IMRT for H/N Cancer

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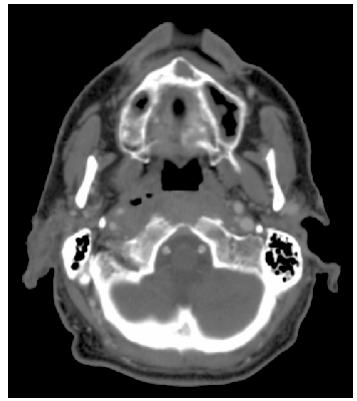
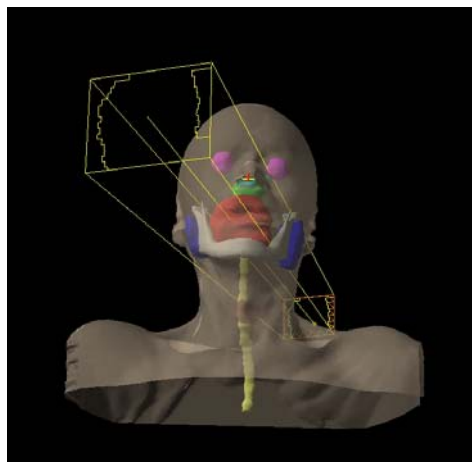
Outline

1. Why IMRT for HN cancer
2. Immbolization
3. Tissue segmentation
4. Treatment planning
5. Plan evaluation
6. Summary





Why IMRT for HN Cancer

Miles et al. Radiother Oncol. 2005;77(3):421-426.

- Complex anatomical region
  - Normal tissues and targets in close proximity
- Inadequate 3D planning techniques
  - No way to deliver concave dose distributions

Kuppersmith et al. Ear Nose Throat J. 1999;78(4):238,241-246.

Pacholke et al. Am J Clin Oncol. 2005;28(4):351-358.

- Absence of organ motion

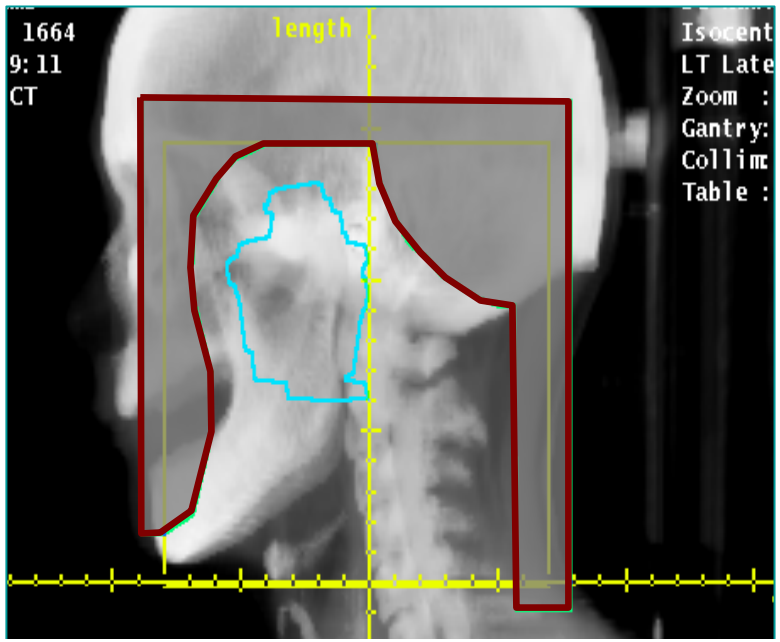
Complex Anatomical Region

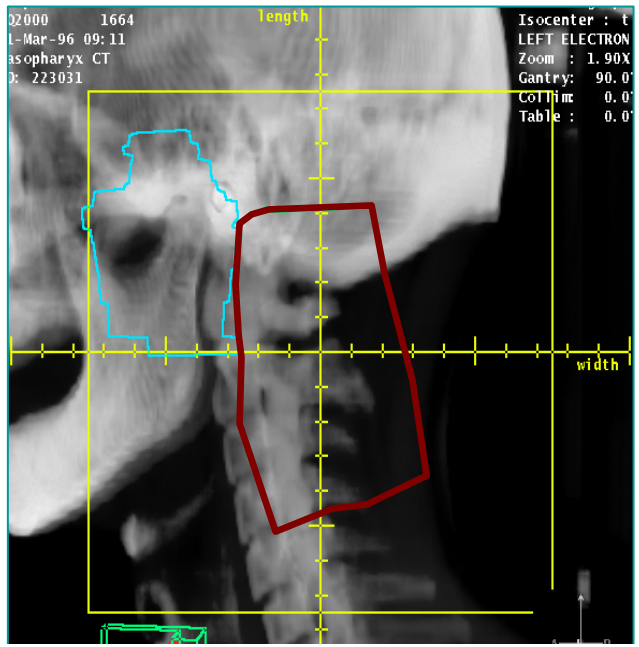
Martinez-Monge et al. Radiology. 1999;211:815-828.

- Optic nerves, chiasm, eyes, lenses
- Spinal cord, brainstem
- Parotid glands
- Oral cavity
- Temporal lobes
- Mandible, TMJ
- Larynx, …

Inadequate Conventional Planning

Pacholke et al. Am J Clin Oncol. 2005;28(4):415-423.





Indications and Contra-Indications

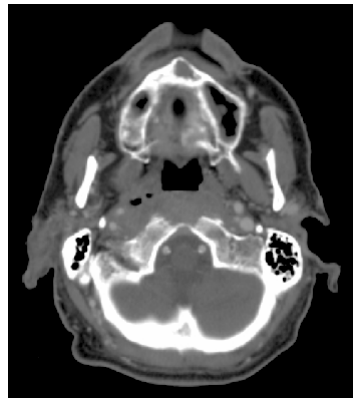
- Cooperative patients
  - No claustrophobia, resting tremors, etc.
- Reduce normal tissue complications
  - Conformal avoidance
- To escalate dose
  - Improve local-regional control
- Avoid unwanted field junctions

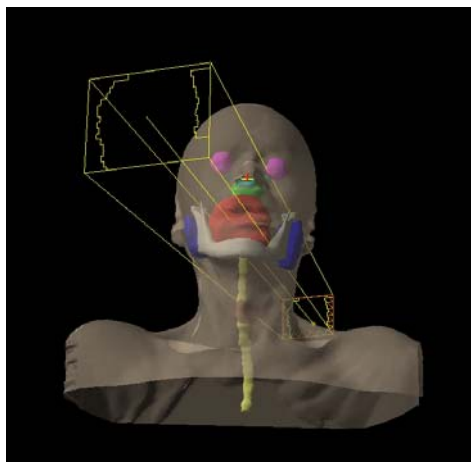
Absence of Organ Motion

- Little or no intra-fraction organ motion
- Inter-fraction setup uncertainty can be controlled with usual intervention

Outline

1. IMRT for HN cancer
2. **Immbolization**
3. Tissue segmentation
4. Treatment planning
5. Plan evaluation
6. Treatment efficacy

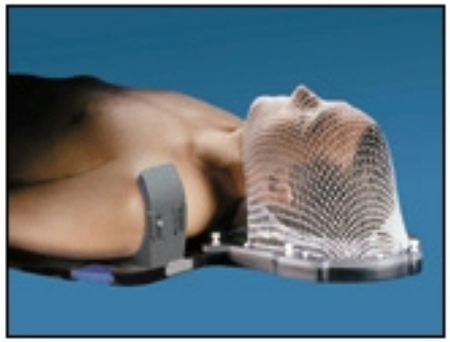




HN Immbolization

- GTV and CTV can be very different structures
- Maximize reproducibility
  - Head
  - Chin
    - Mandible
    - Oral cavity
  - Clavicals
    - Supraclavicular nodes

Immbolization Options

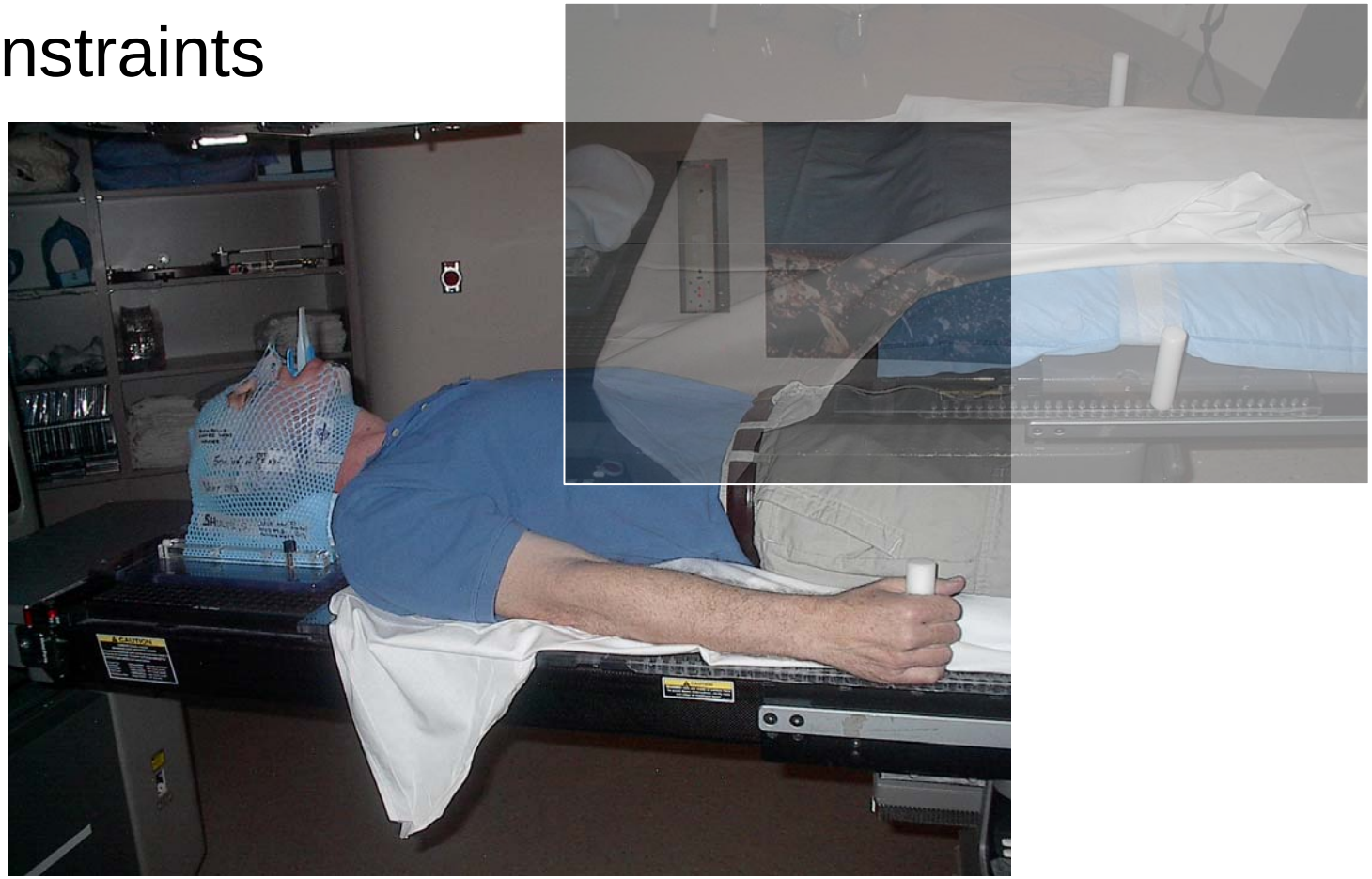


Immbolization Options

- Masking system with Accuform custom neck mold
- Patient comfort and immbolization go hand-in-hand

Immbolization Options

- shoulder constraints



Expected Reproducibility

- Locate isocenter in head or upper neck
- Generally, setup error within 3 mm can be achieved
  - 1 – 2 mm in the head and neck
  - 2 – 3 mm in the shoulder region

Tsai et al. Int J Radiat Oncol Biol Phys. 1999;43(2):455-467.

- However, some variability can be expected
  - Treatment plans should account for those effects

Hong et al. Int J Radiat Oncol Biol Phys. 1005;61(3):779-788.

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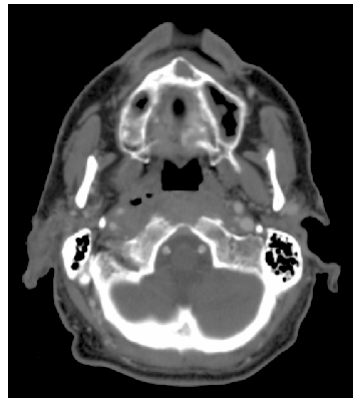
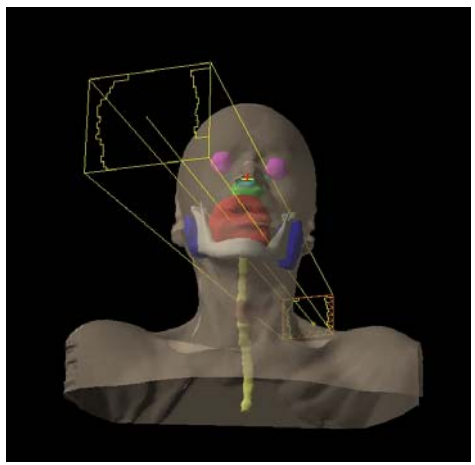




Aspects of Imaging

- Target volumes
- Normal tissues
- Image fusion

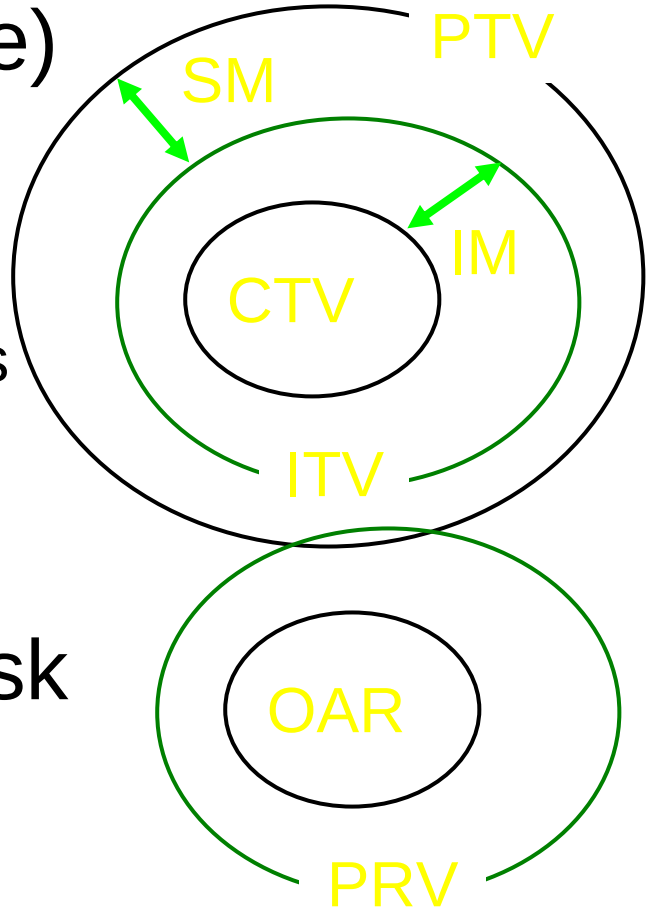
Target Volume Delineation ICRU 50

Example for NPC

- GTV
  - Gross tumor on MRI and PE
- CTV
  - GTV + margin including, nasopharynx, retropharyngeal nodes, clivus, skull base, inferior sphenoid sinus, pterygoid fossae, parapharyngeal space, posterior nasal cavity and maxillary sinuses
- PTV
  - CTV + 3-5 mm

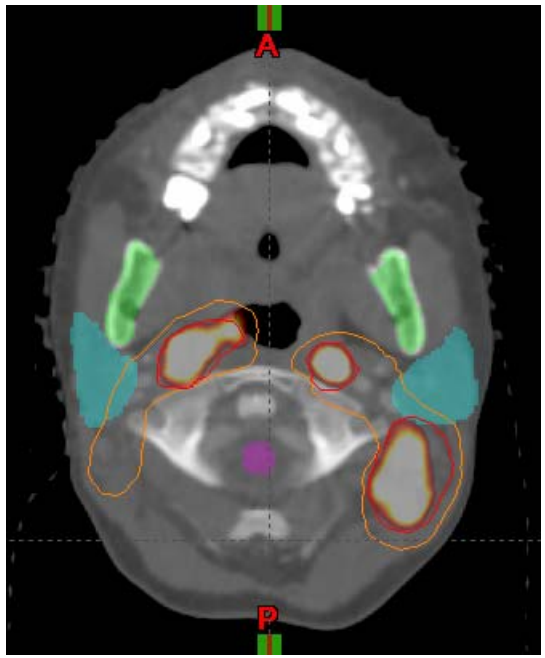
Target Volume Delineation
ICRU 62

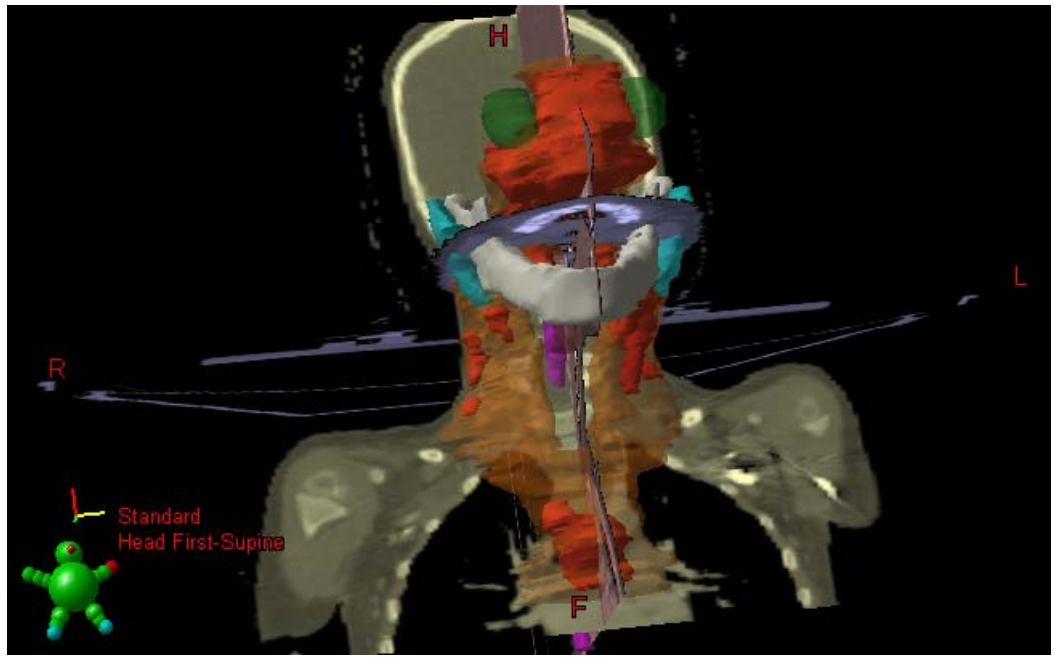
- ITV (internal target volume)
  - ITV = CTV + IM
  - IM (internal margin)
    - Due to physiologic variations
  - SM (setup margin)
    - Due to technical factors
- PRV (planning organ at risk volume)
  - Margin added to OARs



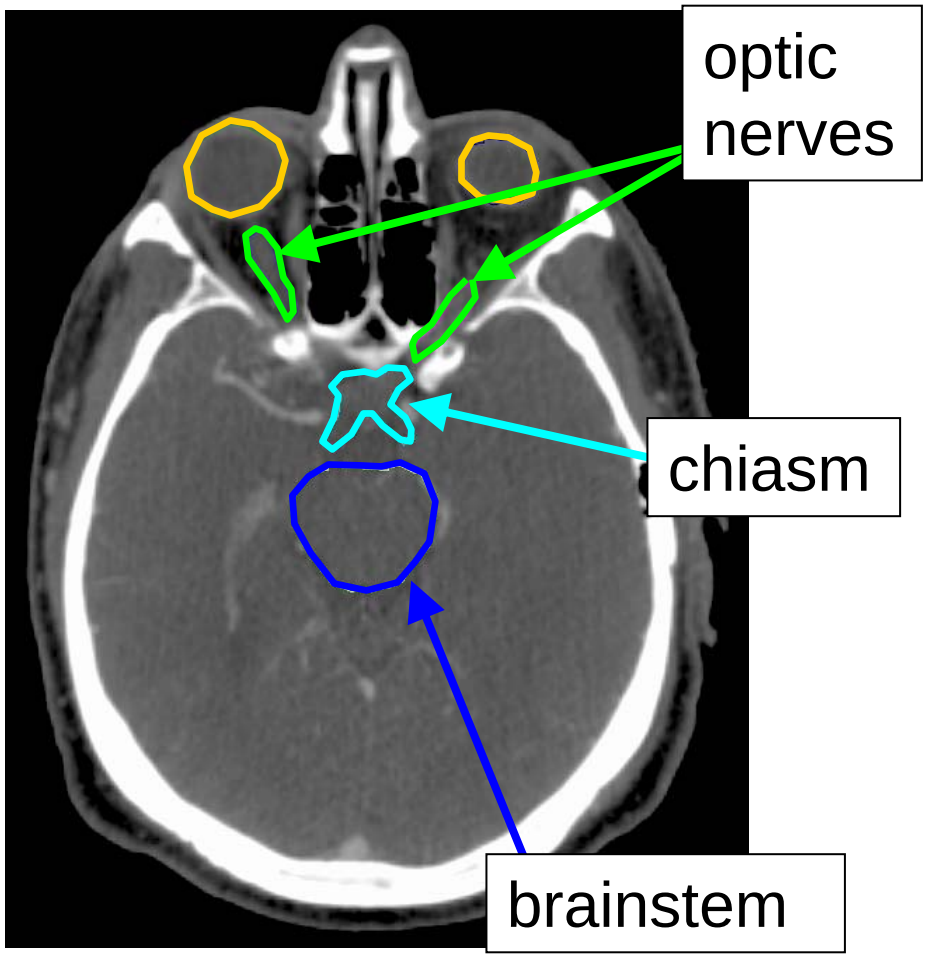
Consistent with ICRU Definitions

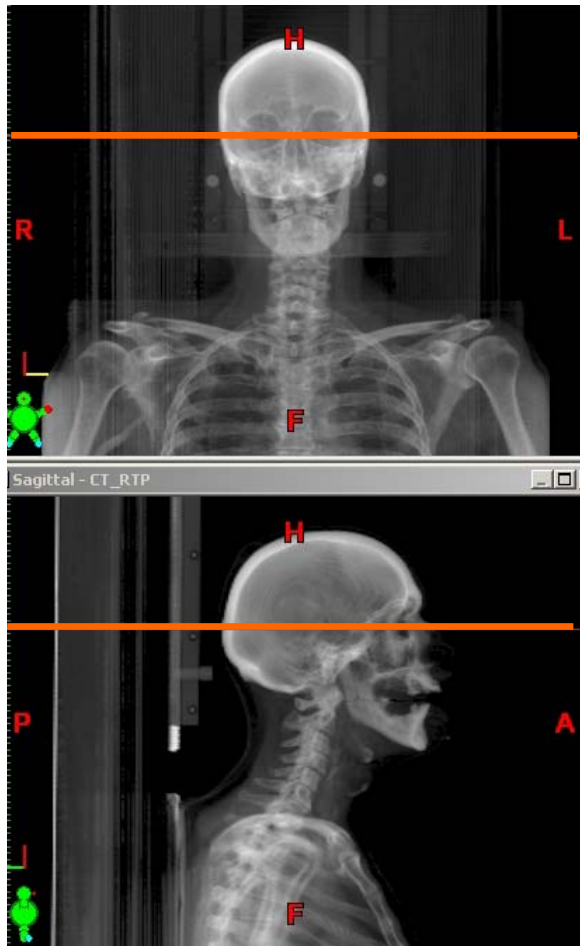
- GTV-T, GTV-N
- CTV-T, CTV-N1, CTV-N2, etc.





CT Anatomy – Head





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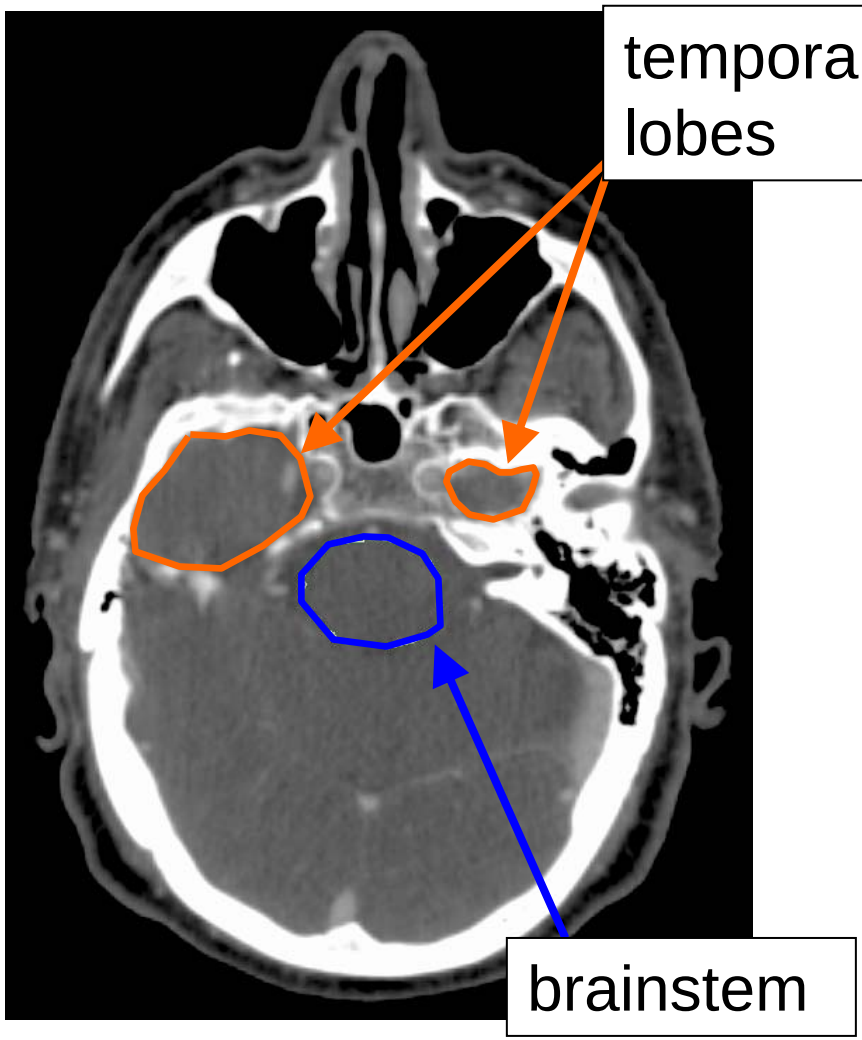

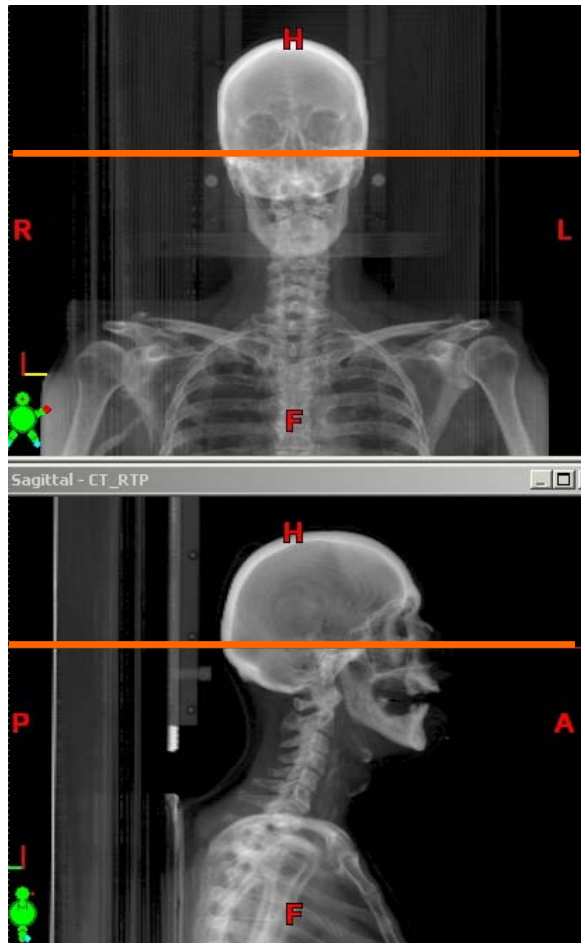

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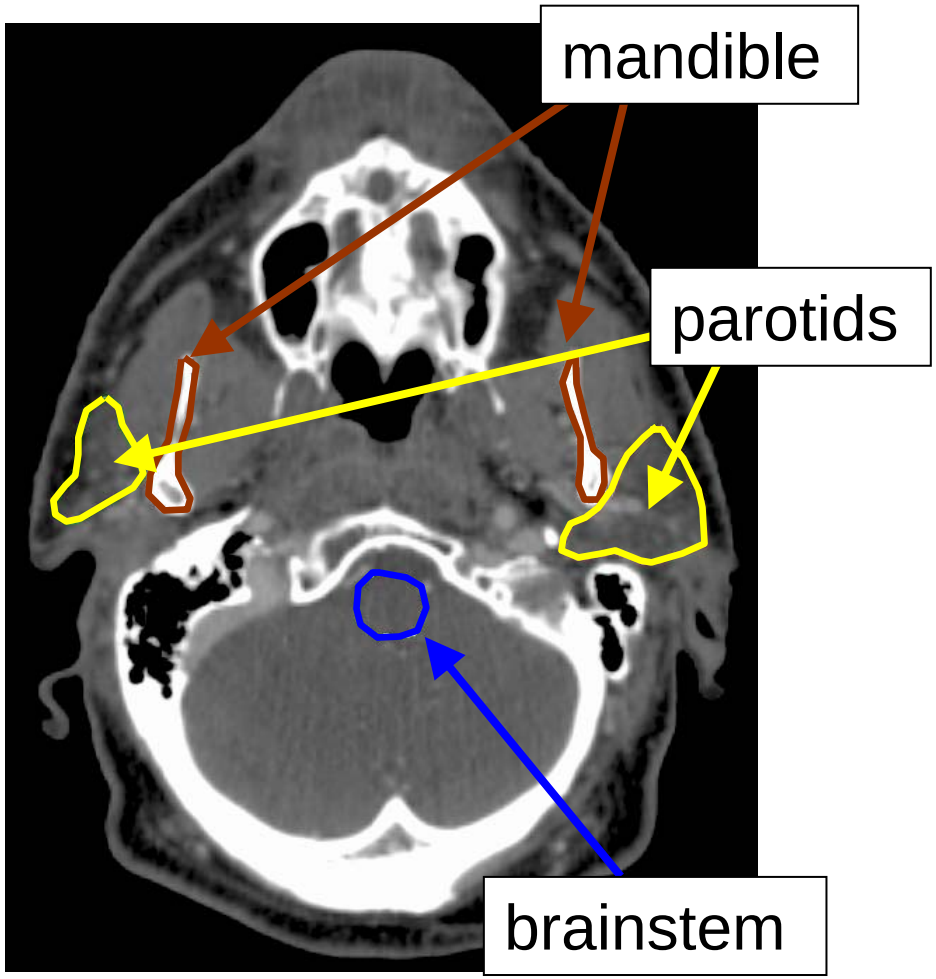
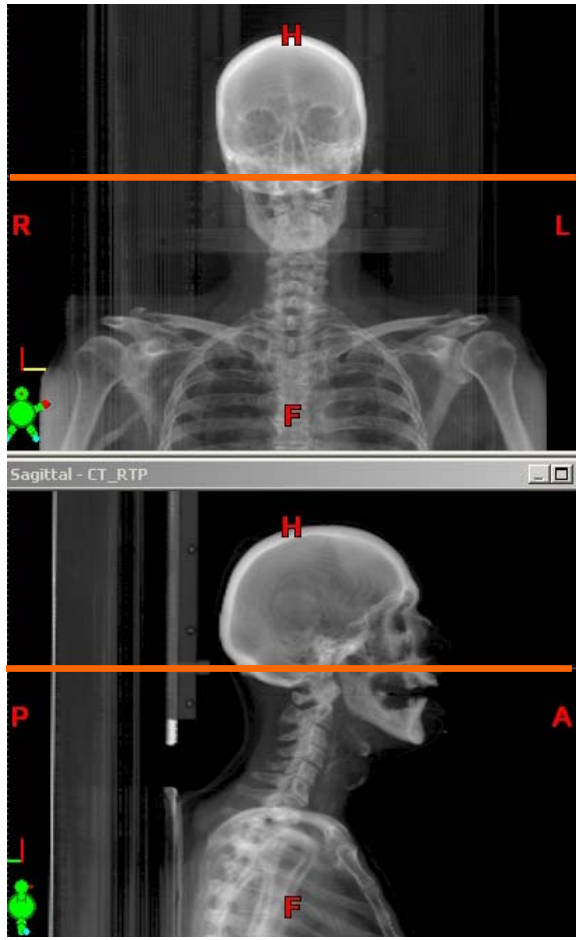
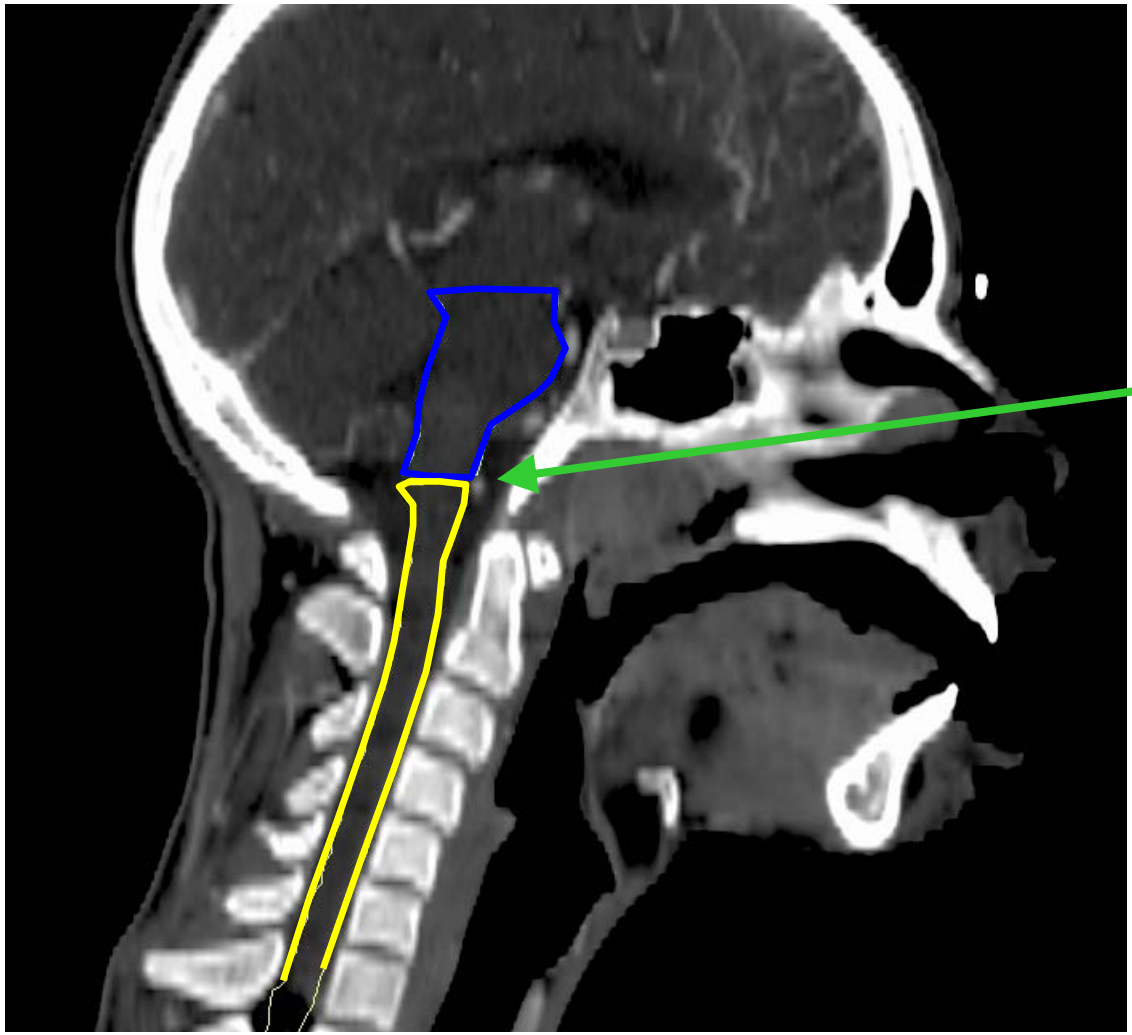


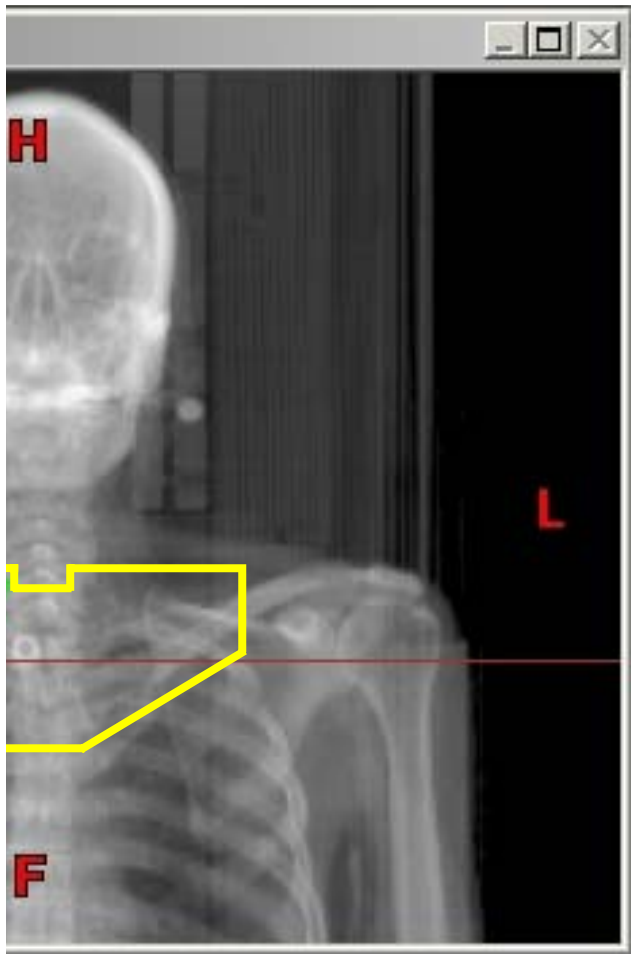


CT Anatomy – Head/Neck

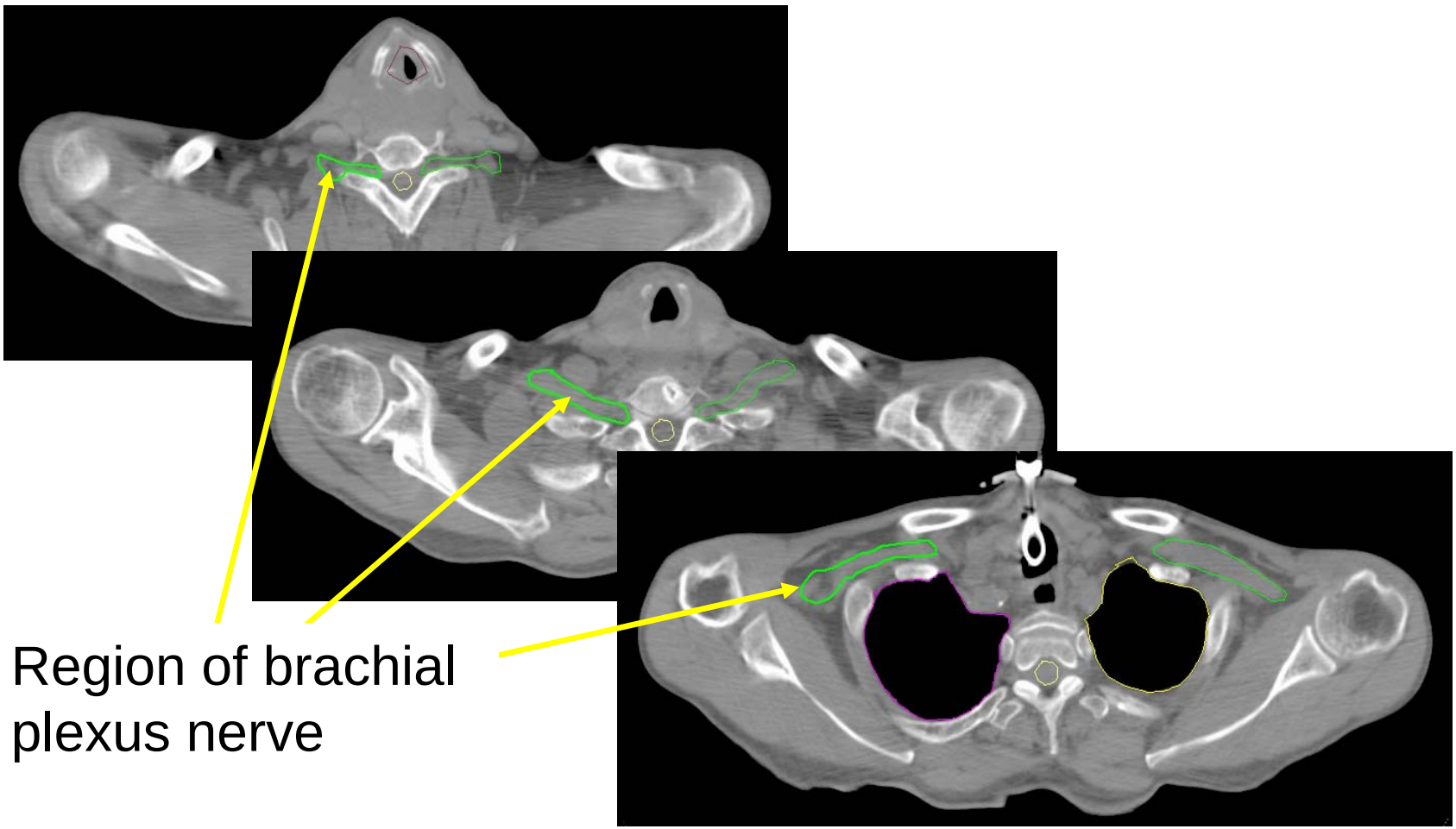


Location of inferior brainstem and superior spinal cord

CT Anatomy – Neck



CT Anatomy – Neck

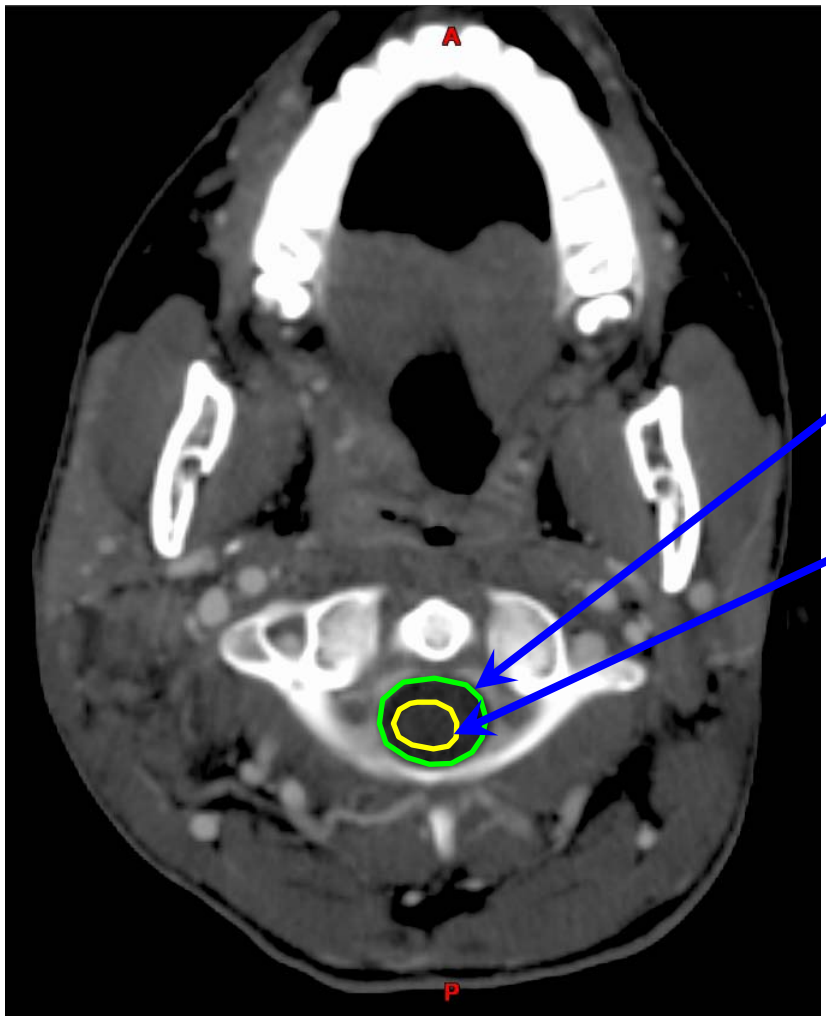


Region of brachial plexus nerve

CT/MR Anatomy

Primarily used for target delineation

CT Anatomy – Neck



Spinal canal

vs

Spinal cord

Use PRV (ICRU-62) for margin around spinal cord

PET Images

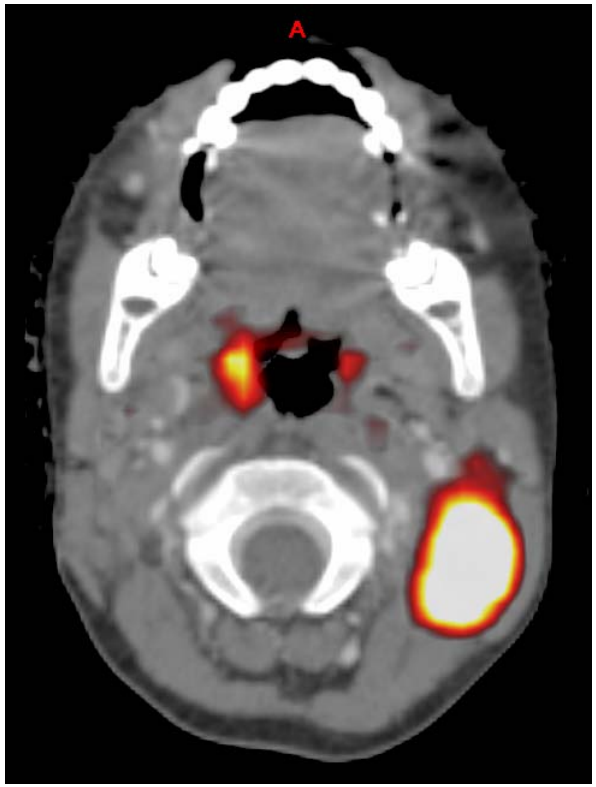
- Malignant cells divide rapidly and metabolize glucose at a higher rate than that of healthy cells
- Attach a positron emitter (fluorine-18) to a glucose analogue
- FDG PET studies depict glucose utilization of the glucose analogue fluorodeoxyglucose
  - Tumor metabolism

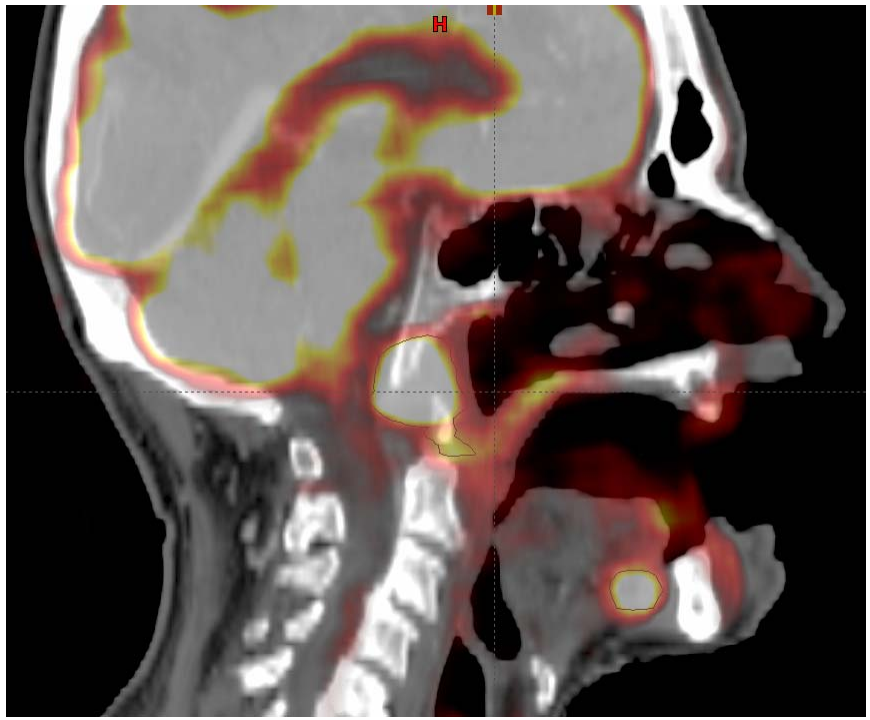
CT/PET Images

Heron et al. Int J Radiat Oncol Biol Phys. 2004;60(5):1419-1424.

Paulino et al. Int J Radiat Oncol Biol Phys. 2005;61(5):1385-1392.

Wang et al. Int J Radiat Oncol Biol Phys. 2006;65(1):143-151.





Multi-modality Image Fusion

- Participate in process before imaging takes place
  - Ensure same position
  - Understand setup/imaging limitations
- Talk with physician about site of interest
  - Location, pre- or post-op, etc.
- Communicate uncertainty of manually fused images

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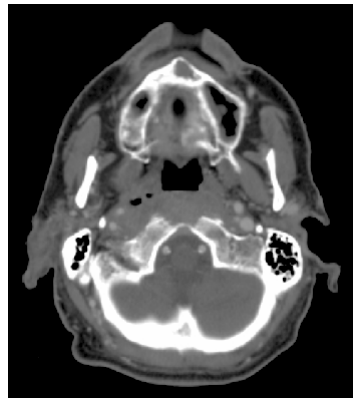
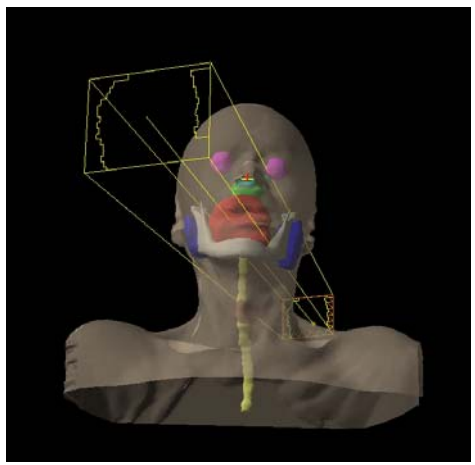




Before Planning Begins

- Is IMRT appropriate for this case?
- Where is the target?
- What are target doses & acceptable normal tissue doses?
  - What can be compromised?
- What is the plan?
  - Simultaneous integrated boost versus sequential cone down plans?

IMRT Planning

- Same primary target as with 3DCRT
- Regional therapy requires specific identification of nodes
- Simultaneous boost
  - Lower regional dose per fraction (e.g. GTV to 66Gy and nodes to 54Gy both in 30 fractions)
- Sequential boost
  - Same dose per fraction for GTV and nodes
  - Requires two plans

Physician Communication

- Isodose lines are not as smooth as 3DCRT
  - Increases dose heterogeneity, which may affect toxicity, tumor control probability
- You can not specify an isodose line to move by millimeters
  - IMRT planning is not like changing a block edge
- Hot/cold spot will fall within the target(s)

Issues with IMRT Treatments

- Time consuming planning process and quality assurance procedures
- Many factors in plan evaluation of uncertain significance
- Exchanges exposure of larger volumes of normal tissue to low doses for smaller volumes exposed to high doses

Tissue Inhomogeneity Corrections

- AAPM Report No. 85: Tissue Inhomogeneity Corrections for Megavoltage Photon Beams
- 4 – 10% error in relative e^- density results in ~2% error in dose
- CT Streak artifacts can be locally significant
  - Do not normalize a plan to a point in this region
  - Little effect on DVH of large structures

Dose Calculation Accuracy

- Two types of dose calculation errors
  - Systematic error (same as in 3DCRT)
  - Convergence error (related to optimization)
- Convergence error
  - The optimization algorithm converges to a solution based on inaccurate beamlets
- Approximate errors at tumor for HN cases
  - Systematic: 0 – 3 $\%D_{max}$
  - Convergence: 3 – 6 $\%D_{max}$

Know Published Dose Limits

Tissue	Maximal Dose* (Gy)	Mean Dose (Gy)	Reference
Brain	60	-	Emami *et al* 1991
Brainstem	54	-	Emami *et al* 1991
Optic chiasm/nerves	54	-	Emami *et al* 1991
Retina	45	-	Emami *et al* 1991
Lens	12	-	Emami *et al* 1991
Parotid	70	26	Eisbruch *et al* 2003
Larynx	70	≤ 25 – 30	Stanford
Mandible	65	≤ 35 – 45	Stanford
Spinal cord	45	-	Emami et al 1991

*We recommend lowering these dose limits by 10% when concurrent chemotherapy is used.

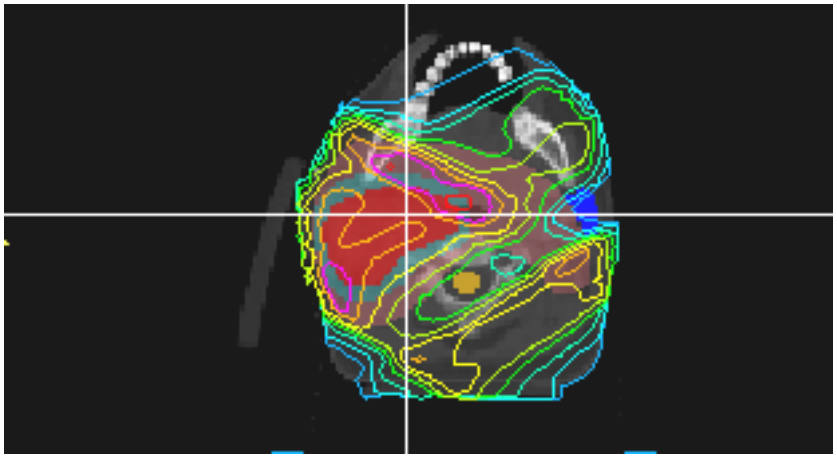
IMRT Planning Parameters

- Dose/volume constraints
- Number of beams
- Beam orientation / Table angles
- Tuning structures
- Collimator angle
- Isocenter placement
- Beamlet size / Intensity levels
- Direct modification of intensity maps

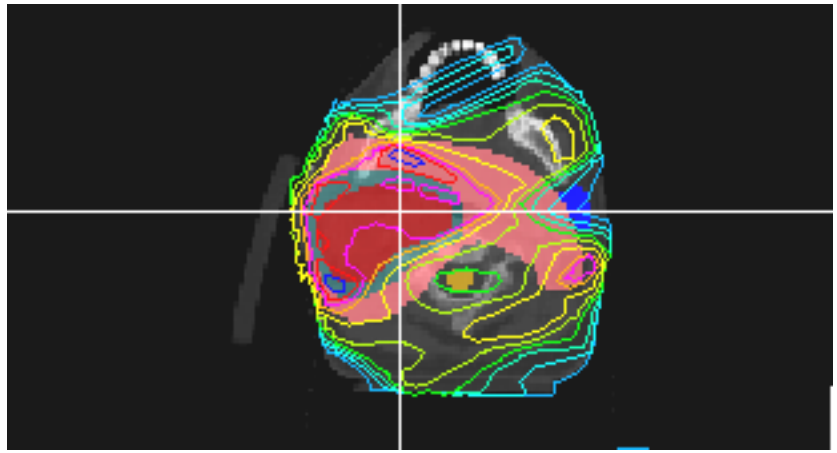
Number of Beams

- More beams = Better plan ?
- Generally Yes
  - But improvement can be marginal over 7 beams
  - Degree of improvement depends on tumor shape and proximity to critical structures

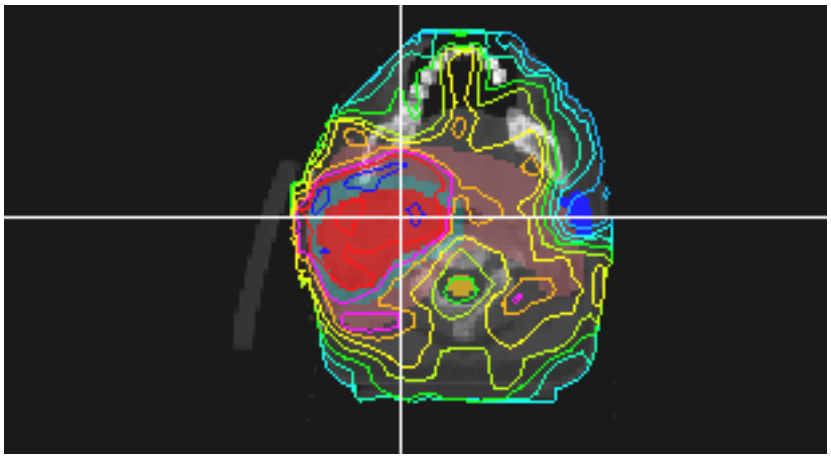
3 – Field



5 – Field



7 – Field

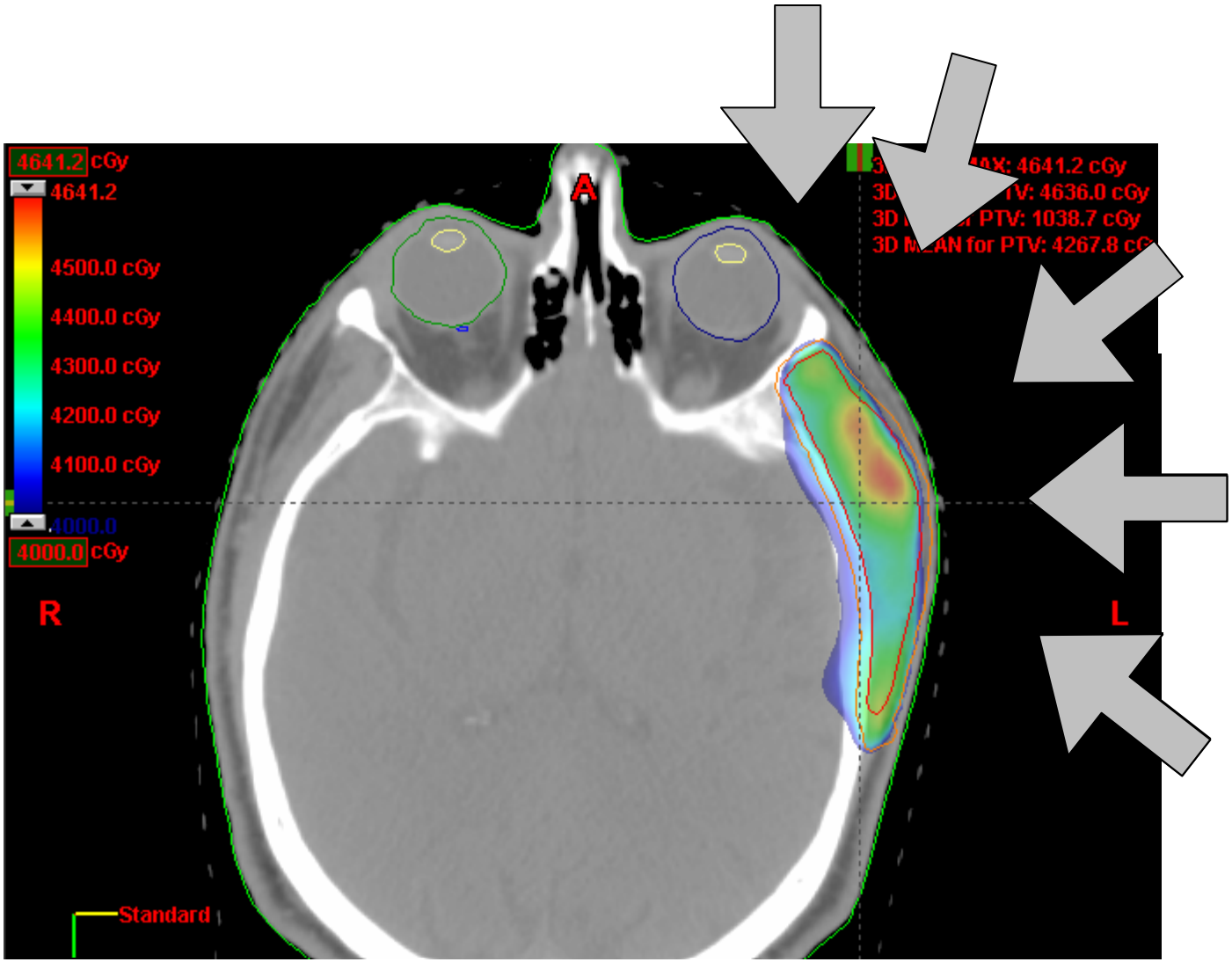


All plans have the same optimization parameters

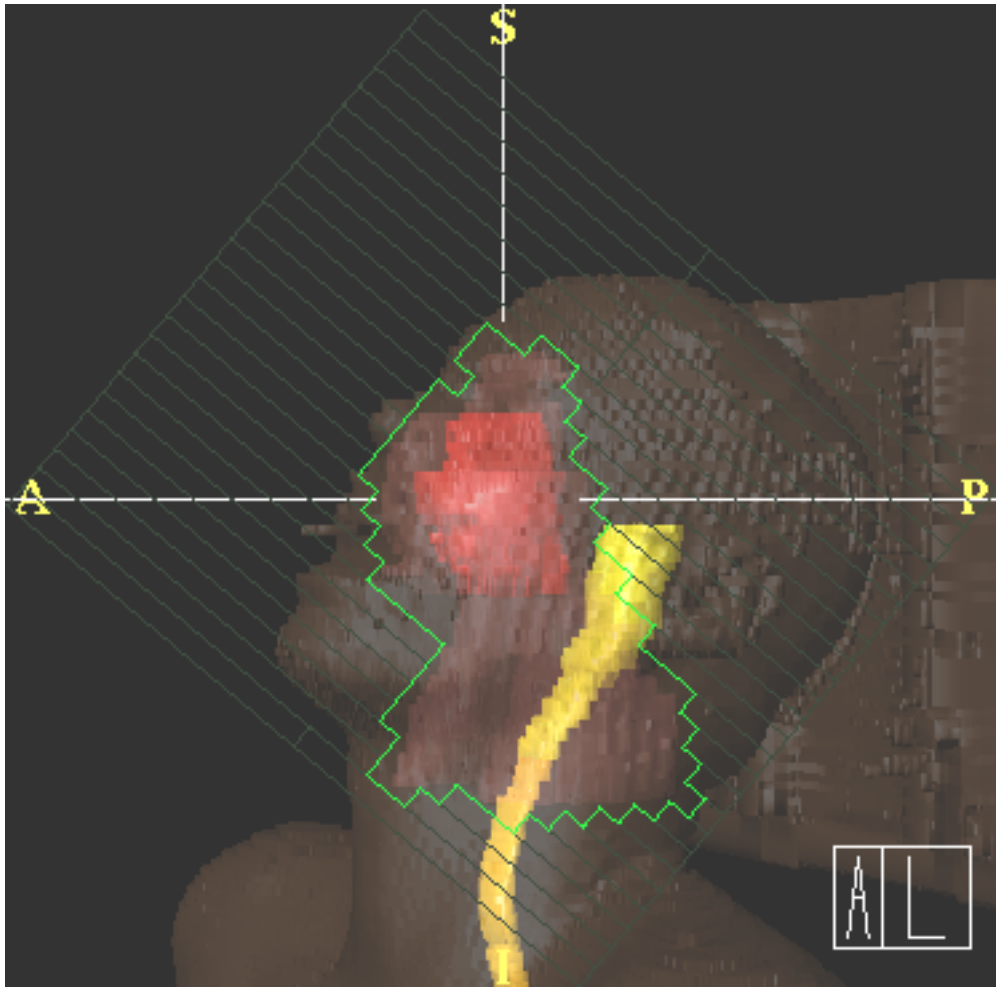
Beam Orientation

- Coplanar vs Non-coplanar
  - Ease of setup
  - Ease of planning
  - Speed of treatment
- Equi-spaced vs Selected angles
  - Entrance through table/immobilization device

Beam Orientation



Collimator Orientation



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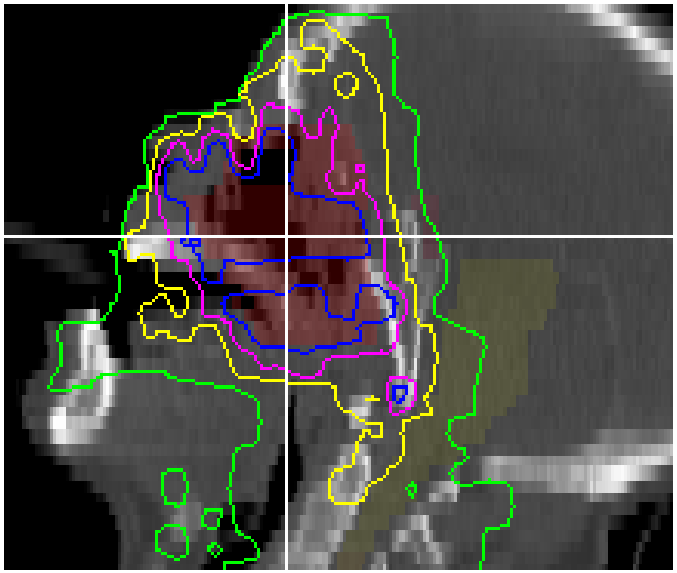
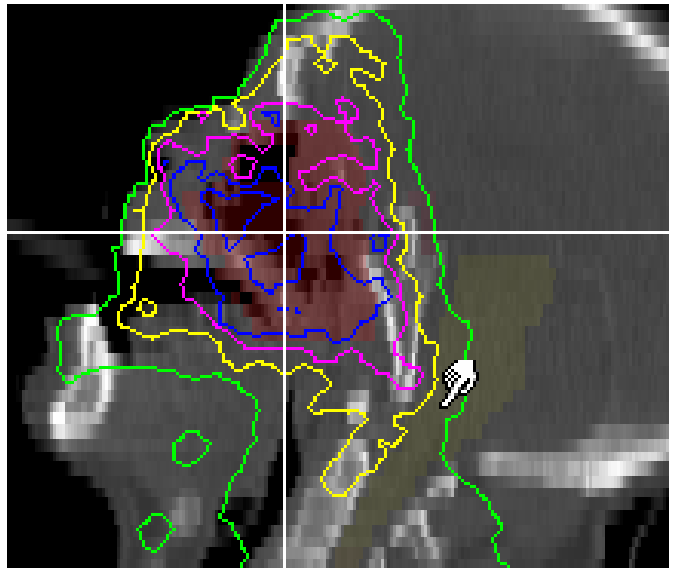
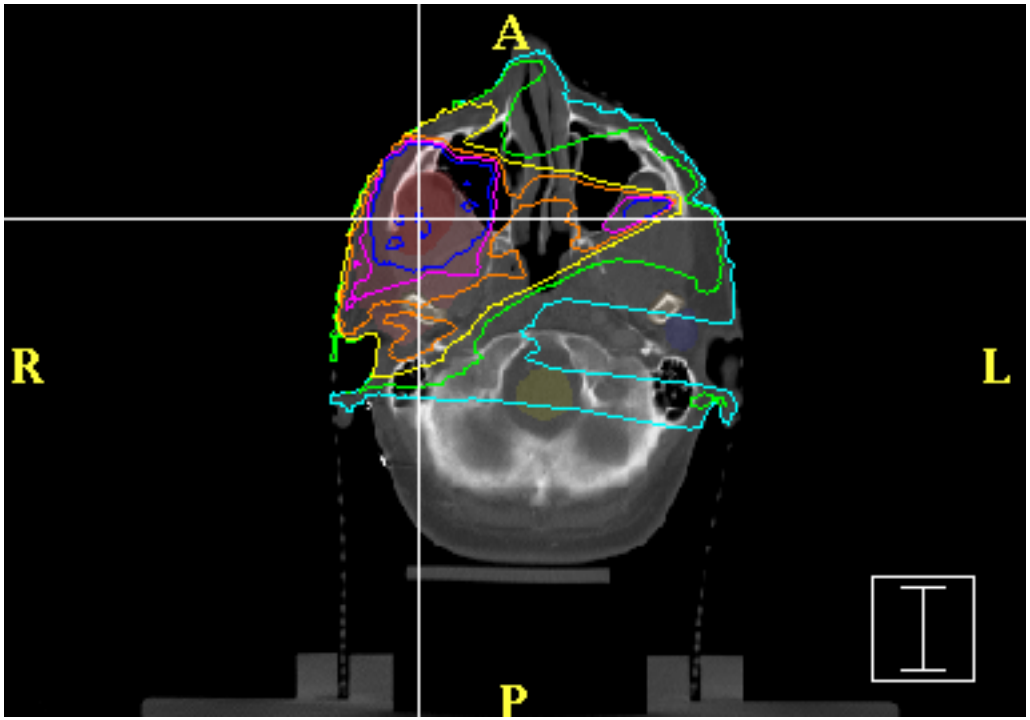




Tuning Structure

- A structure added just for the purpose of treatment planning
- Provides additional control over the dose distribution in IMRT plans
- Reduce normal tissue dose
- Reduce/Increase target dose

Tuning Structure



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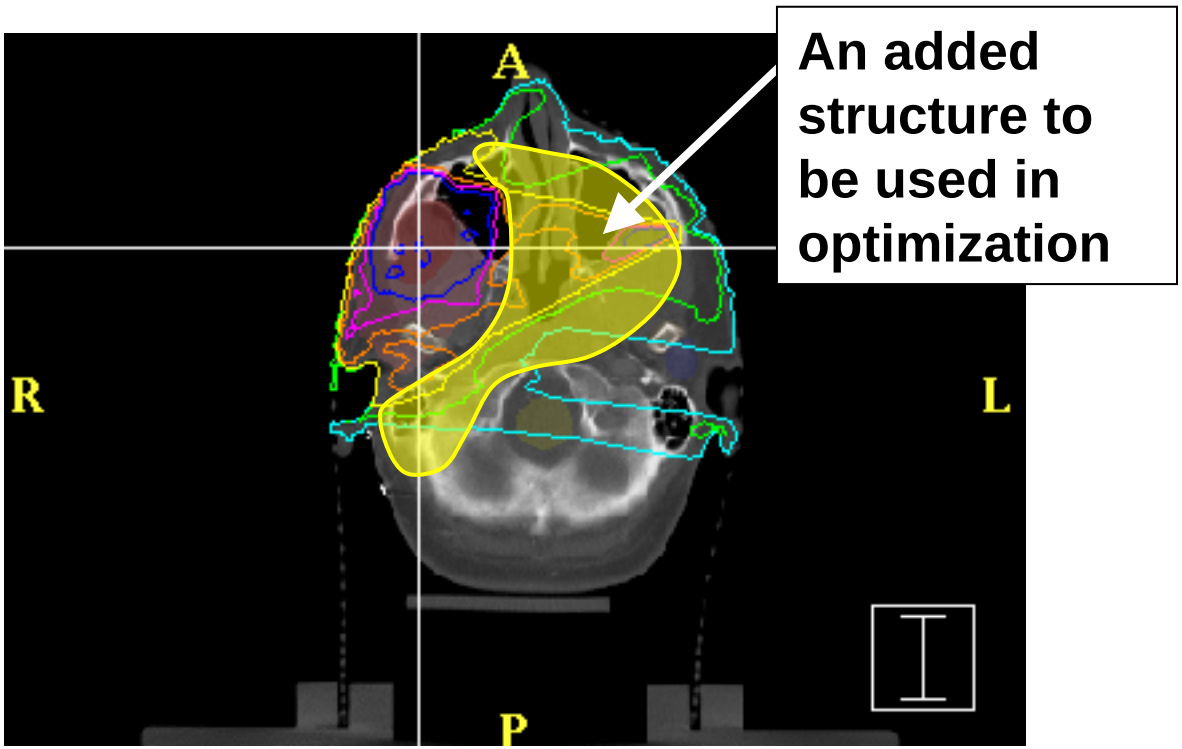
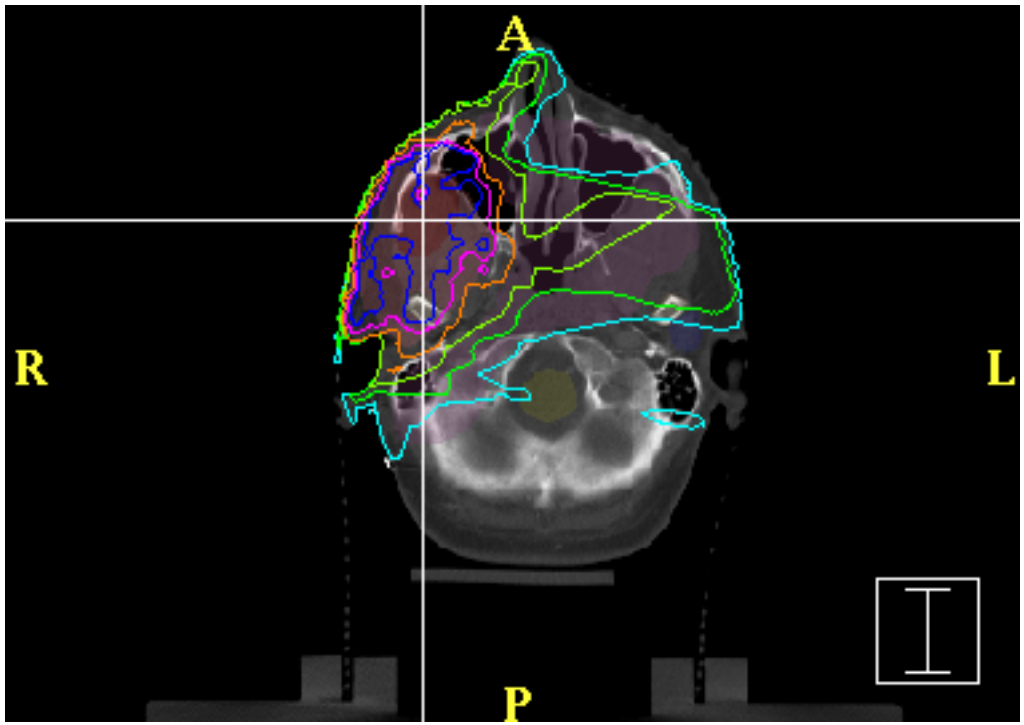
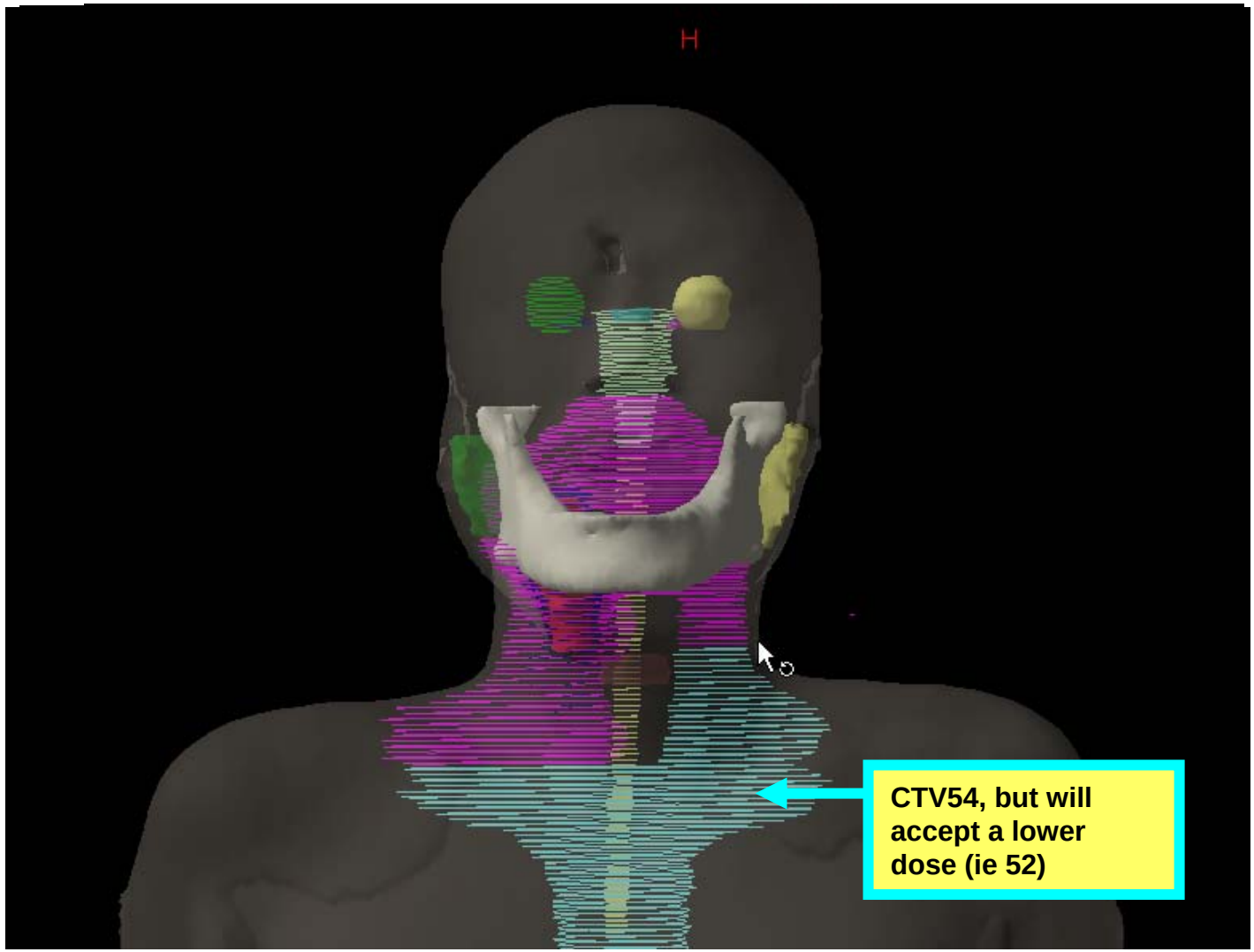


Tuning Structure



Tuning Structure



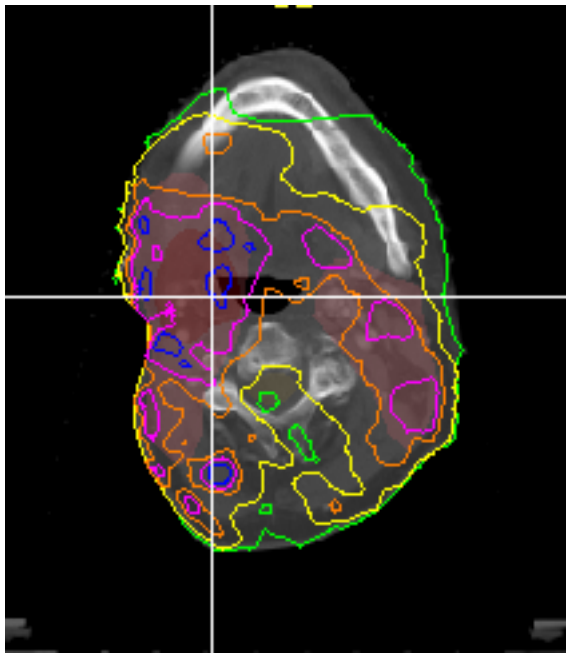
Isocenter Placement

Issues

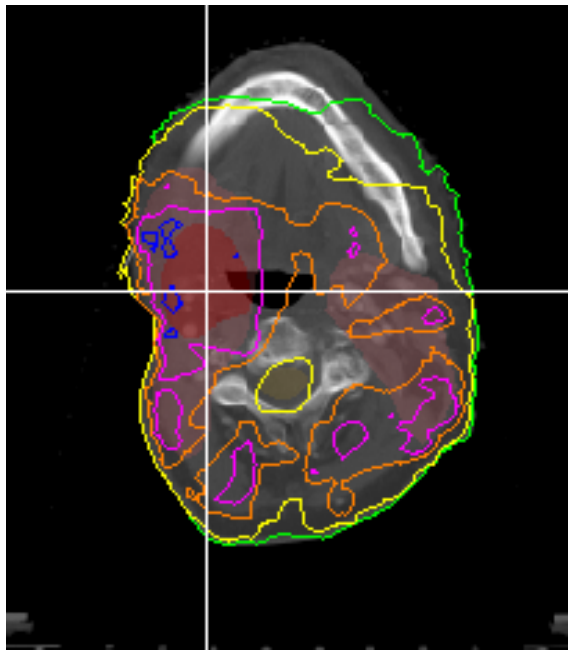
- Sometimes a better plan be achieved by selective isocenter placement
  - Center of GTV vs center of all targets
- Dosimetry and/or QA
- Patient setup
  - Isocenter in region of reliable bony anatomy

Isocenter Placement

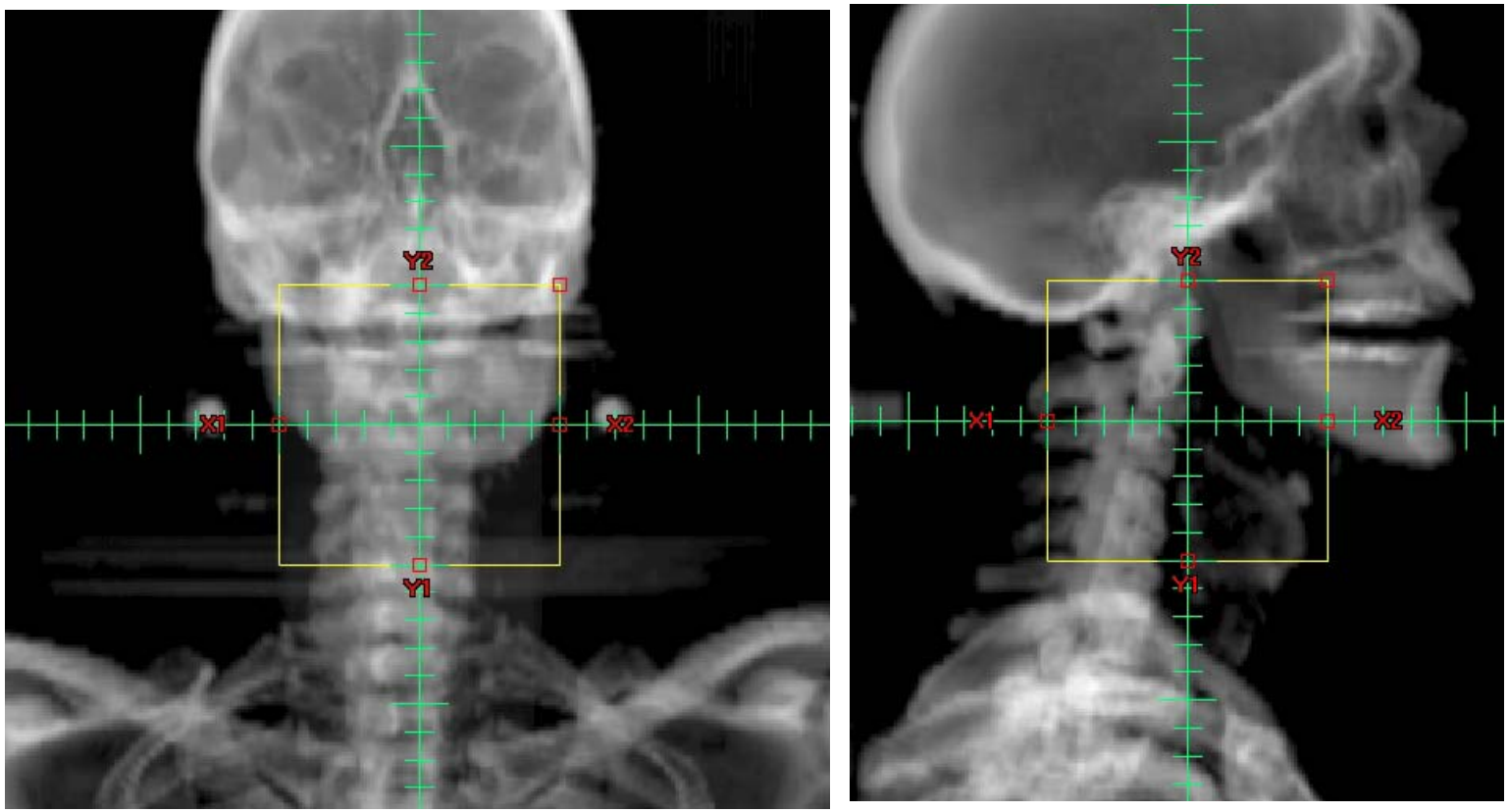
Isocenter in geometric center of targets



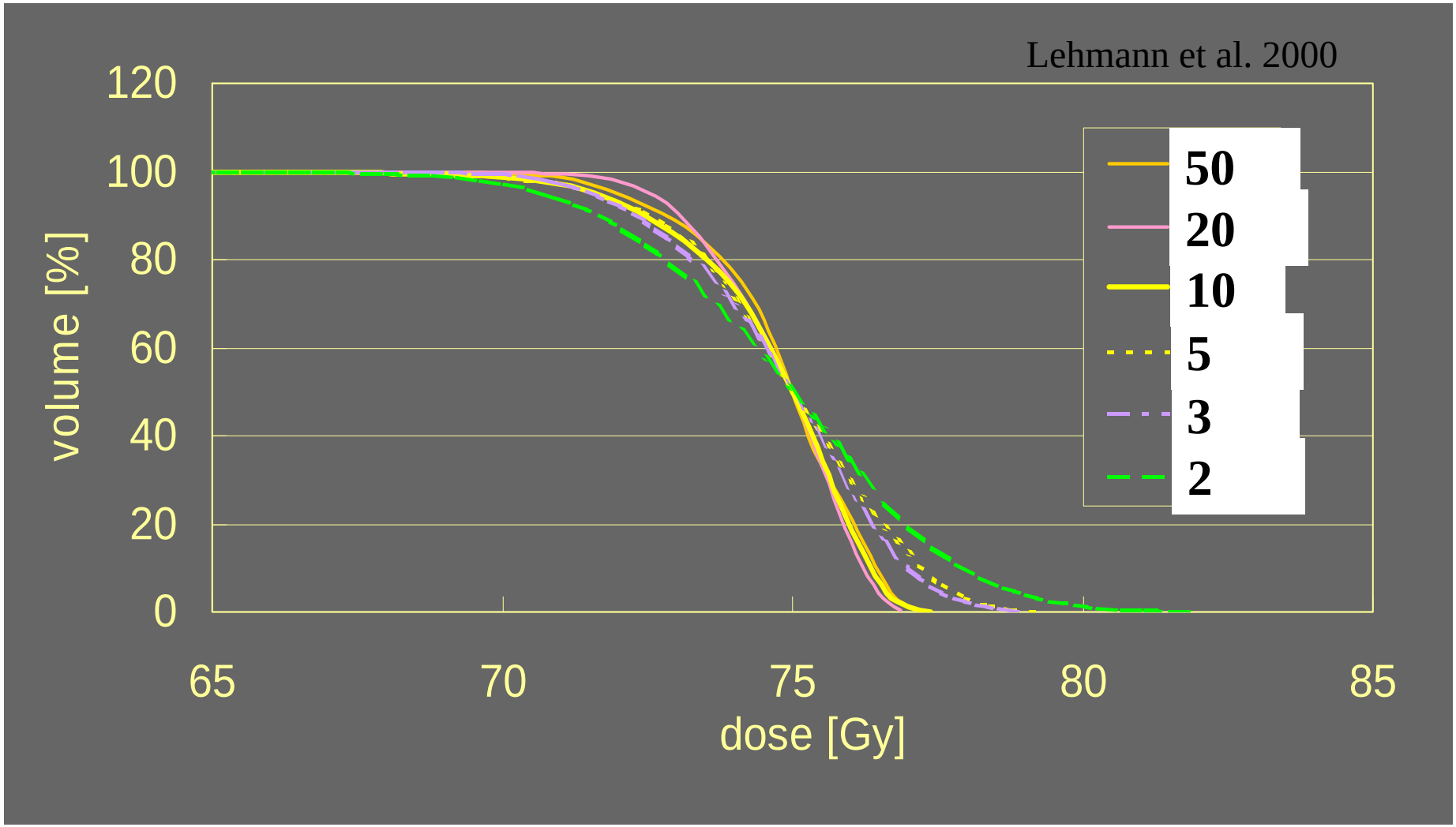
Isocenter in geometric center of GTV



Isocenter Placement

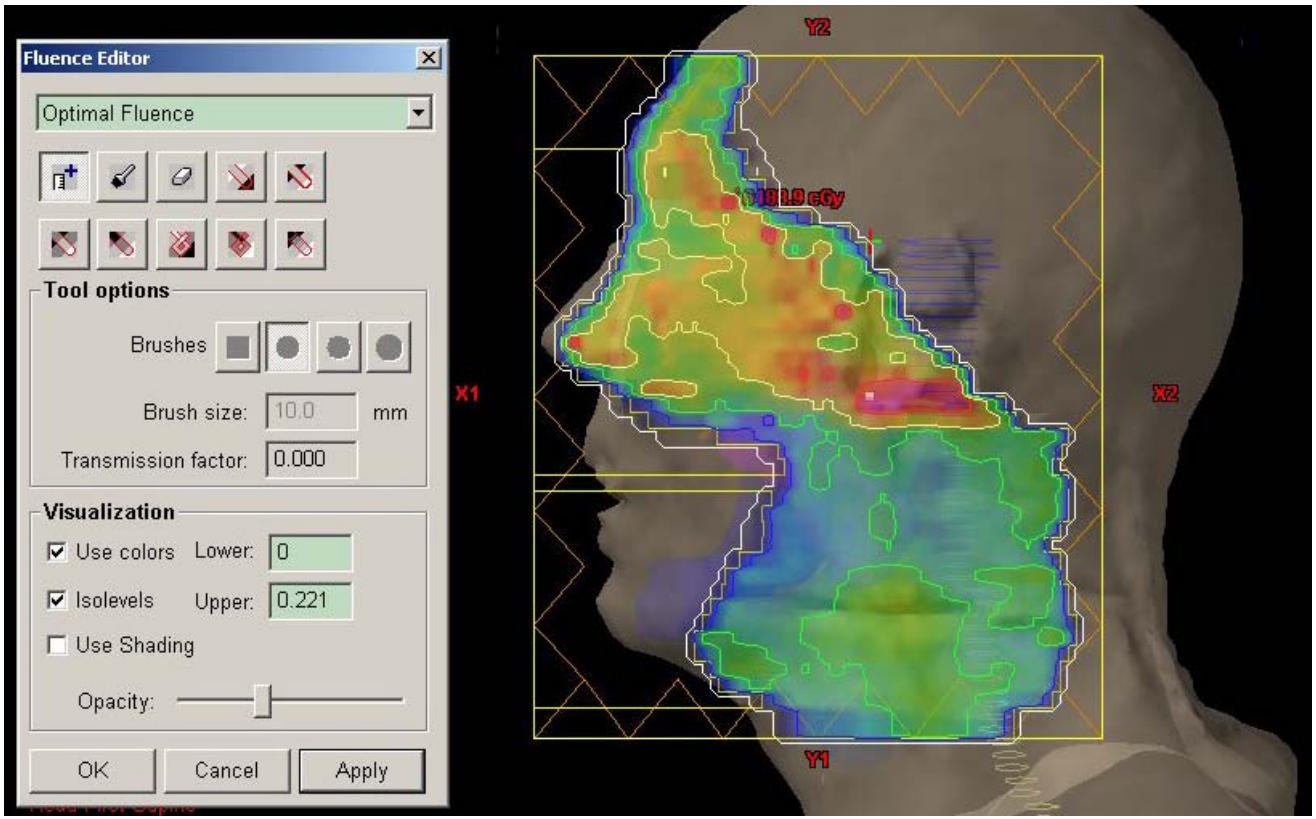


Number of Intensity Levels

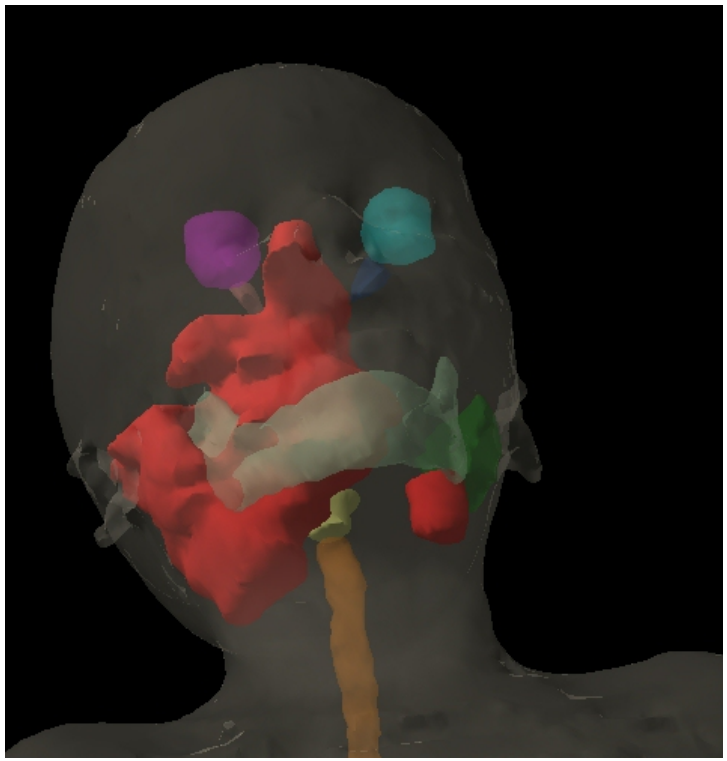


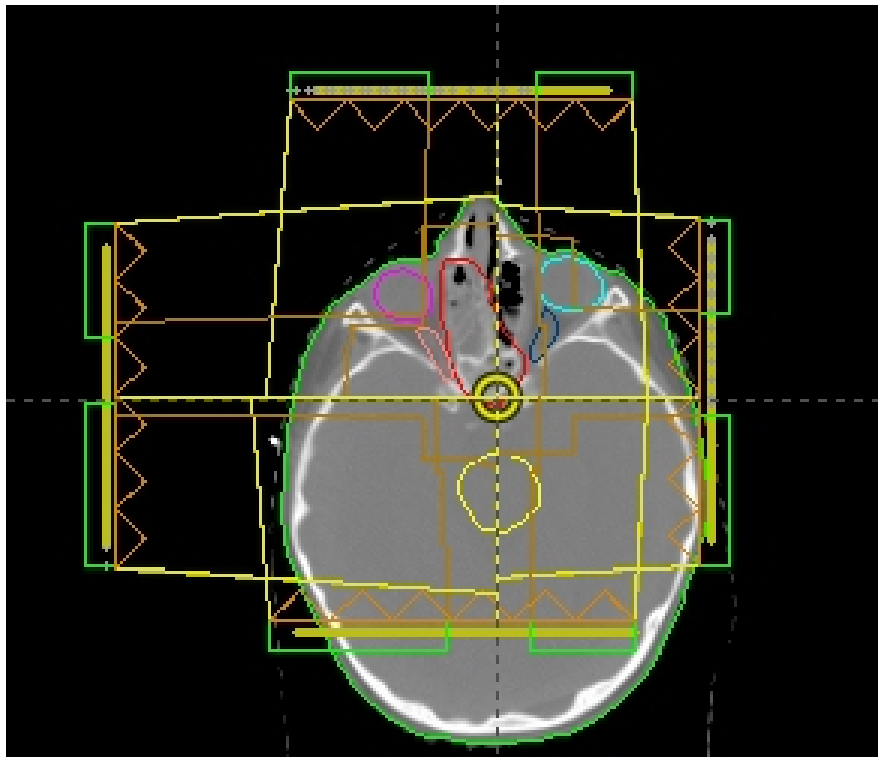
Direct Modification of Intensity Map

An option provided by some planning systems

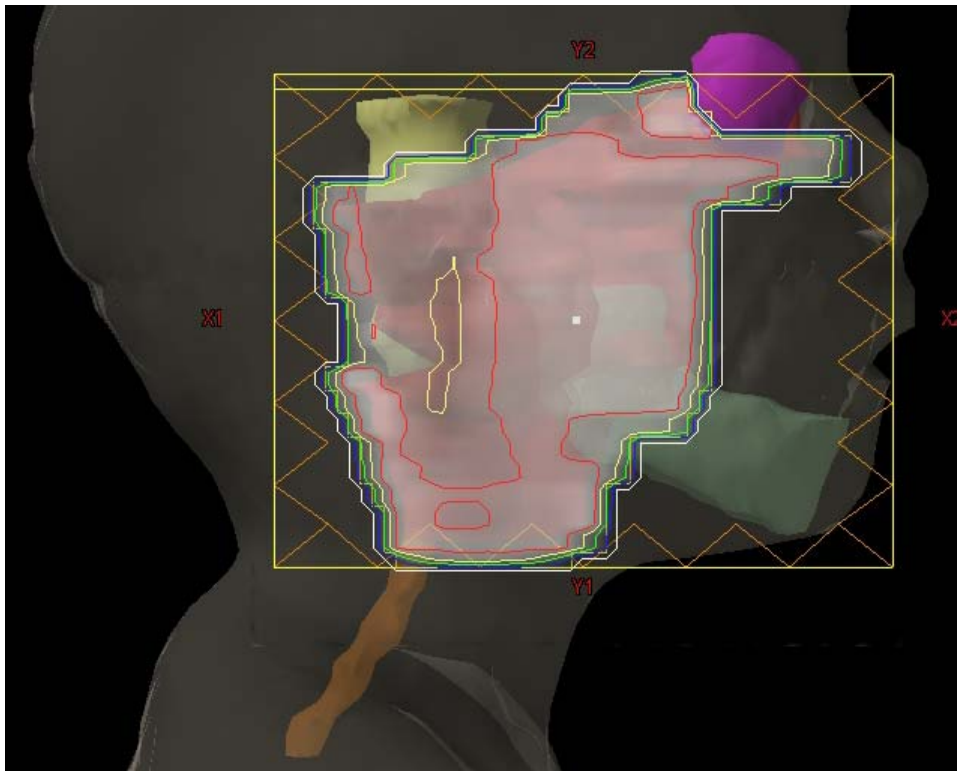


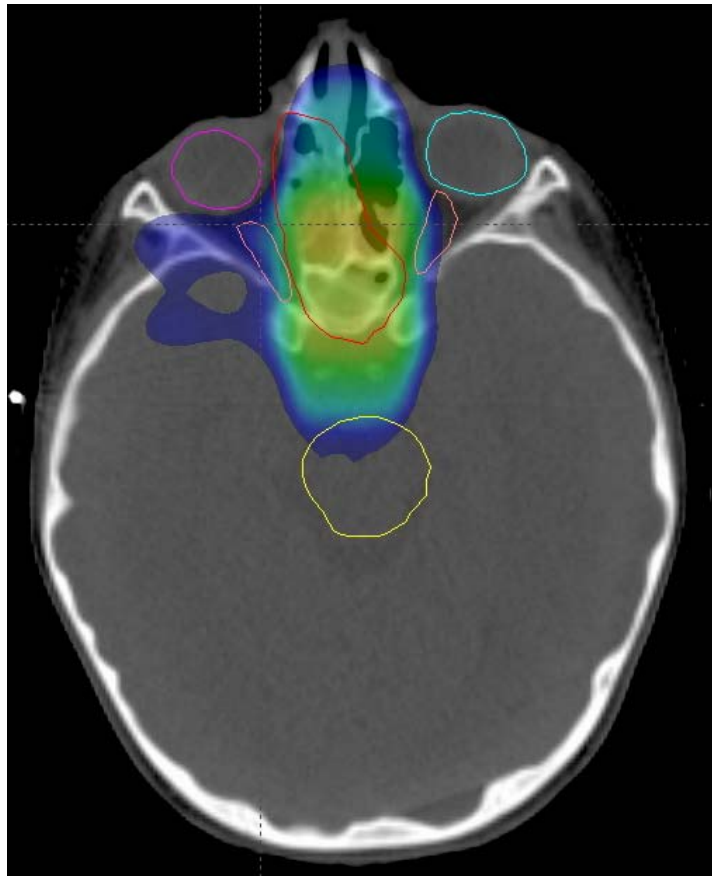
Direct Modification of Intensity Map





Direct Modification of Intensity Map

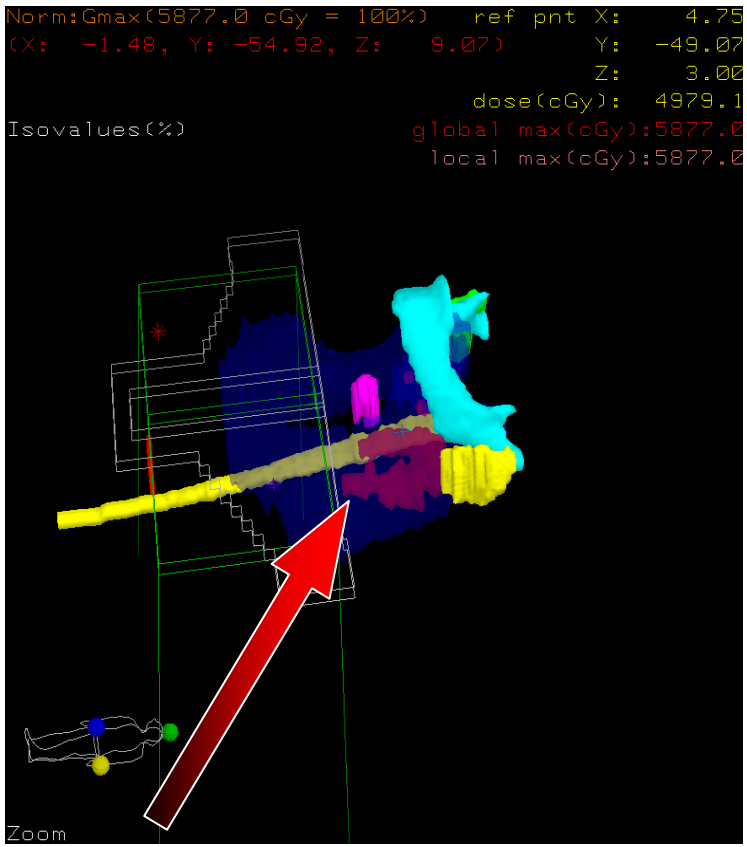




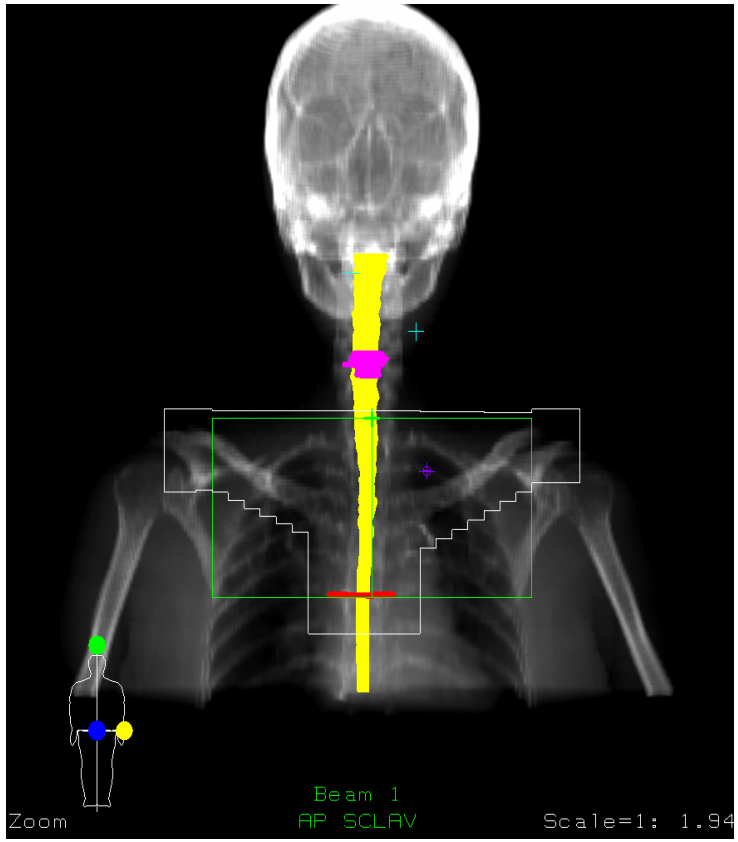
HN IMRT with Supraclav Nodes

- Treating nodes in IMRT
  - Eliminates junction issues
  - Requires extra care to immobolize shoulders
  - Do not treat the supraclav nodes through the shoulders
- Treating nodes with AP field
  - Requires a method to match the IMRT fields
  - Not advised for node positive cases
  - If possible, include SCV field in IMRT optimization

HN IMRT with Supraclav Nodes

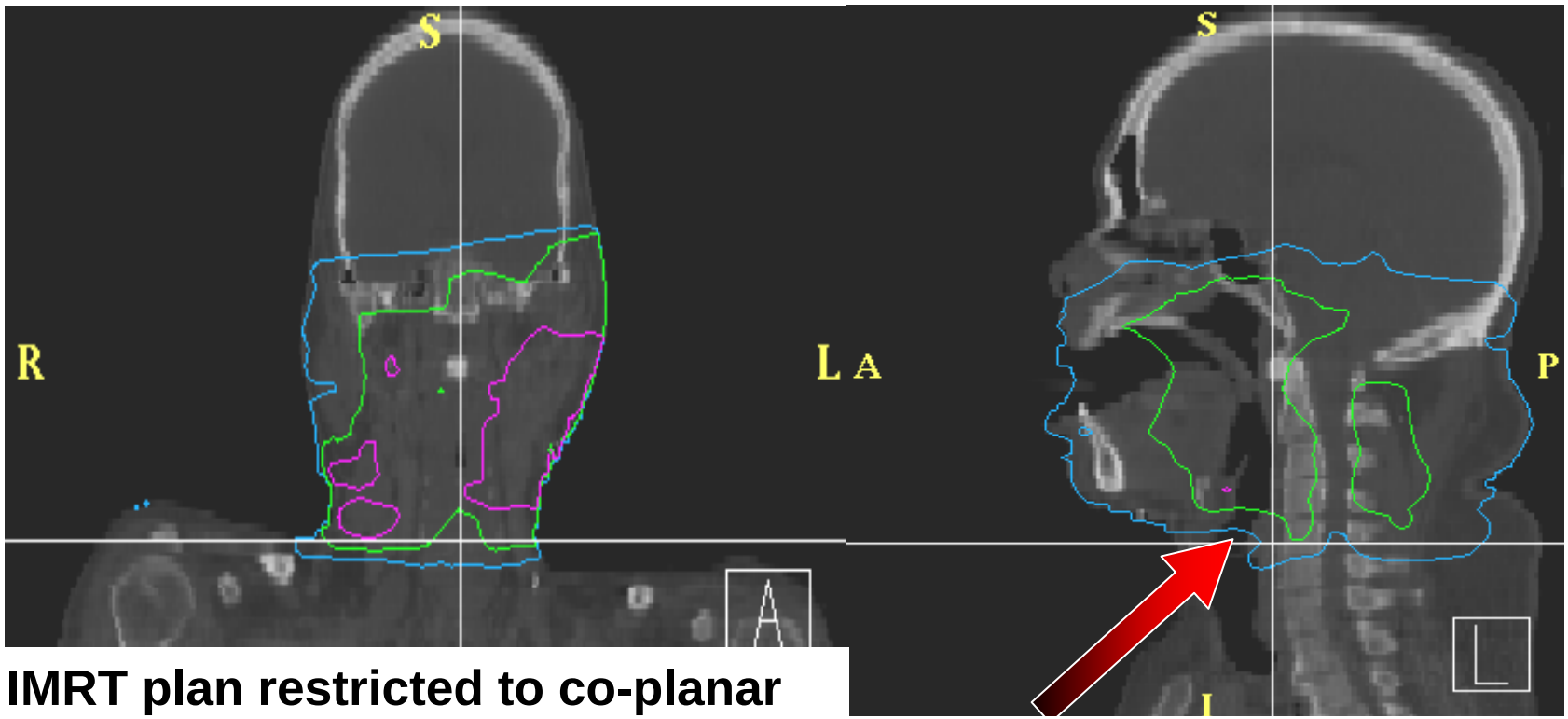


Matched below GTV



No need to contour nodal volumes for conventional technique

Matching IMRT to AP SCV (1)

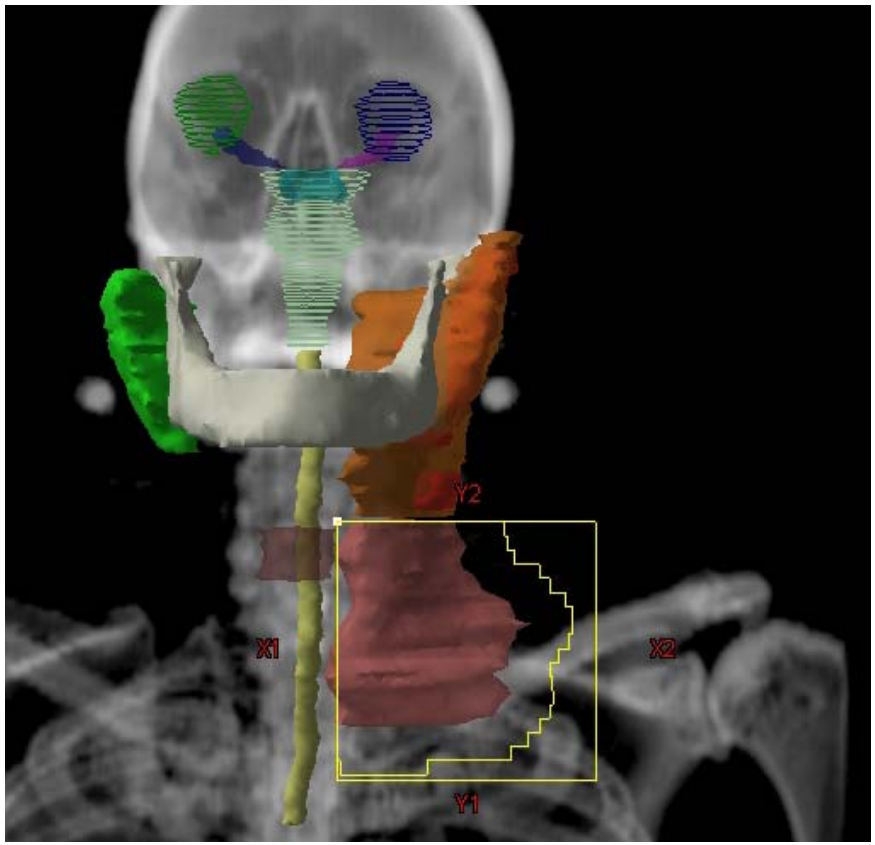


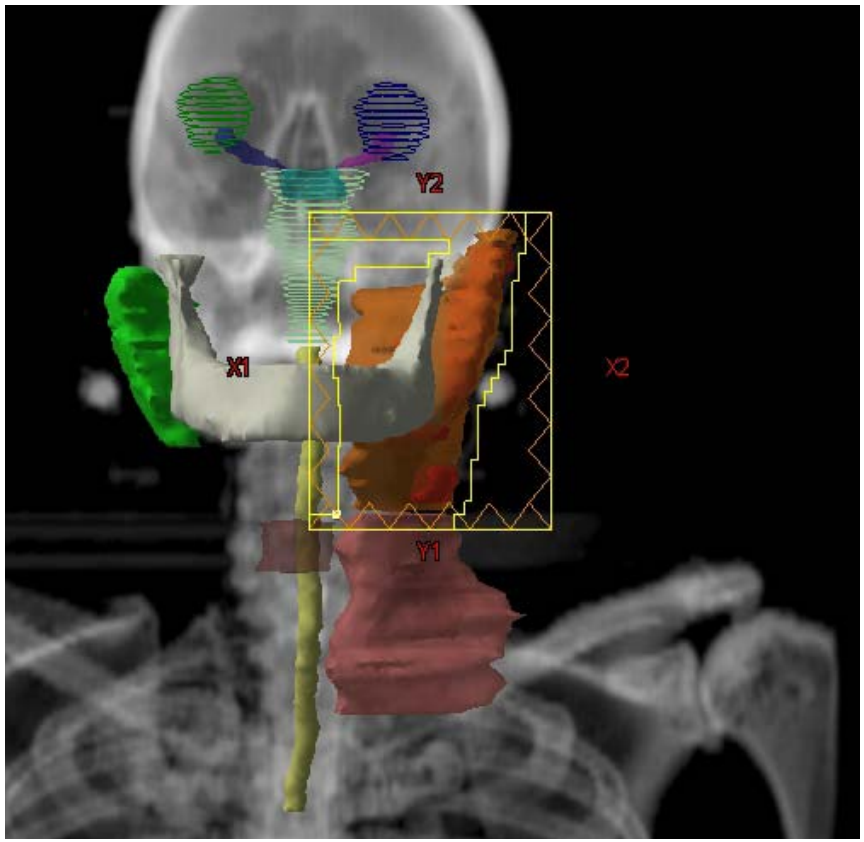
IMRT plan restricted to co-planar beams with standard collimator angle (Varian Col ∠ 180)

50% isodose line on IMRT plan – SCV match line is 2-3 mm inferior

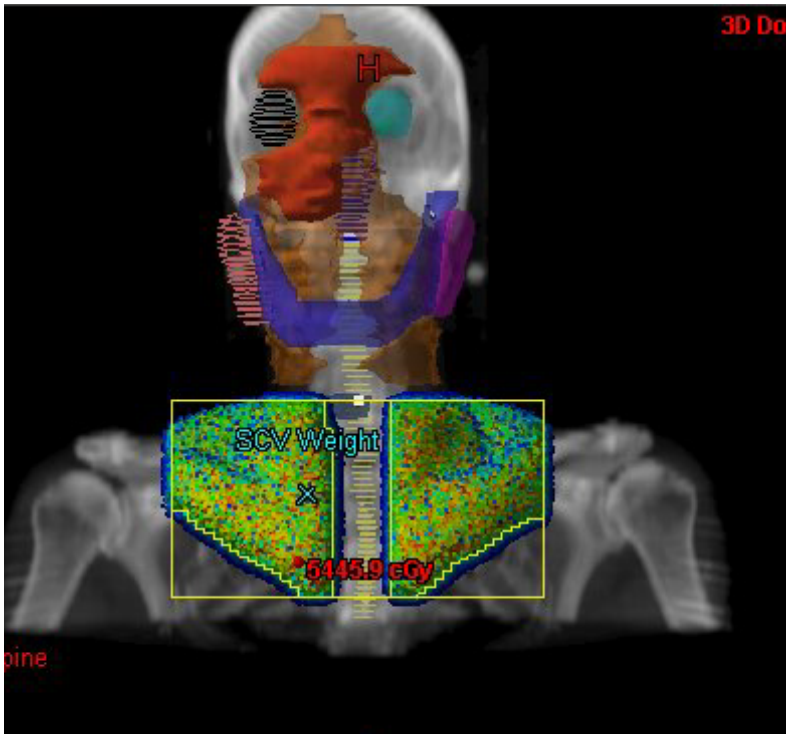
IMRT/AP SCV Single Isocenter

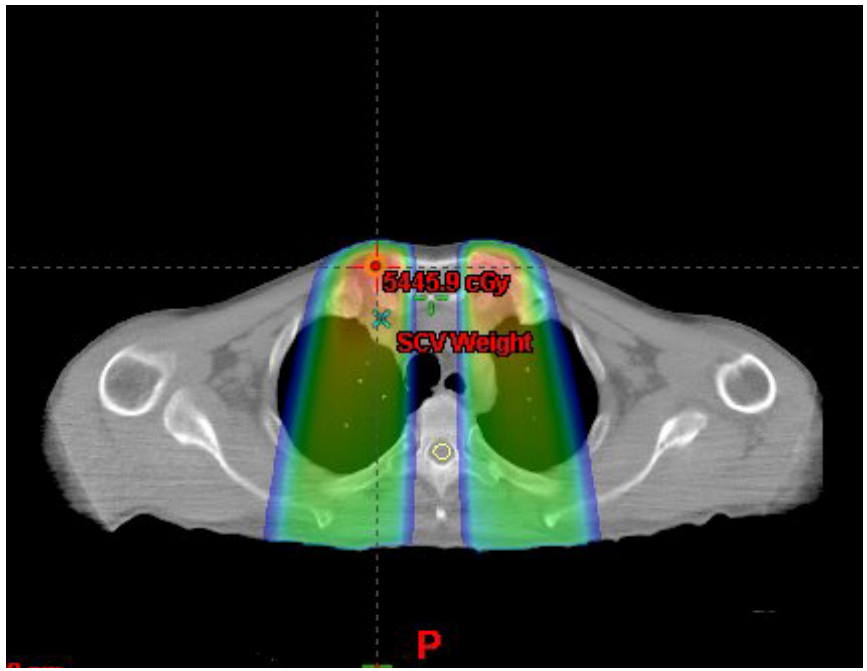
Li et al. Matching IMRT fields with static photon field in the treatment of head-and-neck cancer. Med Dosim. 2005;30(3):135-138.





Matching IMRT to AP SCV (2)



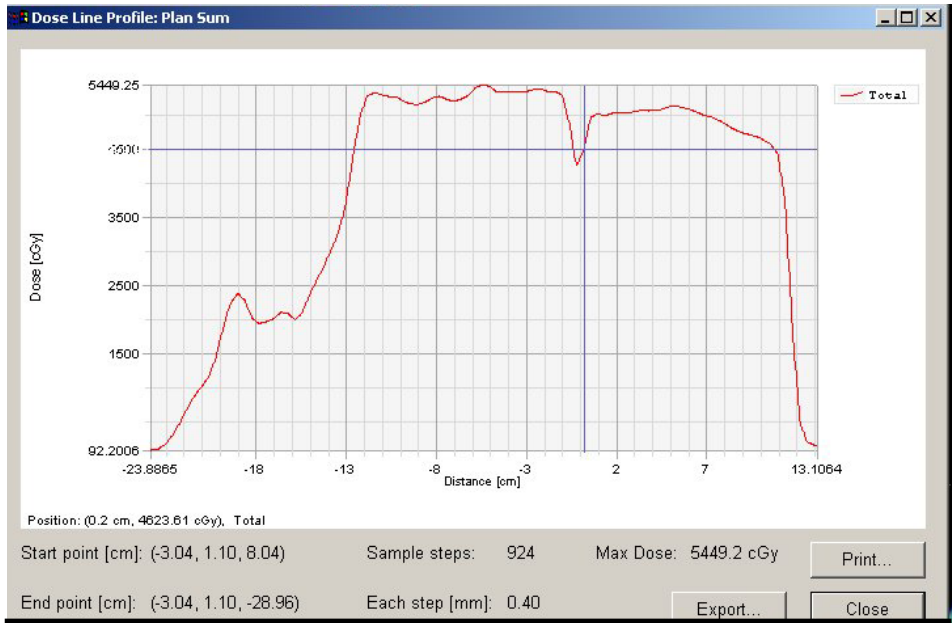


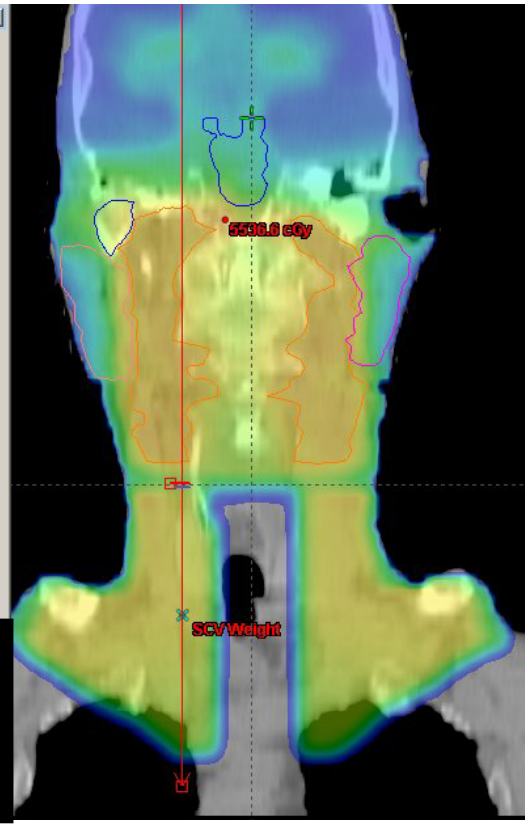
Include SCV field in optimization of IMRT plan.

Matching IMRT to AP SCV (2)

Sethi et al. Matching tomographic IMRT fields with static photon fields. Med Phys. 2001;28(12):2459-2465.

Duan et al. A dynamic supraclavicular field-matching technique for head-and-neck cancer patients treated with IMRT. Int J Radiat Oncol Biol Phys. 2004;60(3):959-972.





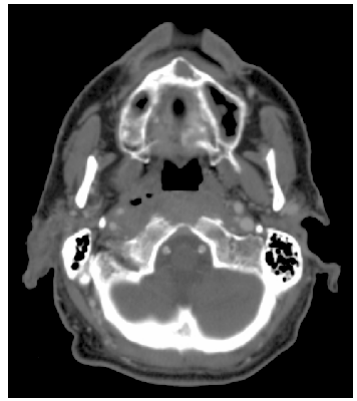
Flexibility to control hot, cold or feathered match-line.

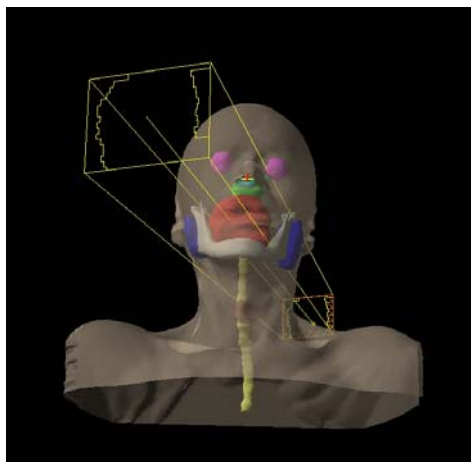
Final Comments on Treatment Planning

- Beam energy
  - 4 – 6MV is usually sufficient
  - Sometimes a higher energy PA beam can help to cover supraclav nodes and reduce posterior hot spots
- Skin dose
  - Immbolization masking systems can act as a bolus to produce a severe skin reaction

Outline

1. IMRT for HN cancer
2. Immbolization
3. Tissue segmentation
4. Treatment planning
5. **Plan evaluation**
6. Summary





Plan Evaluation

- When the planning is “finished”
  - The worst thing you can do
- What are achievable doses
  - An average of 10 HN cases
- Final comments

When The Plan is Finished

- Do not allow the physician to review the plan alone
- Talk through the plan with the physician
  - What is good and bad about this plan?
  - Why did you use those beam angles?
  - Why underdose parts of the target?
  - Why can’t you spare more normal tissue?
- You have to intrude on the physician’s decision making process as much as possible

About Plan Evaluation

- A plan may produce a maximal point dose that exceeds the so-called tolerance dose for a critical structure
- It is important to review the DVH to determine how much of the critical structure volume receives doses exceeding the specified limit
  - In many cases, it only correlates to a few voxels and may be acceptable

About Plan Evaluation

- Hot and cold spots must be identified using the isodose curves on a slice-by-slice basis
- The decision on hot spots should be individualized based on other clinical considerations
  - Previous treatments the region
  - Medical co-morbidities and the use of concurrent chemotherapy

Normal Tissue Constraints

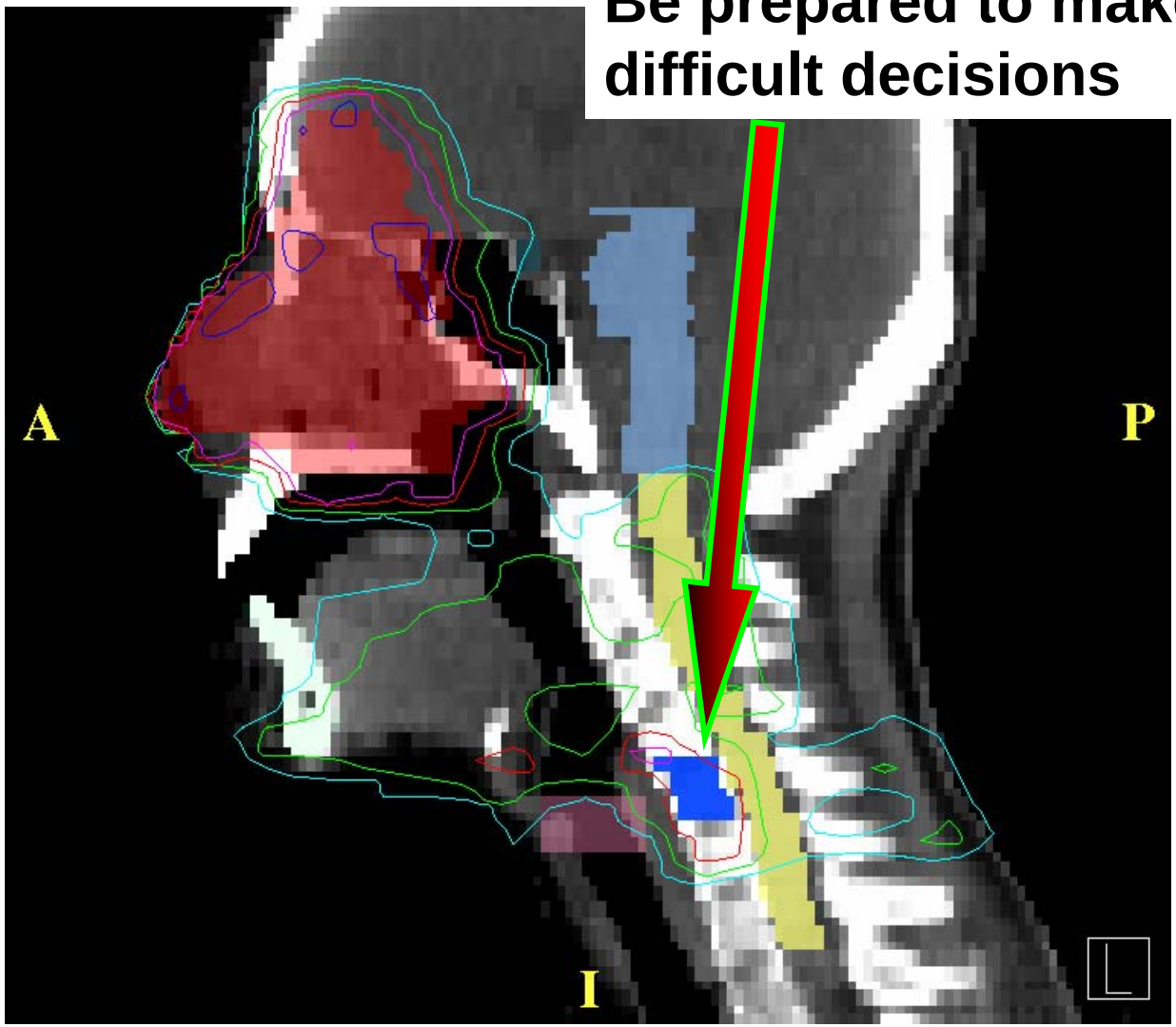
- Optic apparatus < 45Gy max dose
  - Lens < 4-6Gy
- Spinal cord < 45Gy max dose
- Brainstem < 50Gy max dose
- Parotids < 26Gy mean dose
- Oral cavity < 30-40Gy mean dose
- Mandible < 40Gy mean (< Rx Gy max)
- Larynx < 30Gy mean dose

Use All Information Provided By The Planning System

Examples

- 3D structure/dose display for max dose
  - Software search for maximum dose in plan
- Sagittal/coronal isodose display
- Dose profiles
- Color wash

Be prepared to make difficult decisions



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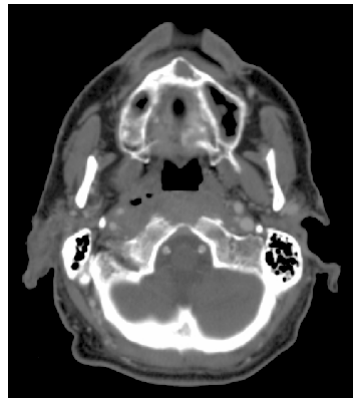

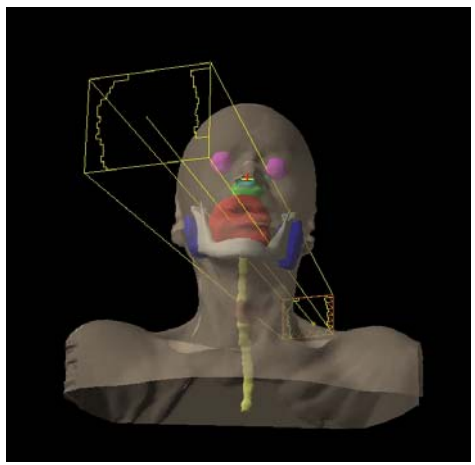

Final Thoughts

- The risk of secondary malignancies is not zero
  - Relative to co-morbidity and the patient's life style
- Setup uncertainty changes the position and magnitude of hot spots
- Recurrences are mainly in the high-dose regions
- Refinements in the IMRT technique are ongoing
- Real-time adaptive IMRT based-on tumor changes is still in the future

Final Thoughts

- In 2002, approximately 1/3 of the radiation oncologists use IMRT
- In 2004, approximately 3/4 of the radiation oncologists use IMRT
- Implementing IMRT in a community does not require a prohibiting amount of resources