Proton Therapy for Head & Neck Cancers

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Why protons for H&N Cancer?

- Protons are attractive to radiotherapy because of their physical dose distribution

- The RBE of protons are indistinguishable from 250 kV X-rays, which means that they are 10-15% more effective than ^{60}Co (RBE=1.1)

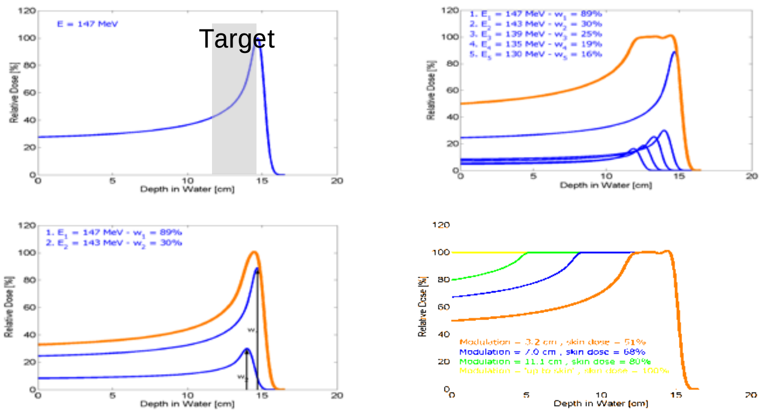
- The OER of proton beams is not distinguishable from X-rays (2.5 – 3)

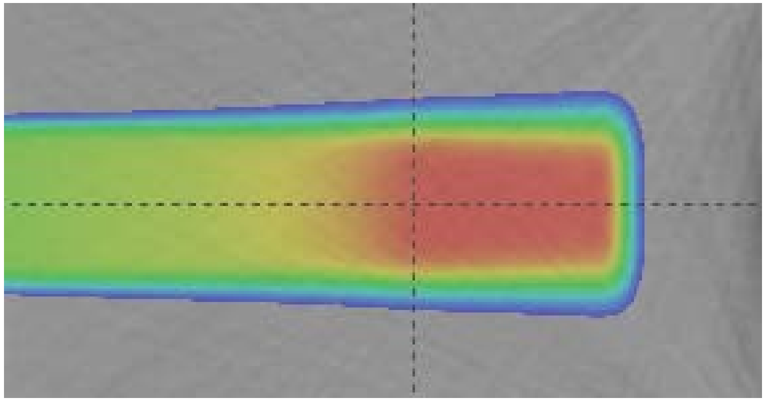
- Protons are sparsely ionizing, except for a region at the end of particles' range

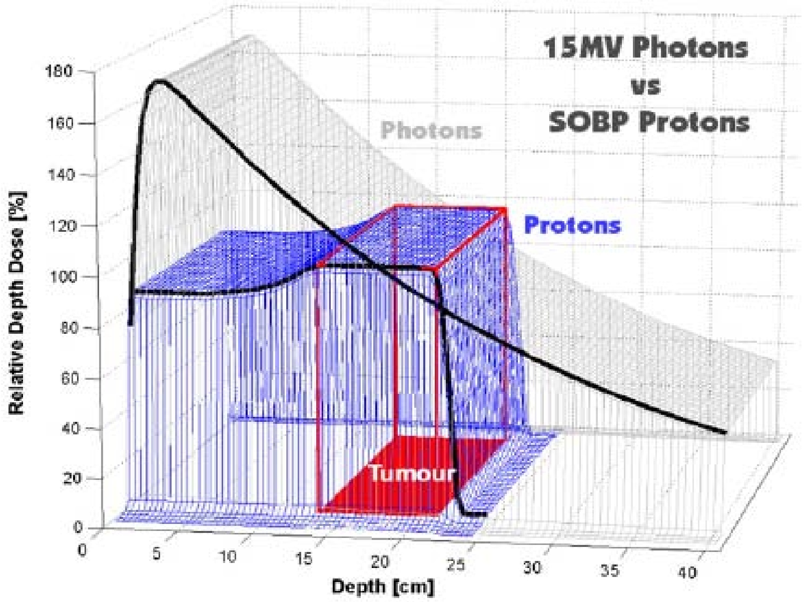
- This high LET component is restricted to a tiny portion of the terminal track (this should be kept in mind when planning treatment close to critical structures)

Why protons for H&N Cancer?

- Biggest advantage is **<u>physical dose distribution</u>**







Why protons for H&N Cancer?

- Preservation of visual function by reduction in dose to optic apparatus

- Potential to further improve quality of life
  - Improved salivary gland function by sparing of parotid and submandibular glands
  - Improved swallowing function

- Potential to escalate dose for hypoxic tumors while maintaining improvement in quality of life

Is there a benefit?

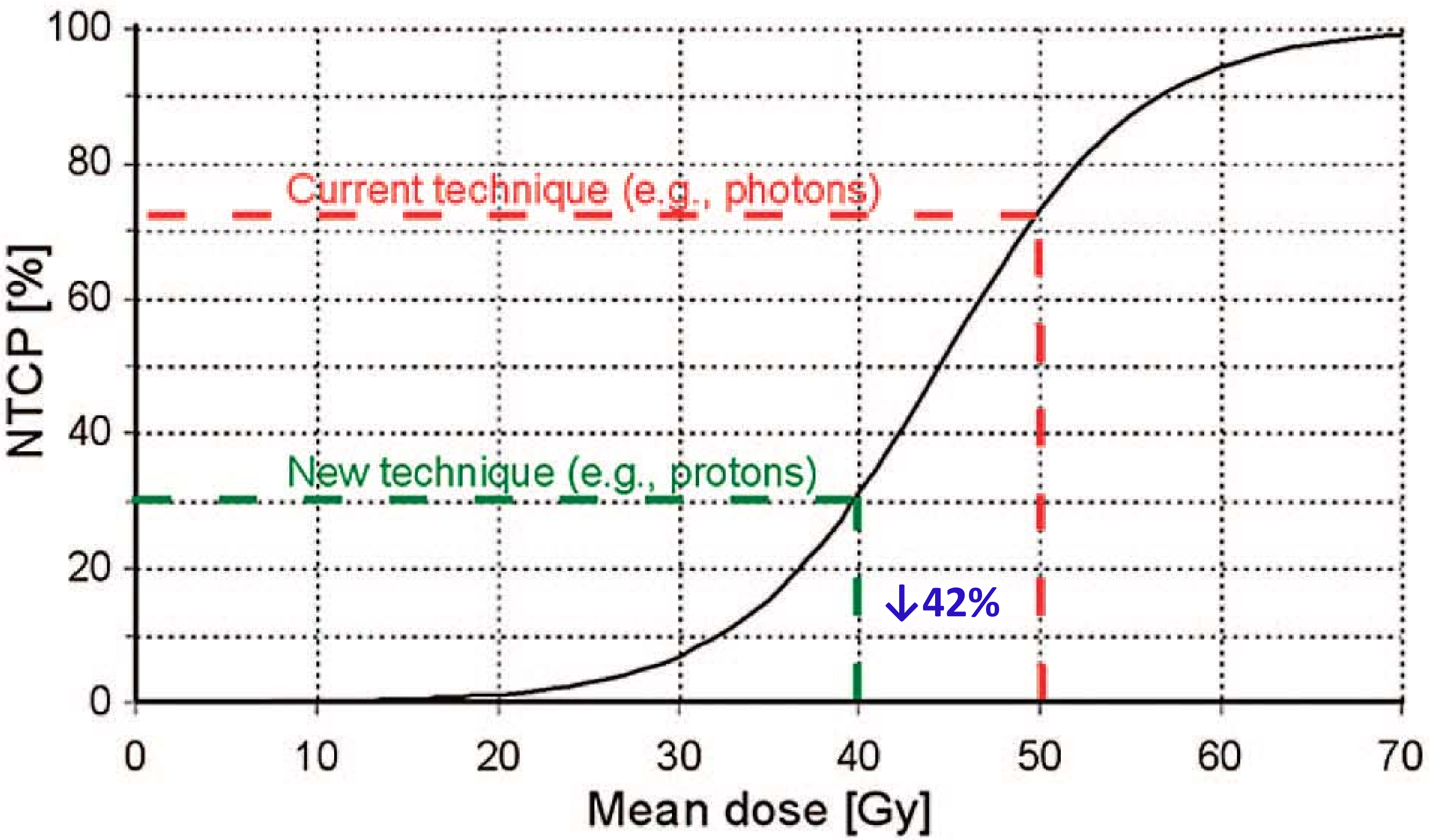
The Potential Benefit of Radiotherapy with Protons in Head and Neck Cancer with Respect to Normal Tissue Sparing: A Systematic Review of Literature

Tara A. van de Water, Hendrik P. Bijl, Cornelis Schilstra, Madelon Pijls-Johannesma, and Johannes A. Langendijk

877 papers were retrieved and 14 relevant and eligible studies were identified and included in this review. Four studies included paranasal sinus cancer cases, three included nasopharyngeal cancer cases, and seven included oropharyngeal, hypopharyngeal, and/or laryngeal cancer cases. Seven studies compared the most sophisticated photon and proton techniques: intensity-modulated photon therapy versus intensity-modulated proton therapy (IMPT). Four studies compared different proton techniques. **All studies showed that protons had a lower normal tissue dose, while keeping similar or better target coverage**. Two studies found that these lower doses theoretically translated into a significantly lower incidence of salivary dysfunction.

Oncologist, March 2011, 16(3):366

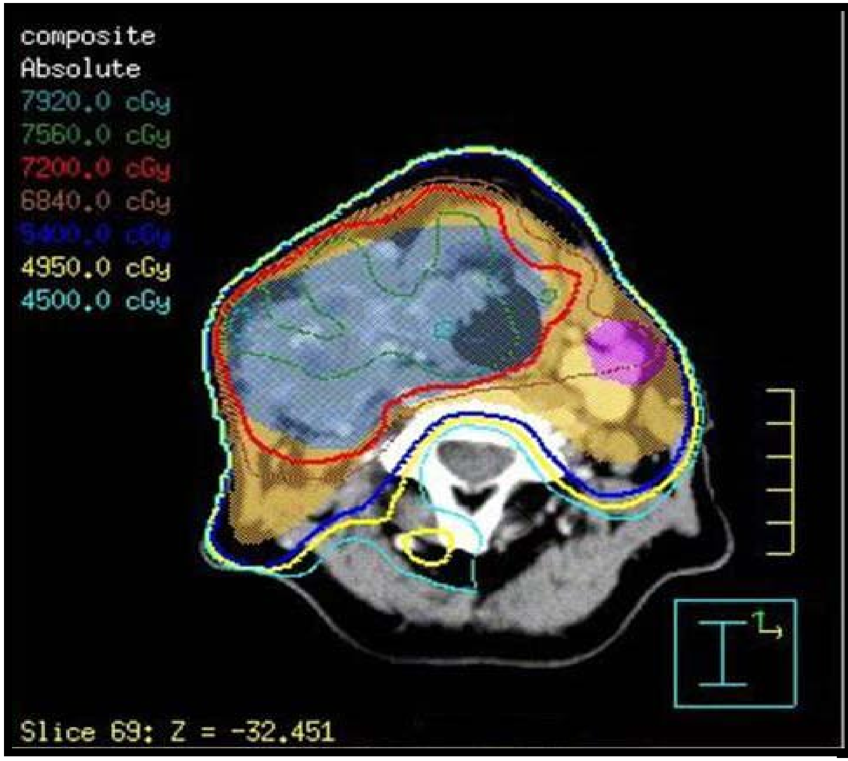
Is there a benefit?

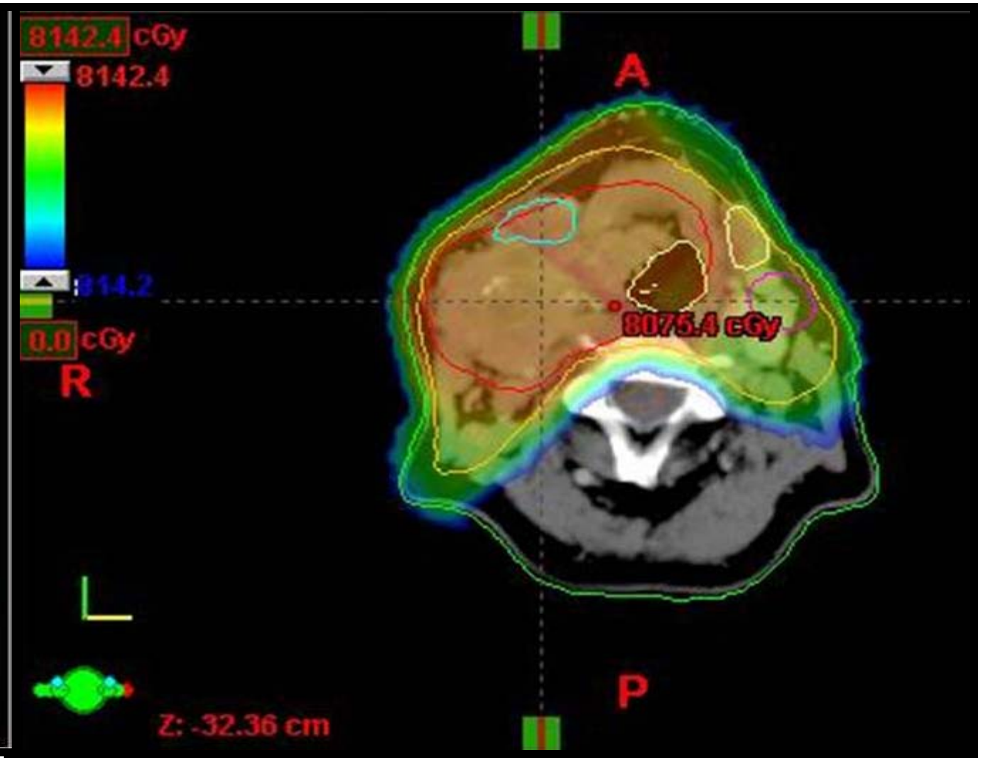


Oncologist, March 2011, 16(3):366

Is there a benefit?

Oropharyngeal Carcinoma 72 Gy





IMRT

PROTONS

Is there a benefit?

	IMRT	Proton Therapy	% PRV Dose ↓
PTV coverage: ≥95% of PTV receives Rx dose	101.6%	99.7%	
PTV coverage: 99% of PTV receives ≥ 93% of Rx dose	100.3%	96.7%	
Hot spot in PTV72 (≤ 20% of PTV 72 receives 110% of prescribed dose)	107.3%	106%	
Contralateral Parotid (mean dose <2600 cGy	2529	1482	43%
Brainstem (5500 cGy to 0.1 c.c.)	5020	2685	46%
Spinal cord (5000 cGy to 0.1 c.c.)	4400	546	87%

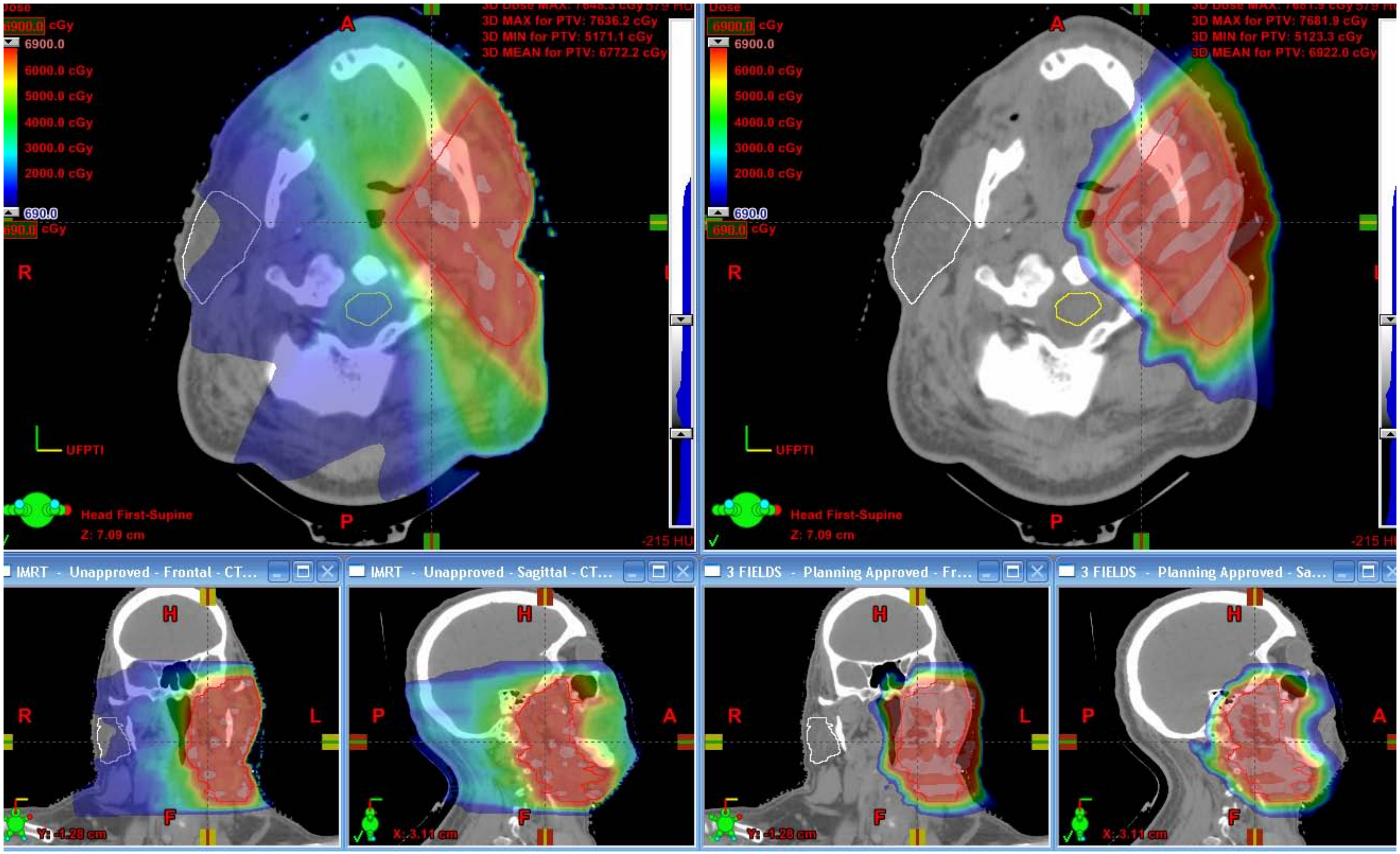
Is there a benefit?

	IMRT		Proton Therapy	
	Composite 72 Gy	CCB only 1.5x12=18 Gy	Composite 72 CGE	CCB only 1.5x12=18 CGE
Contralateral parotid (mean dose ≤ 2600 cGy	2529	460	1482	0
Brainstem (5500 cGy to 0.1 c.c.)	5020	890	2685	0
Spinal cord (5000 cGy to 0.1 c.c.)	4400	1106	546	0
Contralateral submandibular gland	6928	1533	6148	820

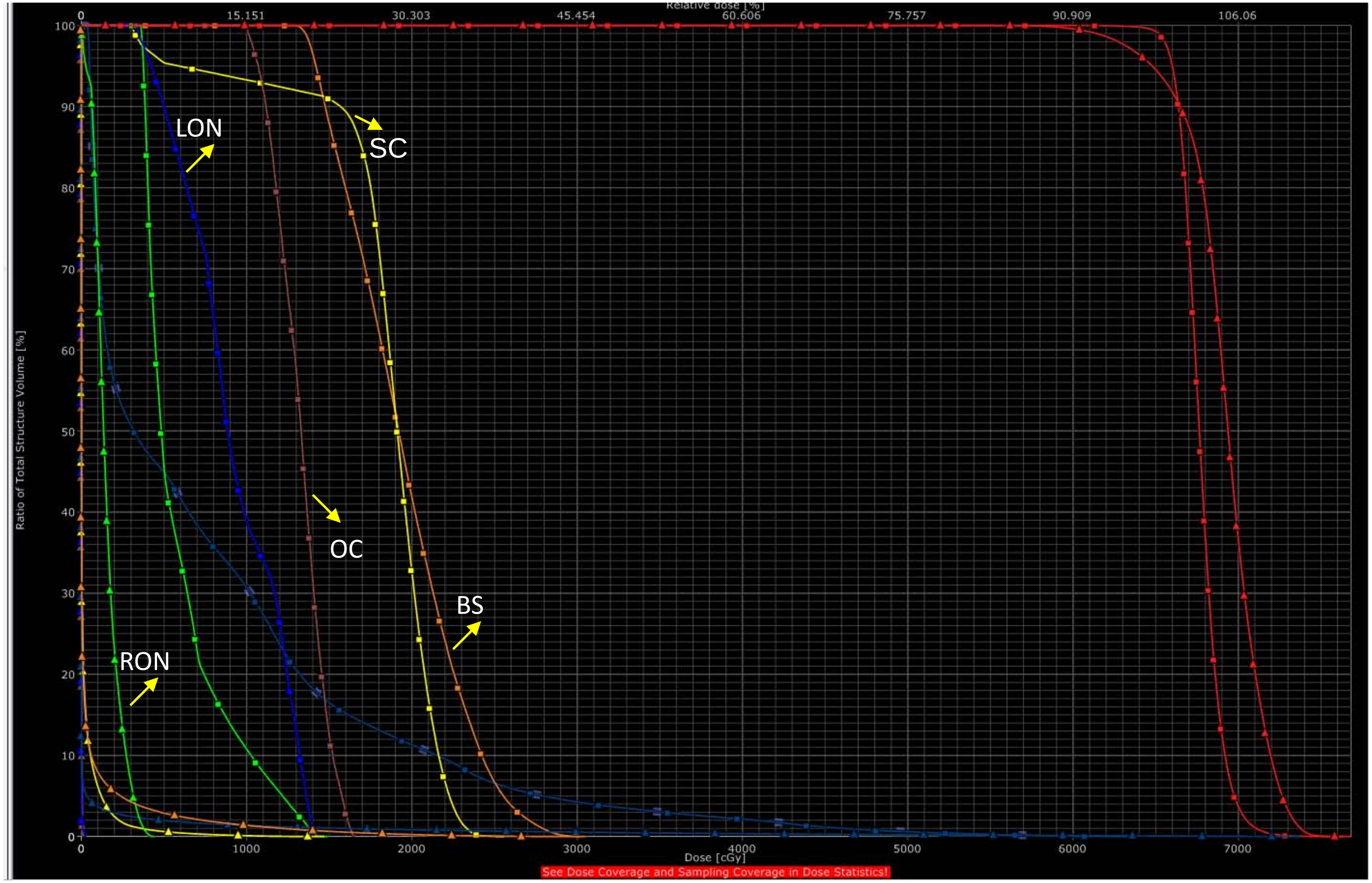
Is there a benefit?

IMRT

Protons



Is there a benefit?



Patient selection criteria for H&N proton therapy

- Lymph node involvement
- Tumor extent that may require overly complex beam arrangements
- Tumor location relative to high-Z dental implants

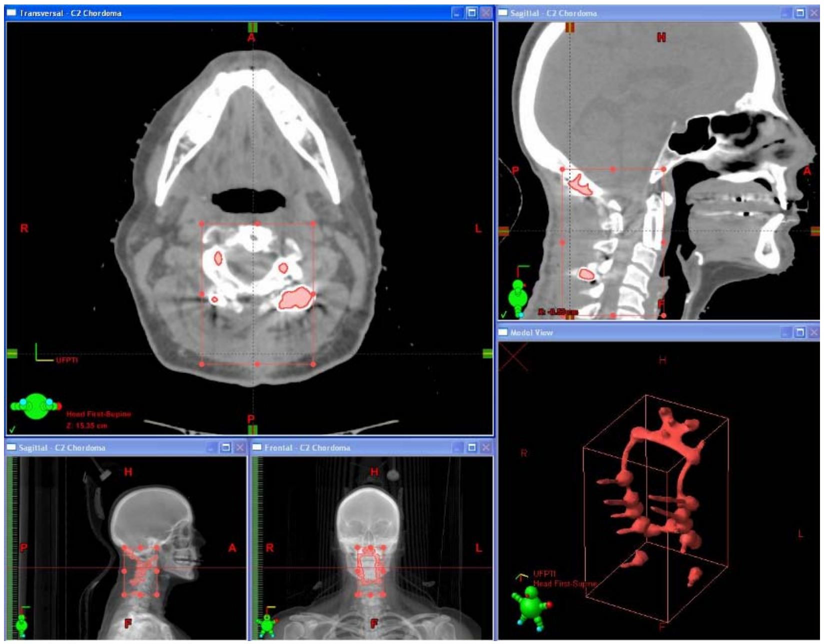
CT simulation for H&N cancer

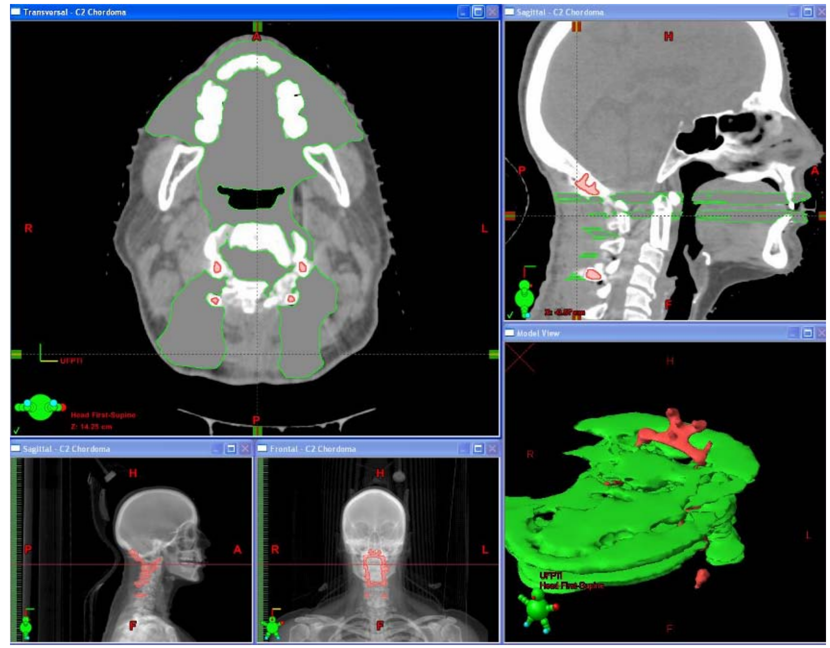
- 1 mm slice thickness **non-contrast scan for dose calculation**
- CT with contrast injection used for segmentation but not for dose calculation

Metal Artifacts

- ☐ H&N patients often have tooth fillings and metal implants
- ☐ Tooth fillings can completely stop the proton beam
- ☐ Titanium objects can perturb proton beams. Their presence in the beam path should be minimized by selection of beam angles
- ☐ Streaking and high intensity artifacts should be contoured and appropriate HU values assigned to them

Metal Artifacts

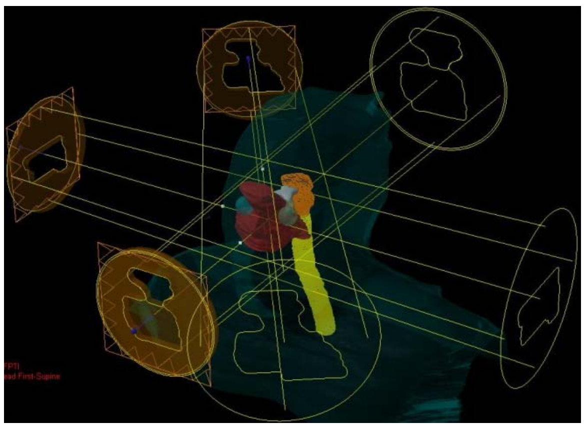


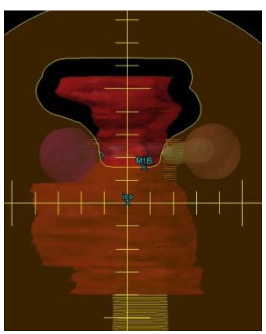


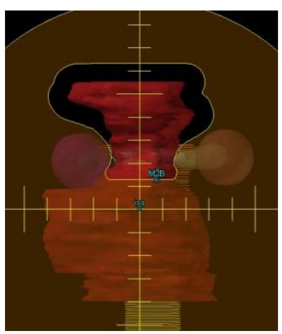
- Appropriate auto-contouring technique selected to match the physical dimension of titanium rod
- All of artifacts outside titanium rod overridden with tissue HU
- Beam paths chosen to avoid dental implant alloy

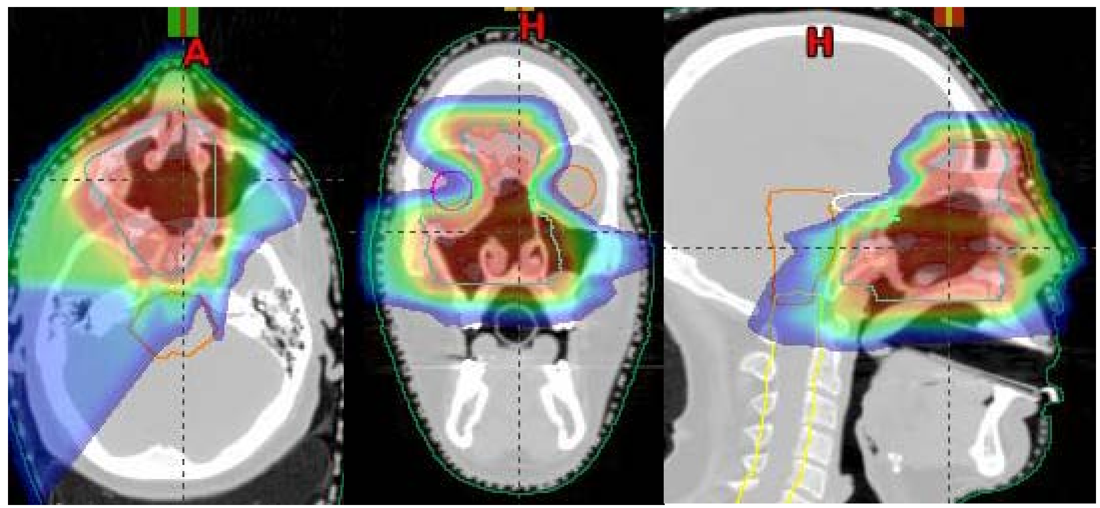
Proton beam arrangements in H&N

- 3D conformal beam arrangements suitable for scattered beams
- Avoid stopping beam on critical organs
- Match-line change if necessary









Proton-specific treatment planning concepts

- Distal Margin calculated from estimated uncertainty in CT HU-stopping power conversion table
  - Range uncertainty (~2.5% of total range)
- Relative Biological Effect (RBE): accounting for higher RBE near distal range
- Proximal Margin
- Compensator smearing: 5 mm for H&N
- Compensator border smoothing: 10 mm for H&N
- Through-patch fields

Proton-specific treatment planning concepts

- **High skin dose**: Selection of beam angles to minimize field overlap on skin
- **Higher dose inhomogeneity** at air-bone or tissue/implanted metal interfaces
- **Range and penumbra uncertainties due to presence of metal objects**: avoid beams passing through and stopping on cord
- **Increased RBE** at the end of range: AVOID/Minimize number of beams exiting on critical organs

Proton-specific treatment planning concepts

- Aperture margins account for beam penumbra at target depth

- Overly tight aperture margins increase dose distribution inhomogeneity and reduce dose distribution calculation accuracy

- Due to limited variation of range in H&N treatments, an aperture margin of 0.6 cm is generally used

Normal tissue constraints

PROTON THERAPY

Status Date: 5/3/2012 7:41:14 PM
Approved By: Hunter, Maria M., Physicist
Status: Partially Approved

H&N Treatment Dosimetry Check List

Patient ID: ____ Patient Name: ____ Dosimetrist: ____ MD: ____
Age: ____ Disease Site: ____ Tx Room: ____
Scan Date: ____ Start Date: ____ Final Plan Name: ____

Image Fusion Checked:

CT without contrast ☐ CT with contrast ☐ MR: ☐

Contours Checked:

Normal Organs:

Dosimetrist: Mandible ☐ Spinal Cord ☐ Cord+5 ☐ Retinas ☐
BS+3 ☐ Brain ☐ LT/RT O.N. ☐

Physician: LT/RT SMG ☐ Brainstem ☐ LT/RT Lacrimal Gland ☐
LT Parotid ☐ RT Parotid ☐ Chiasm ☐ Other: ____

Targets: GTV ☐ CTVs ☐ PTVs ☐

DVH: (ALL DOSES IN CGE) Green: w/ tolerance Red: out of tolerance Blue: not defined

PTV D95%= ____ % (100%) or PTV D ____ %=100% PTV D99%= ____ % (≥ 93%)
PTV Hotspot: V110%= ____ % (≤ 20%) PTV D2%= ____ %

Brainstem 0.1cc= ____ (≤ 55 CGE) Cord 0.1cc= ____ (≤ 50 CGE)
Brainstem Surface≤64 ____ Middle≤55 ____ Post<50 ____ Cord+5mm 0.1cc= ____ CGE
BS+3mm 0.1cc= ____ CGE

Chiasm 0.1cc= ____ (< 55 CGE) f OC+3mm (exp) 0.1cc= ____ CGE
(functional Chiasm: will effect vision)
OC+3mm 0.1cc= ____
RT O.N. 0.1cc= ____ (< 55 CGE) LT O.N. 0.1cc= ____ (< 55 CGE)
RON+3mm 0.1cc= ____ CGE LON+3mm 0.1cc= ____ CGE
RT Retina (posterior globe) D0.1cc= ____ (≤ 50 CGE) LT Retina (posterior globe) D0.1cc= ____ (≤ 50 CGE)
Contralateral Parotid mean dose= ____ (≤ 26 CGE)

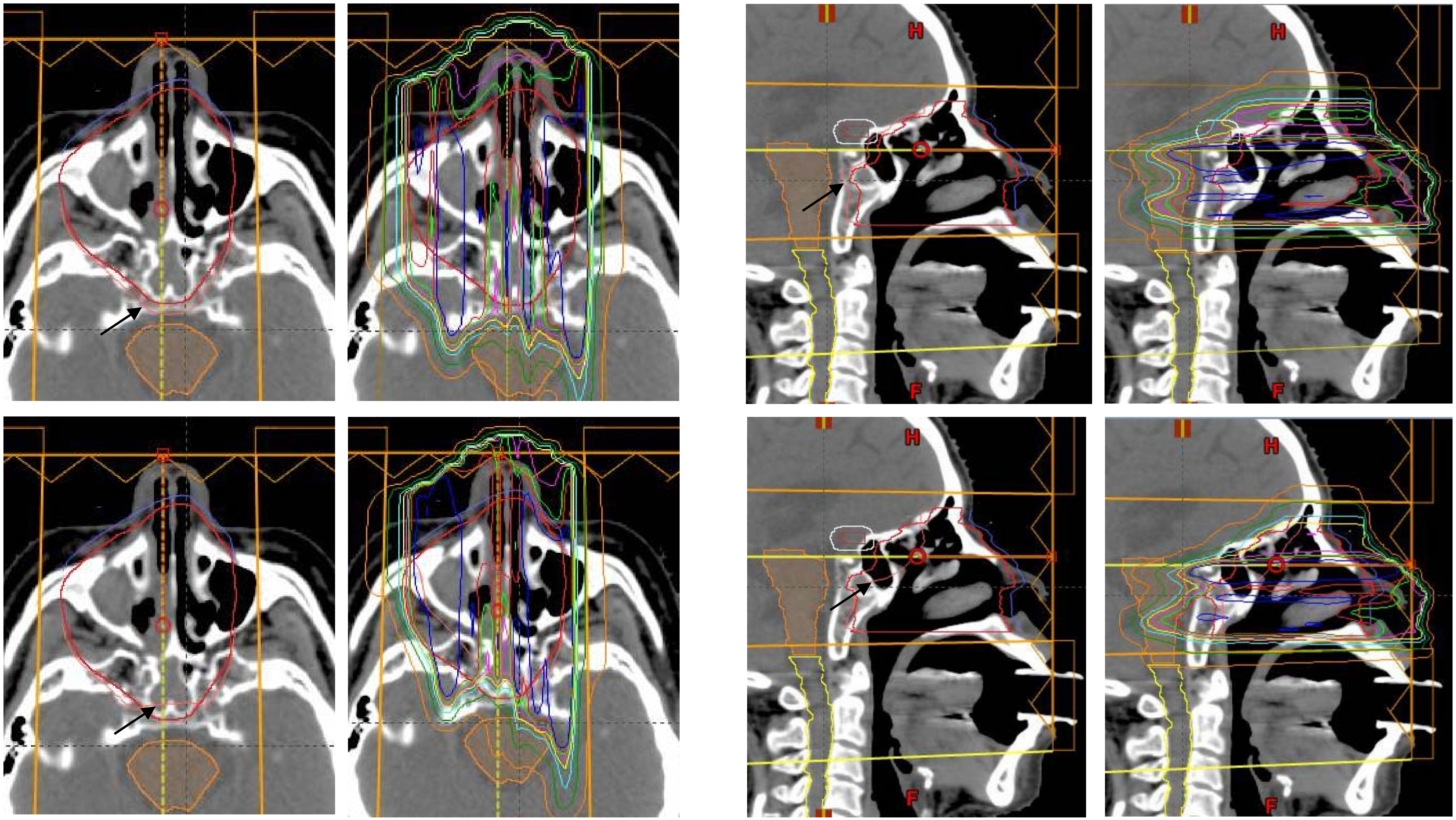
Chart:

Dose: Initial: ____ CGE **Boost:** ____ CGE **Total Dose:** ____ CGE

☐ QD ____ CGE/Day ☐ BID ____ CGE/Fx **# Fields/Fx:** ____

Note: (Physician's Note or Distal Blocking Settings)

Proton-specific treatment planning concepts – SOBP and distal blocking



Proton-specific treatment planning concepts – SOBP and distal blocking

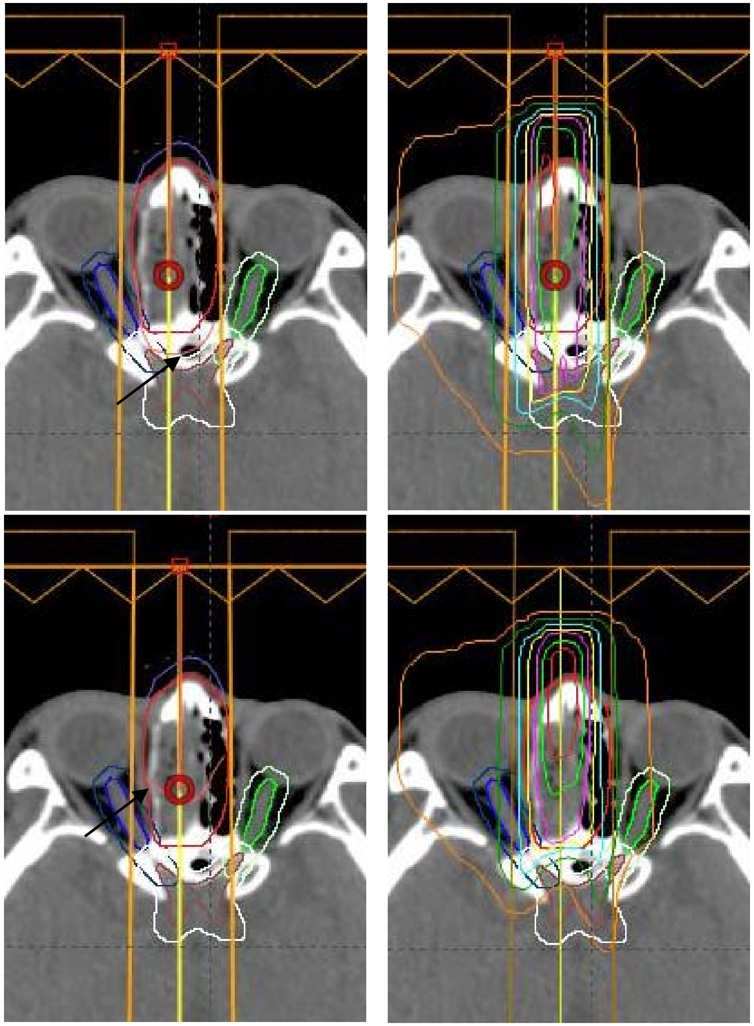
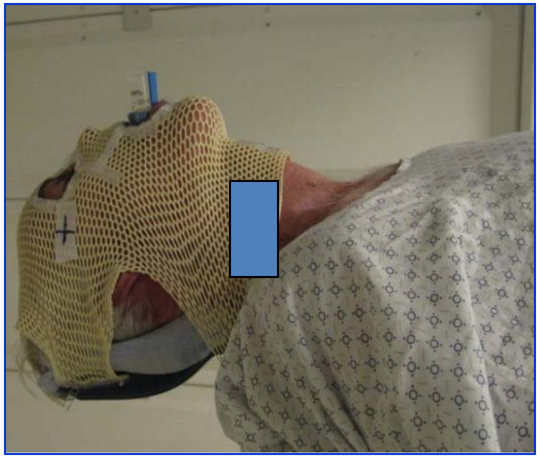
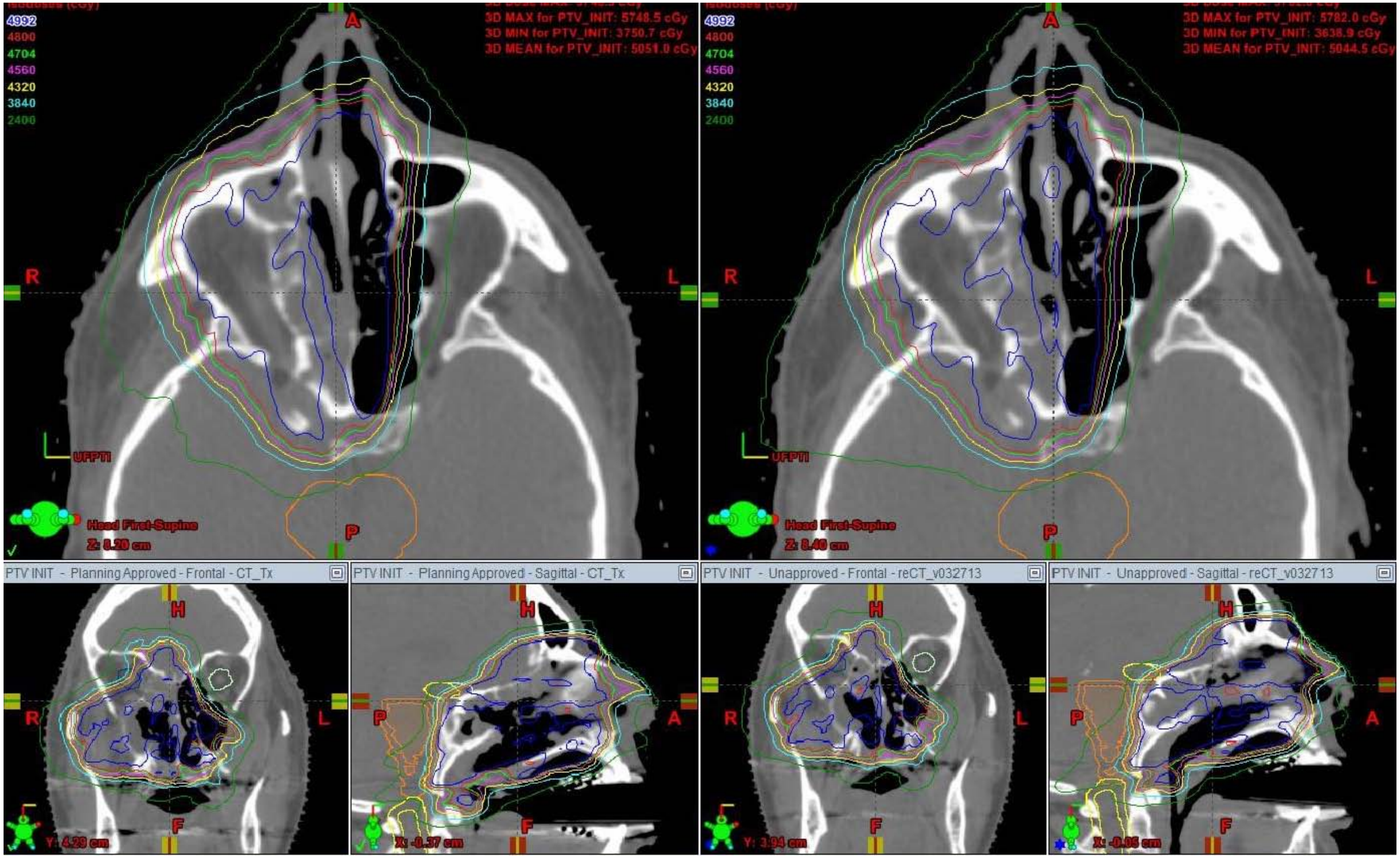


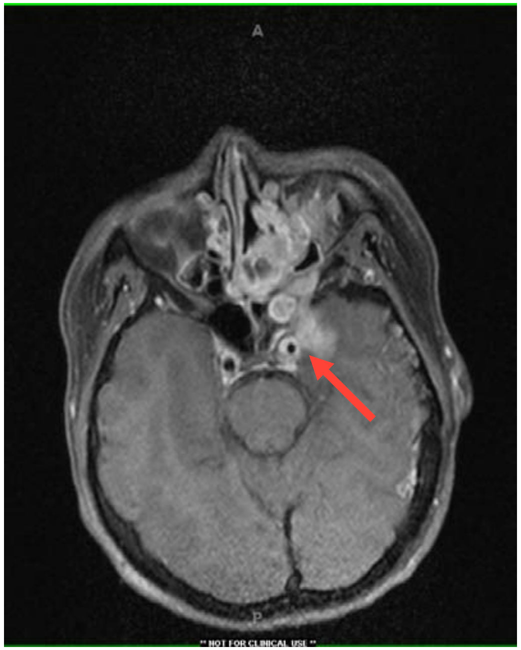
Image-guided treatment delivery

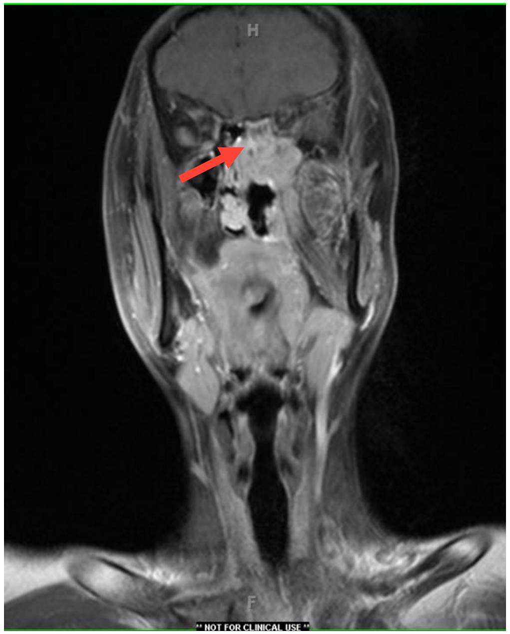


Verification scans during treatment



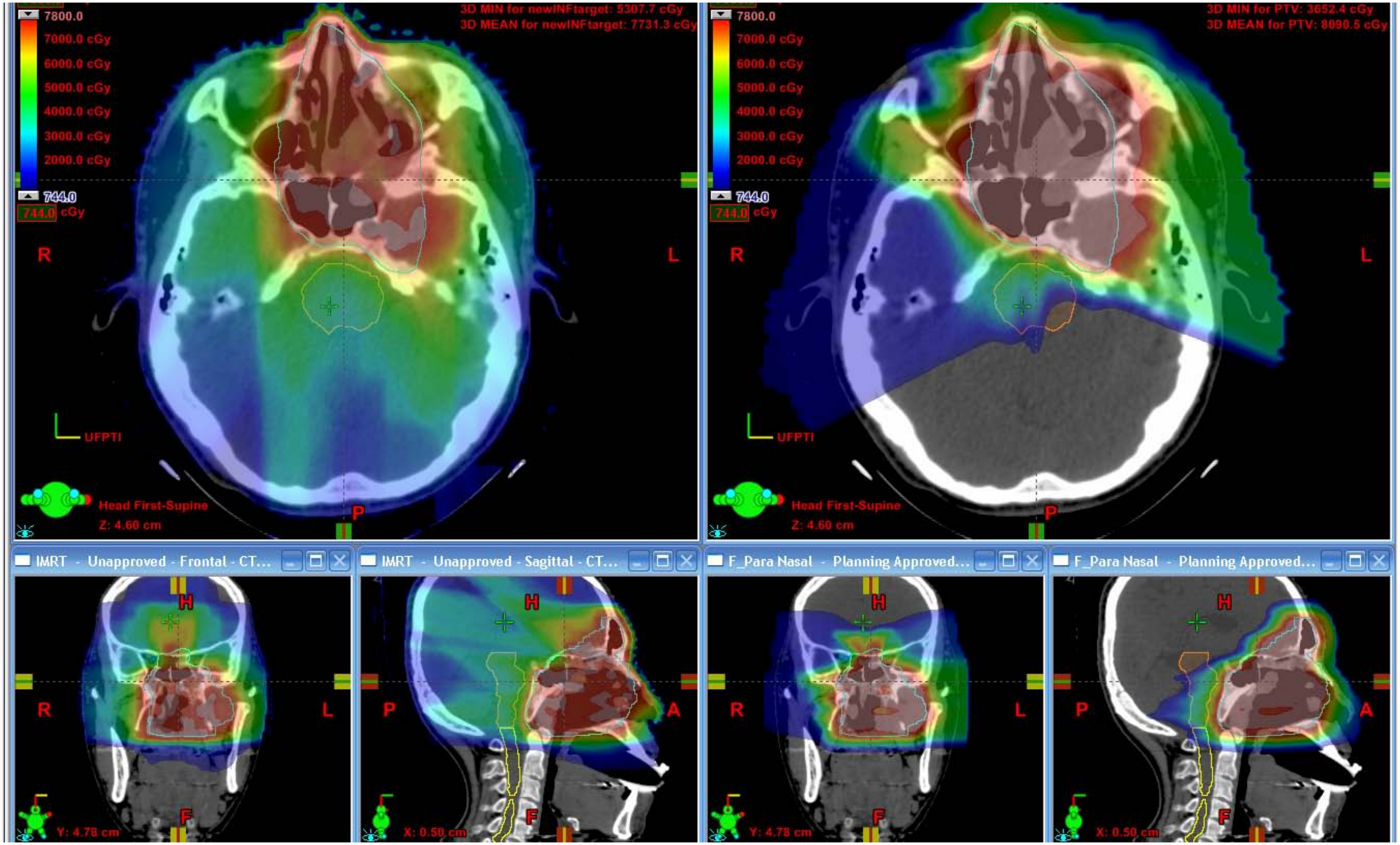
Clinical examples – Ca ethmoid



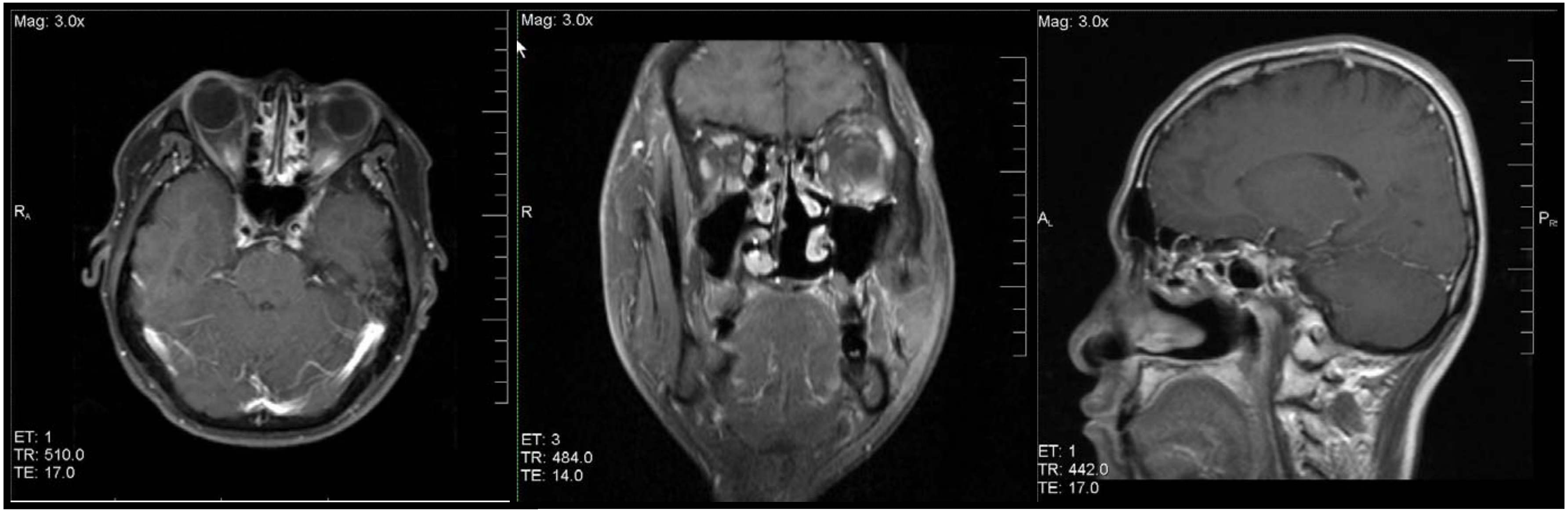


30 year male with adenoid cystic carcinoma Lt ethmoid and extension to base of skull

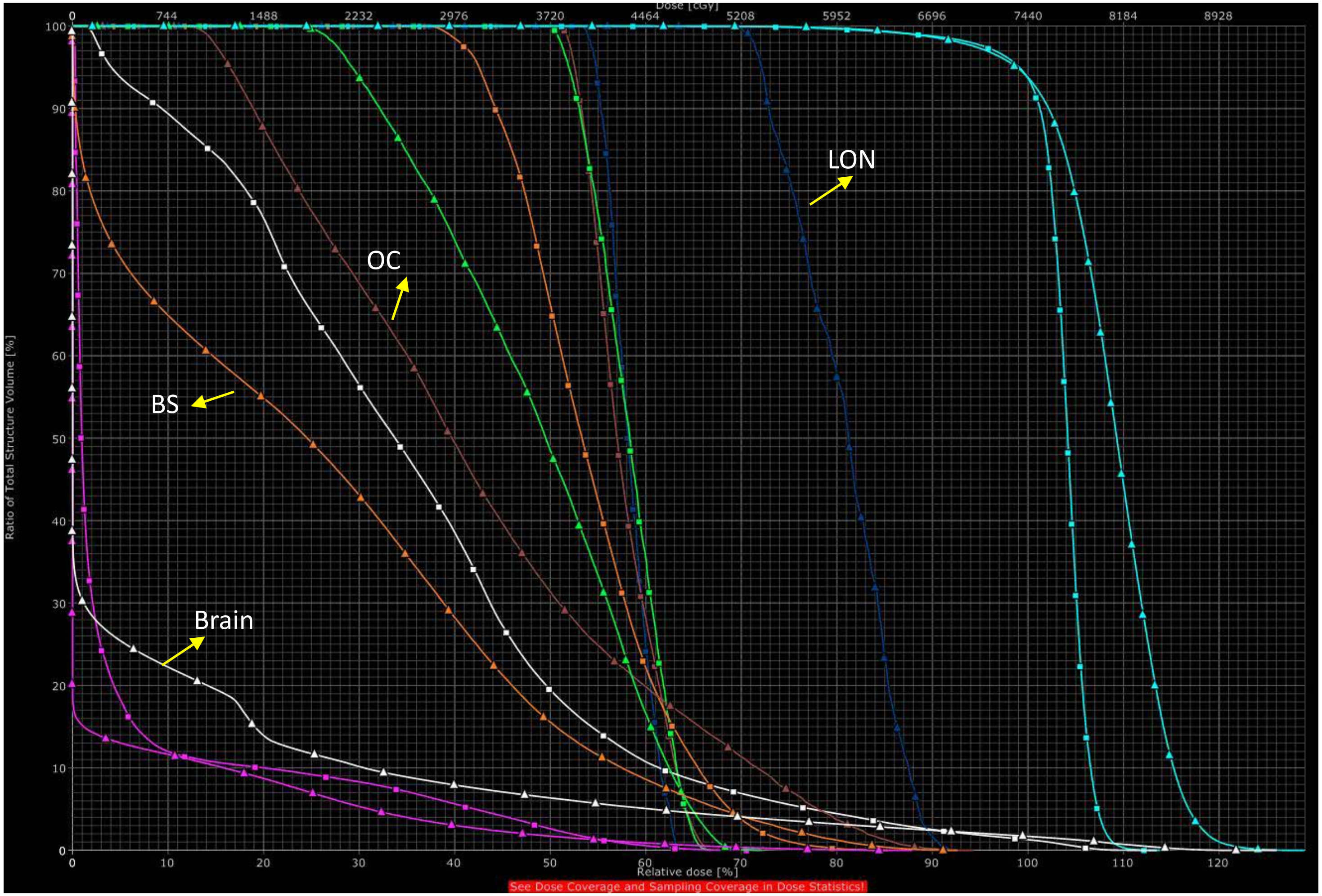
Ca ethmoid – IMRT vs. Protons



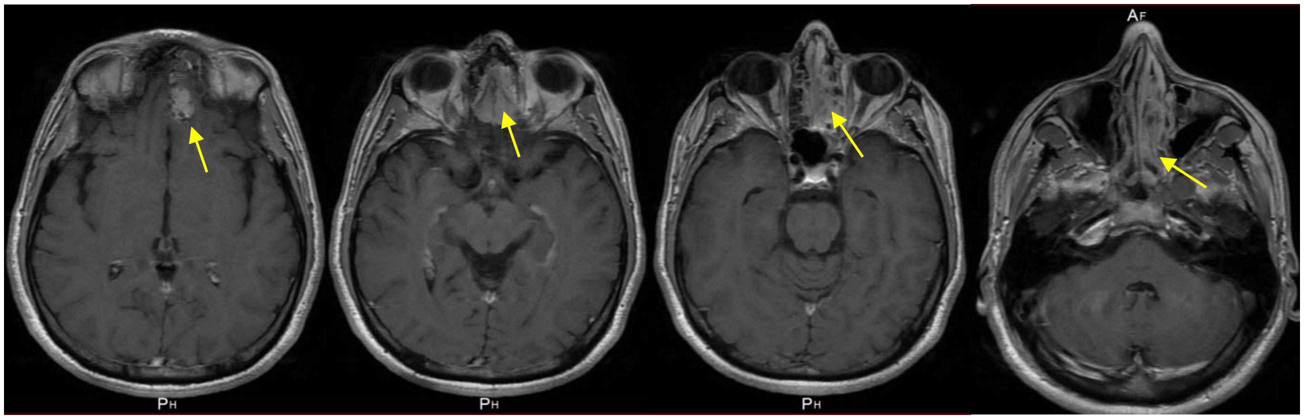
Ca ethmoid – Post treatment

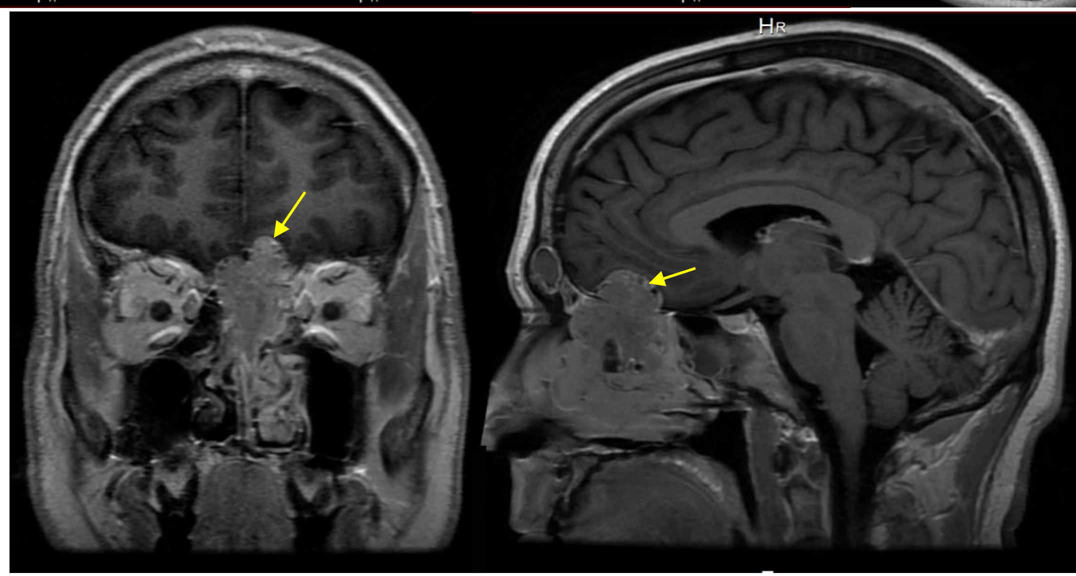


Ca ethmoid – IMRT vs. Protons

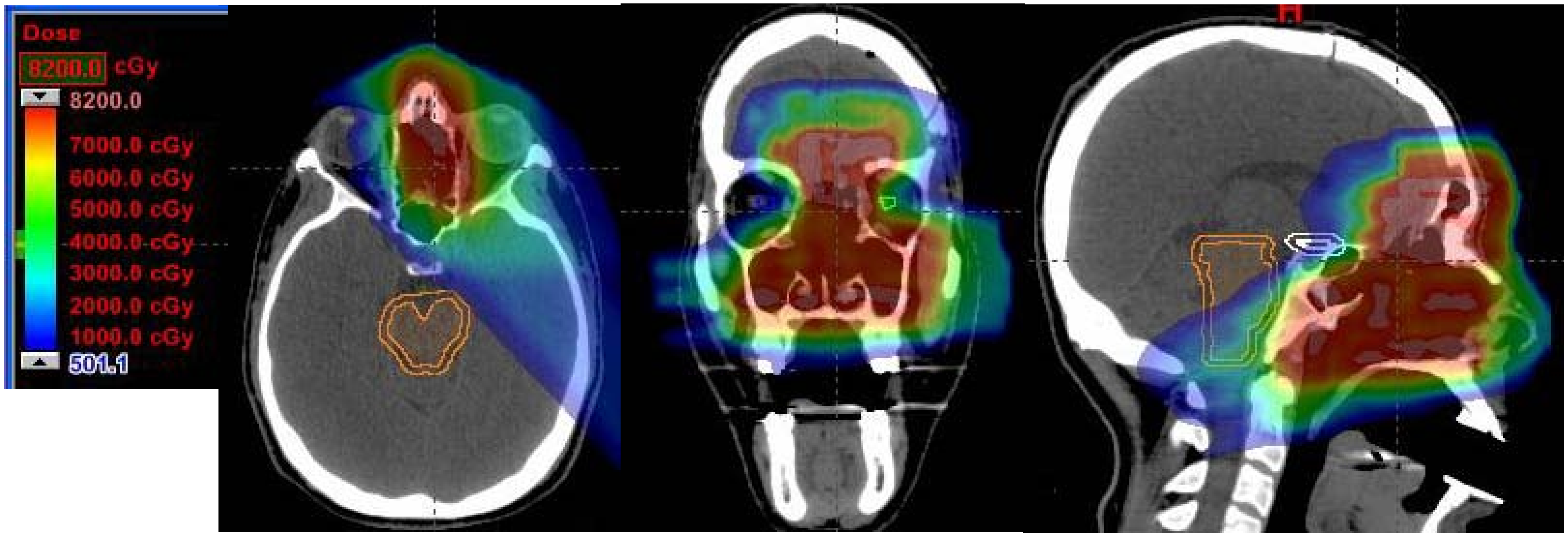


Esthesioneuroblastoma



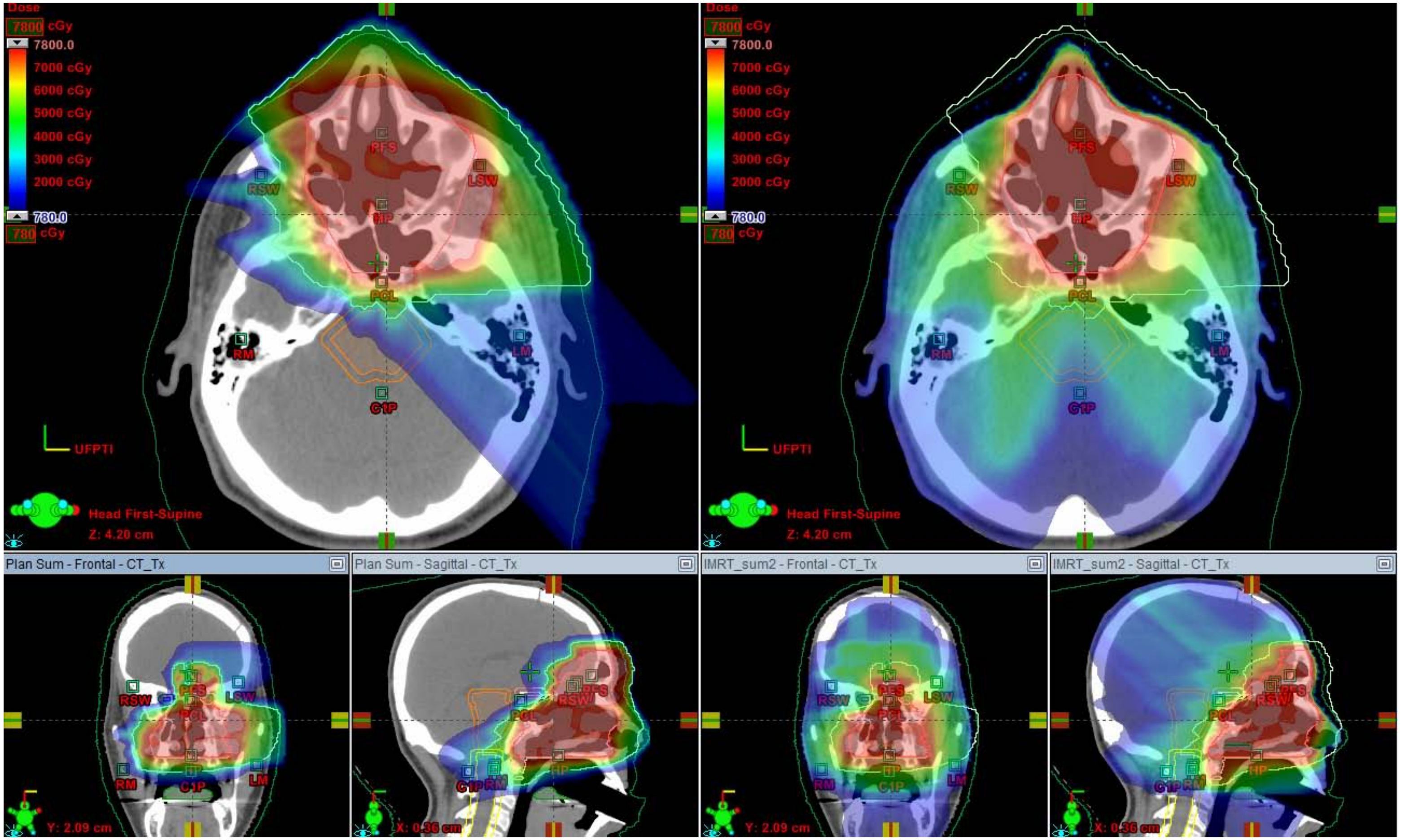


Esthesioneuroblastoma

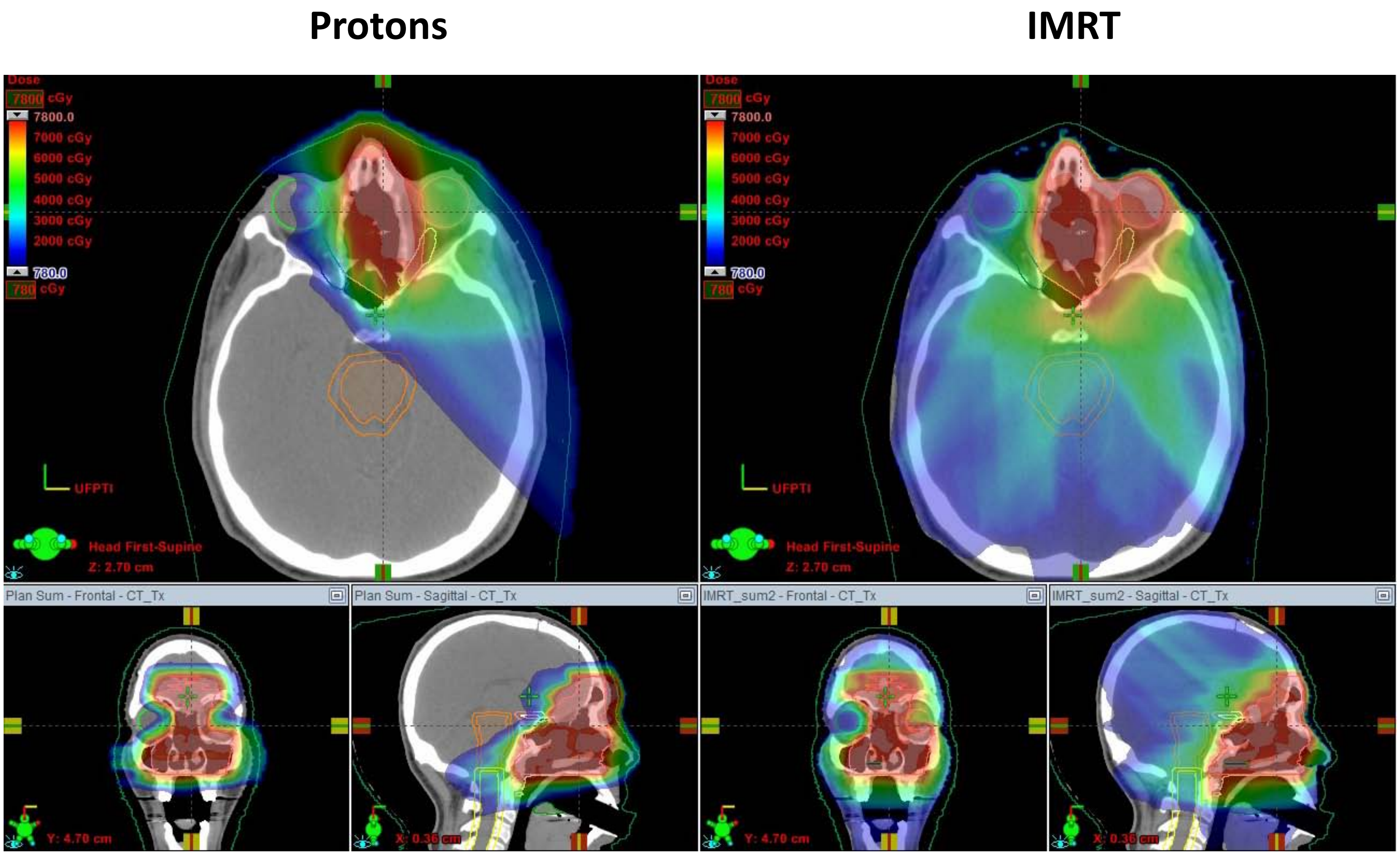


74.4 CGE @ 1.2 CGE BID

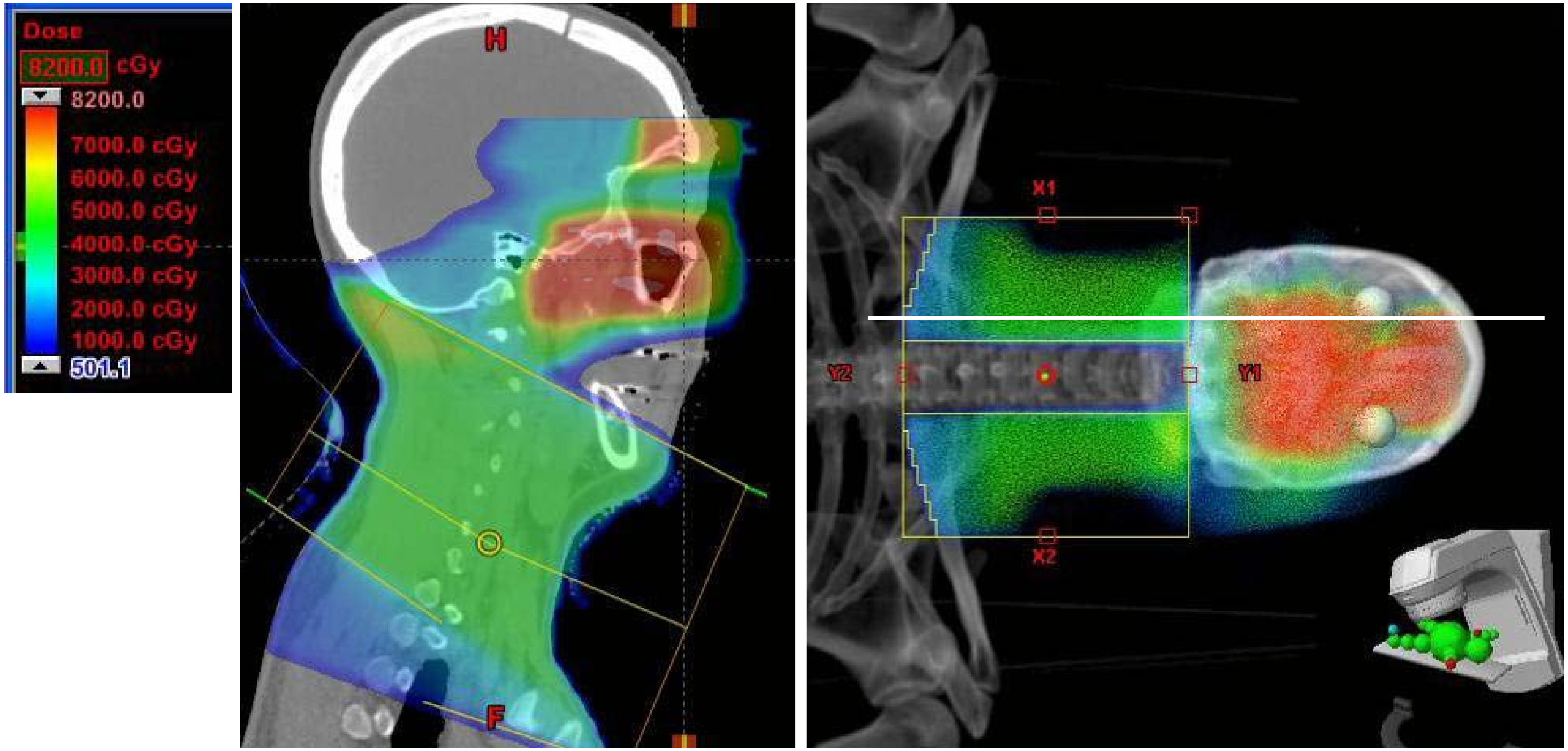
Esthesioneuroblastoma: Sinus slice view



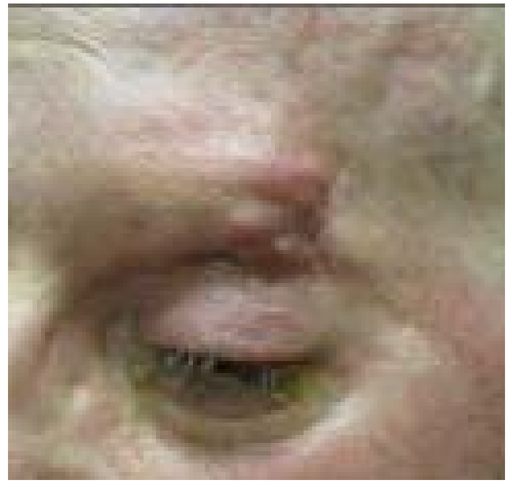
Esthesioneuroblastoma: Orbital slice view



Proton-Photon Match Fields



Skin with perineural invasion



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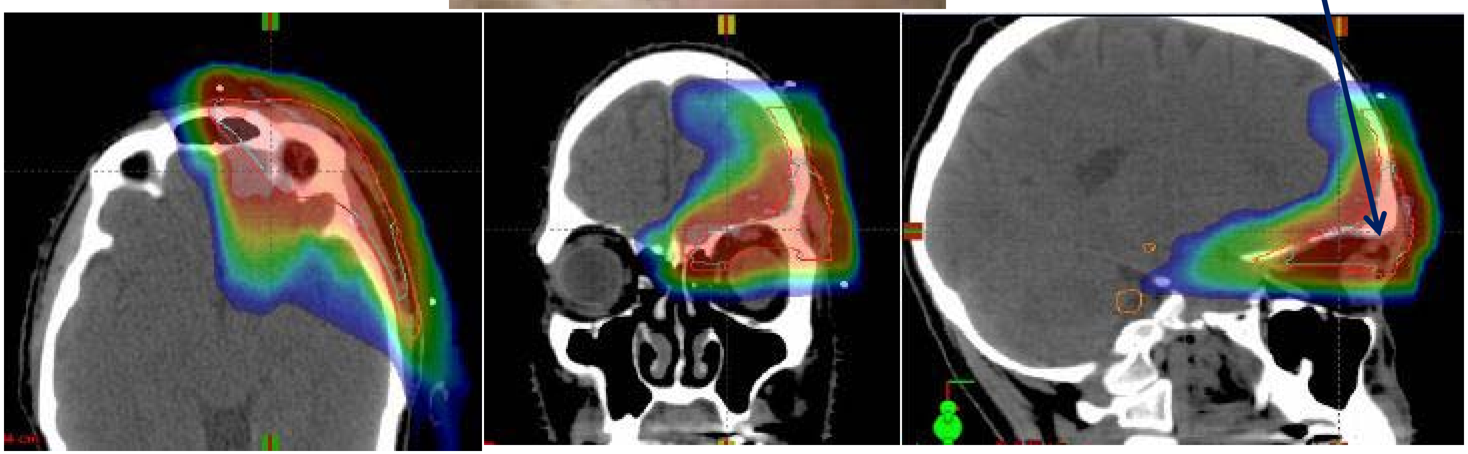
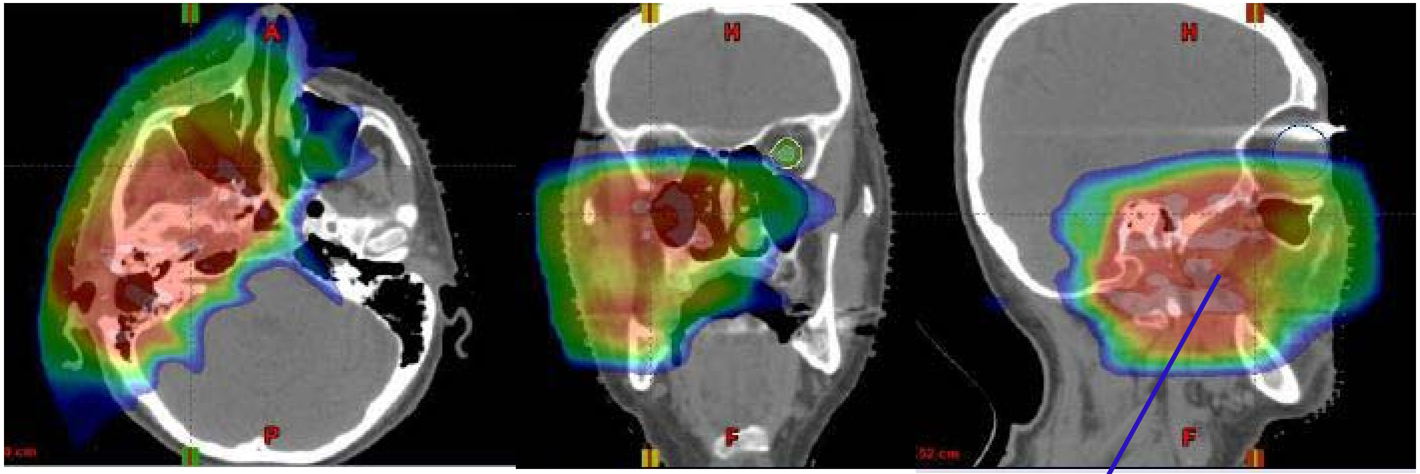
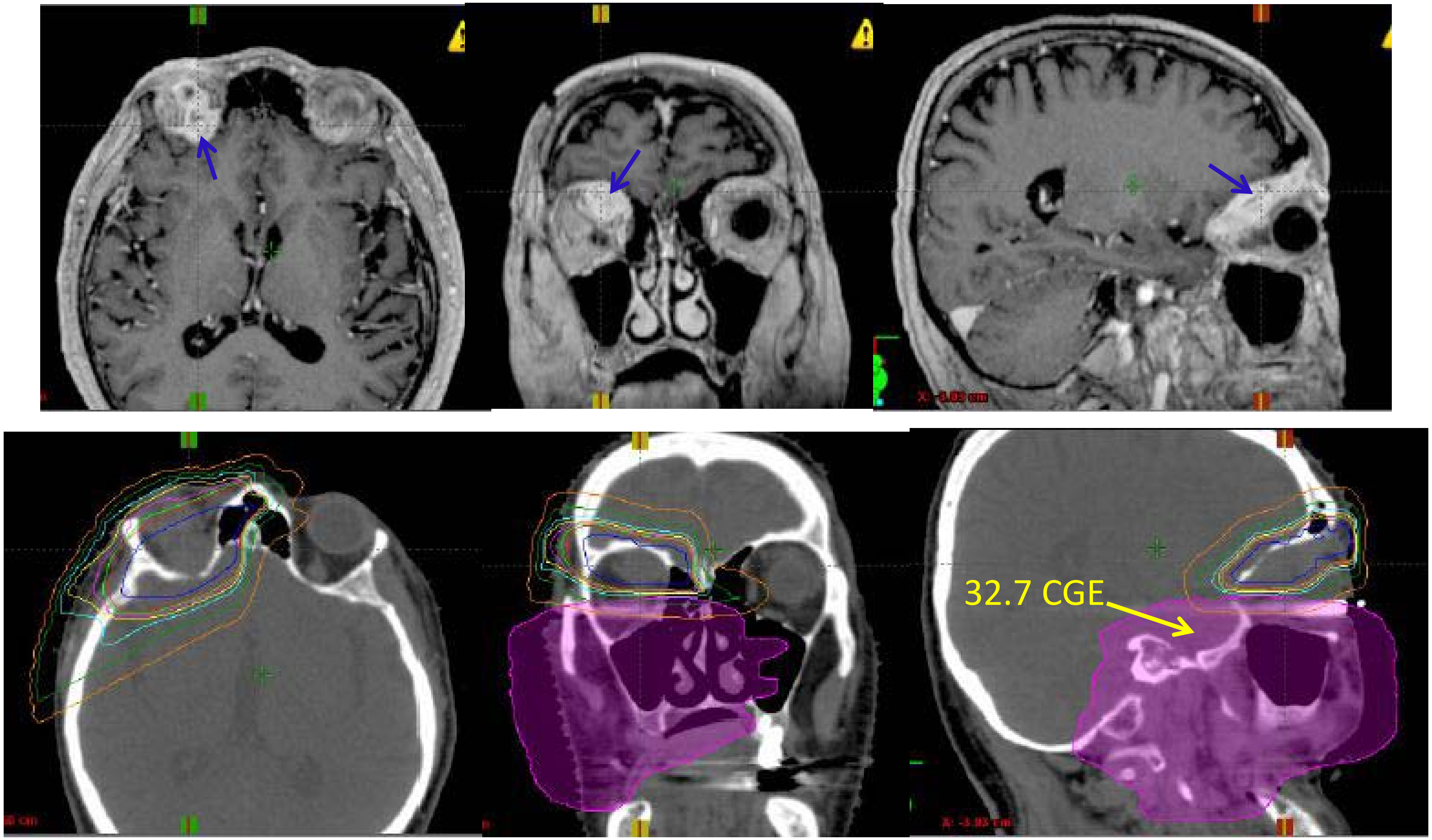


Re-irradiation: Skin with perineural invasion



74.4 CGE @ 1.2 CGE BID

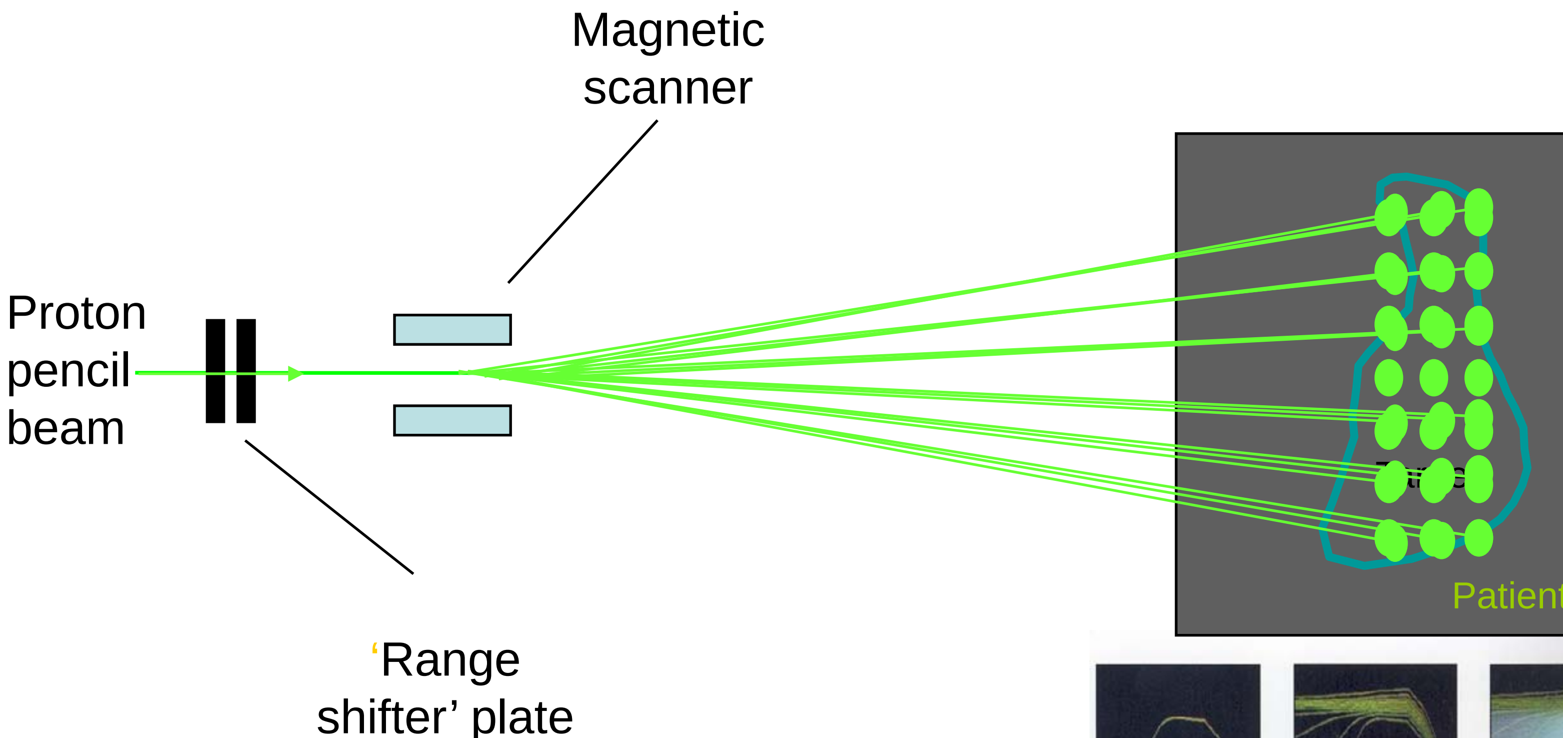
Re-irradiation: Skin with perineural invasion



PAUL SCHERRER INSTITUT
PSI
Dr. Ralf Schneider

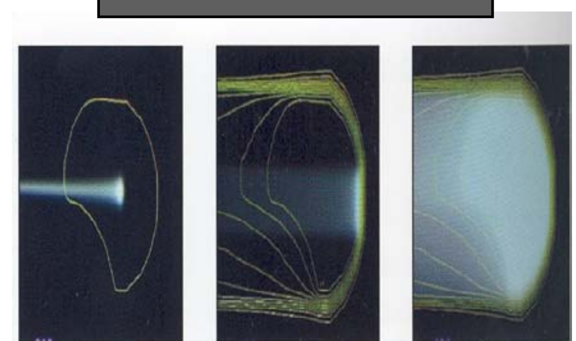
Spot Scanning Proton treatment delivery

Spot Scanning Technique: Developed at PSI and in Clinical Practice since 1996



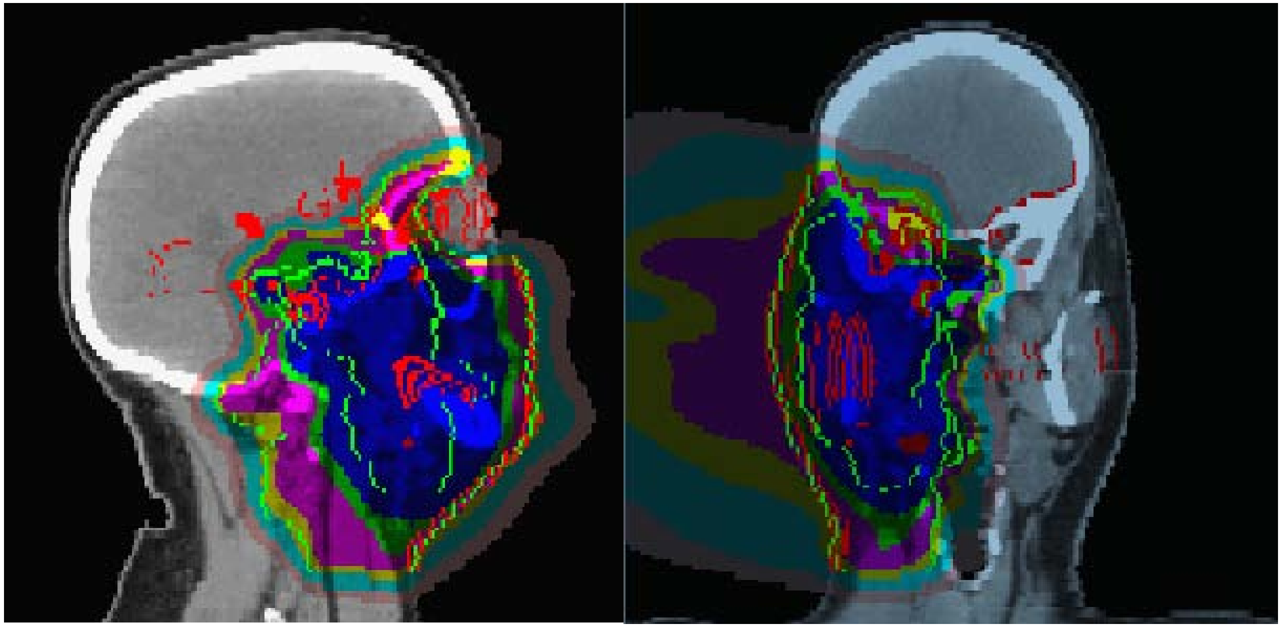
Spot scanning speed on Gantry 1:

3 000 Spots / min



The principle of the Spot-Scanning technique developed at PSI. This new technique allows us to adapt the dose distribution in three dimensions and very precisely to the tumour volume.

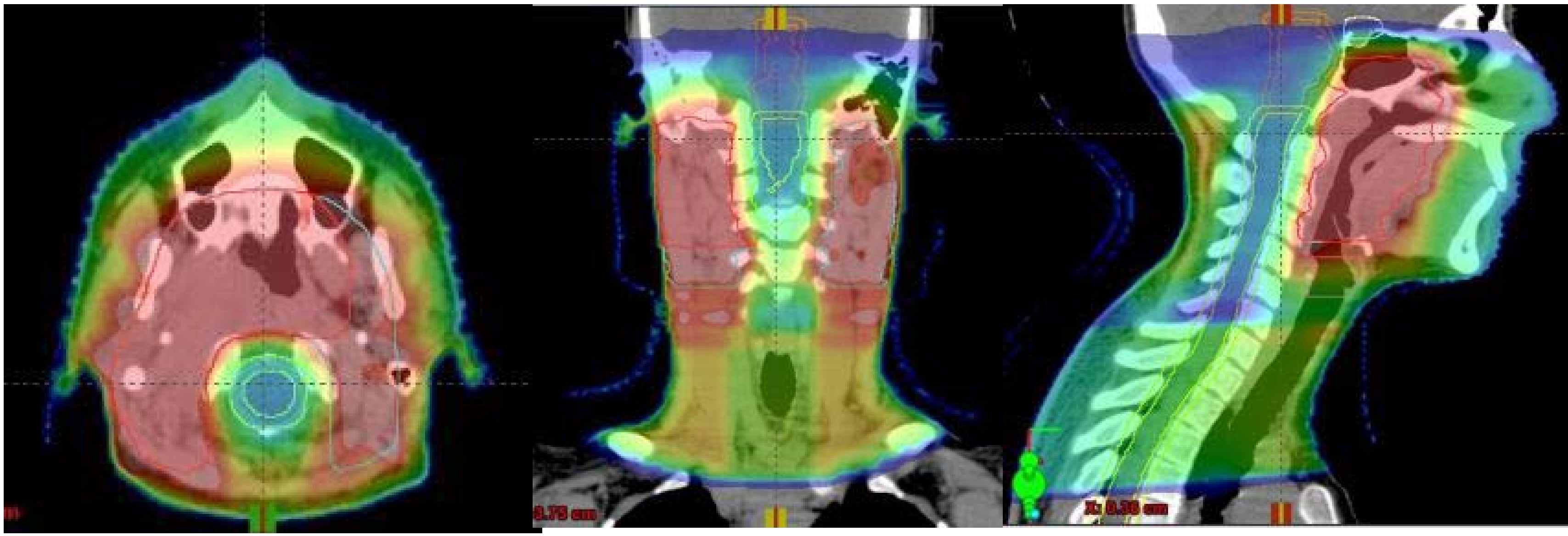
Spot Scanning Proton treatment delivery



Adenoid Cystic Carcinoma Submandibular Gland:
59.4 CGE; 68.4 CGE; 75.6 CGE @ 1.8 CGE/fx

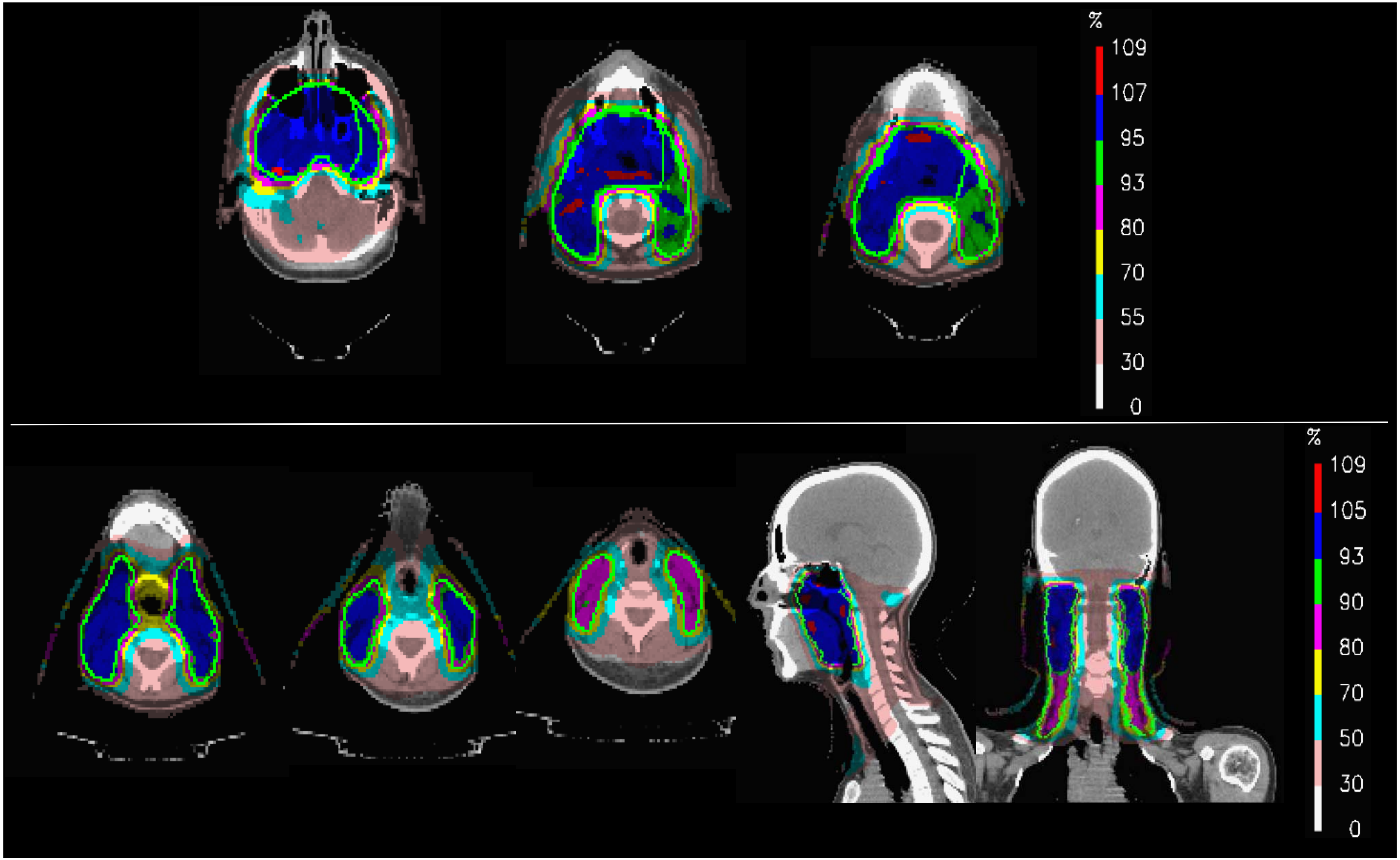
Dr. Ralf Schneider

Ca nasopharynx: IMRT + Protons



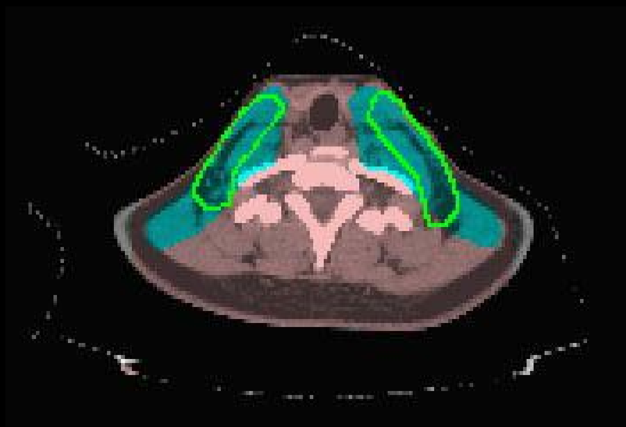
IMRT: PTV 60 Gy; PTV 69.6 Gy
Proton Boost: 4.8 Gy
Total PTV Dose = 74.4 Gy @ 1.2 Gy BID

IMPT Full Treatment 74.4 Gy(RBE)

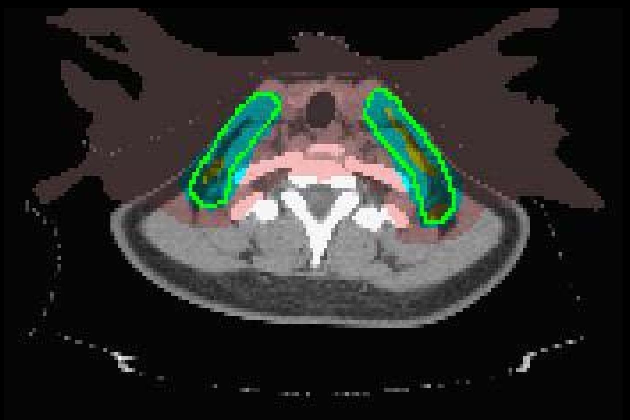


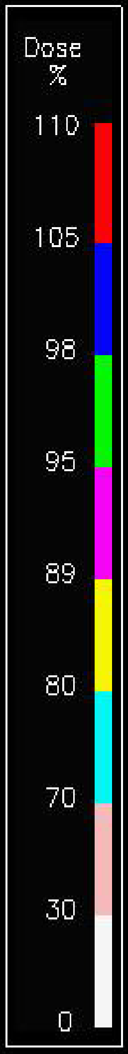
Full Treatment 74.4 Gy(RBE)

UF PTI



PSI CPT





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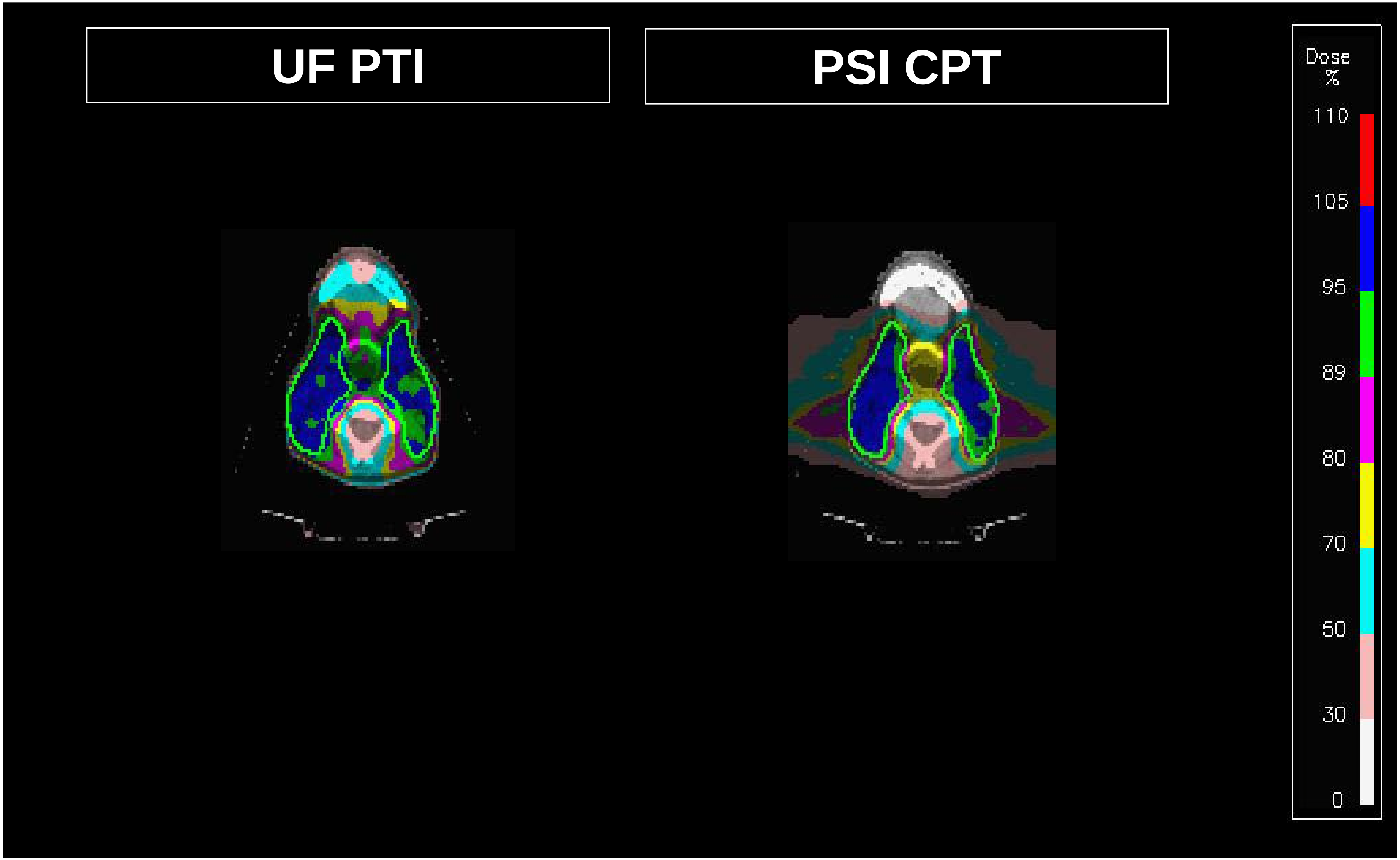

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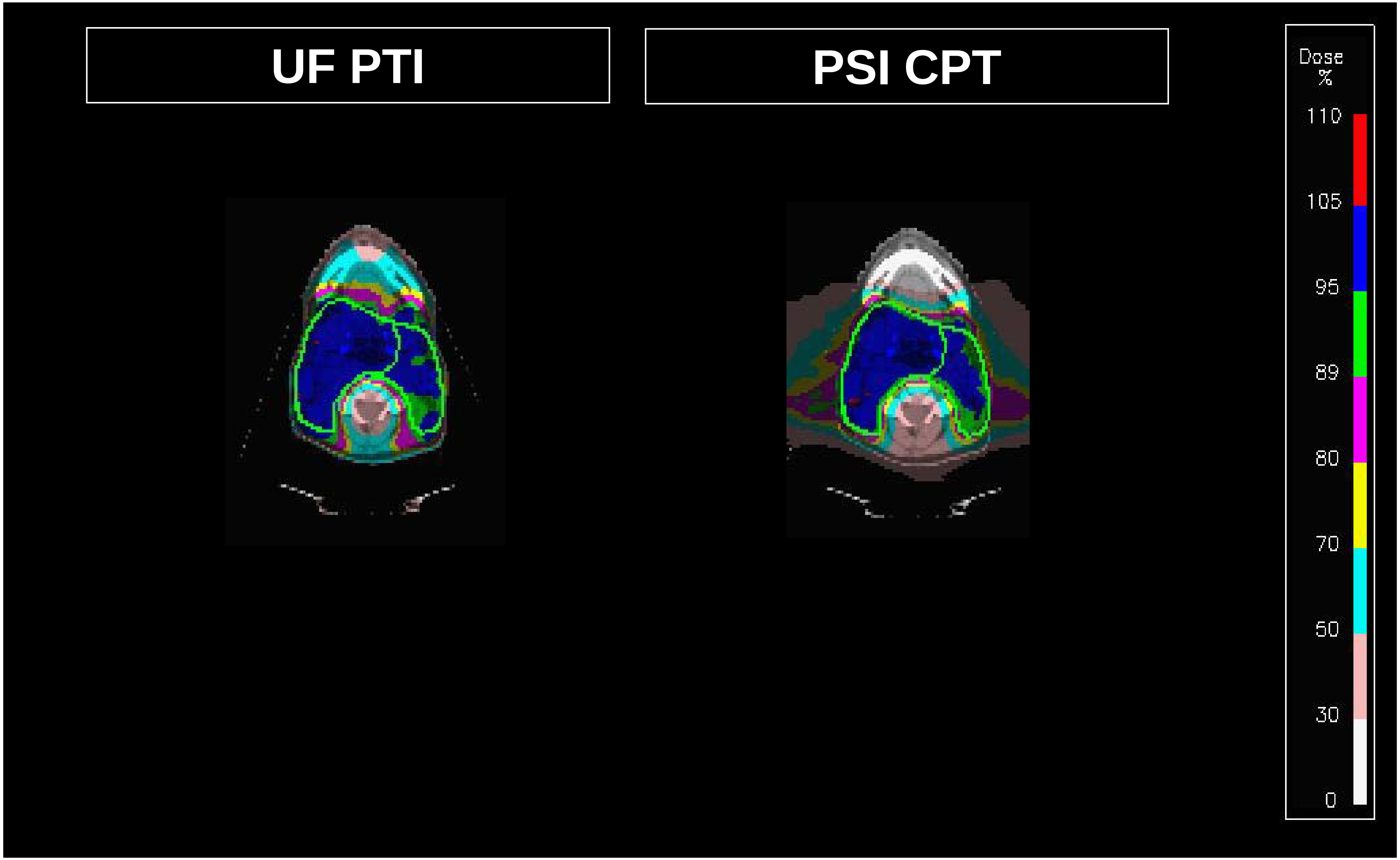

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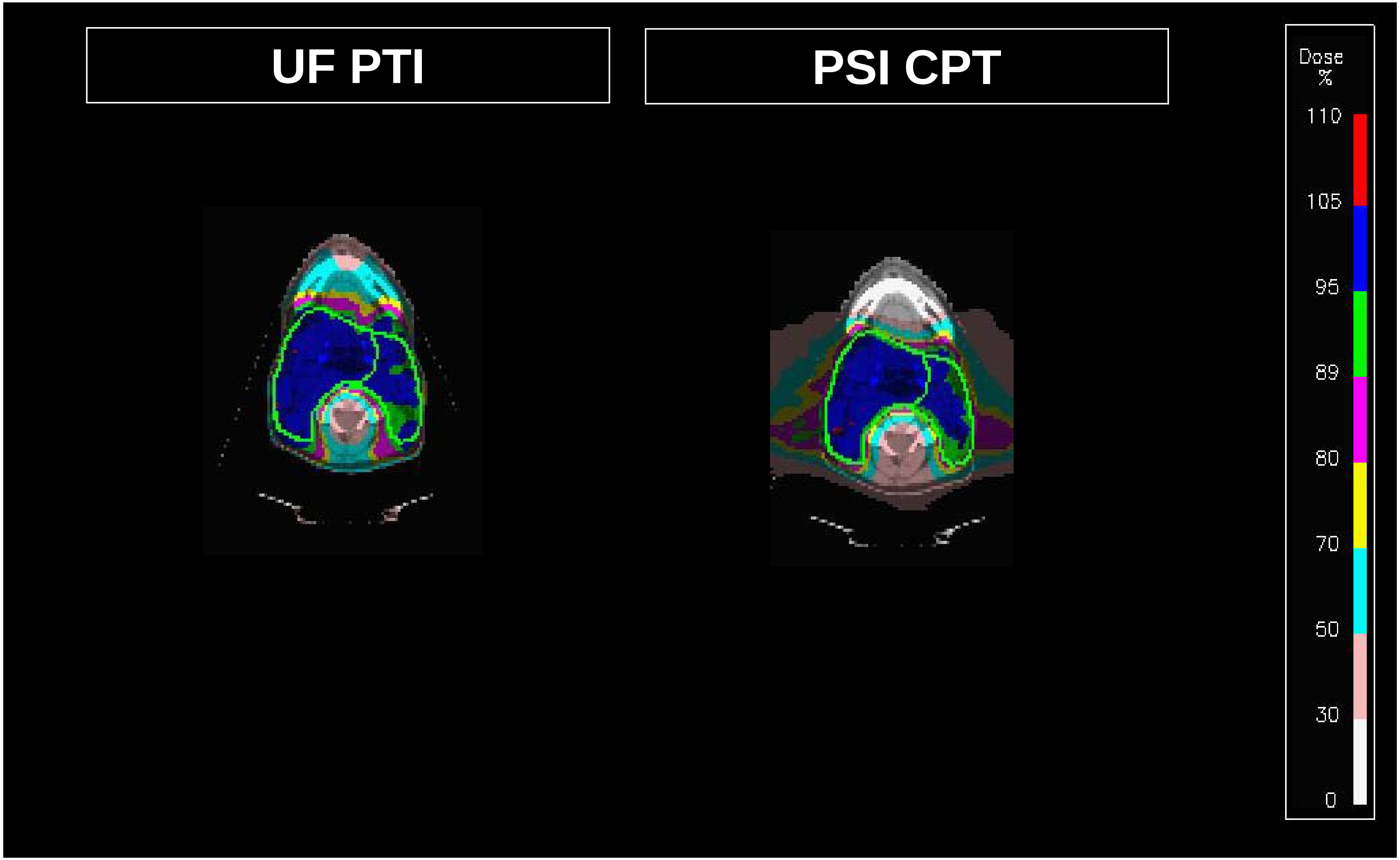

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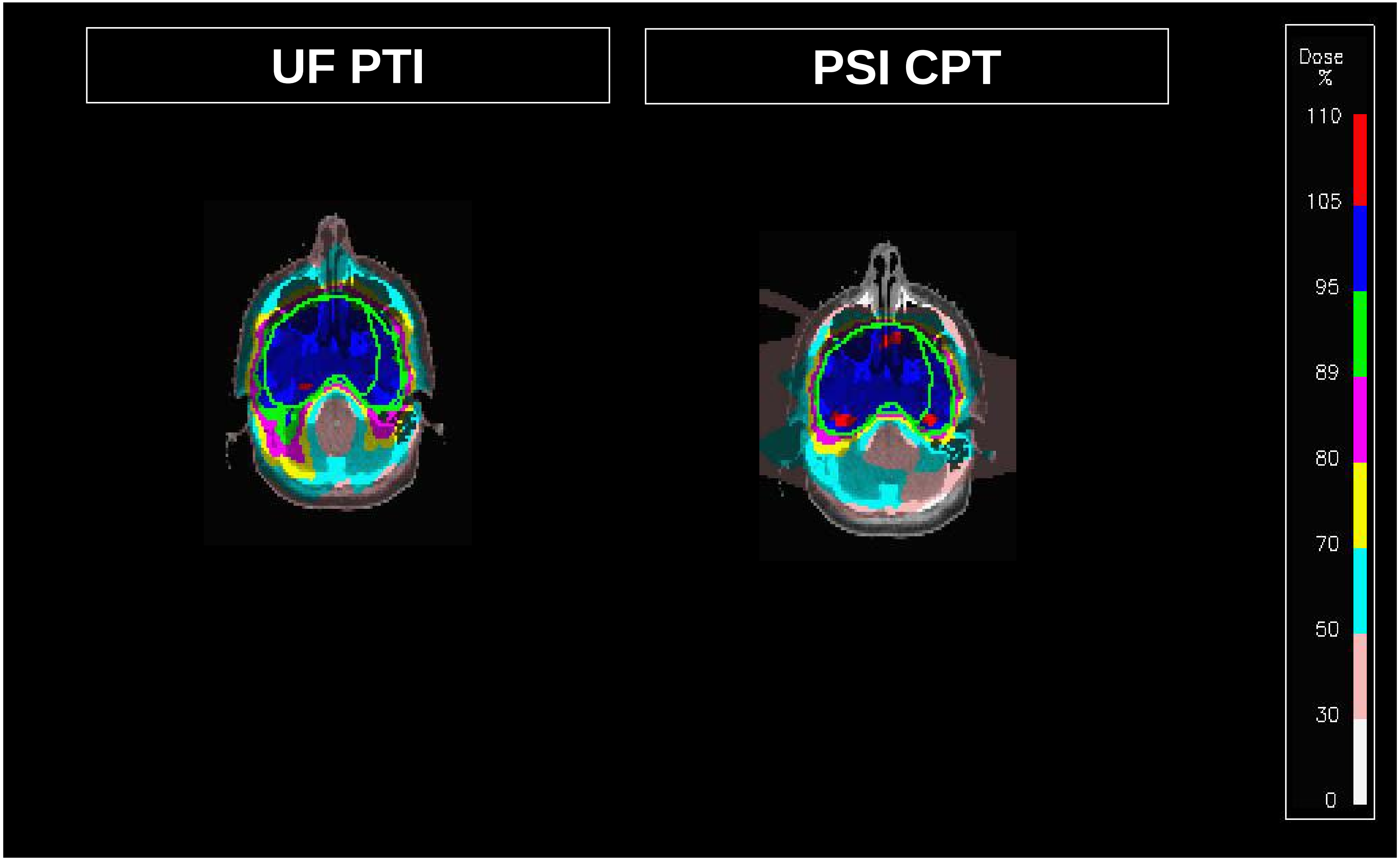

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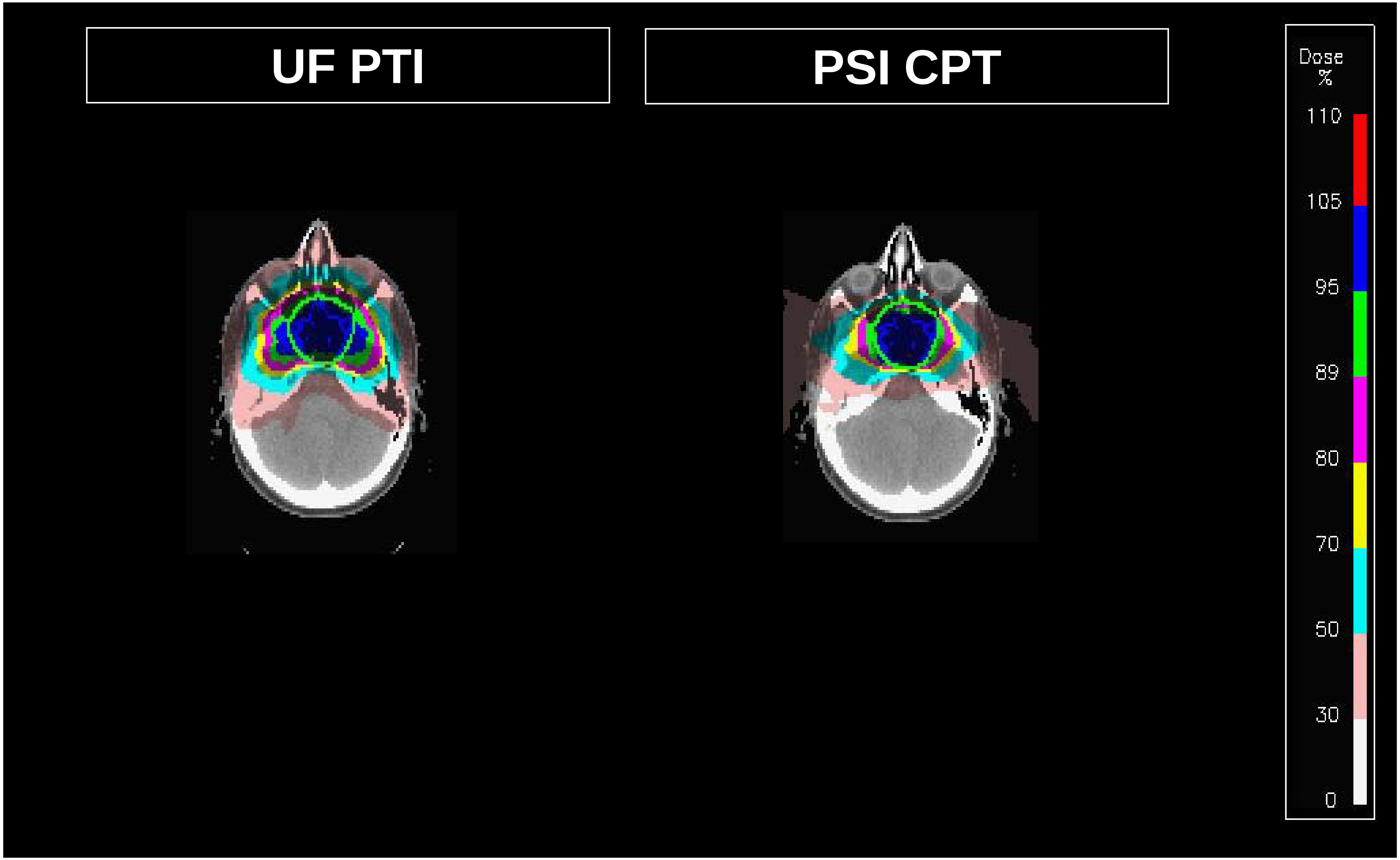

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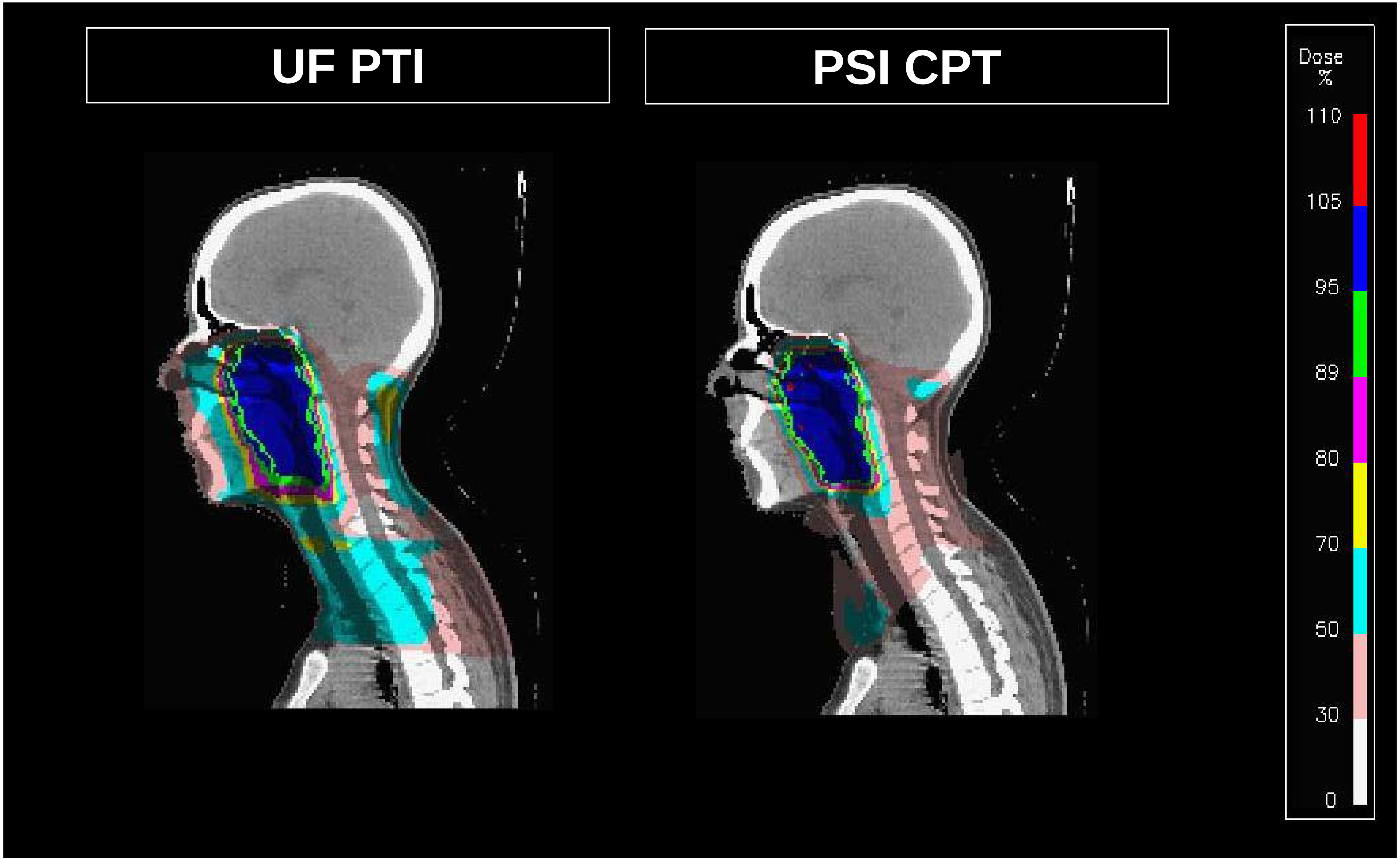

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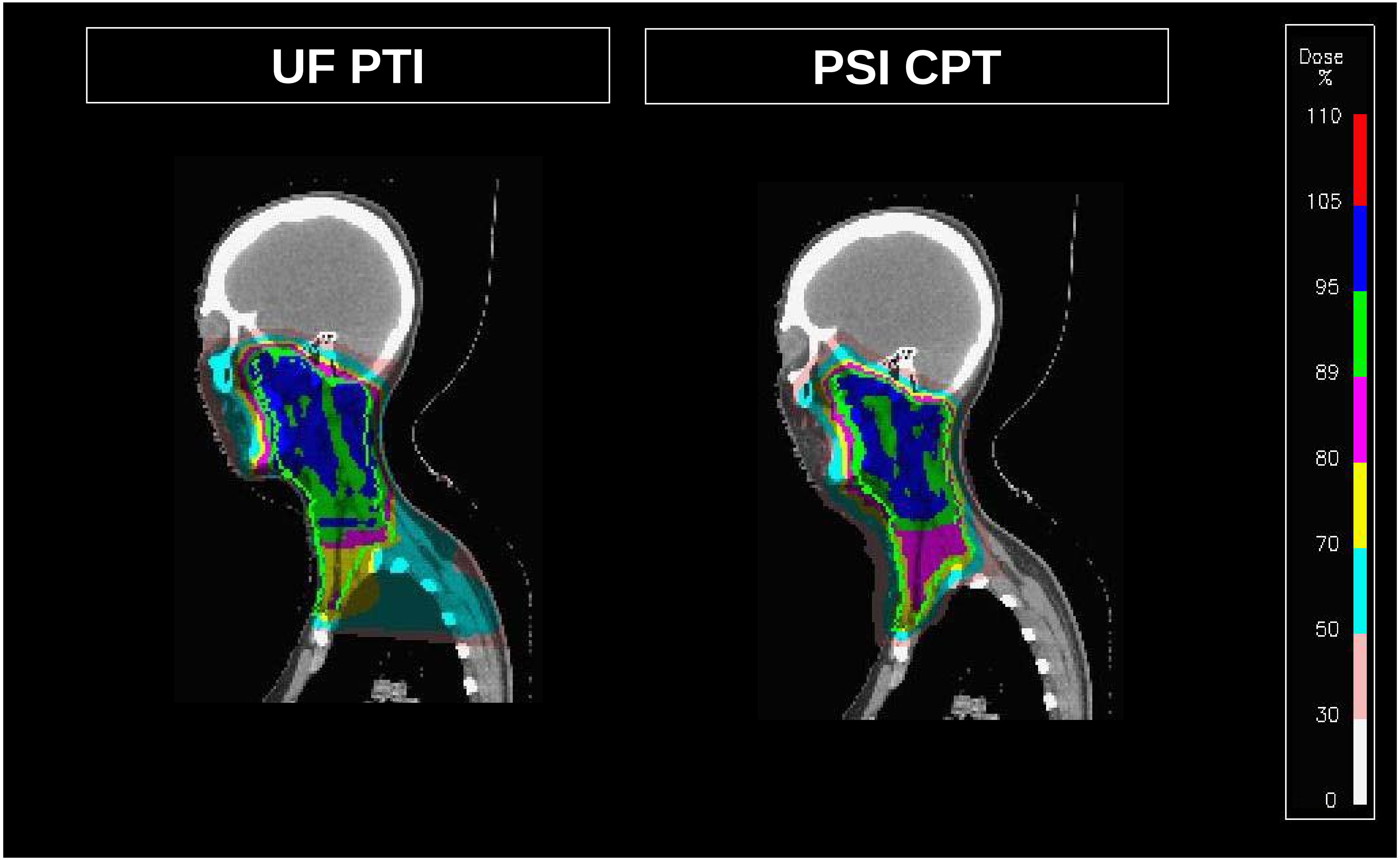

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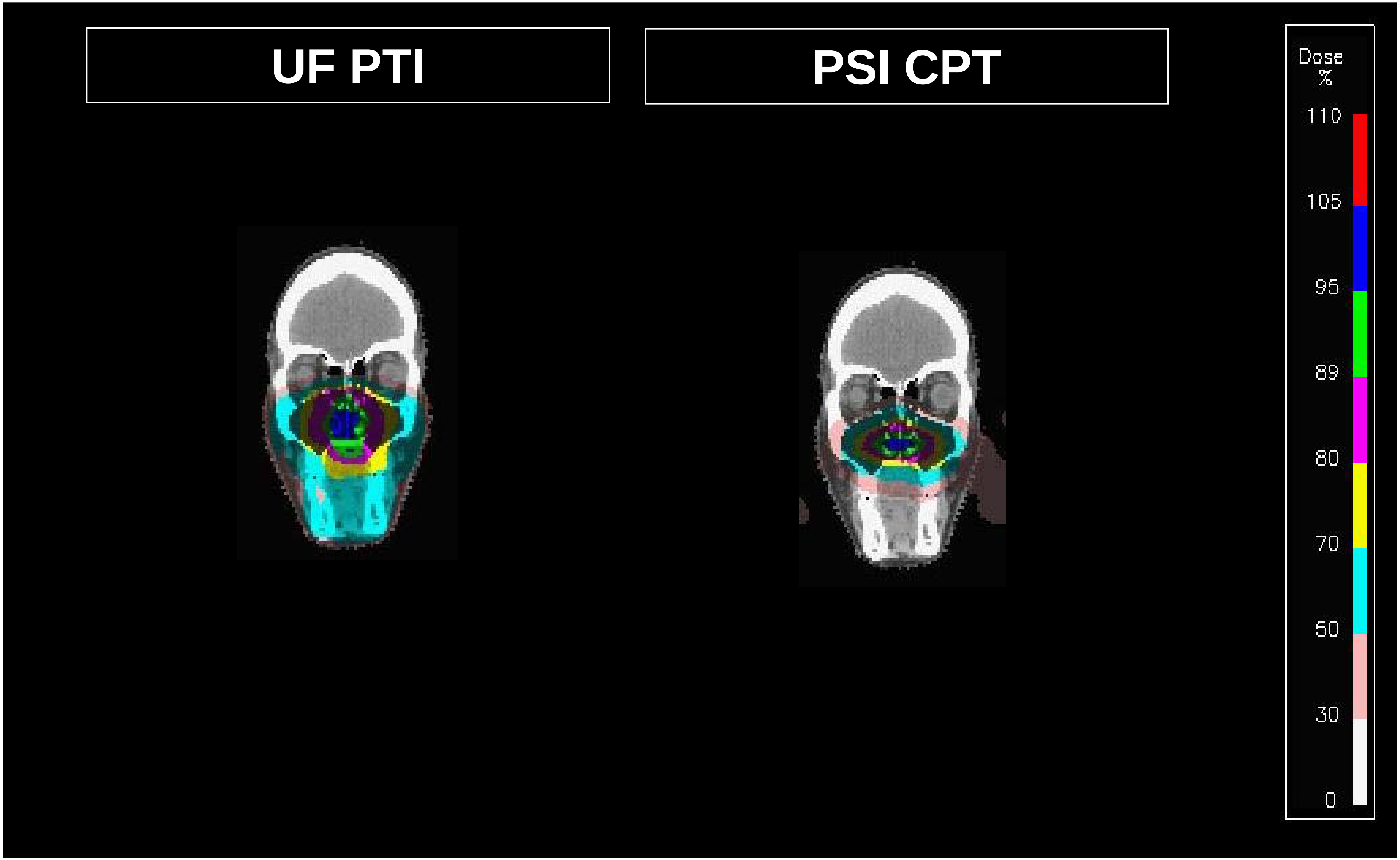

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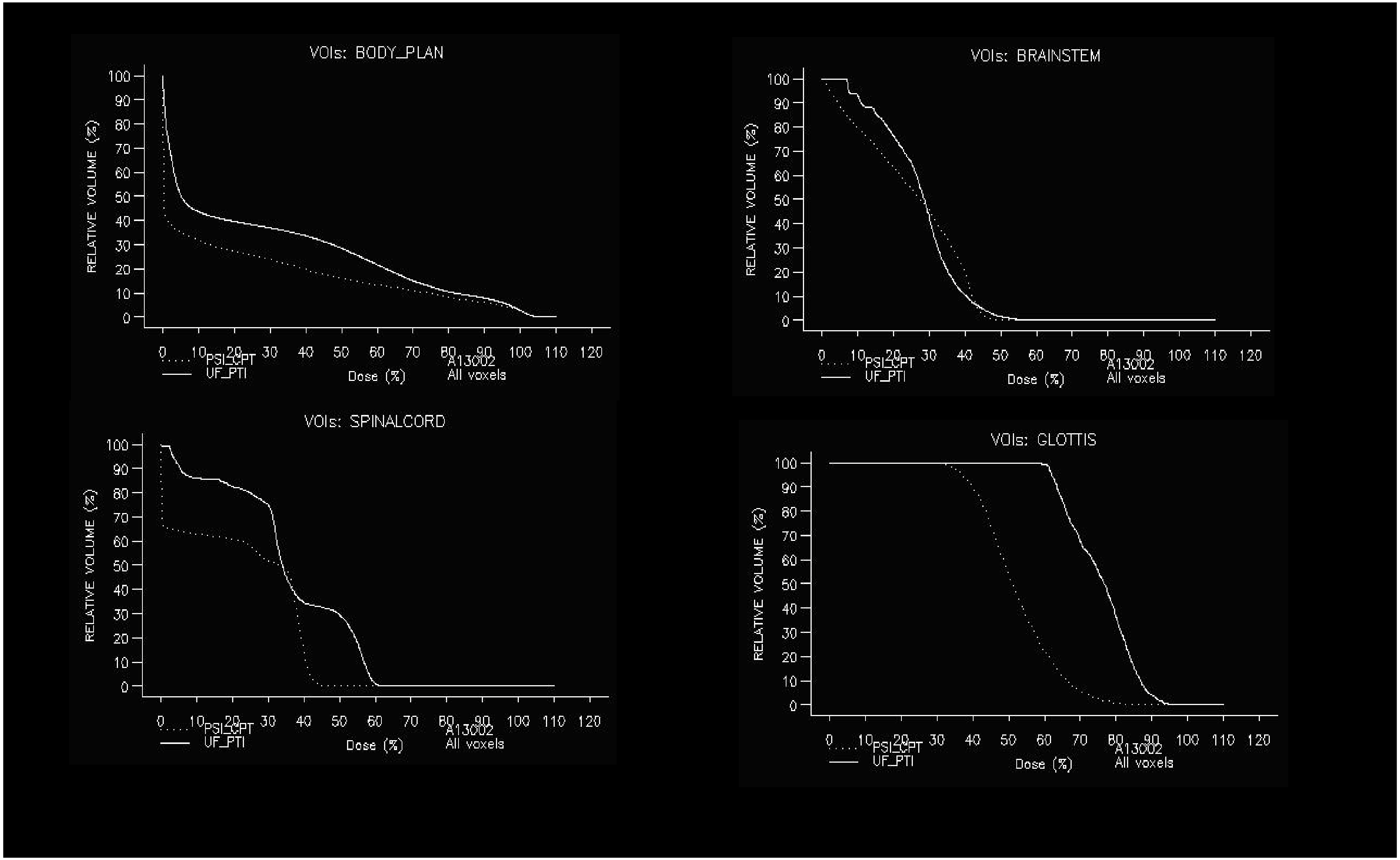

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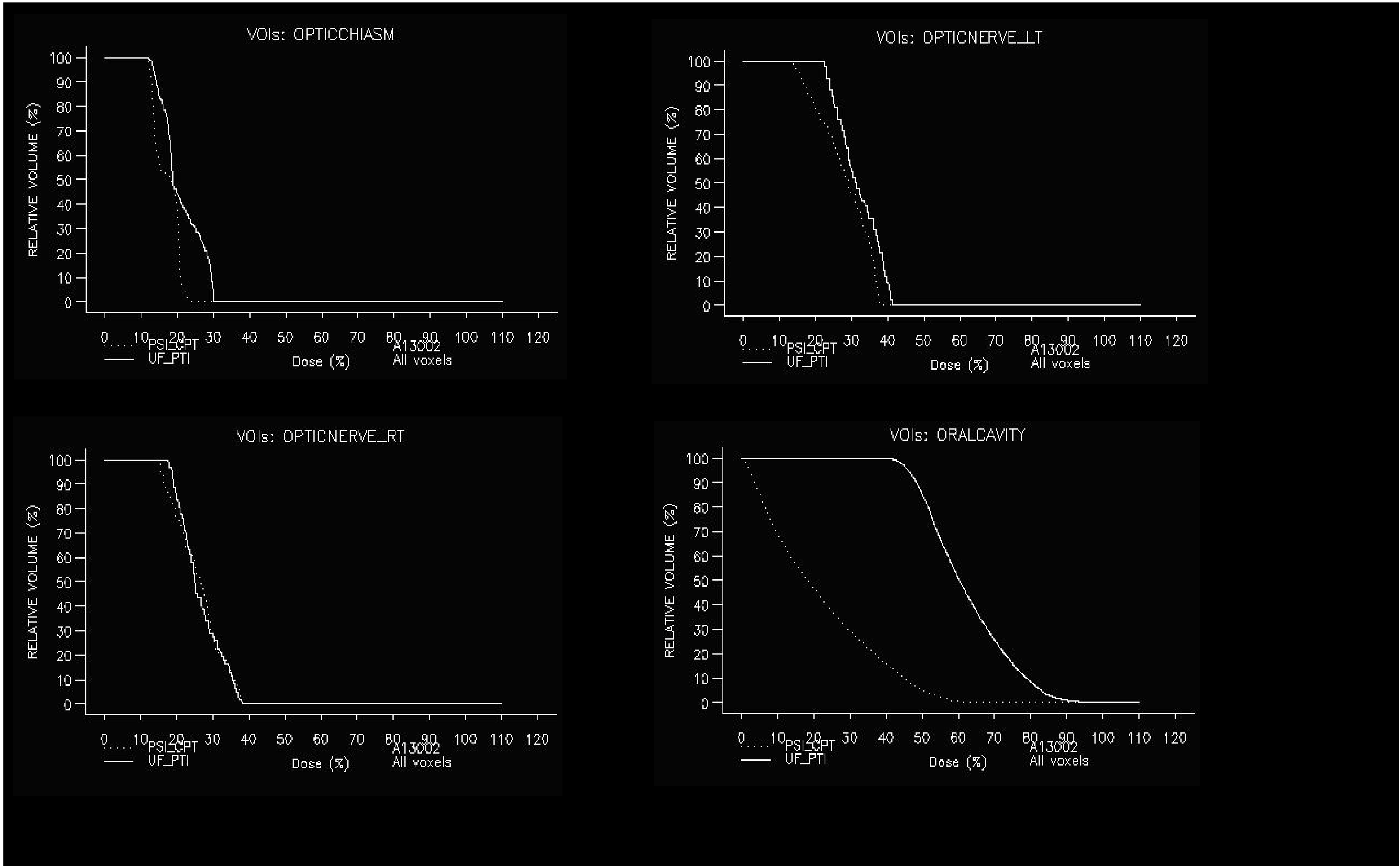
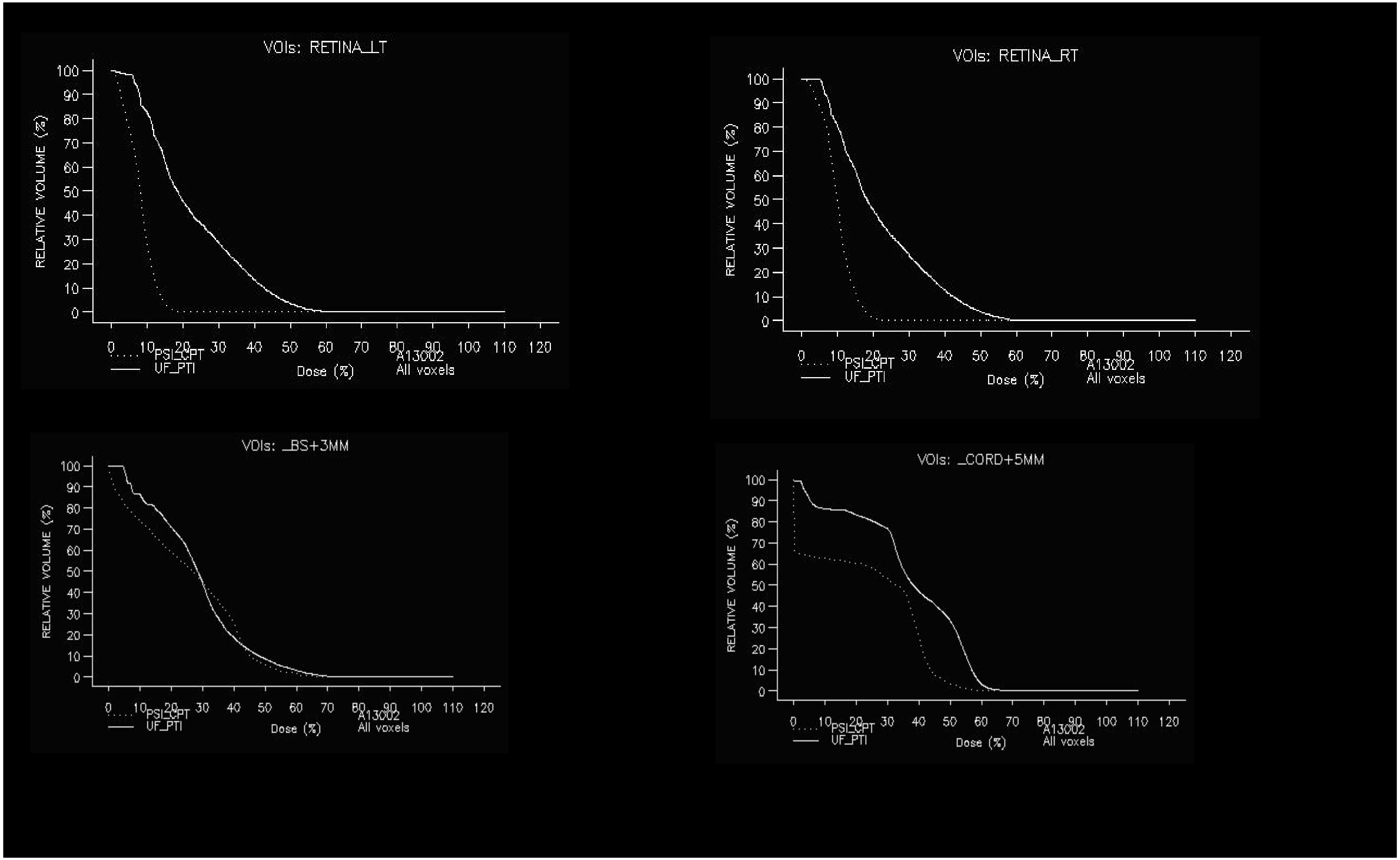
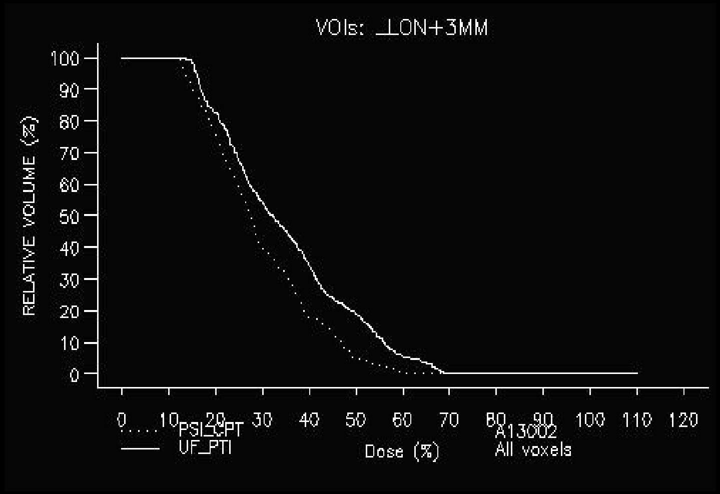
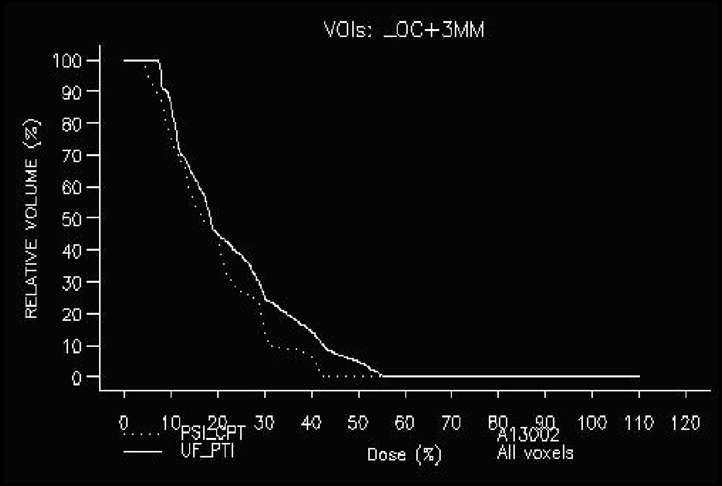


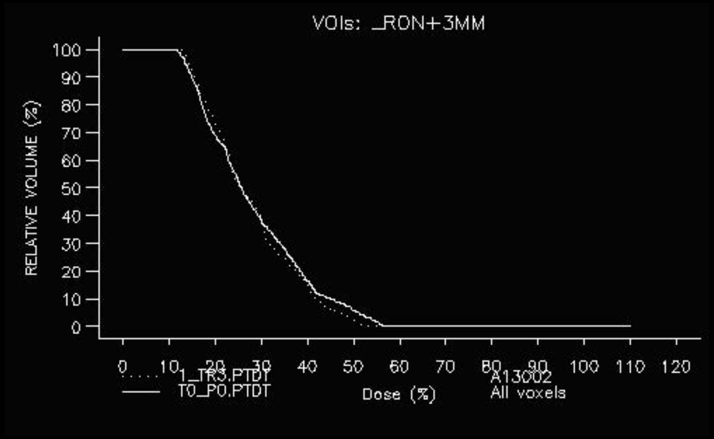
Full Treatment 74.4 Gy(RBE)



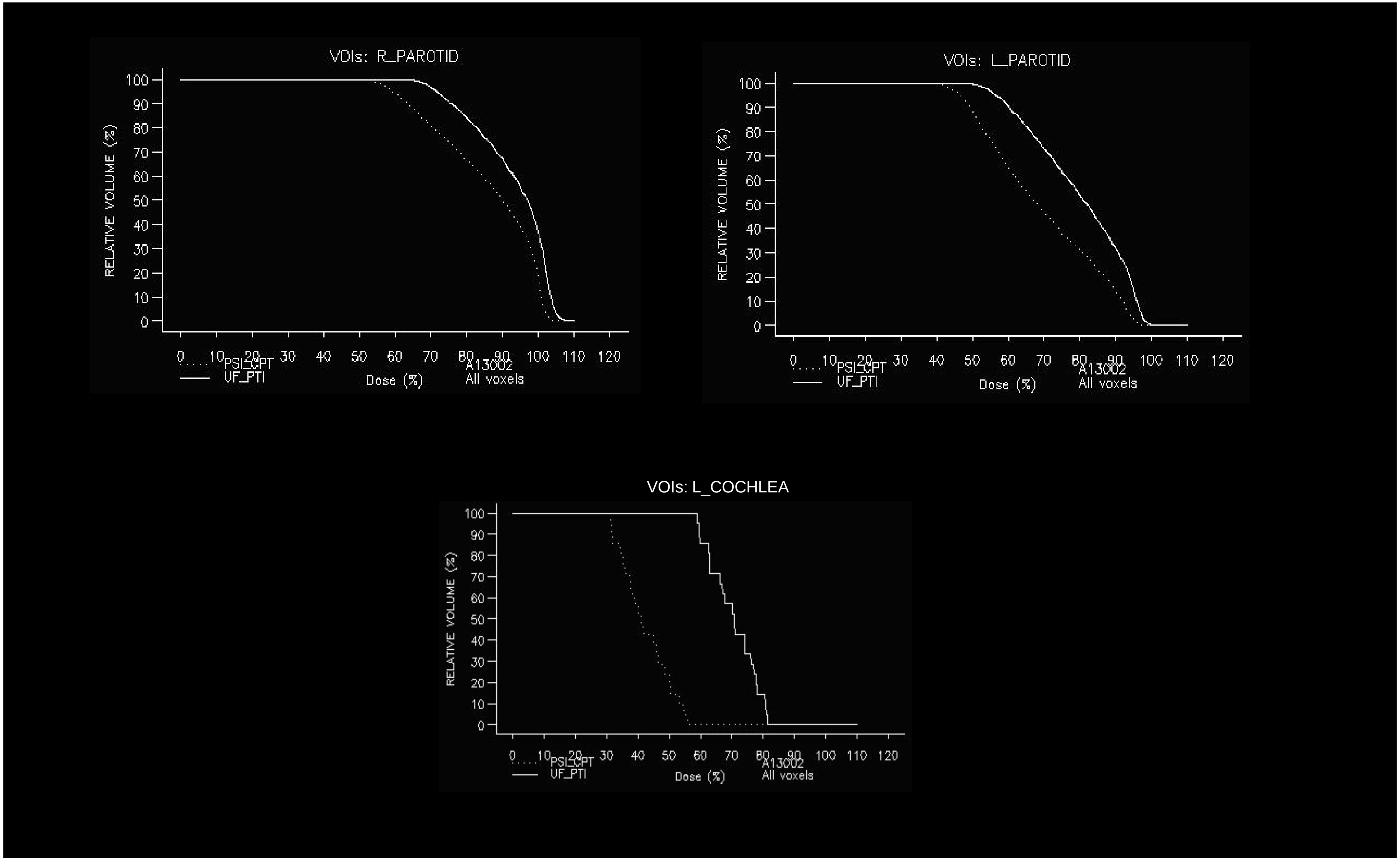
Full Treatment 74.4 Gy(RBE)







Full Treatment 74.4 Gy(RBE)



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