Stereotactic Radiosurgery SGRT for Trigeminal Neuralgia & Arteriovenous Malformation (AVM) Treatments

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We extend the healing ministry of Christ by caring for those who are ill and by nurturing the health of the people in our communities.

centura

Disclosures

- Vision RT is providing travel assistance for this talk.
- I provide physics consultation services to both Varian and Vision RT.

Disclaimer

- Commercial products are highlighted in the text so that readers unfamiliar with the software, hardware and/or delivery systems being referred to can easily look them up and can distinguish commercial products from QA tests and procedures. They are not to be seen as an endorsement by Centura or their representatives.

Objectives

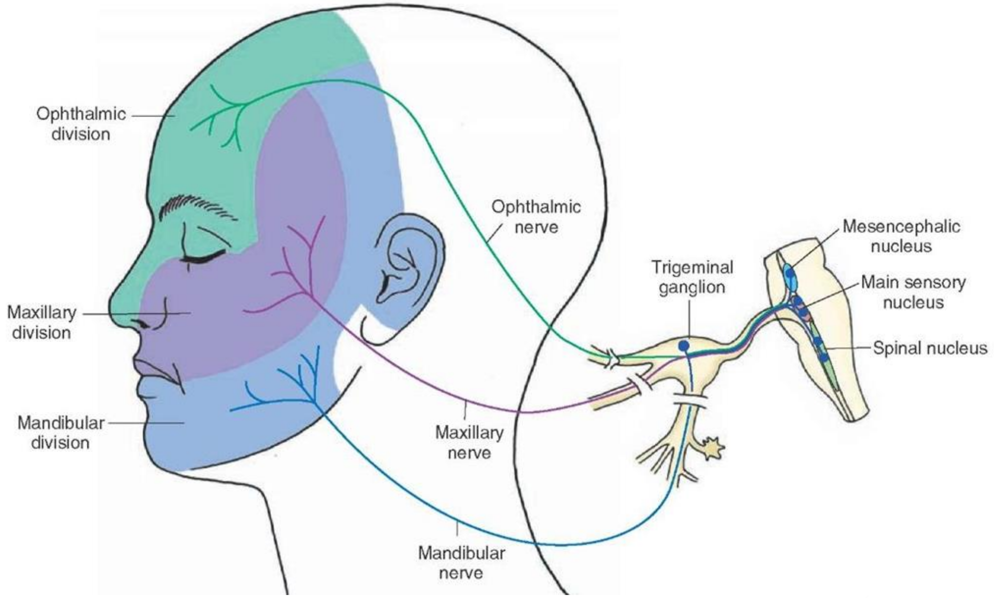
- Look at characteristics of Stereotactic Radiosurgery (SRS) treatments for non-malignant indications like **Trigeminal Neuralgia (TN)**, **Sphenopalatine Ganglion Neuralgia (SPG)**, and **Arteriovenous Malformations (AVMs)**.
- Discuss how we treat these cases at Centura.
- Discuss what aspects of these treatments are pertinent to the use of SGRT.
- Compare SGRT techniques to “real-time” imaging techniques used on other dedicated SRS platforms.
- Look for patient/targeting characteristics and how they can impact our approach to SRS treatments in general.

Side Missions:

- Look at what SGRT treatment data is telling us.
- Contemplate how we can use SGRT data to refine our SRS treatment approach.

Trigeminal Neuralgia (TN)
Sphenopalatine Ganglion Neuralgia (SPG)

- Both conditions are associated with disfunction of the fifth cranial nerve complex
- There are three divisions or branches of the trigeminal nerve: Ophthalmic division (CN V1 or Va), Maxillary division (CN V2 or Vb), Mandibular division (CN V3 or Vc)
- About 25% of patients diagnosed with TN will not respond to medication
- Another 25% may develop intolerance to medication as part of their management
- Non-Radiosurgical Treatment options for TN
  - Microvascular Decompression (MVD)
  - Radiofrequency Ablation
  - Balloon compression
  - Intra-venous anticonvulsant infusion
  - Glycerol injection
- Non-Radiosurgical Treatment options for SPG
  - Sphenopalatine Ganglion anesthetic block
  - Anticonvulsive drugs such as Gabapentin



Arteriovenous Malformation (AVM)

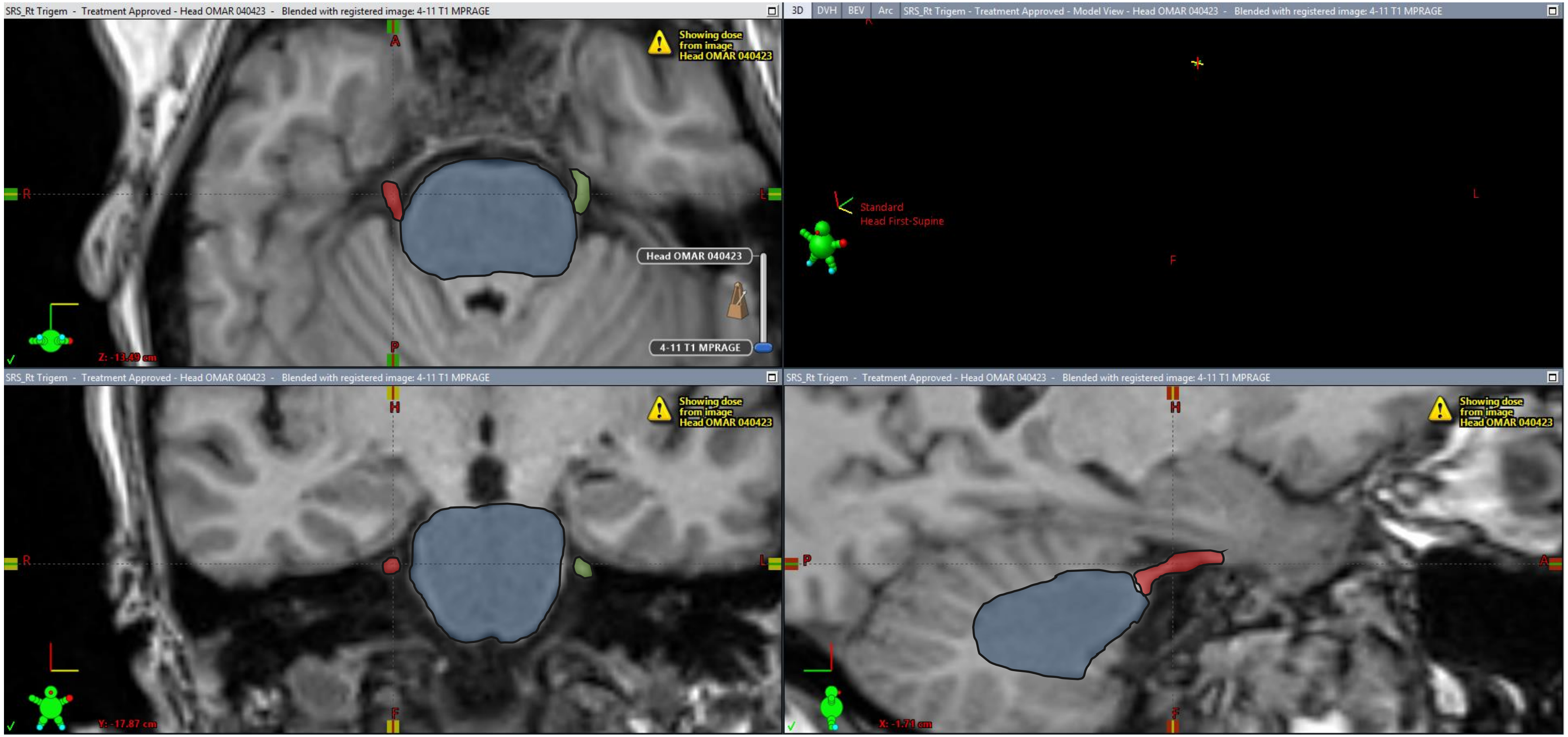
- AVMs are benign
- Intracranial AVMs are abnormal connections between the arteries and veins in the brain
- The AVM disrupts blood flow and oxygen circulation
- Approx. 10-15 percent of people with an AVM experience symptoms (many go undiagnosed)
- AVM symptoms vary based on size and location (AVM volume and brain functional eloquence)
  - Progressive loss of neurological function
  - Headaches
  - Nausea and vomiting
  - Seizures
  - Loss of consciousness
- Non-Radiosurgical Treatment options for AVM
  - Surgery
    - When possible
    - With acceptable neurological consequences
    - Only technique that resolves risk of intracranial bleeding
  - Embolization

Trigeminal Neuralgia (TN)

Stereotactic Radiosurgery (SRS) Process Using Surface Guidance

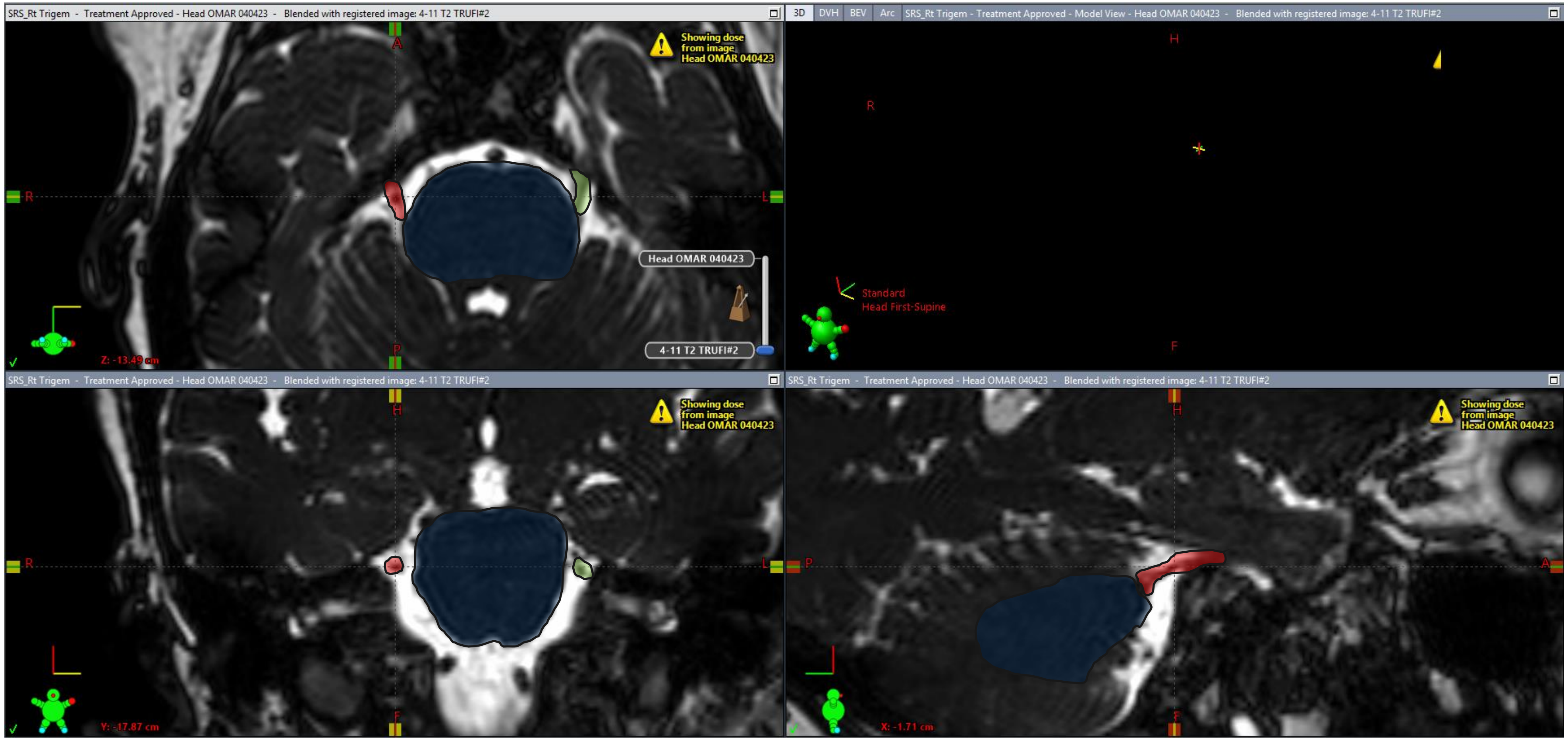
- Patient receives MRI sequence (T1 & T2) followed by high resolution CT simulation in Radiation Oncology
  - CT scan is completed with head in neutral position (favoring chin down) in an open face reinforced orfit mask
- Patient CT is pushed to the Treatment Planning System (TPS) for image fusion and planning
  - Planned using 5-6 arcs using a 4mm ICVI cone on a varian Edge accelerator
  - Targeting the Root Entry Zone (REZ) of the Trigeminal nerve while avoiding the optical structures
  - Placing the 20Gy Isodose Line (IDL) at the surface of the brainstem (max dose of 90Gy centered on visible nerve)
    - No regular modifications are made to the protocol for TN retreatments
- After plan approval the plan is pushed to alignrt® and undergoes standard pretreatment QA procedures.
  - Alignment verification using both an “optics only” and radiographic assisted Winston-Lutz (WL) test.
  - ICVI Cone alignment verification
  - Collision Verification (4mm ICVI cone)

Trigeminal Neuralgia (TN)
Stereotactic Radiosurgery (SRS)



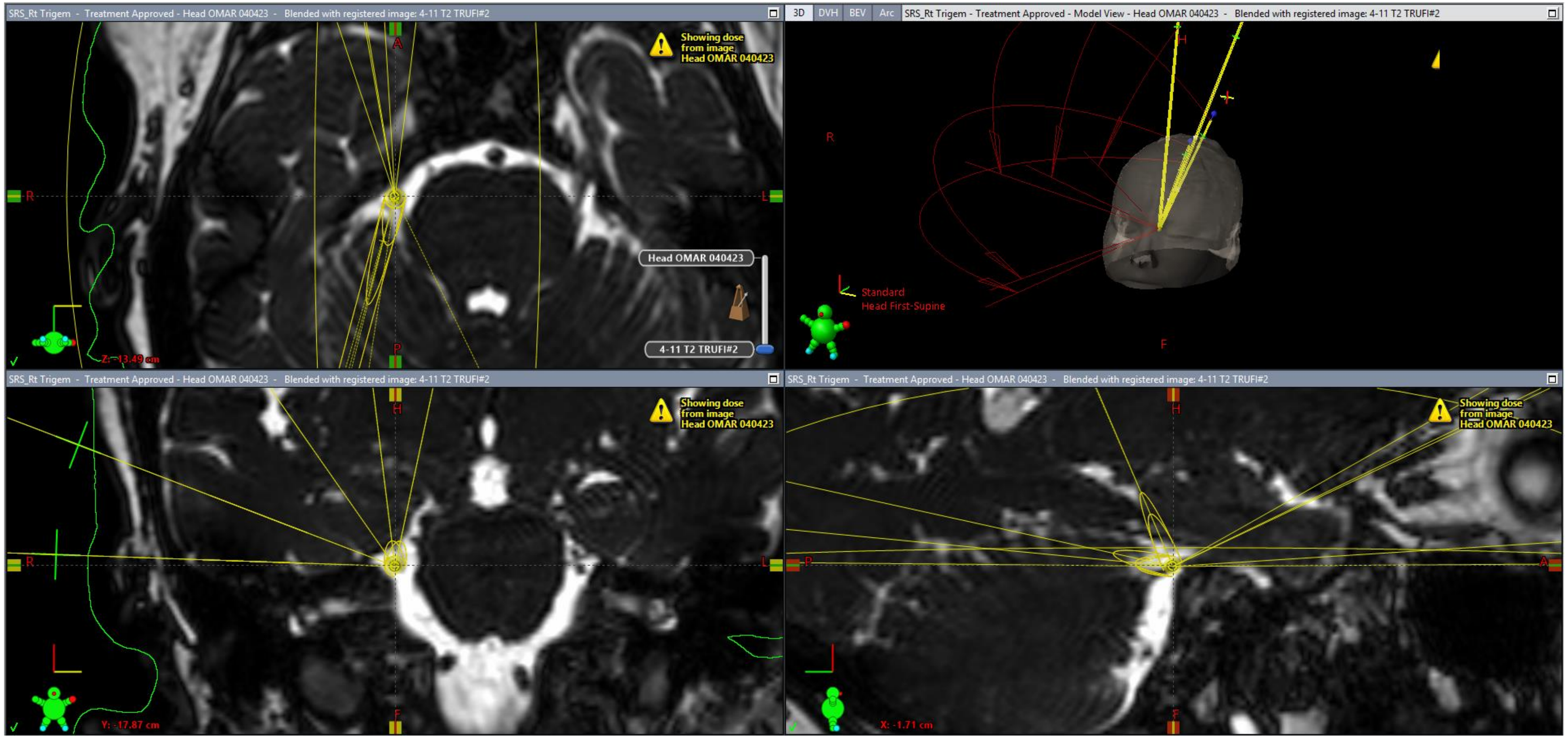
Trigeminal Neuralgia (TN)

Stereotactic Radiosurgery (SRS)



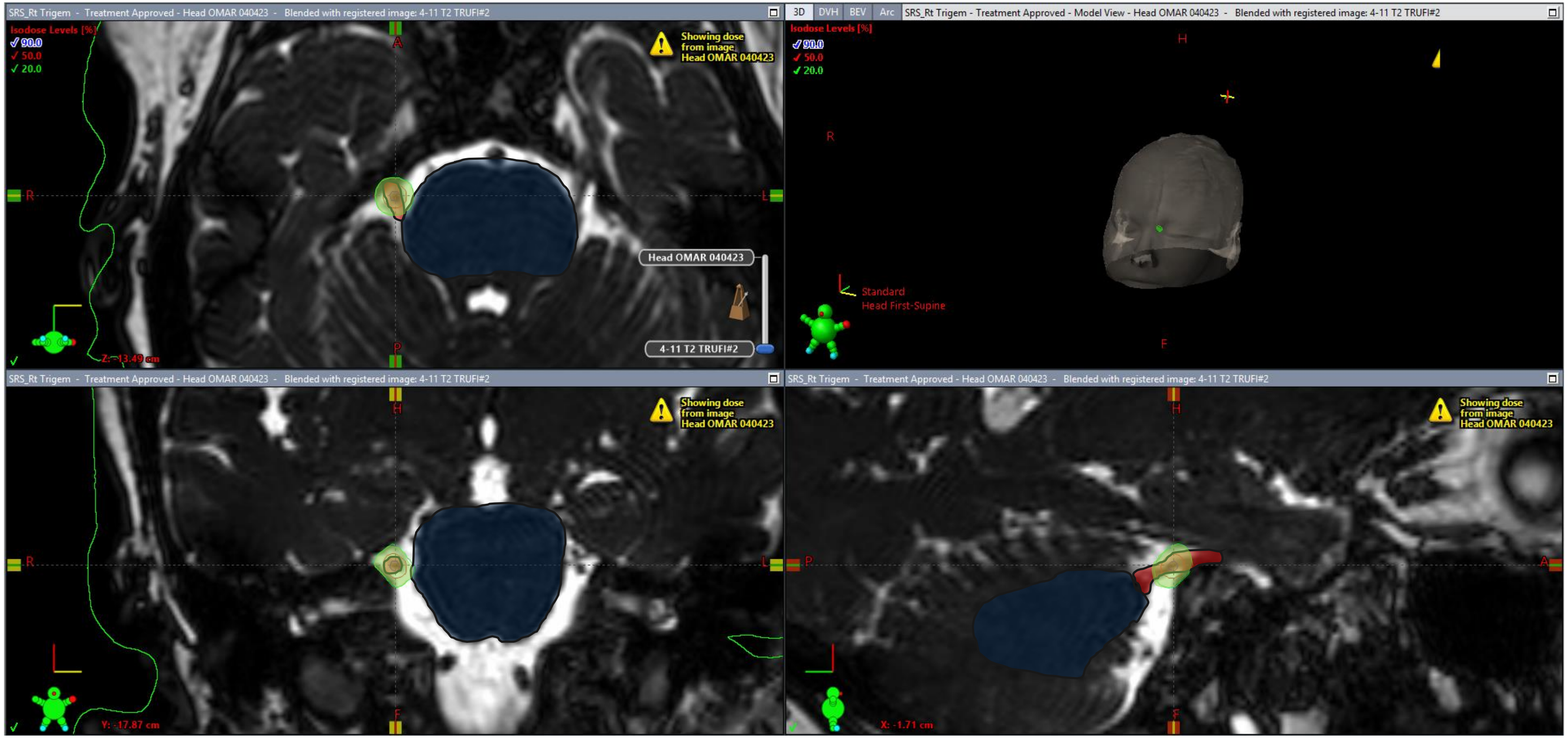
Trigeminal Neuralgia (TN)

Stereotactic Radiosurgery (SRS)



Trigeminal Neuralgia (TN)

Stereotactic Radiosurgery (SRS)



Sphenopalatine Ganglion Neuralgia (SPG)

Stereotactic Radiosurgery (SRS) Process Using Surface Guidance

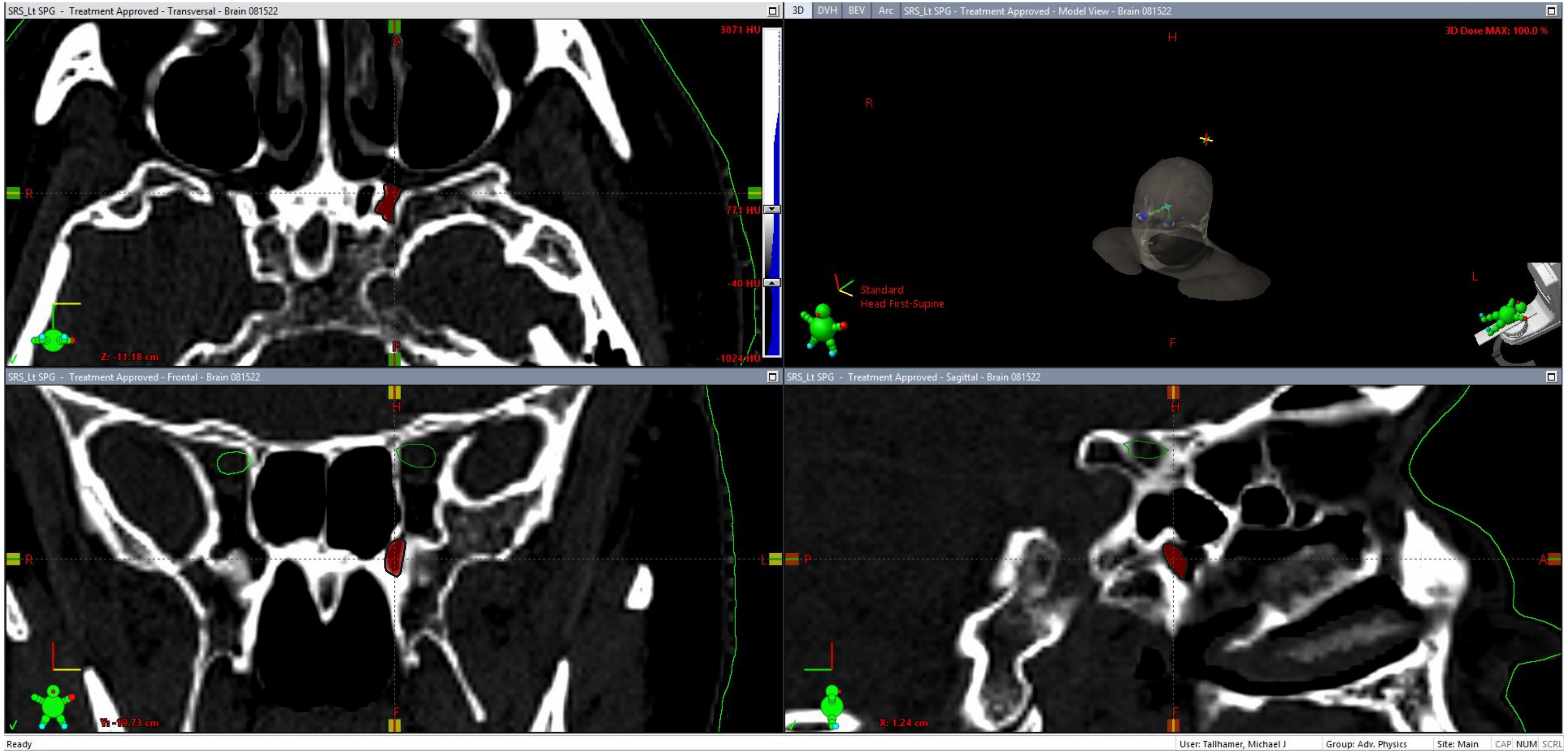
- Patient receives a high-resolution CT simulation in Radiation Oncology
  - CT scan is completed with head in neutral position (favoring chin down) in an open face reinforced orfit mask
  - No MRI is required since we are targeting the boney foramen of the pterygopalatine fossa.

- Patient CT is pushed to the Treatment Planning System (TPS) for image fusion and planning
  - Planned using 5-6 arcs using a 7.5mm ICVI cone on a varian Edge accelerator while avoiding the optical structures
  - Targeting the pterygopalatine fossa (vidian canal) along the maxillary branch of the Trigeminal nerve
  - Centering of the dose distribution within the boney foramen (max dose of 90Gy)
    - No regular modifications are made to the protocol for SPG retreatments

- After plan approval the plan is pushed to alignrt® and undergoes standard pretreatment QA procedures.
  - Alignment verification using both an “optics only” and radiographic assisted Winston-Lutz (WL) test.
  - ICVI Cone alignment verification
  - Collision Verification (7.5mm ICVI cone)

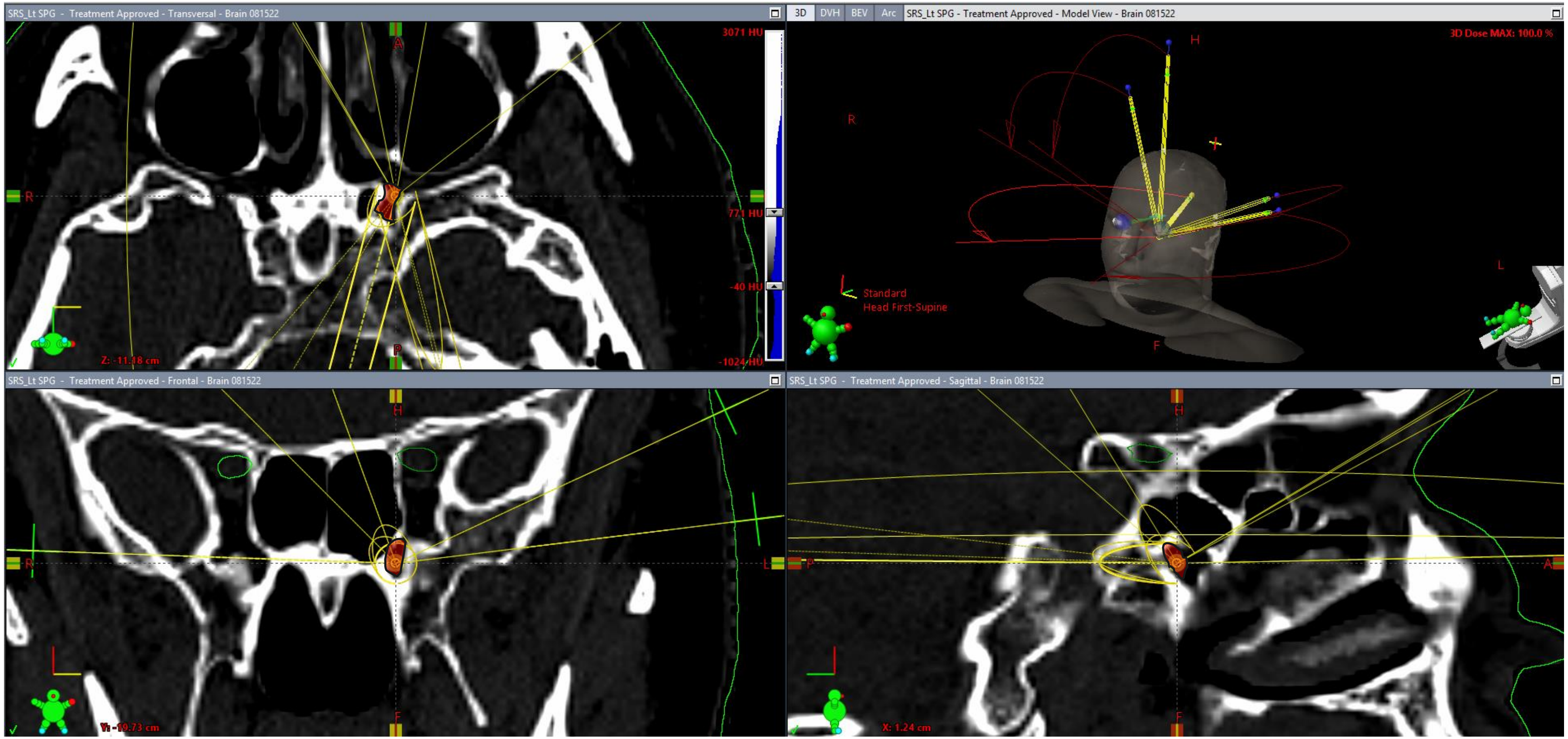
Sphenopalatine Ganglion Neuralgia (SPG)

Stereotactic Radiosurgery (SRS)



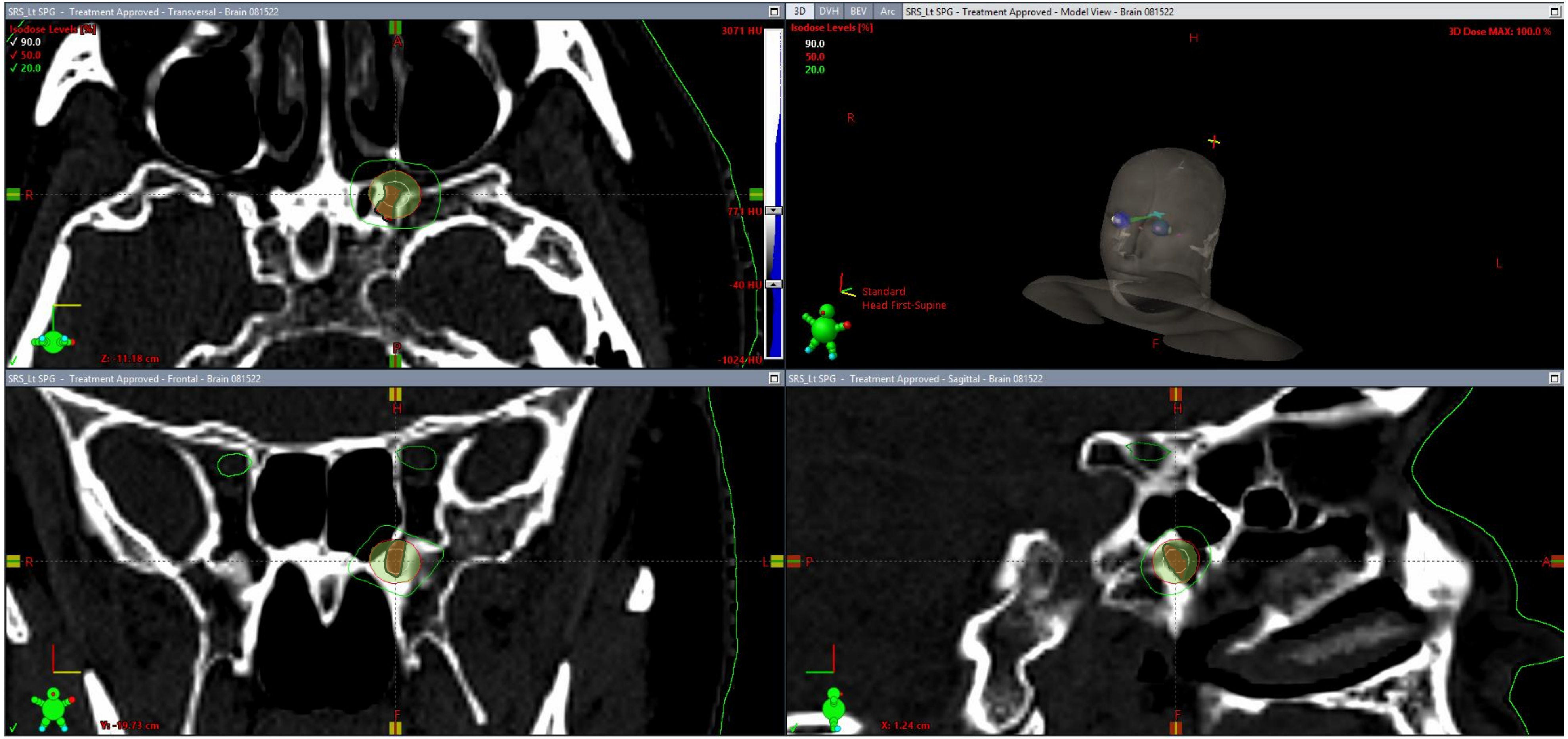
Sphenopalatine Ganglion Neuralgia (SPG)

Stereotactic Radiosurgery (SRS)



Sphenopalatine Ganglion Neuralgia (SPG)

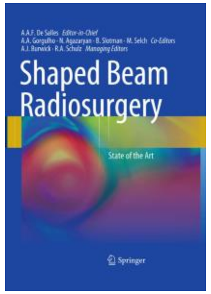
Stereotactic Radiosurgery (SRS)



Arteriovenous Malformation (AVM)

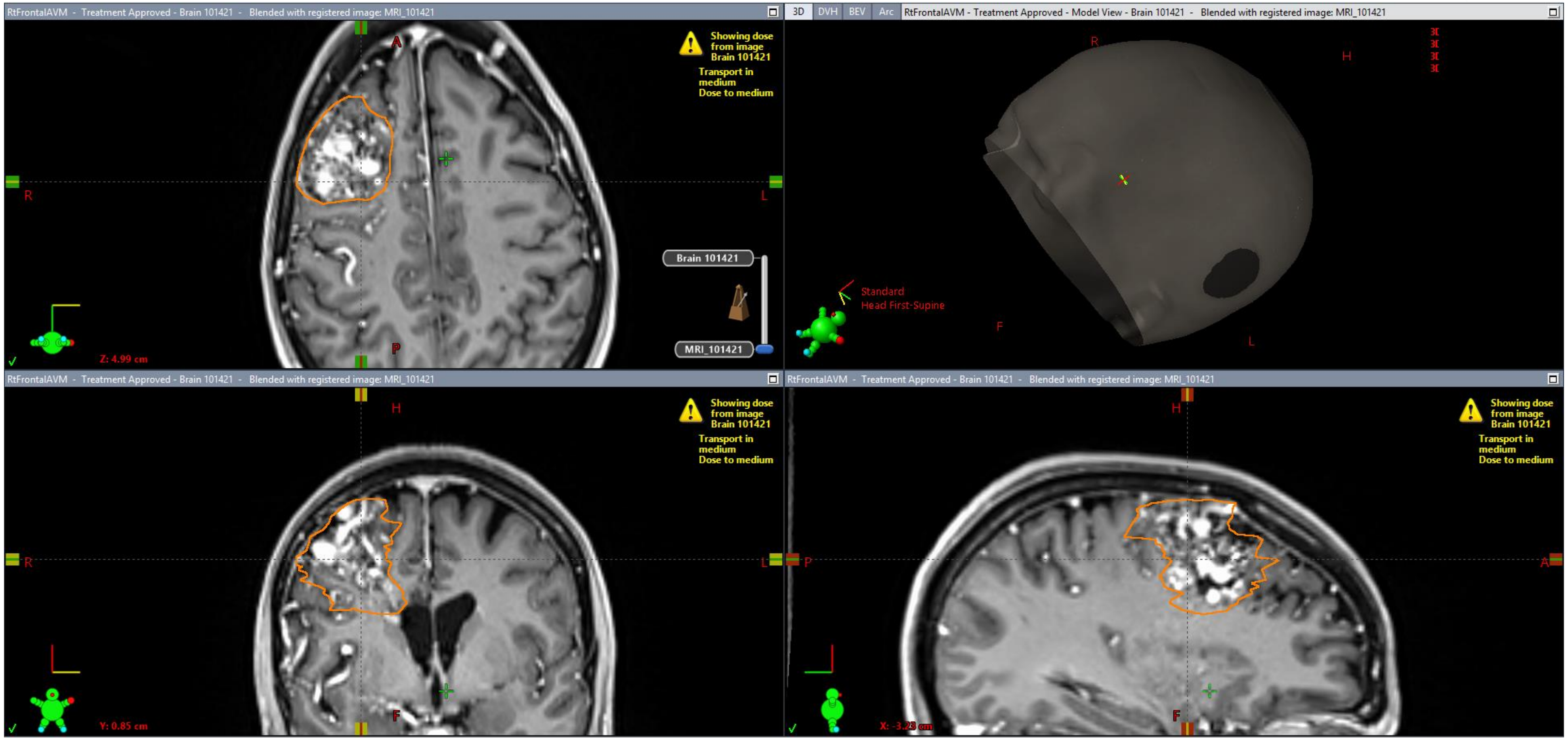
Stereotactic Radiosurgery (SRS) Process Using Surface Guidance

- Patient receives MRI sequence (T1 w/ and w/o contrast) followed by high resolution CT simulation in Radiation Oncology
  - CT scan is completed with head in neutral position (favoring chin down) in an open face reinforced orfit mask
- Patient CT is pushed to the Treatment Planning System (TPS) for image fusion and planning
  - Planned using 4-5 VMAT arcs using a varian Edge accelerator with 6DoF PerfectPitch couch and HDMLC
  - Targeting the AVM nidus (GTV) on MRI w/ contrast where GTV = CTV = PTV (i.e. 0mm margin*)
  - Dose is determined based on Kjellberg's 3% risk of radiation necrosis for AVMs**
  - Plan goal to cover surface of target with 100% of Rx dose while meeting protocol dose constrains for normal brain
- After plan approval the plan is pushed to alignrt® and undergoes standard pretreatment QA procedures.
  - Alignment verification using both an "optics only" and radiographic assisted Winston-Lutz (WL) test.
  - Collision Verification
  - VMAT plan dose verification

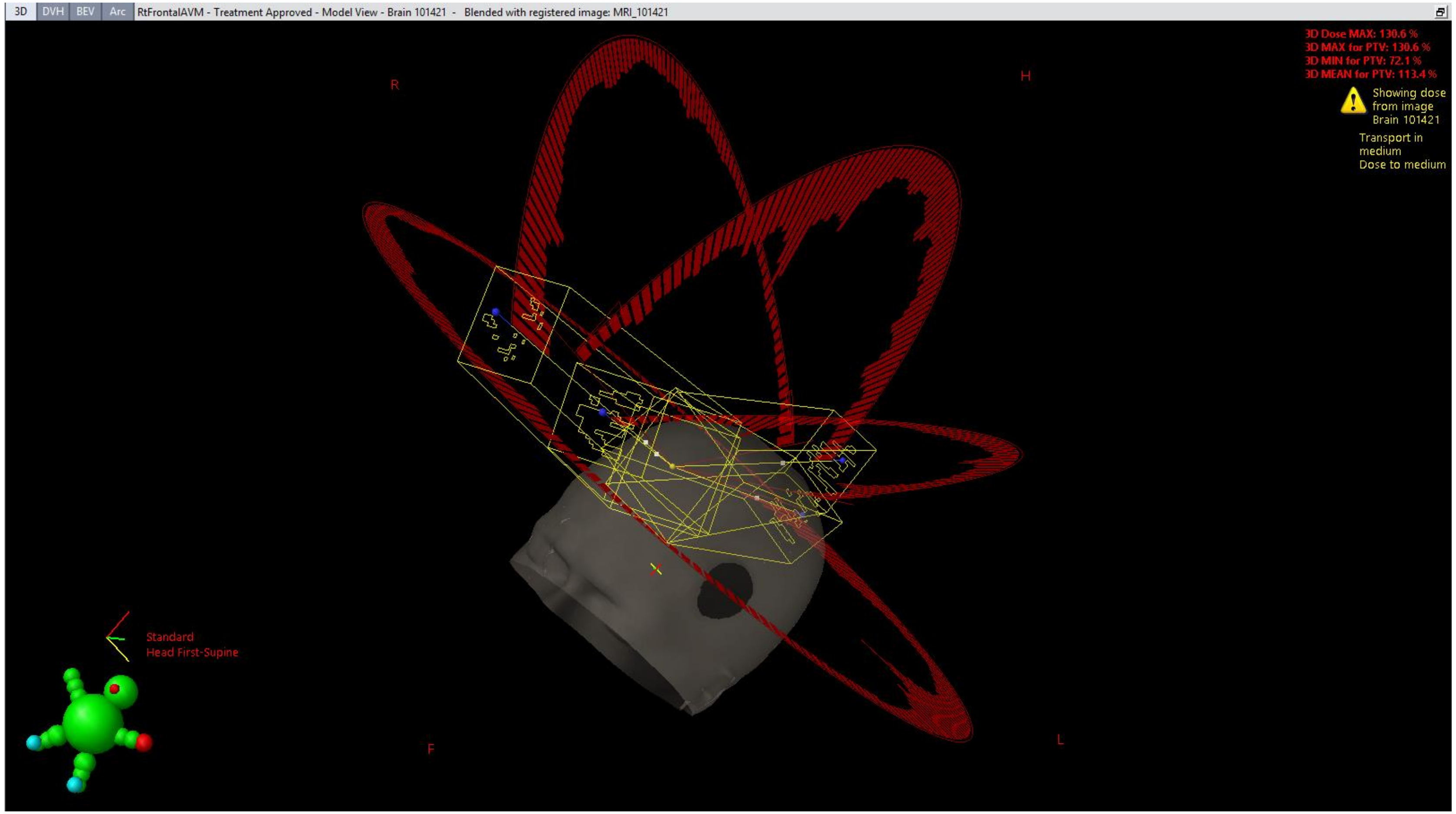


* Margin is sometimes a poorly understood concept and by "sometimes" I mean "all the time"
** Table available in publication or in ***Shaped Beam Radiosurgery***

Arteriovenous Malformation (AVM)
Stereotactic Radiosurgery (SRS)

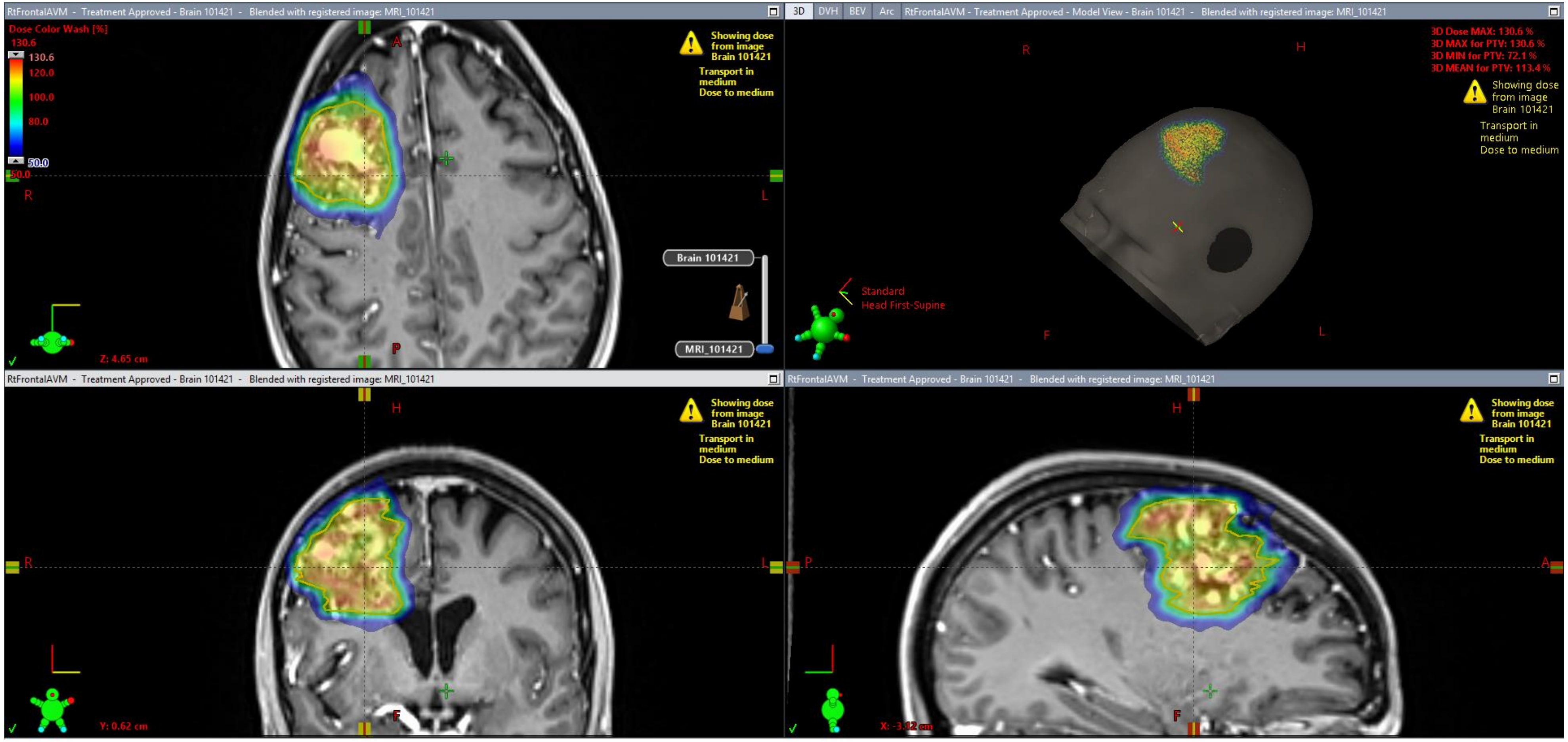


Arteriovenous Malformation (AVM)
Stereotactic Radiosurgery (SRS)



Arteriovenous Malformation (AVM)

Stereotactic Radiosurgery (SRS)



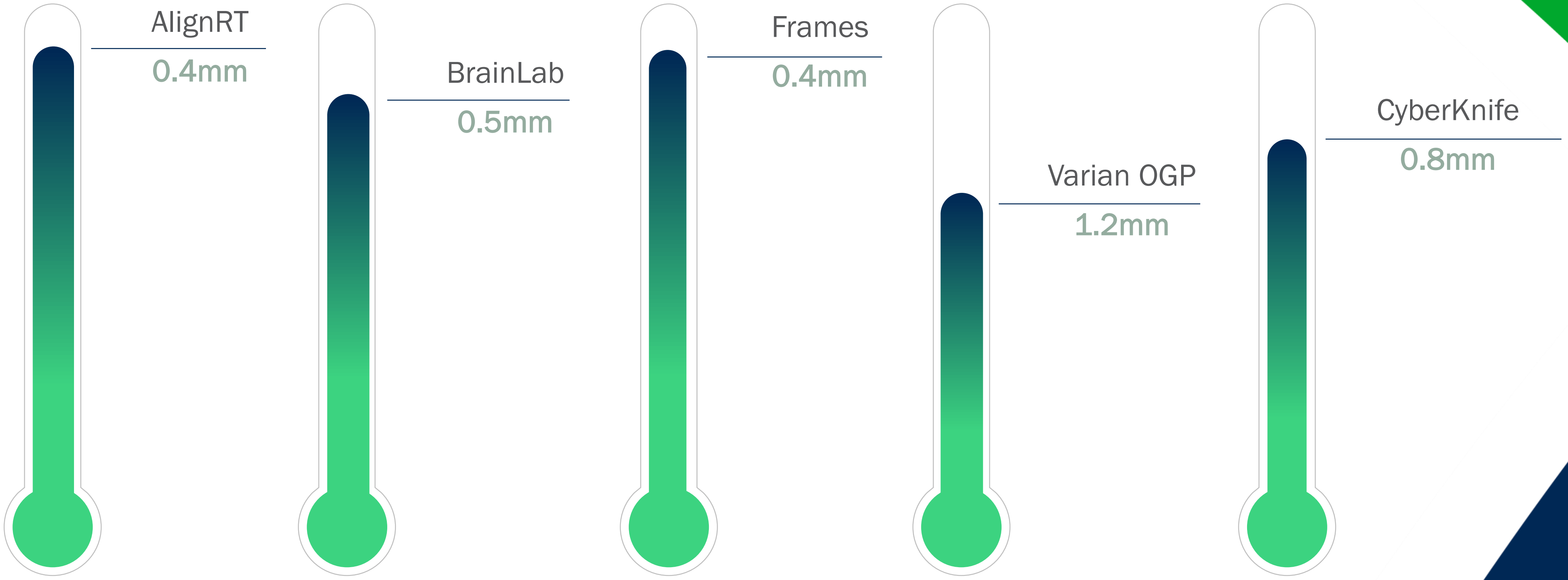
Characteristics of SRS Process Using Surface Guidance

What are we actually worried about with these treatments?

- Is it really the high doses (TN and/or SPG)?
  - The output of the machine is typically not what we are worried about
- In the case of TN and SPG the Rx dose is extremely high and there are sensitive structures nearby
  - We need to have very precise targeting.
    - The REZ targeting is approx. 3mm long and directly adjacent to the brainstem
    - The nerve is approx. 1mm in diameter
  - Dose falloff is steep so small positional errors result in significant changes in the dose to underlying tissue
  - Decreased dose can limit the effectiveness of the treatment and result in need for additional treatments in the future
- In the case of AVM, margins are 0mm and targets can be large and irregular.
  - Margins are not 0mm in reality
  - The surrounding brain's functional eloquence can be a limiting factor in grade and therefore dose

Characteristics of SRS Process Using Surface Guidance

What are we actually worried about with these treatments?



The combined patient setup accuracy should conform to the recommendations of TG142 of 1 mm for SRS and SBRT and within 2 mm for conventional treatments as stated in TG-147.

Characteristics of SRS Process Using Surface Guidance

What SGRT output tells us about targeting and positioning

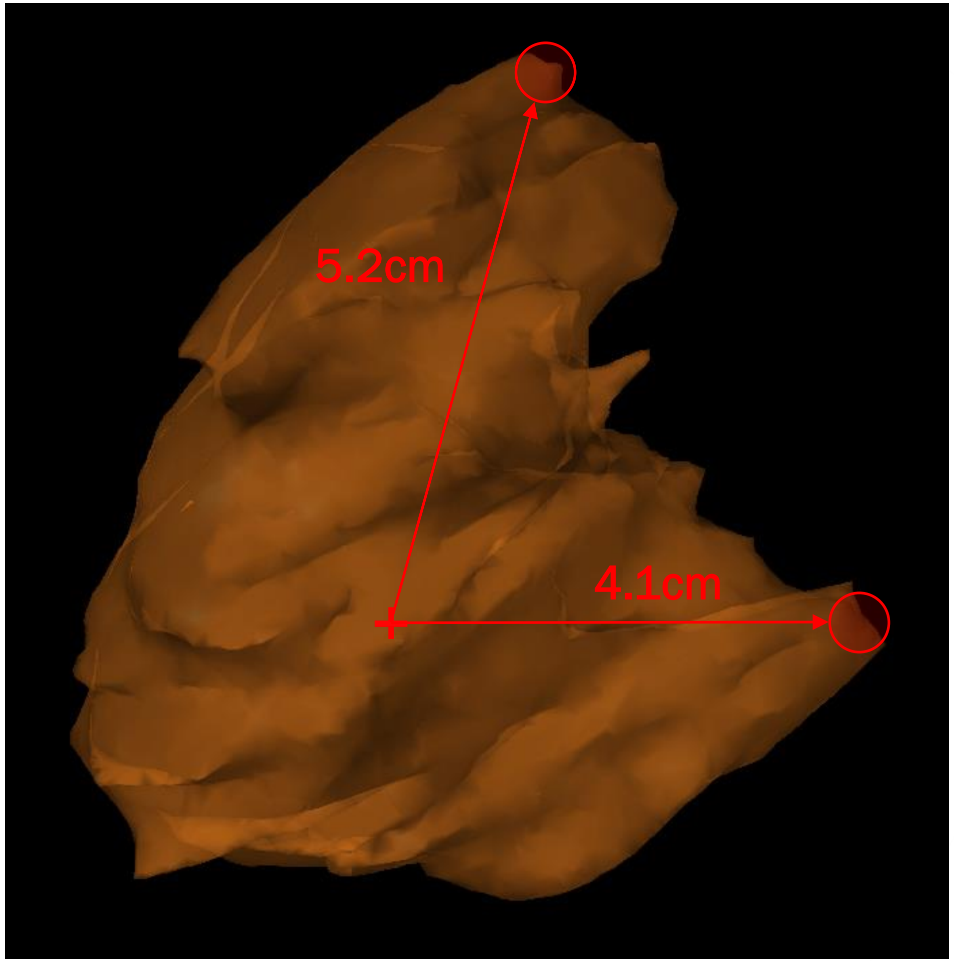
- Initial Positioning
  - Relative to isocenter
- Maintain Positioning
  - Reference surface after imaging (CBCT)
  - Beam Hold if patient moves
- Repositioning
  - Move patient back to reference position (6DoF) after detected deviation

- Critiques
  - Noise in the system
  - Camera Blockage
    - Real issue if combined with self shadowing in camera's view of patient
  - Not internal
    - What is the target doing?
- Advantages
  - Extremely efficient
    - Limits time on table
  - No imaging dose
  - Published accuracy better than 0.3-0.5mm
  - True Real-time

What is our SGRT data telling us?

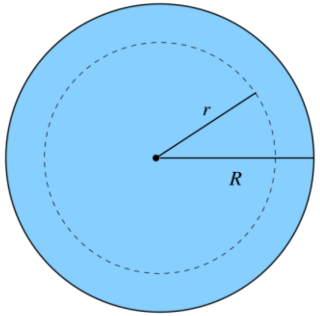
Margins and Targeting

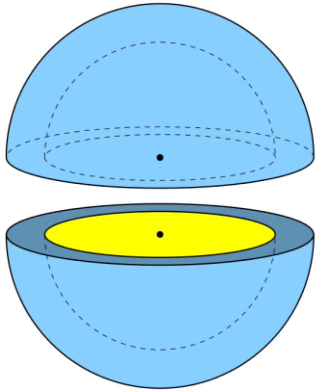
- Well established in literature that SGRT can provide an accuracy of better than 0.5mm.
- This is true for isocenter which is where the data is reported
- Margins and tolerance thresholds have largely been adopted from small target single isocenter treatments (i.e. 1mm/1 degree or 0.5mm / 0.5degrees)
- Can we use our SGRT data to validate these tolerances and their applicability to large irregular targets like AVMs or even off-axis targets in the case of multiple met single isocenter treatments

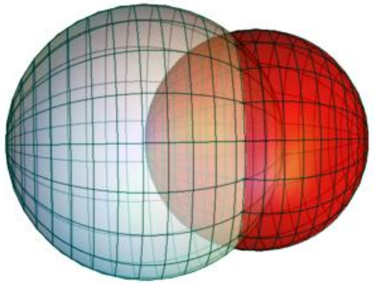


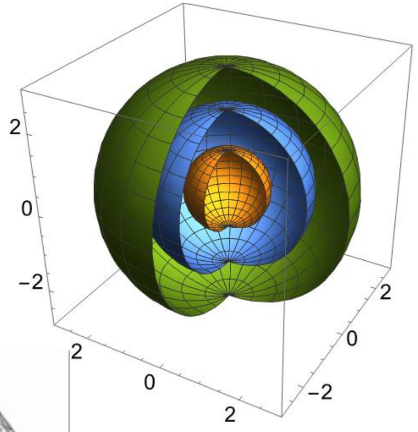
What is happening far from isocenter?

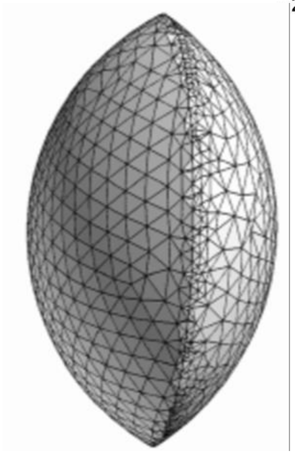
Single Isocenter Small Target (TN / SPG)











Assume the target approximates a sphere

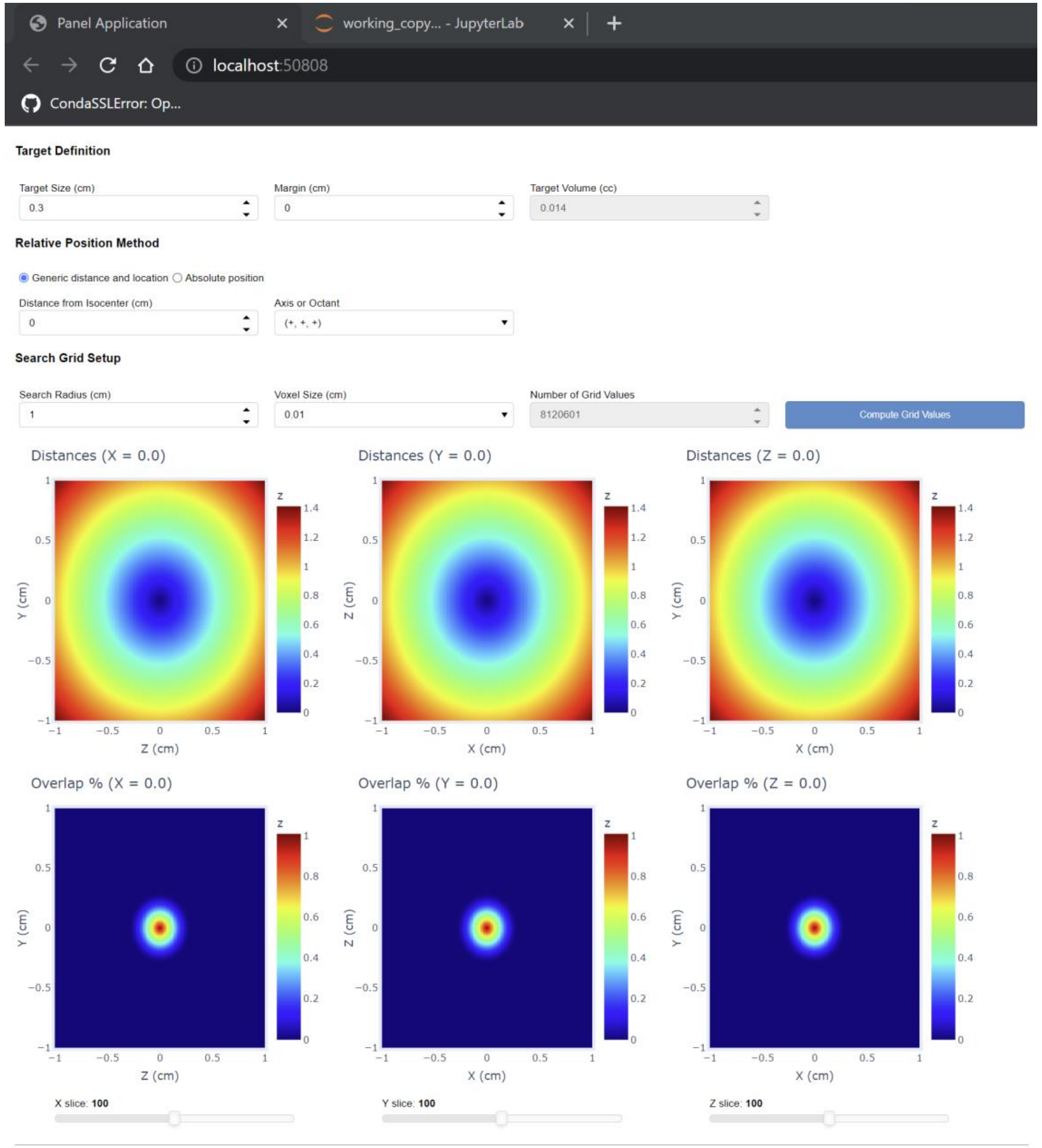
- Target radius = r
- Margin = m
- Coverage radius = R = r + m

Simulate for all permutations of the displacements allowed by your SGRT tolerances.

Compute distances and RTOG conformity / overlap percentage

Determine margin required for the coverage desired

Single Isocenter Small Target (TN / SPG)



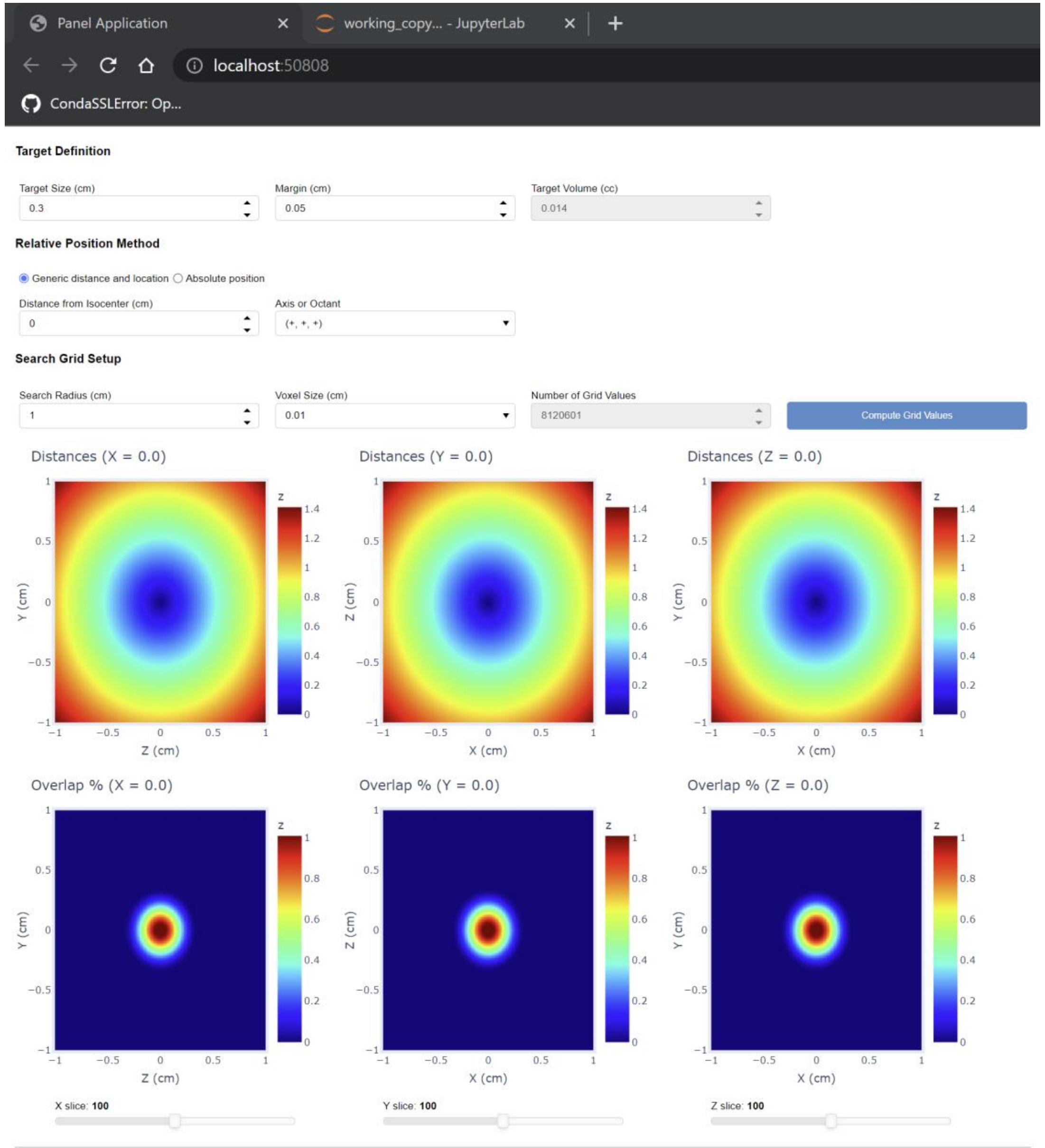
Simple simulation of a single isocenter treatment.

- Target size equal to REZ (TN) or the mouth of the vidian canal (SPG)
- Margin size = 0mm

Simulation shows (as expected) rapid fall off of the dose overlap percentage well within the standard SGRT tolerances set for these treatments (i.e. < 70% coverage at 0.5mm)

This is near the low end for effectiveness (60Gy) for published TN and SPG treatments

Single Isocenter Small Target (TN / SPG)



Simple simulation of a single isocenter treatment.

- Target size equal to REZ (TN) or the mouth of the vidian canal (SPG)
- Margin size = 0.5mm

Simulation shows broader dose overlap percentage within the standard SGRT tolerances set for these treatments (i.e. 100% coverage at 0.5mm and 94% coverage at 0.7mm)

This is on the high end for effectiveness (84.6Gy) for published TN and SPG treatments

Single Isocenter Small Target (TN / SPG)

ORIGINAL CONTRIBUTION

Gamma Knife Radiosurgery for Trigeminal Neuralgia

Results and Expectations

Douglas Kondziolka, MD, MSc, FRCSC; Bernardo Perez, MD; John C. Flickinger, MD; Michael Habeck, PA-C; L. Dade Lunsford, MD

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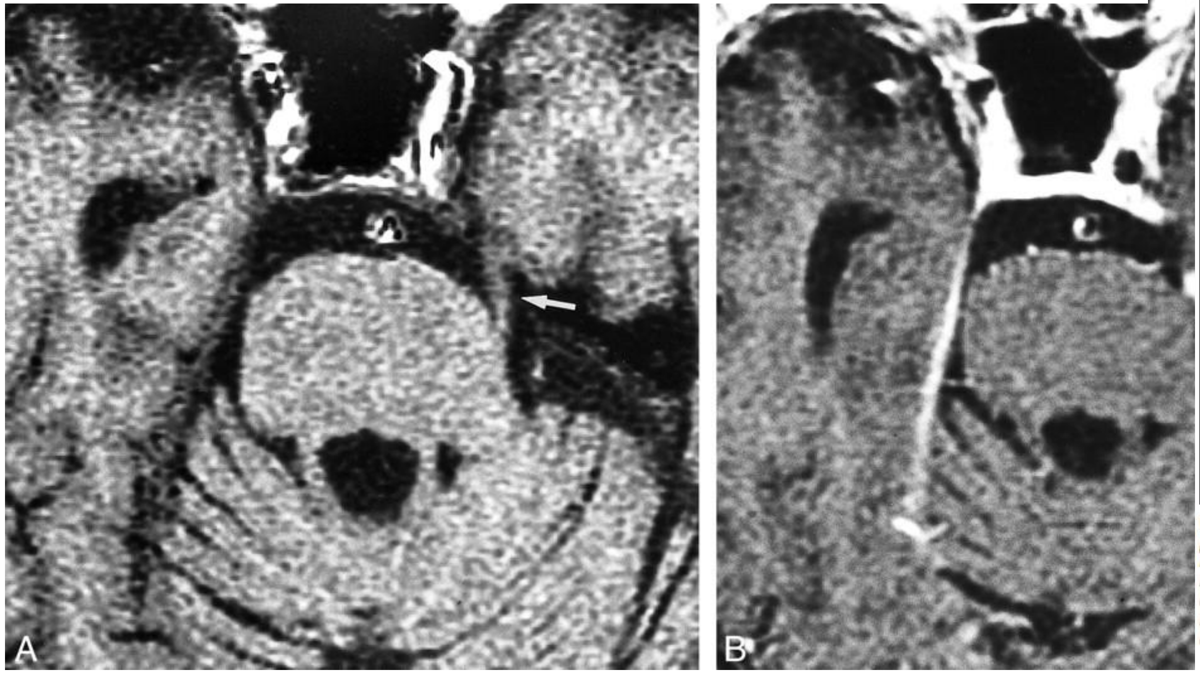


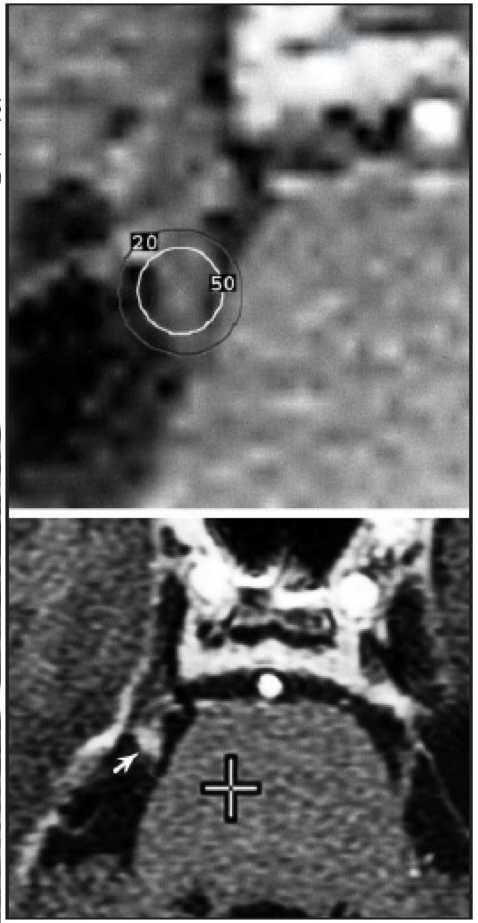
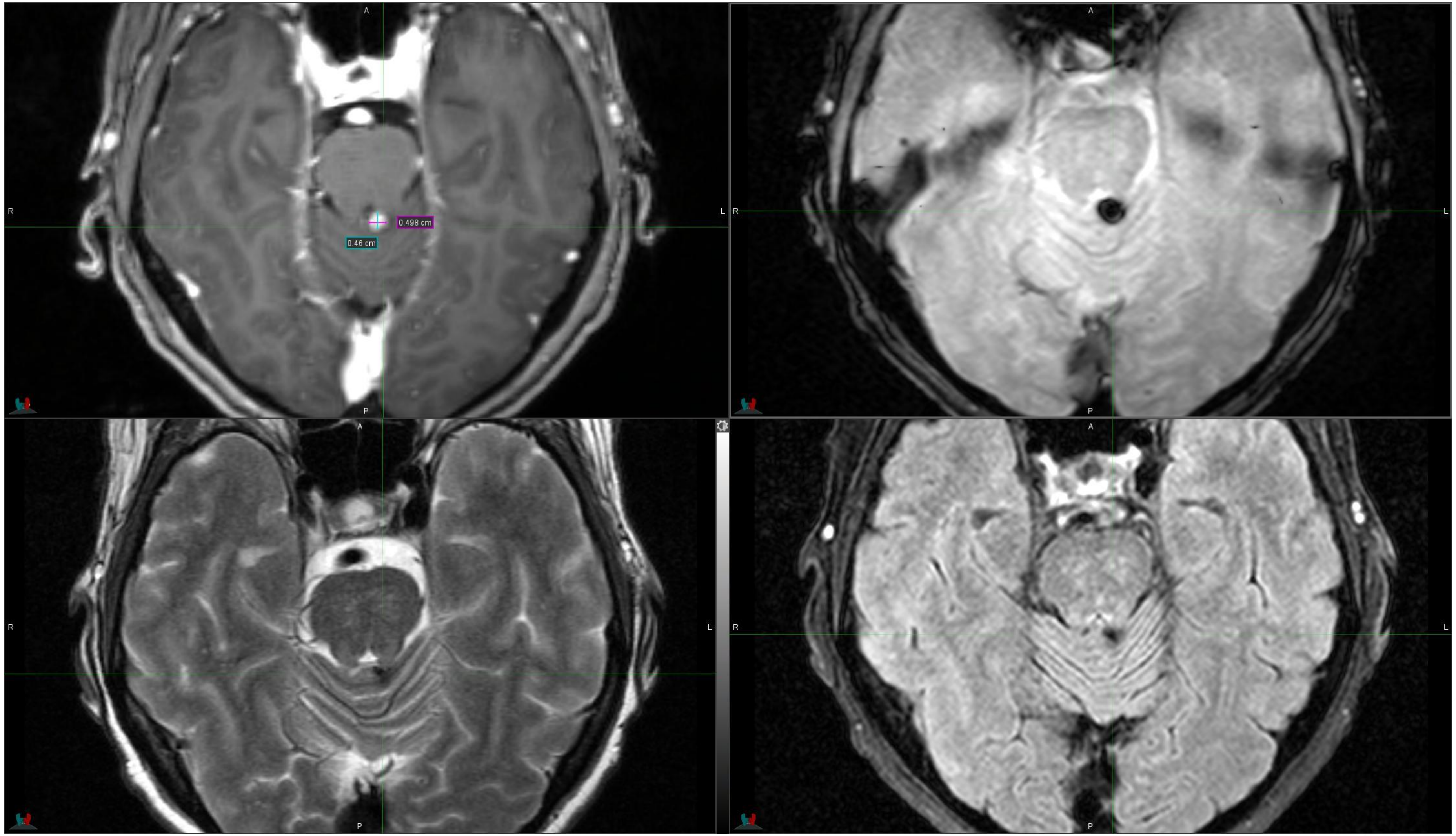
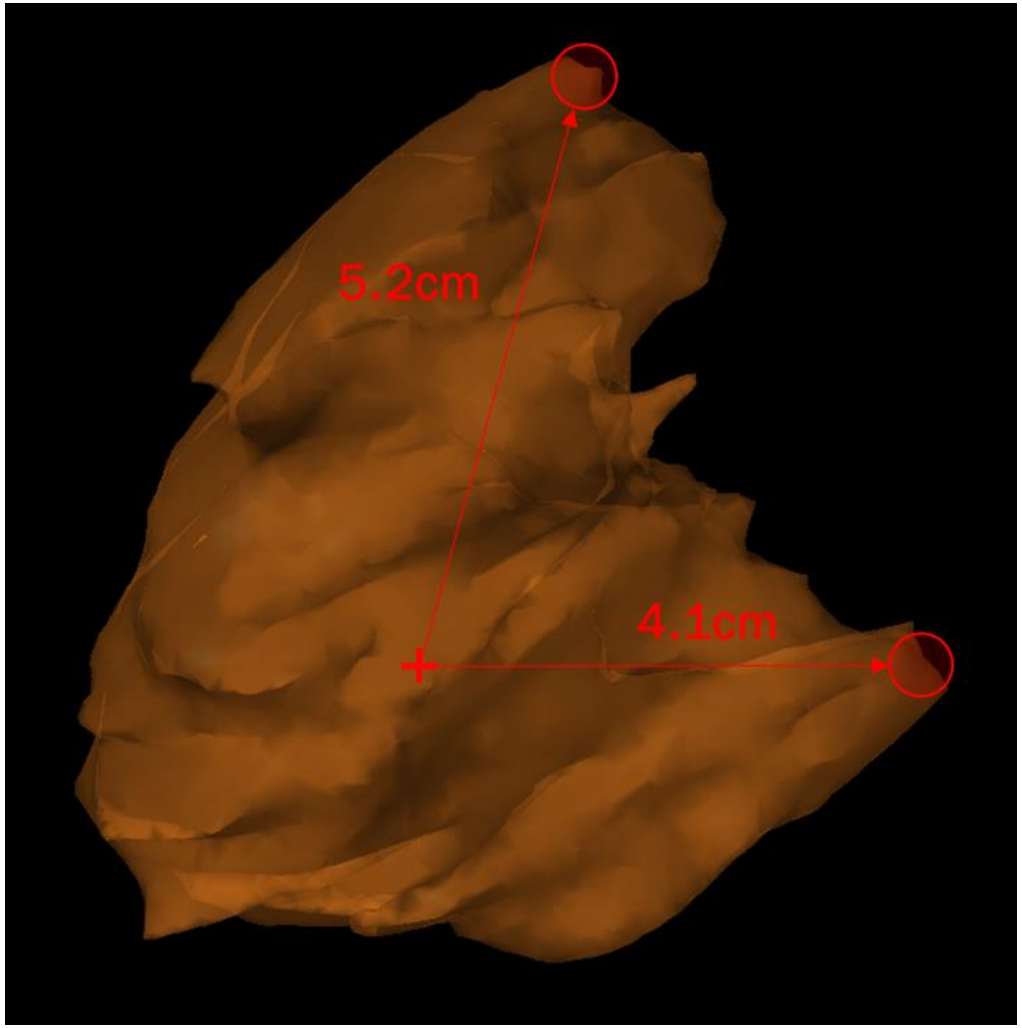


Figure 2. *Axial magnetic resonance imaging scan showing the radiosurgery plan to manage left trigeminal neuralgia in a man whose neuralgia did not respond to prior glycerol and radiofrequency rhizotomy and was intolerant of medication. Top, A maximum dose of 80 Gy was administered. The white circle represents the 50% isodense line. Bottom, Nine months after radiosurgery, a magnetic resonance imaging scan shows contrast enhancement within the trigeminal nerve target volume (arrow).*

Single Isocenter Small Target (TN / SPG)



Single Isocenter Large Irregular Target (AVM)



Simple simulation of a single isocenter treatment with large irregular target.

Small sub volumes can be viewed as multiple individual spherical targets some distance from isocenter.

This same approach works for multi met single isocenter setups

SGRT rotations reported around isocenter may not be inconsequential at large distance

Single Isocenter Large Irregular Target (AVM)

Target Definition

Target Size (cm): 1

Margin (cm): 0

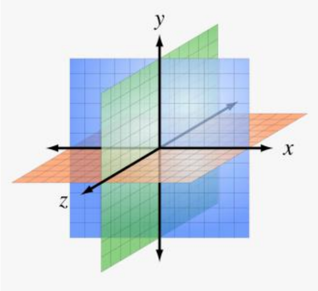
Target Volume (cc): 0.524

Relative Position Method

Generic distance and location / Absolute position

Distance from Isocenter (cm): 5.2

Axis or Octant: (+, +, +)



Set the SGRT Tolerance Parameters for the Sim

SGRT Tolerances | SGRT Tolerances PDFs

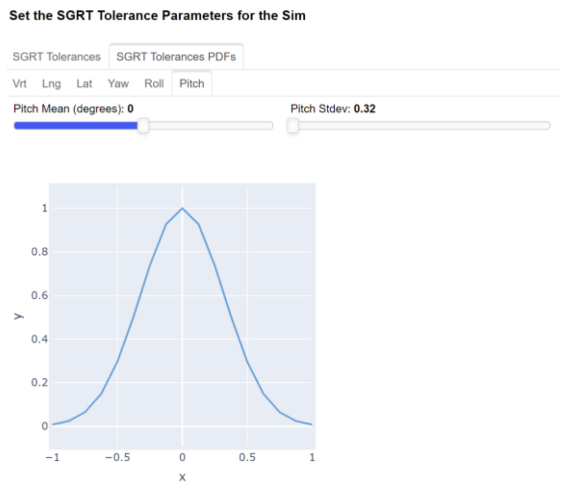
Vrt (cm): **-0.10 .. 0.10**	Vrt Resolution (cm): 0.01
Lng (cm): **-0.10 .. 0.10**	Lng Resolution (cm): 0.01
Lat (cm): **-0.10 .. 0.10**	Lat Resolution (cm): 0.01
Yaw (degrees): **-1 .. 1**	Yaw Resolution (degrees): 0.125
Roll (degrees): **-1 .. 1**	Roll Resolution (degrees): 0.125
Pitch (degrees): **-1 .. 1**	Pitch Resolution (degrees): 0.125

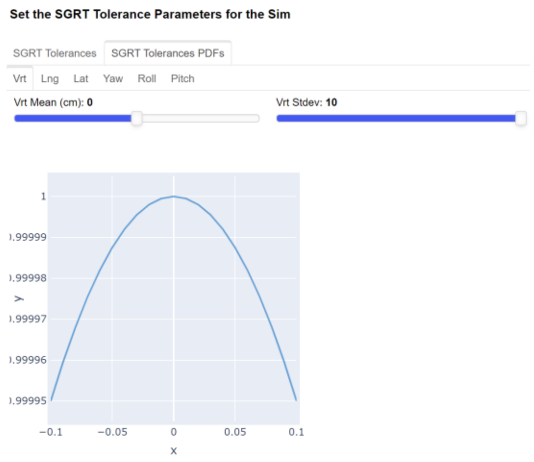
Total Transforms: 45499293

Simple simulation of a single isocenter treatment with target at distance from isocenter.

- Target size equal to largest contained sphere at specified distance (larger irregular target) or largest diameter for multi met single isocenter
- Margin size = 0mm
- Relative location by octant
- Anticipated SGRT tolerance
- Resolution for sampling of SGRT tolerances

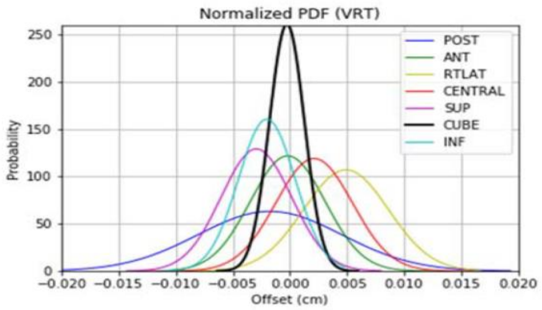
Single Isocenter Large Irregular Target (AVM)

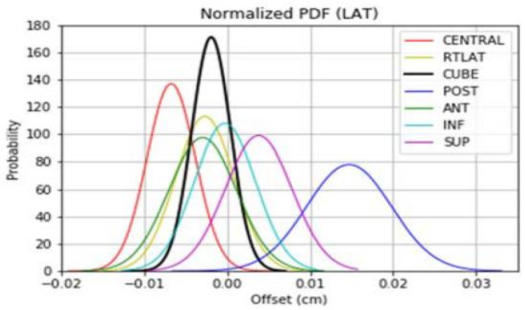


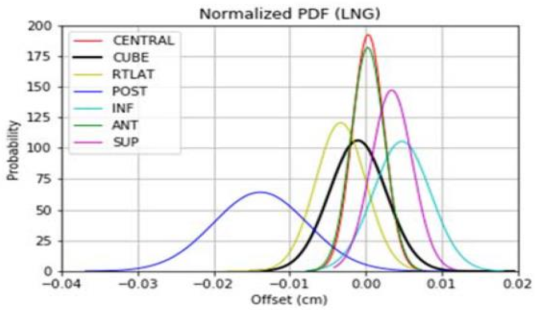


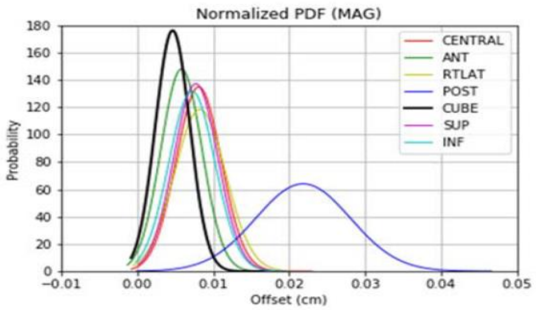
Simple simulation of a single isocenter treatment with target at distance from isocenter.

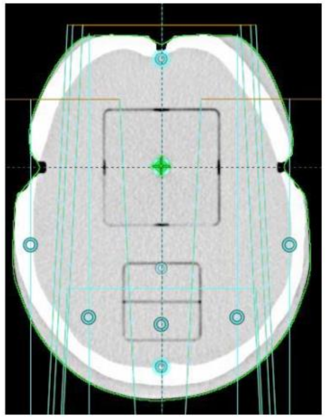
- Set Probability Distribution Function (PDF) for each degree of freedom
  - Can be a guess
  - Can be measured for various locations within the cranial vault

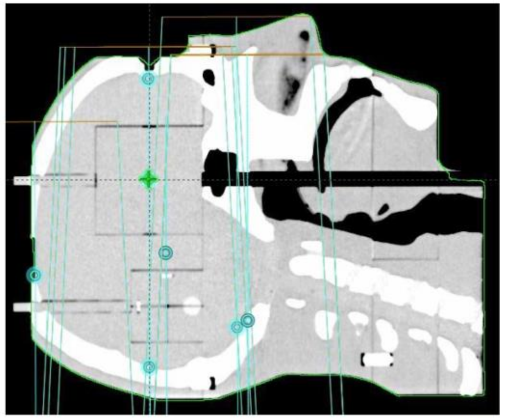




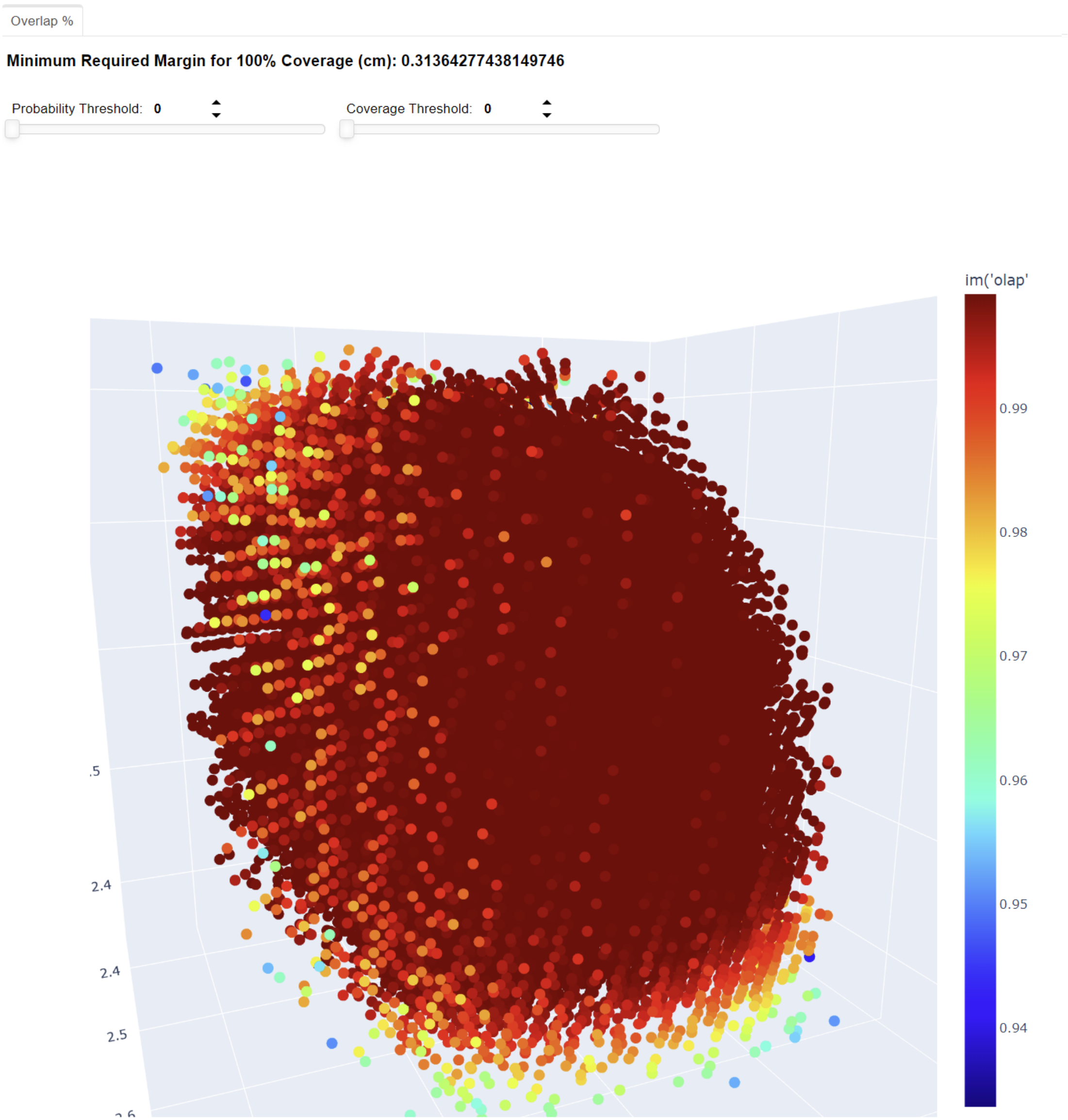








Single Isocenter Large Irregular Target (AVM)



Simulate all permutations of the target position for the SGRT tolerances sampled.

Graph sampled distribution and color based on the target ovelap percentage at each location

Report required margin for coverage of all sampled points

- Filter out low probability locations
- Filter based on coverage percentage
- Apply margin to determine minimum coverage

Maybe SGRT is not the answer?!

Maybe we need newer and fancier machines with "real-time" imaging!

- What if we had something that was
  - Completely isocenteric
  - Had the capability of moving all treatment sub volumes to isocenter
  - Could image continuously or near continuously for position verification and repositioning
- Would that be "better" than our current systems with SGRT?
- Would it prove to be similar just with different trade-offs?

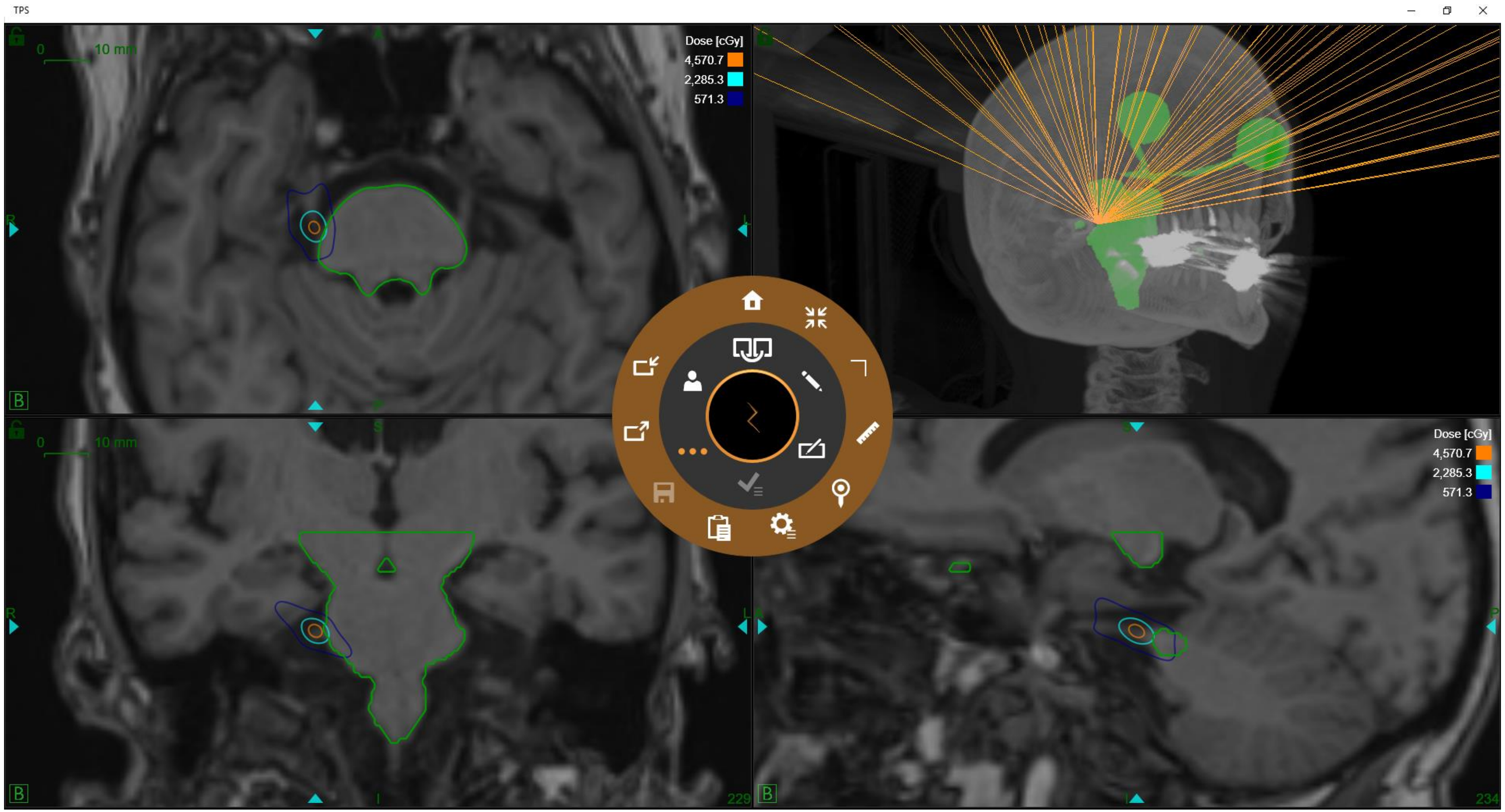
Maybe SGRT is not the answer?!

Maybe we need newer and fancier machines with “real-time” imaging!

Zap-X Simulation and Immobilization

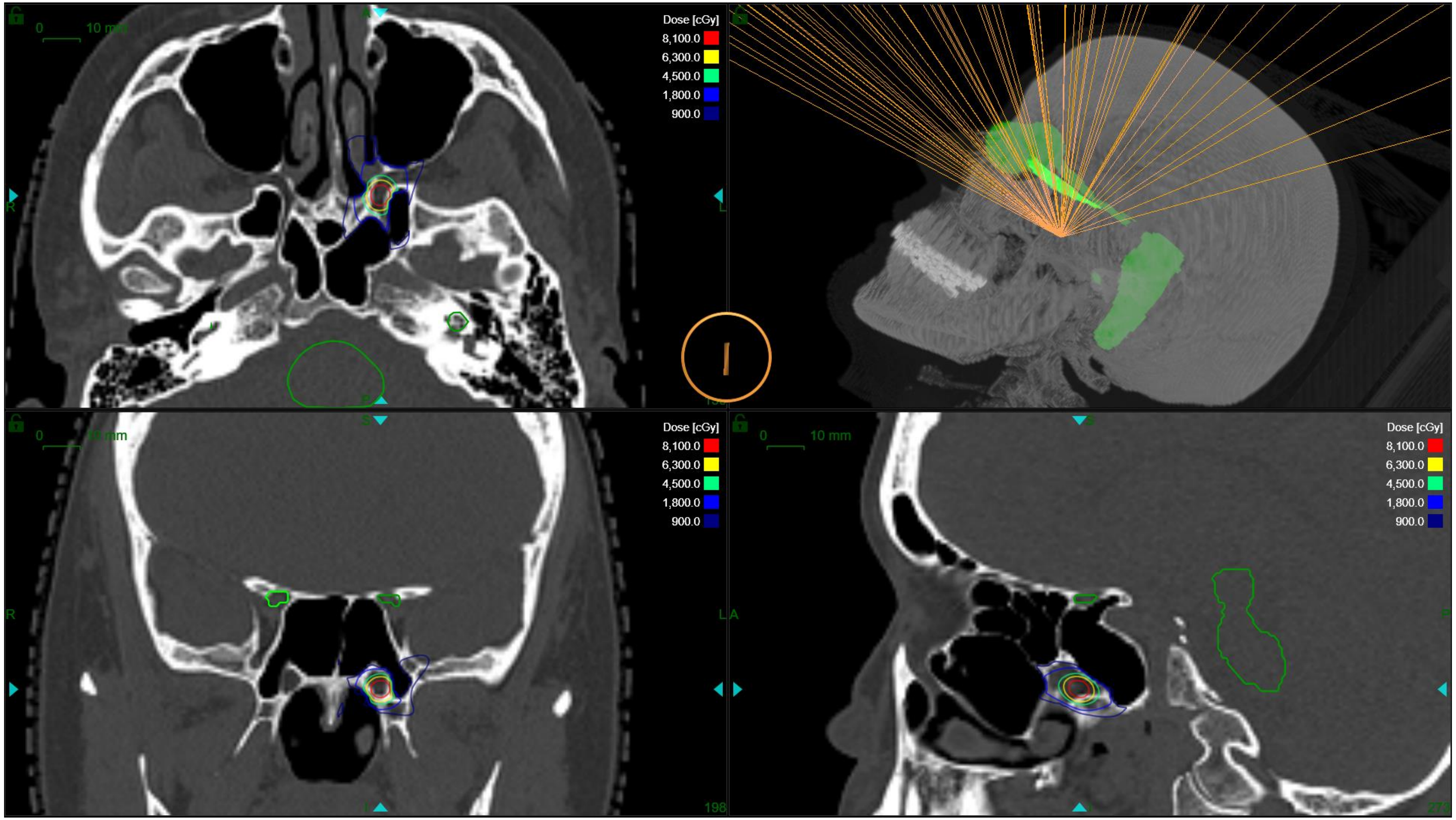
Trigeminal Neuralgia (TN)

Stereotactic Radiosurgery (SRS) Zap-X



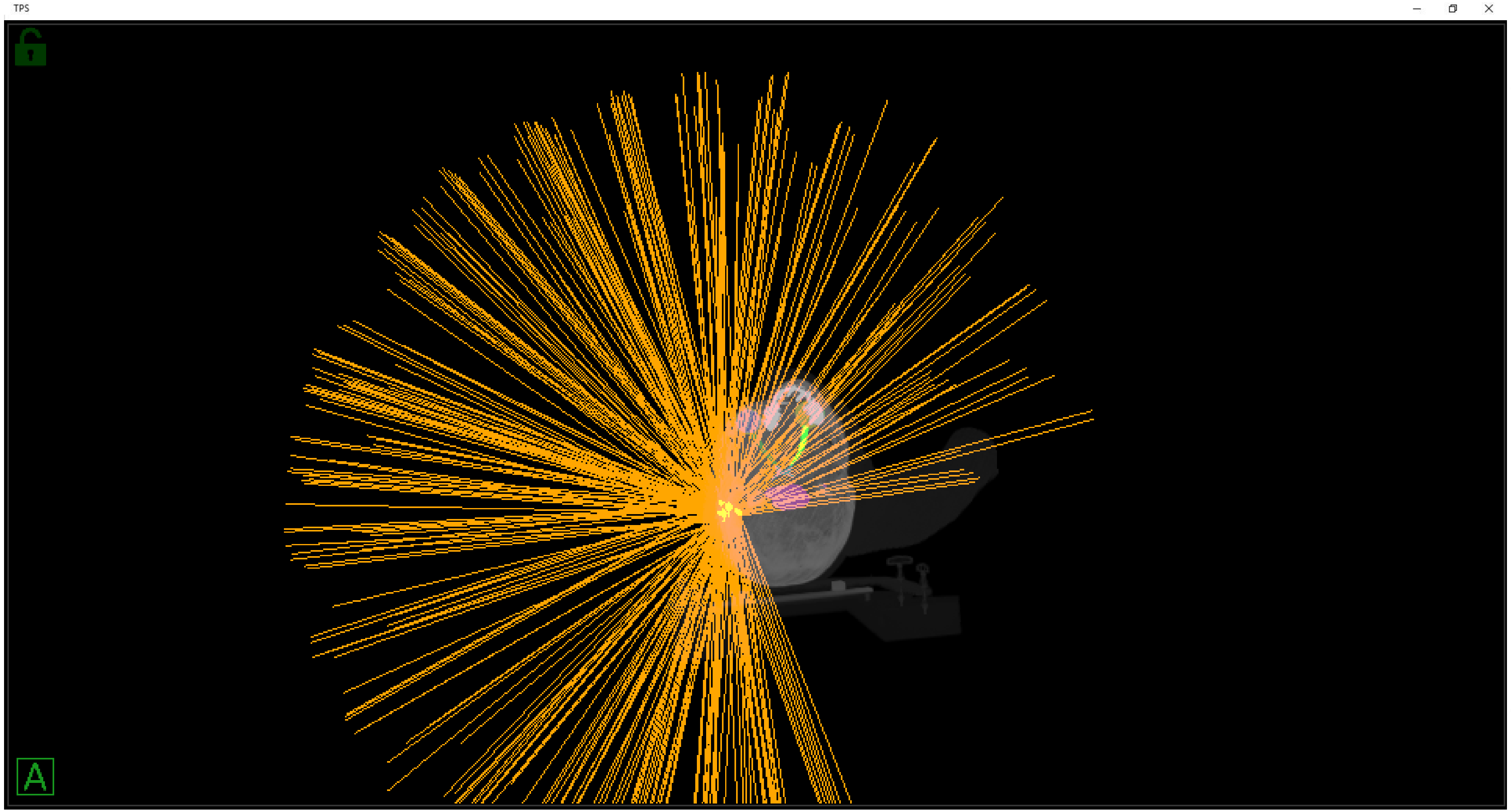
Sphenopalatine Ganglion Neuralgia (SPG)

Stereotactic Radiosurgery (SRS) Using Zap-X



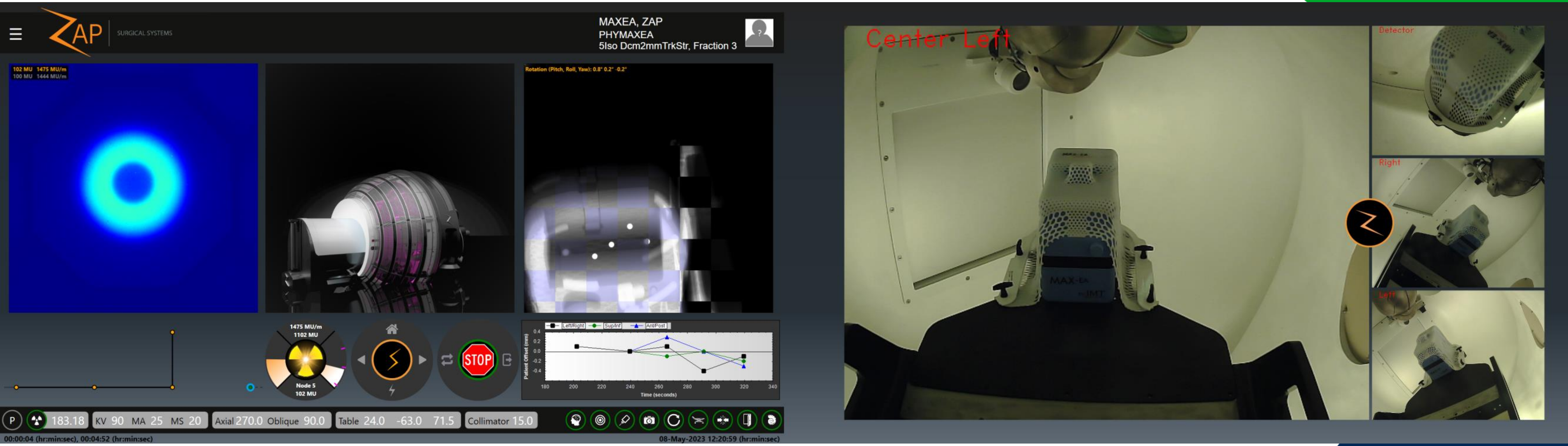
Arteriovenous Malformation (AVM)

Stereotactic Radiosurgery (SRS) Using Zap-X



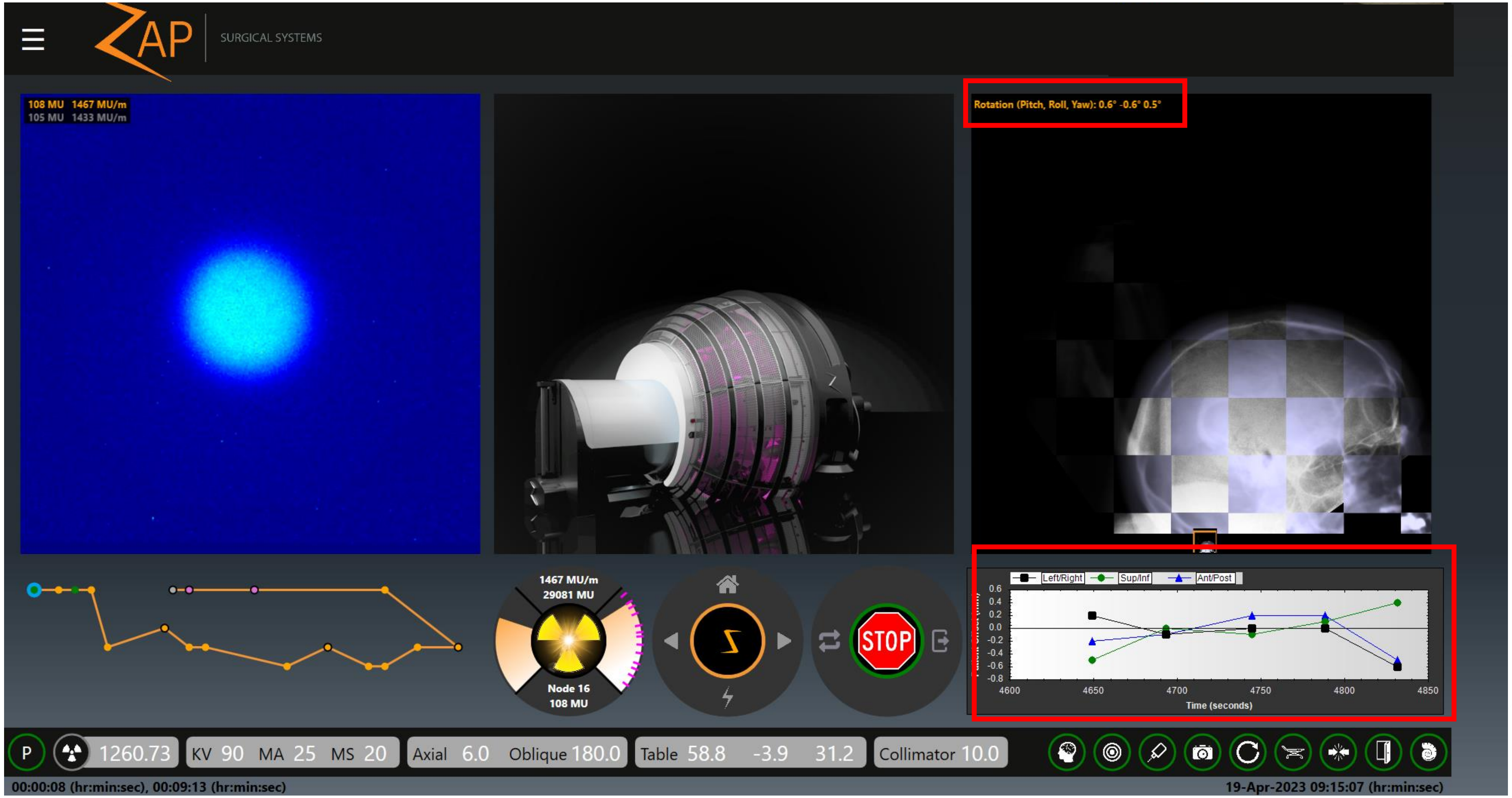
Stereotactic Radiosurgery (SRS) Using Zap-X

Imaging Alignment and Tracking



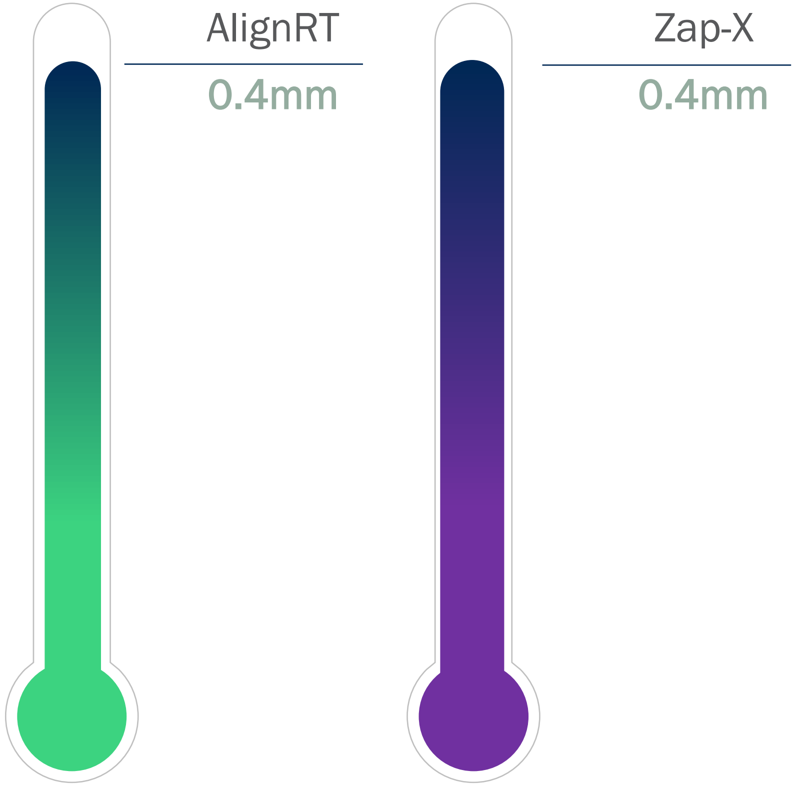
Stereotactic Radiosurgery (SRS) Using Zap-X

Imaging Alignment and Tracking



Characteristics of SRS Process

What can we currently can glean from "real-time" imaging on the Zap-X?



- Mo Technology Mo Problems
  - Real-time internal imaging has its own problems
    - Speed (every 10-45 seconds vs 25 fps with SGRT)
    - Subject to reference quality
    - Different impact of noise and choice of algorithm
- Accuracy is just a number
  - Subject to reference conditions under which it is measured (W/L tests vs patient geometries)
- SGRT systems on modern linear accelerators can deliver high quality SRS treatments
- Regardless of the technology being used for SRS understanding the underlying assumptions made by the vendors and methods implemented is key to operating a safe and reliable program.

The combined patient setup accuracy should conform to the recommendations of TG142 of 1 mm for SRS and SBRT and within 2 mm for conventional treatments as stated in TG-147.

Thank You

Any Questions?

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Special Thanks to my team!

- Justin Keener
- Anton Eagle
- Justin Yates

We extend the healing ministry of Christ by caring for those who are ill and by nurturing the health of the people in our communities.

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