Craniospinal Irradiation—from 2 D to Conformal RT

Dr Vineeta Goel
Radiation Oncologist
Fortis Hospital
Delhi
• CSI has been the main stay of treatment for MB since 1970s....

• Red J Publication 1982

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**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. On the other hand, some very poor results have also been experienced, 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 radiotherapy, histological type (non-desmoplastic), and especially evidence of brain-stem involvement at operation, may all adversely affect outcome. 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 some 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 and also Berry et al. have...
## Radiotherapy Volume

<table>
<thead>
<tr>
<th></th>
<th>SURVIVAL ACCORDING TO RT VOLUME</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Posterior Fossa only</td>
<td>Posterior fossa + spine</td>
<td>Craniospinal</td>
</tr>
<tr>
<td>University of Lund</td>
<td>5%</td>
<td>25%</td>
<td>53%</td>
</tr>
<tr>
<td>University of Toronto</td>
<td>0%</td>
<td></td>
<td>53%</td>
</tr>
<tr>
<td>Strong Memorial Hospital</td>
<td>No RT: 0%</td>
<td>Whole brain RT: 20%</td>
<td>50%</td>
</tr>
</tbody>
</table>
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.

\[
Gap = S_{(field1)} + S_{(field2)} = \frac{1}{2} \left( \frac{L_1 \times \text{Depth}_1}{SSD_1} \right) + \frac{1}{2} \left( \frac{L_2 \times \text{Depth}_2}{SSD_2} \right)
\]
Rotate **collimator** for cranial field to match caudal margin of cranial field with diverging posterior spinal field.

\[
\theta_{\text{collimator}} = \tan^{-1}\left(\frac{1}{2} \times \frac{L}{SSD}\right)
\]
• Rotate couch towards gantry head to prevent lateral cranial field from diverging into posterior spinal field

$$\theta_{couch} = \tan^{-1}\left(\frac{1}{2} \times \frac{L}{SAD}\right)$$
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
CRANIOSPINAL TREATMENT WITH THE PATIENT SUPINE

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RUPAK DAS, PH.D.
Departments of Human Oncology and
Medical Physics, University of Wisconsin, Madison, WI

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

Fleur Huang, MD,1 William Parker, MSc,2 and Carolyn R. Freeman, MBBS1*

A SIMPLE TECHNIQUE OF SUPINE CRANIOSPINAL IRRADIATION

ANUSHEEL MUNSHI, M.D., D.N.B., and RAKESH JALALI, M.D.
Department of Radiation Oncology, Tata Memorial Hospital, Mumbai, Maharashtra, India
TMH technique of Supine CSI

- 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 100 cm
- 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 field 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.
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

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.
Rotate couch by 6 degrees (towards gantry) or calculate by using formula \( \tan \theta^{-1} = \frac{1}{2} \)

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
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
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
Craniospinal Irradiation with Spinal IMRT to Improve Target Homogeneity

Atmaram Pal 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, Re 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

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 3D RT

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

3D plan was superior for V5Gy or below

<table>
<thead>
<tr>
<th>Parameter (%)</th>
<th>2D</th>
<th>3D</th>
<th>IMRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_x$ isodose line</td>
<td>85</td>
<td>84</td>
<td>88</td>
</tr>
<tr>
<td>$V_{95%}$</td>
<td>98</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>$V_{107%}$</td>
<td>37</td>
<td>38</td>
<td>3</td>
</tr>
<tr>
<td>$D_{max}$</td>
<td>118</td>
<td>119</td>
<td>114</td>
</tr>
</tbody>
</table>
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
Compare and correlate Pre and post op MRI to identify residual ds
Challenges in transition from 2D 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 2D & 3D.
  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.

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

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

SIOPÉ – 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

SIOPÉ 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, Edward C. Halperin, Henry S. Friedman, and Orest B. Boyko
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

• Majority of target contouring knowledge comes from 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 cribiform 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.
<table>
<thead>
<tr>
<th>Skull base foramen/Canal</th>
<th>Cranial nerve(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cribiform plate</td>
<td>Olfactory nerve</td>
</tr>
<tr>
<td>Optical canal of sphenoid</td>
<td>Optic nerve</td>
</tr>
<tr>
<td>Superior orbital fissure</td>
<td>Oculomotor, trochlear, and first branch of trigeminal, and abducens nerves</td>
</tr>
<tr>
<td>Foramen rotundum</td>
<td>Second branch of trigeminal nerve</td>
</tr>
<tr>
<td>Foramen Ovale</td>
<td>Third branch of trigeminal nerve</td>
</tr>
<tr>
<td>Internal auditory meatus</td>
<td>Facial and vestibulo-cochlear nerves</td>
</tr>
<tr>
<td>Jugular foramen</td>
<td>Glossopharyngeal, vagus, and accessory nerves</td>
</tr>
<tr>
<td>Hypoglossal canal</td>
<td>Hypoglossal nerve</td>
</tr>
</tbody>
</table>
• Since the entire CSF space is at risk of disease dissemination, the entire subarachnoid 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 Subarachnoid 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
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. 1. Magnetic resonance imaging (MRI) of the spine showing thecal sac termination (arrow) at the mid-S1 vertebral level.

Fig. 2. Distribution of thecal sac termination levels in the 23 children who had spinal magnetic resonance imaging prior to the craniospinal irradiation.
No need to cover sacral nerve roots as multiple studies have shown there is no CSF flow along sacral nerve roots.
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?

<table>
<thead>
<tr>
<th>COMPLETED BONE GROWTH</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT COMPLETED BONE GROWTH</td>
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<table>
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<tr>
<th>3DCRT</th>
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<tbody>
<tr>
<td>VMAT/TOMO</td>
<td>MAYBE NO</td>
</tr>
<tr>
<td>PROTONS</td>
<td>YES</td>
</tr>
</tbody>
</table>
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 <3mm
• 3-5 mm- Discretionary application of shifts
• Define Repositioning level - Our department >5mm
• Longitudinal Shifts should be mandatorily in same direction
### Situation 1

<table>
<thead>
<tr>
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<th>Cranial (mm)</th>
<th>Dorsal (mm)</th>
<th>Lumbar (mm)</th>
<th>Shift applied (mm)</th>
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<tr>
<td>Longitudinal</td>
<td>+3</td>
<td>+4</td>
<td>+5</td>
<td>+3</td>
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<tr>
<td>Vertical</td>
<td>+4</td>
<td>+2</td>
<td>+1</td>
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<tr>
<td>Lateral</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
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## Situation 2

<table>
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<th></th>
<th>Cranial (mm)</th>
<th>Dorsal (mm)</th>
<th>Lumbar (mm)</th>
<th>Shift applied (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>+3</td>
<td>-3</td>
<td>+4</td>
<td>0</td>
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<tr>
<td>Vertical</td>
<td>+4</td>
<td>-3</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>-3</td>
<td>-4</td>
<td>-2</td>
<td>-2</td>
</tr>
</tbody>
</table>
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 1.5 point per year

Yock TI et al Lancet Oncolo 2016; 17:287-298
# Cochlear-Sparing Radiotherapy in Medulloblastoma

<table>
<thead>
<tr>
<th></th>
<th>Median follow-up (months)</th>
<th>Mean dose to cochlea</th>
<th>Mean cisplatin Dose</th>
<th>Pediatric Oncology Group Ototoxicity Grade (number of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grade 0  Grade 1  Grade 2  Grade 3  Grade 4</td>
</tr>
<tr>
<td>Conventional RT</td>
<td>51</td>
<td>54.2 Gy (53.2-55.8)</td>
<td>220 mg/m²</td>
<td>2  2  0  6  1</td>
</tr>
<tr>
<td>N=11</td>
<td></td>
<td></td>
<td></td>
<td>64%</td>
</tr>
<tr>
<td>IMRT N=15</td>
<td>18</td>
<td>36.7 Gy (23.4-50.8)</td>
<td>290 mg/m²</td>
<td>6  4  3  1  1</td>
</tr>
<tr>
<td>IMRT N=88*</td>
<td>41</td>
<td>35.3 (standard risk), 43 Gy (high risk)</td>
<td>300 mg/m²</td>
<td>29  32  11  13  3</td>
</tr>
<tr>
<td>Protons N=35*</td>
<td>12</td>
<td>30 CGE</td>
<td>303 mg/m²</td>
<td>19  14  2  2  5%</td>
</tr>
</tbody>
</table>

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