IMRT for H/N Cancer

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Outline

- IMRT for HN Cancer
- Immbolization
- Multi-modality imaging
- Treatment planning
- Plan evaluation

Why IMRT for HN Cancer

- Complex anatomical region
- Inadequate 3D planning techniques
- Absence of organ motion
- Indications and contra-indications

Complex Anatomical Region

- Optic nerves and chiasm
- Spinal cord, brainstem
- Parotid glands
- Oral cavity
- Temporal lobes
- Mandible, TMJ
- Eyes, Lenses
- Larynx, …

Inadequate Conventional Planning

- Opposed lateral photon beams
- Off-cord electron field
- Questionable dosimetry at photon-electron beam matchline
- Little normal tissue sparing

Absence of Organ Motion

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

Indications and Contra-Indications

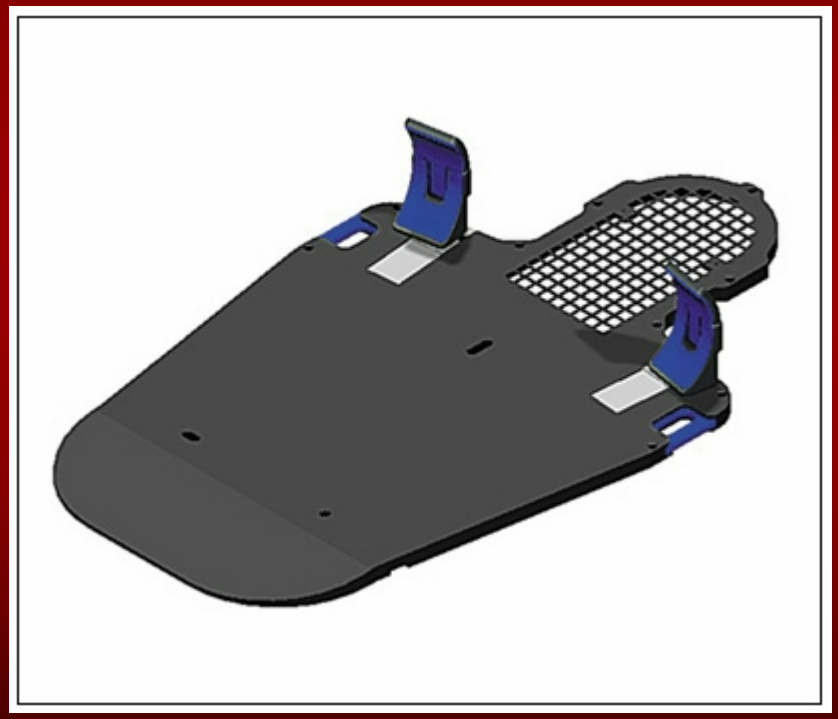
- Cooperative patients
  - No claustrophobia, resting tremors, etc.
- Reduce normal tissue complications
  - Conformal avoidance
- To escalate dose escalation
  - Improve local-regional control
- Avoid unwanted field junctions

HN Immbolization

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

Immbolization Options

("Active")



Immbolization Options

("Passive")

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

Immbolization Options
("Passive")

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

Aspects of Imaging

- Target volumes
- Normal tissues
- Image fusion

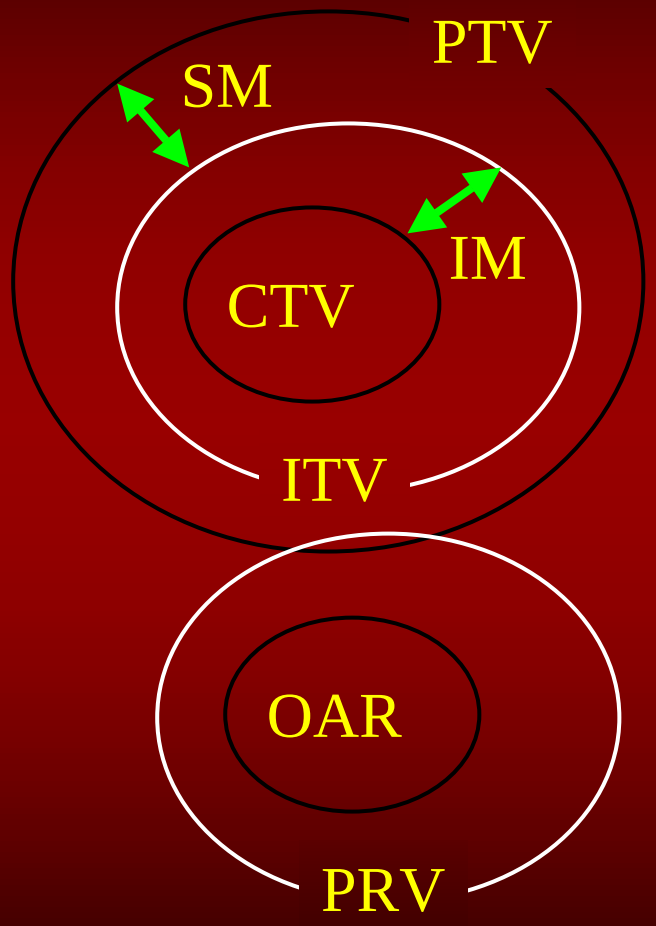
Target Volume Delineation
ICRU 50

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

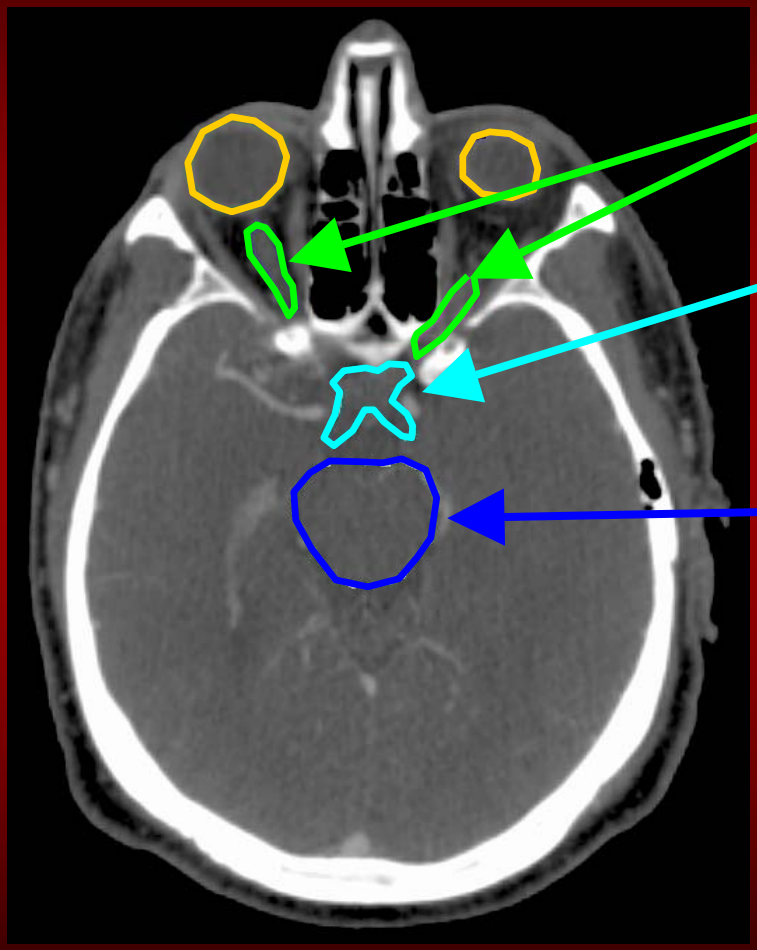


Consistent with ICRU Definitions

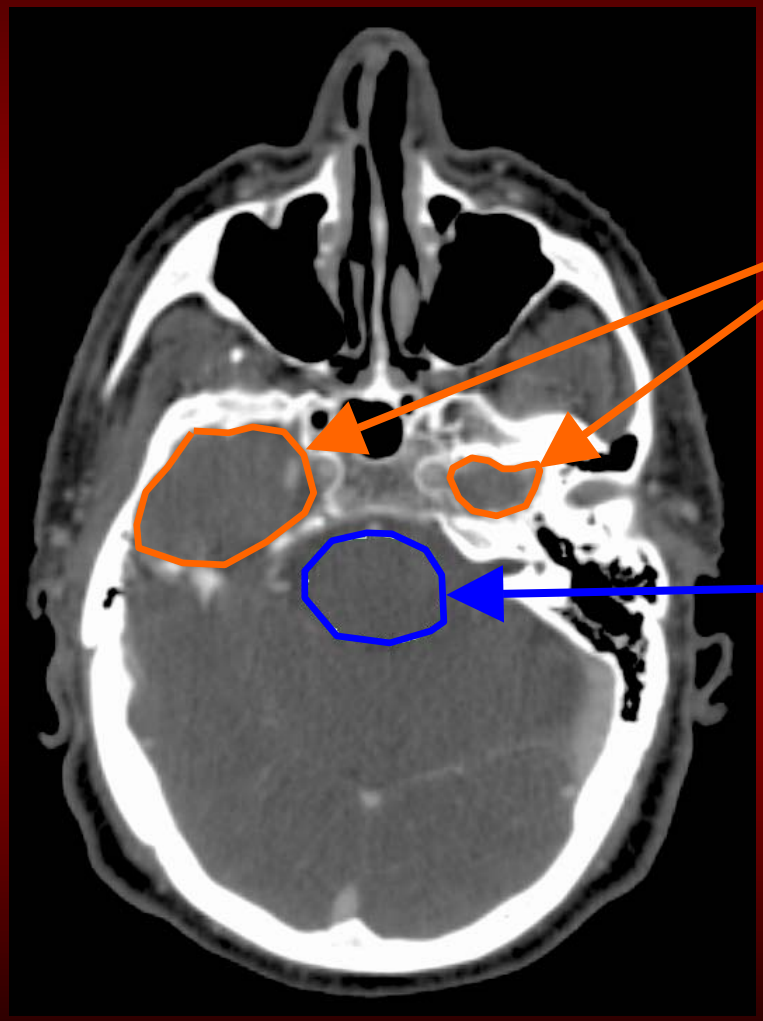
For multiple targets

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

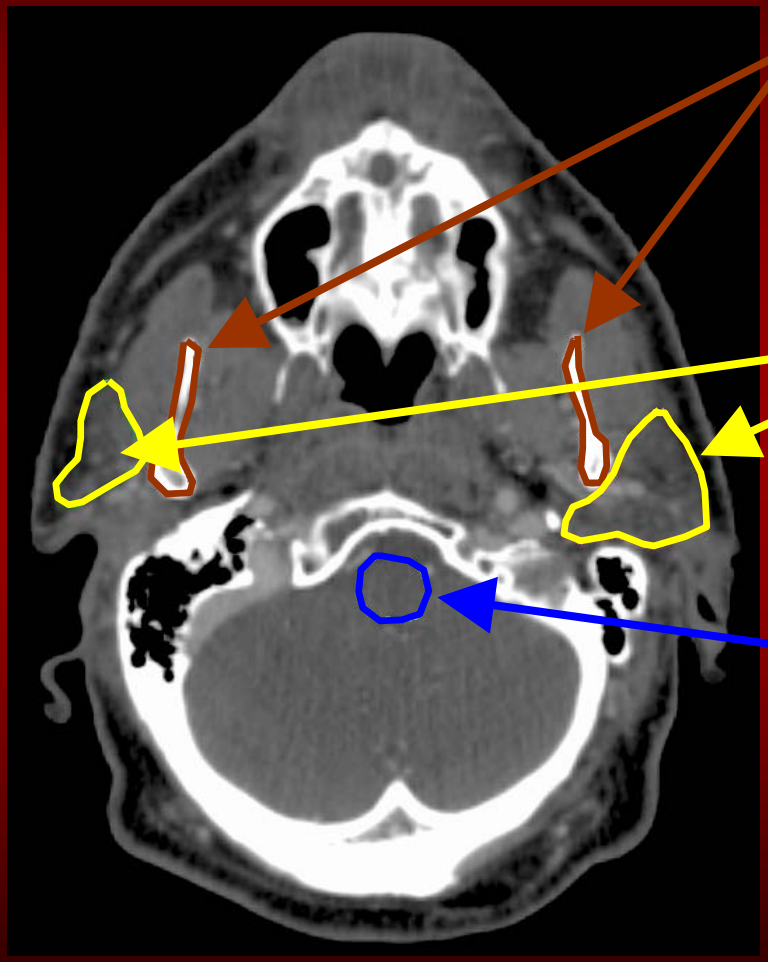
CT Anatomy – Head



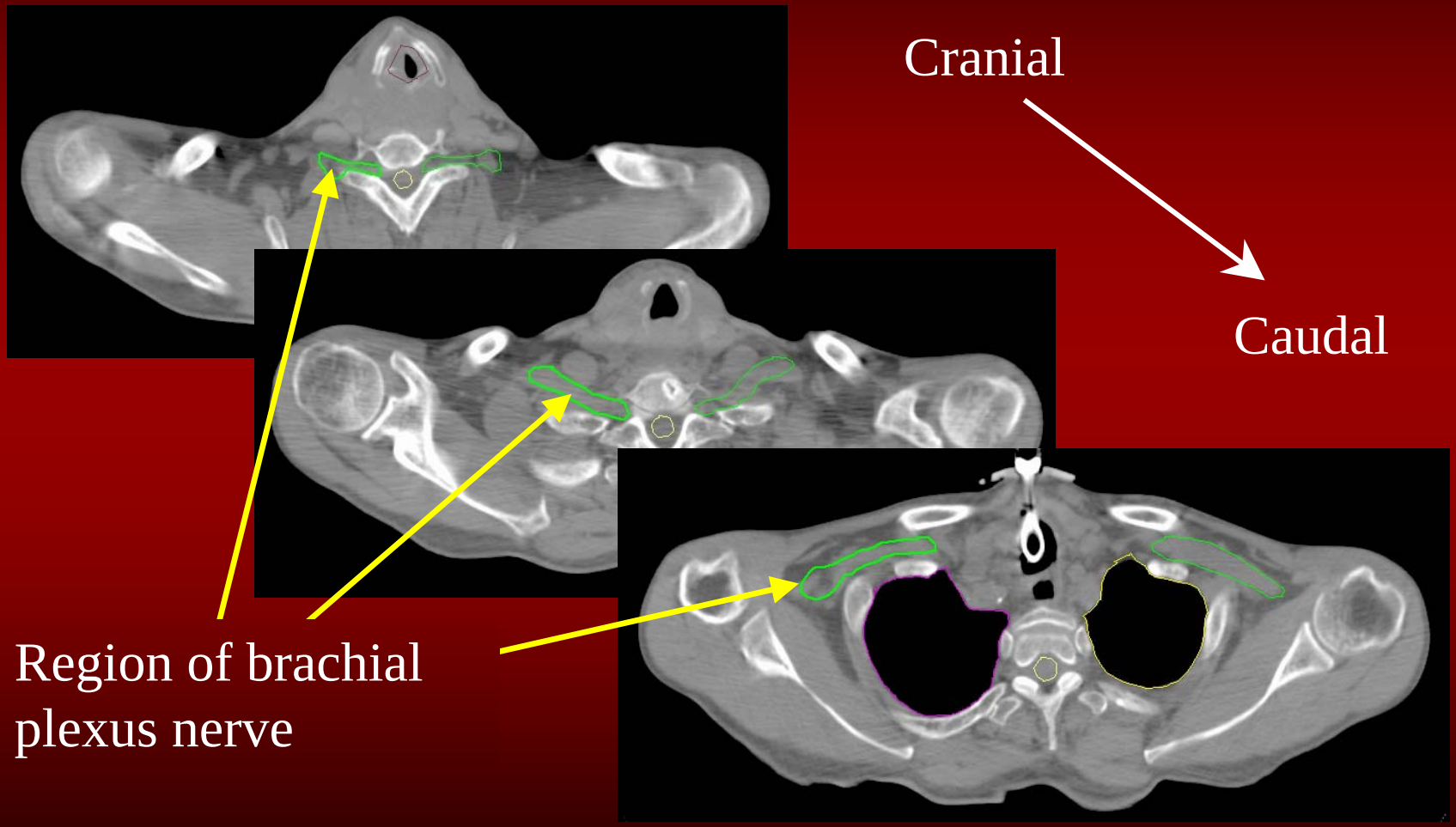
CT Anatomy – Head



CT Anatomy – Head



CT Anatomy – Neck



CT/MR Anatomy

Primarily used for target delineation

PET Images

- ^{18}FDG PET/CT images can be used to identify positive neck nodes
  - These images lack anatomic definition
  - Not always useful for defining the primary tumor
- Generally, use PET to define the *location* of gross tumor
  - Then use CT to contour the extent of gross tumor

Multi-modality 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

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 boosts vs. cone down plans?

IMRT Planning

- Same primary targets as with 3DCRT
- Regional therapy requires specific identification of nodes
- Simultaneous boost
  - Lower regional dose per fraction
  - Example, 30 fxs where GTV gets 2.2Gy/fx and nodes get 1.8Gy/fx
- Sequential boost
  - Same dose per fraction for GTV and Nodes
  - Requires two plans

Physician Communication

(plan expectations)

- 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

(or understand what your physician will accept)

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.

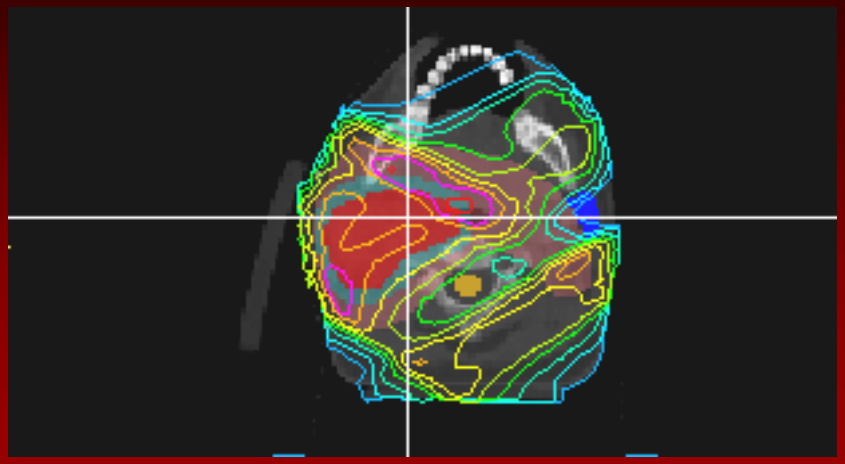
IMRT Planning Parameters

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

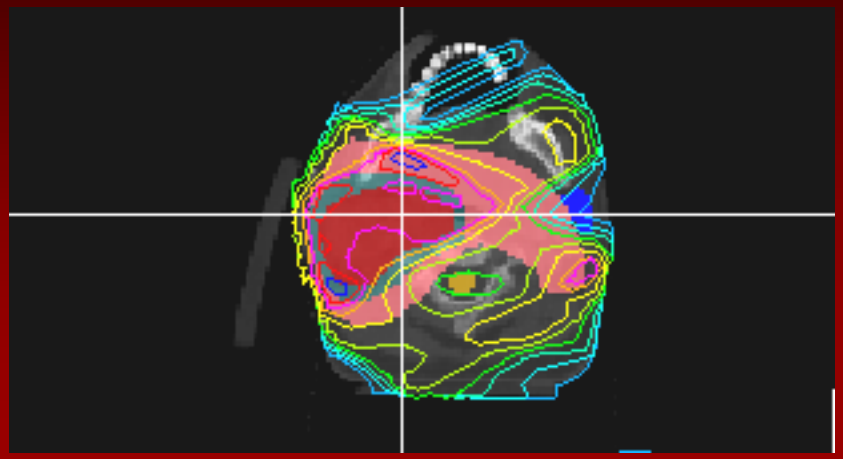
Number of Beams

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

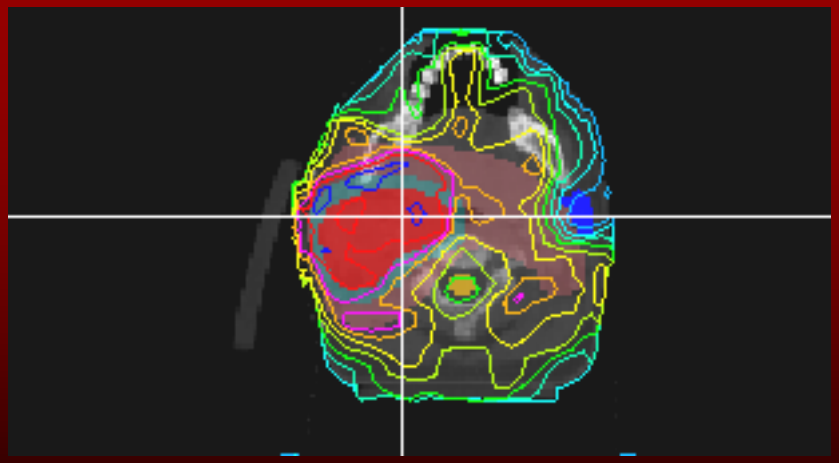
3 – Field



5 – Field



7 – Field

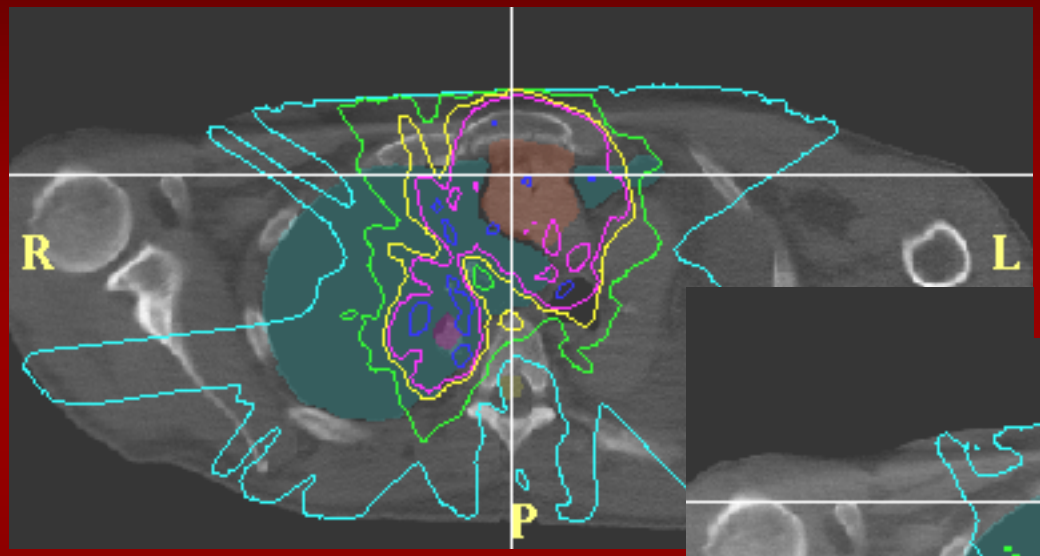


Beam Orientation

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

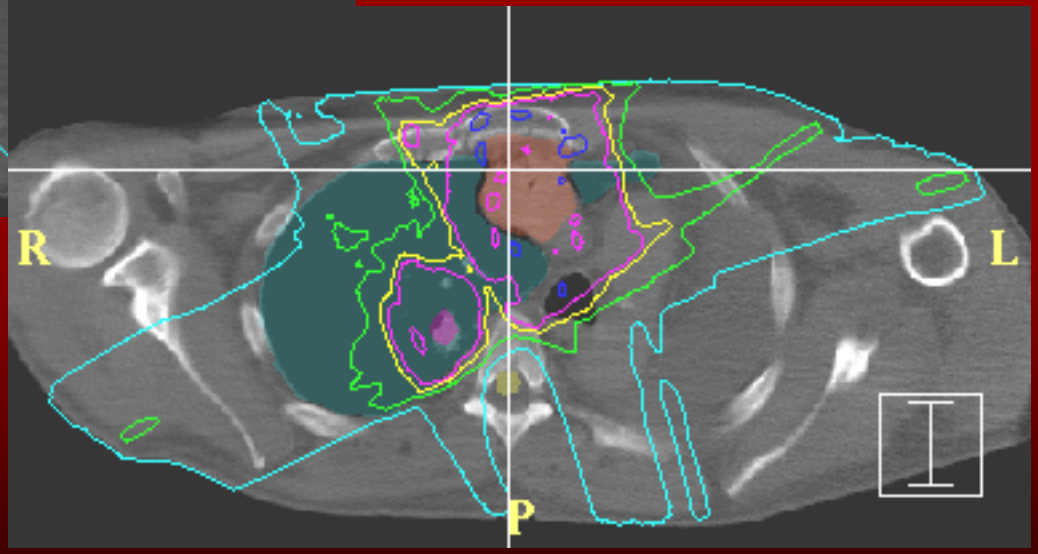
Beam Orientation

9 equi-spaced beams

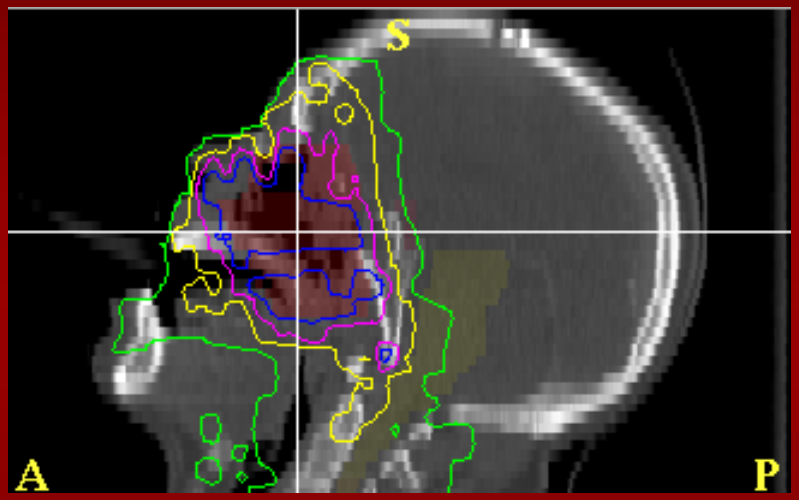


Both plans have the same optimization parameters

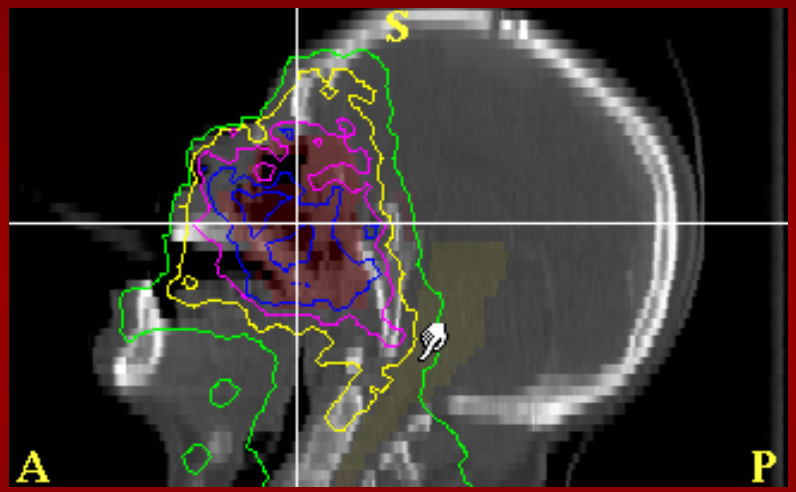
9 selected beam angles



Collimator Orientation



180º collimator angle

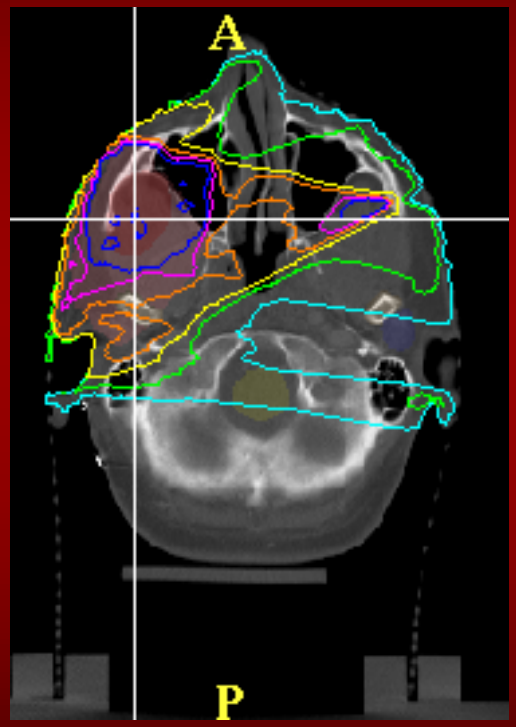


Collimator angle with leaf travel direction perpendicular to the brainstem/spinal cord

Tuning Structure

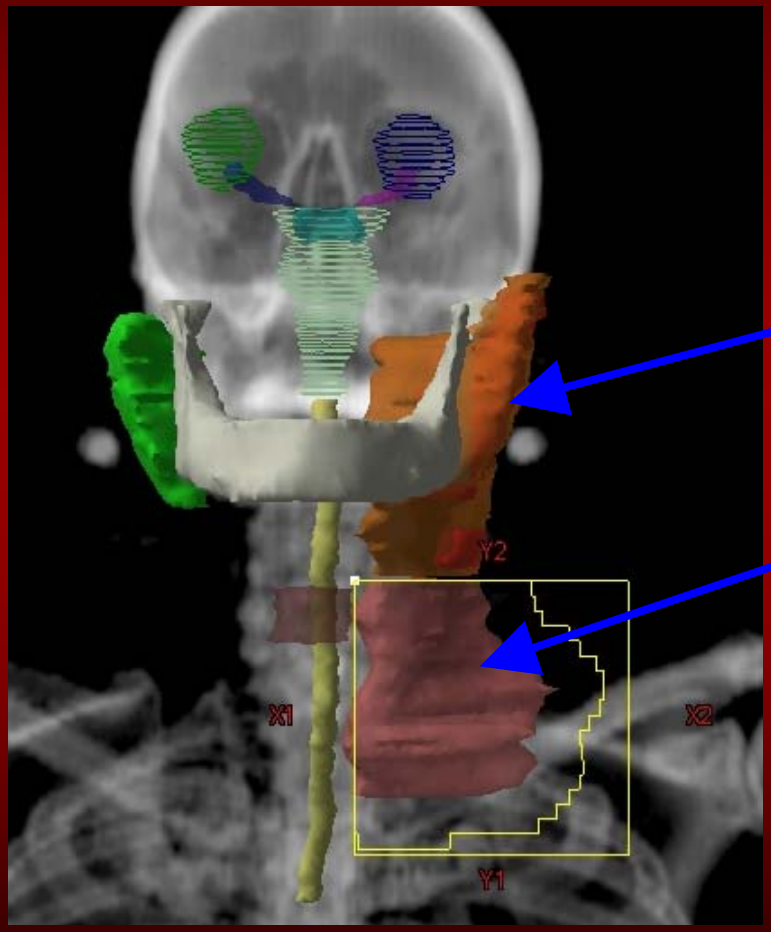
- A structure added just for the purpose of treatment planning
- Provides additional control over the dose distribution in IMRT plans
- Reduce normal tissue dose
- Reduce/Increase target dose

Tuning Structure



An added structure to be used in optimization

Tuning Structure



Split CTV into upper region (including GTV) and lower region to control dose new clavicles

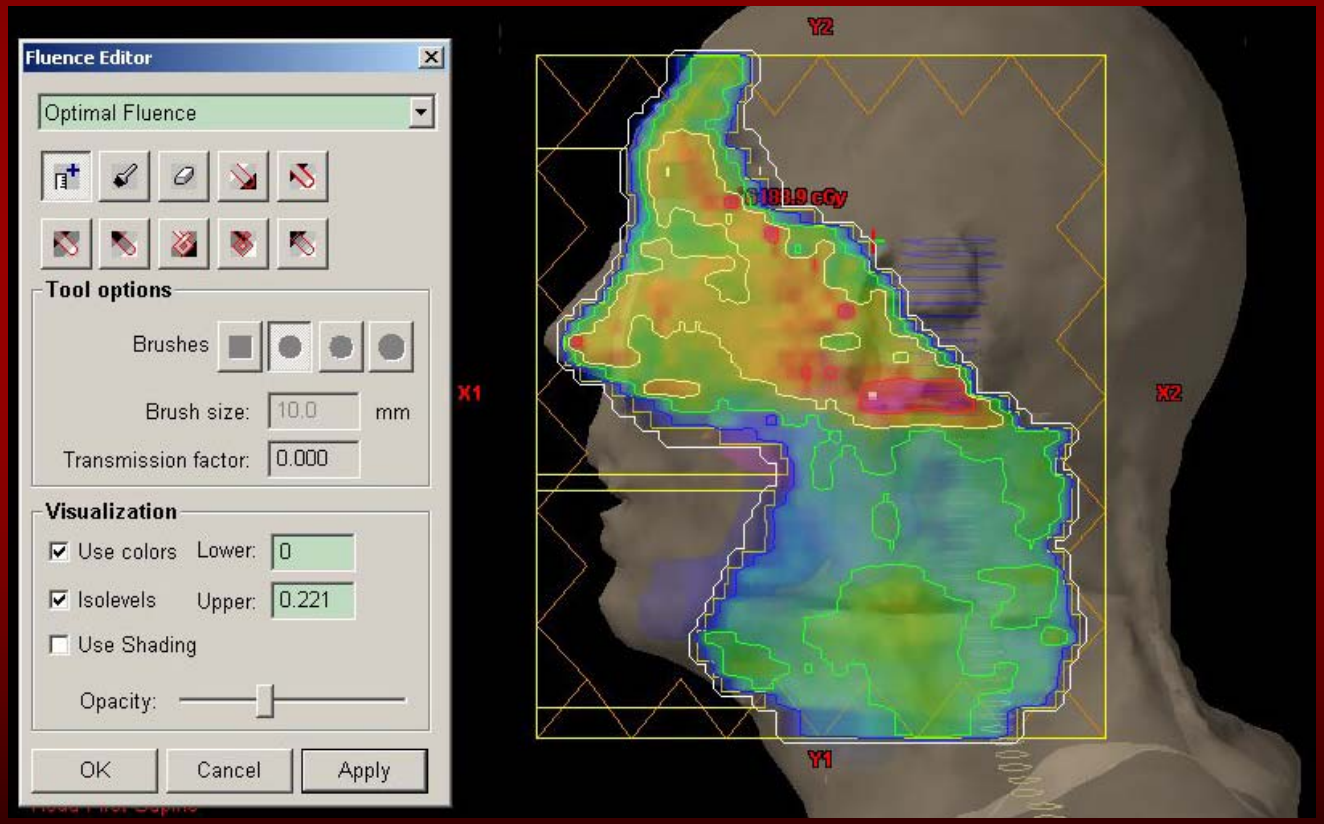
Isocenter Placement

Issues

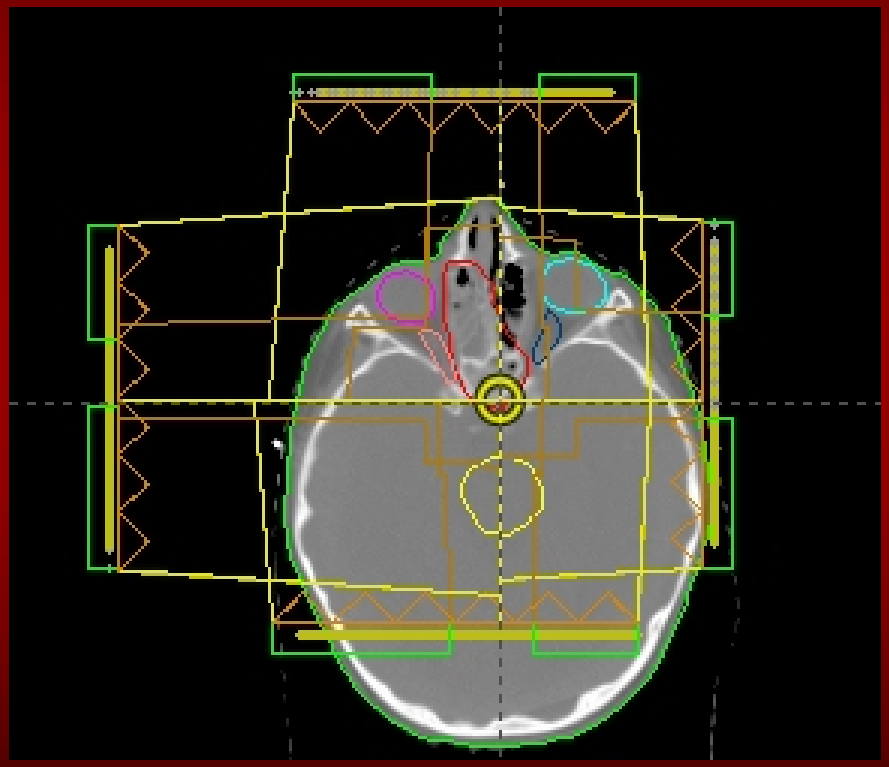
- Sometimes a better plan be achieved by selective isocenter placement
  - Center of GTV vs center of all targets
- Dosimetry and/or QA
- Patient setup
  - Isocenter in region of reliable bony anatomy

Direct Modification of Intensity Map

An option provided by some planning systems

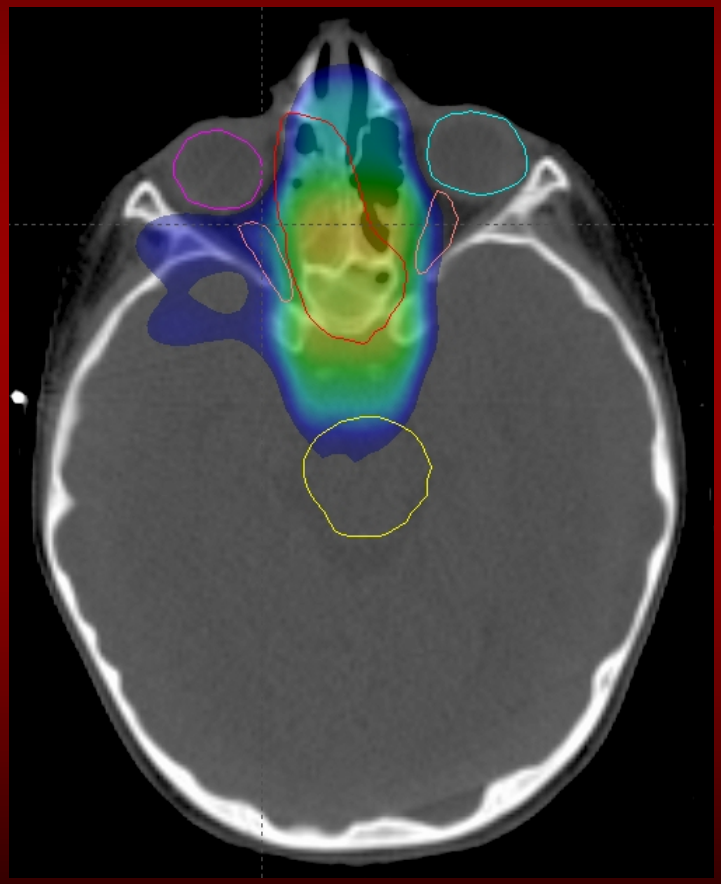


Direct Modification of Intensity Map



Direct Modification of Intensity Map

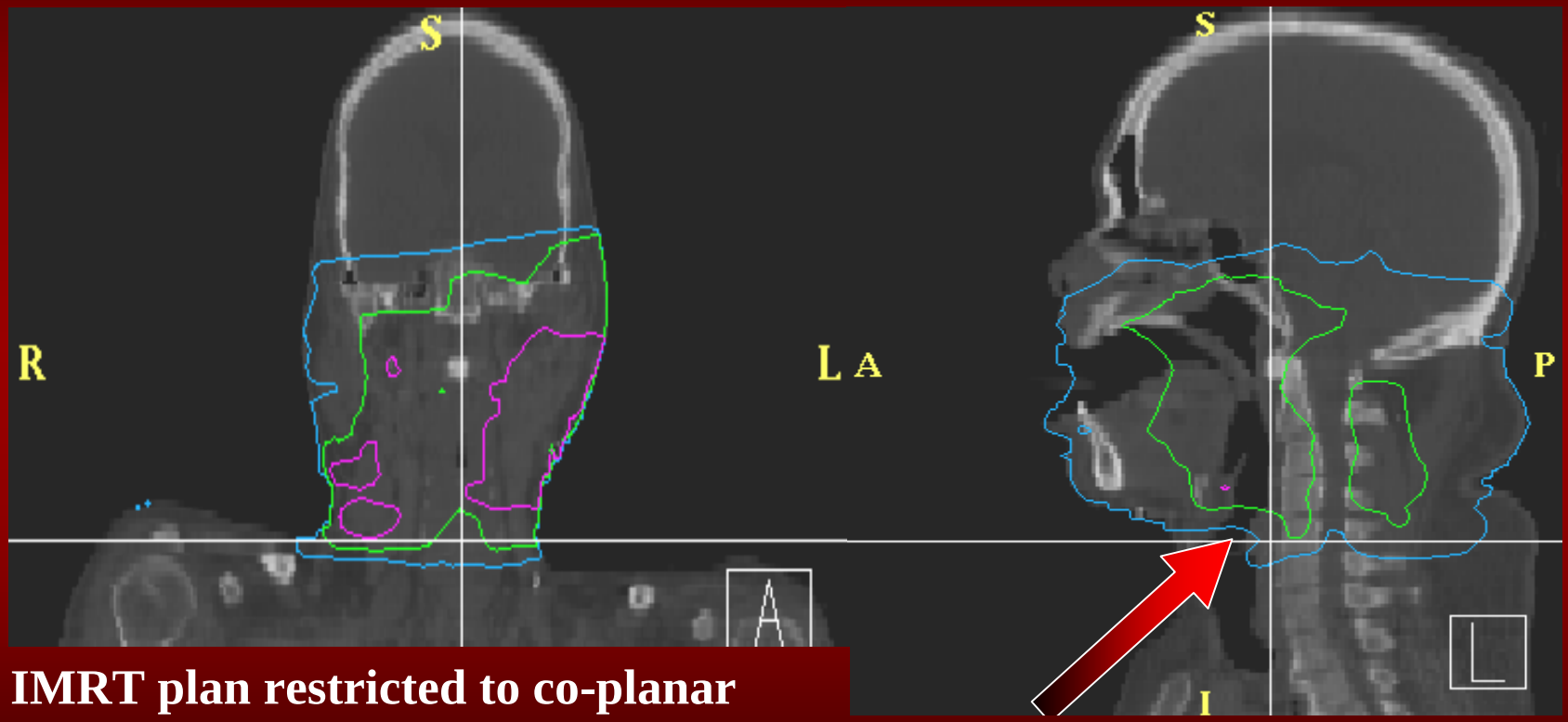
Erase intensity over the RT Eye in all fields



HN IMRT with Supraclav Nodes

- Treating nodes with 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

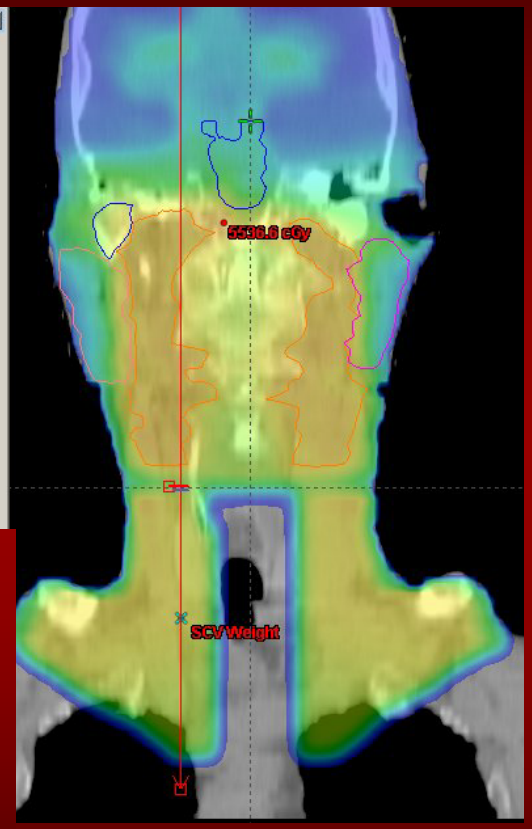
Matching IMRT to AP SCV (1)



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

Matching IMRT to AP SCV (2)



Flexibility to control cold match or hot match depending on the needs of each case.

Use dose profile tool to investigate composite dose distribution.

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

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's good and bad about this plan? Why those beam angles? Why underdose parts of the target? Why can't you spare more normal tissue? Etc.
- You have to butt in to 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 should 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 (radiation or surgery) to the location
  - Medical comorbidities and the use of concurrent chemotherapy

Target Doses – 10 Cases

GTV Rx 66Gy, Nodal Rx 54Gy

Structure	Vol (cc)	Min (Gy)	Mean (Gy)	Max (Gy)
GTV	82.4 20.2 to 195.8	54.2 24.3 to 63.6	70.6 69.9 to 72.4	78.4 74.6 to 82.5
Nodes	423.3 258.2 to 710.3	26.0 14.0 to 35.7	62.0 56.1 to 64.3	77.8 74.2 to 80.5

Serial Structures – 10 Cases

Structure	Vol (cc)	Min (Gy)	Voxel Max (Gy)	1cc Max (Gy)
Brainstem	27.4 22.5 to 33.3	7.3 1.9 to 16.7	46.1 31.8 to 55.5	39.9 26.8 to 48.9
Spinal cord	17.7 7.1 to 24.1	1.6 0.4 to 7.8	38.4 16.1 to 45.0	34.3 13.9 to 40.5

Parotid Glands – 10 Cases

Structure	Vol (cc)	Min (Gy)	Mean (Gy)	Max (Gy)
Ipsilateral	22.0 10.9 to 42.5	15.4 7.1 to 35.7	34.7 18.0 to 61.1	61.2 45.0 to 74.5
Contra-lateral	25.4 10.5 to 47.1	8.8 3.4 to 12.3	21.6 13.3 to 27.9	49.5 31.4 to 56.9

Other Structures – 10 Cases

Structure	Vol (cc)	Min (Gy)	Mean (Gy)	Max (Gy)
Mandible	66.6 40.8 to 85.6	11.8 3.8 to 20.2	43.3 39.4 to 49.9	66.7 58.0 to 73.5
Larynx	9.8 3.7 to 23.4	9.9 2.9 to 24.7	18.2 7.5 to 40.7	42.1 30.9 to 68.0

Use All Information Provided By The Planning System

Examples

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