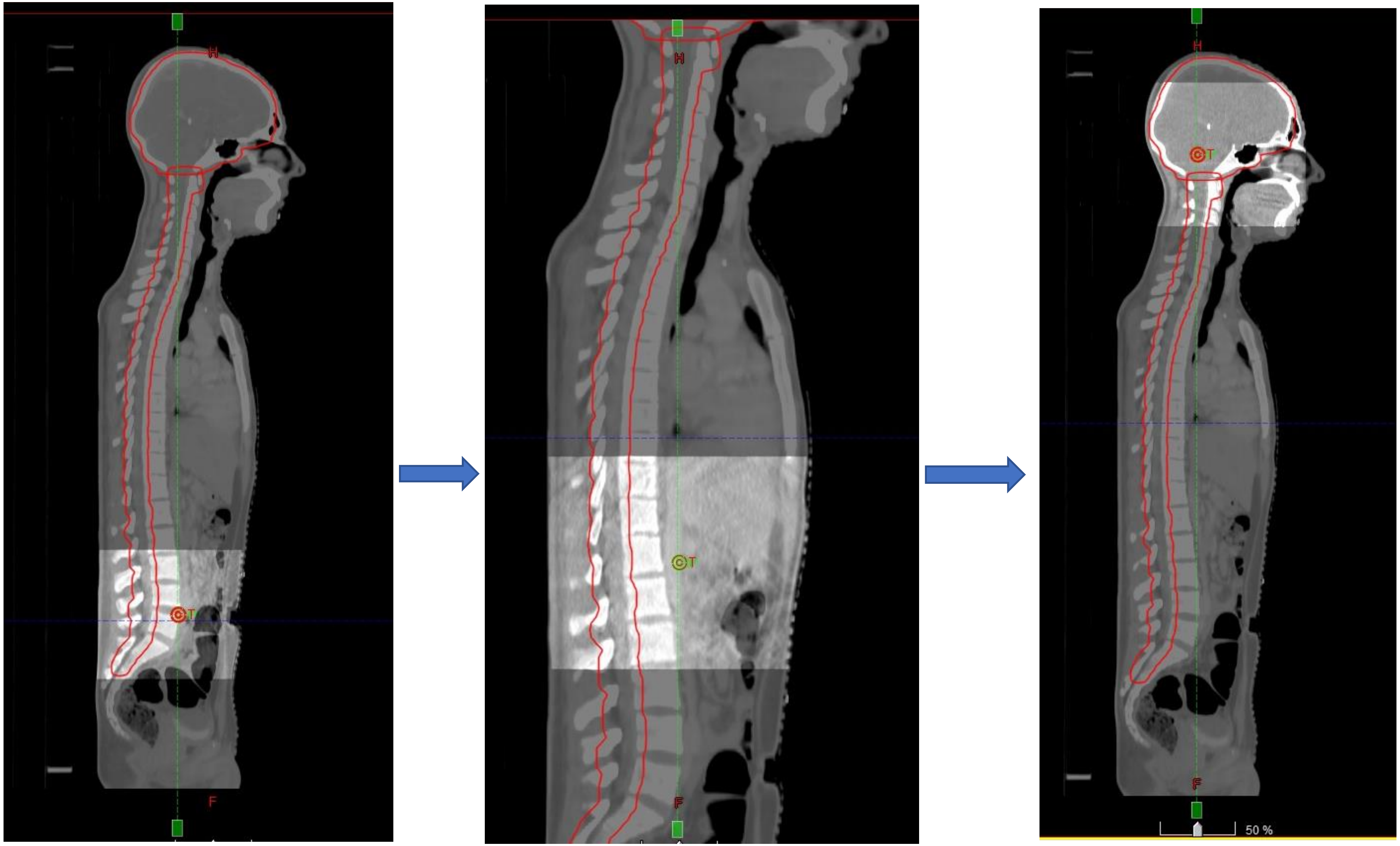
Cranial IMRT dose distribution -50% isodose colour wash



Cranio Spinal IMRT dose distribution -50% isodose colour wash

OBI imaging protocol

- Target volume is large and complex & plan has multiple isocentres
- Capture imaging minimum at three levels- Start with Lumbar, Dorsal and then Cranial
- Match and tabulate all shifts and apply shifts after analyzing all shifts
- Only translational shifts are applied; rotational shifts not applied
- Define no action level (NAL) – Our department $\leq$3mm
- 3-5 mm- Discretionary application of shifts
- Define Repositioning level - Our department >5mm
- Longitudinal Shifts should be mandatorily in same direction



CBCT Lumbar Dorsal Cranial

Situation 1

	Cranial (mm)	Dorsal (mm)	Lumbar (mm)	Shift applied (mm)
Longitudinal	+3	+4	+5	+3
Vertical	+4	+2	+1	+2
Lateral	-3	-2	-1	0

Situation 2

	Cranial (mm)	Dorsal (mm)	Lumbar (mm)	Shift applied (mm)
Longitudinal	+3	-3	+4	0
Vertical	+4	-3	+1	0
Lateral	-3	-4	-2	-2

Proton Beam Therapy

- Physical advantage of delivering lowest possible dose to normal tissues adjacent to tumour and reduce treatment related toxicities
- Phase II single arm study of proton CSI- 5YPFS 80%, 5Y OS83%
- 5 Y cumulative rate of grade 3-4 hearing loss was 16%. Full scale IQ decreased by 1.5point per year

Yock TI et all Lancet Oncolo 2016; 17:287-298

Cochlear-Sparing Radiotherapy in Medulloblastoma

	Median follow-up (months)	Mean dose to cochlea	Mean cisplatin Dose	Pediatric Oncology Group Ototoxicity Grade (number of patients)				
				Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
Conventional RT N=11	51	54.2 Gy (53.2-55.8)	220mg/ m^2	2	2	0	6 64%	1
IMRT N=15	18	36.7 Gy (23.4-50.8)	290mg/ m^2	6	4	3	1 13%	1
IMRT N=88*	41	35.3 (standard risk), 43 Gy (high risk)	300 mg/ m^2	29	32	11	13 18%	3
Protons N=35*	12	30 CGE	303 mg/ m^2	19	14		2 5%	

Hunag E IJROBP 2002;52:599-605, Paulino AC IJROBP 202; 78:1445-50, Moeller BJ Radiotherapy Oncology 2011; 6:58

IMPT

- More conformal doses – Reduced incidence of Hearing loss, second malignancies

- Some concerns about edge effect of proton therapy and brain stem necrosis
- Vertebral growth

- Science is always evolving

- Keep reading and upgrading your knowledge and skills.

- Thanks