Improving Craniospinal Irradiation Technique Through Volumetric Modulated Arc Therapy

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Medulloblastoma

- Medulloblastoma tumors account for 18 percent of pediatric brain tumors\(^1\)
  - Most common brain tumor in children under four\(^1\)
- Often seen in children 2–12 years old\(^2\)
- Standard treatments for medulloblastoma
  - Surgery to remove gross tumor\(^3\)
  - Postoperative radiation therapy is used to treat non resected gross tumor and possible seeding or spreading\(^2\)
    - Most frequent RT technique used: 3D conformal craniospinal irradiation (CSI)
Traditional CSI Technique

- Treats entire subarachnoid space and upper cervical spine through opposed lateral craniocervical fields with matching divergent posterior spinal fields.

- Usually prescribed to 23.4 – 36 Gray (Gy).

- After CSI, the posterior fossa is boosted to a final dose of 54 Gy.

- Since this technique is not able to spare dose to organs at risk, devastating late toxicities, such as bone growth, hormonal deficiencies and cardiac dysfunction, have been experienced by patients receiving traditional 3D conformal CSI.
Siviero–Machon et al\textsuperscript{5} compared 16 medulloblastoma survivors who received childhood 3D Conformal CSI to control subjects with similar age, gender, body mass index, and cardiovascular traits. It was found that:

- 40 percent of the childhood medulloblastoma CSI survivors had a growth hormone deficiency
- 44 percent of survivors required levothyroxine sodium replacement therapy
- 25 percent experienced radiation therapy–induced hypothyroidism
- 19 percent required a thyroidectomy secondary to a thyroid nodule
- Three female patients needed hormonal replacement therapy due to therapy–induced gonadal failure
- Systolic functions in medulloblastoma survivors were also greatly reduced due to decrease in growth hormone
- Waist–to–hip ratio and waist–to–height ratio were statistically higher– can result in centripetal adiposity and increased rate of obesity
- Average height of the survivors was also significantly decreased due to reduced bone development as a result of CSI
- Survivors also presented with higher levels of glucose, insulin, or were insulin resistant
Another study conducted at The Children’s Hospital of Pennsylvania\textsuperscript{6} researched cardiac dysfunction after childhood CSI. It was found that:

- Medulloblastoma survivors had a high amount of electrocardiogram abnormalities
  - Eight of the 26 participants had pathologic Q-waves in two leads and ventricular fibrillation during the rest period
- 75 percent of participants performed below the fifth percentile on a maximal cardiac index test

On a questionnaire given to participants, over half stated they had difficulty with physical exertion and rated their exercise ability less than average.\textsuperscript{6} Consequently, childhood CSI can have a significant effect on cardiac dysfunction and is recommended for those patients to undergo long term cardiac monitoring.
In the past, there was not much concern of potential late side effects from traditional CSI because of the low survival rate.

However, current survival rates have increased to more than 70 percent.\(^2\)

Due to this survival increase, the concern of reducing late side effects has become very important, thus encouraging the study of CSI through different modalities, specifically volumetric modulated arc therapy (VMAT).
Volumetric Modulated Arc Therapy

- VMAT is a form of radiotherapy that uses dynamic rotational therapy to deliver a highly conformal dose to the planned target volume.\(^7\)

- During treatment delivery, the multileaf collimator positions, gantry speed, and dose rate continually change which allow for faster treatment times and will also deliver a dose distribution similar to other helical techniques.\(^8\)

- Currently, VMAT is in preliminary studies to compare, contrast, and discuss the advantages and disadvantages of VMAT CSI in regards to dose conformity, homogeneity, and dose to organs at risk. Only dosimetric plans were reviewed. Currently, no patients have been treated with VMAT CSI.
Recently, Lee et al.\textsuperscript{7} conducted a study to compare and contrast VMAT CSI with traditional 3D conformal CSI. It was found that VMAT CSI plans:

- Created greater conformity and homogeneity for all five patients
- Generated a more uniform dose distribution specifically around the vertebral column which will allow for reduced incidence of uneven bone growth in children receiving CSI
- Delivered a lower mean dose to a variety of vital organs
  - Heart, thyroid, esophagus and right and left lenses were delivered a mean dose of at least 4 Gy or less with VMAT
- Maximum doses in all nine labeled organs at risk were also reduced using VMAT techniques besides the optic chiasm and left eye
- Produced higher mean doses to the right and left kidney but less maximum dose to those structures
- Resulted in significant reductions in dose to organs at risk around the brain, neck, and chest regions

This reduction in dose to critical structures could possibly lead to improvement of late side effects and overall increased quality of life.
Potential Disadvantages of VMAT CSI

- Low dose volumes spread throughout many organs$^5,11$
  - Could lead to increased risk of secondary malignancies
- Decrease in monitor unit efficiency
Conclusion

- It was shown that VMAT craniospinal irradiation technique can produce acceptable dosimetric plans with improved dose conformity and homogeneity in the PTV along with reducing dose to organs at risk. VMAT CSI could greatly reduce late side effects while increasing overall quality of life for medulloblastoma survivors.

- Future of VMAT CSI
  - Continual research of the future outcomes of increased low-dose volumes
  - VMAT CSI techniques should be further tested with a verification study including a follow up on late toxicities, eventually preparing for a prospective clinical trial
References


