



O uso de arcoterapia (VMAT) para tratamentos de Neuroeixo – Setup e Planejamento

Mauricio Russo

Sensumed - AM

REALIZAÇÃO



SBRT
SOCIEDADE BRASILEIRA
DE RADIOTERAPIA

GERENCIAMENTO



AGÊNCIA OFICIAL



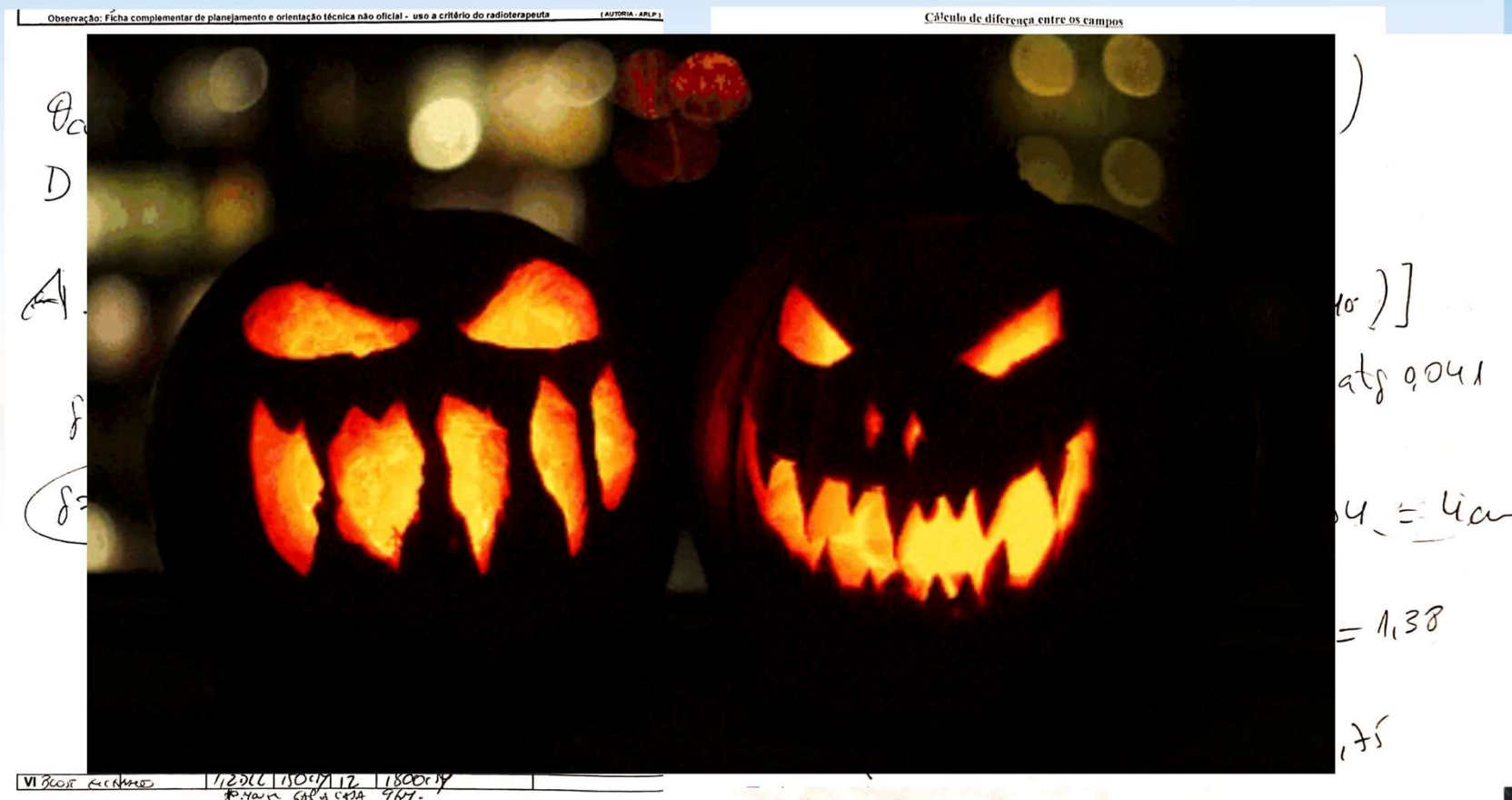
Declaração de Conflito de Interesse

Dr (a). Mauricio Russo afirma não ter conflito de interesse a declarar

Exigência da RDC Nº 96/08 da ANVISA



Neuroeixo - O Terror dos físicos!



Neuroeixo - O Terror dos físicos!

Observação: Ficha complementar de planejamento e orientação técnica não oficial - uso a critério do radioterapeuta

(AUTORIA: ARLP)

Cálculo de diferença entre os campos

$$\theta_{cw} = 38,7^\circ$$

$$D = [11,8 \times \sin 38,7 - A \times \cos 38,7] = 7,38 - 4,68 = 2,7$$

$$A = (SAD) \times \sin 4 = 6$$

$$\delta = \arctg \cdot (12 / [2(88) \cdot \cos \theta_{mc}])$$

$$\delta = 4^\circ$$

$$\theta_{ang} = 90 - 10 + 4$$

$$S = [11,8 \times \cos \theta_{cw} - A \sin \theta_{cw}] = 8,6$$

VI 8005 4/2011 1/150 1/12 1/1800 1/4

$$\delta = \arctan(W / [2(SAD) \cos \theta_{mc}])$$

$$W = 8 \text{ cm}$$

$$\theta_{mc} = 10^\circ$$

$$\delta = \arctg [8 / (2 \times 100 \times \cos 10^\circ)]$$

$$\delta = \arctg [8 / 200 \times 0,985] = \arctg 0,041$$

$$\delta = 2,3$$

$$A = 100 \times 0,041 = 4,1$$

$$D = (9,77 \times \sin 32 - 4,1 \cos 32) = 1,38$$

$$S = (9,77 \cos 32 + 4,1 \sin 32) = 9,75$$



Original Article

Craniospinal Irradiation by Rapid Arc® Technique in Supine Position: A Dosimetric and Clinical Analysis

Vijayaprabhu Neelakandan, S. Sherly Christy¹, Ashutosh Mukherji, K. Sathyanarayana Reddy²

CONCLUSIONS

Irradiation of the craniospinal axis of patients in the supine position is reproducible and easily maintained. Acute skin, hematological, and gastrointestinal reactions were comparable with declared historical literature. Treatment in supine position would be comfortable for adult patients and would minimize anesthesia-related risks.

RA® technique is suited to plan complex-shaped target volumes, avoiding junction, field-matching, and abutment dosimetry. It also provides benefit of image guidance for precise dose delivery and is favorable regarding target volume coverage, dose homogeneity, conformity, OAR sparing, treatment time, and reduction of IDs to nontarget tissues.

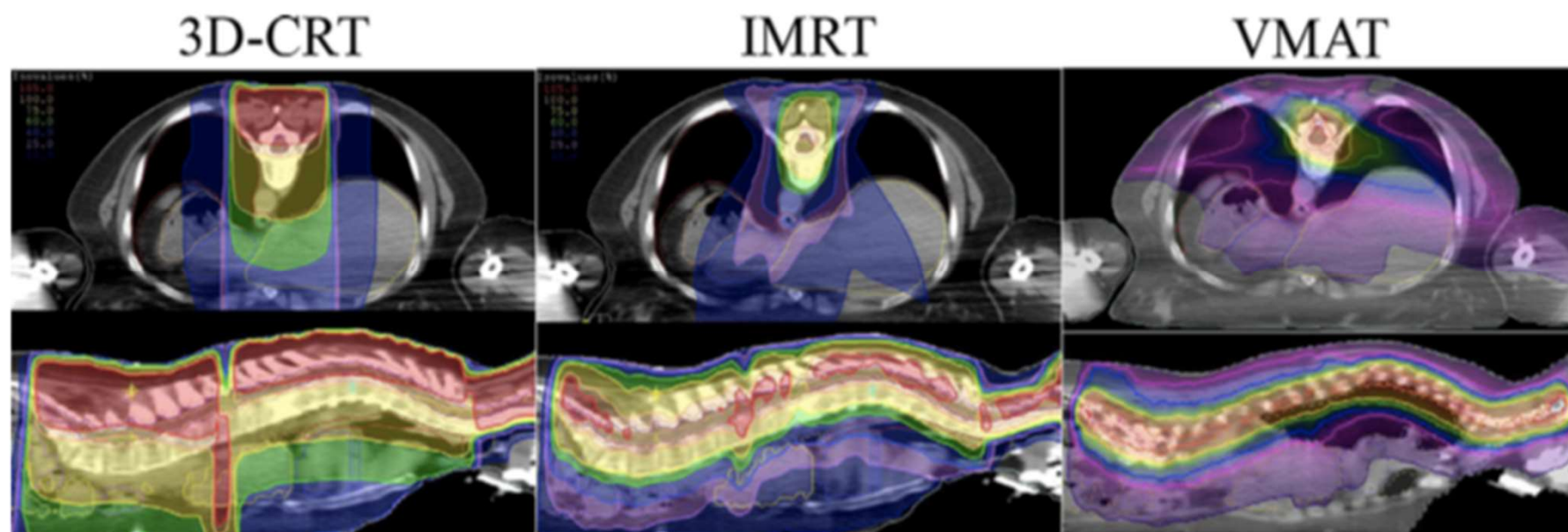
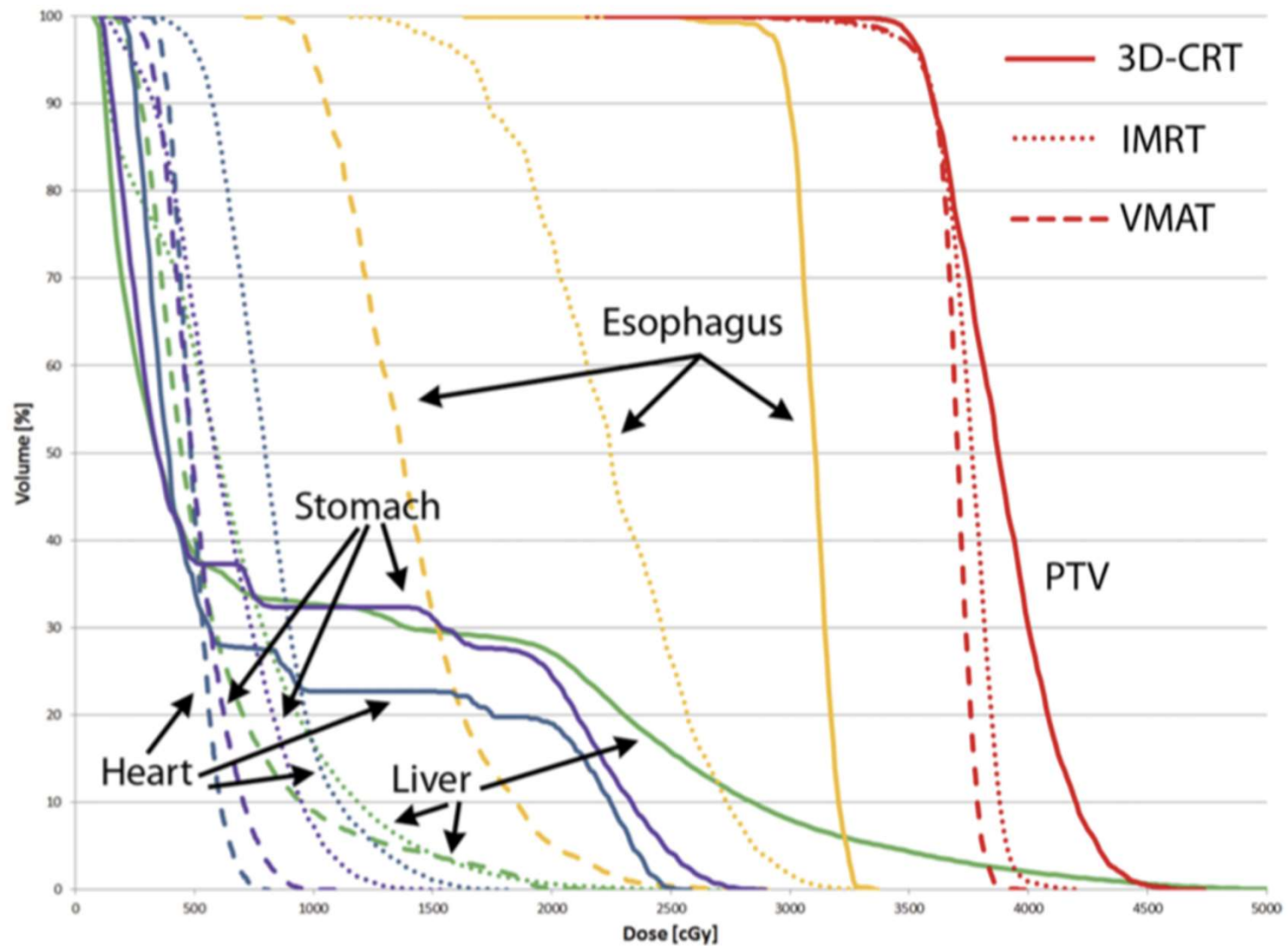


Fig. 1. Axial and sagittal slices from the treatment plans for 1 patient from the dosimetric study showing the differences in isodose distributions among 3D-CRT, IMRT, VMAT. The conformity achieved by the IMRT and VMAT techniques is evident. The low dose spread associated with the VMAT technique can also be observed.

Comparação - OARs



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Compari tomother

In order to evalua
cal measures were
normal tissues and

$$P(D) = \exp\left(-\alpha\left(1 + \frac{d}{\alpha/\beta}\right)^2\right)$$

where $P(D)$ is the
the tissue is irradi

$$EQD_{2Gy} = D \cdot \frac{1 + \frac{d}{\alpha/\beta}}{1 + \frac{2}{\alpha/\beta}} = \frac{BED}{1 + \frac{2}{\alpha/\beta}} \quad (2)$$

where 2 Gy represents the reference dose level used for the determination of the dose-response parameters, D is the total physical dose, d is the dose per fraction and α/β is the organ-specific dose that accounts for the fractionation characteristics of the tissue and at which the linear and quadratic components of cell killing are equal.⁽³⁾ BED is the biological effective dose, which is a measure of the biological dose delivered to a tumor or organ and it is the theoretical total dose that would be required to produce a particular isoeffect using an infinitely large number of infinitesimally small dose fractions. BED has been used for comparing different treatment strategies.⁽¹²⁻¹⁴⁾ The relation of the parameters D_{50} and γ with α and β that leads to equality of Eq. (1) is the following:

$$\alpha = \frac{e\gamma - \ln(\ln 2)}{D_{50} \left(1 + \frac{d}{\alpha/\beta}\right)} \quad \text{and} \quad \beta = \frac{e\gamma - \ln(\ln 2)}{D_{50} \left(\frac{\alpha}{\beta} + d\right)} \quad (3)$$

where d_{ref} is the reference dose per fraction to which the parameter D_{50} and γ refer.

The response of a normal tissue to a nonuniform dose distribution is calculated using the relative seriality model in which the volume effect is taken into account. The mathematical expression of the relative seriality model is given by the following equation:^(2,6,11)

$$P_j = 1 - \prod_{i=1}^{N_{organs}} (1 - [1 - \prod_{j=1}^{M_i} (1 - P(D_j)^{s_j})^{\Delta v_j}]^{\frac{1}{s_j}}) \quad (4)$$

where N_{organs} is the total number of organs at risk; $P(D_j)$ as described by Eq. (1) is the probability of response of organ j , which is irradiated with dose D_j and has the reference volume; Δv_j is the fractional subvolume of the organ being irradiated compared to that of the reference volume; and M_i is the total number of subvolumes in the organ. s_j is the relative seriality parameter which describes the internal structure of the examined organ, and it is approximately unity for a completely serial structure and zero for a completely parallel structure.⁽⁶⁾ For the estimation of the expected normal tissue complications, other models have also been proposed, such as the Lyman-Kutcher-Burman (LKB) model, the Parallel model, and the Critical Volume model.⁽¹⁵⁻¹⁸⁾ Even though the LKB model is well known, the Relative Seriality model was applied in this study due to its previous extensive use in studies involving radiobiological evaluation or optimization of treatment techniques and due to the previous experience of the authors with this model and the relevant dose-response parameters in the calculation of the normal tissue complication probability (NTCP) values.

Due to the fact that tumor control is achieved when the separate tumor cells are completely eradicated, it is assumed that tumors have a parallel structure. Consequently, the probability of benefit or tumor control is given by the following equation:

$$P_B = \prod_{j=1}^{N_{tumors}} \left(\prod_{i=1}^{M_j} P(D_i)^{\Delta v_i} \right) \quad (5)$$

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$$\left. \begin{aligned} & \text{Eq. (1)} \\ & \text{Eq. (2)} \end{aligned} \right\} \quad (1)$$

lications when
alized gradient

Estudo

$$EQD_{2Gy} = D \cdot \frac{1 + \frac{d}{\alpha/\beta}}{1 + \frac{2}{\alpha/\beta}} = \frac{BED}{1 + \frac{2}{\alpha/\beta}} \quad (2)$$

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$$P_i = 1 - \prod_{j=1}^{N_{organs}} (1 - [1 - \prod_{k=1}^{M_j} (1 - P(D_j)^{S_j})^{\Delta v_j}]^{\frac{1}{S_j}}) \quad (4)$$

In order to evaluate and compare the different treatment modalities, a number of radiobiological measures were employed. The Poisson model describes the dose-response relationship of normal tissues and tumors according to the following expression:^(2,6,10,11)

$$P(D) = \exp\left(-e^{e\gamma - \alpha nd - \beta nd^2}\right) = \exp\left(-e^{e\gamma - (EQD_{2Gy} / D_{50}) (e\gamma - \ln \ln 2)}\right) \quad (1)$$

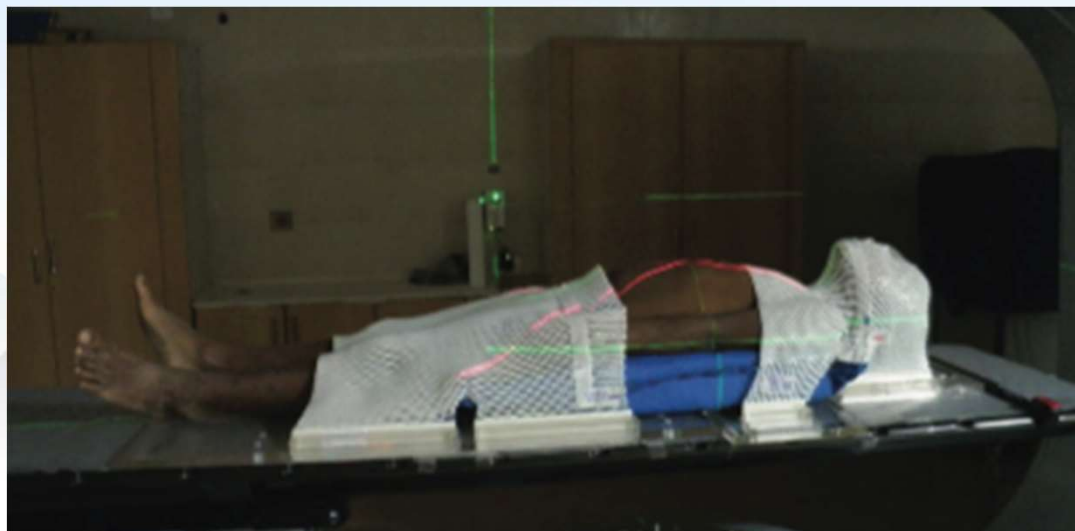
where $P(D)$ is the probability of inducing tumor control or normal tissue complications when the tissue is irradiated with a uniform dose of EQD_{2Gy} , γ is the maximum normalized gradient

complication probability (NTCP) values.

Due to the fact that tumor control is achieved when the separate tumor cells are completely eradicated, it is assumed that tumors have a parallel structure. Consequently, the probability of benefit or tumor control is given by the following equation:

$$P_B = \prod_{j=1}^{N_{tumors}} (\prod_{k=1}^{M_j} P(D_j)^{\Delta v_j}) \quad (5)$$

Setup Decúbito Dorsal



Setup - Decúbito Ventral



Setup – Vantagens

Decúbito Dorsal

- Posicionamento mais confortável e reprodutível
- Mais fácil para anestesia

Decúbito Ventral

- Visualização do Campo de tratamento
- Setup mais simples
- Menos chances de erros



Setup – Desvantagens

Decúbito Dorsal

- Mesa (Couch) na direção do campo da coluna
- Órgãos podem ficar mais posteriores
- Não é possível usar a coluna como referência de posicionamento

Decúbito Ventral

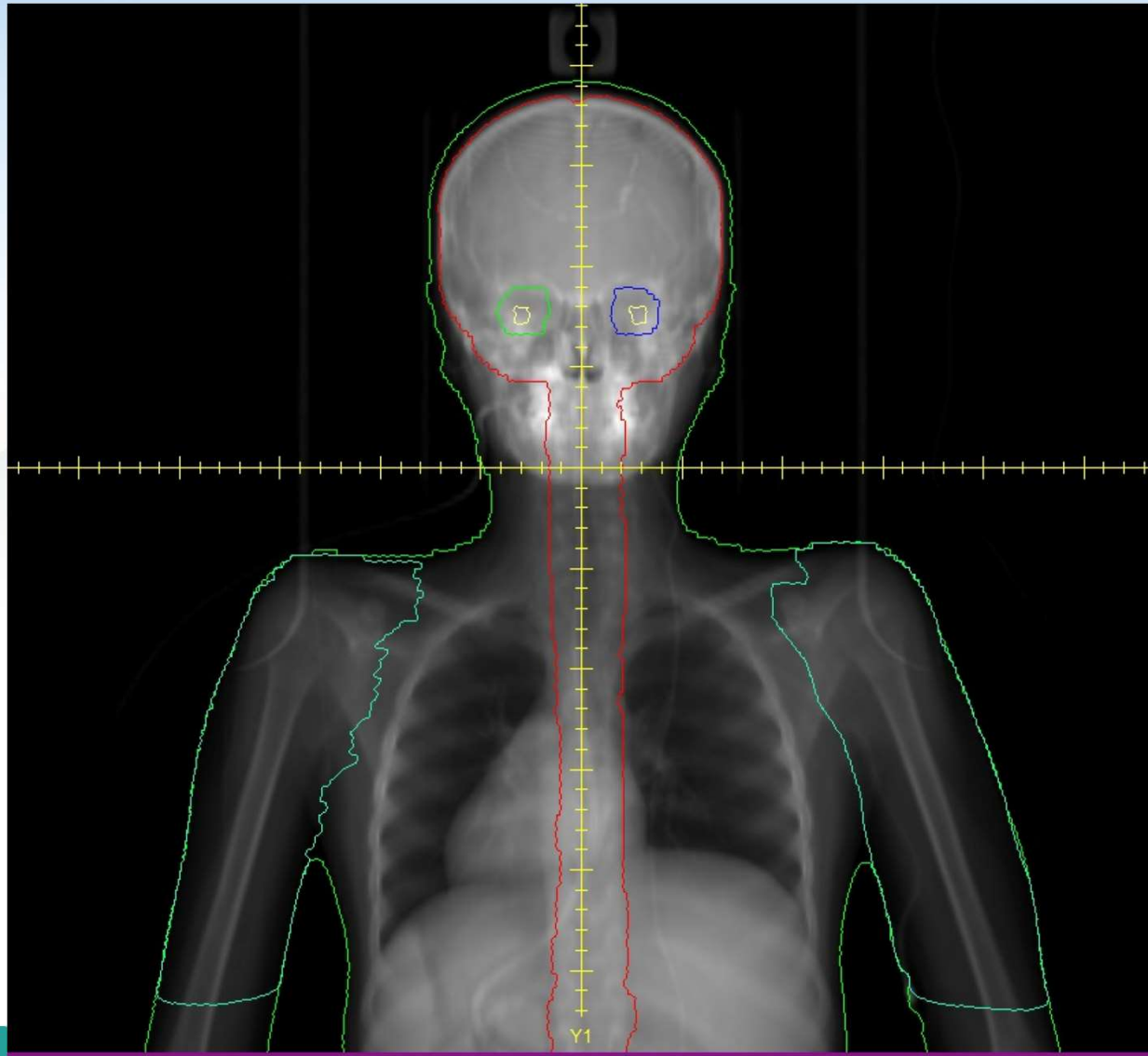
- Visualização do Campo de tratamento
- Setup mais simples
- Menos chances de erros
- Dificuldade para anestésiar
- “A via aérea (nariz/boca), fica menos acessível pra gente da anestesia, a fisiologia respiratória fica um pouco prejudicada, é mais difícil de ventilar o paciente”



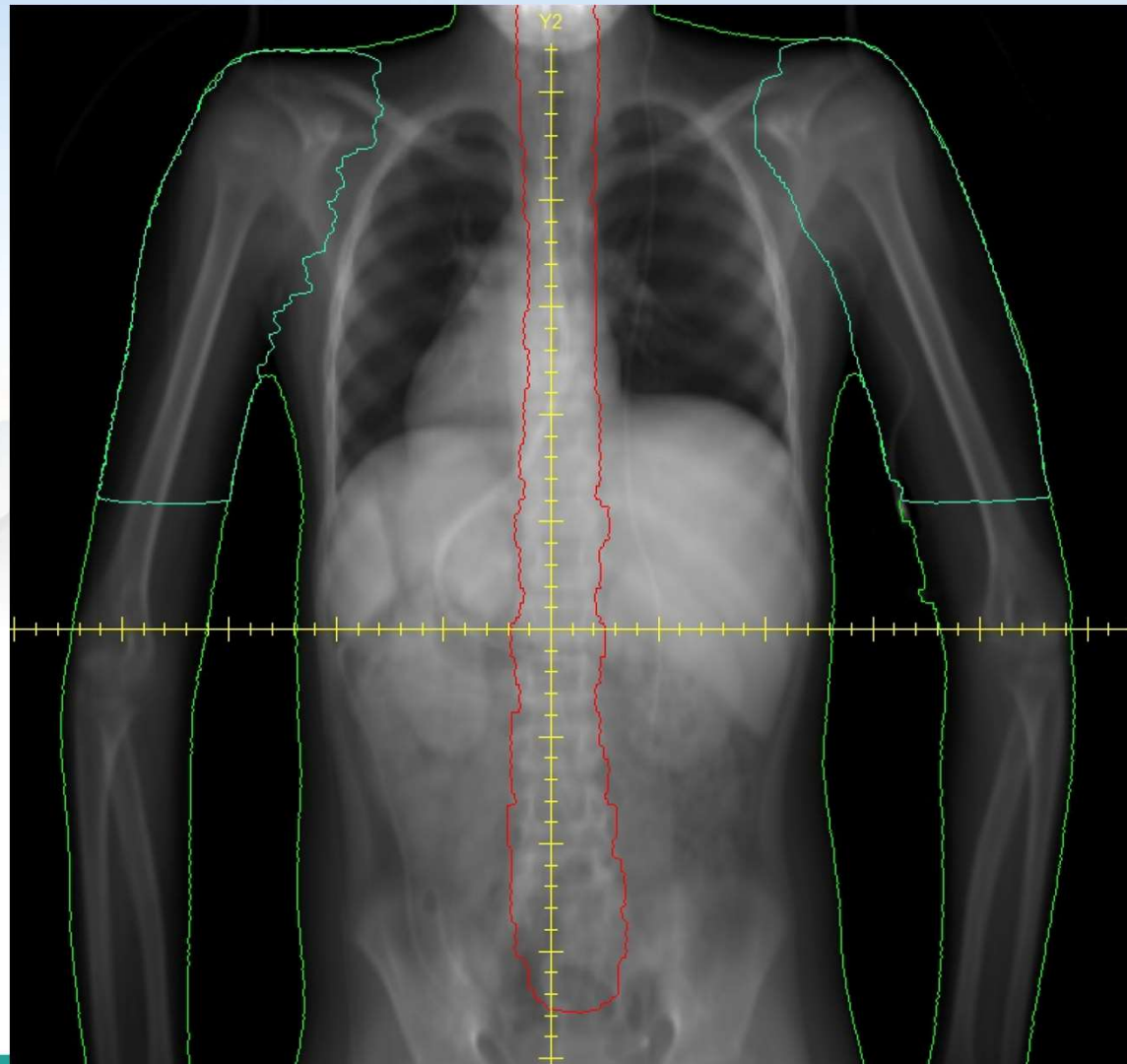
Planejamento – Escolha dos Isocentros



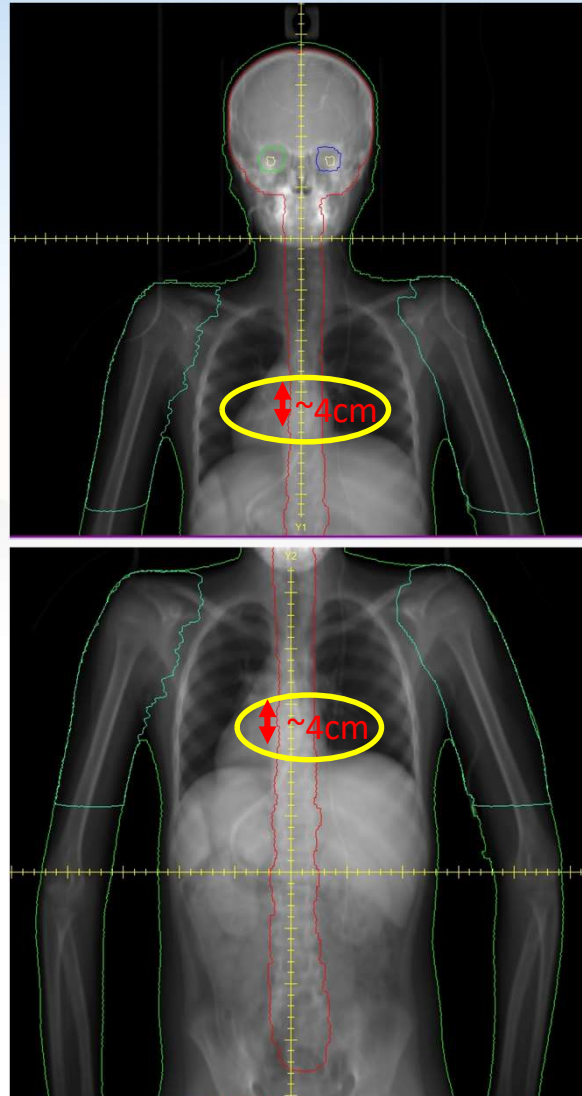
Planejamento – Escolha dos Isocentros



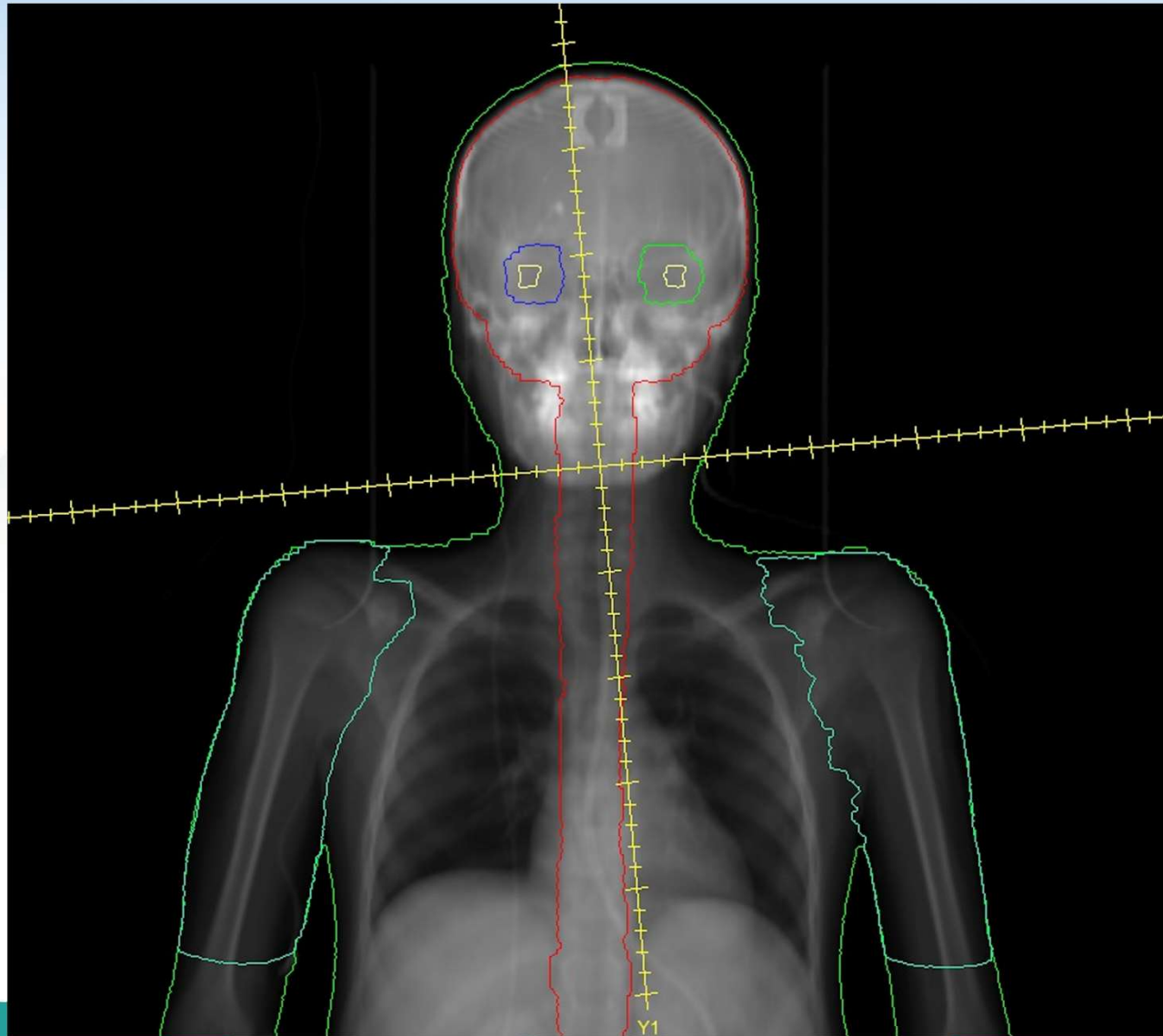
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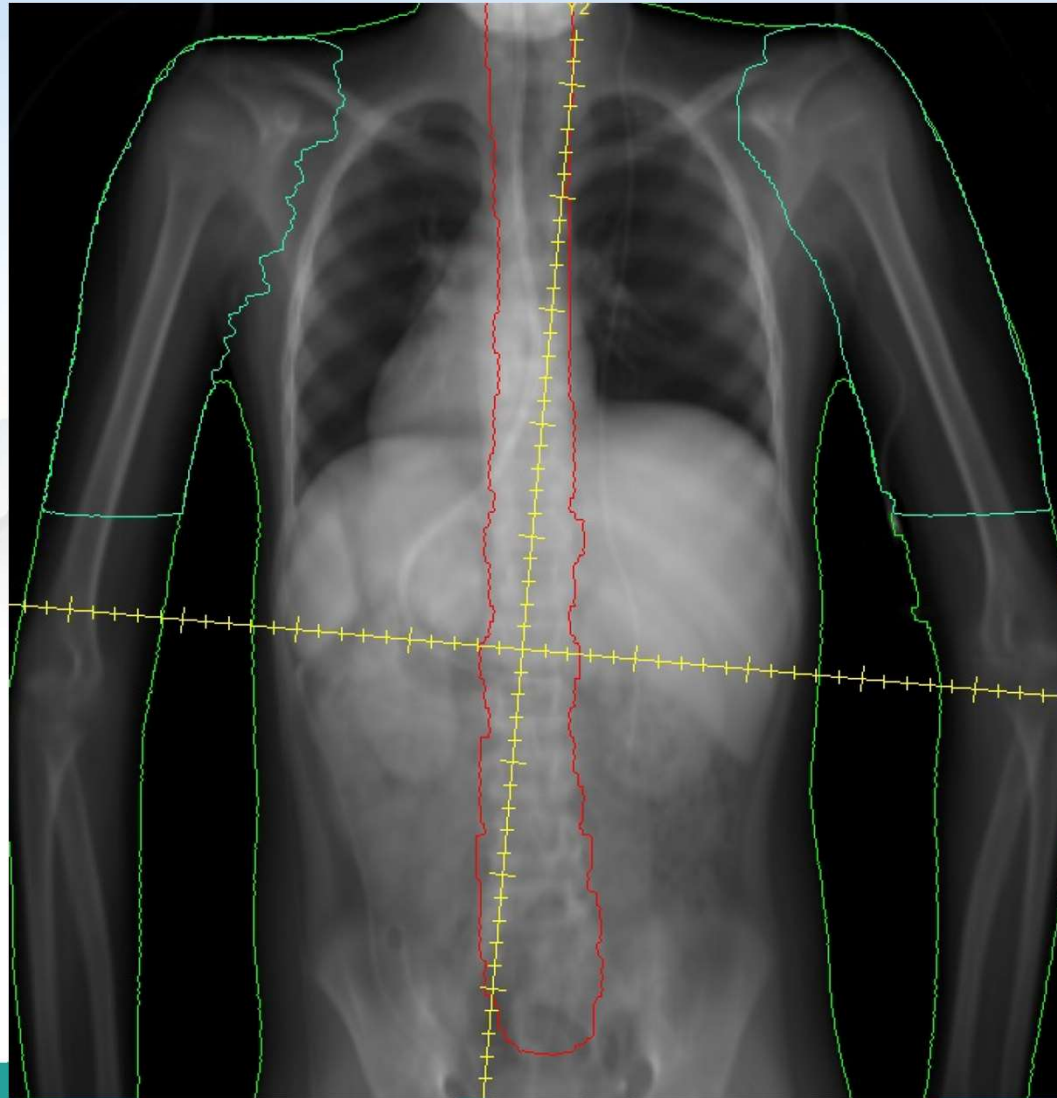
Planejamento – Escolha dos Isocentros



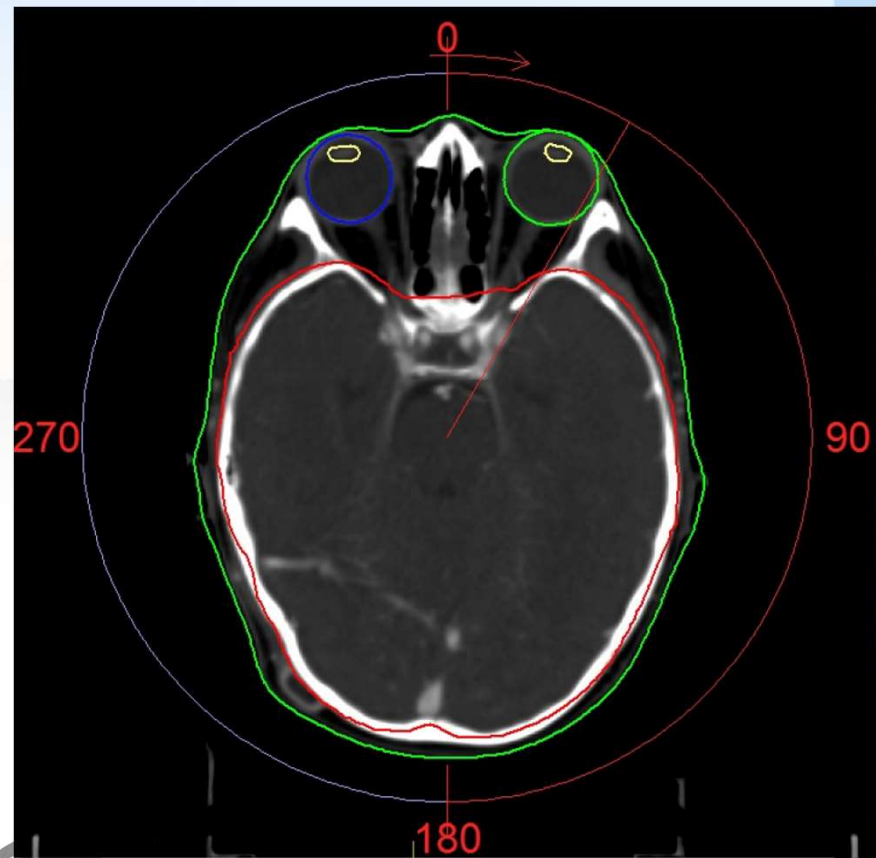
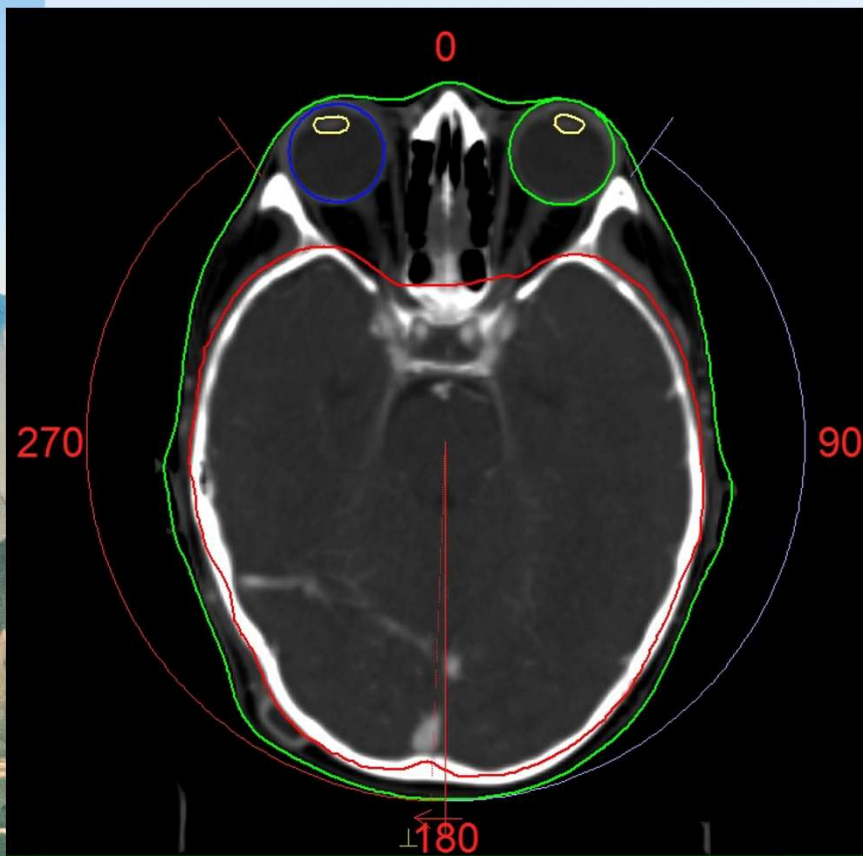
Planejamento – Colimador



Planejamento – Colimador

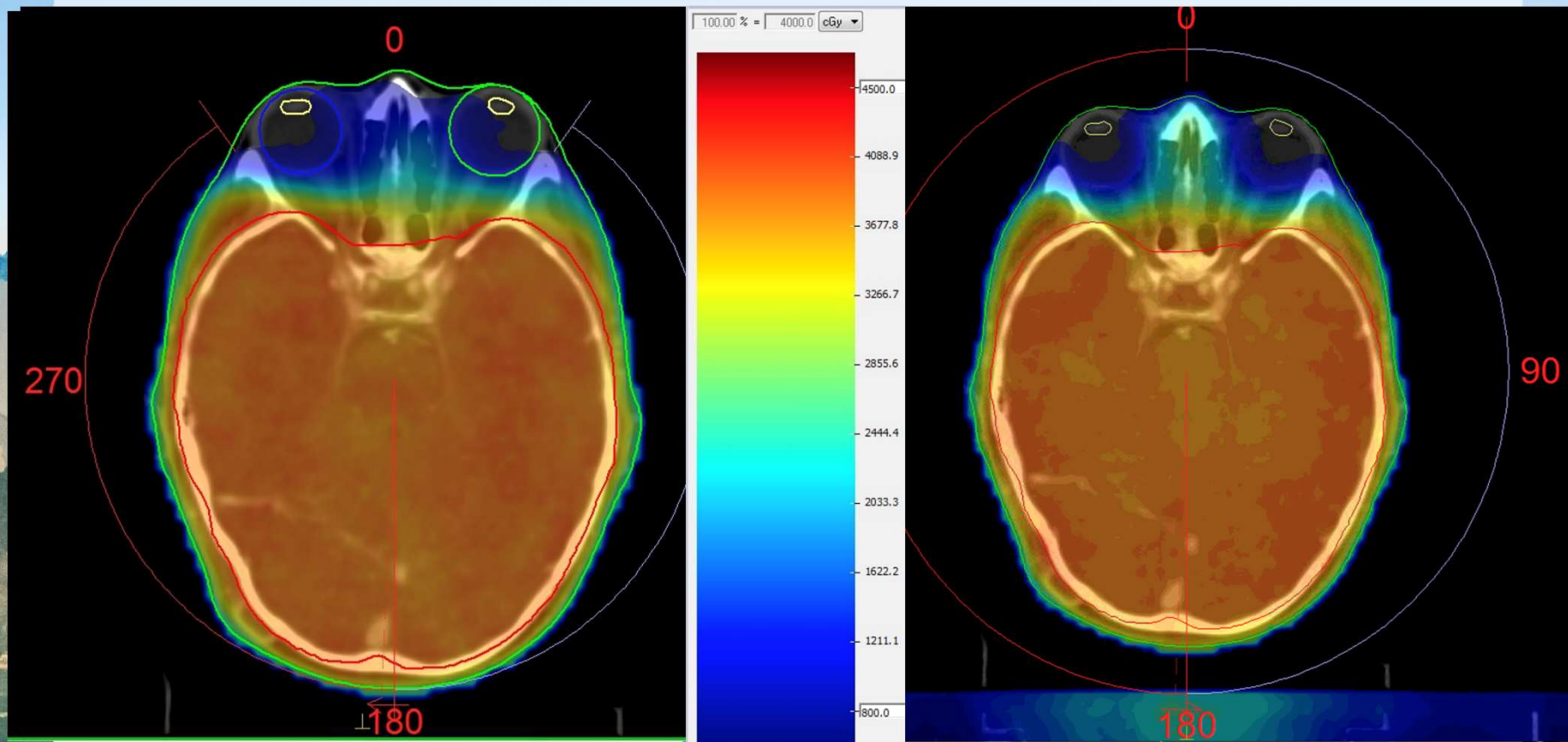


Planejamento – Escolha dos Arcos

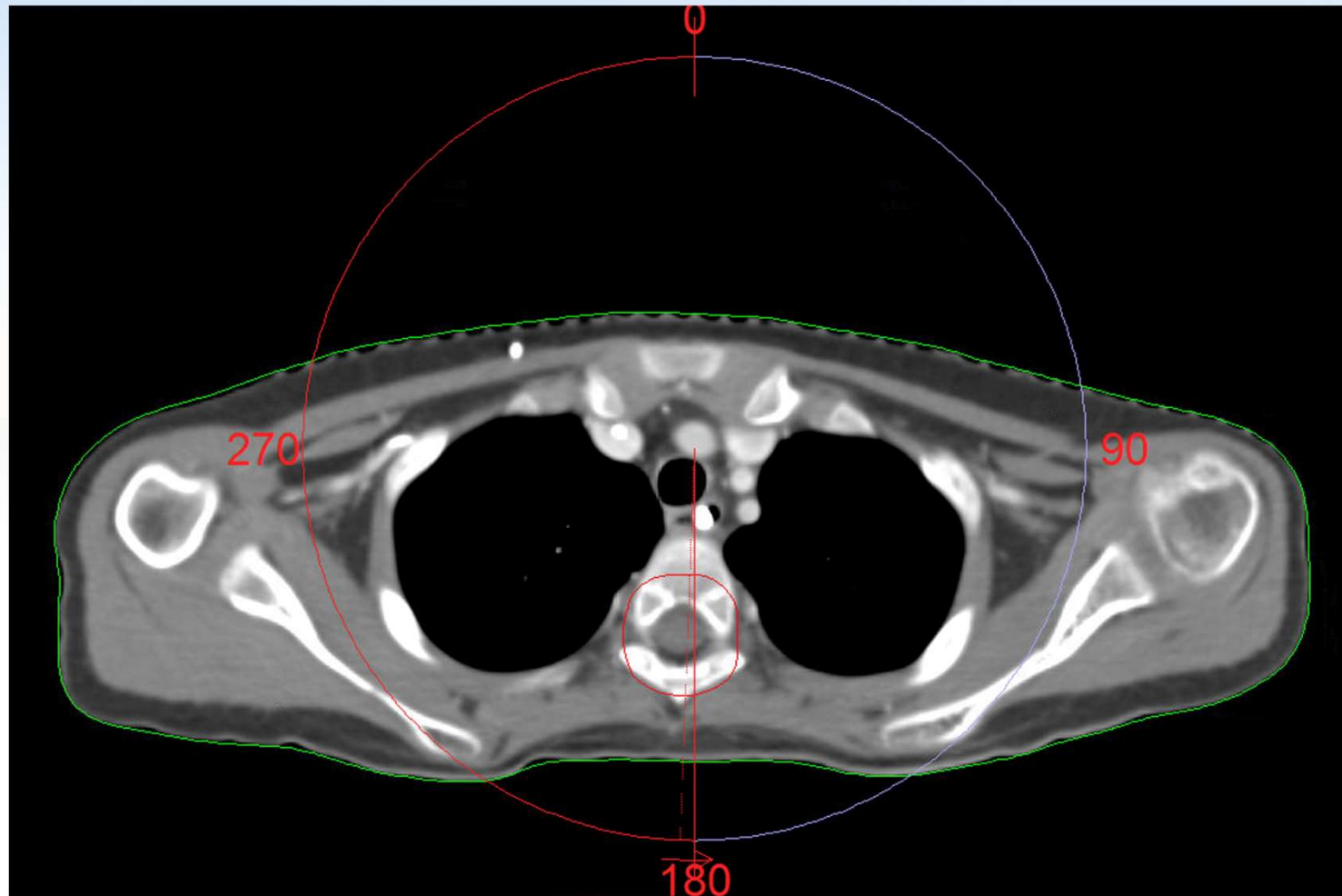


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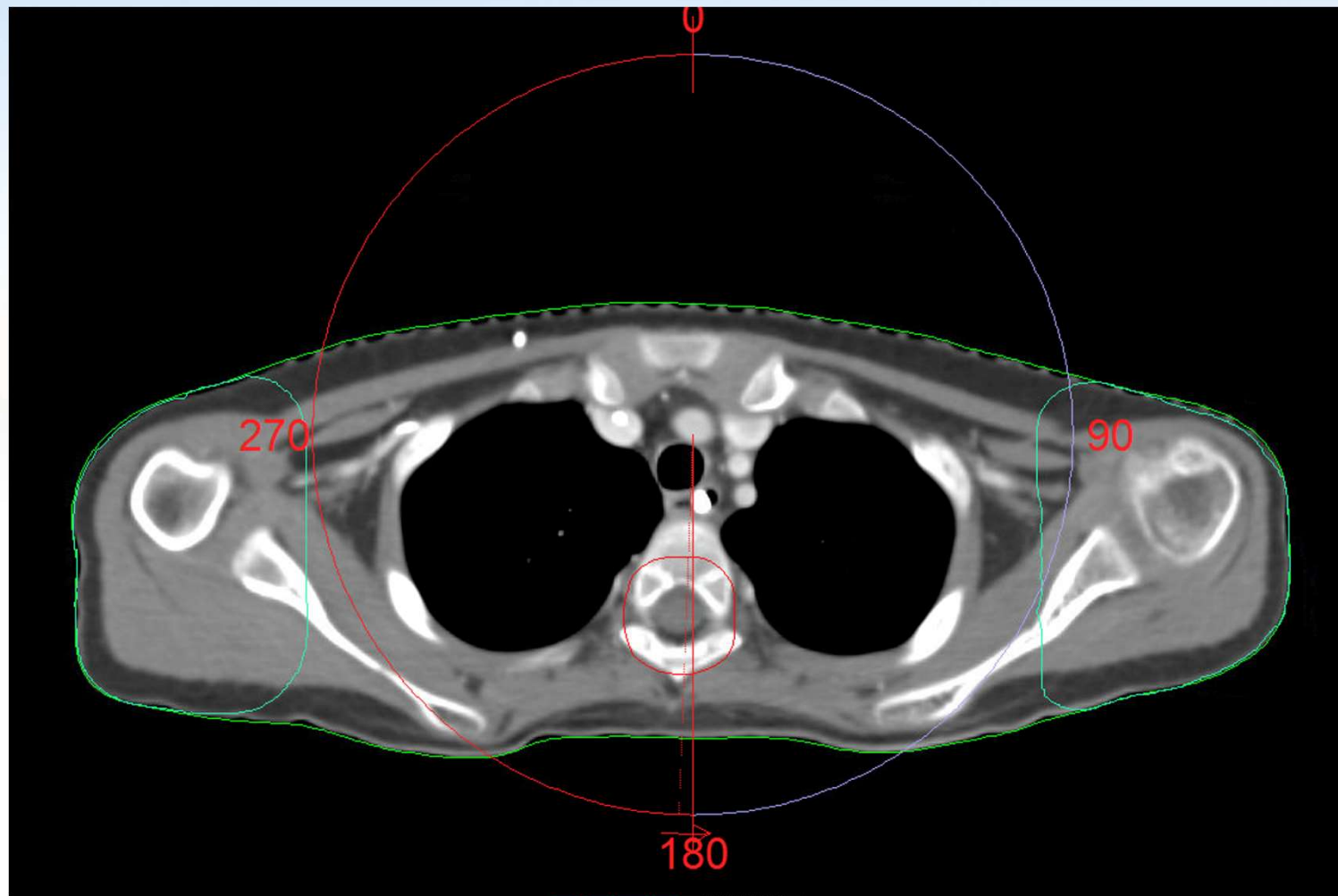
Planejamento – Escolha dos Arcos - Crânio



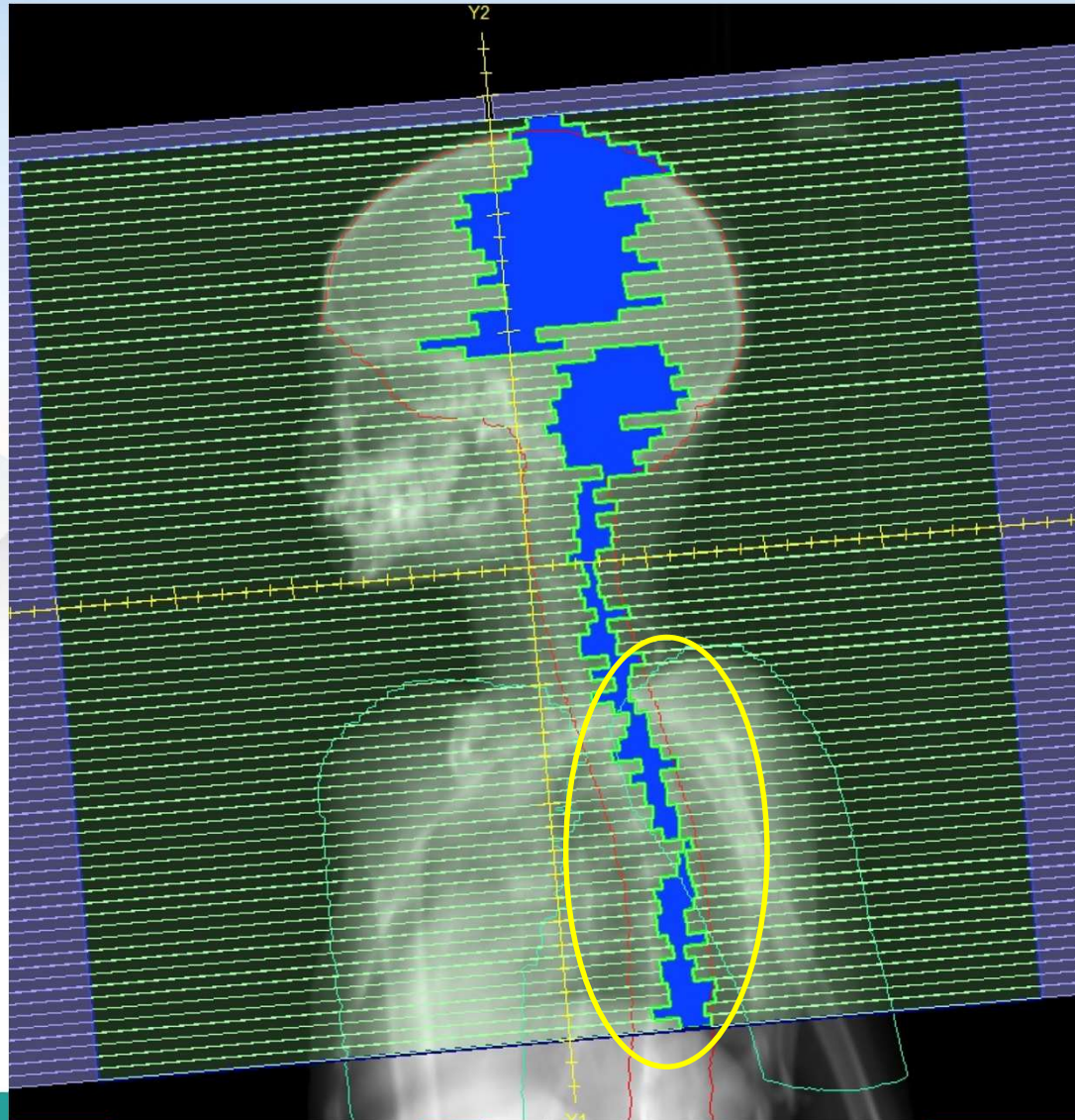
Planejamento – Escolha dos Arcos - Coluna



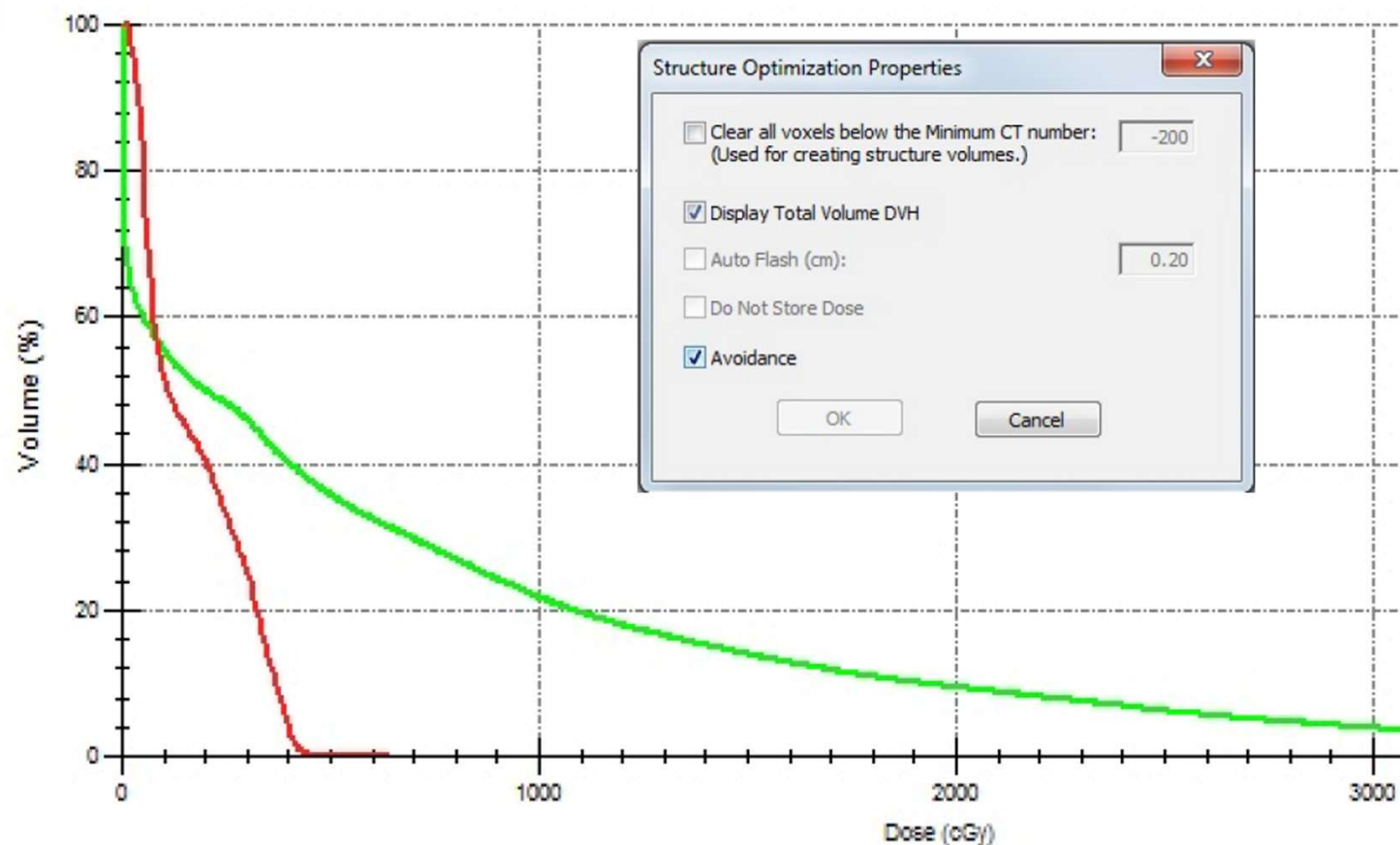
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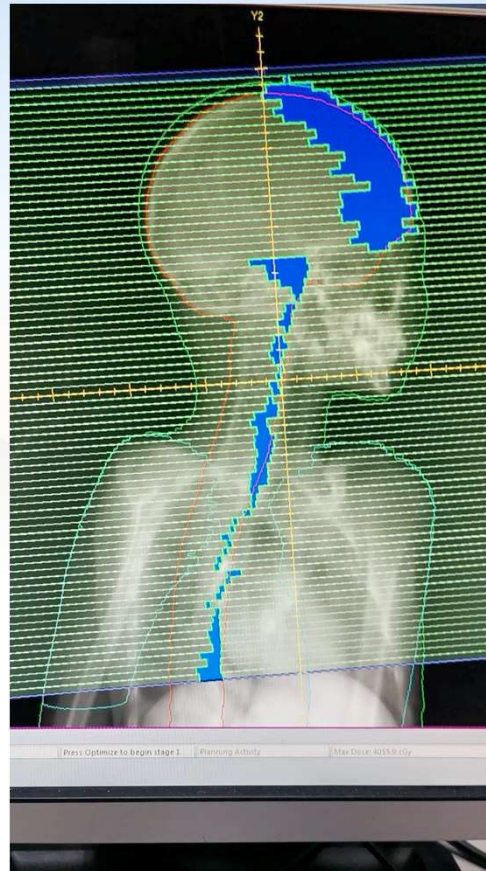
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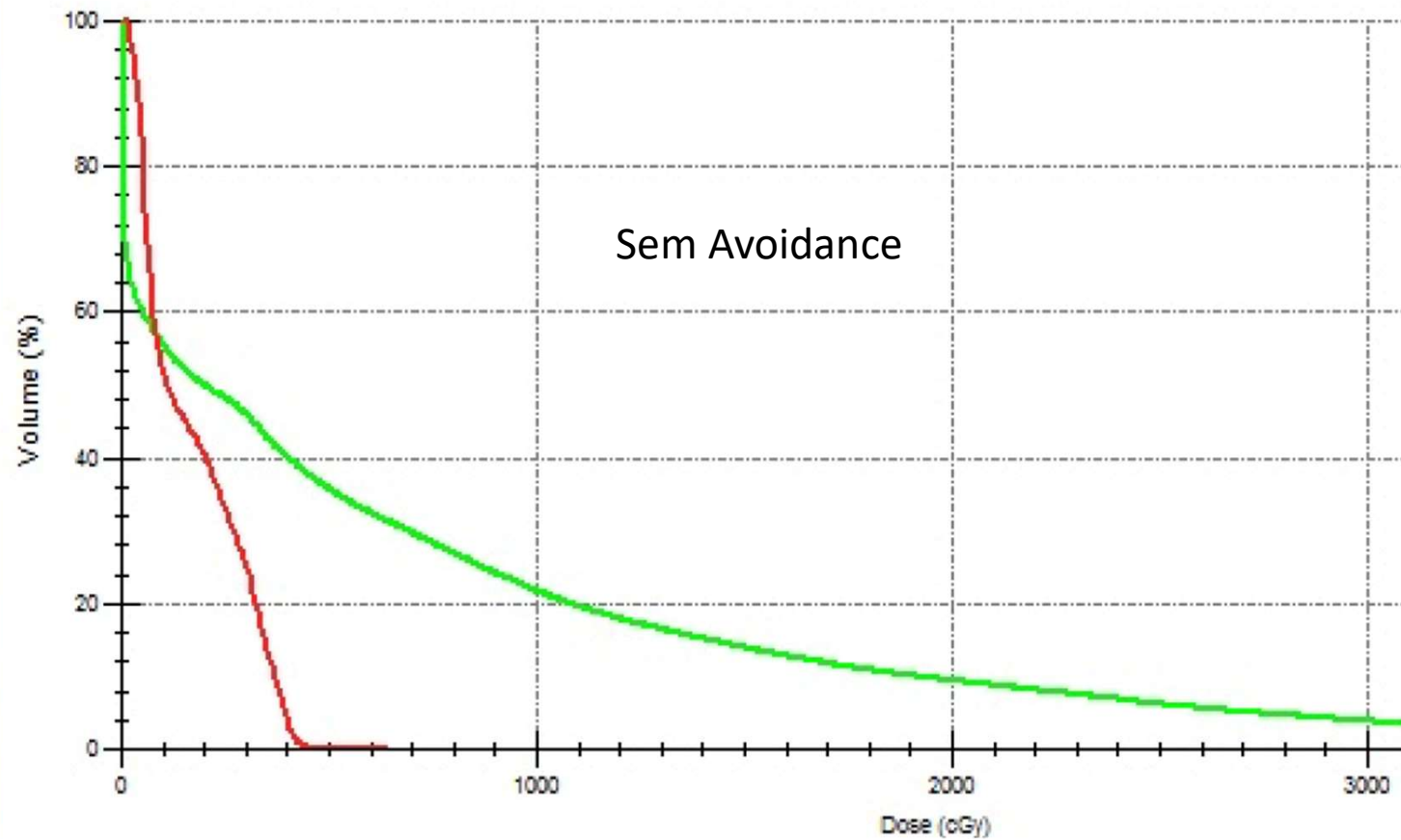
Planejamento – Escolha dos Arcos - Coluna



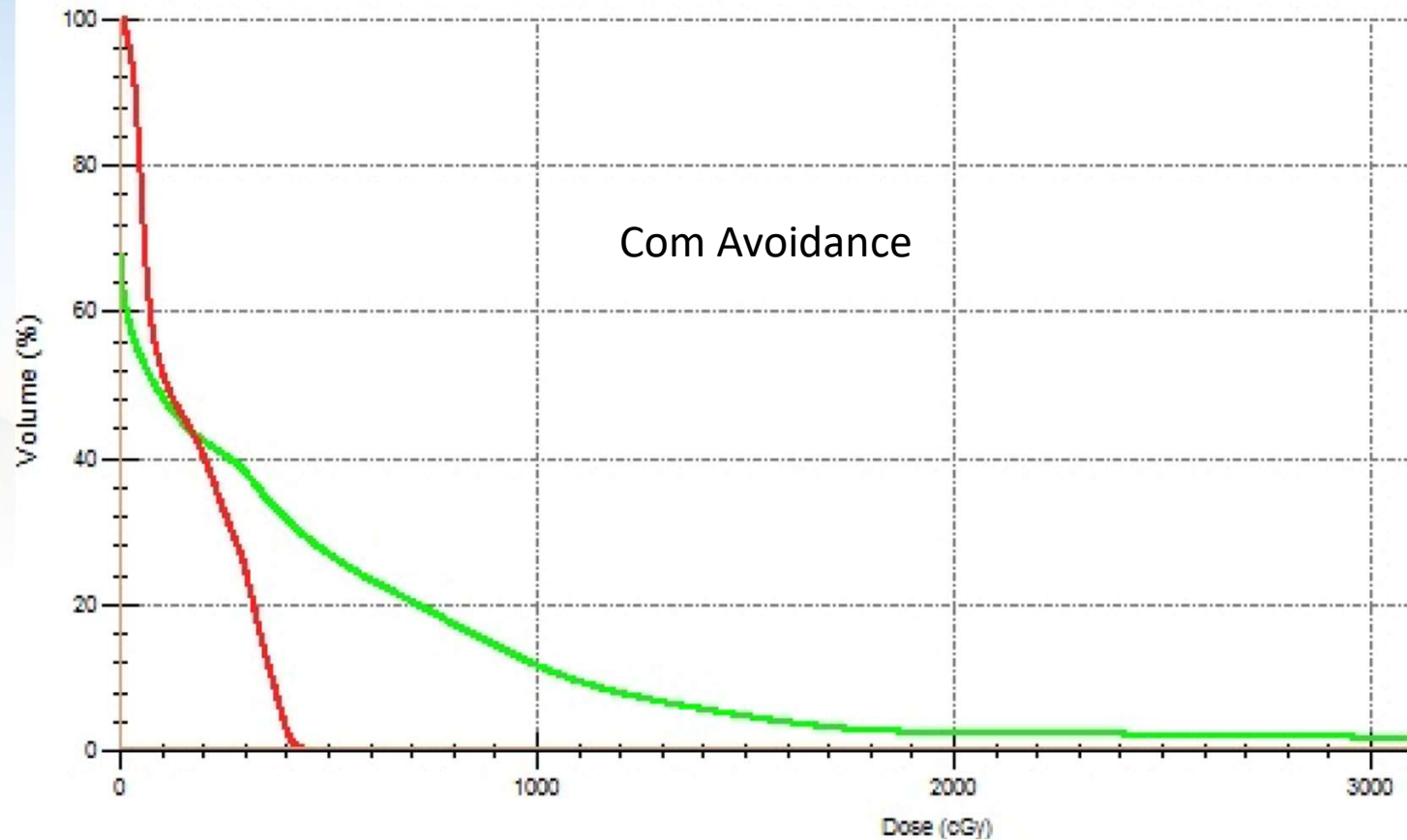
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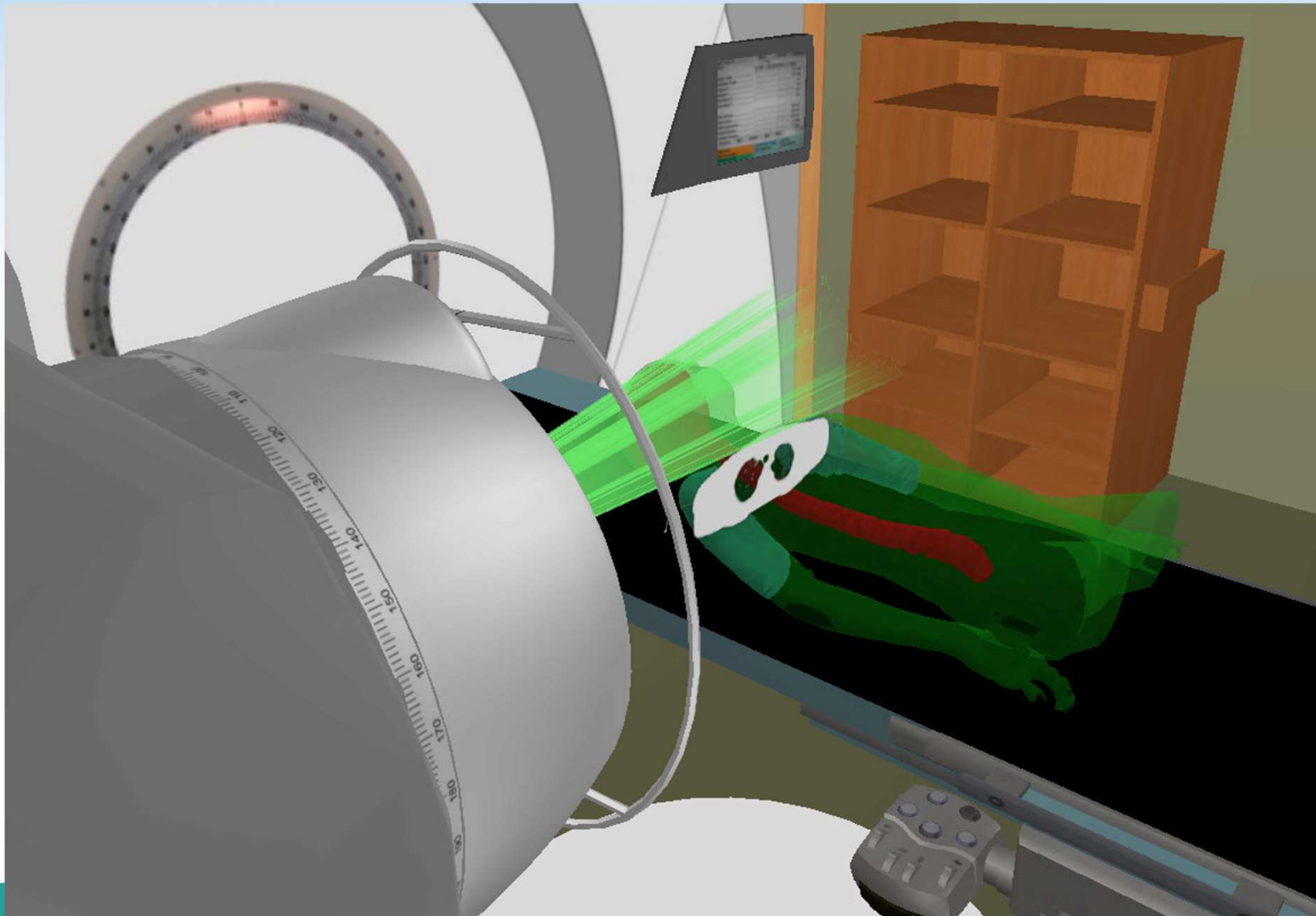
Planejamento – Escolha dos Arcos - Coluna



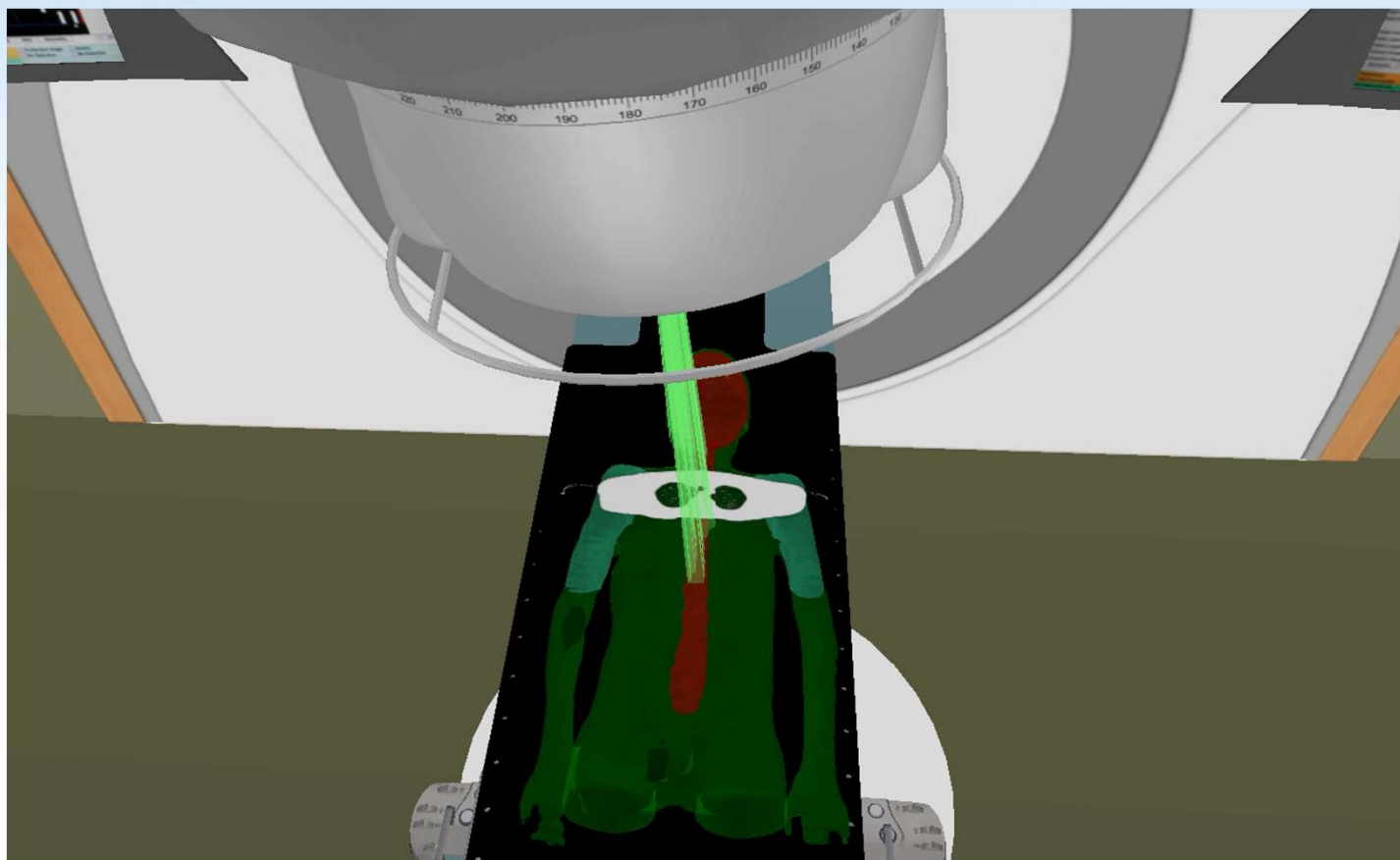
Planejamento – Escolha dos Arcos - Coluna



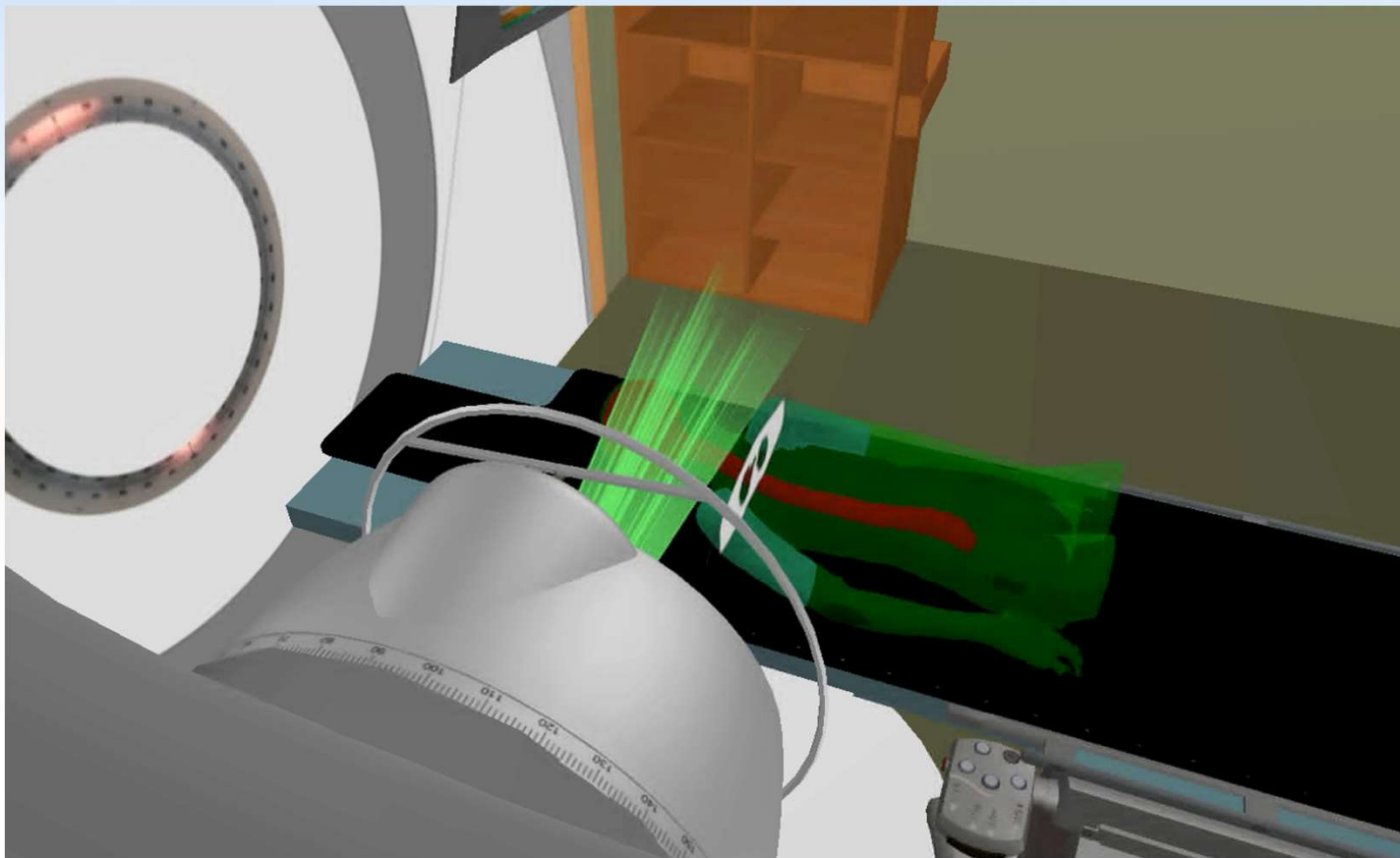
Planejamento - Ombros



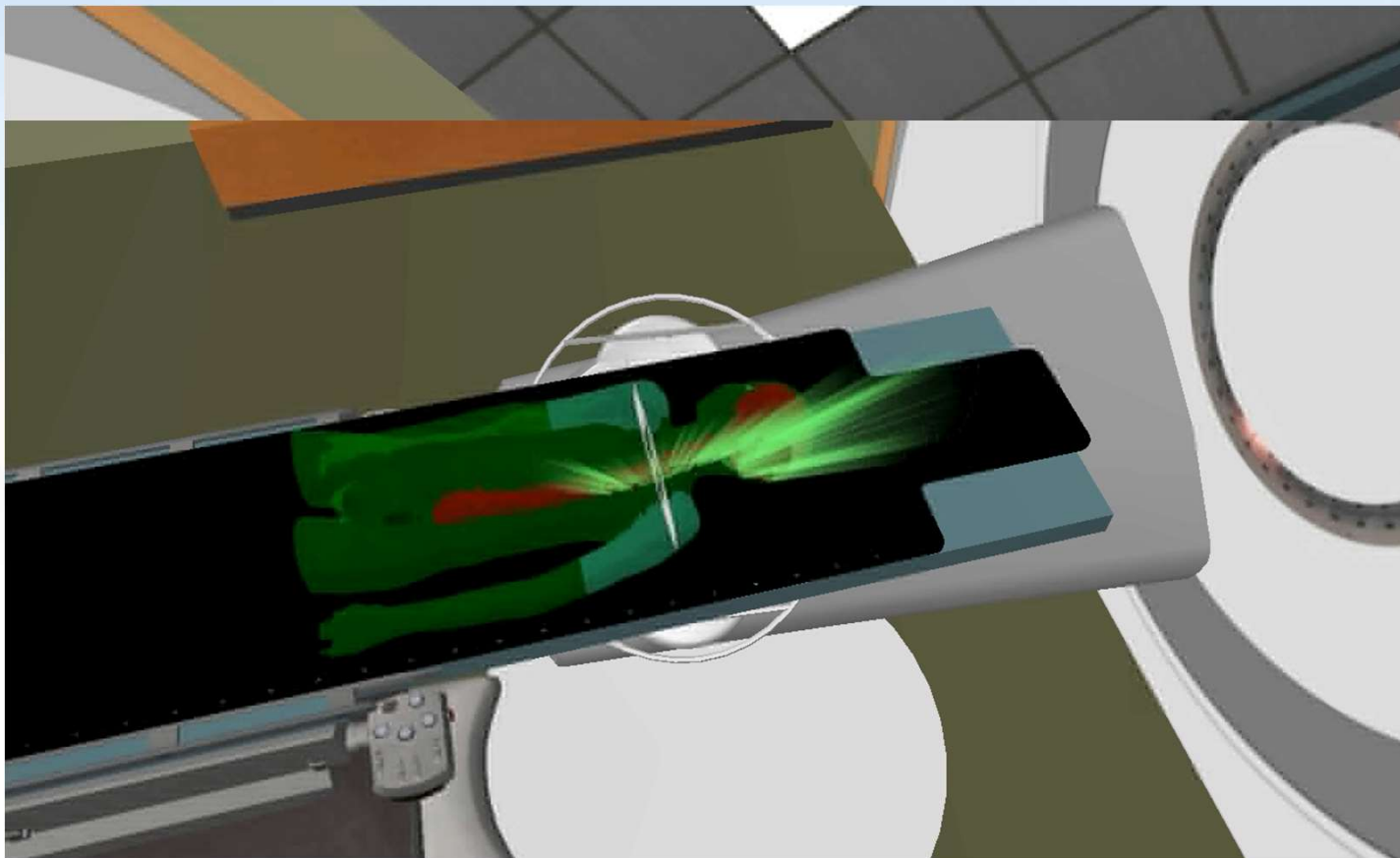
Planejamento - Ombros



Planejamento - Ombros



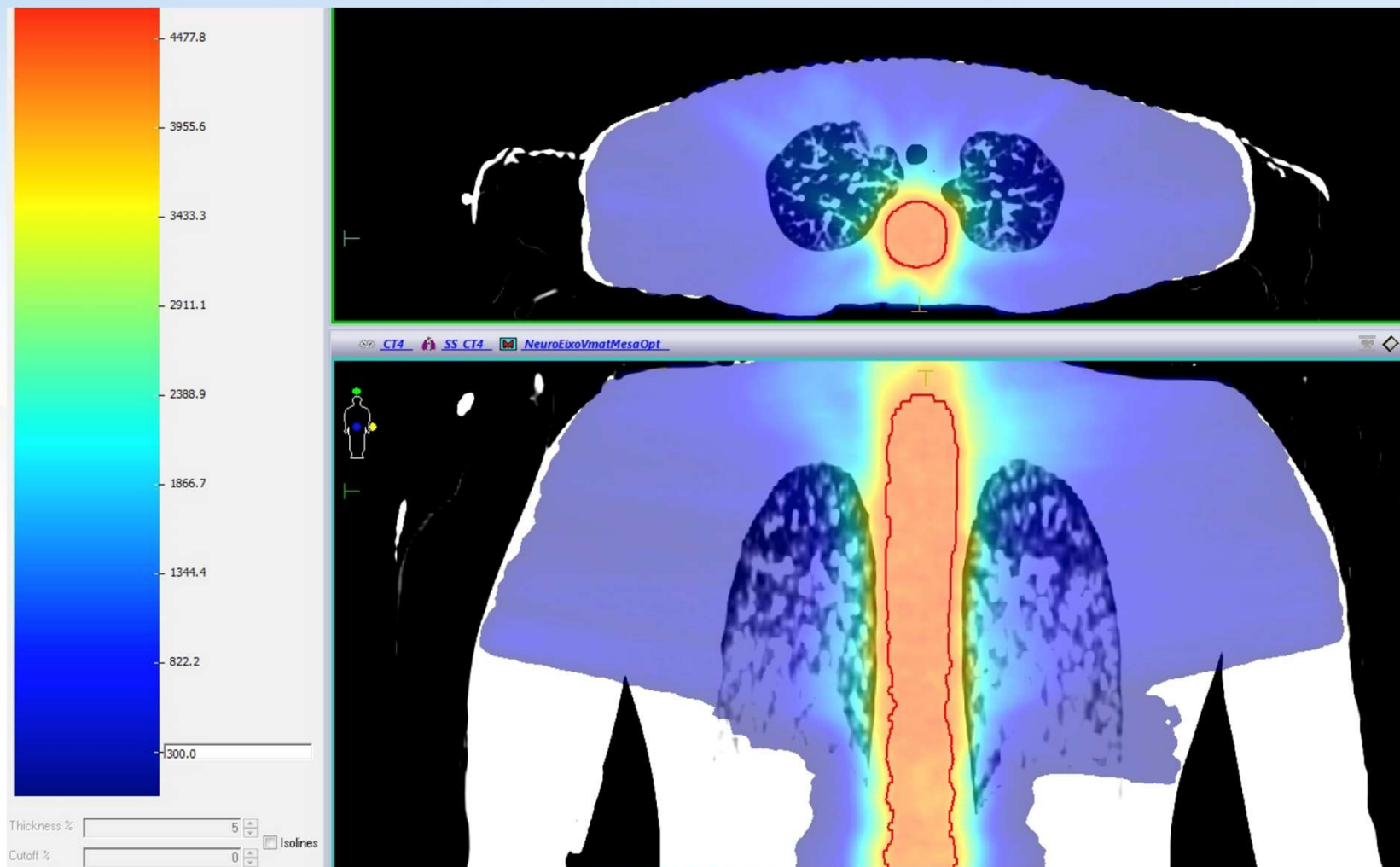
Planejamento - Ombros



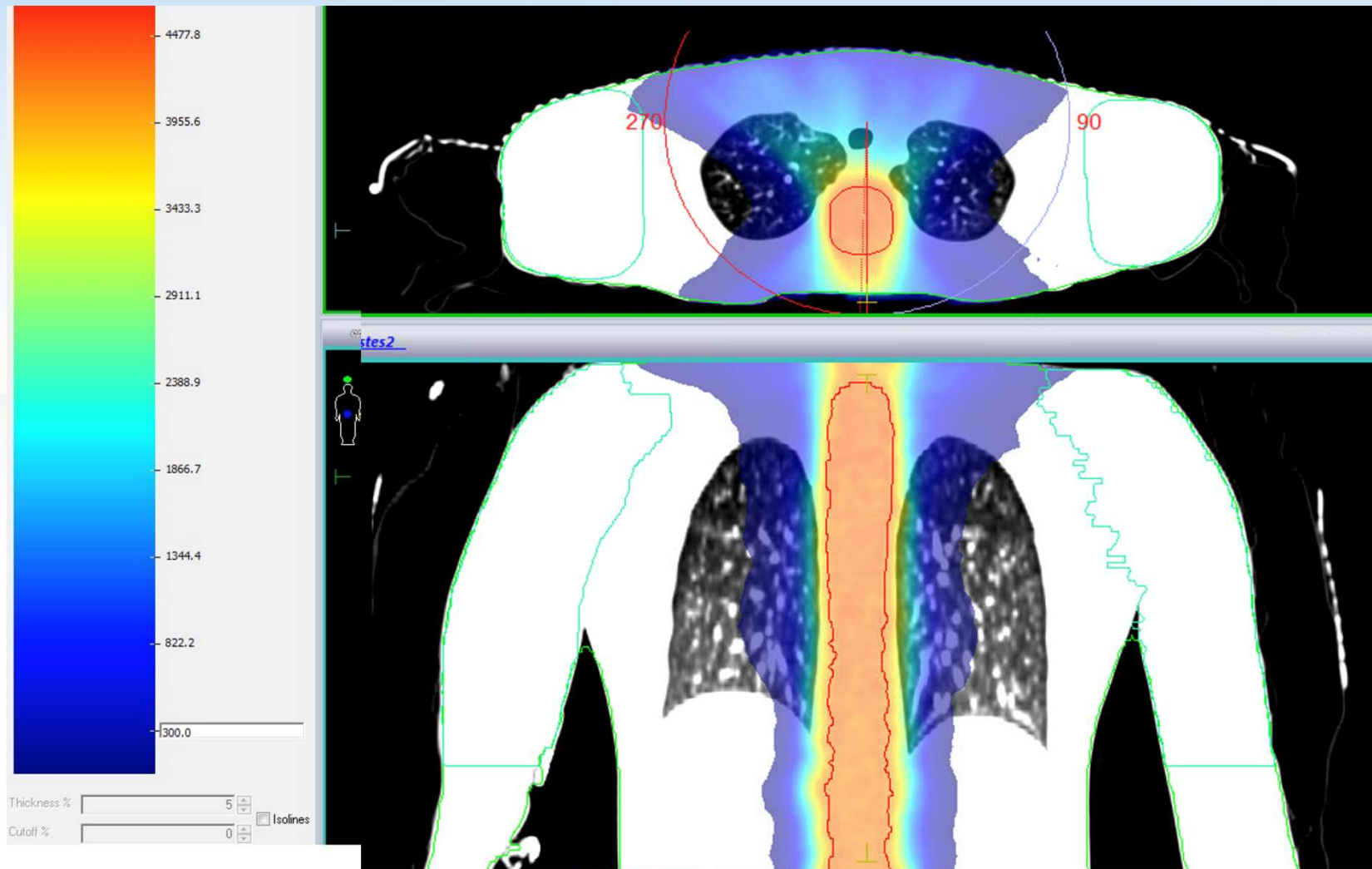
Planejamento - Ombros



Planejamento – Escolha dos Arcos - Coluna



Planejamento – Escolha dos Arcos - Coluna



Planejamento – Escolha dos Arcos - Coluna



Original Article

Choice of appropriate beam model and gantry rotational angle for low-dose gradient-based craniospinal irradiation using volumetric-modulated arc therapy

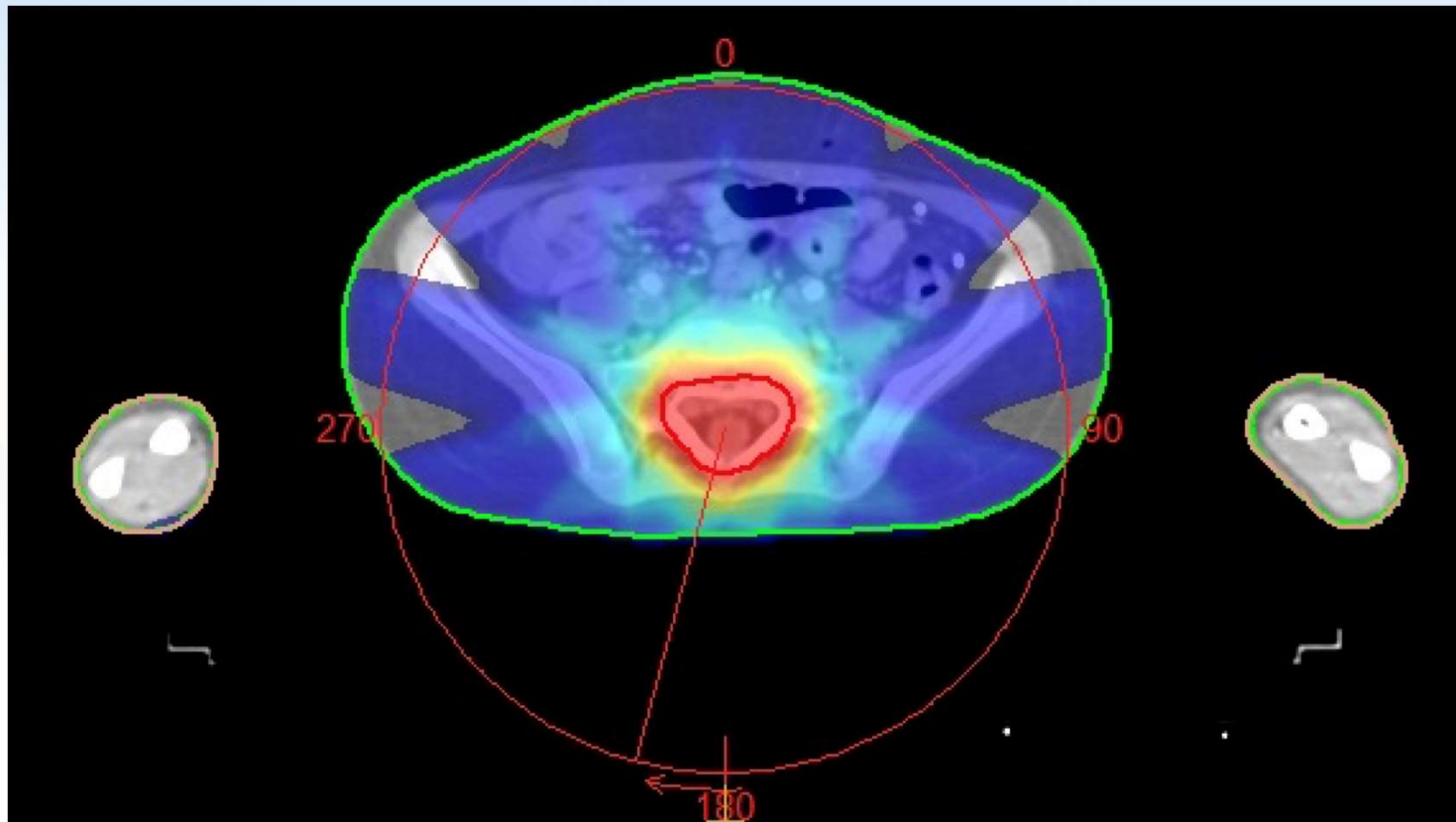
Biplab Sarkar^{1,2}, Anirudh Pradhan³

VMAT with use of shorter arc for the spine PTV reduces the delivery time as well as the low-dose area significantly. Use of full rotational arcs for spinal fields should be strongly discouraged.

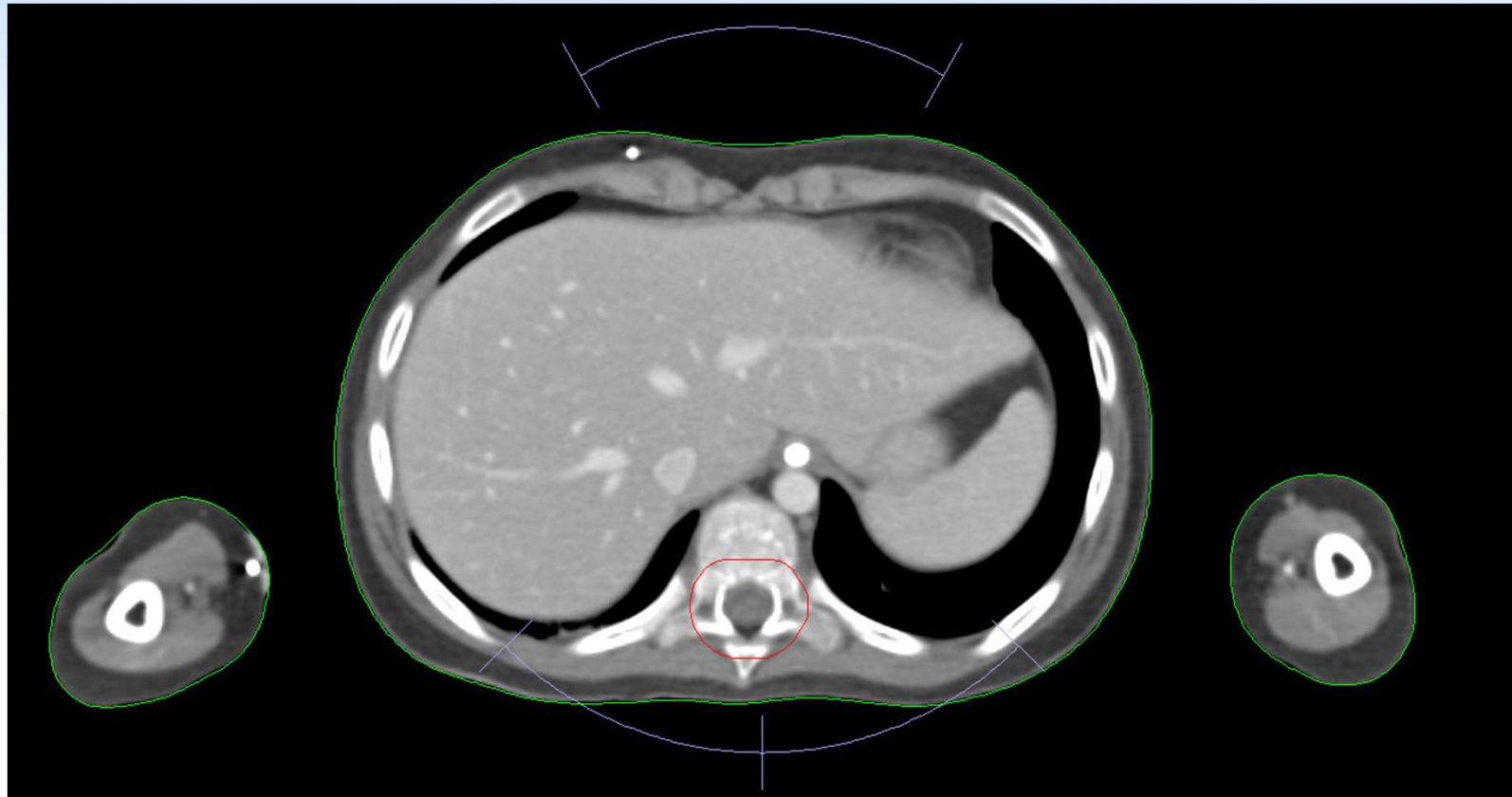
Advanced MLC models with 5 mm MLC leaf width (Agility) in combination with 3F beam offer no advantage over the conventional 1 cm MLC (Synergy) using flat beam in CSI. The only likely benefit of using a 3F beam is faster treatment delivery. VMAT shows a notable advantage over conventional technique at the cost of significantly high low-dose spillage.



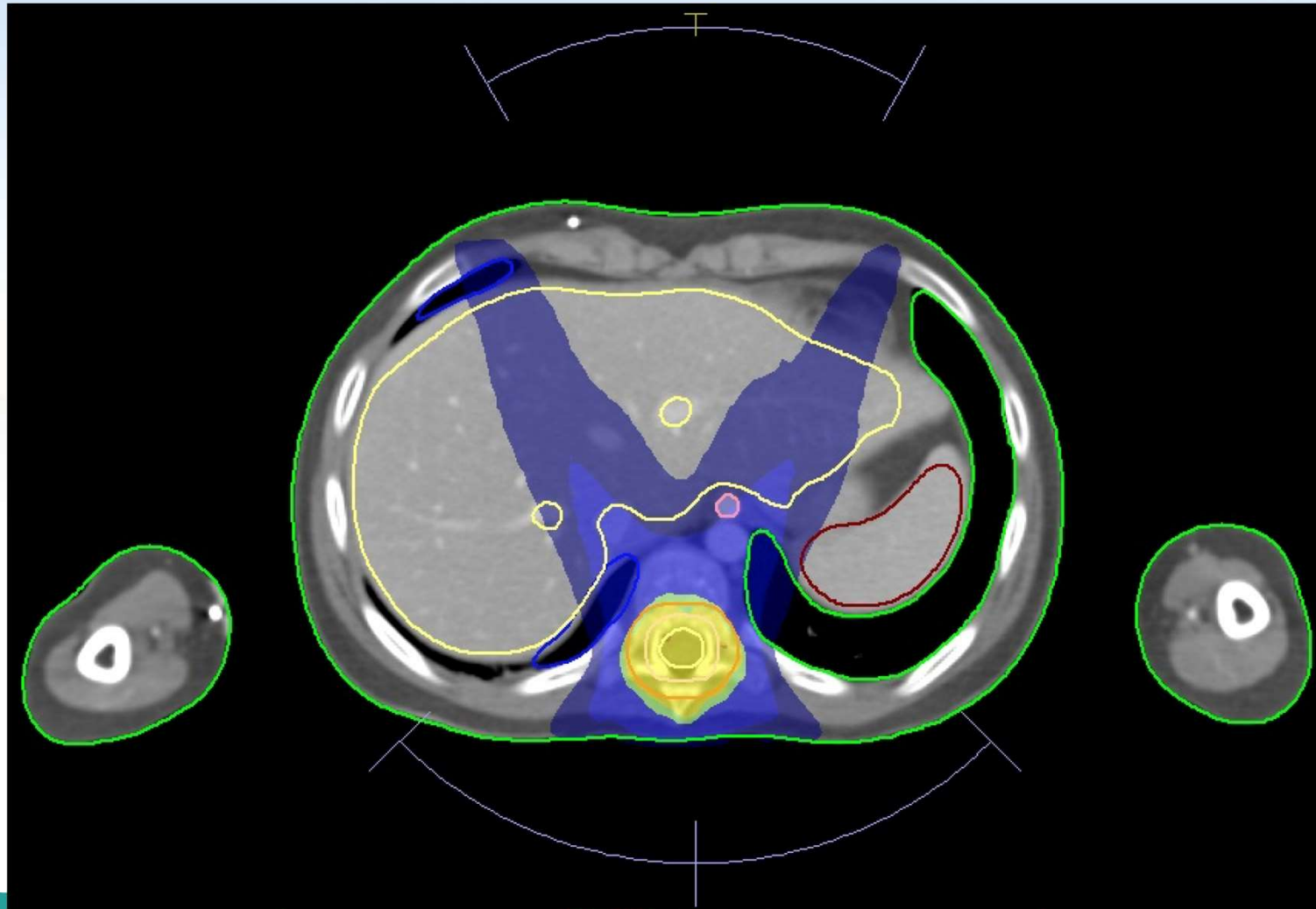
Planejamento – Escolha dos Arcos - Coluna



Planejamento – Escolha dos Arcos - Coluna



Planejamento – Escolha dos Arcos - Coluna

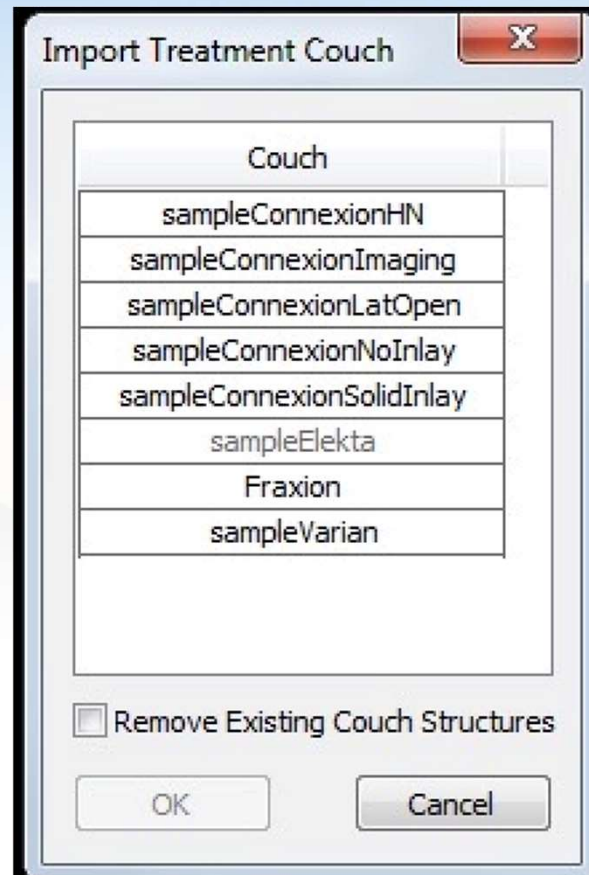


Esquecemos de algo?

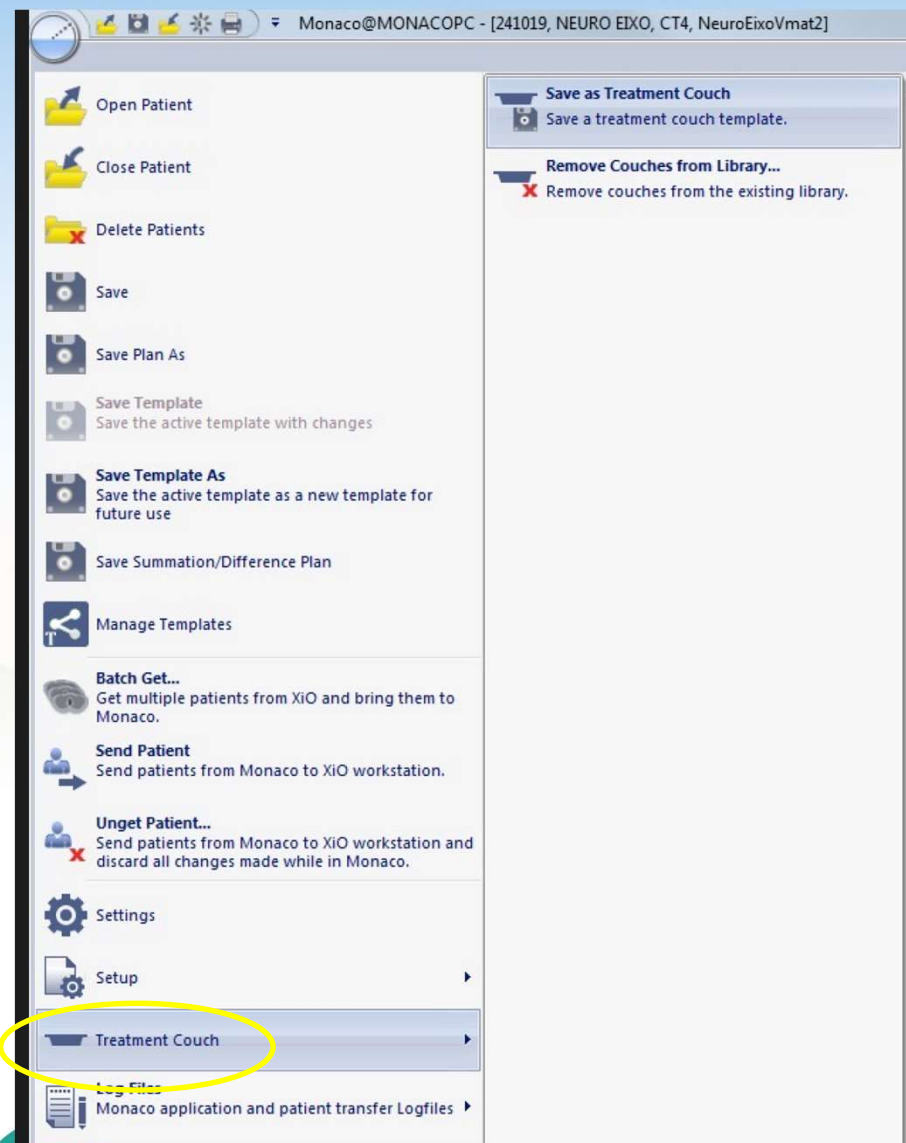
- Mesa!!



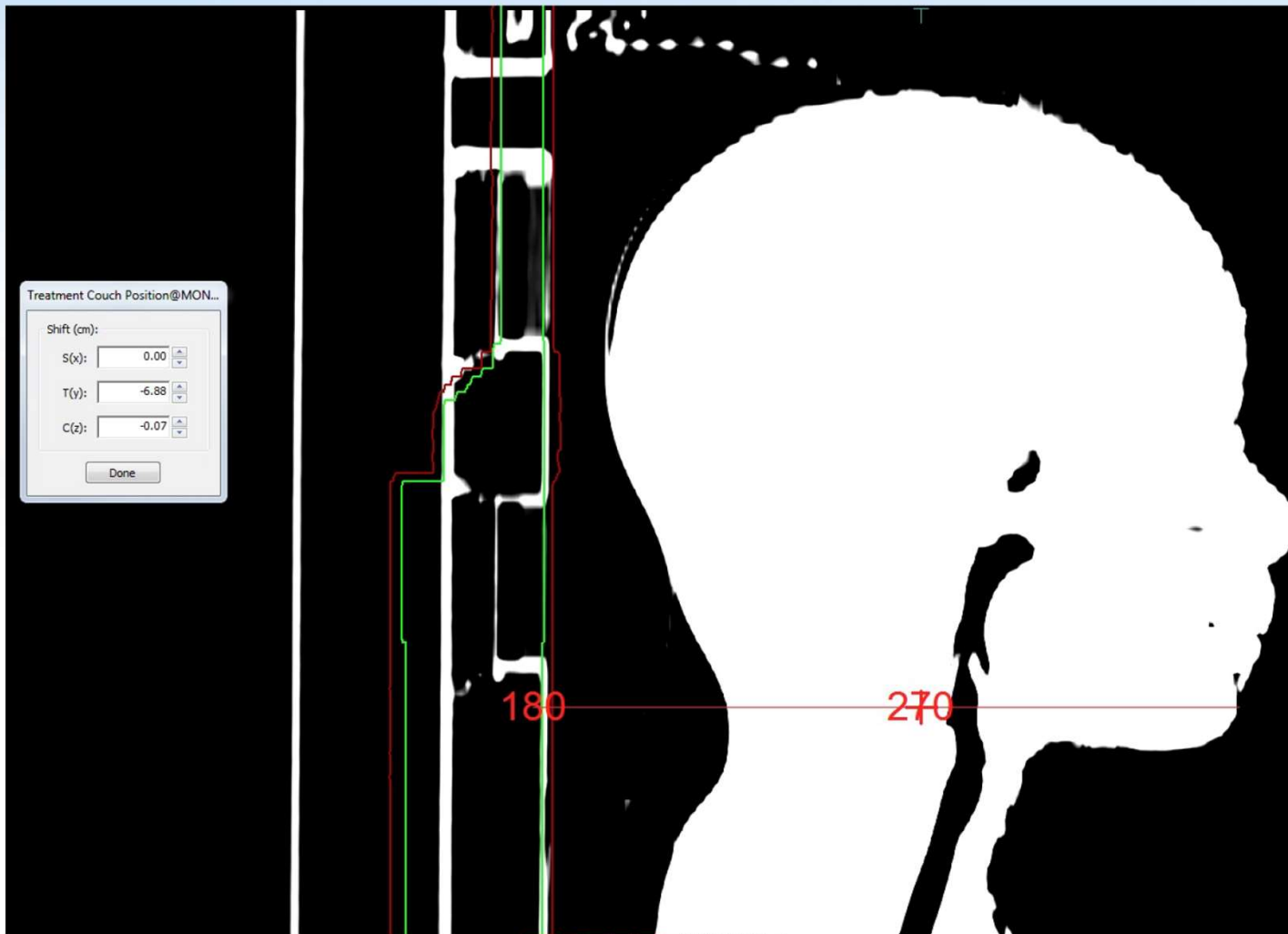
Couch



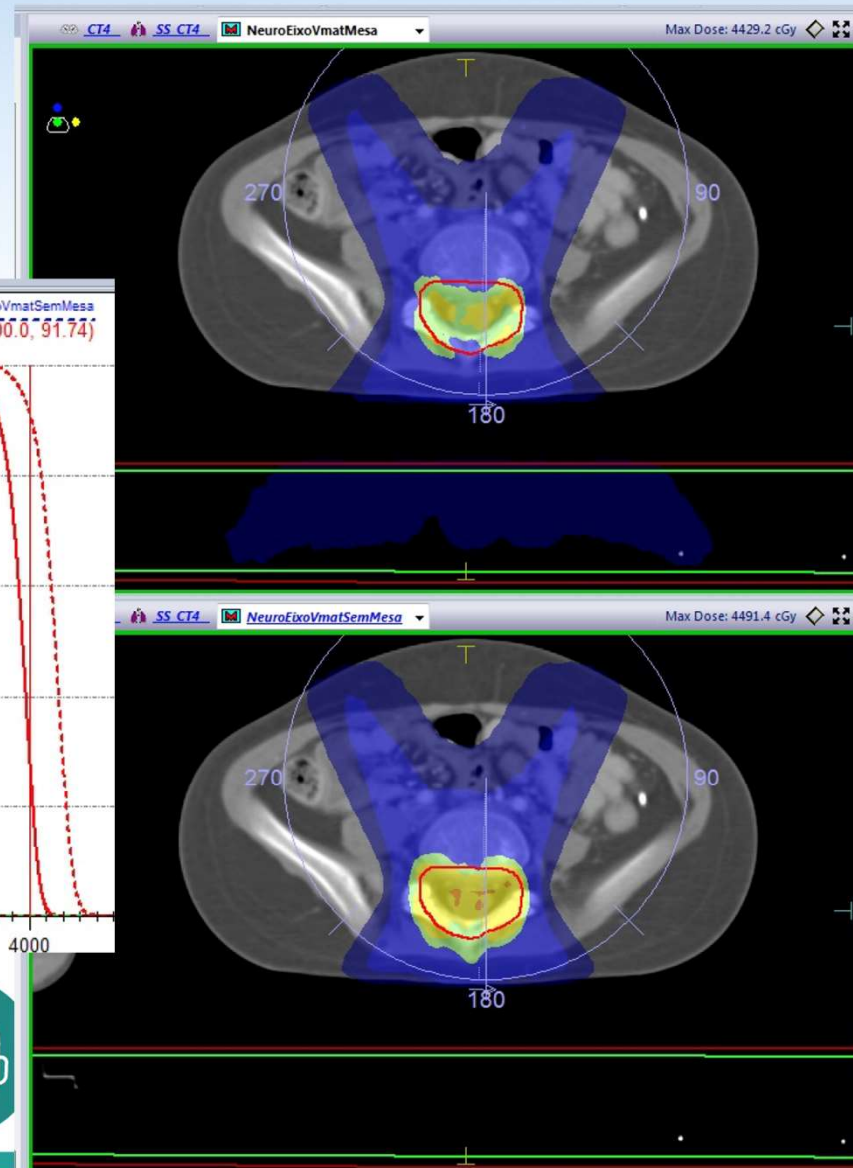
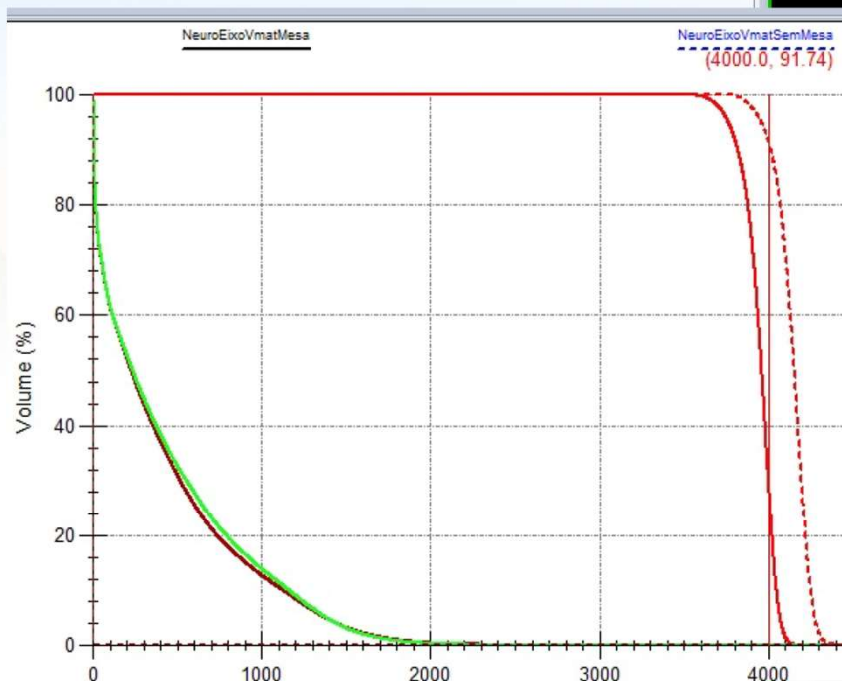
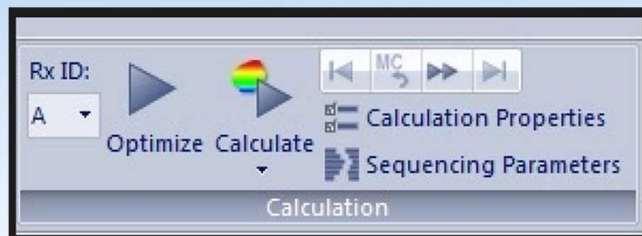
Couch - Mesa

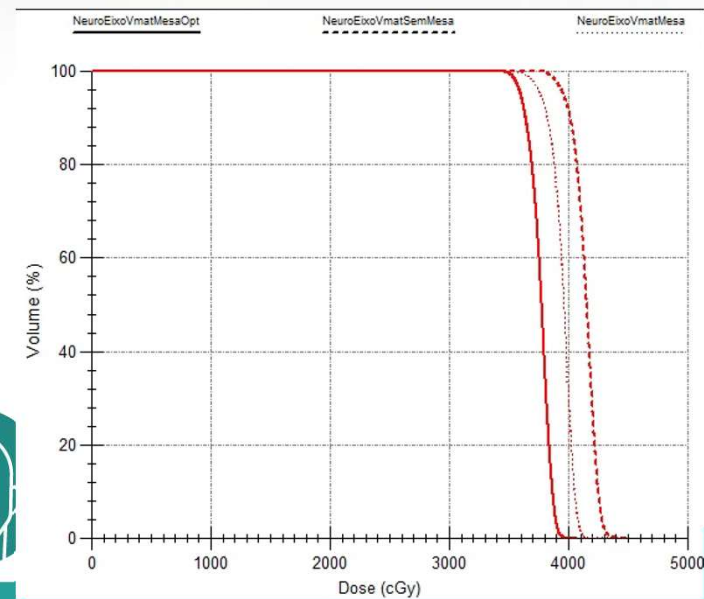


Couch – Mesa – Posicionando



Recalculando com a Mesa





Volume modulated arc therapy

Cranio-spinal irradiation with volumetric modulated arc therapy: A multi-institutional treatment experience

Antonella Fogliata^{a,*}, Stefan Bergström^b, Ines Cafaro^c, Alessandro Clivio^a, Luca Cozzi^a

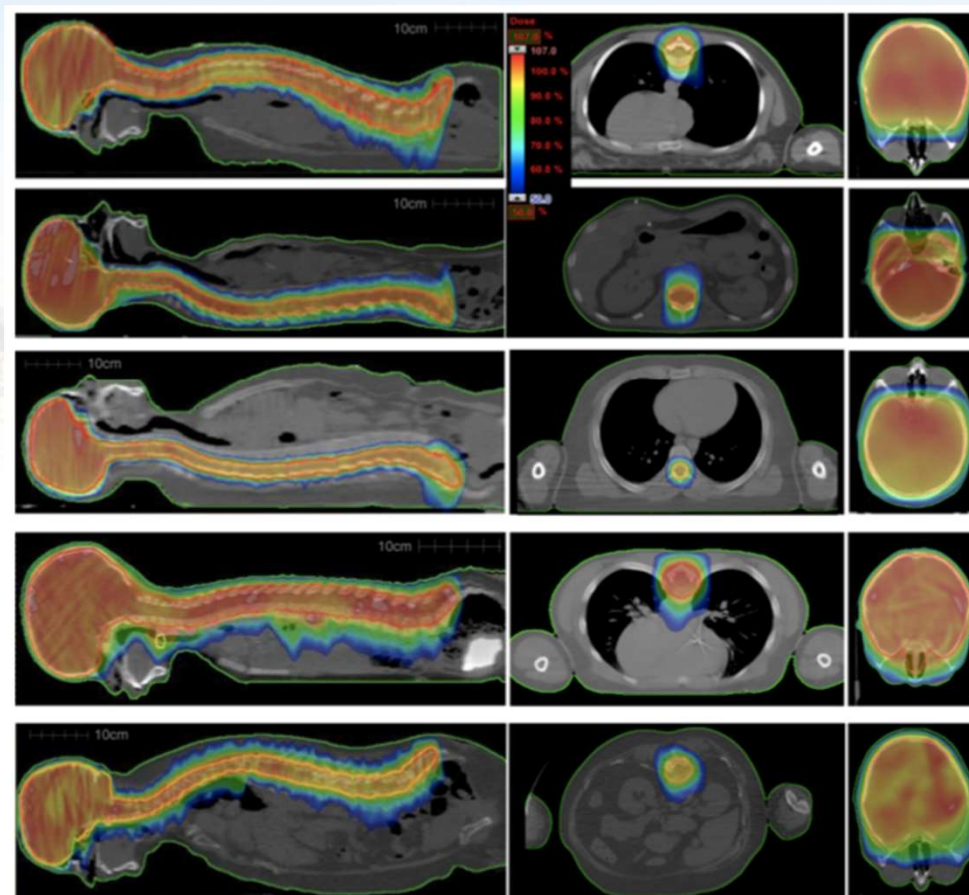
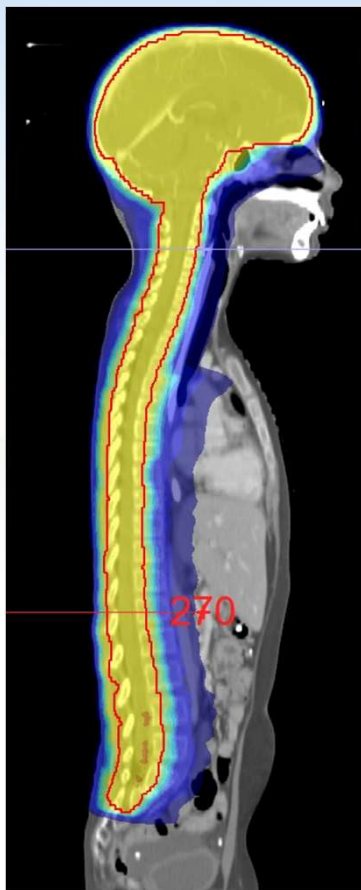


Fig. 1. First column: sagittal views for all cases; second column: selected transversal views. Colourwash range: 50% to 107%.

Conclusão



Conclusions

CSI is one of the most challenging processes in radiation planning and delivery. The five studied cases, treated with RapidArc technology in different European institutions with various planning approaches, indicated that this technique is usable in clinical practice and can be advantageous in treating patients requiring CSI.

Referências

1. Ritchey, A.K.; Pollock, B.H.; Lauer, S.J.; *et al.* Improved survival of children with isolated CNS relapse of acute lymphoblastic leukemia: A pediatric oncology group study. *J. Clin. Oncol.* **17**:3745–52; 1999. Erratum in: *J. Clin. Oncol.* 2000;18:703.
2. Packer, R.J.; Gajjar, A.; Vezina, G.; *et al.* Phase III study of craniospinal radiation therapy followed by adjuvant chemotherapy for newly diagnosed average-risk medulloblastoma. *J. Clin. Oncol.* **24**:4202–8; 2006.
3. Bentel, G.C. Radiation therapy planning, 2nd ed. McGraw-Hill, New York; 1996.
4. Frange, P.; Alapetite, C.; Gaboriaud, G.; *et al.* From childhood to adulthood: Long-term outcome of medulloblastoma patients. *The Institut Curie experience (1980–2000)*. *J. Neuro Oncol.* **95**:271–9; 2009.
5. Merchant, T.E.; Pollack, I.F.; Loeffler, J.S. Brain tumors across the age spectrum: Biology, therapy, and late effects. *Semin. Radiat. Oncol.* **20**:58 – 66; 2010.
6. Parker, W.; Brodeur, M.; Roberge, D.; *et al.* Standard and nonstandard craniospinal radiotherapy using helical TomoTherapy. *Int. J. Radiat. Oncol. Biol. Phys.* **77**:926 –31; 2010.
7. Wilkinson, J.M.; Lewis, J.; Lawrence, G.P.; *et al.* Craniospinal irradiation using a forward planned segmented field technique. *Br. J. Radiol.* **80**:209 –15; 2007.
8. Pai Panandiker, A.; Ning, H.; Likhacheva, A.; *et al.* Craniospinal irradiation with spinal IMRT to improve target homogeneity. *Int. J. Radiat. Oncol. Biol. Phys.* **68**: 1402–9; 2007.
9. St Clair, W.H.; Adams, J.A.; Bues, M.; *et al.* Advantage of protons compared to conventional X-ray or IMRT in the treatment of a pediatric patient with medulloblastoma. *Int. J. Radiat. Oncol. Biol. Phys.* **58**:727–34; 2004.



Referências

10. Lee, C.T.; Bilton, S.D.; Famiglietti, R.M.; *et al.* Treatment planning with protons for pediatric retinoblastoma, medulloblastoma, and pelvic sarcoma: How do protons compare with other conformal techniques? *Int. J. Radiat. Oncol. Biol. Phys.* **63**:362– 72; 2005.
11. PeOagarâcano, J.A.; Papanikolaou, N.; Yan, Y.; *et al.* Feasibility of cranio-spinal axis radiation with the Hi-Art tomotherapy system. *Radiother. Oncol.* **76**:72– 8; 2005.
12. Sharma, D.S.; Gupta, T.; Jalali, R.; *etal.* High-precision radiotherapy for craniospinal irradiation: Evaluation of three-dimensional conformal radiotherapy, intensity- modulated radiation therapy and helical TomoTherapy. *Br. J. Radiol.* **82**:1000–9; 2009.
13. Yom, S.S.; Frija, E.K.; Mahajan, A.; *etal.* Field-in-field technique with intrafraction- ally modulated junction shifts for craniospinal irradiation. *Int. J. Radiat. Oncol. Biol. Phys.* **69**:1193– 8; 2007.
14. Seppälä, J.; Kulmala, J.; Lindholm, P.; *etal.* A method to improve target dose homogeneity of craniospinal irradiation using dynamic split field IMRT. *Radiother. Oncol.* **96**:209 –15; 2010.
15. Fogliata, A.; Bergström, S.; Cafaro, I.; *etal.* Cranio-spinal irradiation with volumetric modulated arc therapy: A multi-institutional treatment experience. *Radiother. Oncol.* **99**:79 – 85; 2011.
16. Michalski, J.M.; Klein, E.E.; Gerber, R. Method to plan, administer, and verify supine craniospinal irradiation. *J. Appl. Clin. Med. Phys.* **3**:310 – 6; 2002.
17. South, M.; Chiu, J.K.; Teh, B.S.; *etal.* Supine craniospinal irradiation using intrafractional junction shifts and field-in-field dose shaping: Early experience at Methodist Hospital. *Int. J. Radiat. Oncol. Biol. Phys.* **71**:477– 83; 2008.
18. Parker, W.A.; Freeman, C.R. A simple technique for craniospinal radiotherapy in the supine position. *Radiother. Oncol.* **78**:217–22; 2006.
19. Low, D.A.; Harms, W.B.; Mutic, S.; *etal.* A technique for the quantitative evaluation of dose distributions. *Med. Phys.* **25**:656 – 61; 1998.



Esquecemos mais algo?
Sugestões?
Perguntas?





OBRIGADO!