



MDS Instructor

VMAT GBM Brain Treatment Planning



This course will give an overview of the radiation planning process for a GBM Brain treatment. We will use VMAT treatment planning techniques and walk through some of the fundamentals of



Simulation



Contouring



Beam Setup



Treatment Planning



Plan Evaluation

Simulation



MDS Instructor

Simulation is a process that allows radiation treatment fields to be delivered in a reproducible manner. The simulator is a large-bore computed tomography (CT) scanner. The CT images are used to delineate targets as well as organs at risk, which allows the dosimetrist or physician to arrange the radiation beams and make a customized plan. It is here that special care is taken to make the patient as comfortable as possible, to ensure treatment can be delivered in the same position each day.

- Imaging: CT simulation, ≤ 0.3 cm thickness
- Position: Supine
- Immobilization: Head immobilization
- Other: Recommend MRI fusion
- Technique: IMRT/VMAT or 3D if possible
- Image-guidance. At least weekly image verification (EPID, cone-beam CT, mega-voltage CT [MVCT])

CT Simulation

Immobilization

For GBM brain treatment immobilization, there exist a variety of commercially available head immobilization devices, most commonly thermoplastic masks with a custom head-rest. To obtain more precise positioning, generally not required a stereotactic thermoplastic mask may be used.

For CT scan simulation involving the brain, the patient is placed in the positioning device and scanned. The isocenter or reference markers are selected and marked on the thermoplastic mask.



Simulation

Mask markings (bb & markers)

For patients who are simulated with a thermoplastic mask, the markings are usually marked on the patient's mask as shown above.

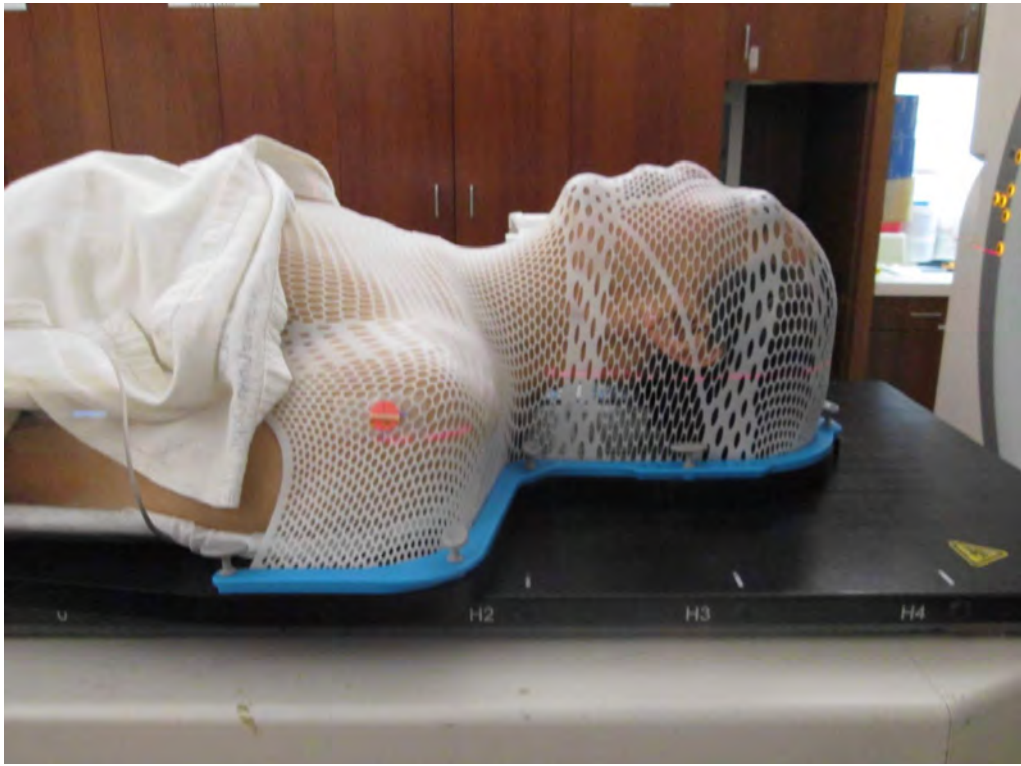
The therapists will take several photographs of the patient in the simulation position. The photographs and marks will be used as guides to position the patient correctly each day during treatment.



Simulation

Mask: A five-point mask, reinforced along the chin.

Sometimes a five point mask is used to reinforce along the chin and help with shoulder placement.



Contouring



MDS Instructor

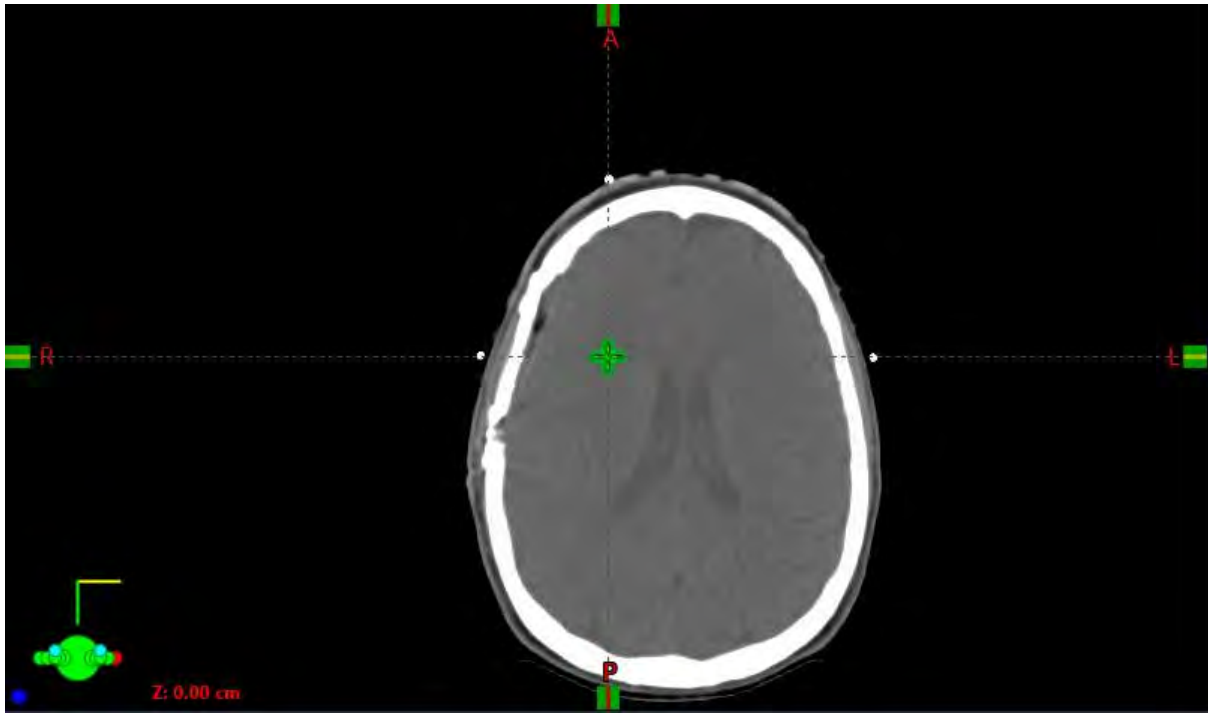


Import & Localization

Each patient starts with the Importing and Localization of the CT images into the treatment planning system.

Step 1

Importing and Localization



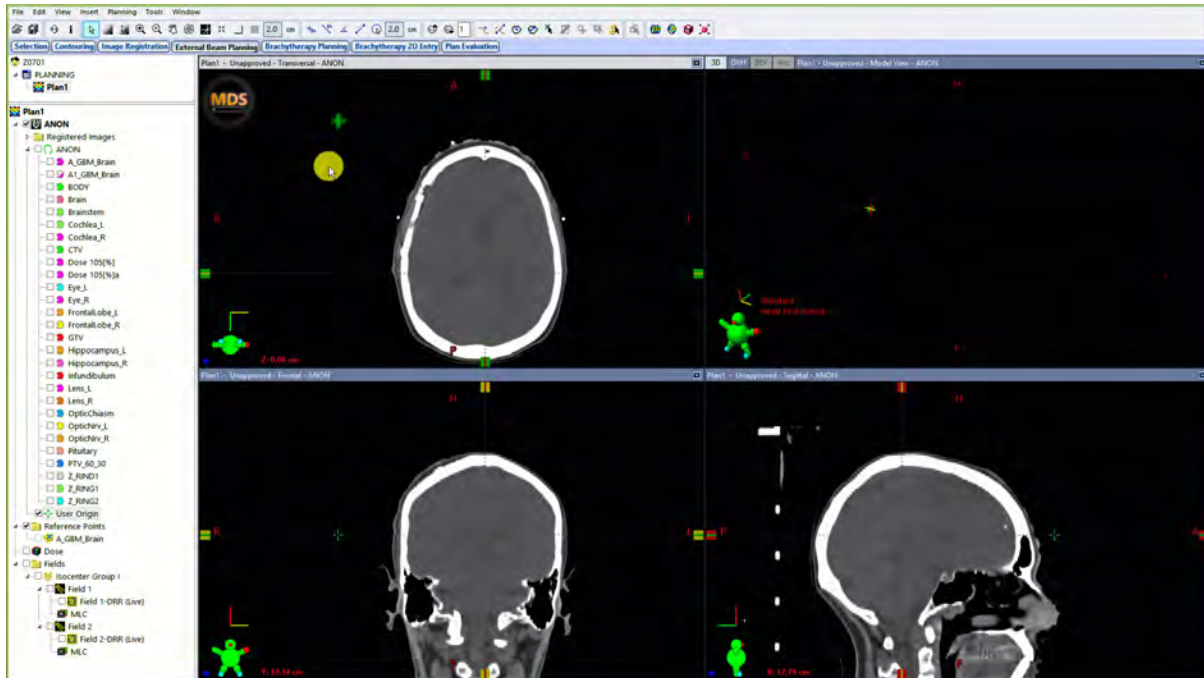
After a patient is simulated, the CT data set is imported into the Treatment Planning System. These images are in DICOM format and you may hear people referring to this folder as the DICOM import folder.

Once imported, the CT scan is used to localize the patient in a system of coordinates/markings is used to track the patient's geometric location in space.

At the time of sim, a patient is often marked to facilitate set up during treatment, BBs are often used to mark this setup location in a triangular fashion, generally 3 points (anterior and laterally). We will set the user origin or localization at this location.

Step 2

Set User Origin Eclipse (Localization)



Next, we will set the user origin for the image. This will localize the coordinate systems to the TPS.

To Localize the patient, scroll to the slice of the bbs and set user origin to viewing plane intersection

Step 3

Set User Origin RayStation (Localization)



Set the Localization for the image. This will localize the coordinate systems to the TPS.

To Localize the patient, scroll to the slice of the bbs and set user origin to viewing plane intersection

Step 4

Set User Origin Pinnacle (Localization)



Set the Localization for the image. This will localize the coordinate systems to the TPS.

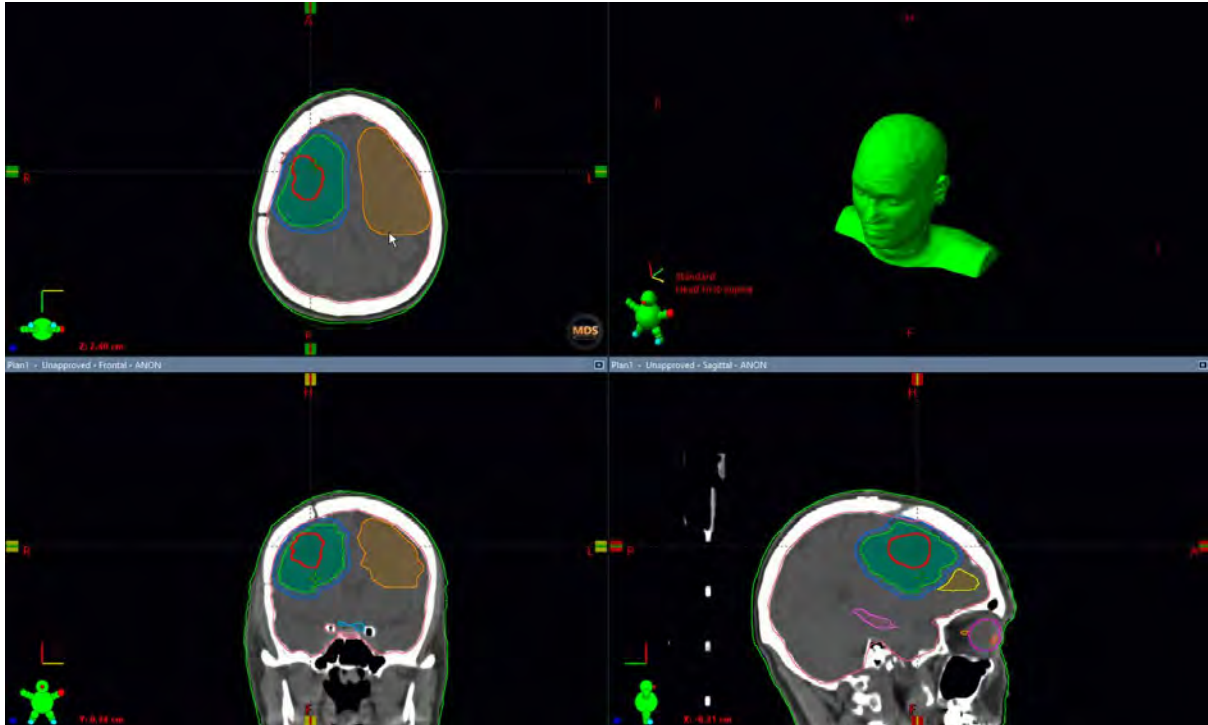
To Localize the patient, scroll to the slice of the bbs and set user origin to viewing plane intersection

Summary

You can use this workflow for other treatment sites as well. (Brain, Thorax, Abdomen, Pelvis, and Extremities).

Just import the DICOM images, scroll to the setup marks and set the user origin to the triangulation location.

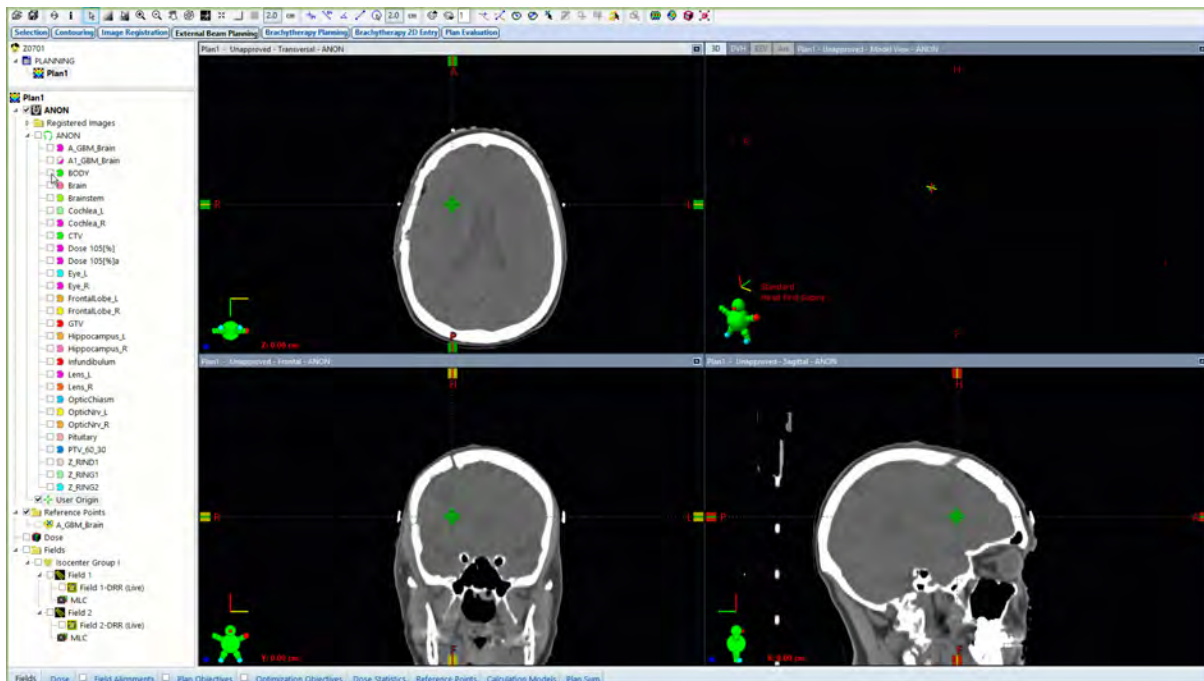
Contouring



Here we'll contour in the structures relevant to the GBM Brain treatment plan. It's a good habit to review contours before planning. This will allow you to familiarize yourself with the nearby structures, any overlap or problem areas to consider during planning. Also any structures that are missing can be added before planning starts.

Step 1

BODY

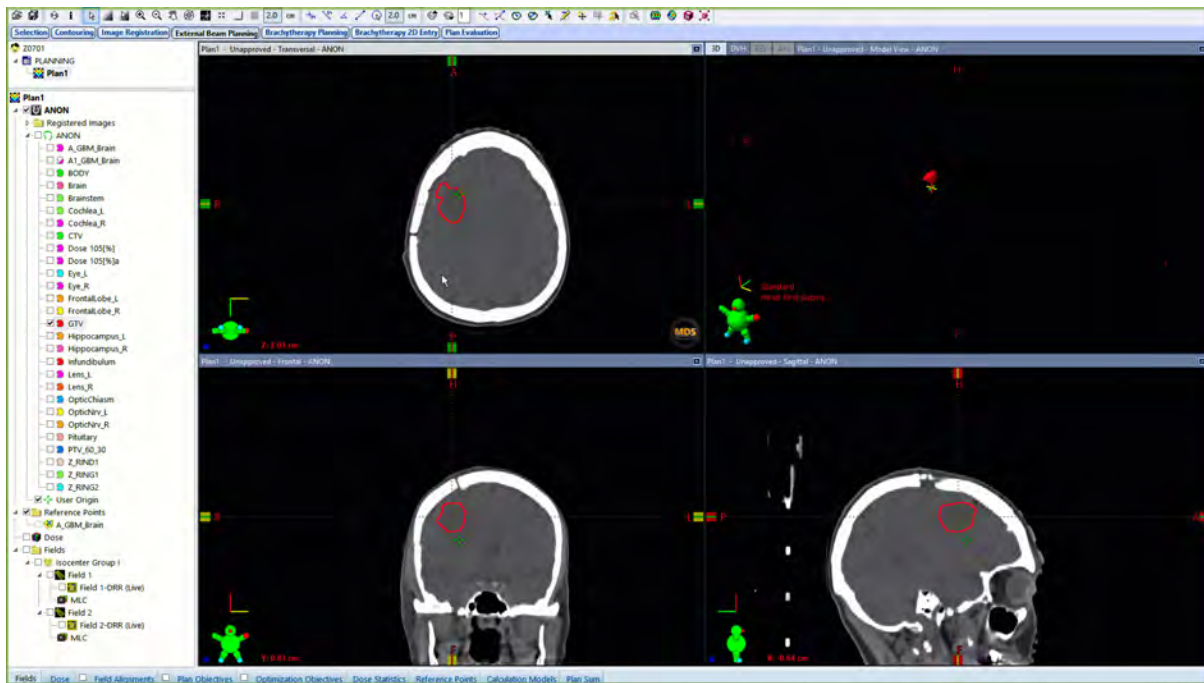


Review BODY contour for any air pockets or discontinuity. Sometimes immobilization devices may need to be included in the body contour to account for transmission and attenuation.

If you don't have a BODY structure you can create one with the search body tool at an air threshold of -350 HU.

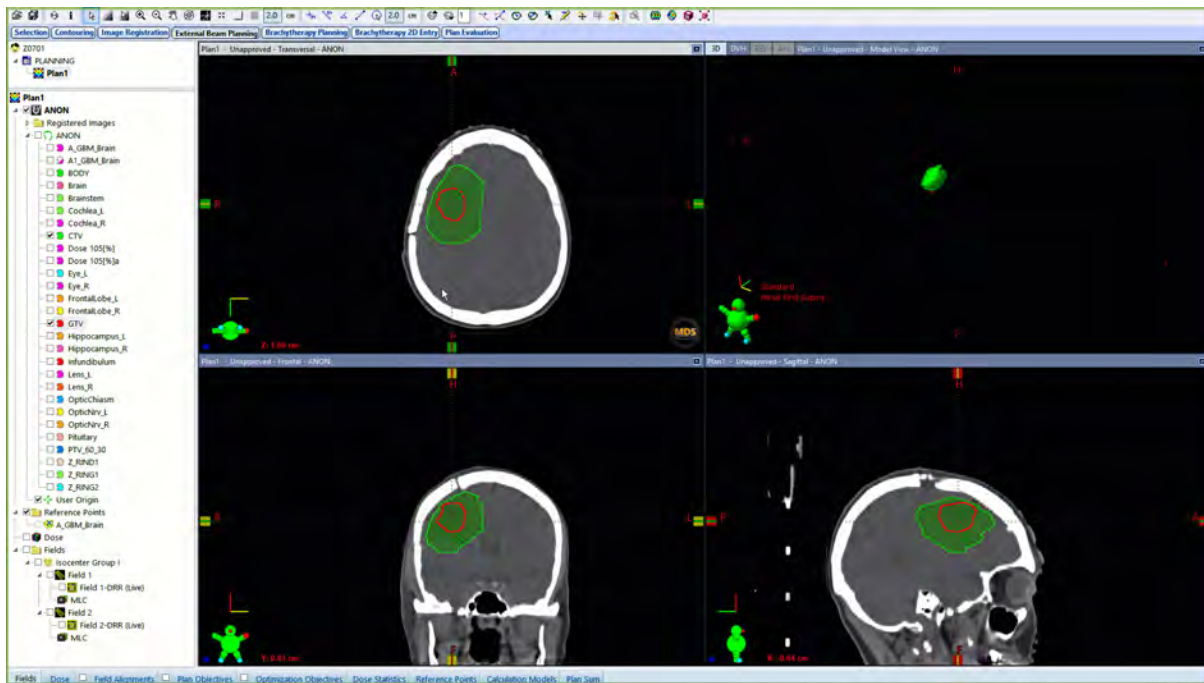
Step 2

GTV



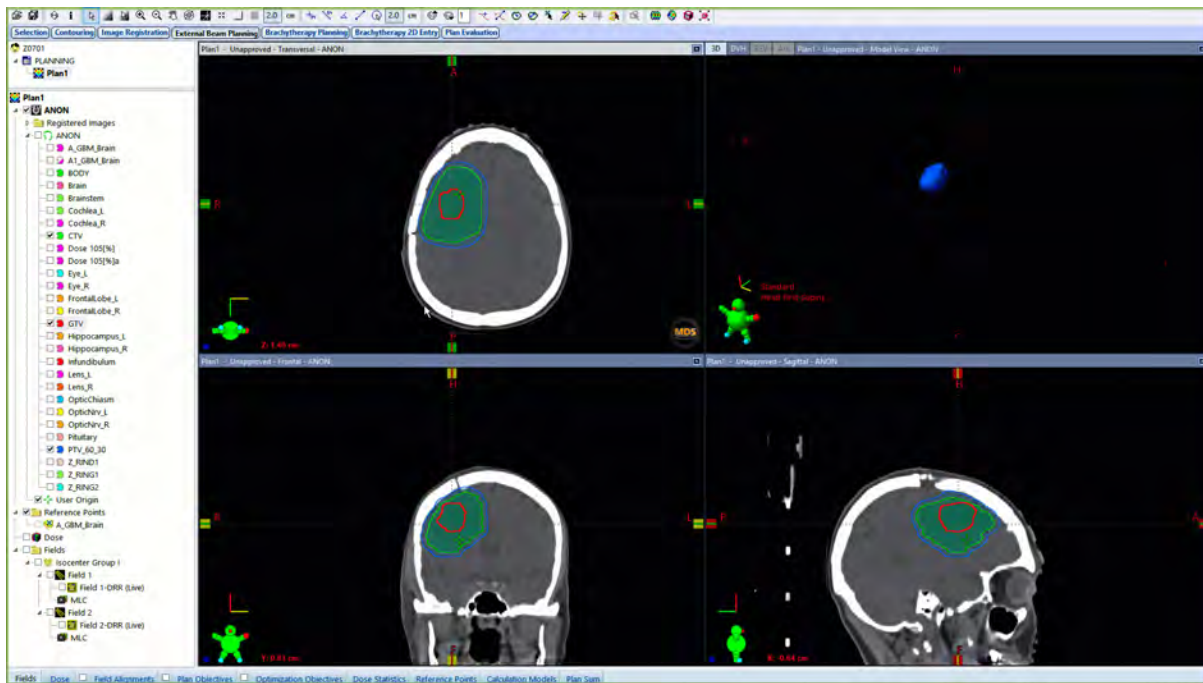
Step 3

CTV



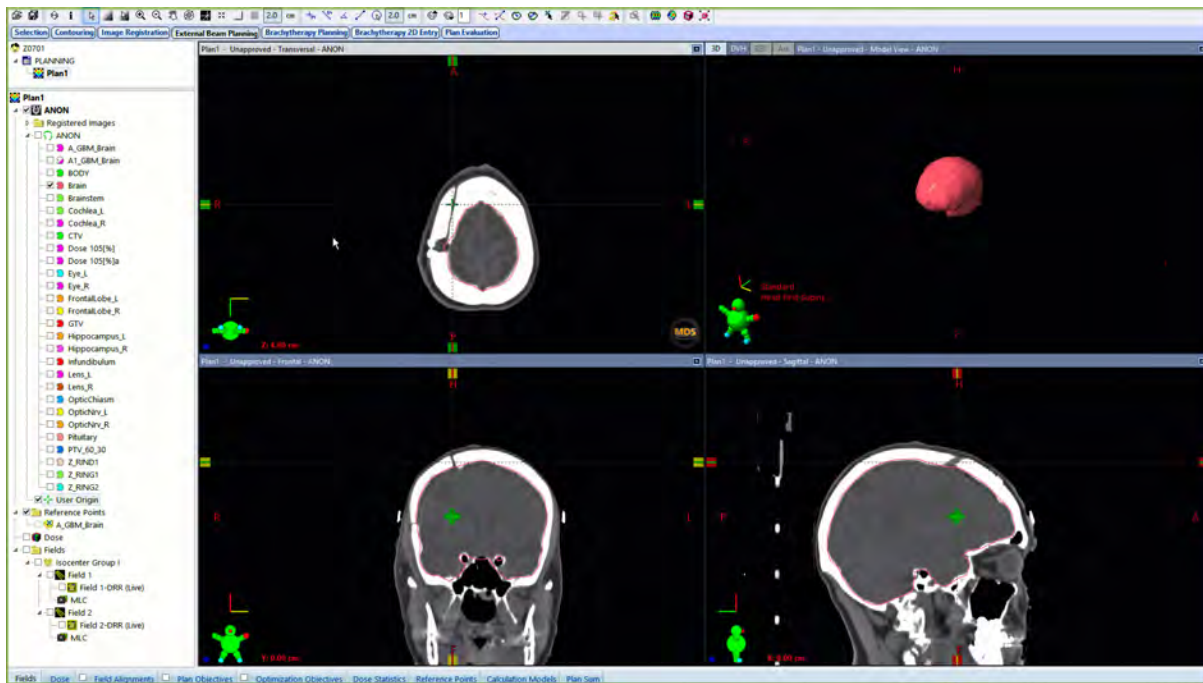
Step 4

PTV



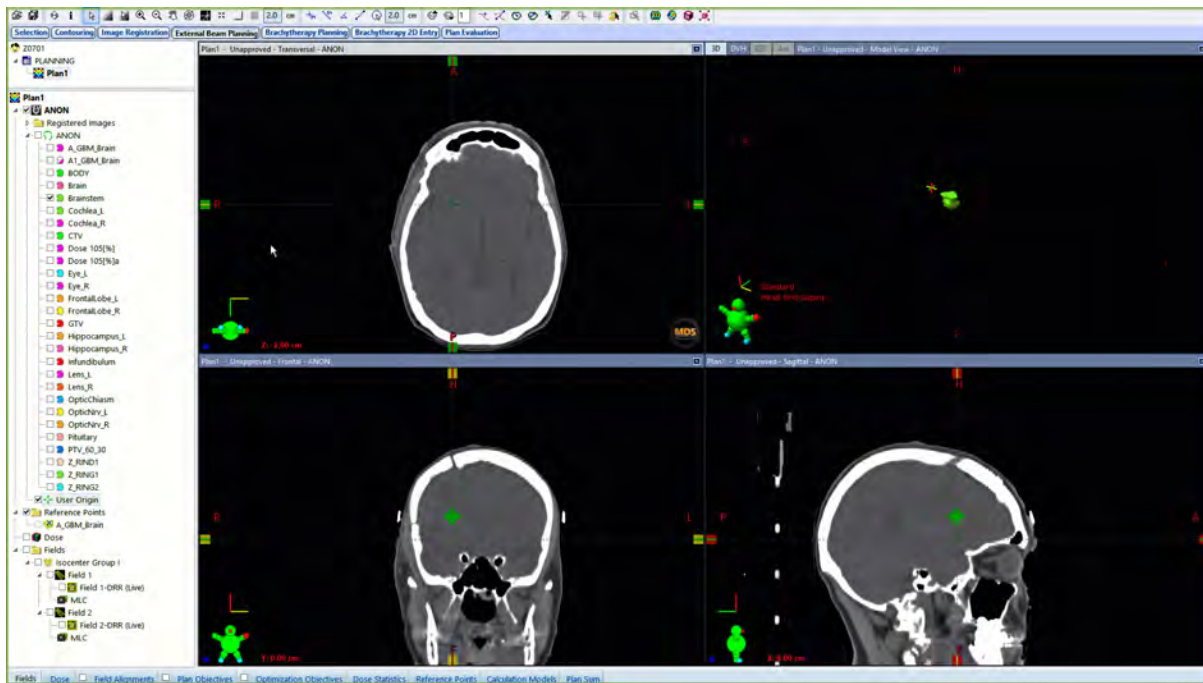
Step 5

Brain



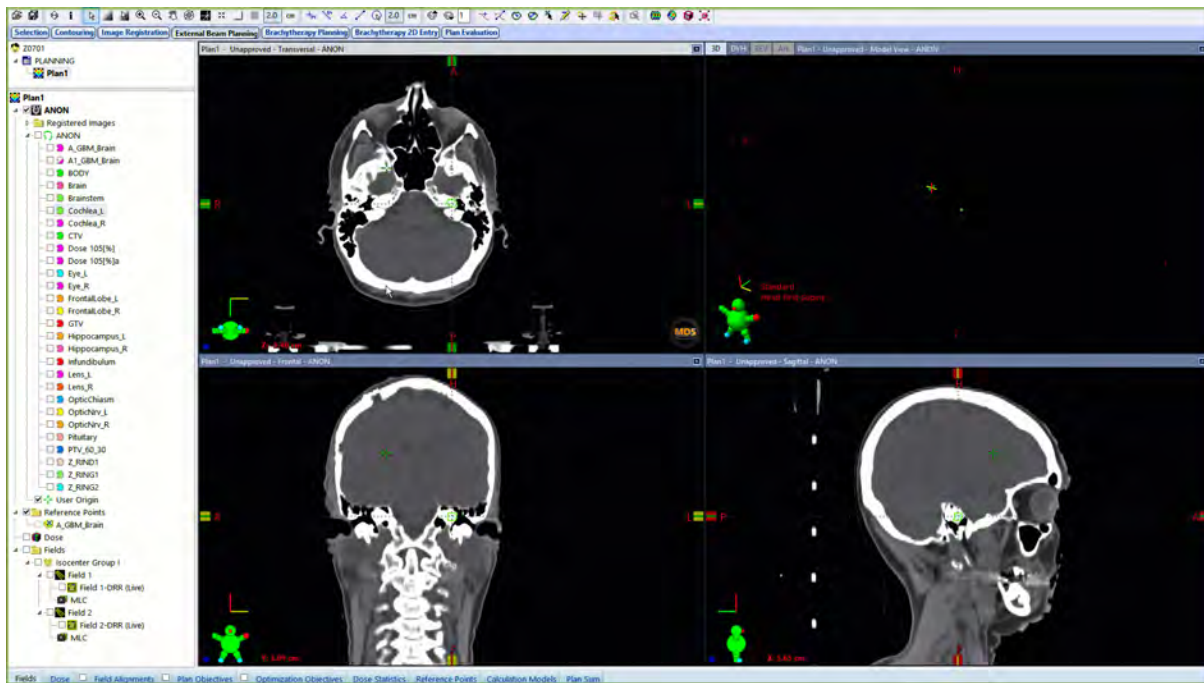
Step 6

Brainstem



Step 7

Cochlea_L



Step 8

Cochlea_R



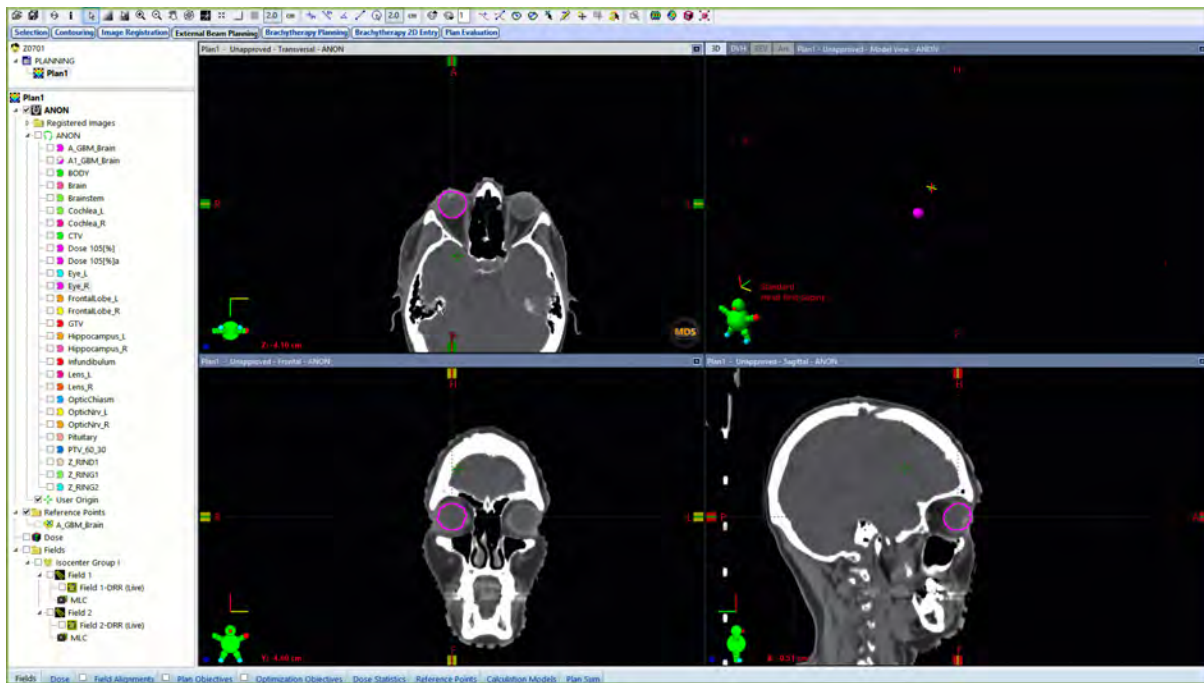
Step 9

Eye_L



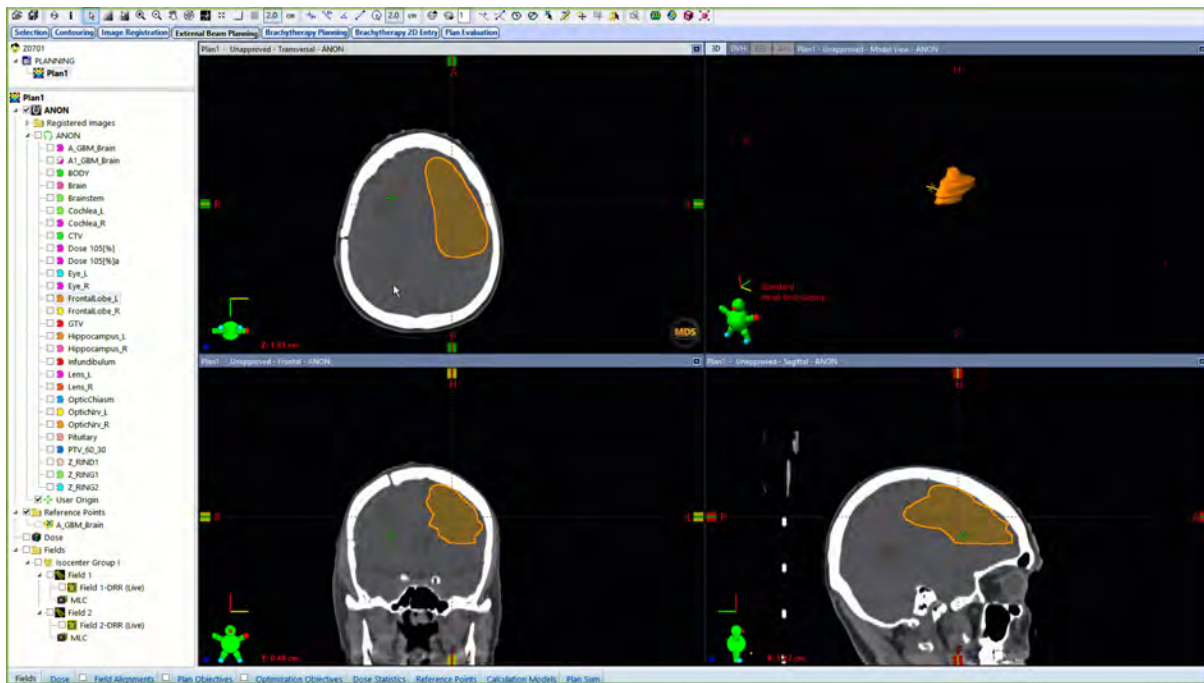
Step 10

Eye_R



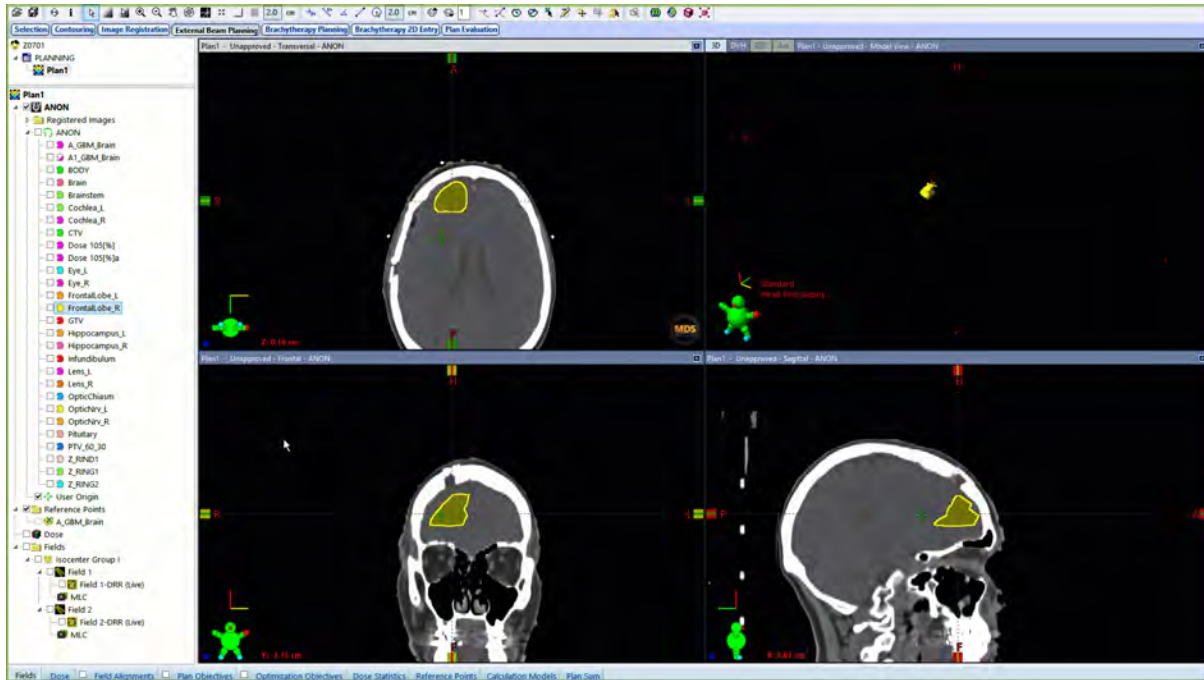
Step 11

FrontalLobe_L



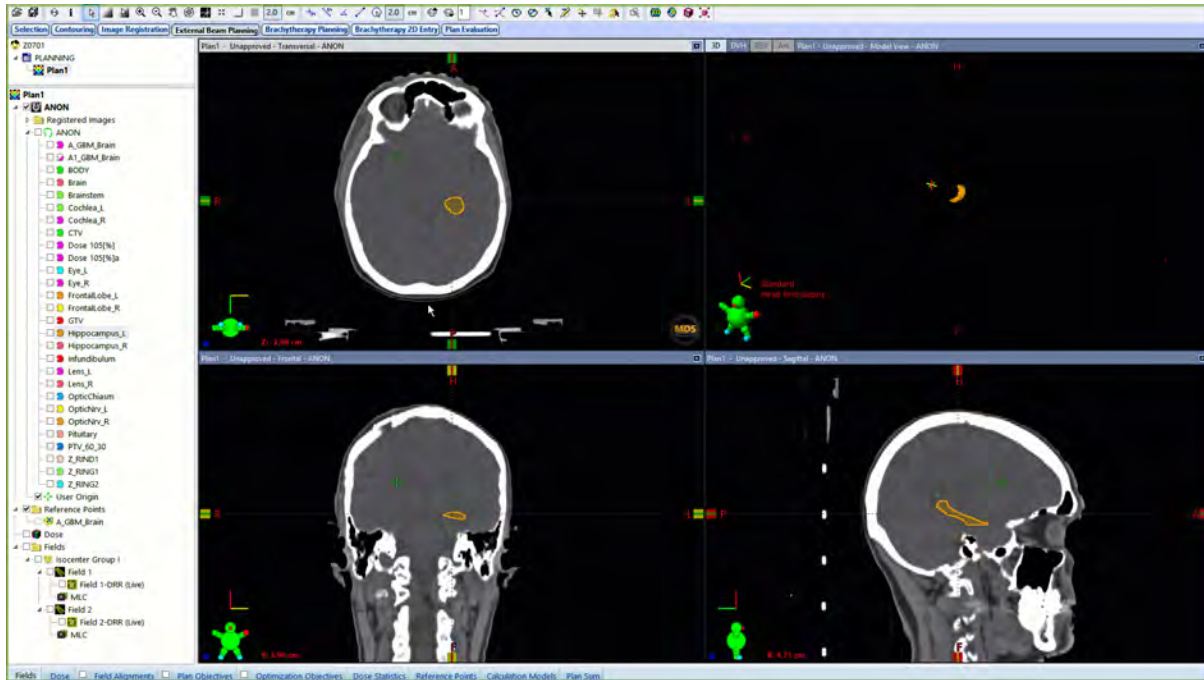
Step 12

FrontalLobe_R



Step 13

Hippocampus_L



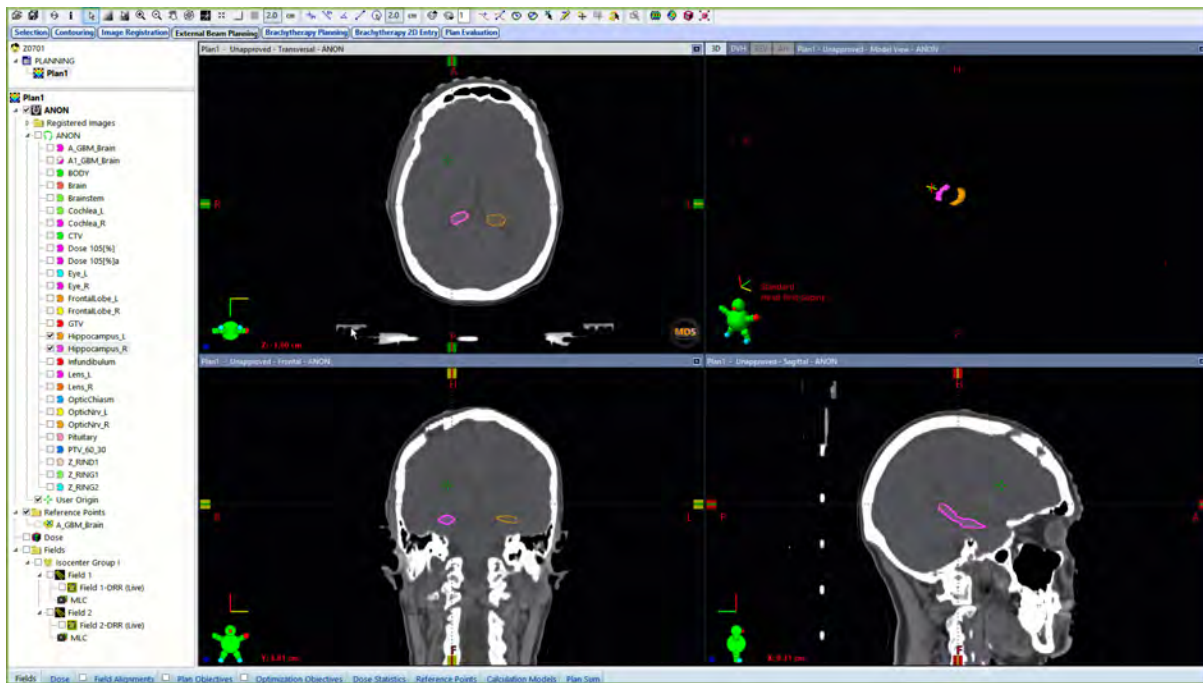
Step 14

Hippocampus_R



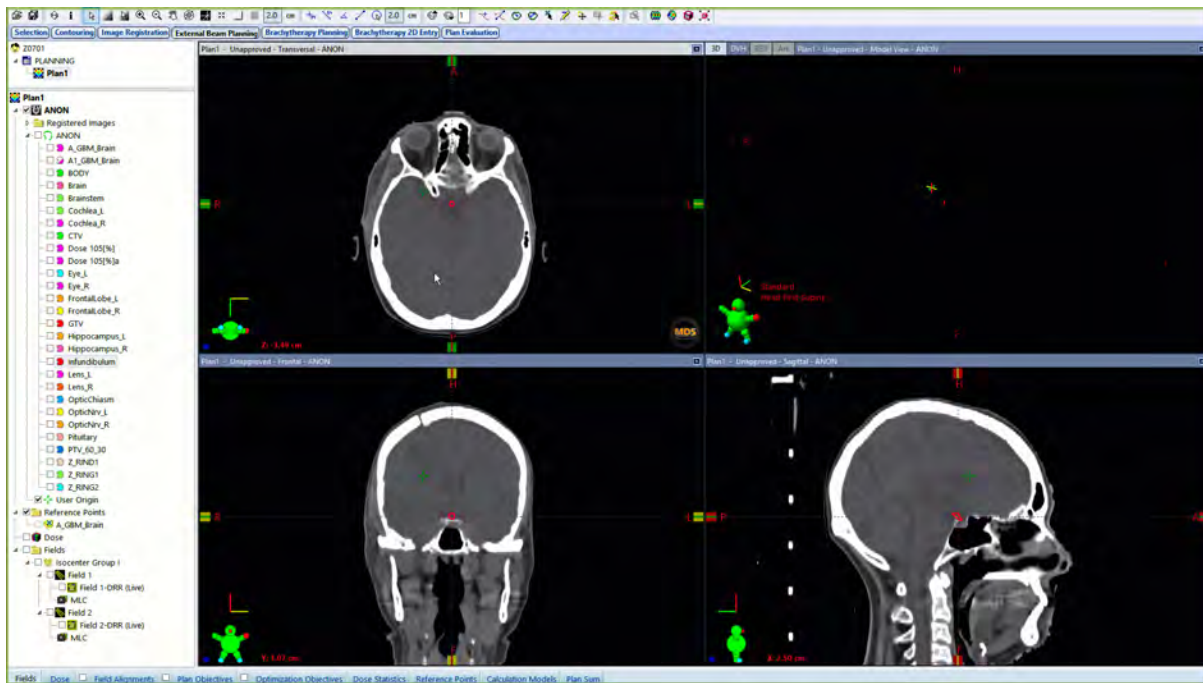
Step 15

Hippocampus R/L



Step 16

Infundibulum



Step 17

Lens_L



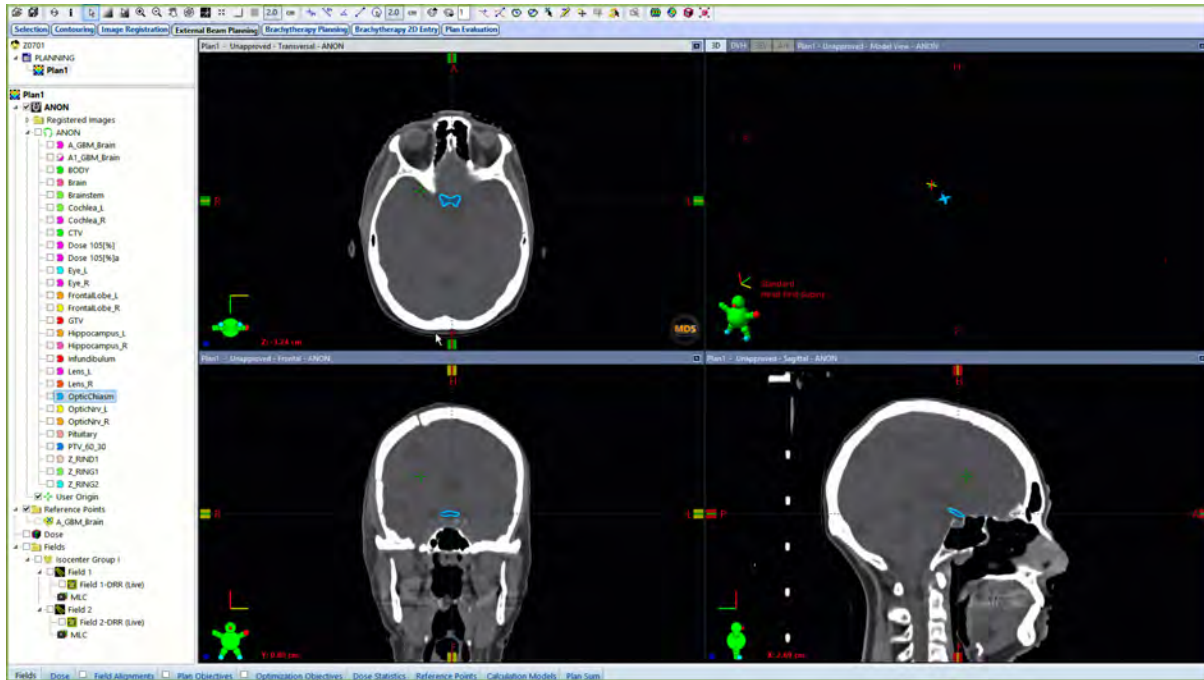
Step 18

Lens_R



Step 19

Optic_Chiasm



Step 20

Optic_Nerves_L



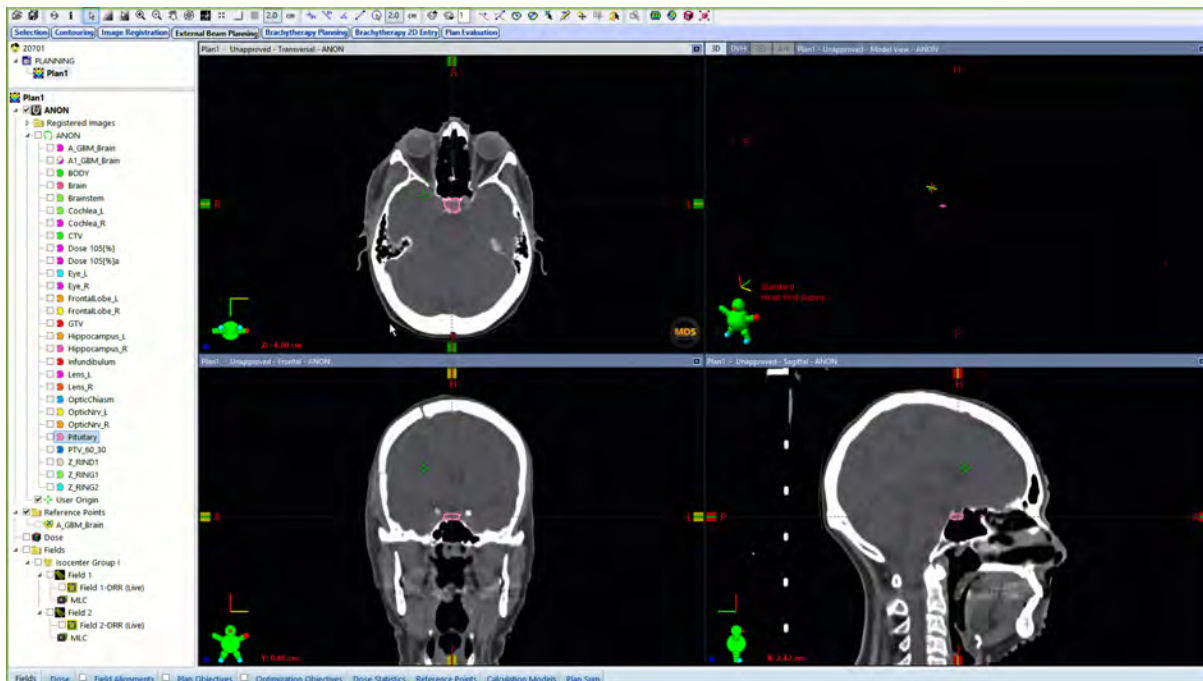
Step 21

Optic_Nerves_R



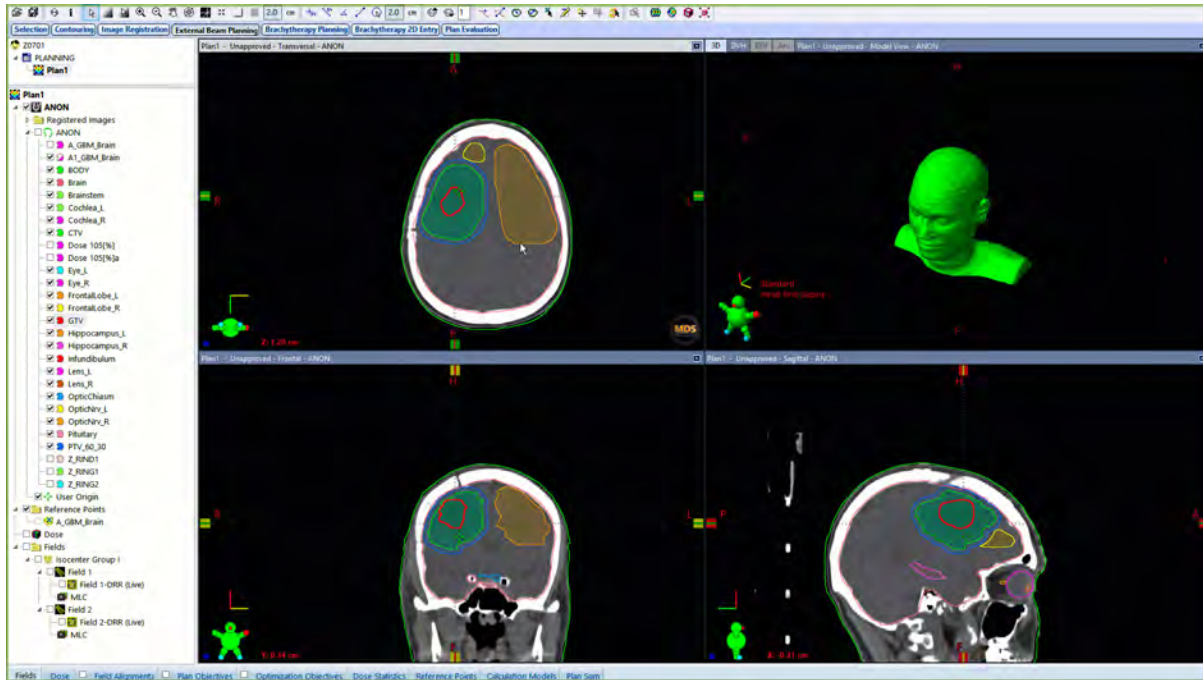
Step 22

Pituitary Gland



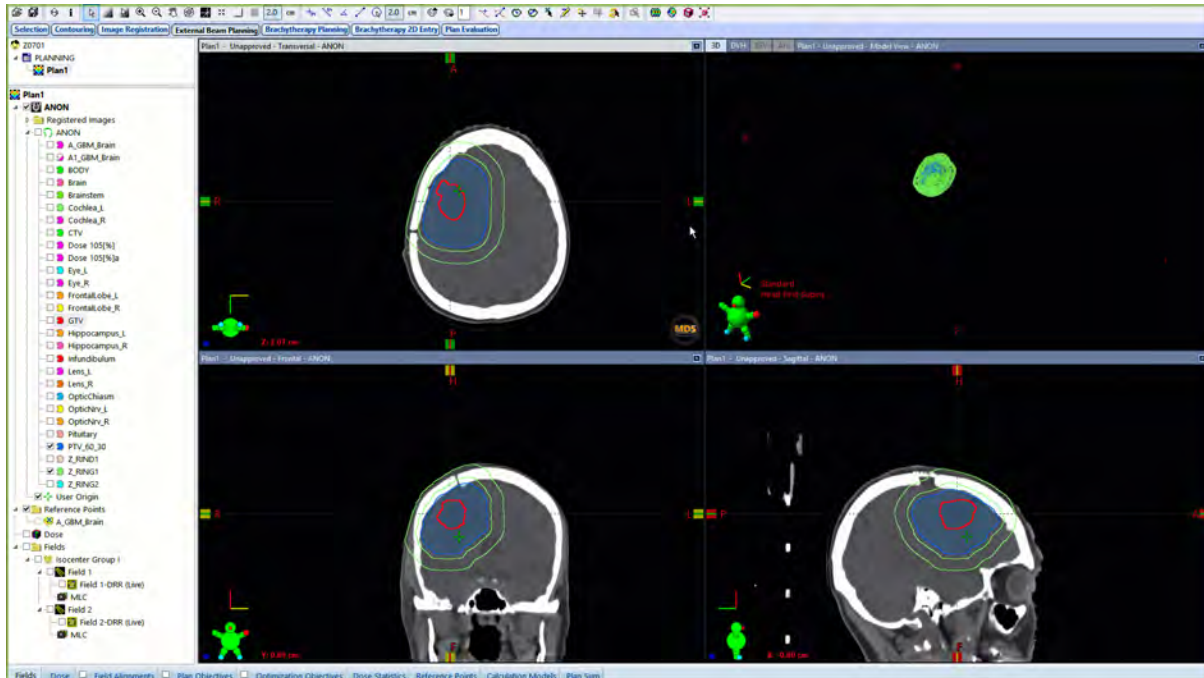
Step 23

All Structures



Step 24

RING1



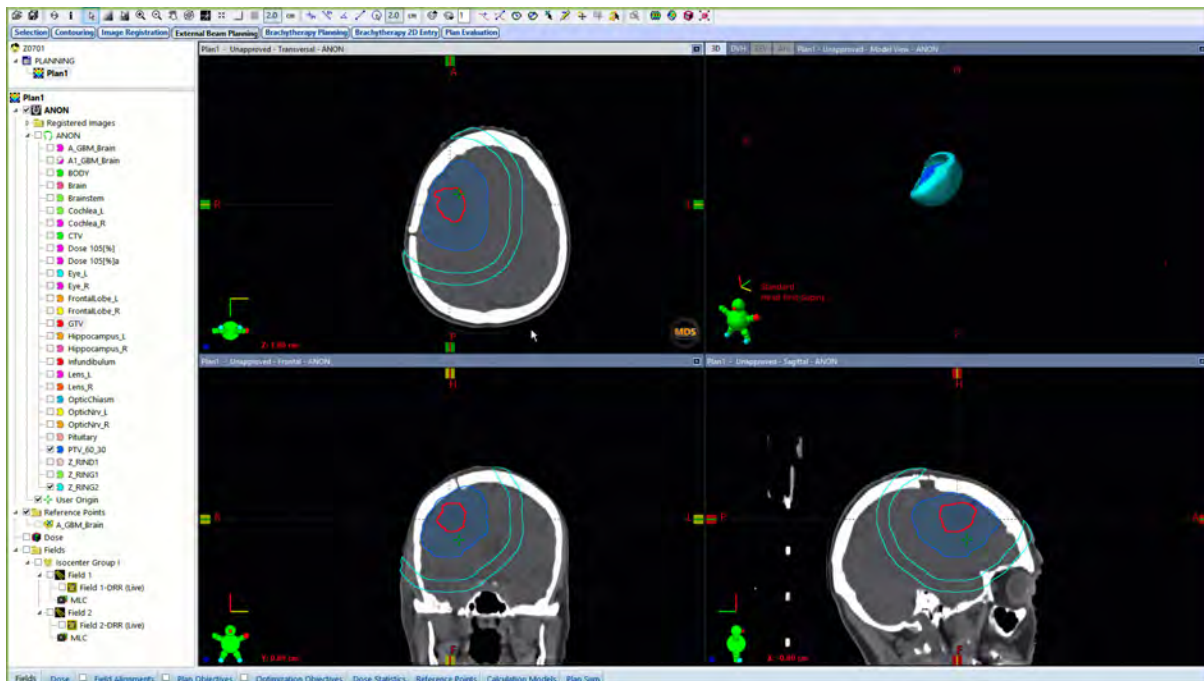
The RING1 Structure is an optimization structure

Category: Control Structure

Purpose: Dose fall off from 100-90%

Step 25

RING2



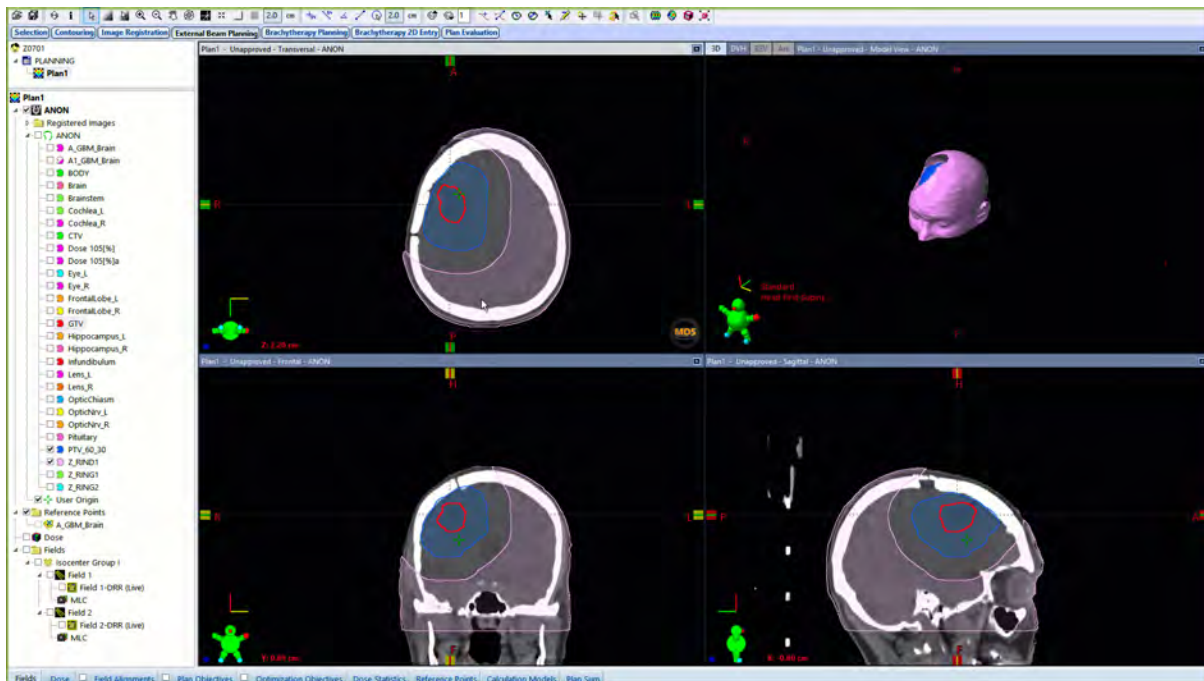
The RING2 structure is an optimization structure

Category: Control Structure

Purpose: Helps control dose fall off from to 50% isodose line

Step 26

RIND1



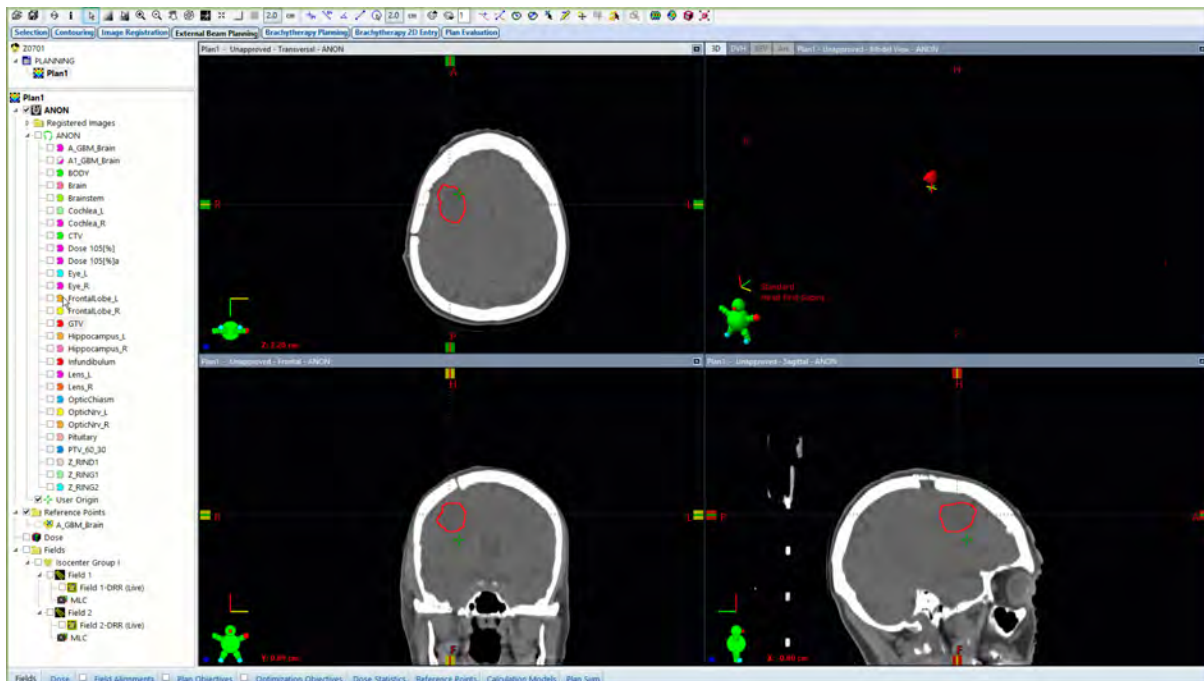
The RIND1 structure is an optimization structure

Category: Control Structure

Purpose: helps control low dose <50%. Also, helps controls dose to normal tissue

Step 27

SAVE CONTOURS



This is the most important step! Save your contours, its an important habit.

Step 28

Any other Critical Structures?

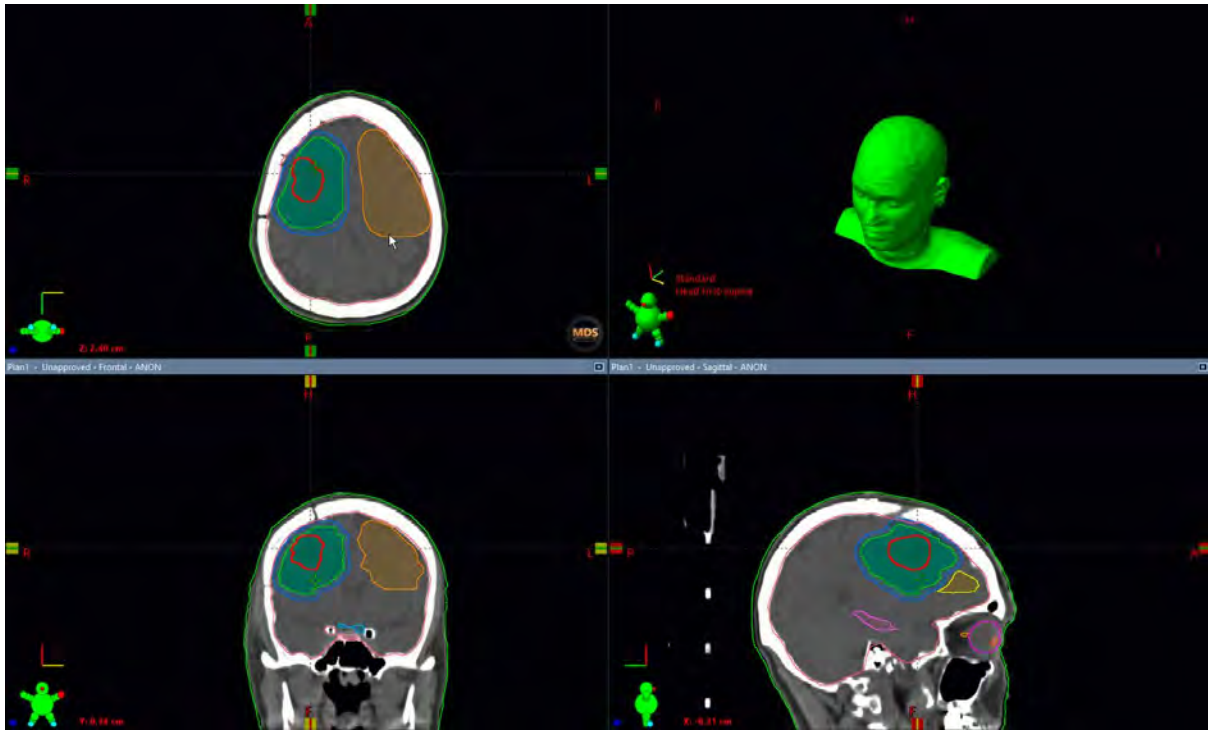
Contour any additional critical structures relevant to the case.

Step 29

Any Density Overrides?

If there are artifacts or materials that need to be overridden, this is the time to do so.

Summary



Ok now that we've completed our list of contours, We're ready to start planning.



Complete the content above before moving on.

Takeaway

Remember to review automated contours such as the Body and have a second pair of eyes review your contours.

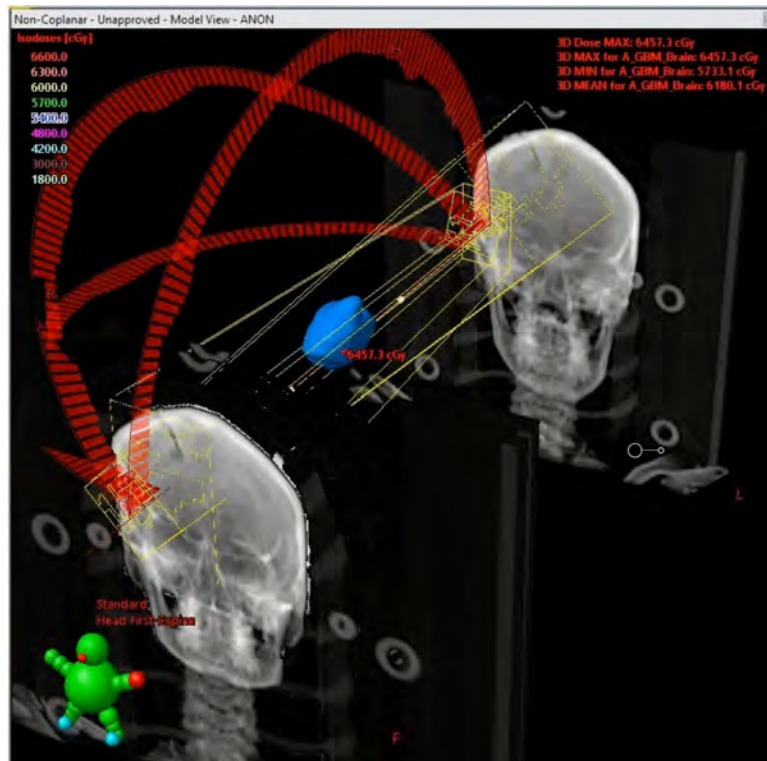
Beam Setup



MDS Instructor



Beam Arrangement

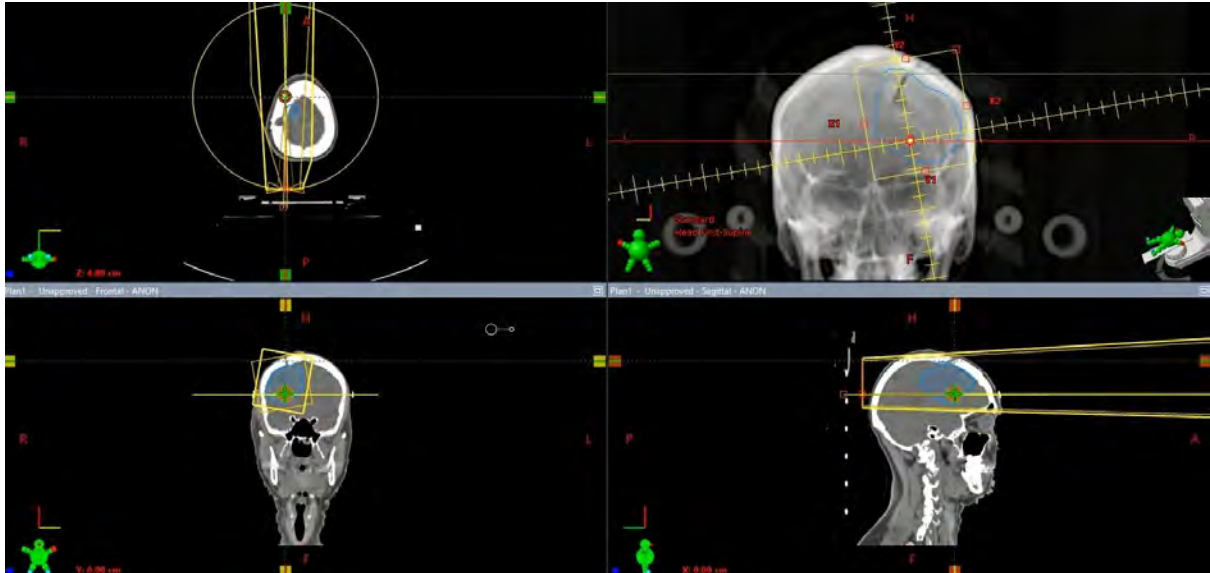


VMAT GBM Brain cases commonly use 2 arcs. 2 Full arcs or 2 partial arcs are common, depending on the complexity of the Target proximity to optic structures and organ at risk structures.

Another important consideration is the use of non-coplanar to improve target projection or limit exit dose to underlying structures.

Step 1

VMAT 2 Full Arcs



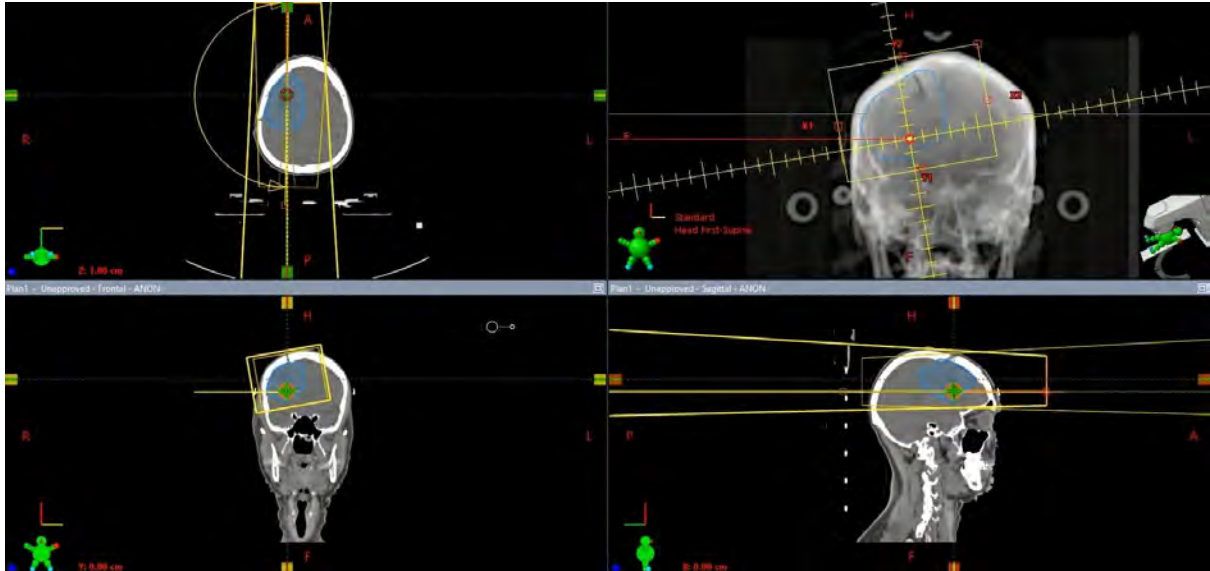
Field Arrangement 2 full Arcs

01 CW ARC: 181-179, Collimator: 350 deg, Couch: 0 deg

02 CCW ARC: 179-181 Collimator: 10 deg, Couch: 0 deg

Step 2

VMAT 2 Partial Arcs



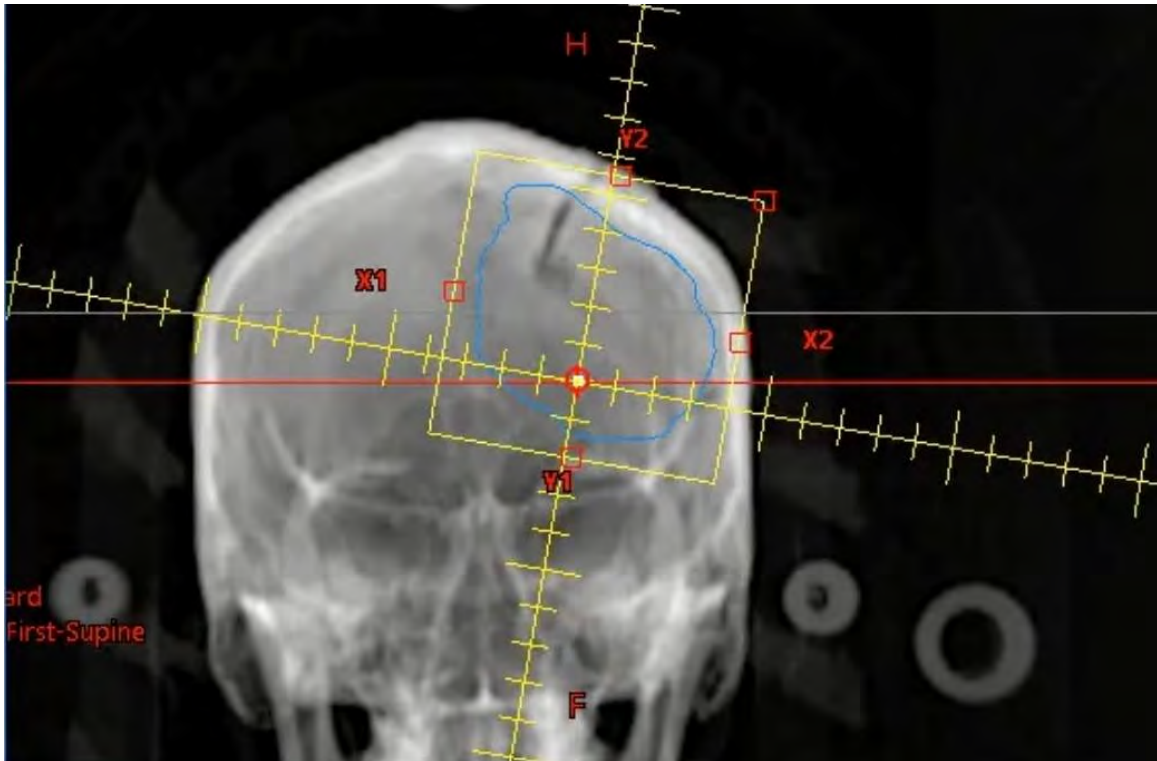
Field Arrangement 2 partial Arcs

01 CW ARC: 181-0, Collimator: 350 deg, Couch: 0 deg

02 CCW ARC: 0-181 Collimator: 10 deg, Couch: 0 deg

Step 3

Field Margins



As the arc rotates through, the projection of the PTV volume needs to be within the treatment field. Ideally we want 100% of the time for the the PTV to be in the BEV with adequate margin to account for the field edge and penumbra. To Achieve this we try to place the PTV within the center of the field and a 5mm margin around the PTV is set.

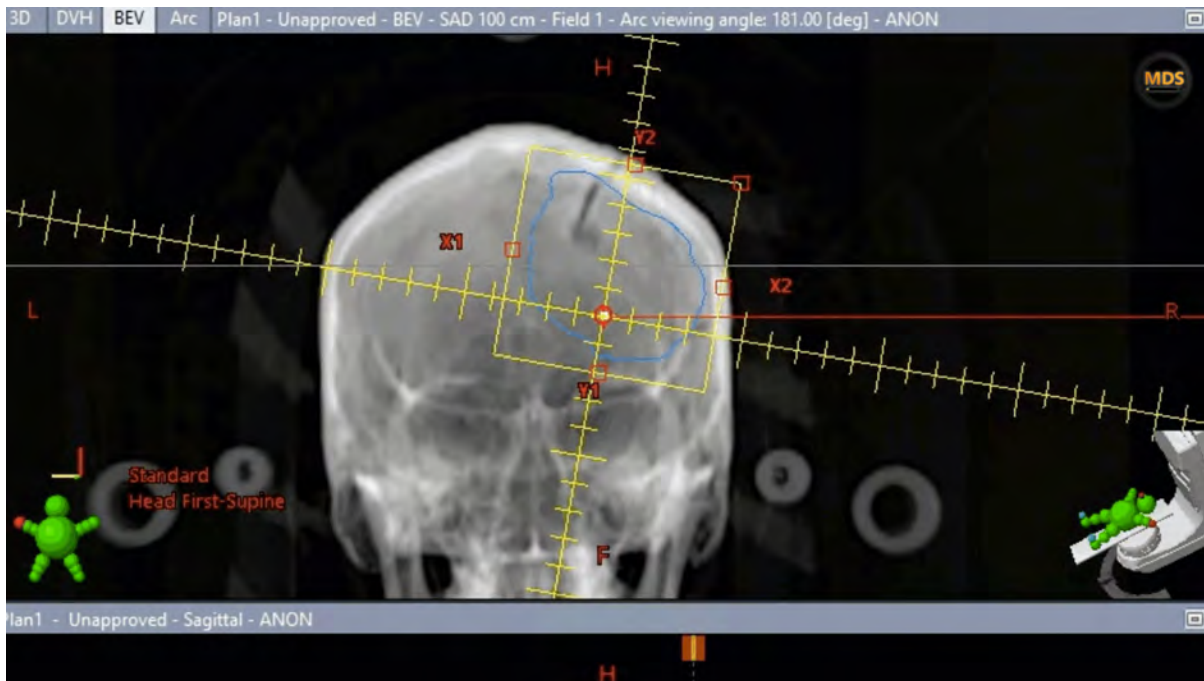
GBM Brain cases often use IGRT during time of treatment. The Isocenter of the field should be placed at the center of the PTV.

To minimize shifting, sometimes the CT_Origin/Localization point is a good location to place the ISO.

Reviewing the arc rotation and target projection helps ensure that the field has adequate margin for dose delivery to the target.

Step 4

Set Field Margin



While setting up the field borders please keep in mind.

- Treat the PTV with adequate margin.
- Direction of the MLCs relative to the plane of travel of the arc.
- The X jaws are usually the direction of the MLC travel, we do not want to be in-plane with the gantry travel in order to minimize leakage from the tongue and groove effect.
- In most cases rotating the collimator by 10 degrees helps us achieve this.
- In the image, the Red Line is the plane of arc travel. The yellow graticule from left to right is offset by 10 deg. For our linac this is the direction the MLCs will travel..

Summary



Now things are setup and we'll create a plan similar to the one shown.

Treatment Planning



MDS Instructor



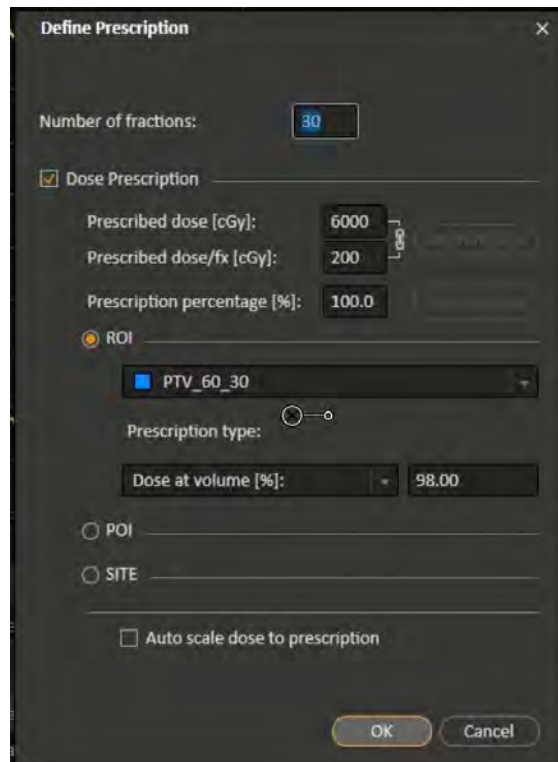
Introduction



Once we place fields and set field blocking. We need to calculate the dose and look at the dose distribution.

Step 1

Calculation Volume



The image shows a 'Define Prescription' dialog box with the following settings:

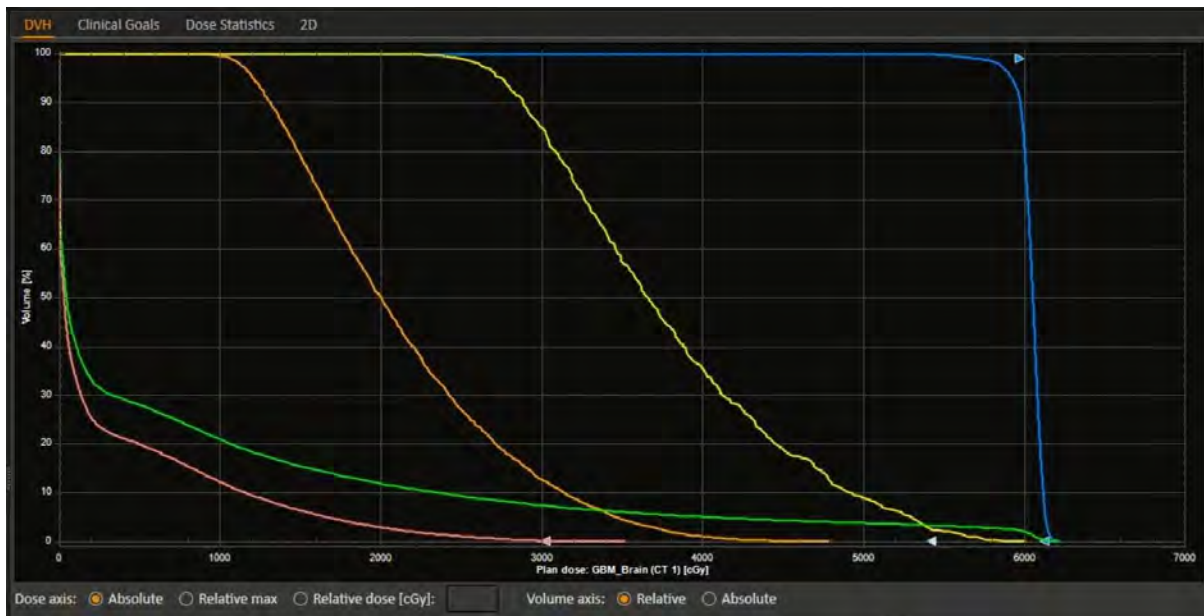
- Number of fractions: 30
- ☒ Dose Prescription
 - Prescribed dose [cGy]: 6000
 - Prescribed dose/fx [cGy]: 200
 - Prescription percentage [%]: 100.0
- ☒ ROI
 - PTV_60_30
- Prescription type:
 - ☒ Dose at volume [%]: 98.00
 - ☐ POI
 - ☐ SITE
- ☐ Auto scale dose to prescription

Buttons: OK, Cancel

For VMAT treatments we set the prescription to the PTV volume, and try to maintain 95% coverage or better.

Step 2

Normalize the plan



Normalizing the plan to the PTV volume prescribing to cover >95% of the PTV to 100% of the Rx Dose.

Step 3

Optimization Parameters PTV

| Function | Constraint | Dose | ROI | Description | Robust | Weight | Value |
|---------------|------------|------|---------------|--|--------|--------|-------|
| Dose Fall-Off | Plan | | BODY | Dose Fall-Off [H]6000 cGy [L]5000 cGy, Low dose distance 1.00 cm | * | 50.00 | |
| Dose Fall-Off | Plan | | BODY | Dose Fall-Off [H]6000 cGy [L]500 cGy, Low dose distance 5.00 cm | * | 50.00 | |
| Max Dose | Plan | | FrontalLobe_L | Max Dose 4500 cGy | * | 150.00 | |
| Max DVH | Plan | | Z_Hot1 | Max DVH 6100 cGy to 0% volume | * | 150.00 | |
| Max DVH | Plan | | Z_RING1 | Max DVH 3000 cGy to 0% volume | * | 50.00 | |
| Max DVH | Plan | | Z_RING2 | Max DVH 3000 cGy to 0% volume | * | 50.00 | |
| Max Dose | Plan | | FrontalLobe_R | Max Dose 5200 cGy | * | | |
| Min DVH | Plan | | PTV_60_30 | Min DVH 6000 cGy to 97% volume | * | | |
| Max DVH | Plan | | PTV_60_30 | Max DVH 6100 cGy to 0% volume | * | | |

Here is an example of the optimization parameters used to create our dose distribution, cover the PTV, and spare the OARs.

In this example, the optimization is trying to cover 97% of the PTV to 60Gy while limiting the max dose to 0% >61Gy. A weight of 100 or (star symbol in image) constraint parameter may be used to give a high importance.

Step 4

Optimization Parameters OARs

| ID/Type | cm ³ | Vol [%] | Dose[cGy] | Actual Dose [cGy] | Priority | gEUD a |
|--------------------------|-----------------|---------|-----------|-------------------|-------------------|--------|
| PTV_60_30 | 132.3 | | | | | |
| Upper | 0.0 | 0.0 | 8100 | 6353 | 100 | 5 |
| Upper | 0.0 | 0.0 | 8100 | 6353 | 100 | 5 |
| Lower | 132.3 | 518.6 | 3681 | 5161 | 100 | 5 |
| Lower | 132.3 | 100.0 | 3681 | 5161 | 100 | 5 |
| Eye_R | 7.0 | | | | | |
| Upper | 0.0 | 0.0 | 1000 | 448 | 50 | 5 |
| FrontalLobe_L | 106.9 | | | | | |
| Upper | 0.0 | 0.0 | 2580 | 3711 | 75 | 5 |
| Lens_R | 0.2 | | | | | |
| Upper | 0.0 | 0.0 | 70 | 181 | 50 | 5 |
| OpticNrv_R | 0.8 | | | | | |
| Upper | 0.0 | 0.0 | 1000 | 620 | 50 | 5 |
| Z_RING1 | 2304.6 | | | | | |
| Upper | 0.0 | 0.0 | 2790 | 2961 | 75 | 5 |
| Z_RING1 | 223.5 | | | | | |
| Upper | 0.0 | 0.0 | 3600 | 5949 | 50 | 5 |
| Z_RING2 | 276.1 | | | | | |
| Upper | 0.0 | 0.0 | 3250 | 2961 | 50 | 5 |
| A_GBM_Brain | 132.3 | | | | | |
| BODY | 6359.7 | | | | | |
| Brain | 1407.6 | | | | | |
| Normal Tissues Objective | | | | | 100/Automatic NTQ | |
| MU Objective | | | | | | |
| Base Dose Plan | | | | | None | |
| Settings | | | | | Normal (2.6 mm) | |

In this example the optimization is trying to achieve the following goals for optimization.

Eye_R ~V150 cGy <0% Weight 50 (less importance relative to the PTV)

Lens_R ~V70 cGy <0% Weight 50 (less importance relative to the PTV)

FrontalLove_L ~V30 cGy <0% Weight 75 (less importance relative to the PTV)

OpticNrv_R ~V150 cGy <0% Weight 50 (less importance relative to the PTV)

Depending on the planning system, entrance avoidance or complete avoidance function can be used on structures to help limit their dose.

In this example the Eye_R, Lens_R, and OpticNrv_R structures all have entrance avoidance functions applied to the optimization objective.

Step 5

Optimization Parameters Opti Structures

| ID/Type | cm ³ | Vol [%] | Dose[Gy] | Actual Dose [Gy] | Priority | gEUD α |
|--------------------------|-----------------|---------|----------|------------------|-------------------|--------|
| PTV_60_30 | 132.3 | | | | | |
| Upper | 0.0 | 0.0 | 8100 | 6352 | 100 | 5 |
| Upper | 0.0 | 0.0 | 8100 | 6353 | 100 | 5 |
| Lower | 132.3 | 518.6 | 3681 | 5161 | 100 | 5 |
| Lower | 132.3 | 106.0 | 3681 | 5161 | 100 | 5 |
| Eye_R | 7.0 | | | | | |
| Upper | 0.0 | 0.0 | 1080 | 448 | 80 | 5 |
| Frontal.lobe_L | 106.9 | | | | | |
| Upper | 0.0 | 0.0 | 2580 | 3711 | 75 | 5 |
| Lens_R | 0.2 | | | | | |
| Upper | 0.0 | 0.0 | 75 | 181 | 80 | 5 |
| Opticerv_R | 0.8 | | | | | |
| Upper | 0.0 | 0.0 | 1080 | 620 | 80 | 5 |
| Z_RING1 | 2304.6 | | | | | |
| Upper | 0.0 | 0.0 | 2790 | 2961 | 75 | 5 |
| Z_RING1 | 223.5 | | | | | |
| Upper | 0.0 | 0.0 | 3600 | 5949 | 80 | 5 |
| Z_RING2 | 276.1 | | | | | |
| Upper | 0.0 | 0.0 | 2580 | 2961 | 75 | 5 |
| A_GBM_Brain | 132.3 | | | | | |
| BODY | 6359.7 | | | | | |
| Brain | 1407.6 | | | | | |
| Normal Tissues Objective | | | | | 100/Automatic NTQ | |
| MU Objective | | | | | | |
| Base Dose Plan | | | | | None | |
| Settings | | | | | Normal (2.6 mm) | |

RING1 V90%Rx < 0% Weight 50 (less importance relative to the PTV, goal to limit the dose falloff from 100-90% within the ring)

RING2 V50%Rx < 0% Weight 75 (less importance relative to the PTV, goal to limit the dose falloff from 100-50% within the ring)

RIND1 V50%Rx < 0% Weight 75 (less importance relative to the PTV, goal to limit the dose falloff from 100-50% within the ring)

The RIND structure is also commonly referred to as the normal tissue.

Step 6

Review Dose Distribution

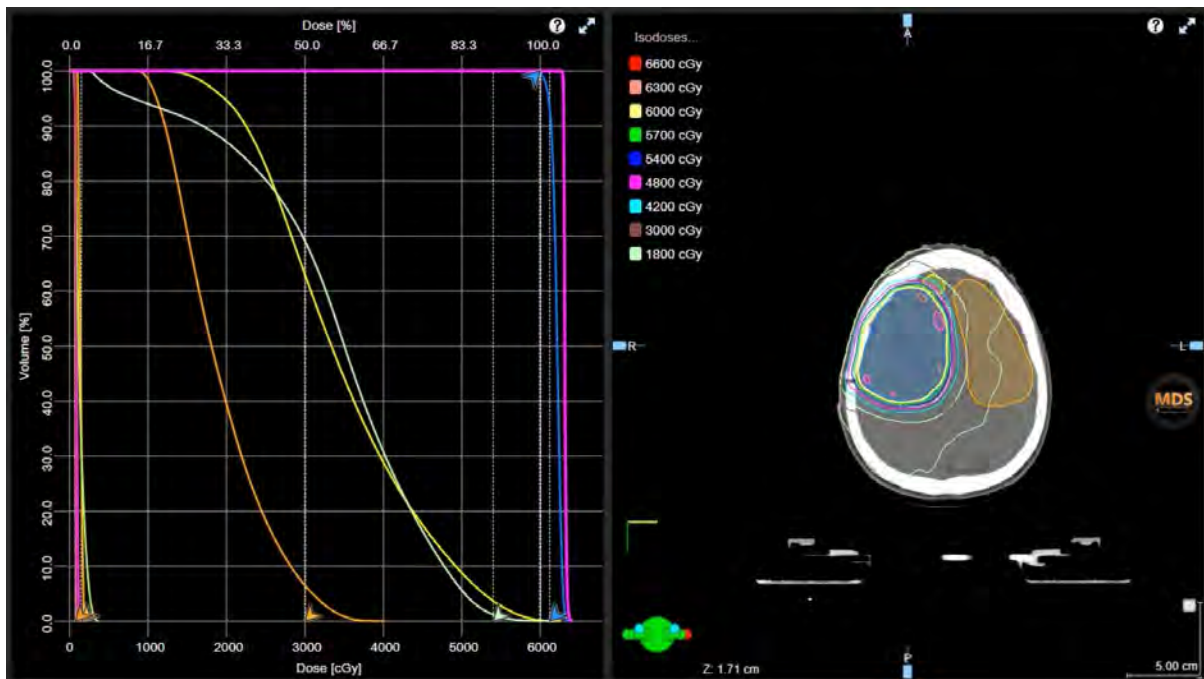


Once complete a dose distribution is created. We will review dose distribution for coverage and conformality.

In this example we have hotspots of 105% Rx, which we can create a isodose volume from. (Dose 105[%]) is the hotspot structure created from the isodose volume. We will then use this structure to re-optimize and decrease the hotspot.

Step 7

Review the DVH and clinical goals.

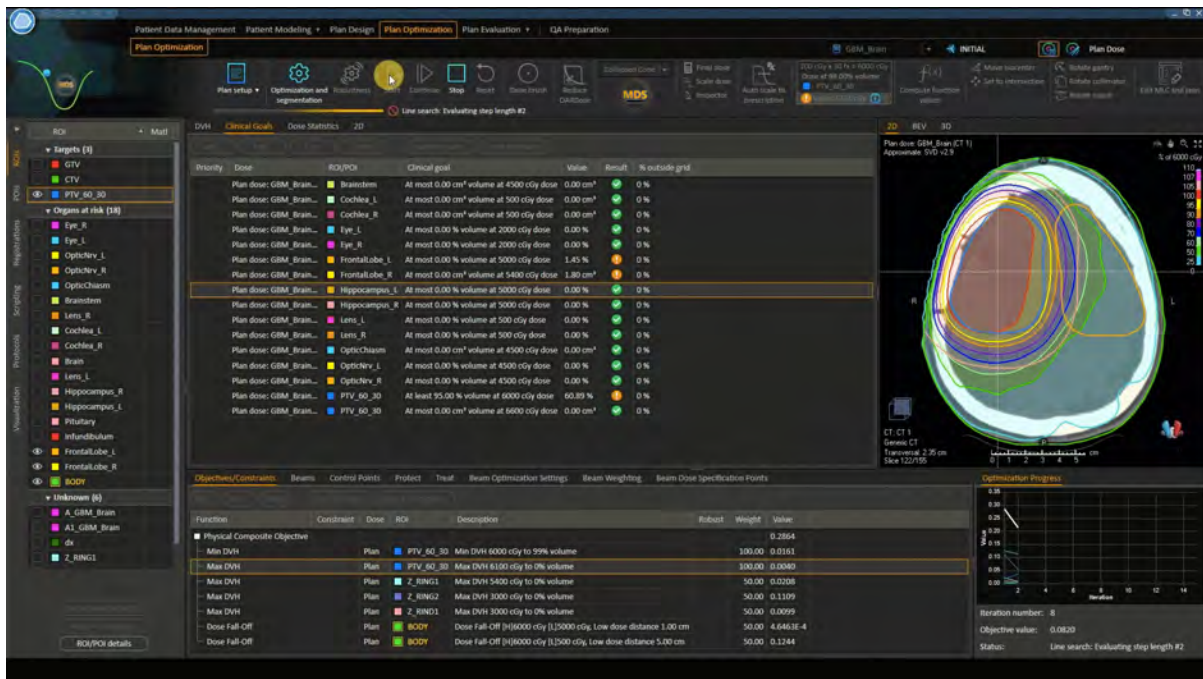


During the planning phase, the planner needs to head towards a solution for meeting target coverage and limiting OAR/critical structure doses. Consideration to the clinical goals and physician intent are also factors which guide the direction of the plan.

To do this, close attention to the Optimization DVH helps guide which constraints to push and which objectives have been met.

Step 8

Review the DVH and clinical goals.



The use of clinical goals, or treatment protocols during optimization helps display to the planner which structures have met planning goals, and which structures still needs work.

Above is an example of a clinical goals table during optimization.

Step 9

Re-Optimization and x hotspots.



After initial review, if we find problem areas in the dose distribution, DVH, or hotspots/cold spots in the plan, we can create new volumes to correct the issues and improve the plan.

Treatment planning is an iterative process, and optimizing multiple trials/plans is recommended in order to improve the quality of the plan.

In this example, the hotspot (Dose 105%) is added to the optimization and objective weights for the PTV and hotspot are increased. This increases the importance of those objectives in the optimization.

Summary

Next let's evaluate the plan to see if it achieves the dose distribution we're looking for. We'll also check the max dose of the plan and OAR dose statistics.

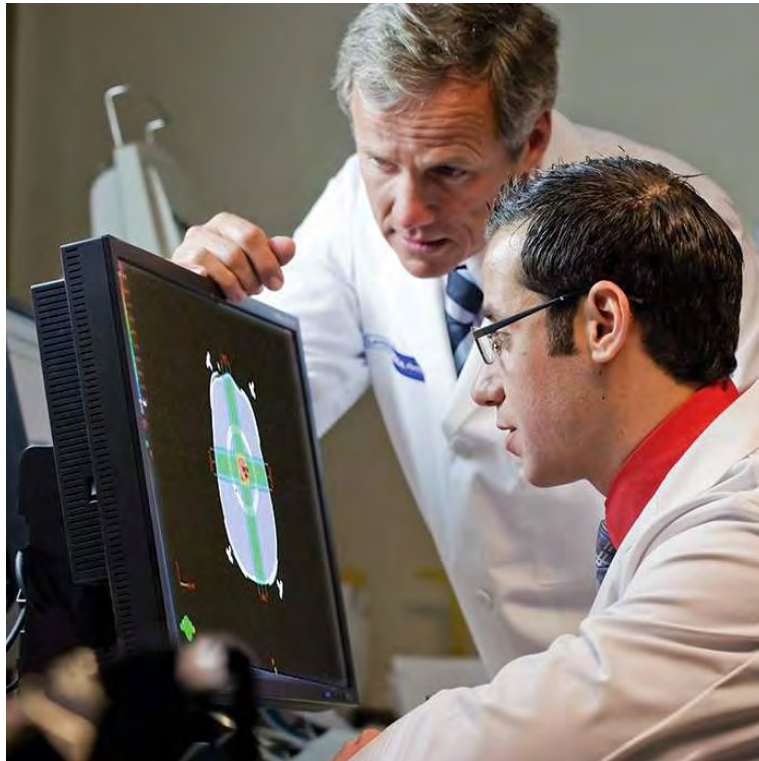
Plan Evaluation



MDS Instructor



Introduction



Once we have good plans for review, we'll begin the plan evaluation with the physician.

In most cases treatment planners will have multiple trials or plans for comparison. This ensures the patient receives the best plan possible.

While reviewing with the physician in some cases they may ask to improve dose to either the PTVs, or spare dose to specific OARs. This is part of the communication process to improve the plan's quality.

Step 1

Dose Distribution RayStation



Here are some of the items we are looking for during the plan evaluation. This is done by scrolling up and down the scan and reviewing the dose distribution.

While doing this we note hotspots, max dose of the plan, location of max dose, cold spots, and coverage of the isodose lines around the target.

Step 2

Dose Distribution Eclipse

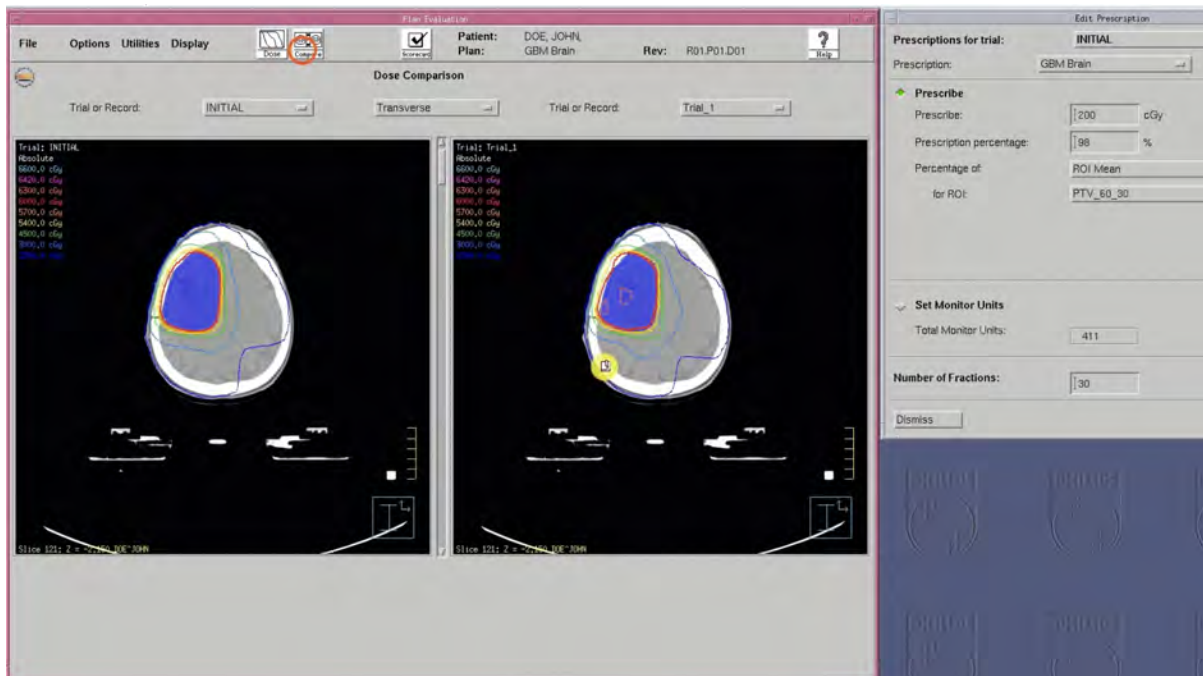


(Continued)

Look out for hotspots, max dose of the plan, location of max dose, cold spots, and coverage of the isodose lines around the target.

Step 3

Dose Distribution Pinnacle

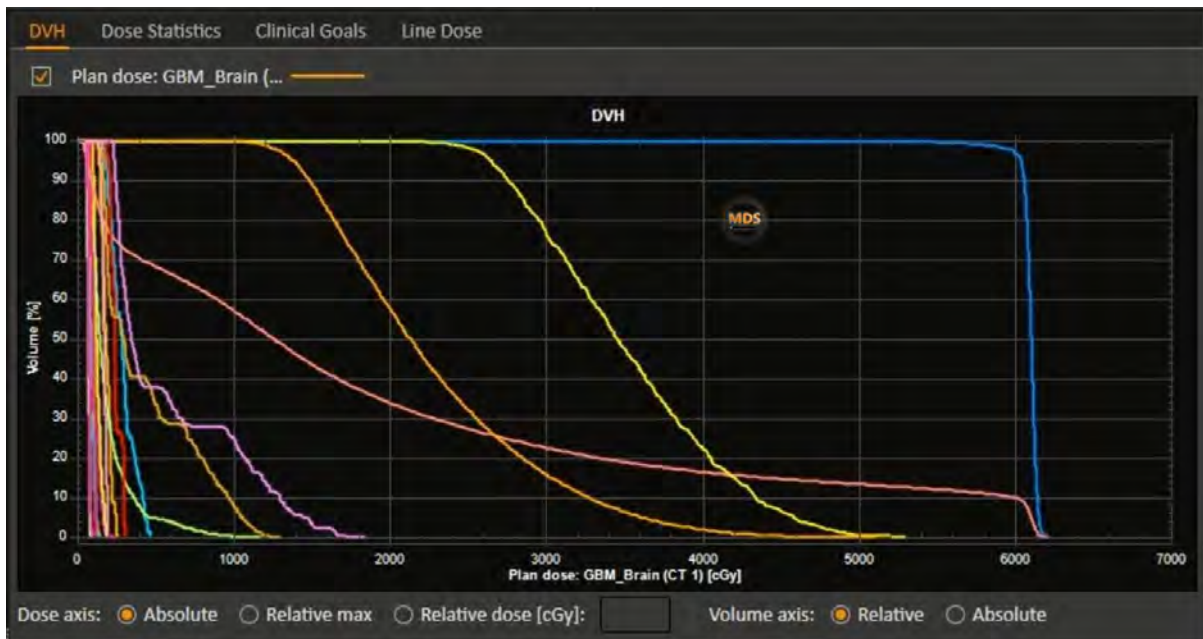


(Continued)

Look out for hotspots, max dose of the plan, location of max dose, cold spots, and coverage of the isodose lines around the target.

Step 4

Clinical Goals and Metrics



The Dose Volume Histogram (DVH) provides a quick review of clinical goals and metrics.

Example of some data points to look for in this DVH

Step 5

Clinical Goals and Metrics

| Dose Statistics Clinical Goals Beams (Current) Control Points (Current) BEV (Current) | | | | | | | | | | |
|---|---------------|----------------|------------|------|------|---------|------|------|------|-----------|
| ROI statistics POI statistics MOS | | | | | | | | | | |
| Dose | ROI | ROI vol, [cm³] | Dose [cGy] | | | | | | | % outside |
| | | | D99 | D98 | D95 | Average | D50 | D2 | D1 | |
| Plan dose: GBM_Brain... | Brain | 1465.36 | 41 | 47 | 63 | 1898 | 1258 | 6129 | 6142 | 0 % |
| Plan dose: GBM_Brain... | Brainstem | 27.36 | 63 | 65 | 73 | 194 | 147 | 738 | 829 | 0 % |
| Plan dose: GBM_Brain... | Cochlea_L | 0.28 | 65 | 65 | 66 | 75 | 75 | 87 | 88 | 0 % |
| Plan dose: GBM_Brain... | Cochlea_R | 0.32 | 85 | 85 | 86 | 105 | 105 | 122 | 122 | 0 % |
| Plan dose: GBM_Brain... | Eye_L | 6.73 | 57 | 59 | 63 | 92 | 91 | 133 | 139 | 0 % |
| Plan dose: GBM_Brain... | Eye_R | 6.99 | 77 | 80 | 88 | 125 | 123 | 181 | 190 | 0 % |
| Plan dose: GBM_Brain... | FrontalLobe_L | 106.41 | 1187 | 1267 | 1382 | 2265 | 2132 | 3977 | 4182 | 0 % |
| Plan dose: GBM_Brain... | FrontalLobe_R | 13.65 | 2407 | 2528 | 2651 | 3512 | 3455 | 4810 | 4910 | 0 % |
| Plan dose: GBM_Brain... | Hippocampus_L | 3.76 | 159 | 160 | 166 | 446 | 297 | 1136 | 1176 | 0 % |
| Plan dose: GBM_Brain... | Hippocampus_R | 3.55 | 232 | 234 | 239 | 591 | 349 | 1632 | 1656 | 0 % |
| Plan dose: GBM_Brain... | Infundibulum | 0.10 | 184 | 186 | 201 | 248 | 244 | 305 | 306 | 0 % |
| Plan dose: GBM_Brain... | Lens_L | 0.18 | 63 | 65 | 68 | 78 | 77 | 97 | 99 | 0 % |
| Plan dose: GBM_Brain... | Lens_R | 0.21 | 89 | 89 | 89 | 107 | 108 | 127 | 129 | 0 % |

During plan evaluation, dose statistics for the individual OARs are also reviewed. The common dose statistics reviewed are for the mean, max doses. In this example a few other data points are shown.

Step 6

Clinical Goals and Metrics

| Dose Statistics Clinical Goals Beams (Current) Control Points (Current) BEV (Current) | | | | | | |
|--|-------------------------|---------------|--|----------|--------|----------------|
| Add... Edit... Delete... Load template... Create template... MDS | | | | | | |
| Priority | Dose | ROI/POI | Clinical goal | Value | Result | % outside grid |
| | Plan dose: GBM_Brain... | Eye_L | At most 0.00 % volume at 2000 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | Eye_R | At most 0.00 % volume at 2000 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | FrontalLobe_L | At most 0.03 cm³ volume at 5000 cGy dose | 0.02 cm³ | ✓ | 0 % |
| | Plan dose: GBM_Brain... | FrontalLobe_R | At most 0.03 cm³ volume at 5400 cGy dose | 0.00 cm³ | ✓ | 0 % |
| | Plan dose: GBM_Brain... | Hippocampus_L | At most 0.00 % volume at 5000 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | Hippocampus_R | At most 0.00 % volume at 5000 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | Lens_L | At most 0.00 % volume at 500 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | Lens_R | At most 0.00 % volume at 500 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | OpticChiasm | At most 0.00 cm³ volume at 4500 cGy dose | 0.00 cm³ | ✓ | 0 % |
| | Plan dose: GBM_Brain... | OpticNrv_L | At most 0.00 % volume at 4500 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | OpticNrv_R | At most 0.00 % volume at 4500 cGy dose | 0.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | PTV_60_30 | At least 95.00 % volume at 6000 cGy dose | 97.00 % | ✓ | 0 % |
| | Plan dose: GBM_Brain... | PTV_60_30 | At most 0.00 cm³ volume at 6600 cGy dose | 0.00 cm³ | ✓ | 0 % |

Clinical goals, clinical protocols or scorecards are a good tool for quickly identifying if plan metrics and goals have been met. In this example all the clinical goals have been met in this plan.

PTV >95% Coverage

Plan Max Dose <110%

Summary



This wraps up treatment planning for VMAT GBM Brain case.

We covered the simulation, beam arrangement, field margins, optimization and we learned how to evaluate a plan.

Please watch the treatment planning video demonstrations and take the post quiz to test what you've learned.