SRS with Gamma Knife Perfexion: *the Marshfield experience*

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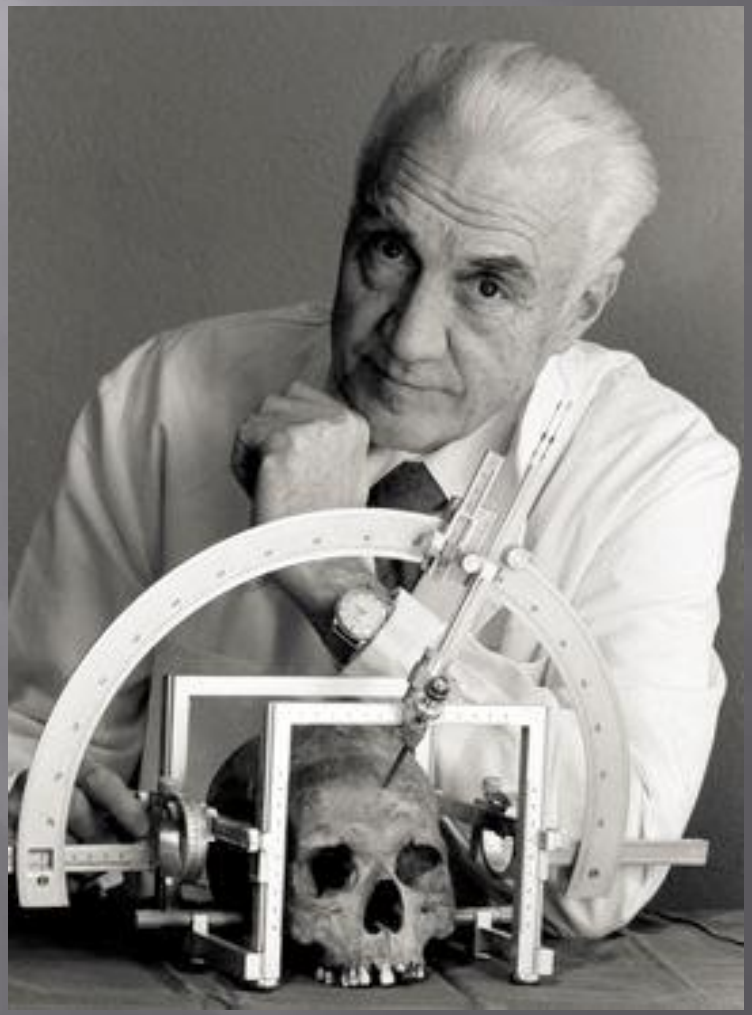
Marshfield Clinic

Marshfield Clinic
Don't just live. Shine.

Disclosure

I have no Conflict of Interest in Presenting this talk!

Lars Leksell



1951: Lars Leksell, a Neurosurgeon, *introduces the idea of Stereotactic Radiosurgery*

"The stereotactic technique enables the accurate insertion of a needle electrode into any given structure of the brain…

… It would therefore be feasible to replace the needle by narrow beams of radiant energy directed at the target in the brain and thereby produce a local destruction of the tissue…"

The stereotaxic method and radiosurgery of the brain -
L. Leksell, Acta Chir Scand 102:316-319, 1951

Leksell Gamma Knife

Model U: (Introduced 1986)

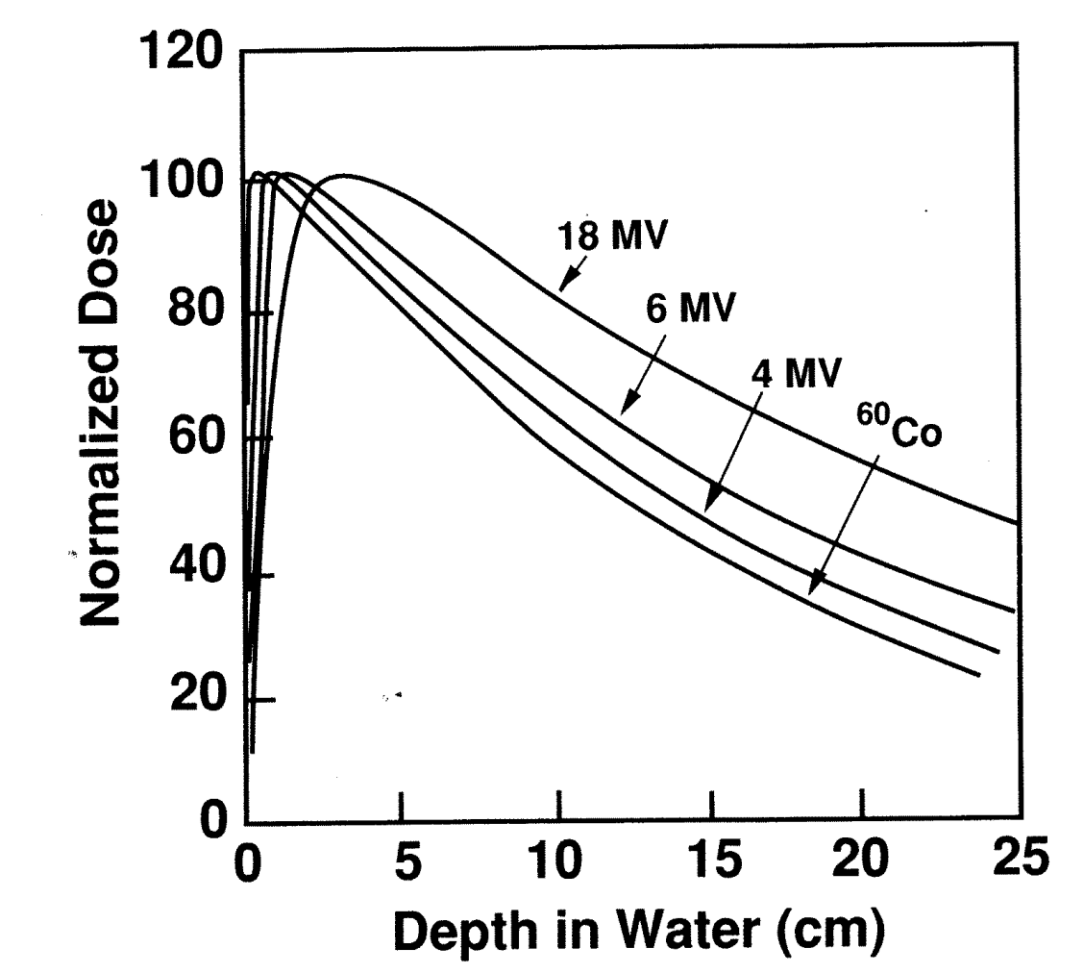
Model 4C with APS :
(Introduced 1999)

Perfexion: (Introduced 2006)

Properties of Leksell Gamma Knife®

- ~200 ^{60}Co sources (6000 Ci total initial activity)
- Sources positioned and collimated to focus radiation precisely at isocenter
- Rx vol. shaped to match the target vol. by:
  - translating the patient in 3 orthogonal directions between “shot” settings
  - using appropriately sized collimators for each shot

Properties of ^{60}Co

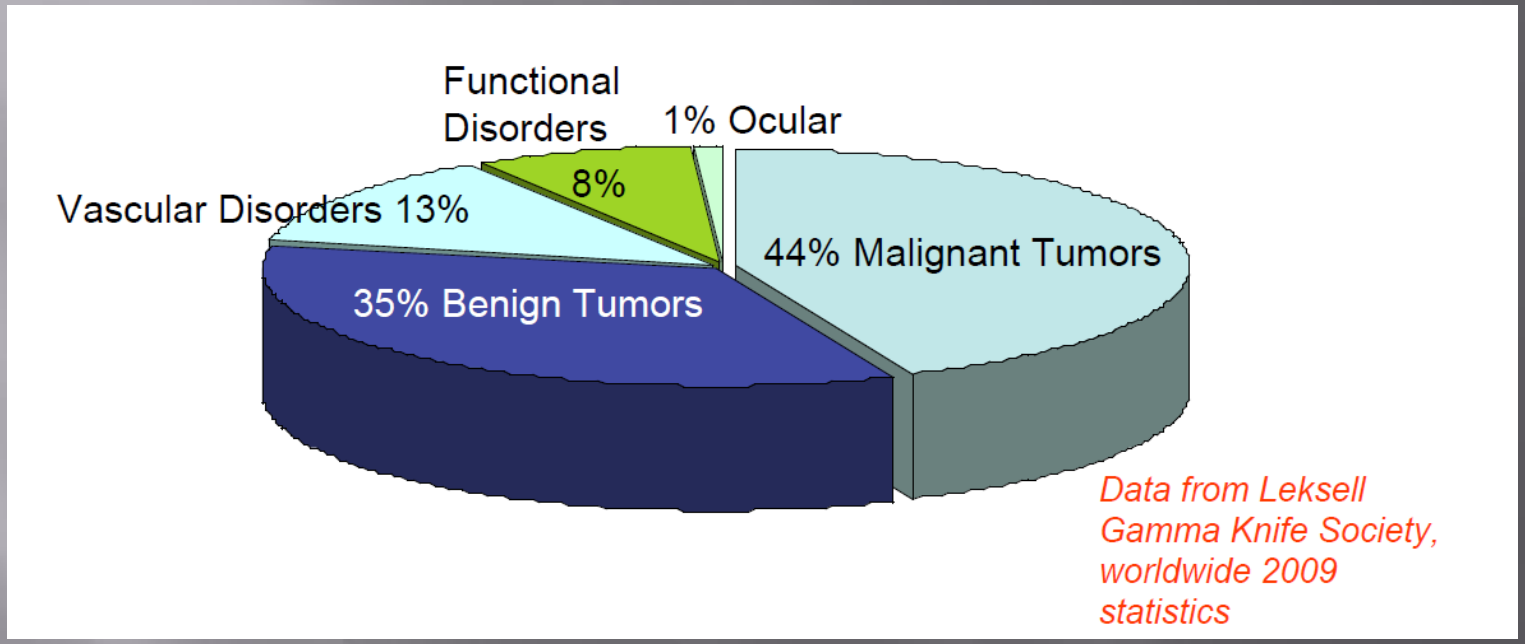


^{60}Co isotope is produced by bombarding ^{59}Co with neutrons in a nuclear reactor

^{60}Co decays via β decay, producing 2 mono-energetic γ rays, 1.17 and 1.33 MeV

The half life of ^{60}Co is 5.27 yrs.

Indications for Gamma Knife Radiosurgery



Malignant tumors:	Brain metastases, glial tumors
Benign tumors:	Meningioma, vestibular schwannoma, pituitary adenoma
Vascular disorders:	Arteriovenous Malformation
Functional disorders:	Trigeminal Neuralgia

Treatment Applications

- Brain tumors

Treatment Applications

- Brain tumors
  - Malignant OR benign

Treatment Applications

- Brain tumors
  - Malignant OR benign
    - Glioma
      - Astrocytoma
      - Ependymoma
      - Oligodendroglioma

Treatment Applications

- Brain tumors
  - Glioma
  - Single & Multiple metastasis
  - Pituitary Adenoma
  - Meningioma
  - AVM (Arterio Venus Malformation)
  - Trigeminal Neuralgia
  - Acoustic Neuroma (Vestibular Schwannoma)
  - Cerebellopontine angle (CPA) Tumors

Treatment Applications

- Parkinson's disease
- Tremors
- Epilepsy

Current Technology for SRS

- Gamma Knife® by Elekta
  - Uses 192 (Perfexion) 201 (4C) ^{60}Co beams
  - highly-focused gamma rays
  - All beams aim at a single isocenter

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  - Deliver high-energy x-rays = photons

  - Uses Klystron/Magnetron microwave technology to accelerate photons

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- Proton beam machine

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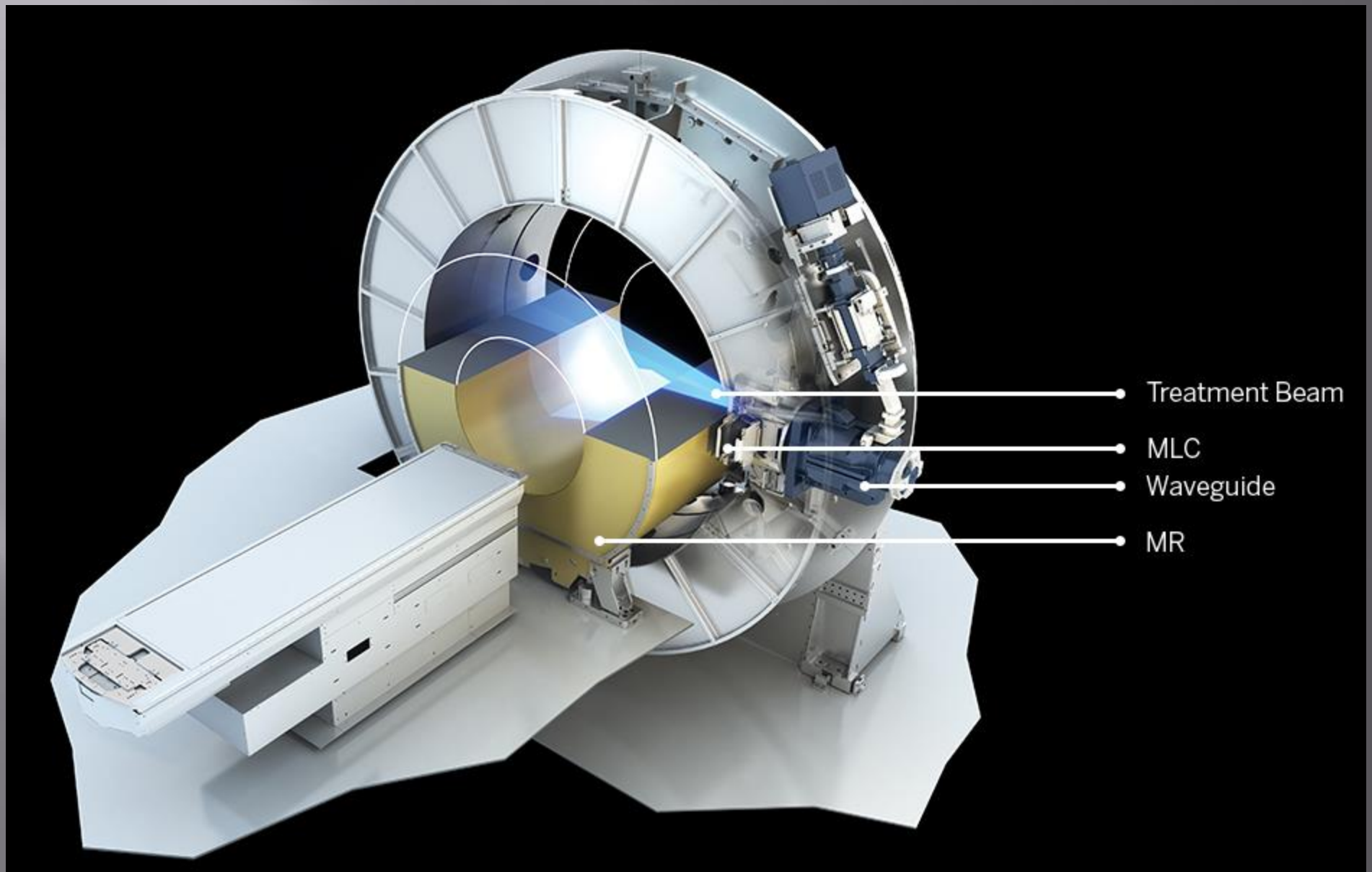
Gamma Knife Perfexion®

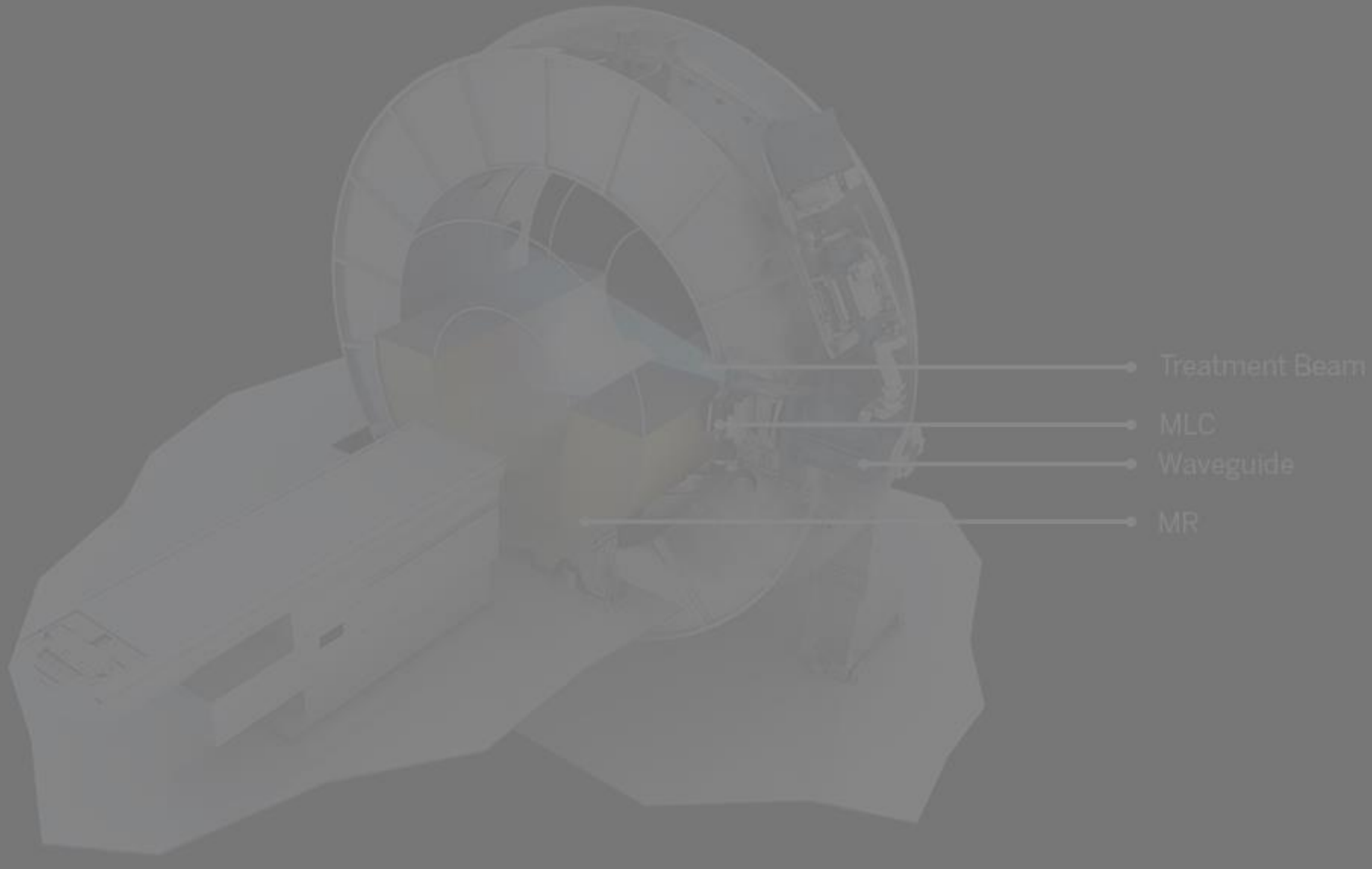
Truebeam ® 2.5 Gated Linac

Accuray Cyberknife®

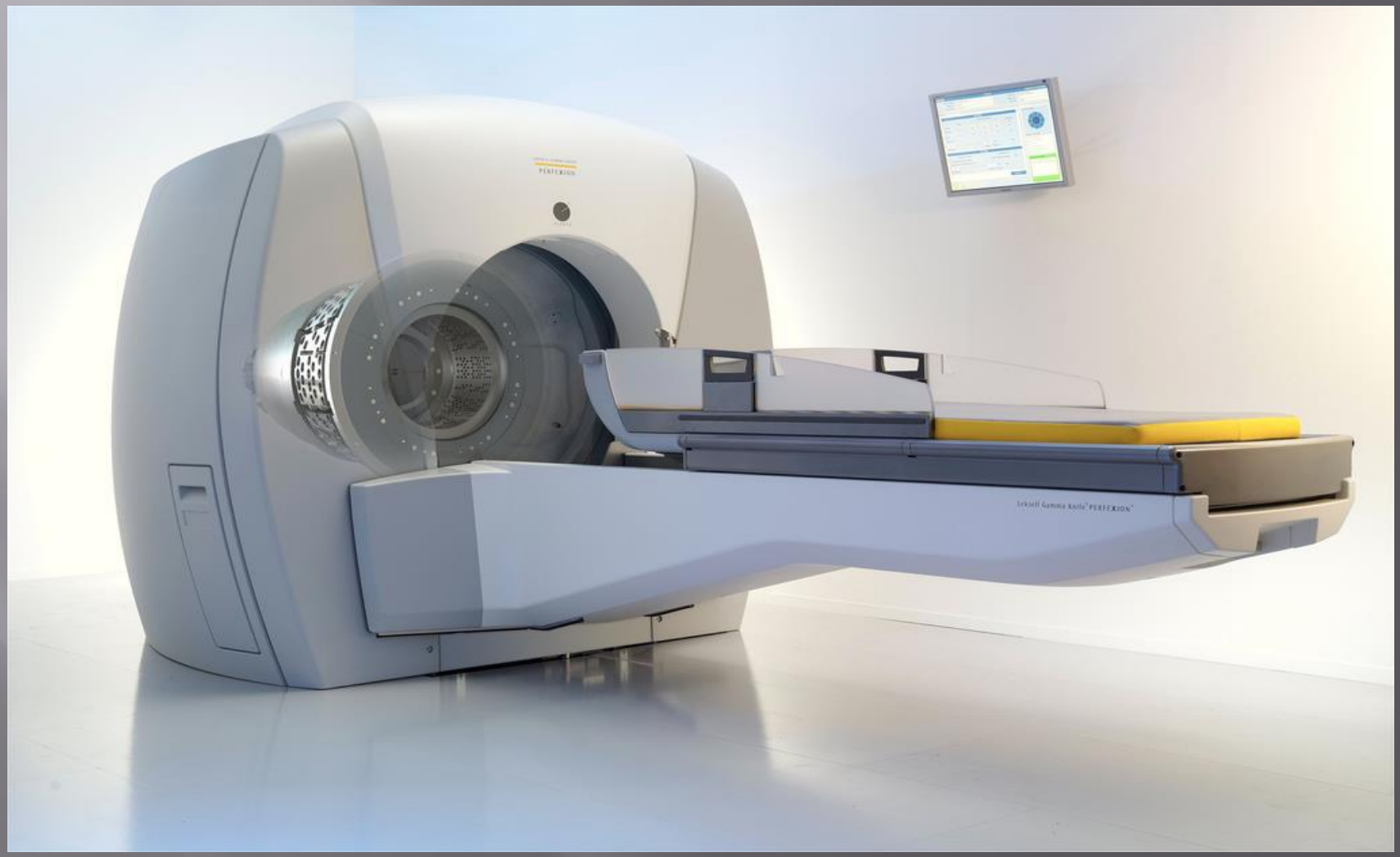
Proton/Particle Therapy

MR – Linac




Treatment Beam
MLC
Waveguide
MR

Elekta Gamma Knife Perfexion® @ Marshfield



Elekta Gamma Knife @ Marshfield 4C & Perfexion®

	In Service	No. of Cases
MODEL 4C	**(6/5/2000 to 8/8/2014)**	1061
PERFEXION	**(10/13/2014 to present)**	232
TOTAL	**(6/5/2000 to present)**	1293

Elekta Gamma Knife @ Marshfield 4C & Perfexion®

	MODEL 4C	PERFEXION
ACOUSTIC NEUROMA	118 (11.1%)	19 (8.2%)
AVM	32 (3%)	10 (4.3%)
Metastasis Multiple	420 (39.6%)	119 (51.3%)
Pituitary	17 (1.6%)	4 (1.7%)
Oligodendroglia	6 (0.57%)	0 (0%)
Trigeminal Neuralgia	240 (22.6%)	35 (15.1%)
Meningioma	141 (13.3%)	39 (16.8%)
Glioma	31 (3%)	3 (1.3%)
Other	56 (5.2%)	3 (1.3%)
TOTAL	1061 (100%)	232 (100%)

Criteria for Gamma Knife Radiosurgery

Single-fraction Gamma Knife SRS

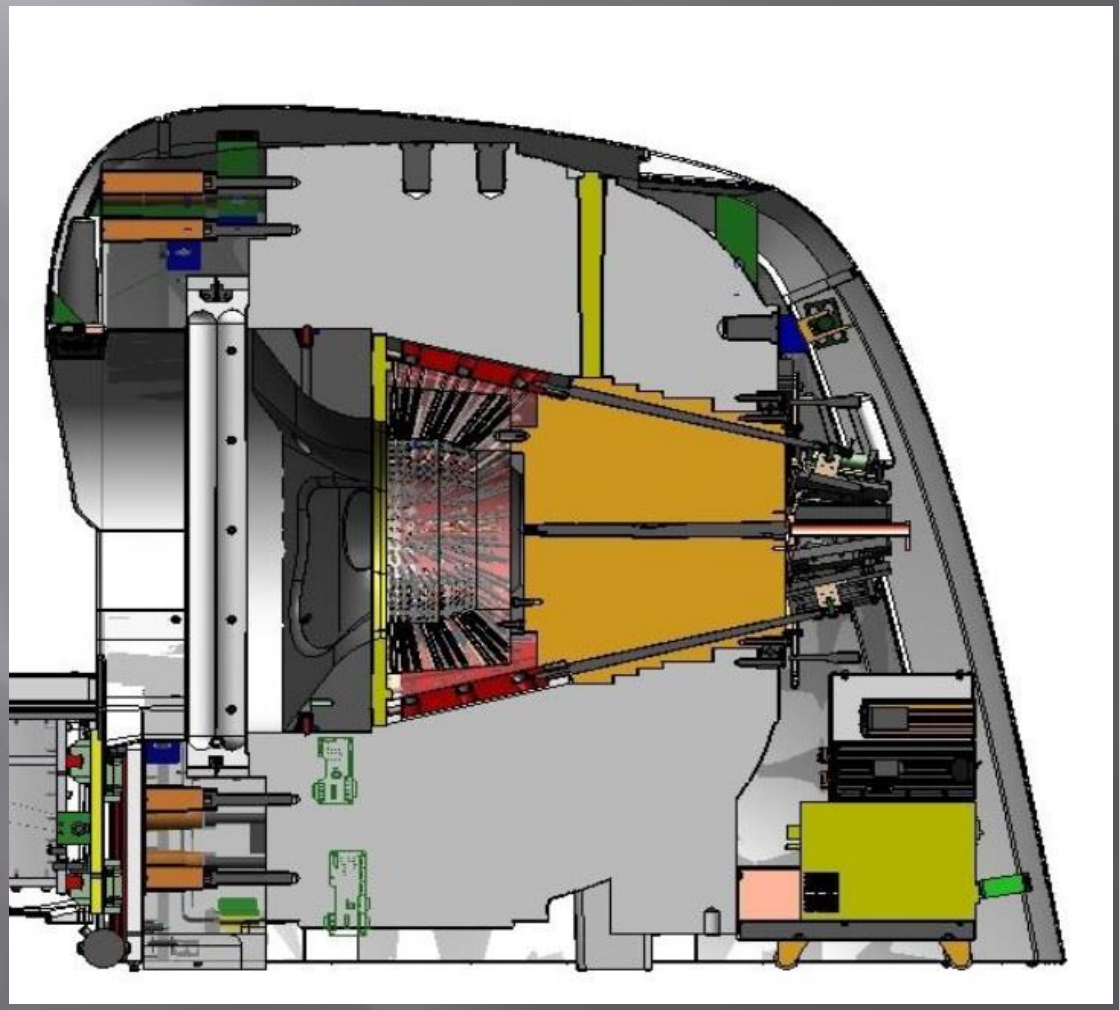
- Largest tumor dimension $\leq$ 3 to 4 cm
- Minimum distance to optic apparatus $\geq$ 2 mm
- Max number of lesions that can reasonably be treated in a **single** session ~ 30
- Can treat very small tumors (e.g. small brain metastases with dimension of the order 2 mm)

Leksell Gamma Knife® Perfexion™

GK Perfexion™: selected technical specifications

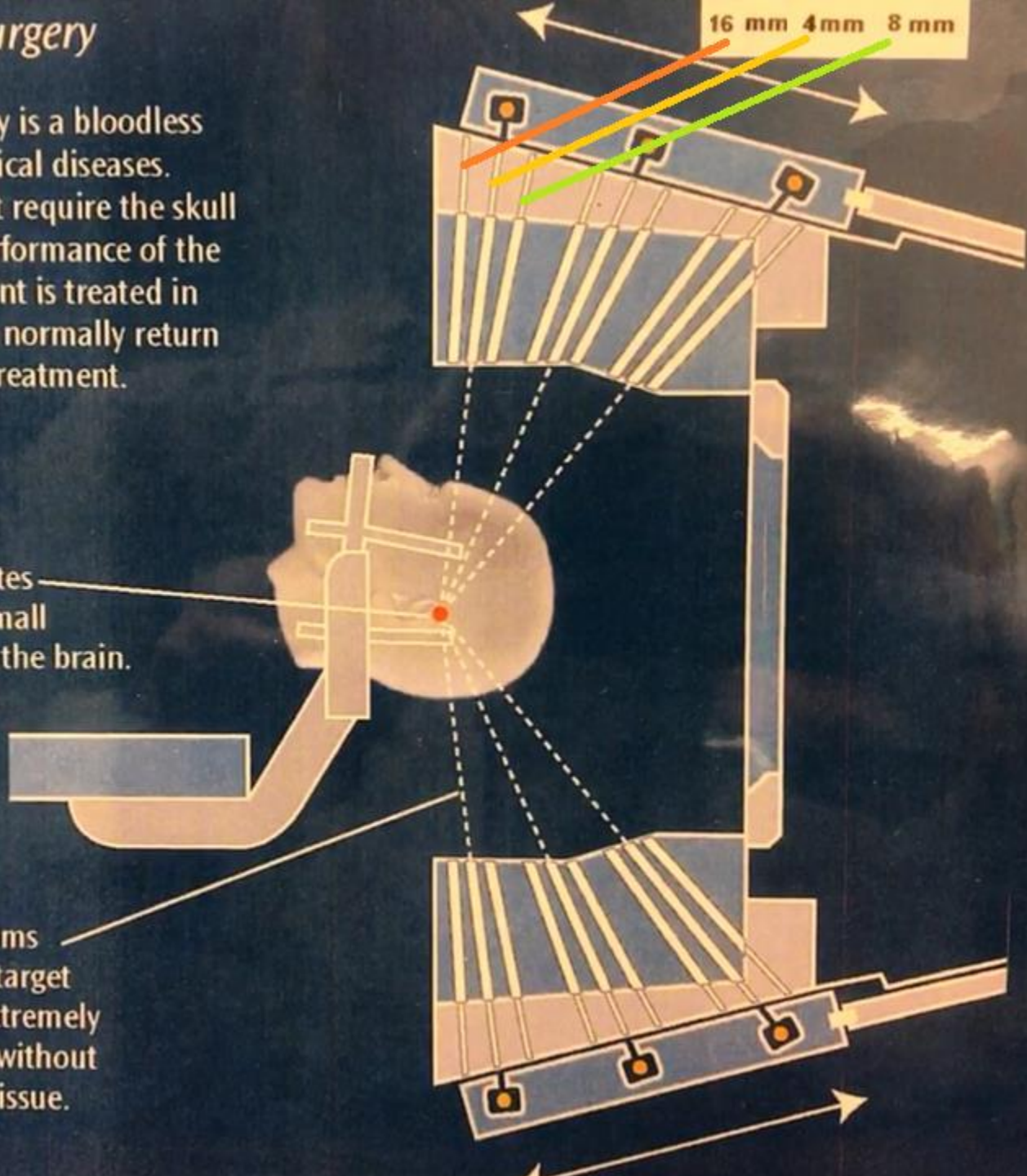
Radiological accuracy	**<0.5 mm**
Typical couch repositioning time	< 3 s
Couch positioning repeatability	< 0.05 mm
Maximum patient weight	210 kg (460 lbs)
Typical collimator size setup time	< 3 s

Leksell Gamma Knife® Perfexion™: the source drive unit



Gamma Knife surgery

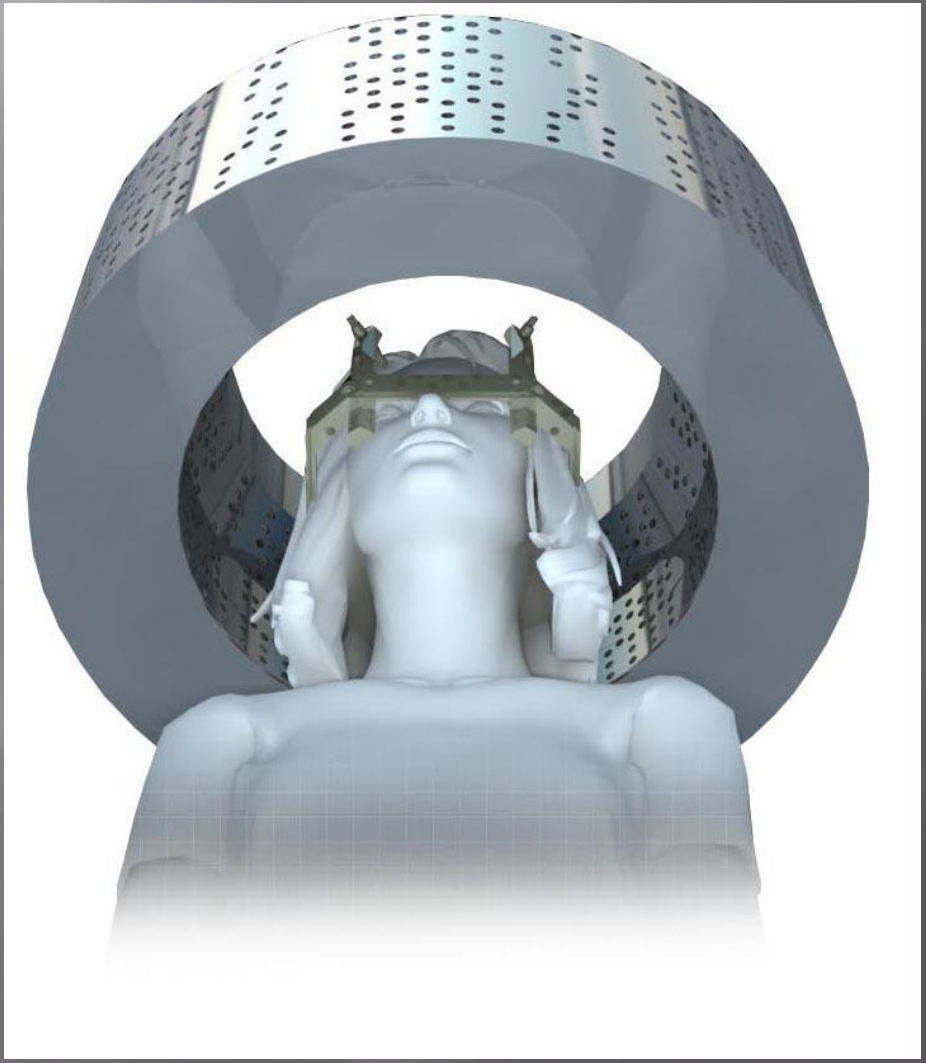
Gamma Knife surgery is a bloodless surgery for neurological diseases. The surgery does not require the skull to be opened for performance of the operation. The patient is treated in one session and can normally return home shortly after treatment.



The method facilitates treatment of very small targets deep within the brain.

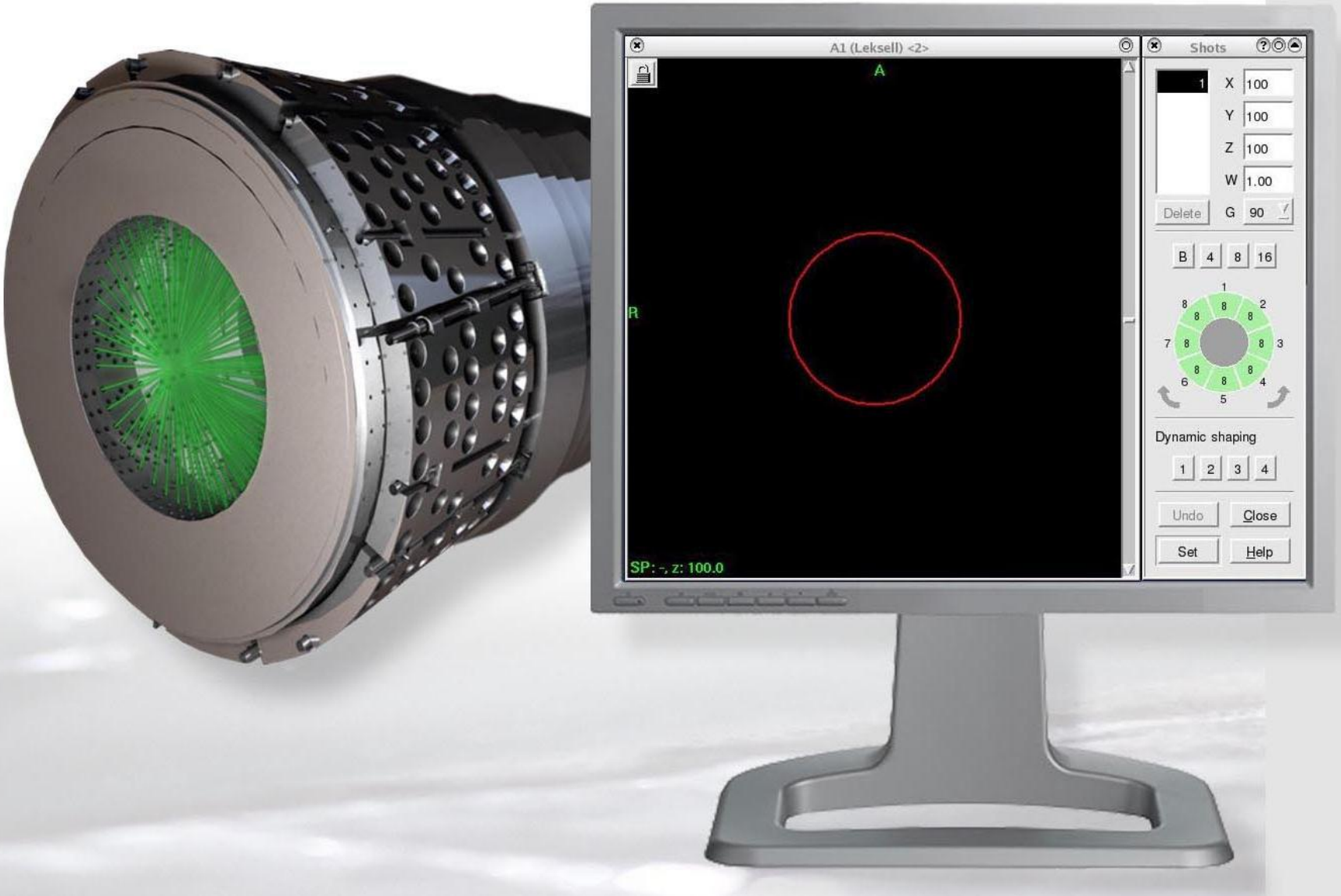
The radioactive beams are focused on the target in the brain with extremely high precision and without damaging healthy tissue.

Fixed Collimator with 16, 4 & 8 mm apertures



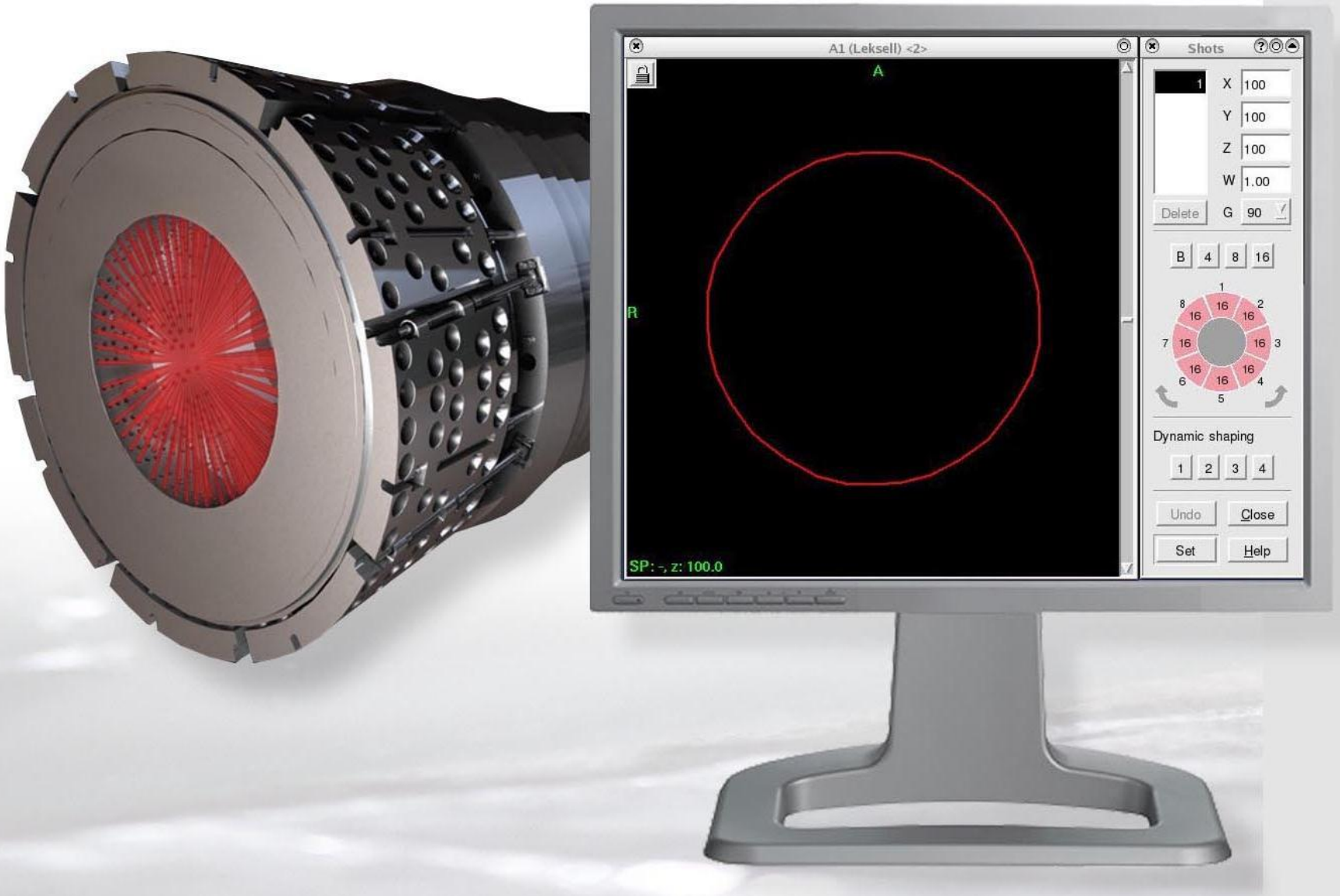
shot placement: all sectors blocked

8 mm collimator

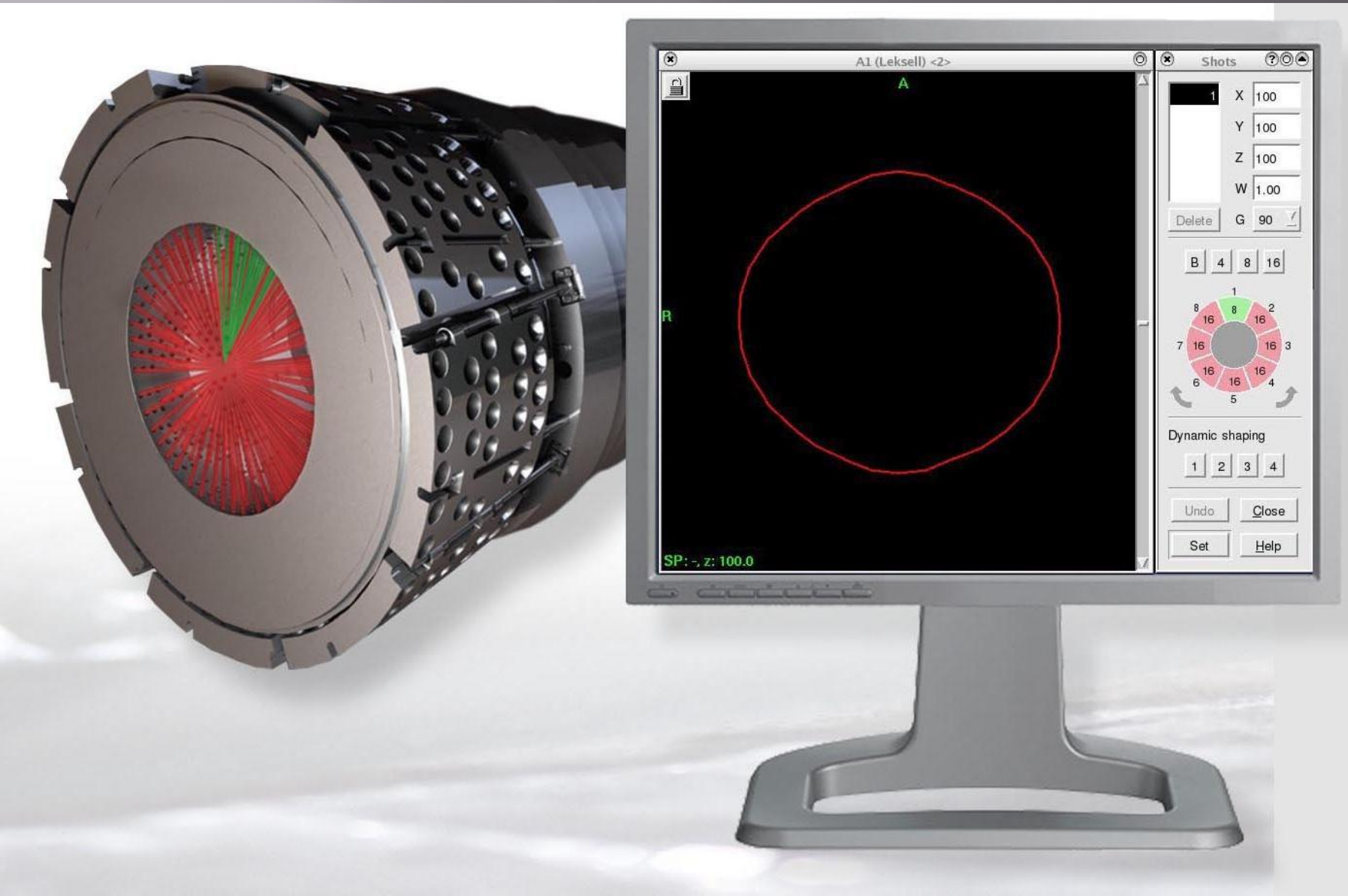


4 mm collimator

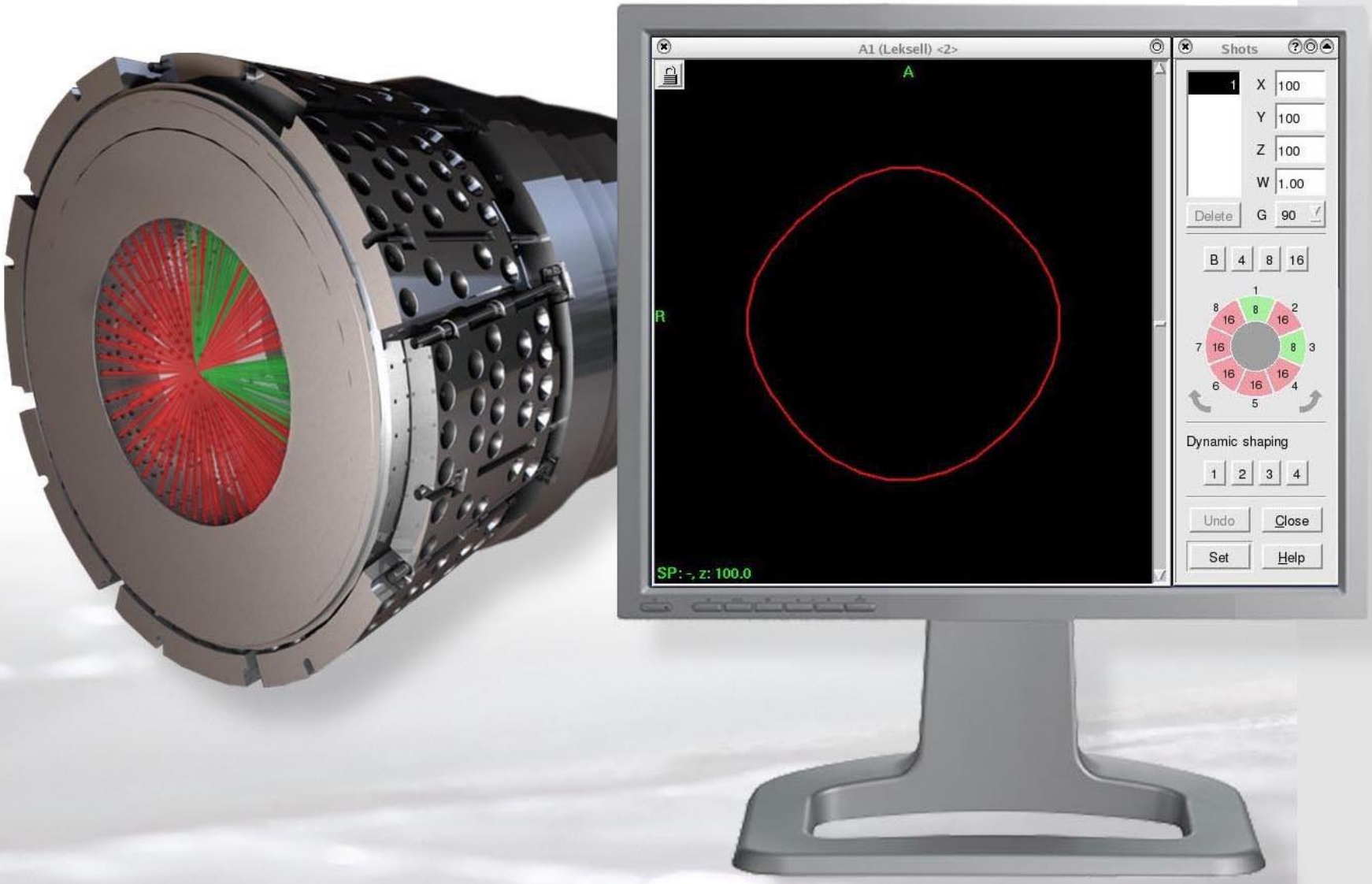
16 MM COLLIMATOR



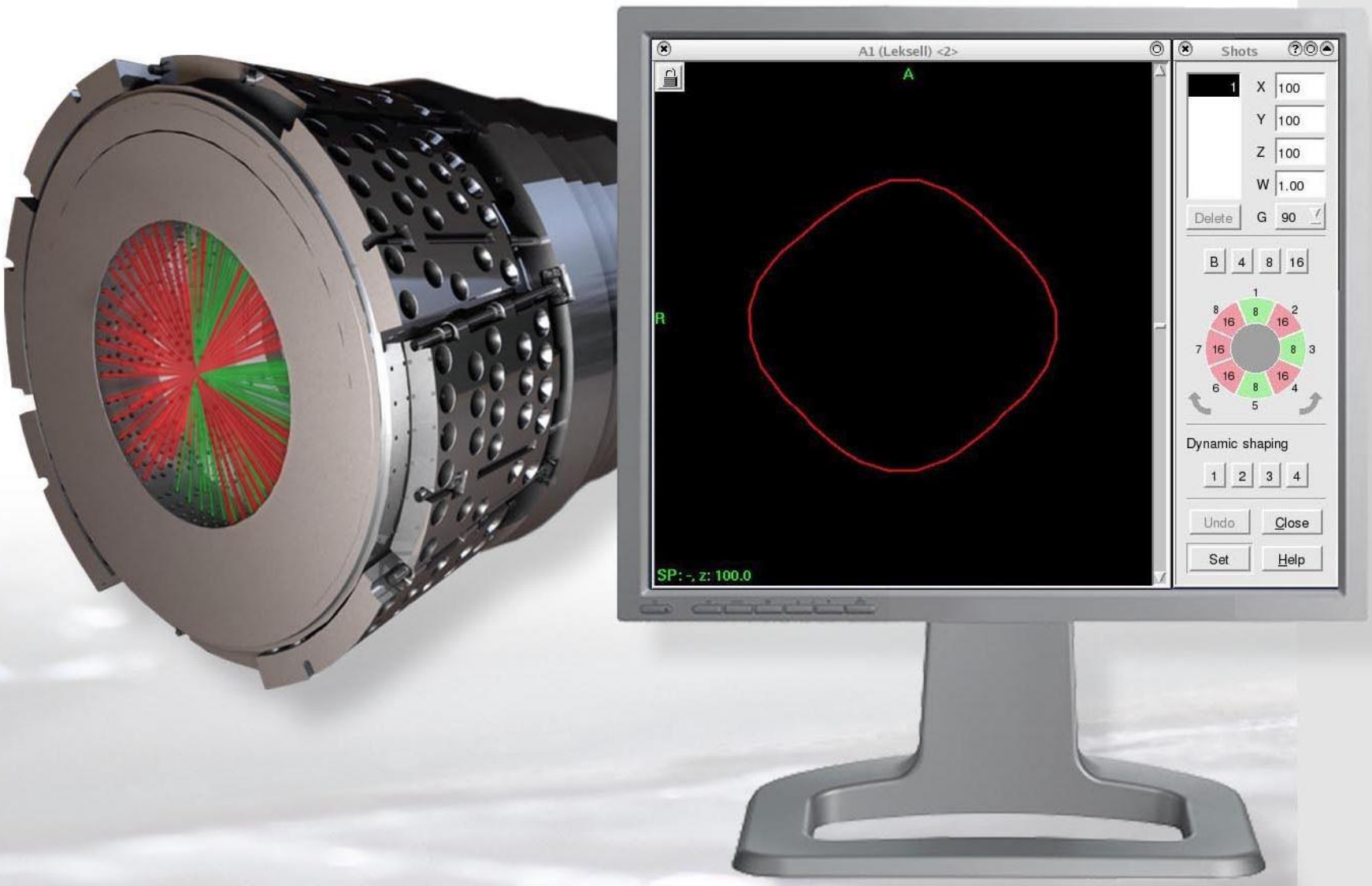
composite shot



COMPOSITE SHOT



composite shot



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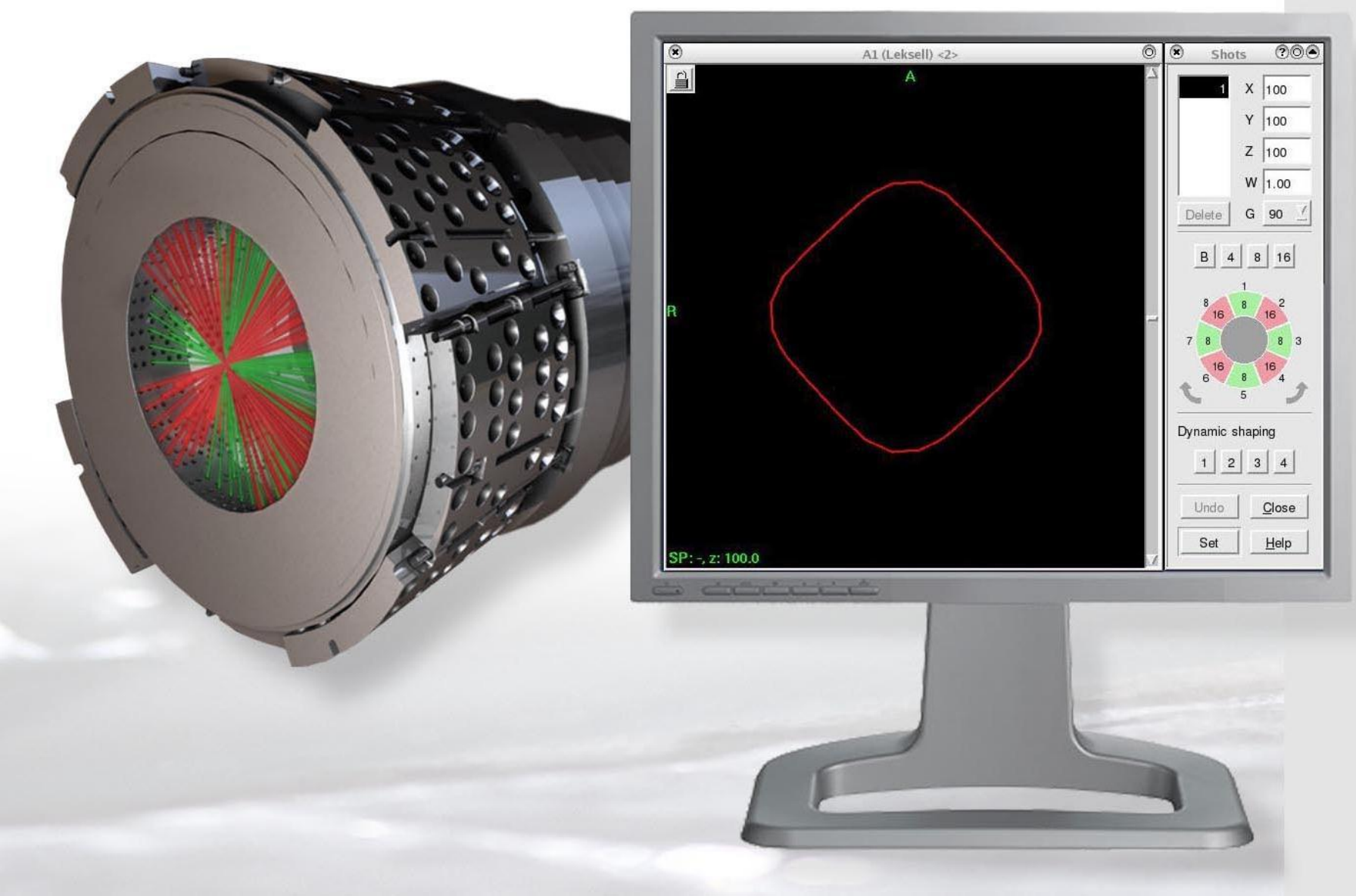
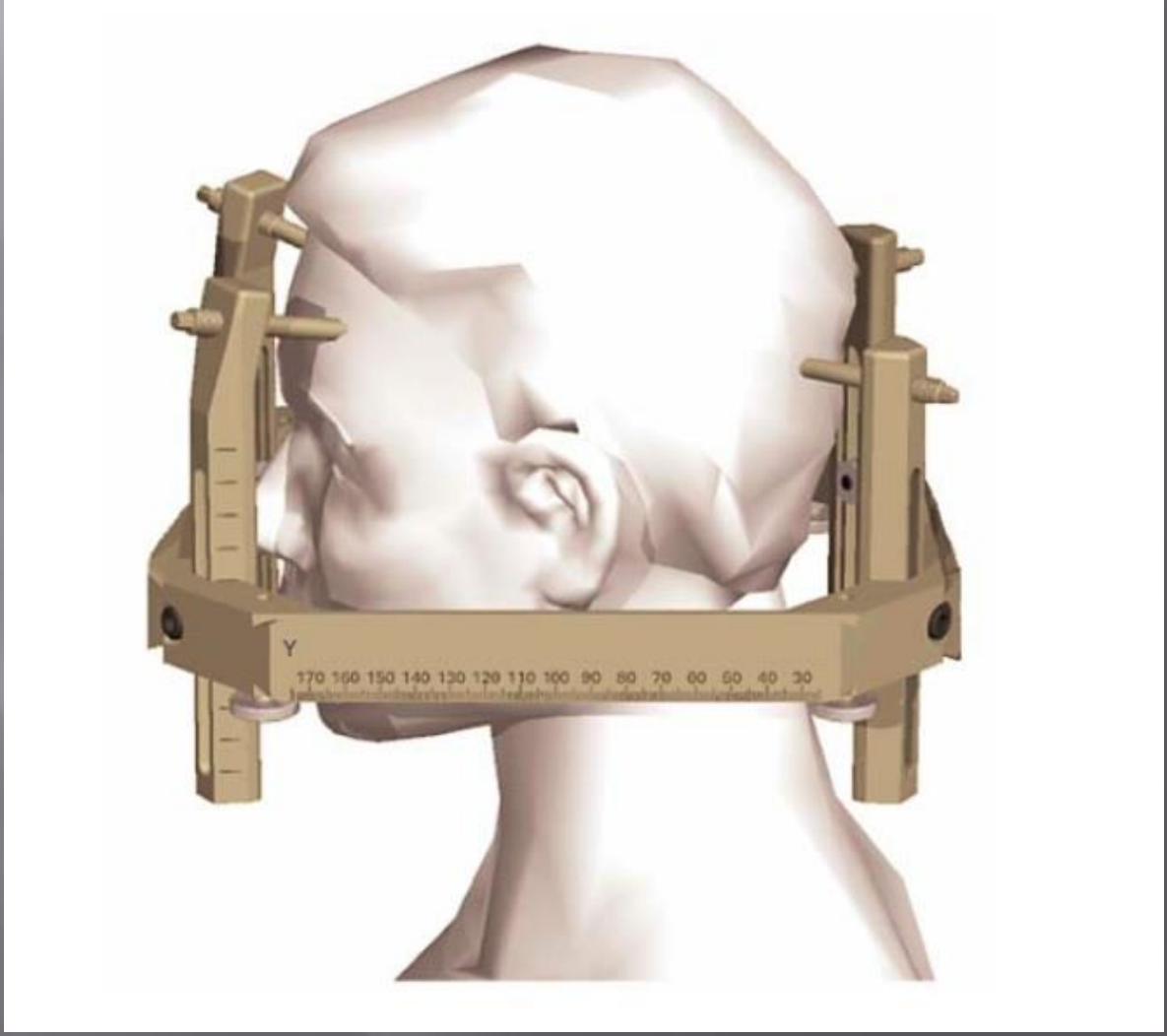
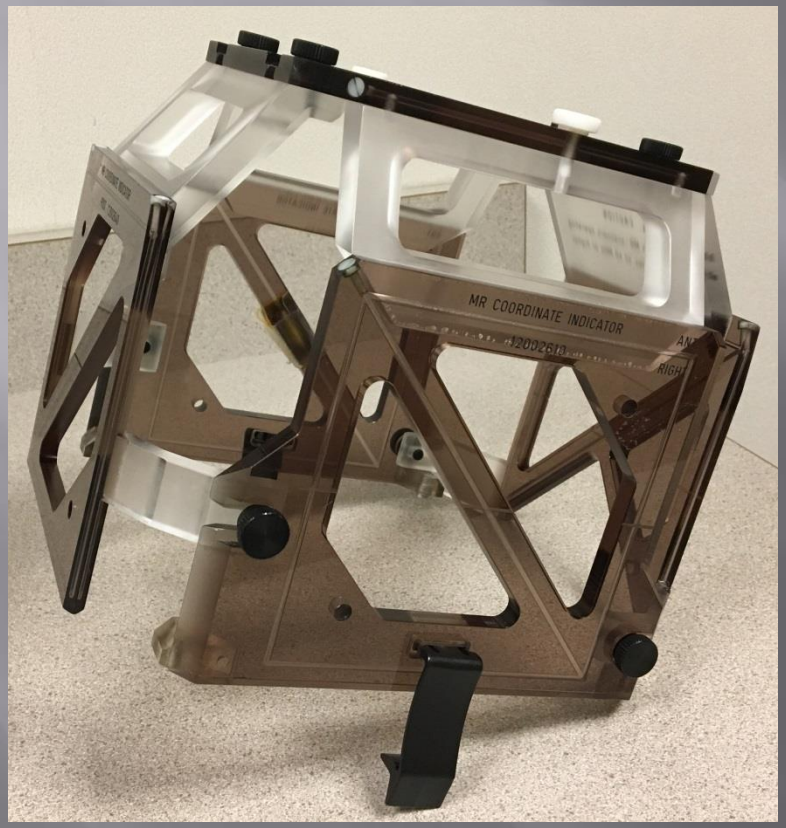
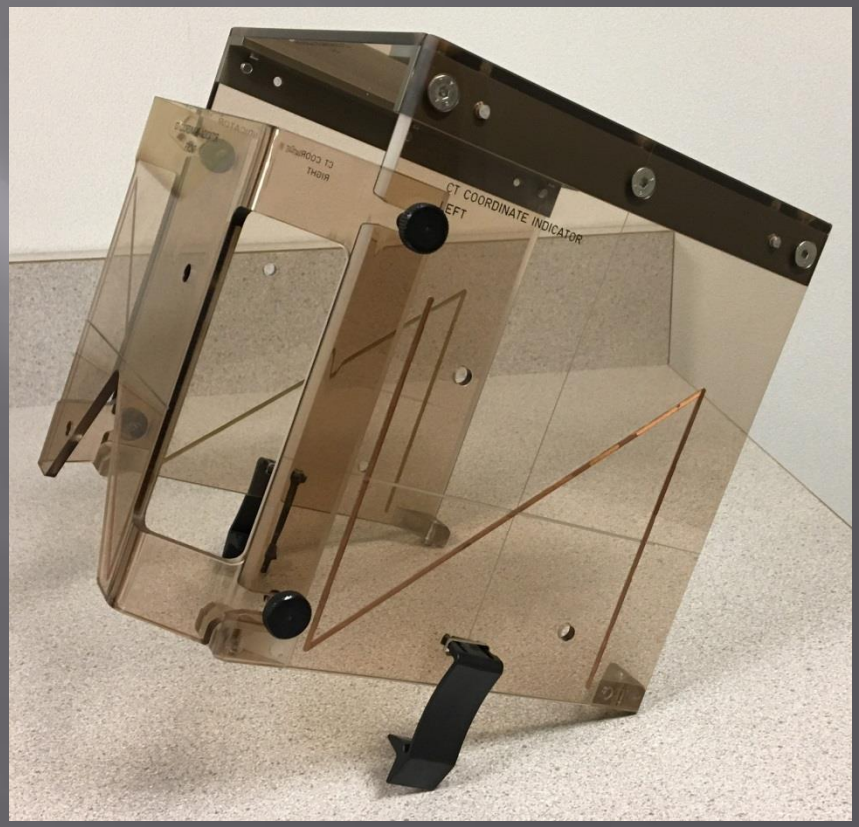


Patient Setup: head frame

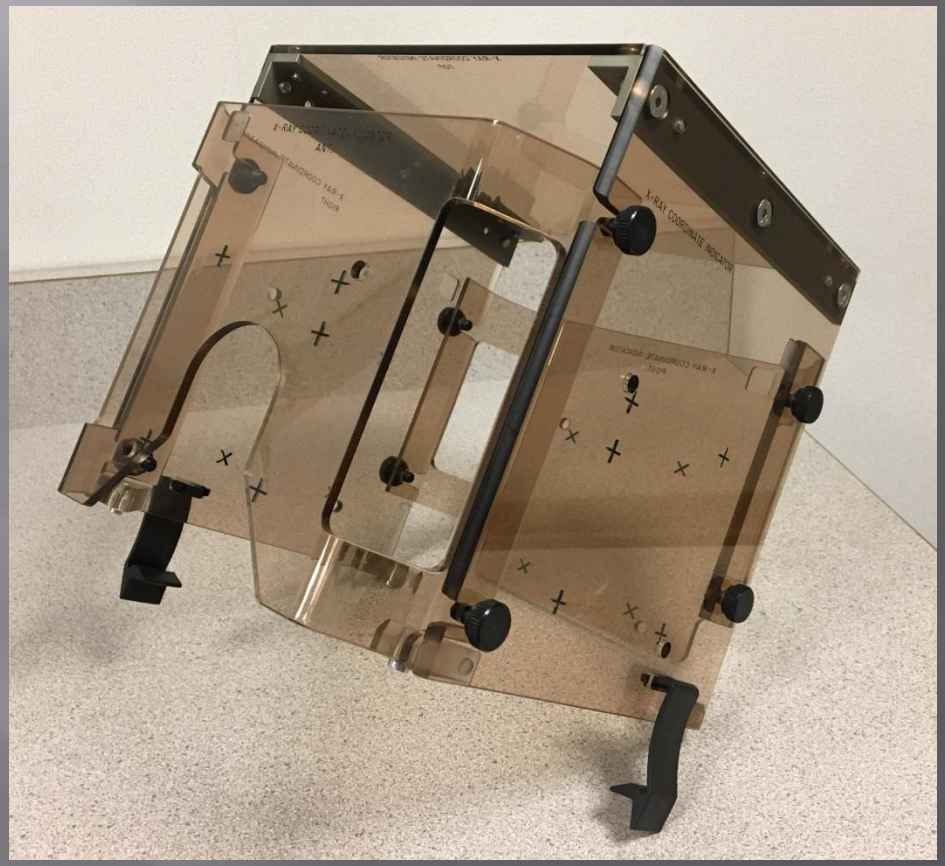


Patient Setup: MR & CT Fiducial Box





Patient Setup : X Ray (angio) fiducial box

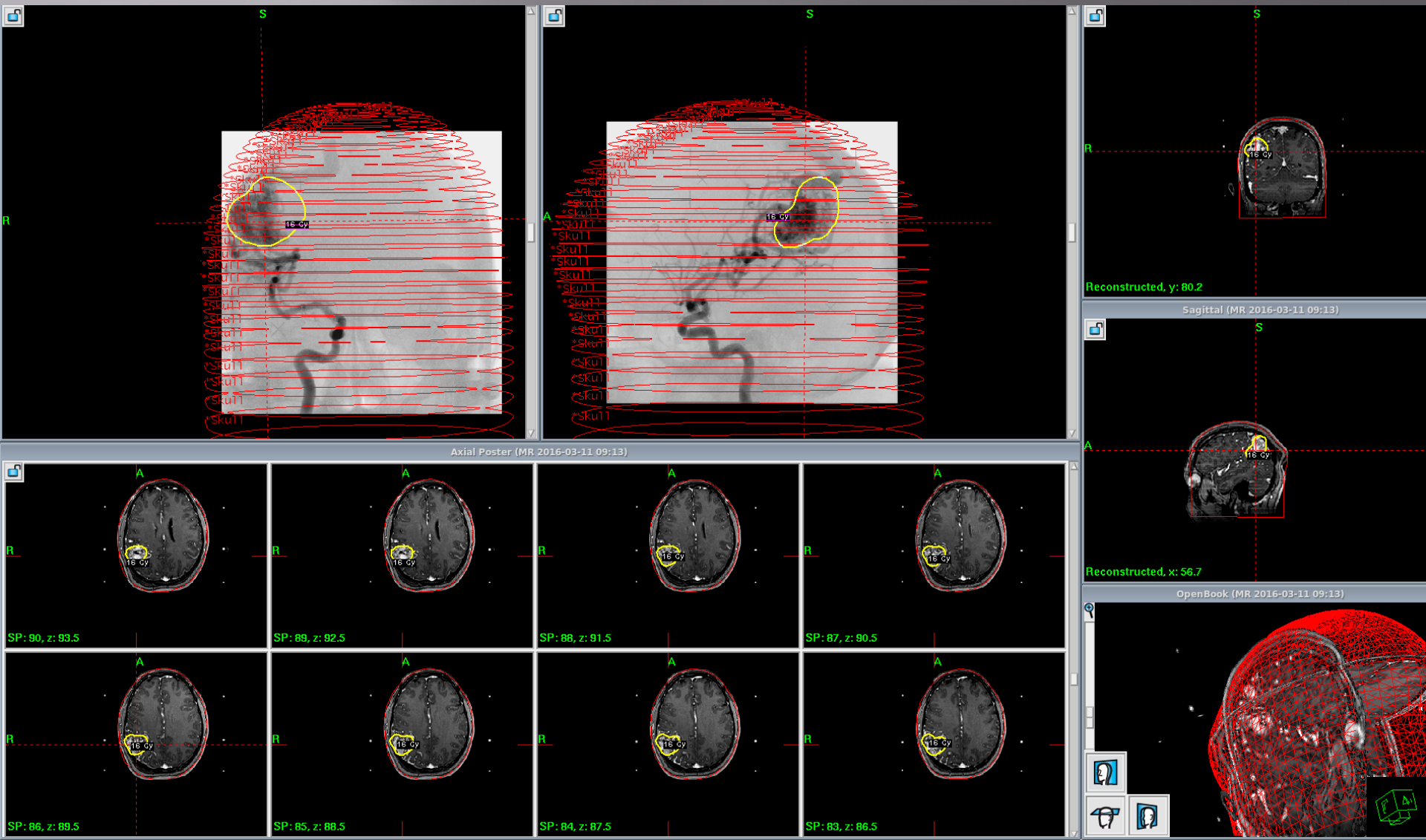


Patient Setup: GK PFX frame adapter

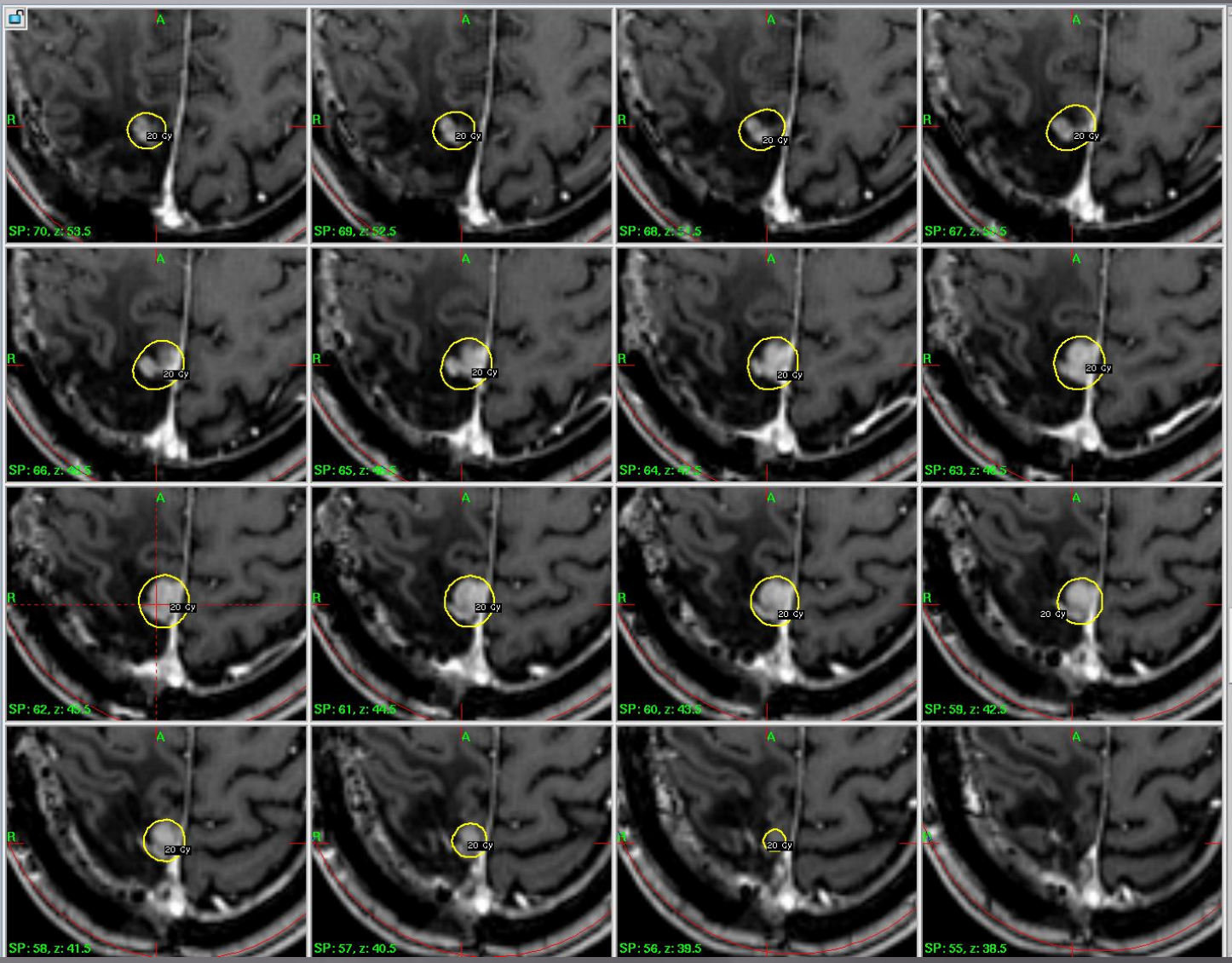
Patient Setup: bubble device & frame cap

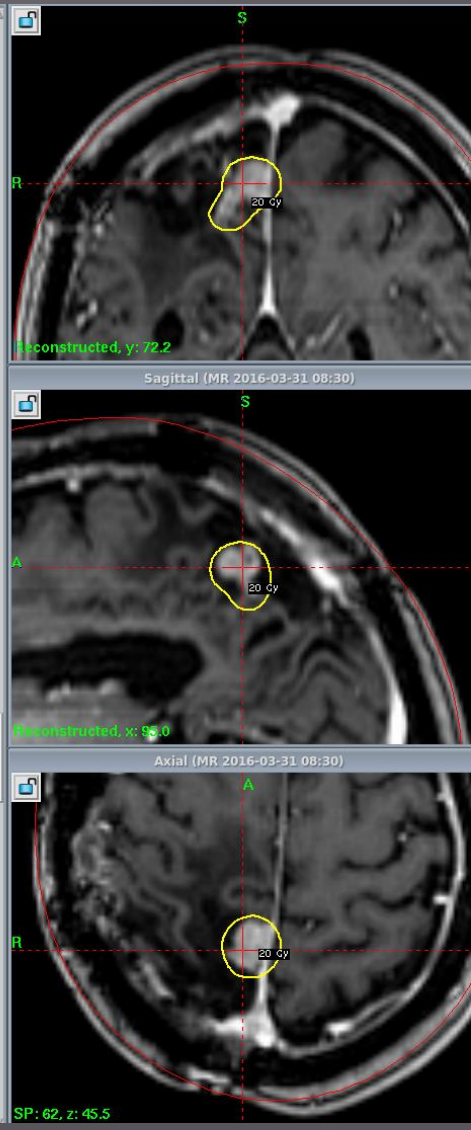
AVM

(arteriovenous malformations)

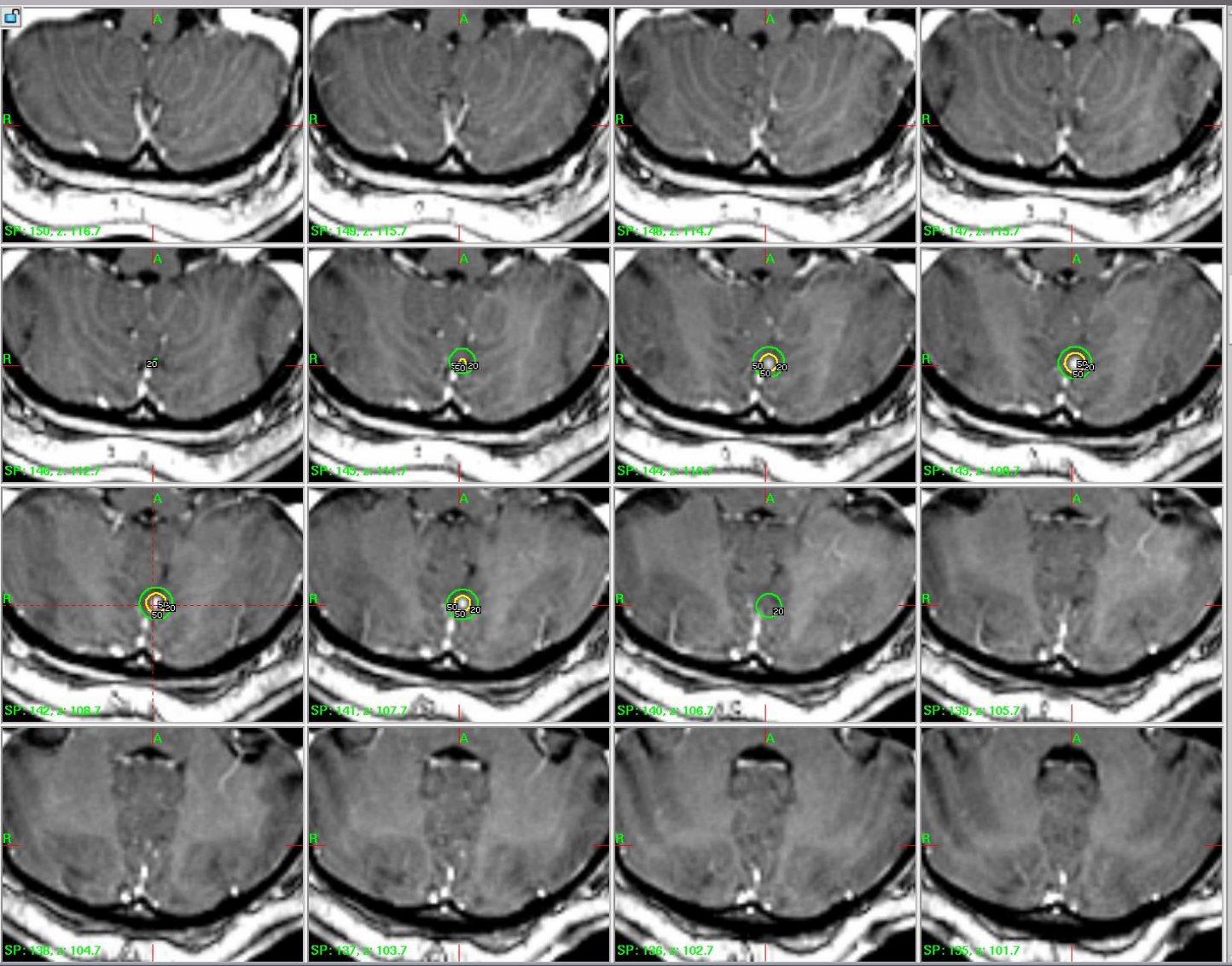


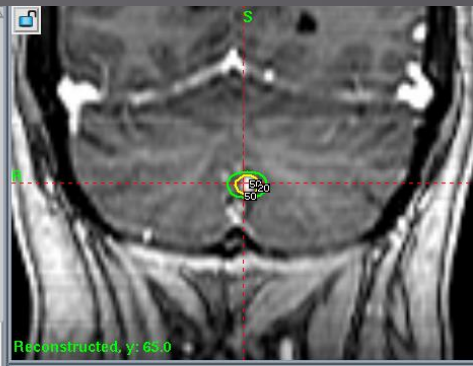
Ependymoma


A
R
20 Gy
SP: 70, z: 53.5
SP: 69, z: 52.5
SP: 68, z: 51.5
SP: 67, z: 50.5
SP: 66, z: 49.5
SP: 65, z: 48.5
SP: 64, z: 47.5
SP: 63, z: 46.5
SP: 62, z: 45.5
SP: 61, z: 44.5
SP: 60, z: 43.5
SP: 59, z: 42.5
SP: 58, z: 41.5
SP: 57, z: 40.5
SP: 56, z: 39.5
SP: 55, z: 38.5

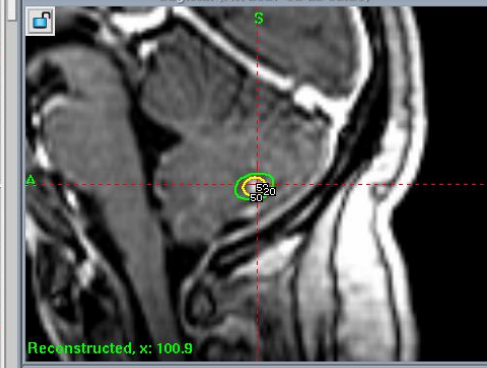

S
R
20 Gy
Reconstructed, y: 72.2
Sagittal (MR 2016-03-31 08:30)
A
Reconstructed, x: 95.0
Axial (MR 2016-03-31 08:30)
SP: 62, z: 45.5

Hemangio Blastoma

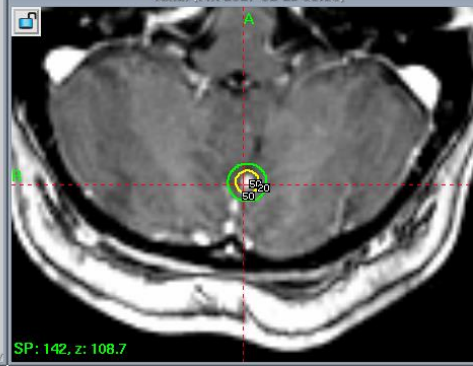




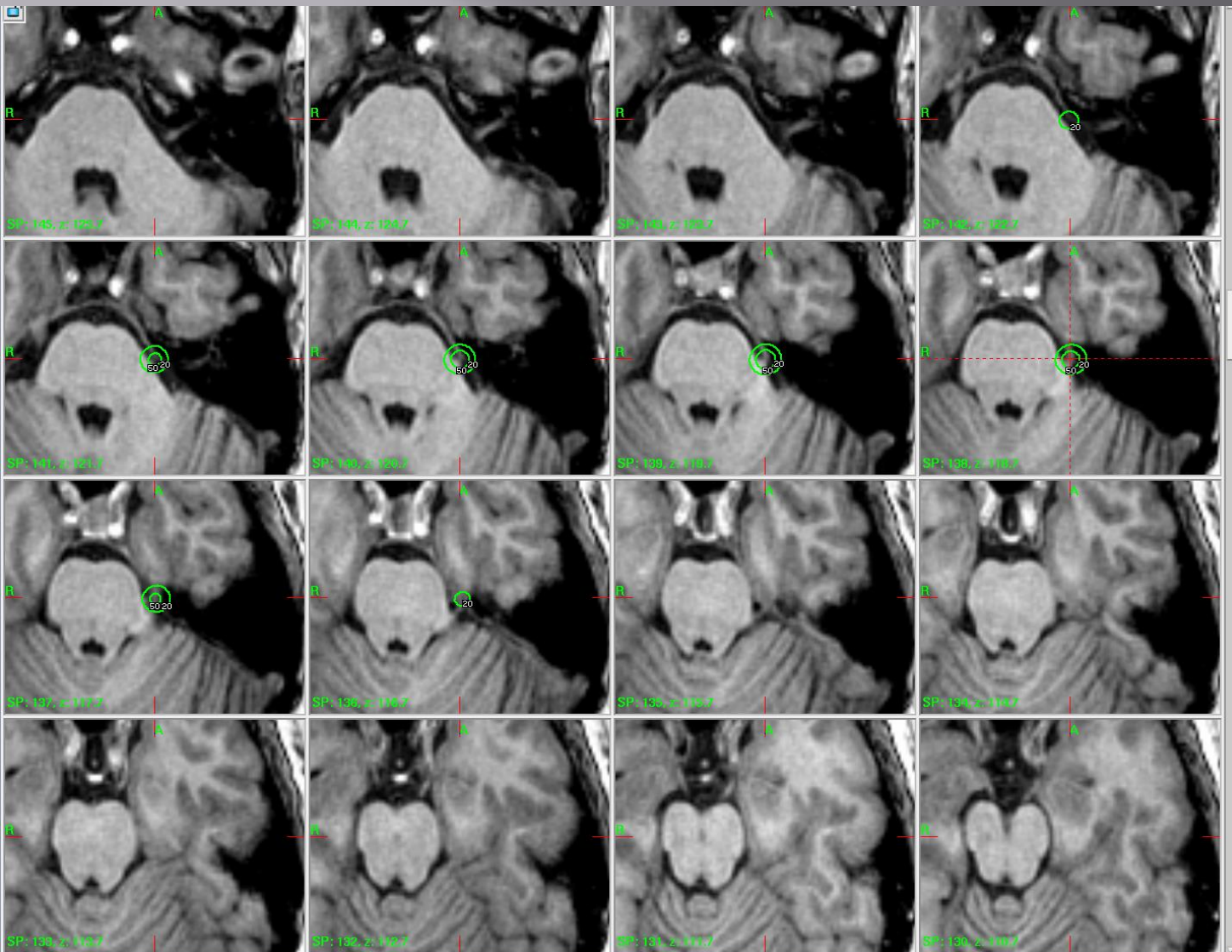
Sagittal (MR 2017-01-13 08:50)

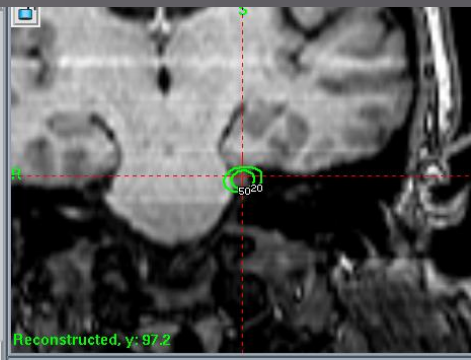


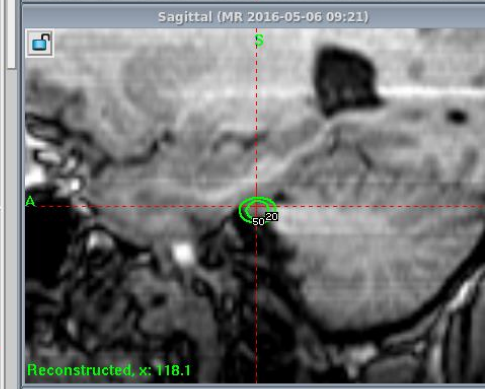
Axial (MR 2017-01-13 08:50)

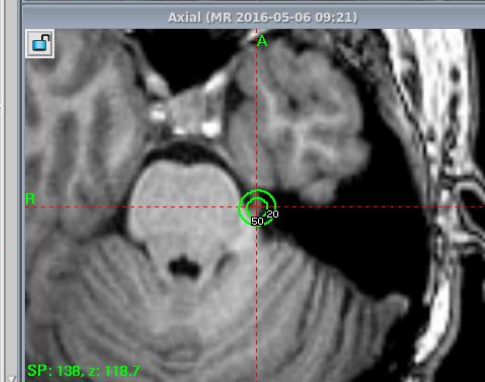


Trigeminal Neuralgia

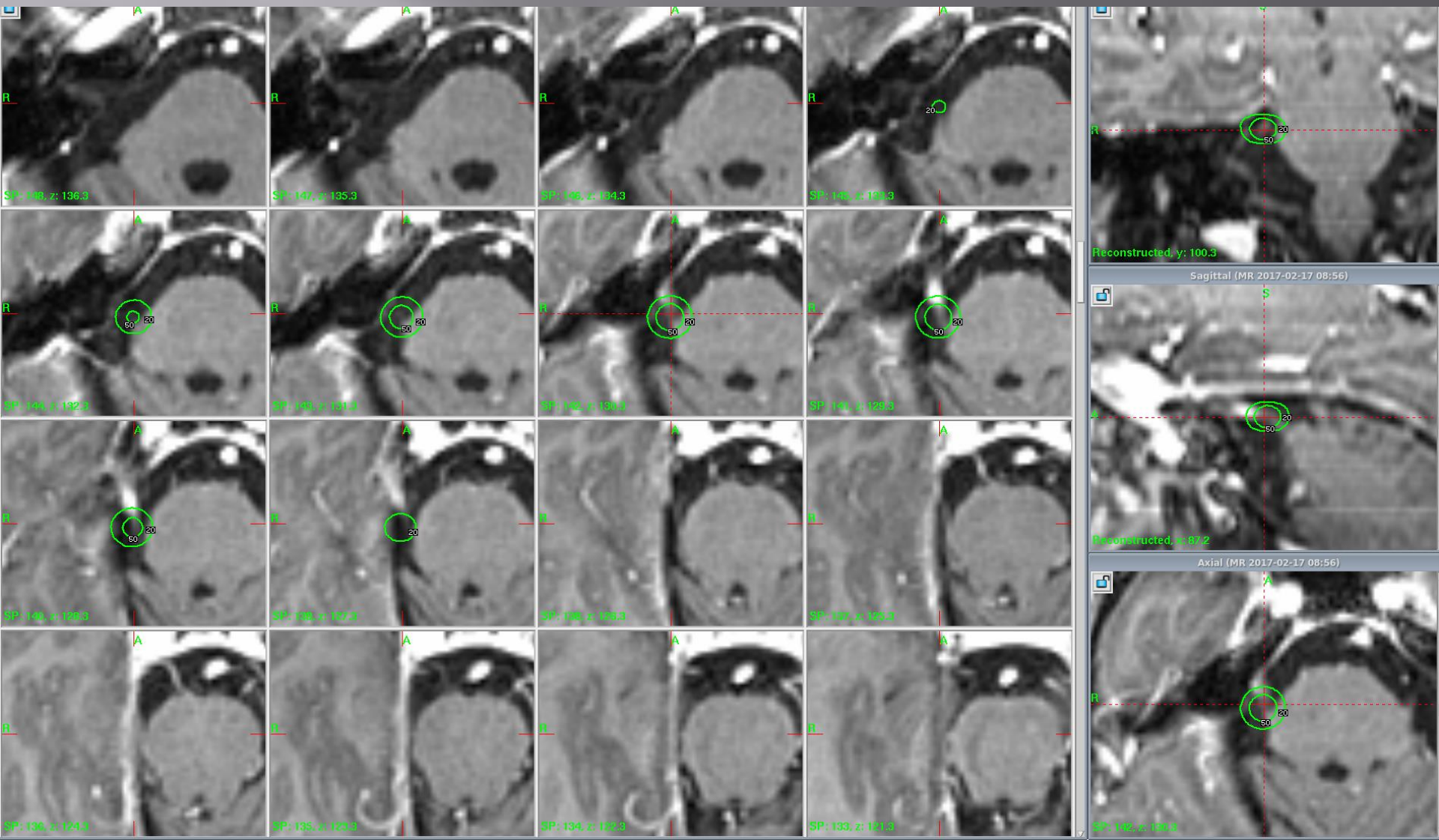




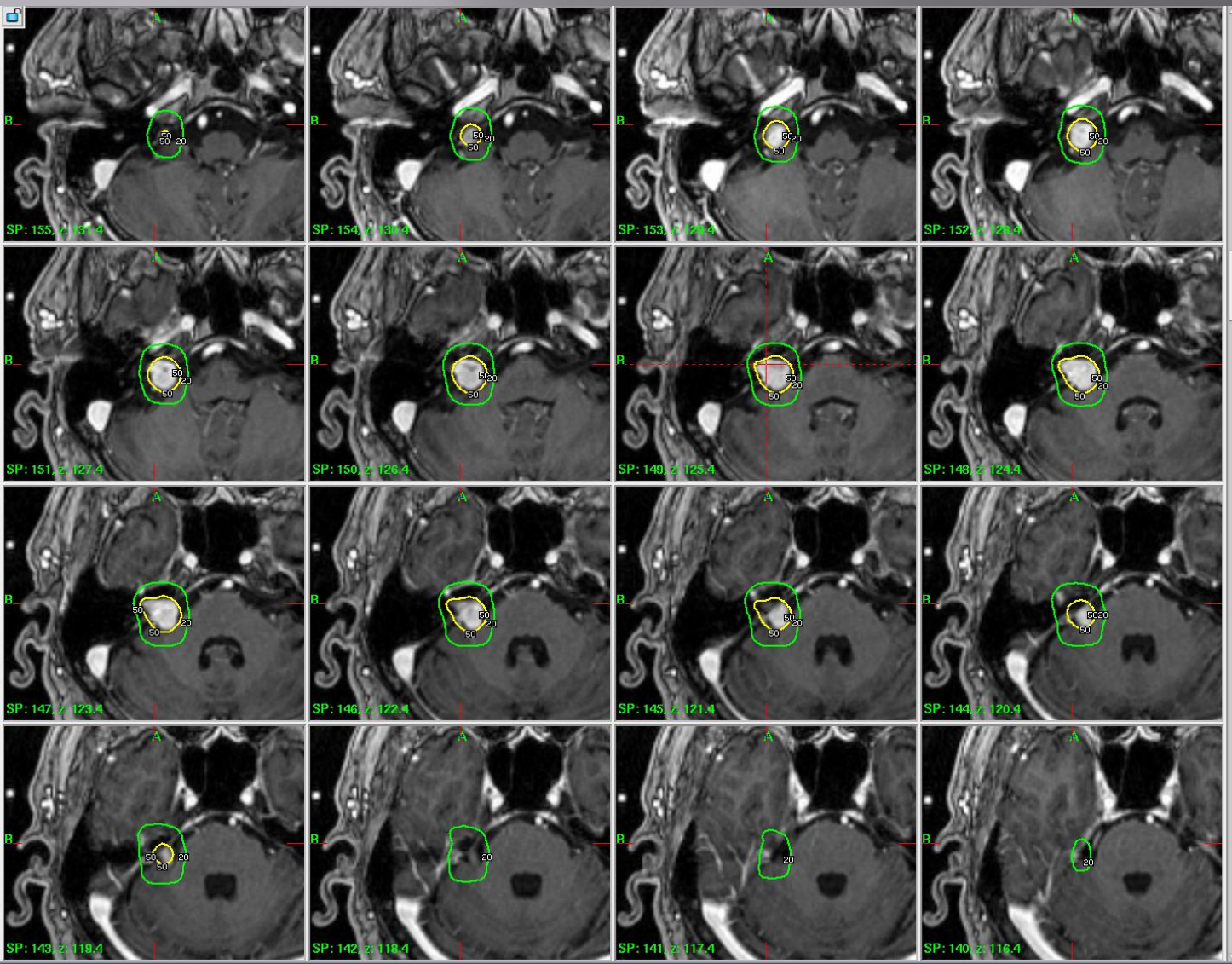


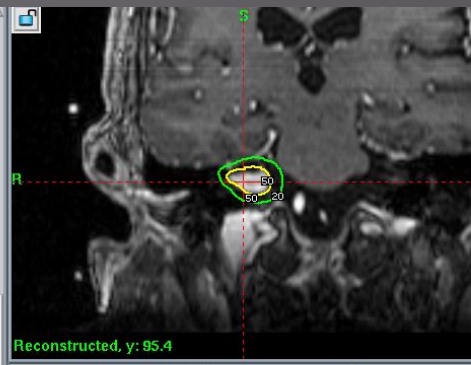


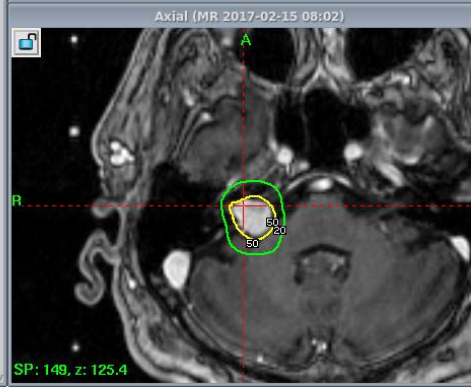
Trigeminal Neuralgia with contrast retreatment



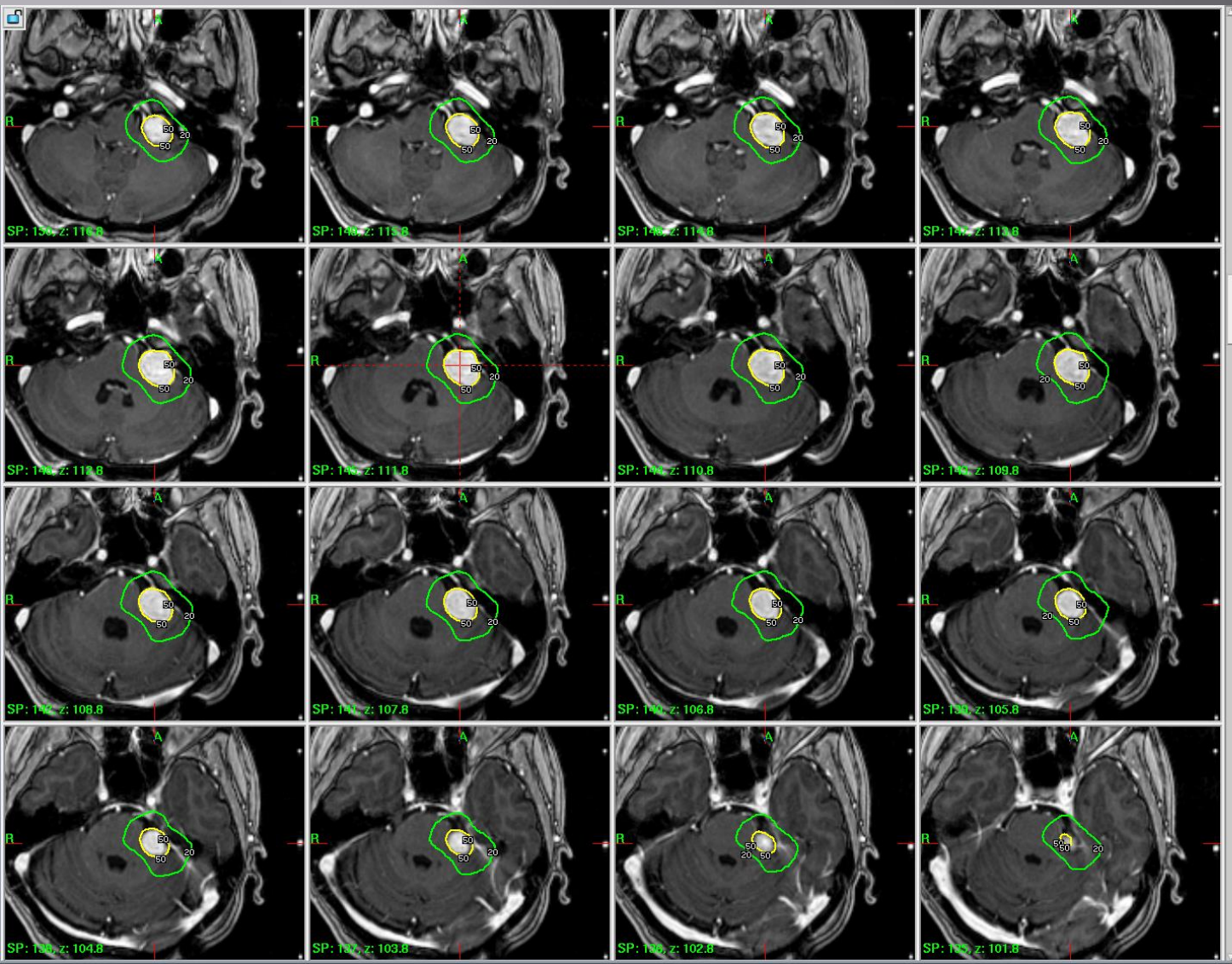
Acoustic Neuroma (Vestibular Schwannoma)

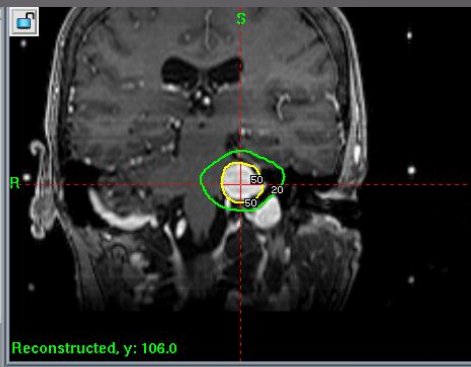


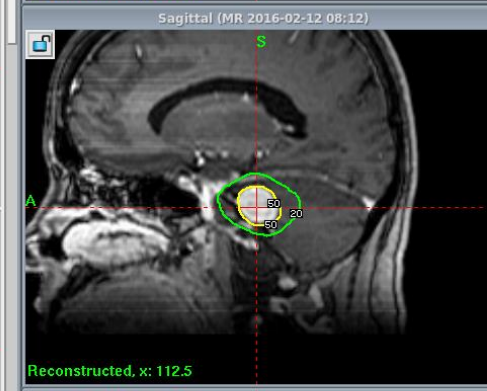


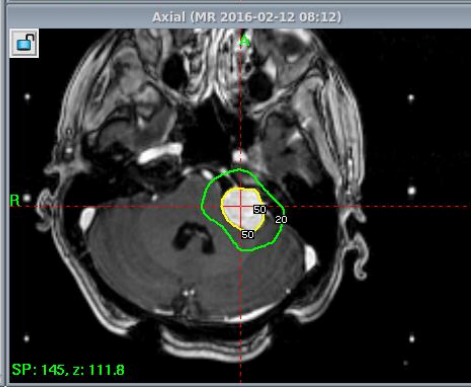


Acoustic Neuroma

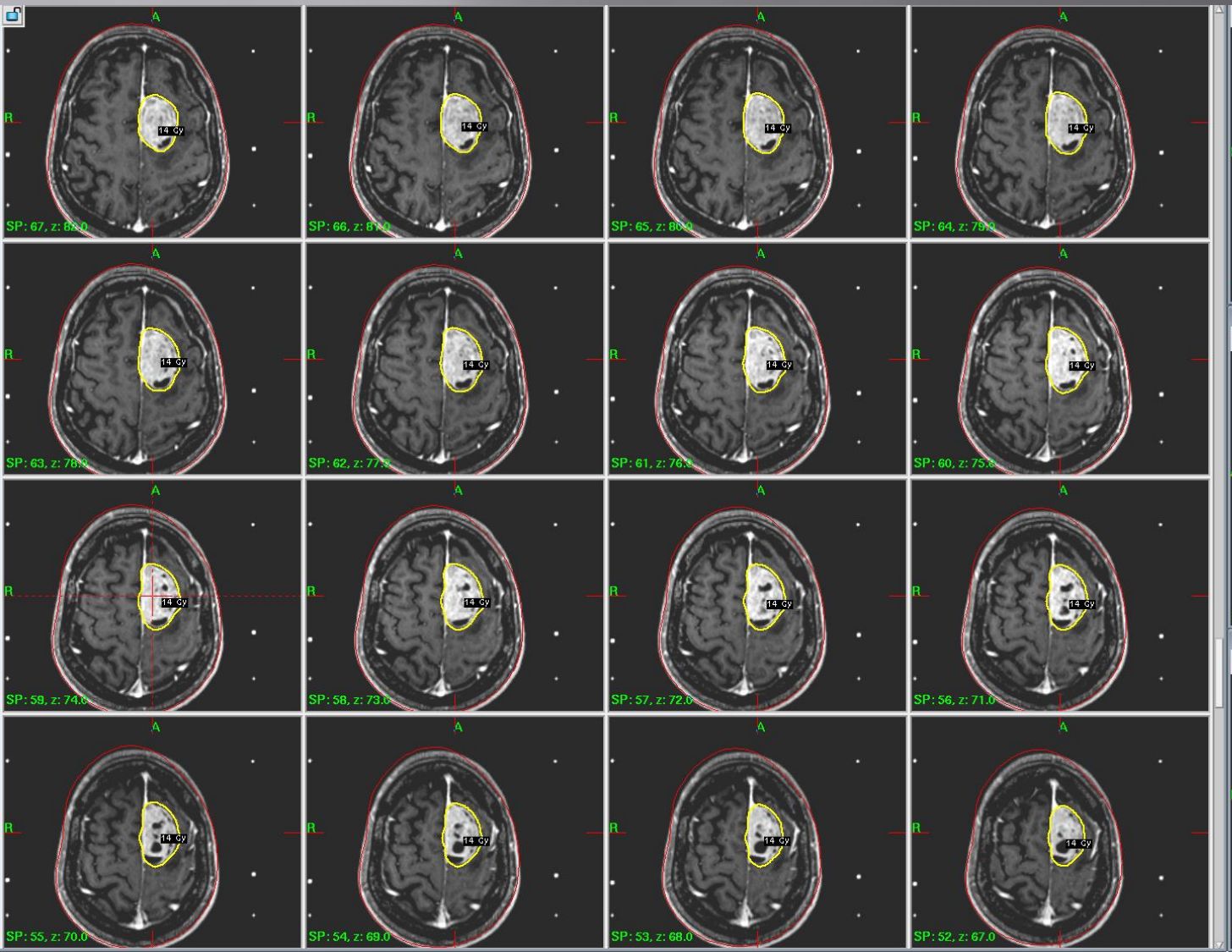


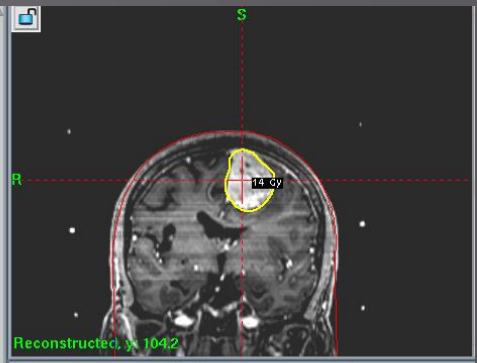


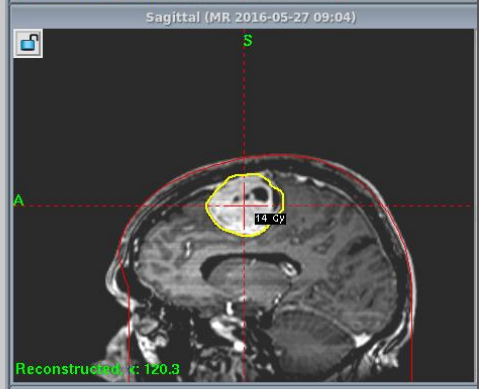


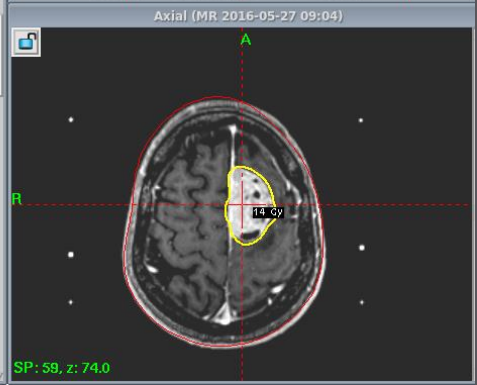


Meningioma

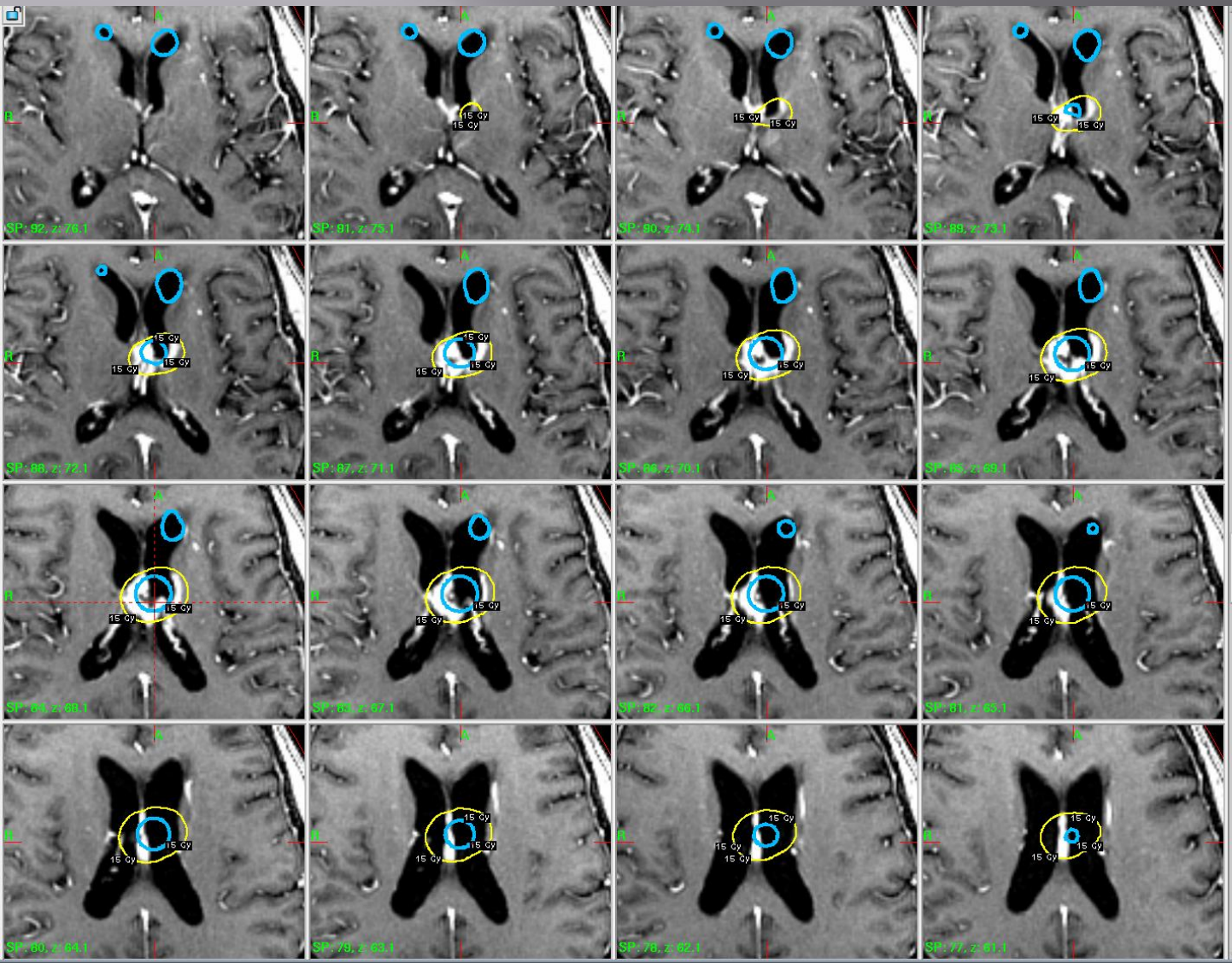

A
R
14 Gy
SP: 67, z: 84.0
SP: 66, z: 81.0
SP: 65, z: 80.0
SP: 64, z: 79.0
SP: 63, z: 78.0
SP: 62, z: 77.0
SP: 61, z: 76.0
SP: 60, z: 75.0
SP: 59, z: 74.0
SP: 58, z: 73.0
SP: 57, z: 72.0
SP: 56, z: 71.0
SP: 55, z: 70.0
SP: 54, z: 69.0
SP: 53, z: 68.0
SP: 52, z: 67.0

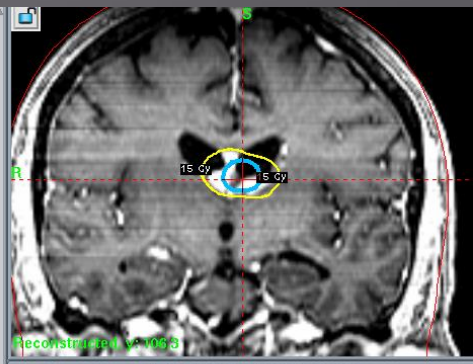

S
R
14 Gy
Reconstructed, y: 104.2

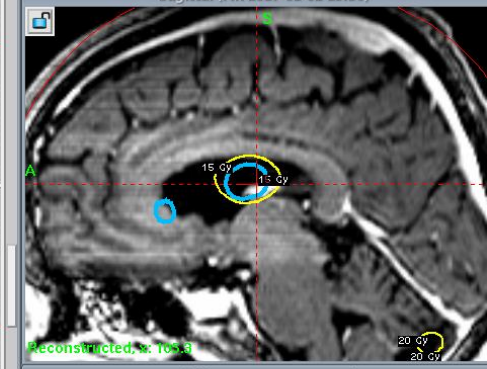

Sagittal (MR 2016-05-27 09:04)
S
A
14 Gy
Reconstructed, x: 120.3

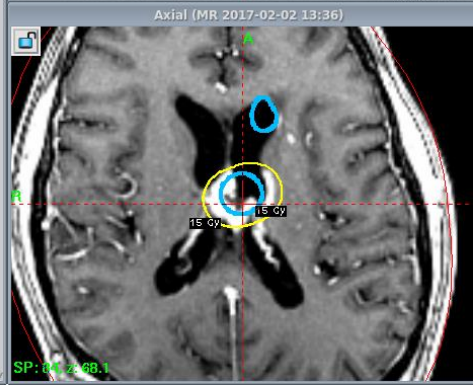

Axial (MR 2016-05-27 09:04)
A
R
14 Gy
SP: 59, z: 74.0

Metastasis Retreatment

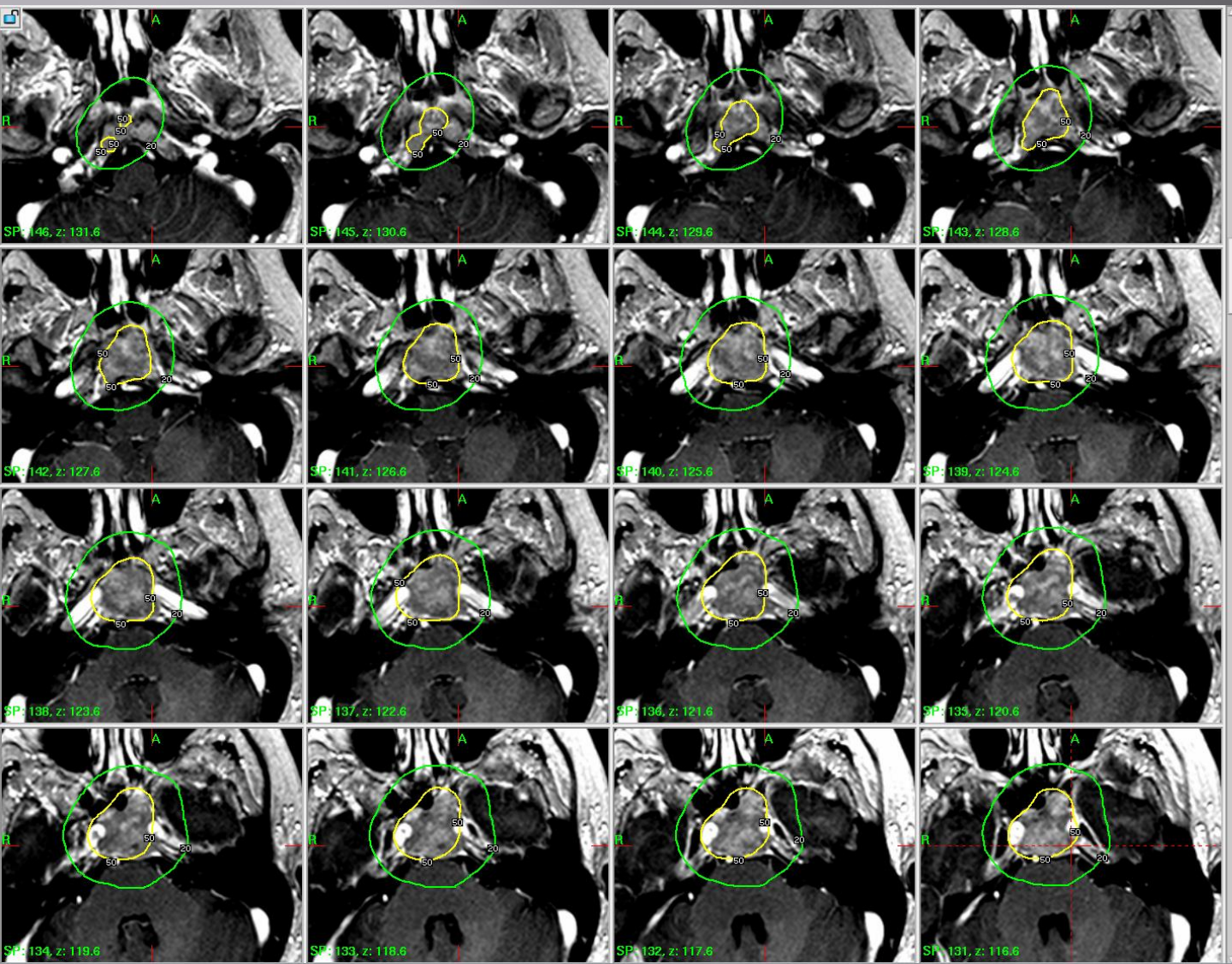


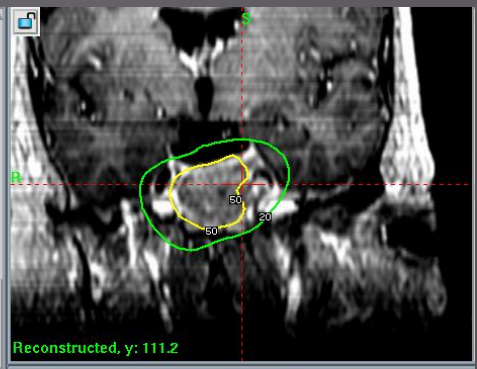


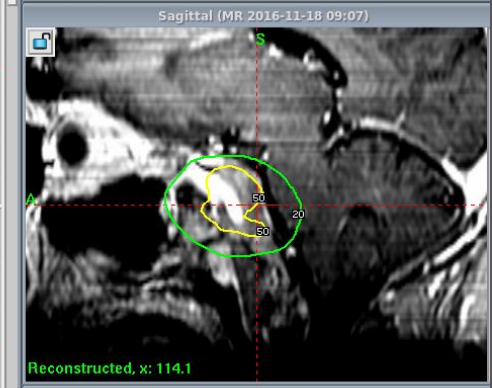


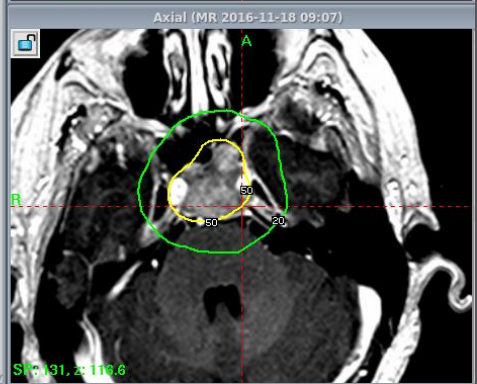


Pituitary Adenoma



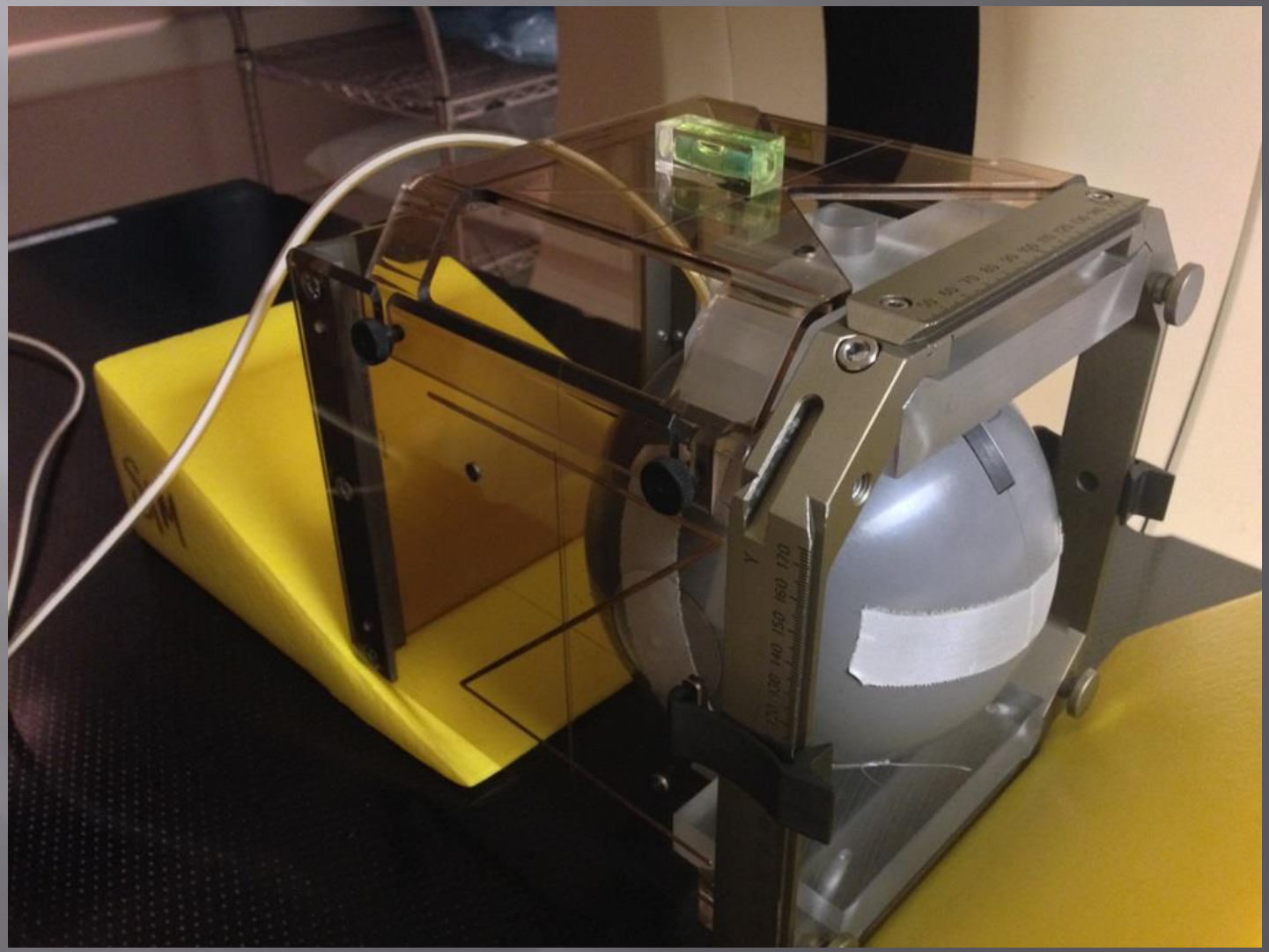




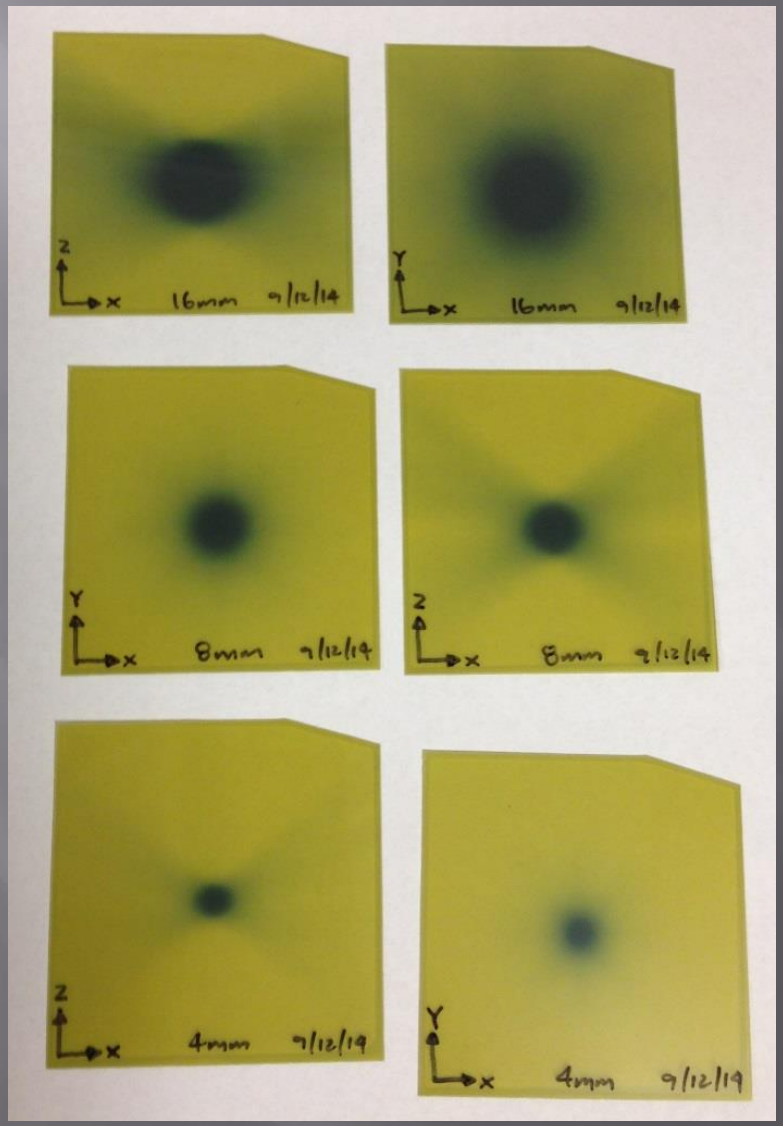


End-to-end QA

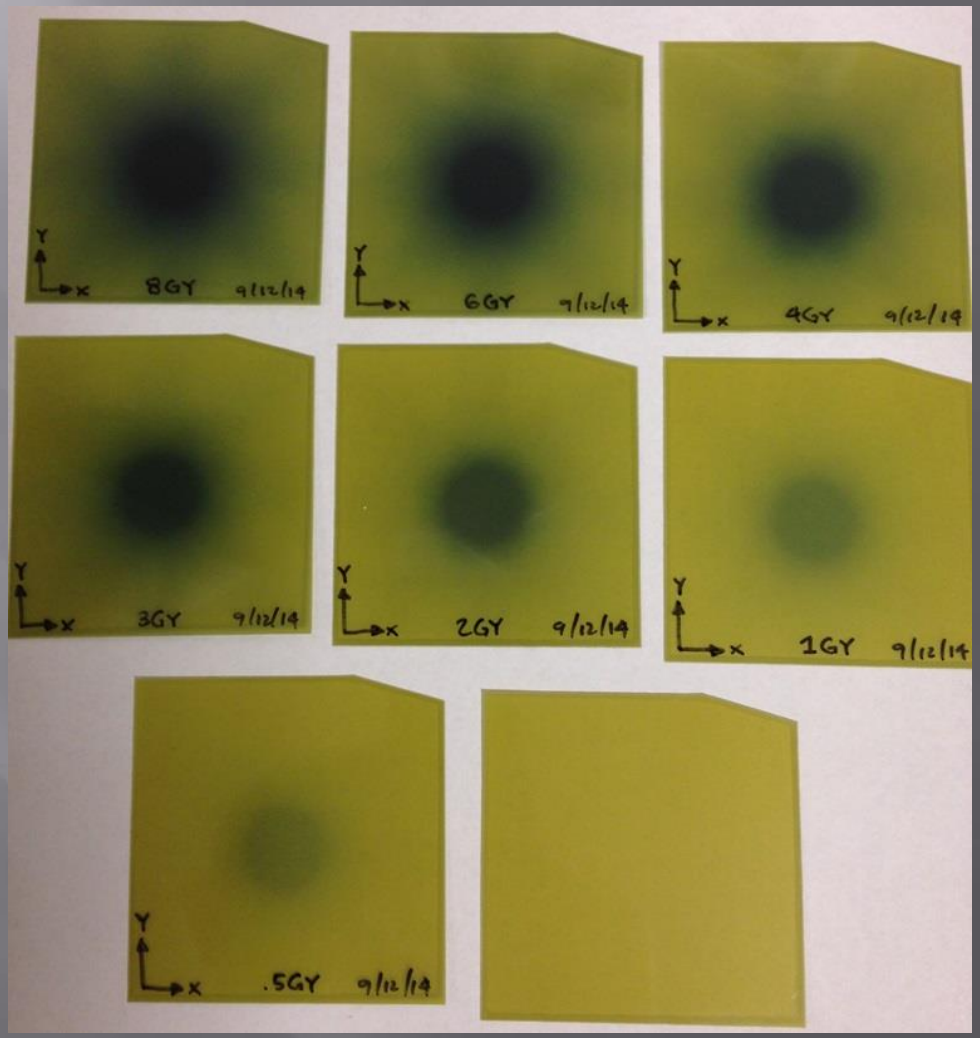
End-to-end QA



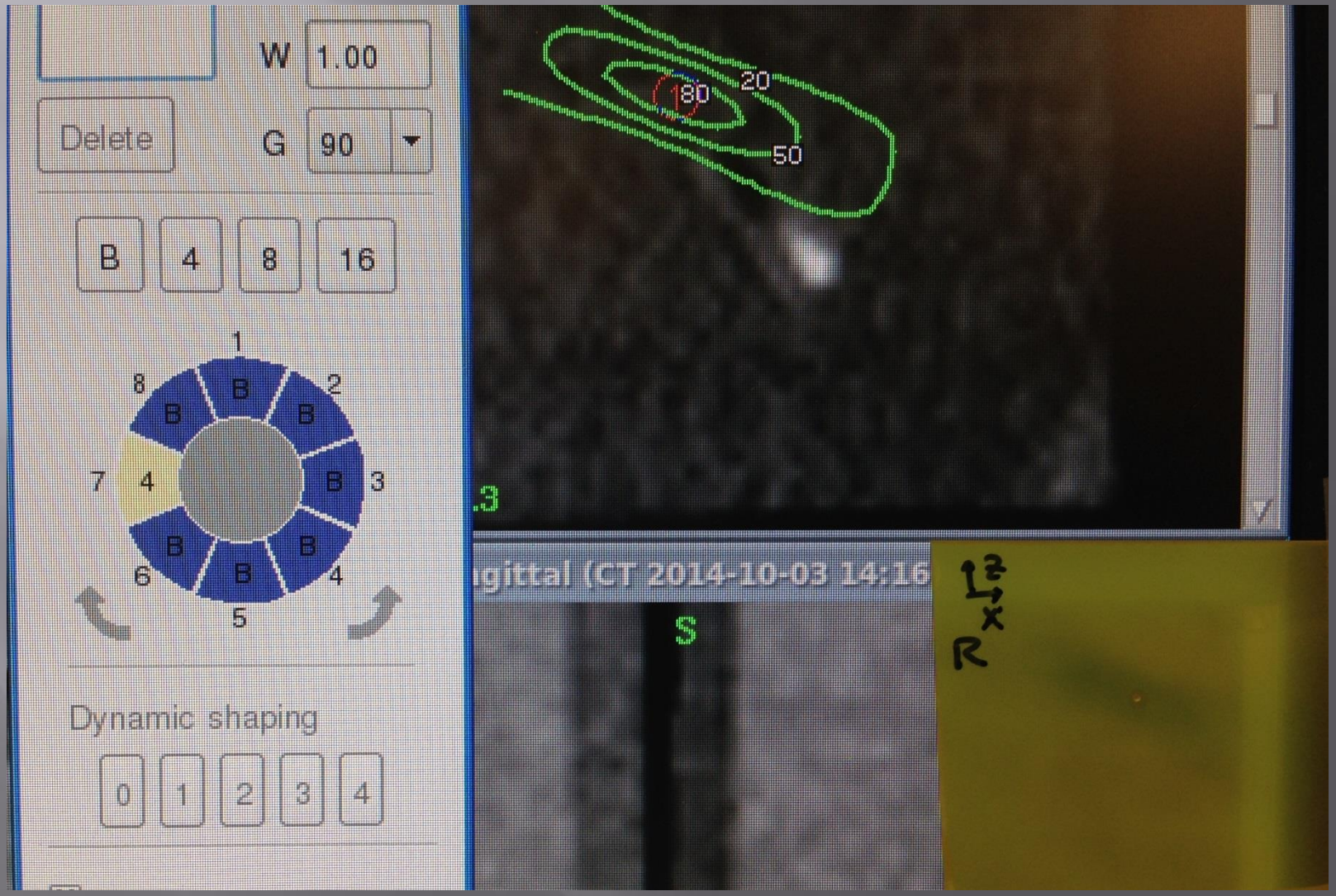
QA: shot profiles



QA: LUT


8GY 9/12/14
6GY 9/12/14
4GY 9/12/14
3GY 9/12/14
2GY 9/12/14
1GY 9/12/14
.5GY 9/12/14

QA: 7TH sector profile



Thanks!

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- Linda Weis-Smith, RN
- John H. Neal, MD Neurological Surgery, Marshfield Clinic Health System