Is Stereotactic Linear Accelerator Can Replace The Treatment By Cyberknife or Gamma Knife?

By

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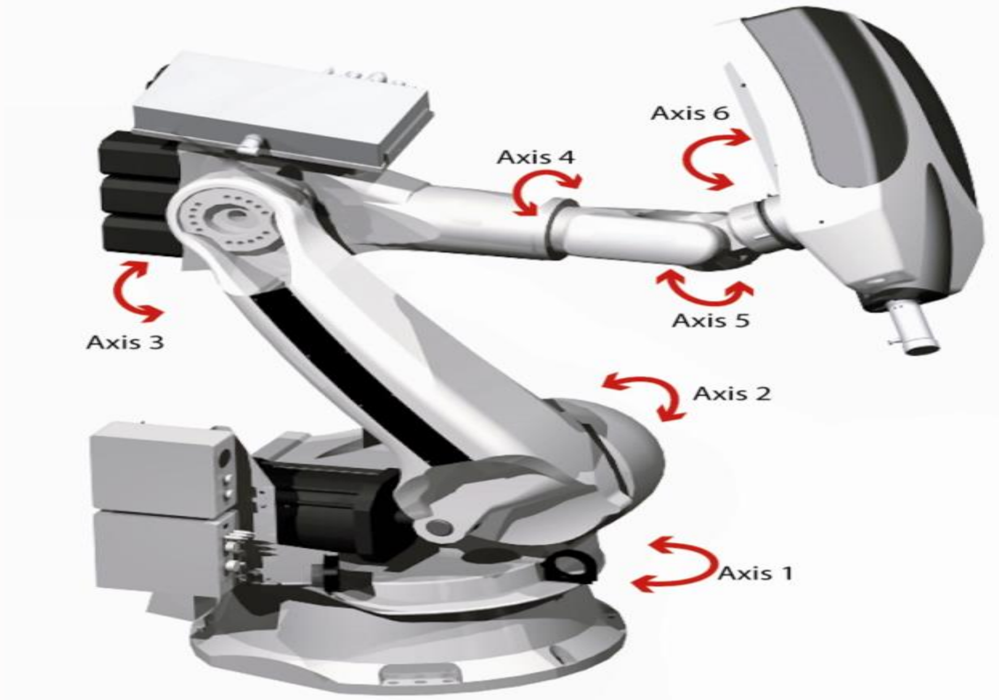
Dr. Nabaa Mohammed Ali

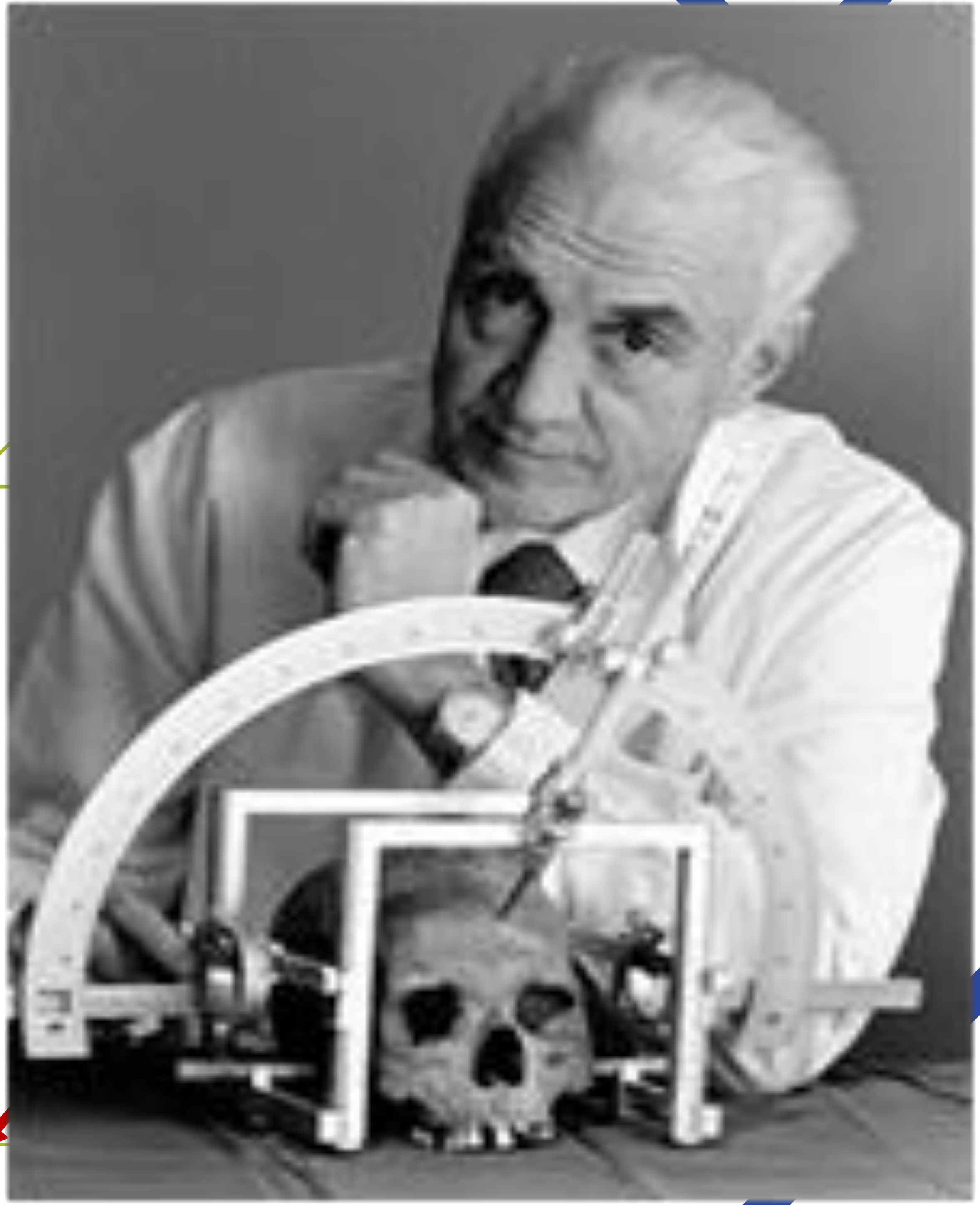


Stereotactic

- Stereo: from Greek word Stereos = 3D solid
- Tactic: from Greek word taxis = orientation
- **Stereotactic**:

– Use of 3D coordinate s system to localize a target more accurately.

– Initially has been accomplished using rigid head ring.



Stereotactic Devices

01 Linear Accelerator (Linac)

02 CyberKnife

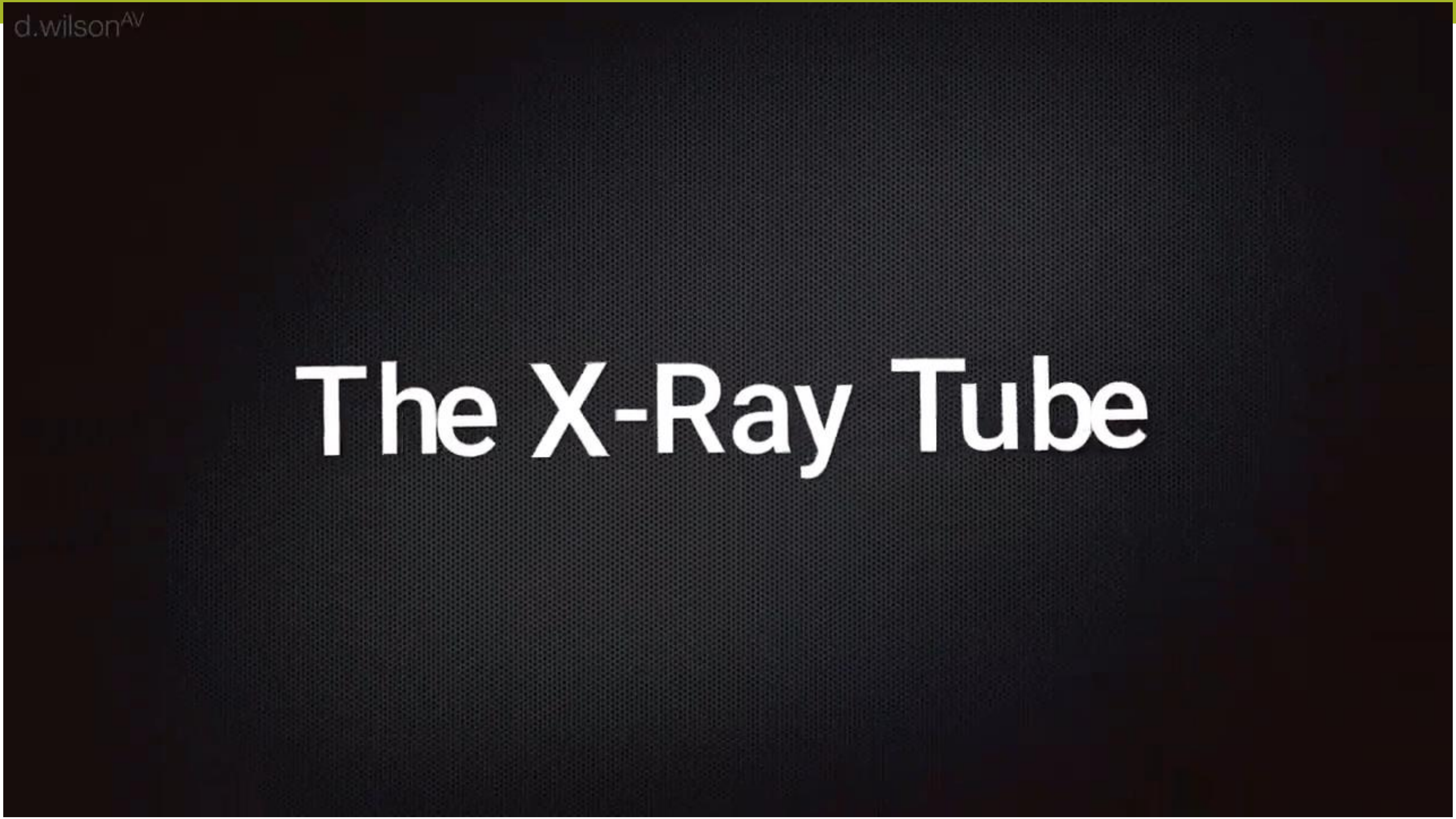
03 Gamma Knife

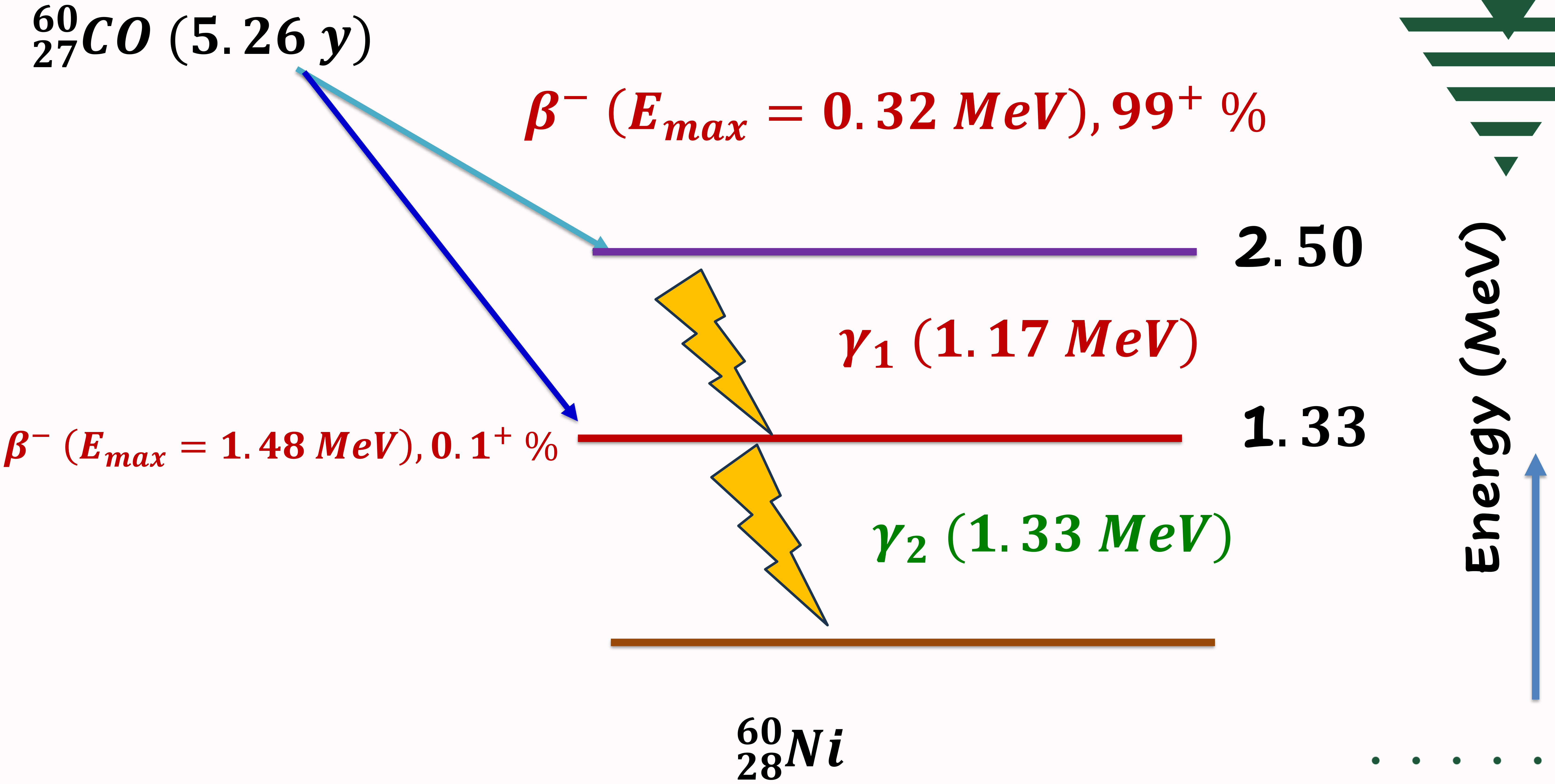
Introduce the project. Provide a quick background and rationale. Briefly share its overall scope as well as expected outcomes.

Interaction of X or γ-photons with human body

- The probability that photon interact with matter by any of three phenomena (photoelectric effect, and Compton scattering, and pair –production) is dependent on ***photon energy*** **(hν)** and on the ***atomic number of the attenuating material***.

- Generally, the photoelectric absorption is the predominant with photon of low energies, Compton scatter is the effect of intermediate energies and at high energies the ***pair-production*** takes place, which is the interaction that predominant with radiation therapy

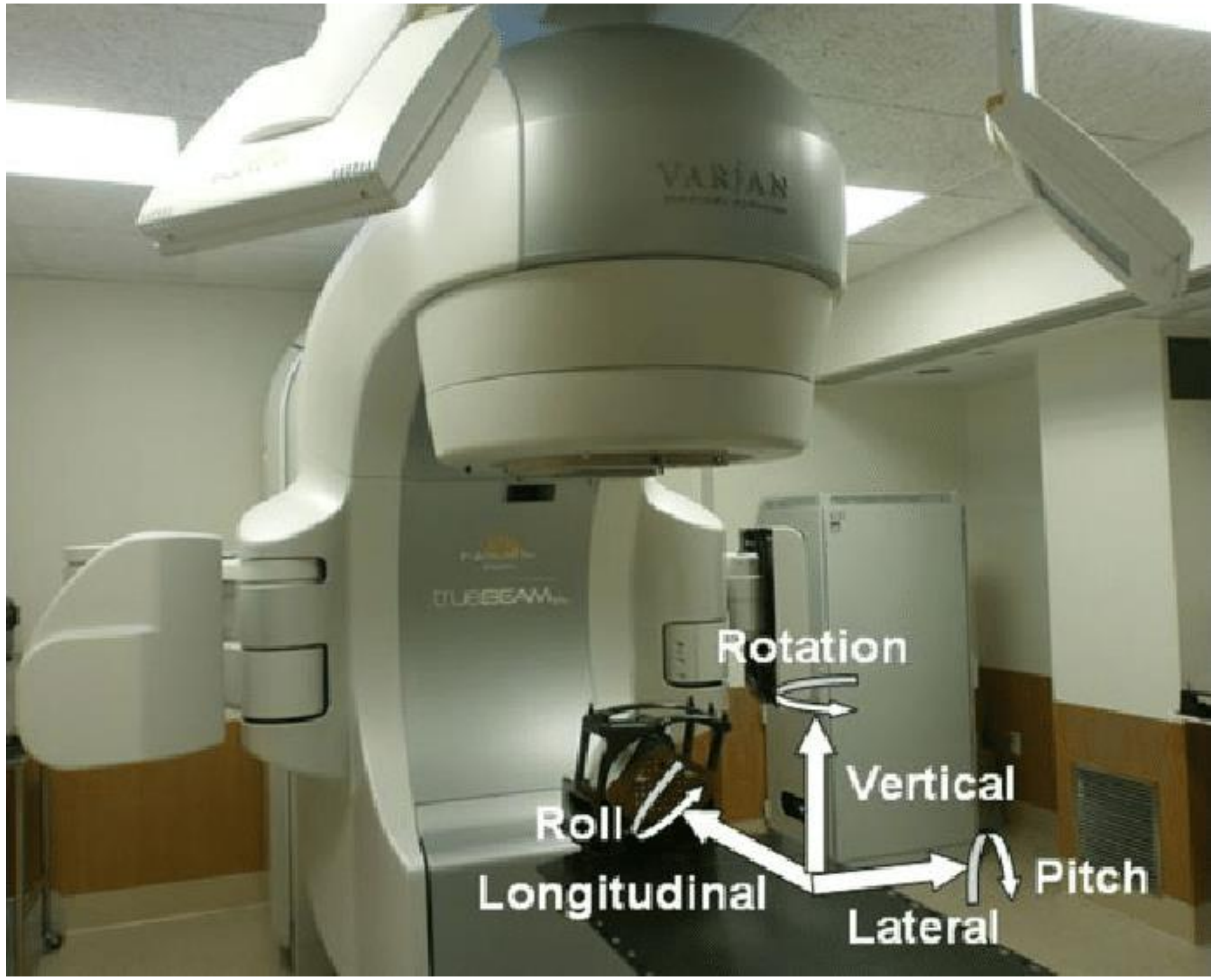

d.wilsonAV
The X-Ray Tube



$^{60}_{27}CO$ (5.26 y)
β^- (E_{max} = 0.32 MeV), 99$^+$ %
2.50
γ_1 (1.17 MeV)
1.33
β^- (E_{max} = 1.48 MeV), 0.1$^+$ %
γ_2 (1.33 MeV)
$^{60}_{28}Ni$
Energy (MeV)

Cyberknife

- The CyberKnife system is a non-invasive treatment frameless stereotactic radiosurgery (SRS) instrument that consists of a 6-megavolt linear accelerator (LINAC) mounted on an industrial robot, a repositionable treatment couch, orthogonally placed digital x-ray cameras, and a computerized targeting system, used to treat spine tumors.
- Stereotactic radiosurgery (SRS) is a form of radiation therapy that focuses high-power energy on a small area of the body.
- The CyberKnife System is a radiation therapy device manufactured by Accuray Incorporated.


VARIAN
Rotation
Vertical
Roll
Longitudinal
Lateral
Pitch

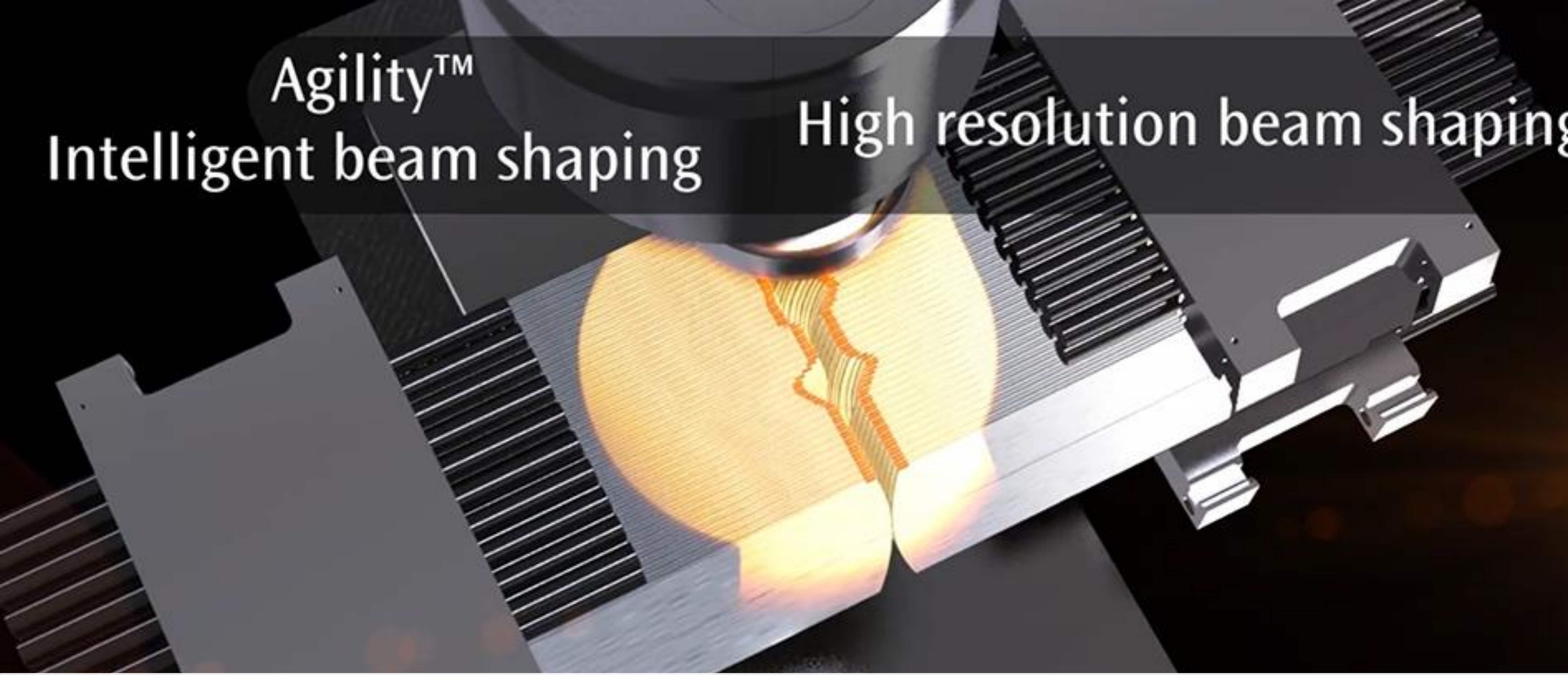
VARIAN STX

WE HAVE-ELEKTA

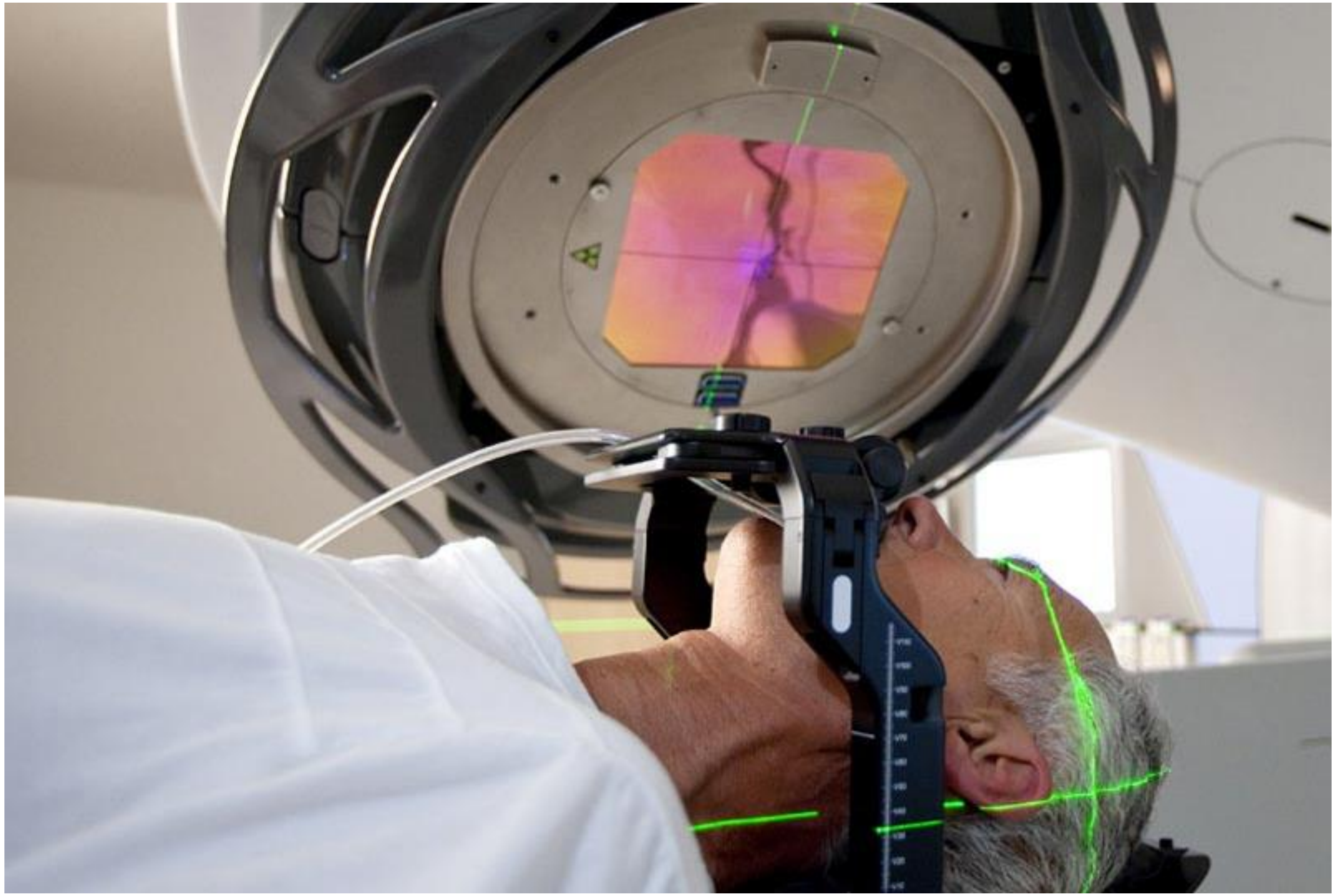
WHAT WE HAVE?

- CONES- FOR SUBCENTEMETER TUMORS
- AGILITY HEAD-MORE CONFIRMITY FOR SMALLER TUMORS
- FRAXION-NON INVASIVE,FRAMELESS COMFORTABLE MASK
- CONE BEAM CT-ONLINE CT BASED CORRECTION
- HEXAPOD-EXTRA DEGREE OF ROTATIONAL CORRECTION

ELEKTA AGILITY

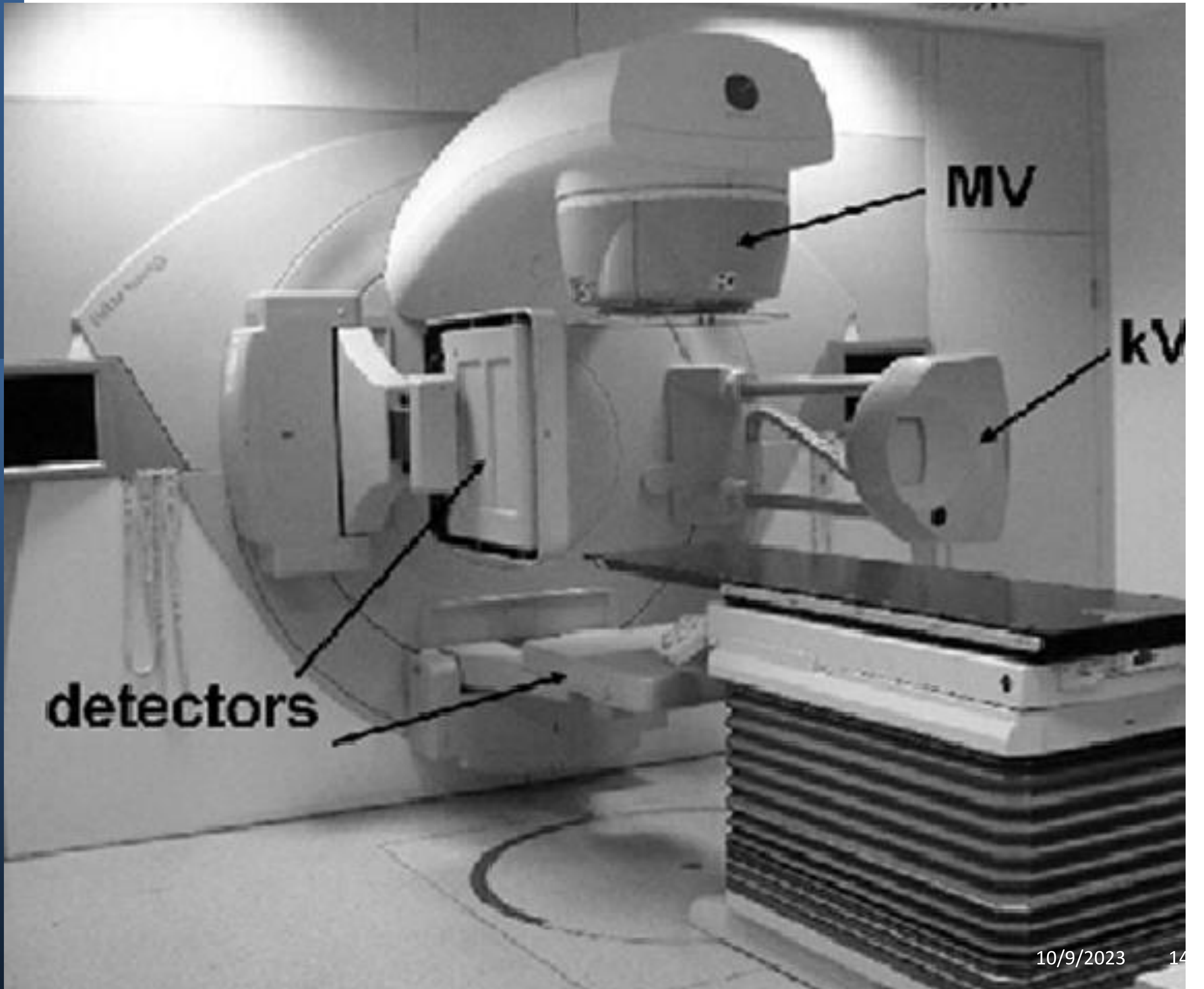


ELEKTA AGILITY

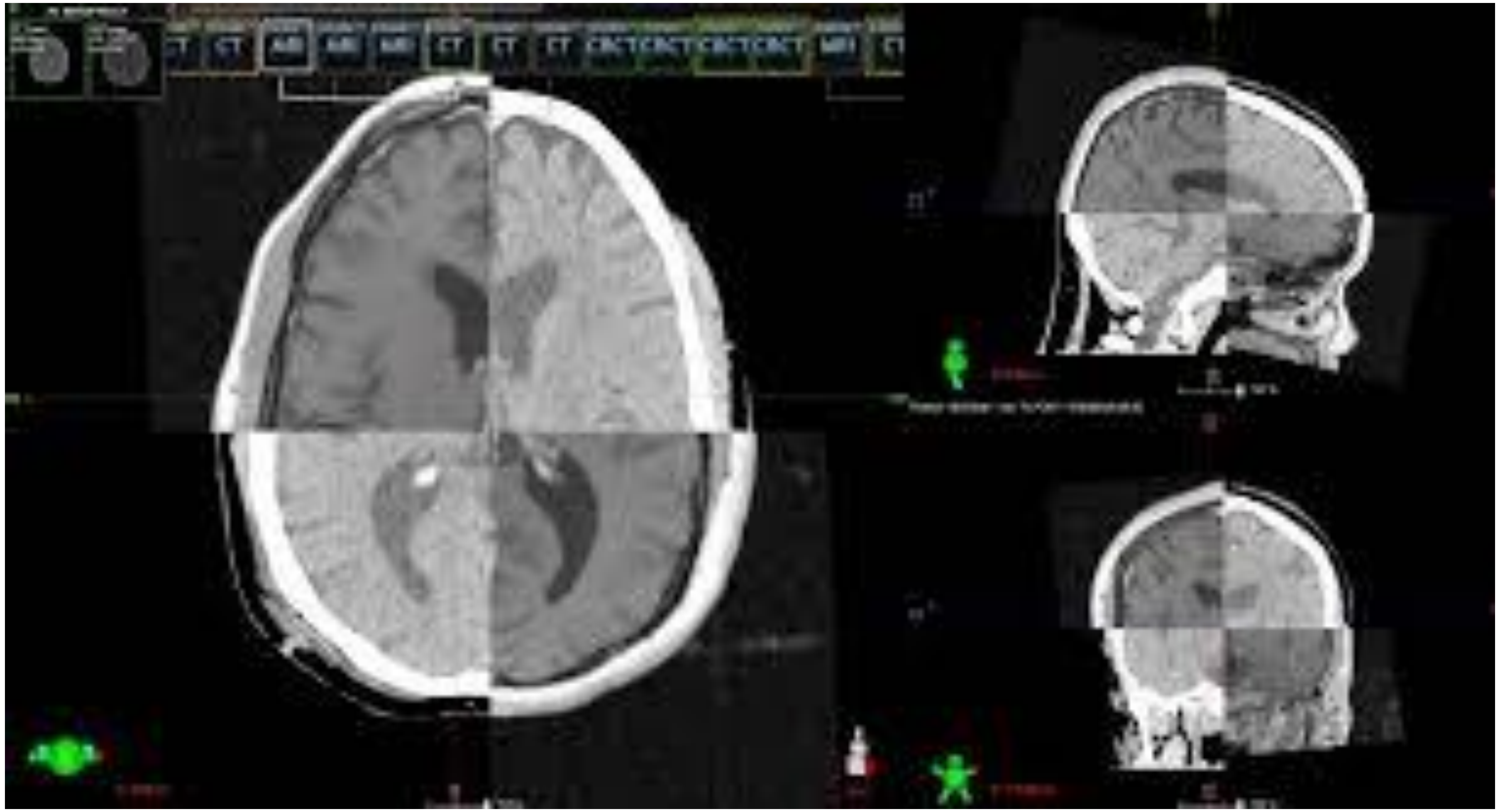


ELEKTA AGILITY

CBCT- CONE BEAM CT



CBCT- CONE BEAM CT



HEXAPOD

SRS SMALL FIELD CONES

Fig. 1. New Elekta's stereotactic collimation system: stereotactic cone and holder attached to the linac's head.

Cyberknife

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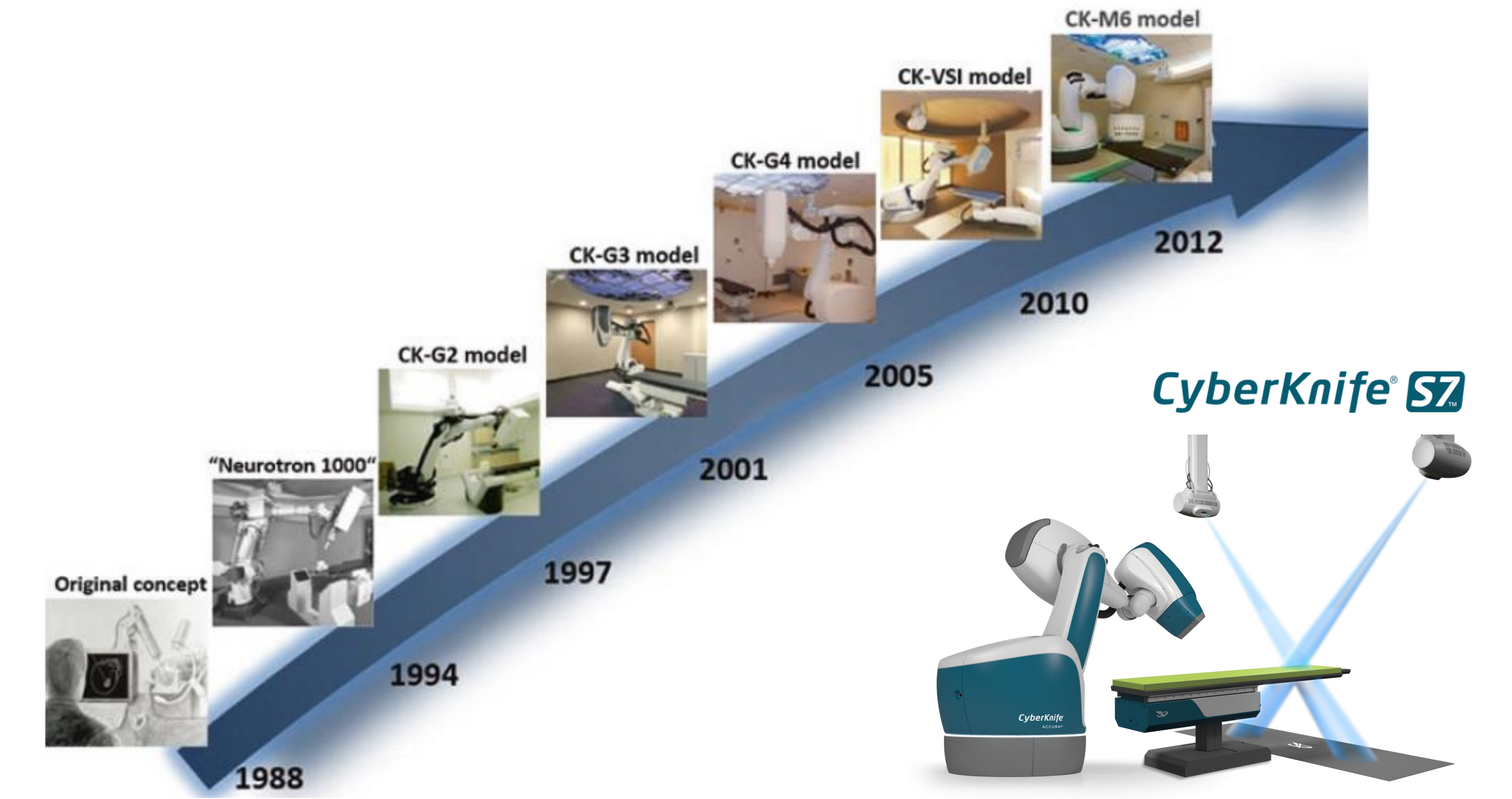
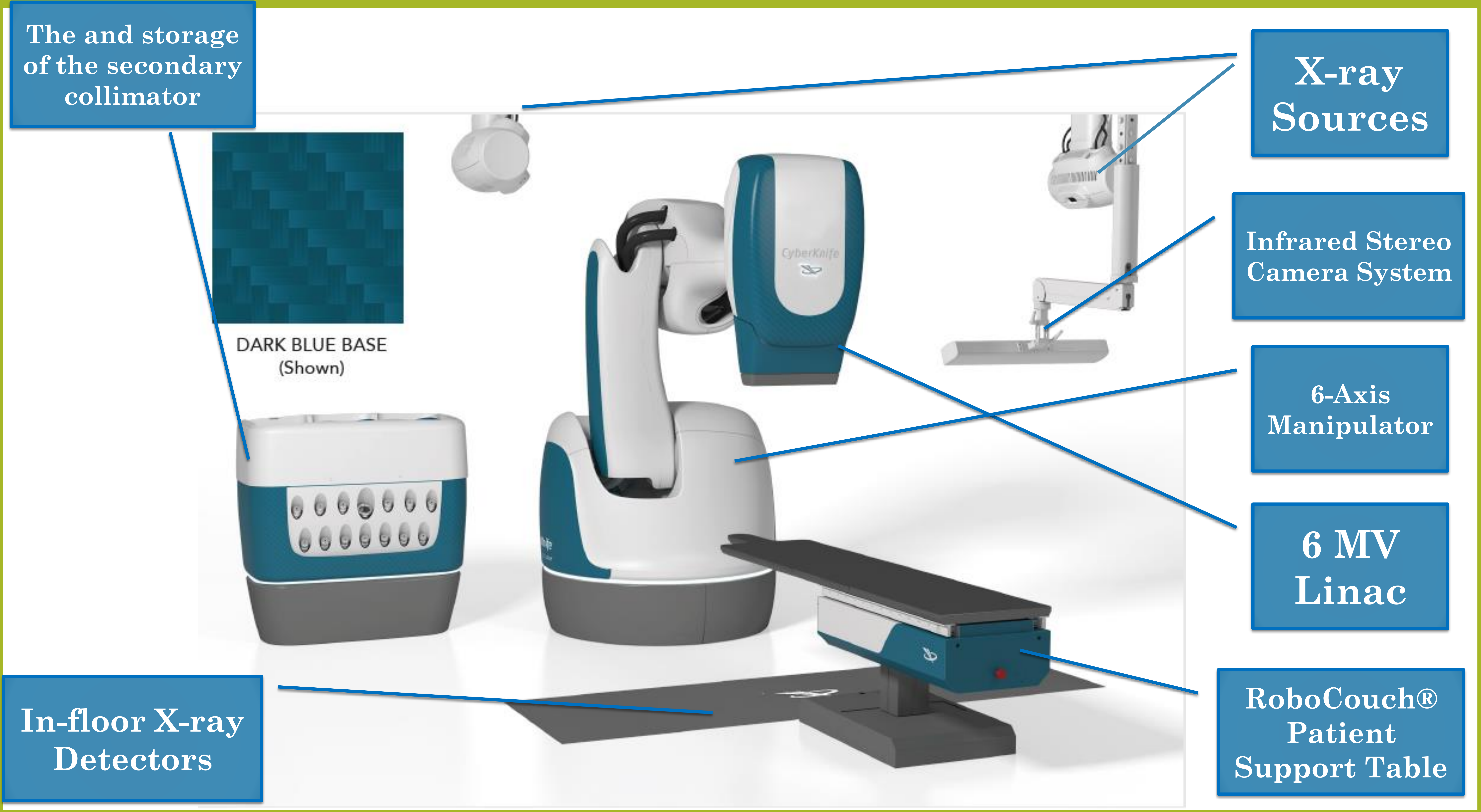

CK-M6 model
CK-VSI model
CK-G4 model
CK-G3 model
CK-G2 model
"Neurotron 1000"
Original concept
1988
1994
1997
2001
2005
2010
2012
CyberKnife® S7™
CyberKnife

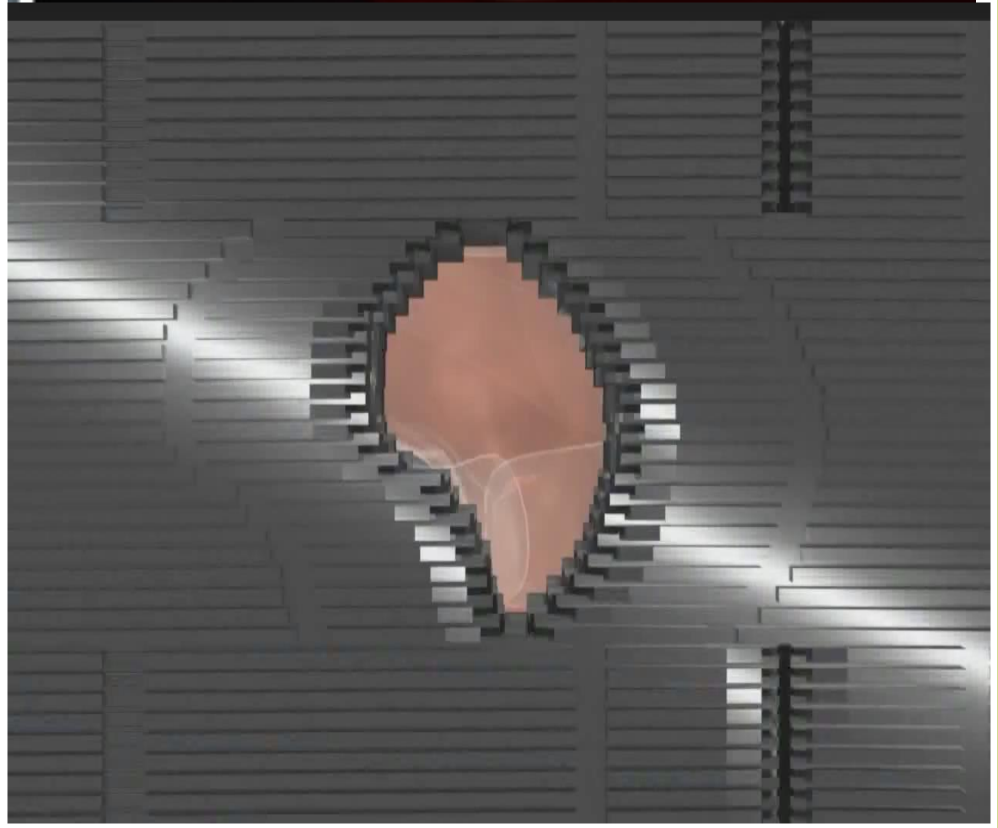

The and storage of the secondary collimator
X-ray Sources
Infrared Stereo Camera System
6-Axis Manipulator
6 MV Linac
RoboCouch® Patient Support Table
In-floor X-ray Detectors
DARK BLUE BASE
(Shown)
CyberKnife

Introduction to CyberKnife

- A treatment unit designed for both intracranial and extracranial radiosurgery.
- CyberKnife has 6-degrees of freedom.
- Pencil beams of radiation are delivered sequentially as the robot moves around patient.

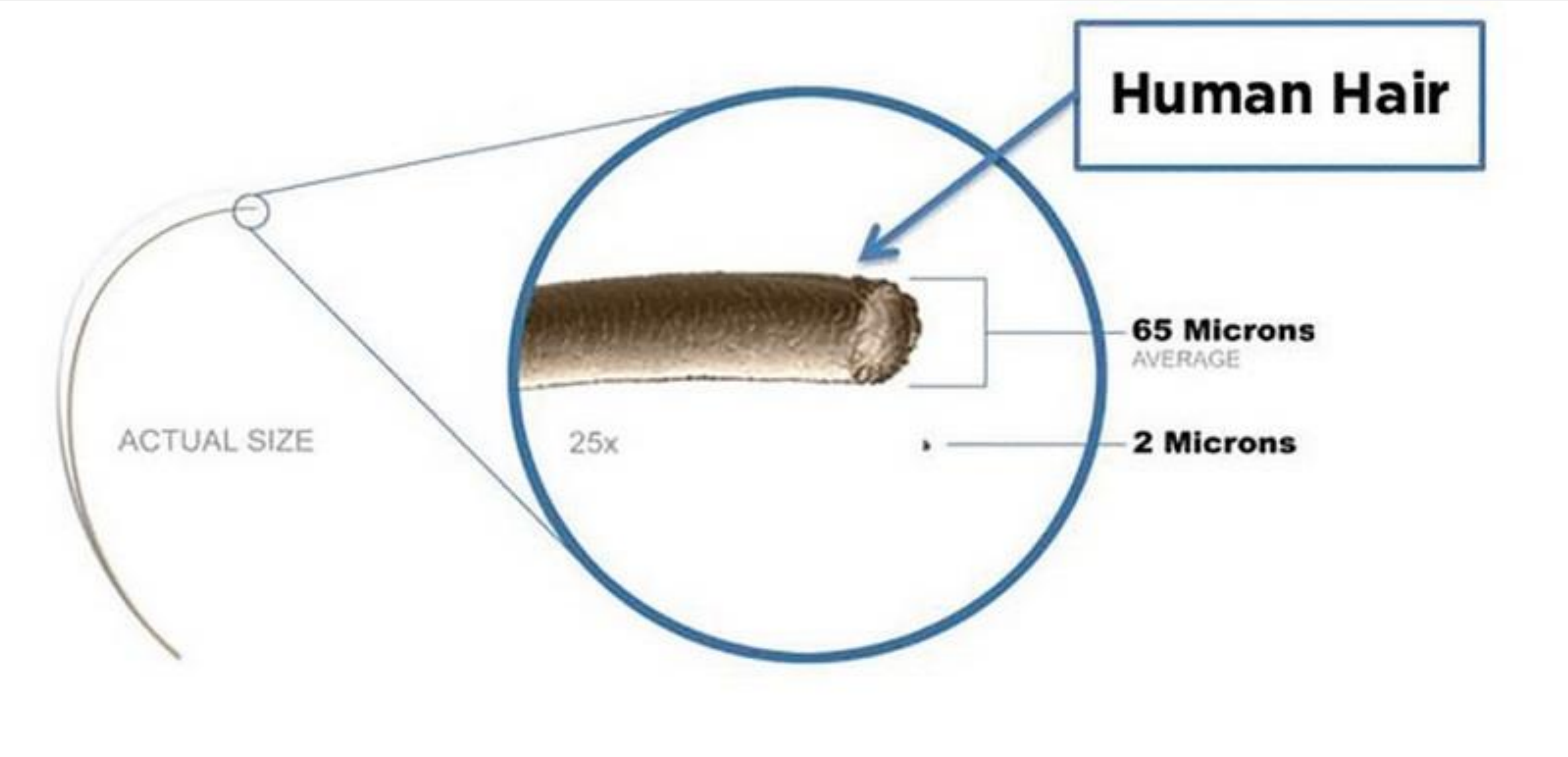
1.The Treatment Head

- one of the three secondary beam collimation systems available
- A set of 12 fixed circular collimator cones with nominal diameters ranging from 5 to 60 mm at 800 mm distance from the source
- the Iris® variable aperture collimator capable of achieving the same nominal field sizes with those of fixed collimators.
- the InciseTM multi leaf collimator exhibiting 3.85 mm leaf width and maximum achievable field size of 100 × 115 mm2 at 800 mm distance from the source



Robotic Accuray

TECHNICAL DATA	
Maximum Reach	2496 mm
Rated Payload	300 kg
Number of Axes	6
Weight	Approx. 1120 kg
Pose Repeatability (ISO 9283)	+/- 0.06mm (60 microns)



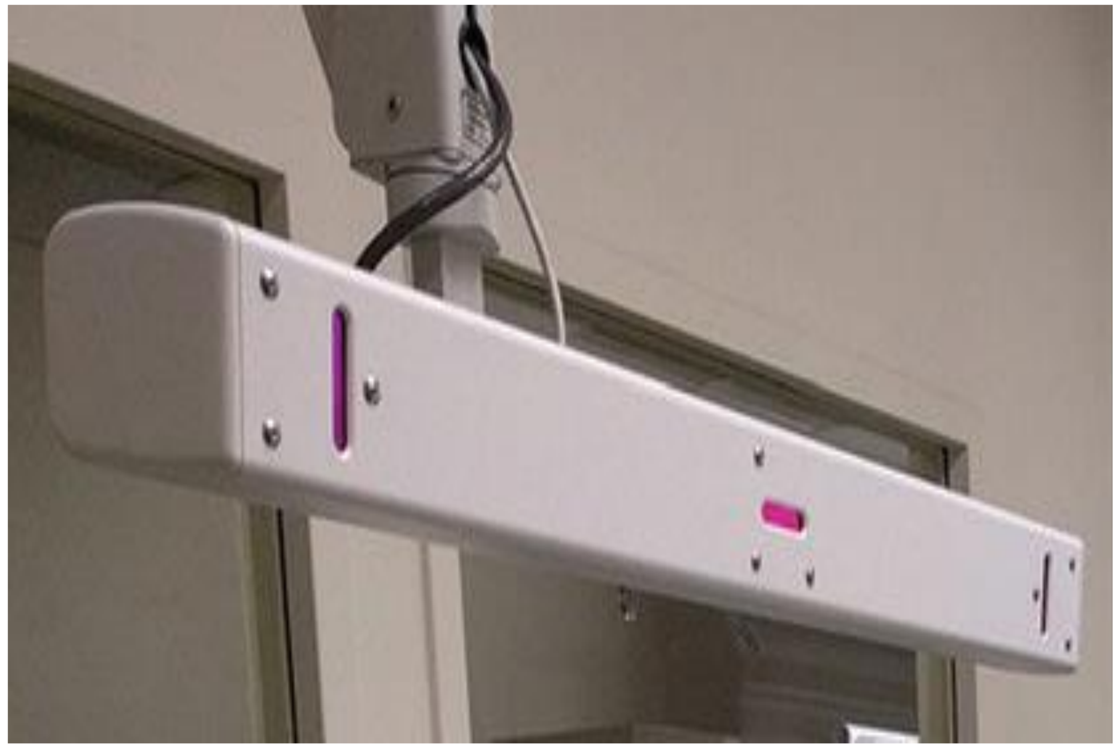
5 microns less than a human hair!

ACCURAY®

2.Image Guidance System (IGRT)

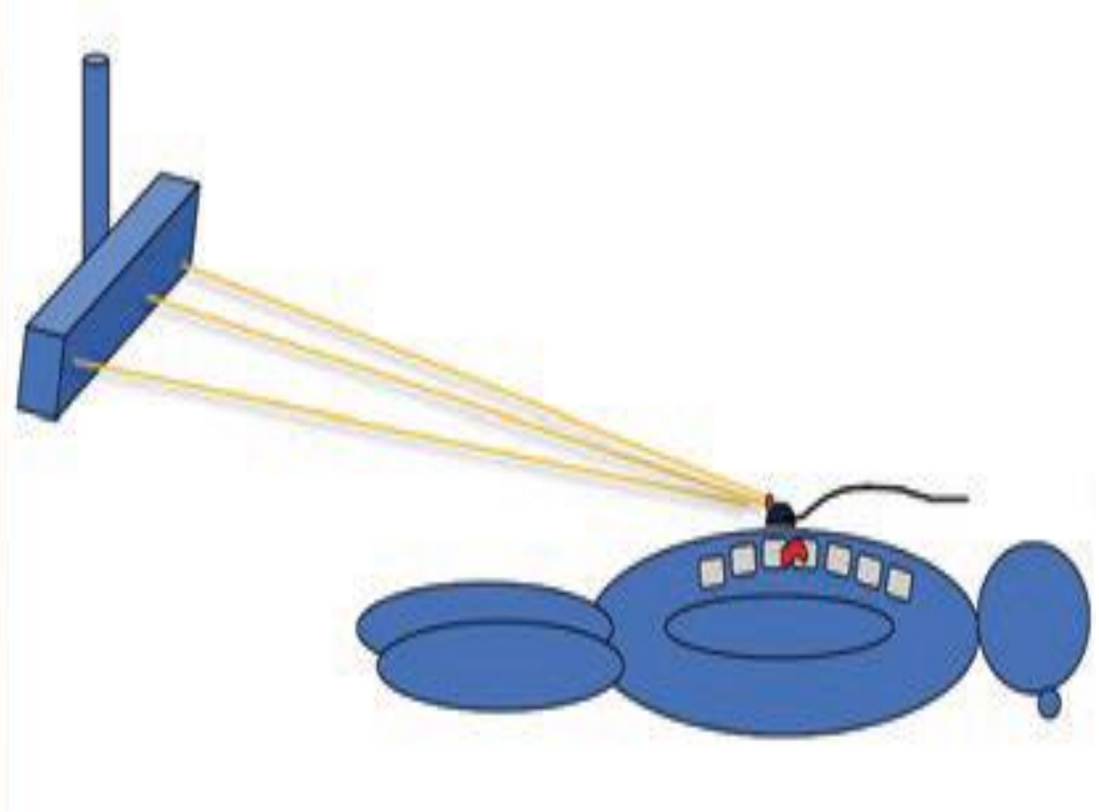
1. The X-Ray Imaging System

- The X-ray tubes are operated at voltages ranging from 40 to 150 kV using one of the two available focal spot sizes (0.6 mm and 1.2 mm)



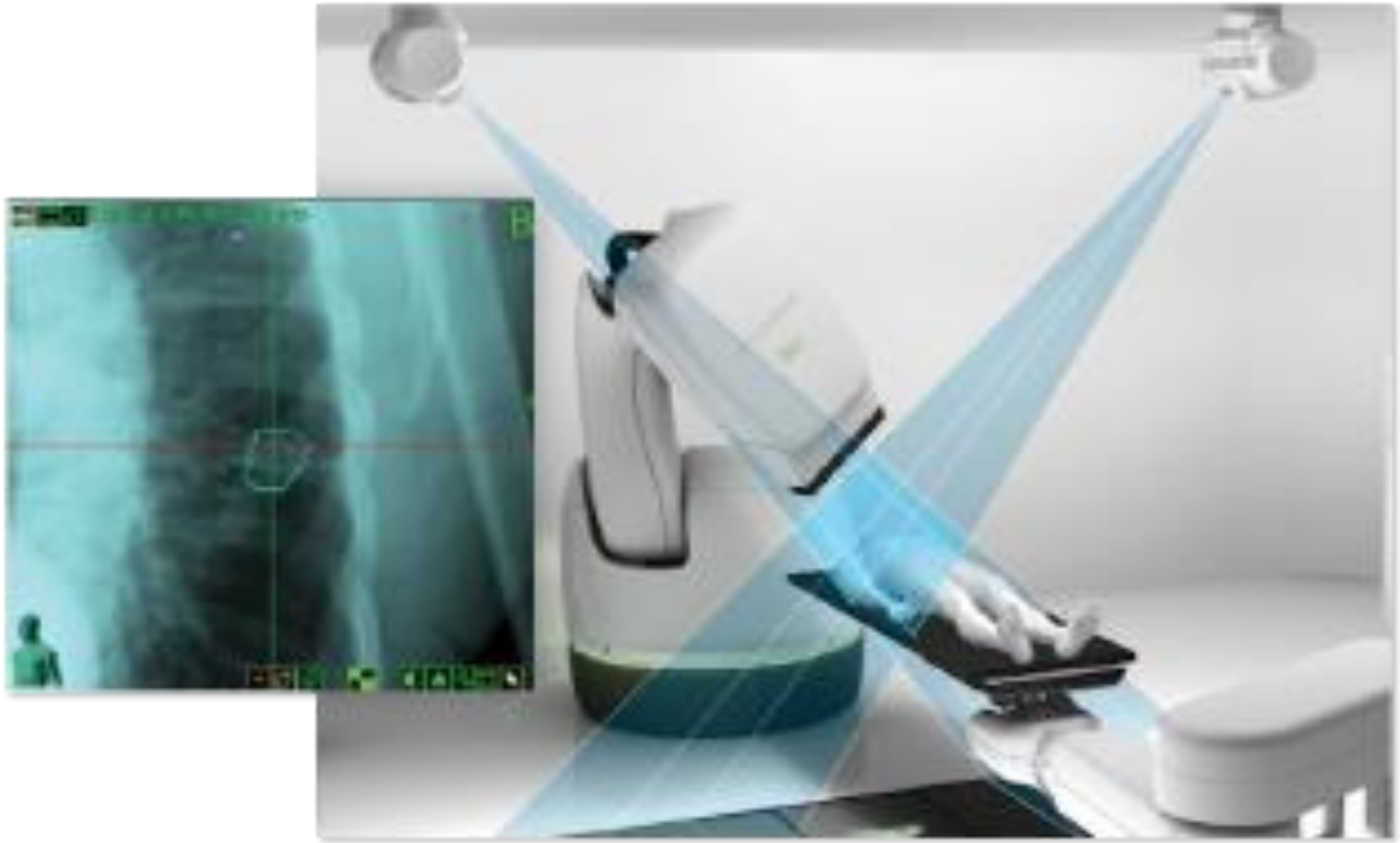
2. The Optical Camera System

- It consists of three cameras in a ceiling-mounted retractable boom-arm and is used to track targets that are affected by respiratory motion in combination with intrafraction X-ray images
- This camera array detects the position of three optical markers (red LEDs communicating with the system via optical fibers) attached to the patient surface.
- These measurements are used to create a correlation model between the patient's breathing pattern, determined by the external markers, and the precise location of the tumor (or a tumor surrogate, e.g. fiducial markers)



Treatment Planning and Delivery Overview

- Treatment planning is performed using a vendor-provided software suite (currently, the Accuray Precision®) and aims to determine the optimum geometric arrangement of treatment beams and radiation fluence per beam
- Treatment Delivery



What if you could:

- Precisely monitor patient and tumor motion in real time with automatic 6D motion tracking and correction
- Detect and correct for tumor motion with sub-millimeter precision with continual image guidance
- Deliver highly accurate and precise treatment for inoperable tumors

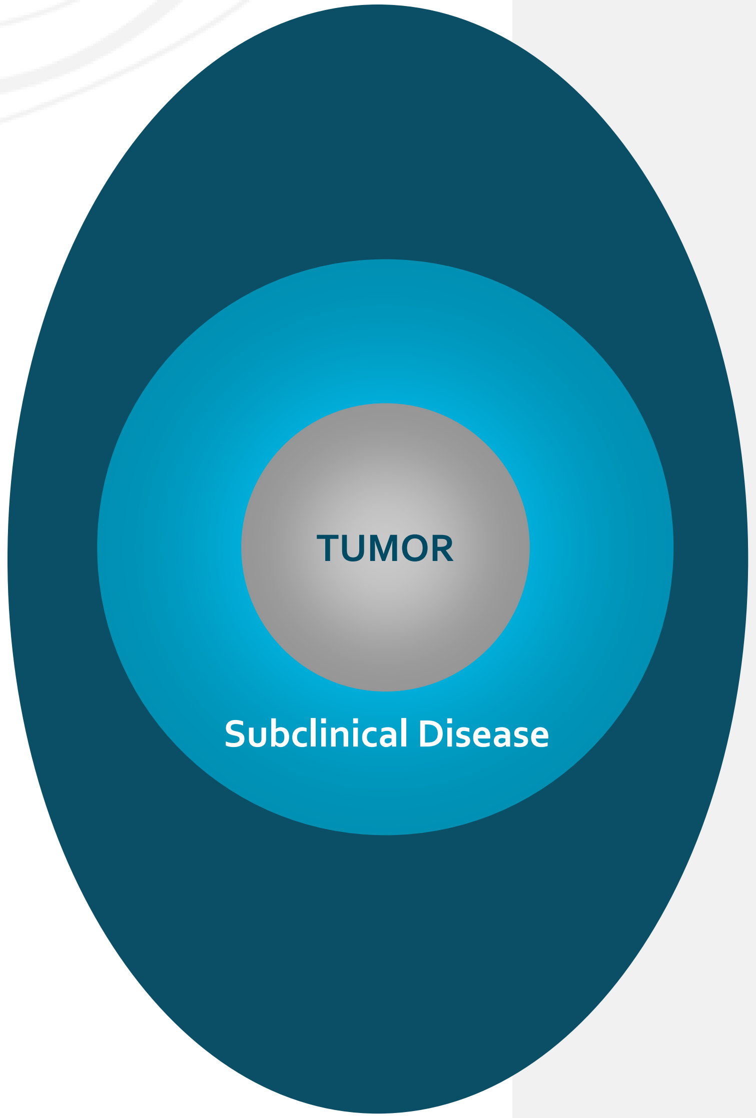
Synchrony ® Respiratory Tracking System

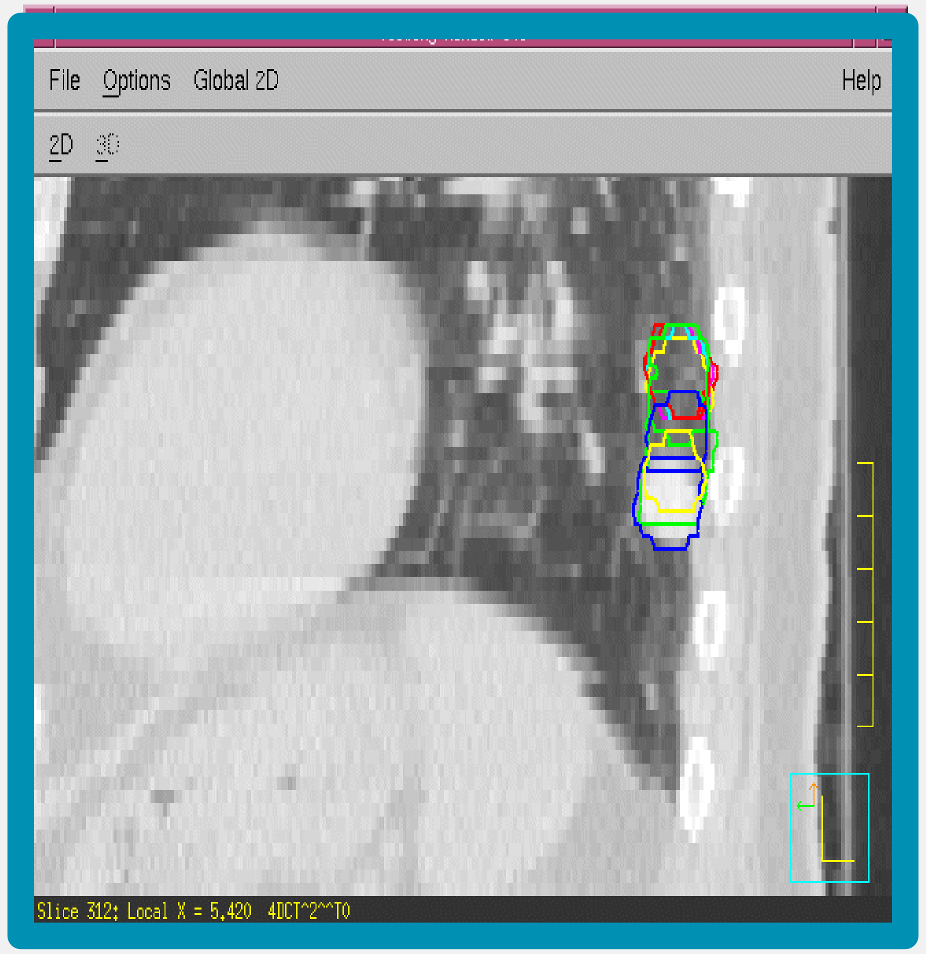
True dynamic real-time tracking

- Monitors chest wall positions throughout treatment in real-time
- Chest wall motion with target position throughout respiratory cycle
- Establishes path of motion for robot during beam-on
- Eliminates need for breath-hold or gating techniques

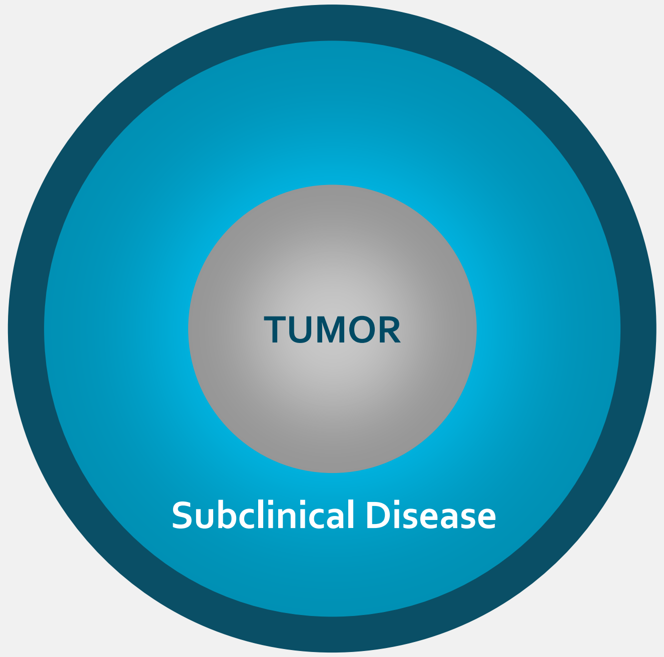
Gantry and CyberKnife® Lung SBRT

Gantry SBRT





CyberKnife® System SBRT



Linac-based lung SBRT requires larger margins to avoid treatment inaccuracies

CyberKnife System treatment deliveries spare 40% of healthy tissue*

* may vary on a case by case basis

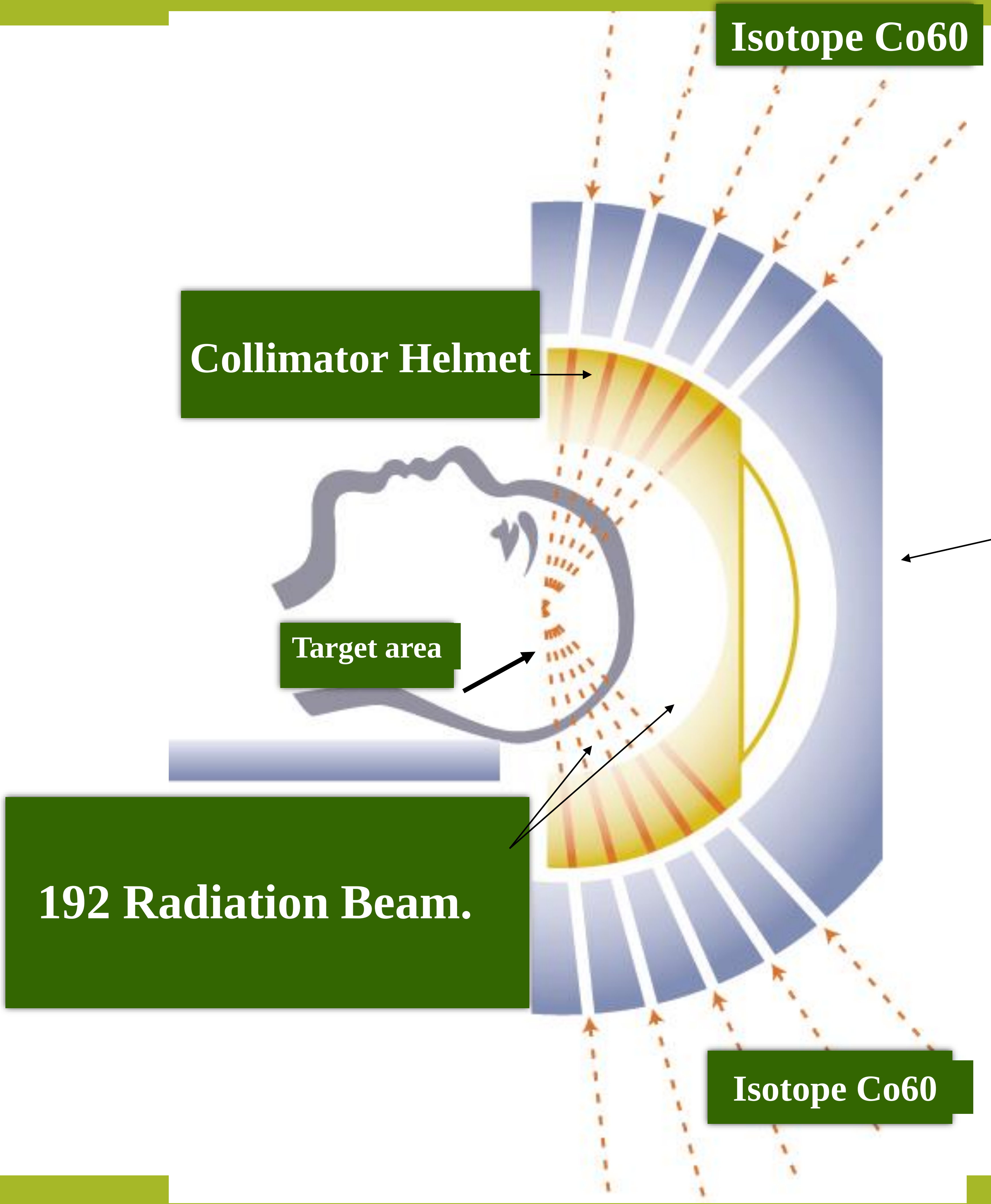
ACCURAY®

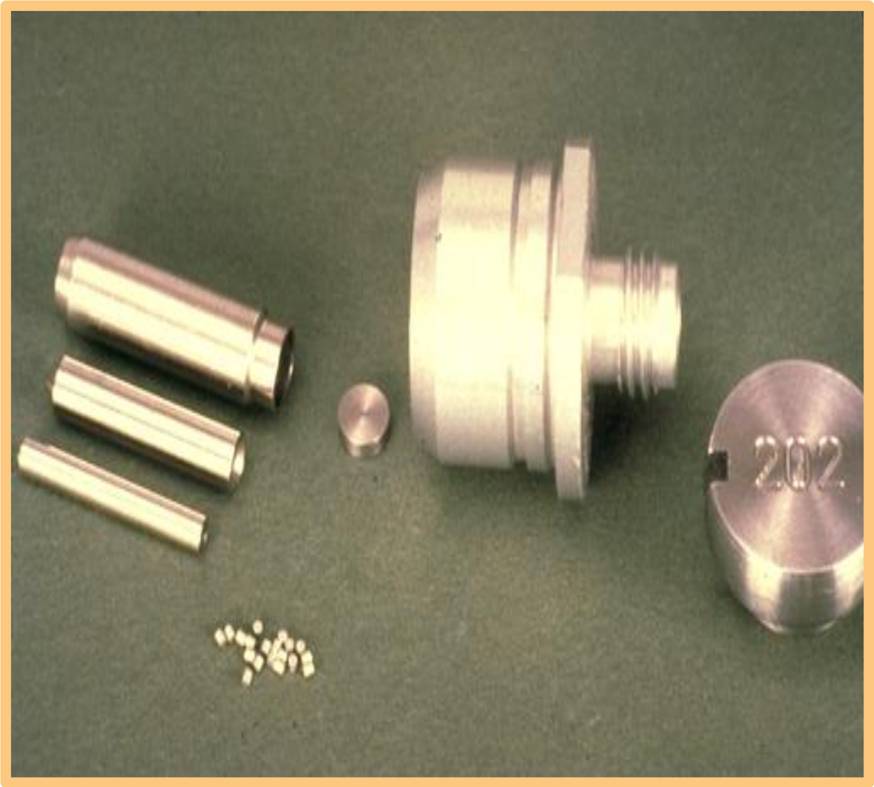
 |

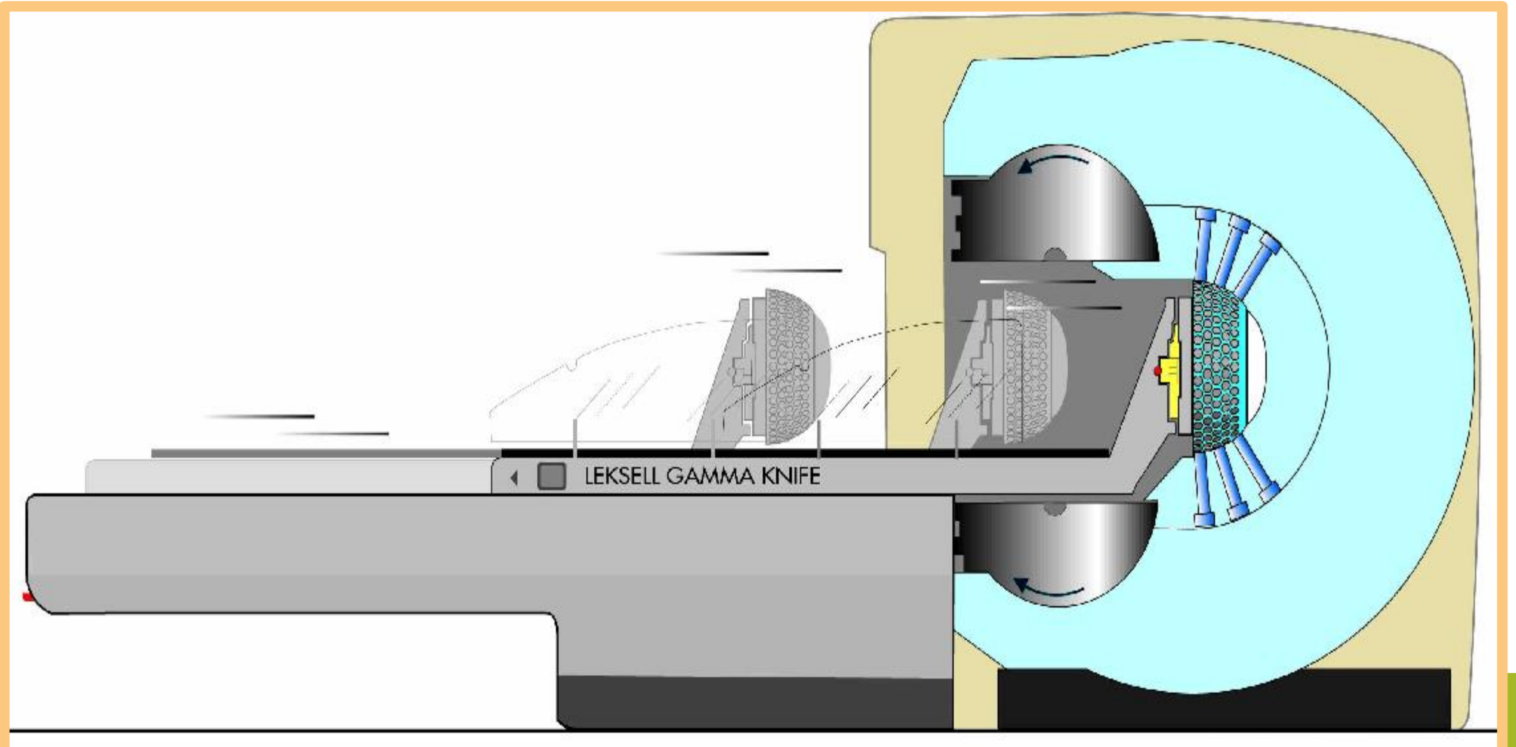
Gamma Knife (GK)

- Contains 192 60Co sources that are channeled through a tungsten collimator helmet.
- Generates narrow radiation pencil beams to coincide within 0.1 mm of each other at the center of the helmet.
- Multiple circular collimators are used to generate “shots” to fill a particular volume using one or multiple isocenters.
- Doses are typically prescribed to the 50% isodose line.
- There are Icon helmets with varying collimator sizes of 4, 8, 14, and 18 mm .

Leksell gamma knife







CyberKnife Routine QA Procedures

Daily QA

- Linac Output
- Various voltages and currents
- Robot perch position
- Safety interlocks
- Coincidence of treatment beam with imaging center (AQA)

Monthly QA

- Beam Energy
- Flatness/symmetry/penumbra
- Robot pointing (b.b. test)
- End-to-end test
- Laser/radiation coincidence
- Imaging system alignment
- Couch position accuracy

Quarterly QA

- Imaging system alignment
- Couch position accuracy

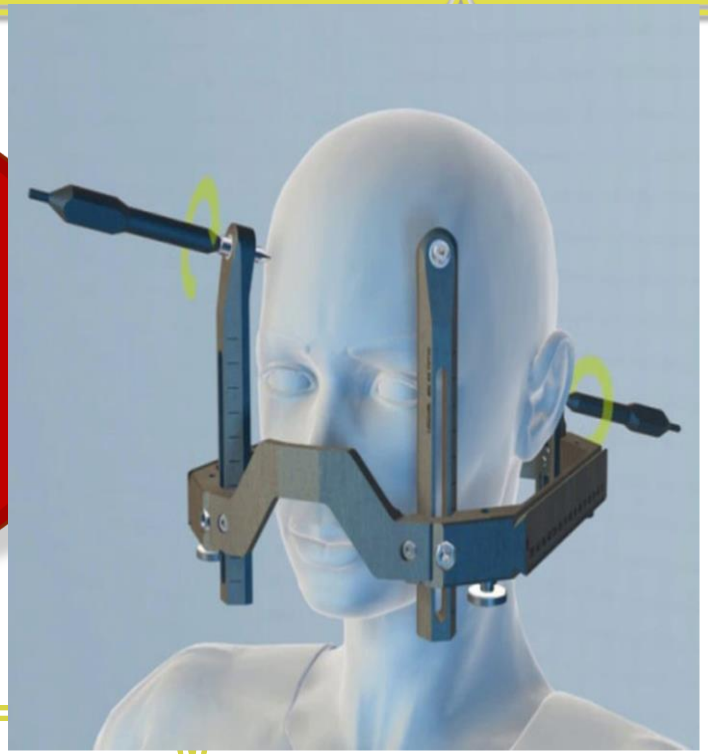
Annual QA

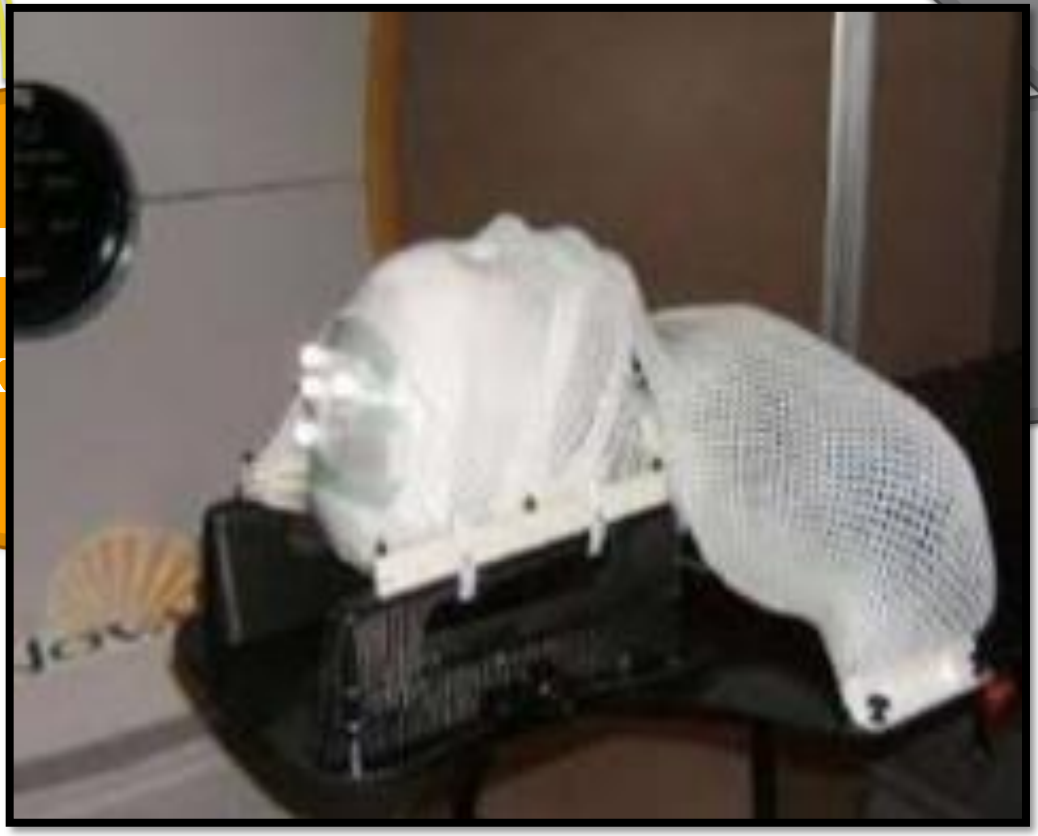
- Spot check beam data
- Treatment planning system beam data and calculation checks.

The Treatment Process

Brain MRI

Frame Fixation





Patient Irradiation

Treatment Planning

CBCT

Plan Approval

Linac

- Low and high X-ray photon beam
- MLC (<6 mm width) for treating small targets especially in the brain
- photon energies (6–18 MeV)
- limited number of beam angles
- frame-based fixation (Mask)
- 3 to more than 15 sessions
- Treat all the body sites

Cyber Knife

- Low X-ray photon beam
- Fixed collimators or dynamic aperture collimator both having a round shape with diameter from 5 up to 60 mm
- photon energies (up to 6 MeV)
- six degrees of freedom
- Farmless
- 1 – 5 sessions
- Specific and non operable sites

Gamma Knife

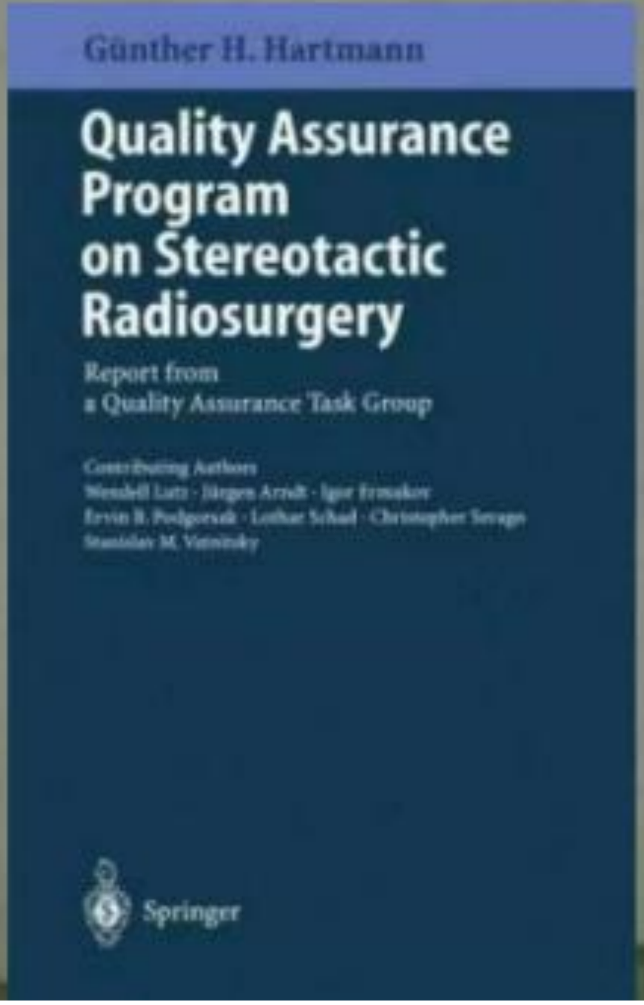
- High energy gamma ray
- fixed collimators
- Dose 20 Gy
- six degrees of freedom
- Frame or Mask
- Single session
- Only brain lesions

Quality Assurance

- The essential requirement for the clinical use of the LINAC is quality control based on well-defined protocols
- The quality-assurance protocols address the precision of the target volume and target point with CT, MRI, PET and angiography, the dosimetry, the planning of the irradiation, and especially with the calibration of the absolute dose and of the dose application.
- For the quality-assurance assessment proper phantoms and specialized dosimetric instruments must be available.

Table 1. Daily QA of the machine

Verify presence of emergency equipment and procedures
Verify audio/visual monitoring
Verify radiation monitors (fixed and portable)
Verify source position indicator lights
Verify that interlocks and interrupts are functional
Verify timer accuracy (2%) and exposure termination
Verify that the docking device is securely mounted to the table and that the frame adapter can be correctly docked in the docking device



Dosimetry and QA devices

SRS VS SRT

- SRS and SRT are very similar, but **SRS** delivers a large dose of radiation on a **single day** and SRT has a fractionated treatment schedule.
- This means that in **a SRT** treatment the patient will have treatments spanning **multiple days.**
- Although, the total dose in SRT may be larger than in SRS any single day will have a much smaller dose delivery.

Choice between SRS/SRT

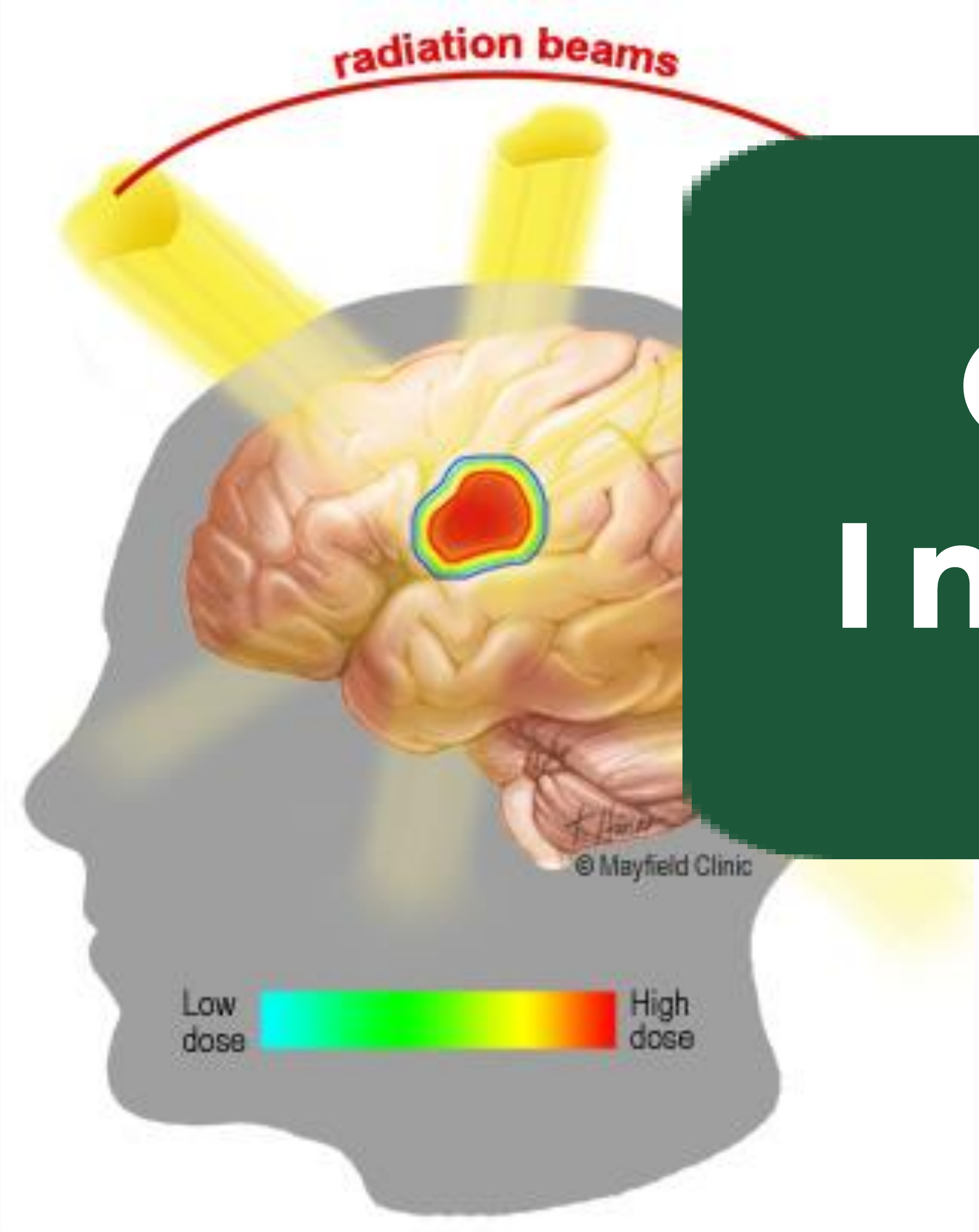
- ***Tumor volume*** — As the size of the target lesion for SRS increases, incidental irradiation to the surrounding normal tissue also increases. This may be important since a much higher dose of irradiation is administered with SRS compared to fractionated RT.
- SRS was not recommended for ***lesions >4 cm*** because adequate control could not be achieved without an unacceptable level of radiation toxicity to surrounding normal tissue.
- ***Proximity to cranial nerves*** — The proximity of a target to cranial nerves can cause radiation neurotoxicity, despite the steep decrease in dose outside the intended target Fractionated RT should be considered when SRS may jeopardize cranial nerve function.
- Cranial nerves II and VIII are more sensitive to radiation injury than the other cranial nerves. SRS is generally avoided if the maximal dose delivered to the optic nerve exceeds 10 Gy.
- ***Location of the lesion*** — The risk of developing permanent damage following SRS varies dramatically with the location of the lesion in the brain. Fractionated RT is often preferred to SRS for the treatment of lesions in the deep gray matter or the brainstem

Advantages of SRS/SRT

- Enhances clinical outcome
- Improves quality of life
- Time factor

Disadvantages of SRS/SRT

- ***High cost of purchase and use***
- ***Risk of neurological injury***
- ***Risk of mechanical inaccuracy***
- ***Potential necessity of multiple visits***

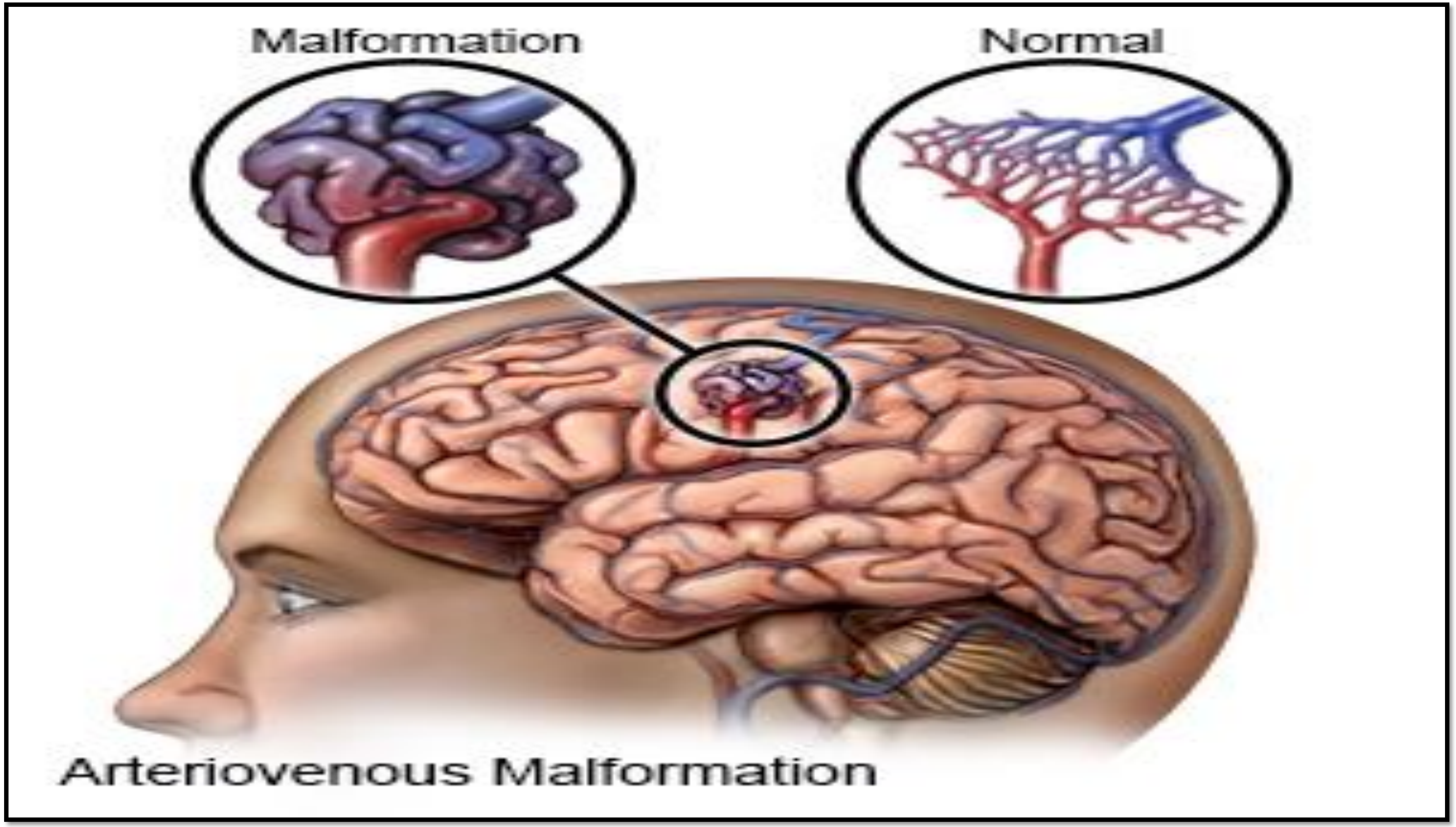


Clinical Indication

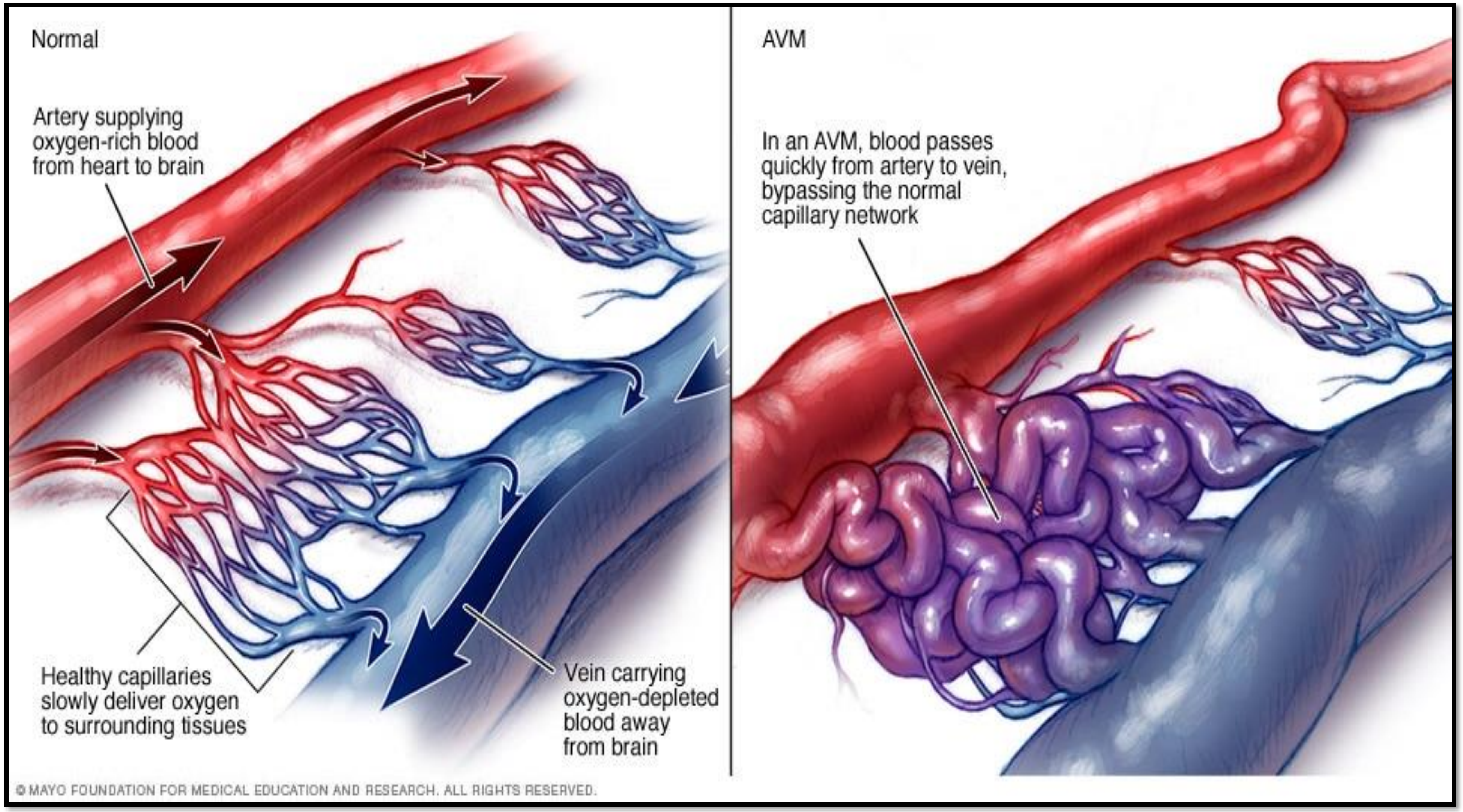
- AVM
- Meningioma
- Pituitary Adenoma
- Acoustic Neuroma
- Skull Base Tumors
- Trigeminal Neuralgia
- Brain Metastasis
- Spinal Hemangiomas
- Reirradiation For Recurrent Gliomas
- Spinal Metastasis

Atrioventricular malformation (AVM)

AVM



AVM



Normal
Artery supplying oxygen-rich blood from heart to brain
Healthy capillaries slowly deliver oxygen to surrounding tissues
Vein carrying oxygen-depleted blood away from brain
AVM
In an AVM, blood passes quickly from artery to vein, bypassing the normal capillary network
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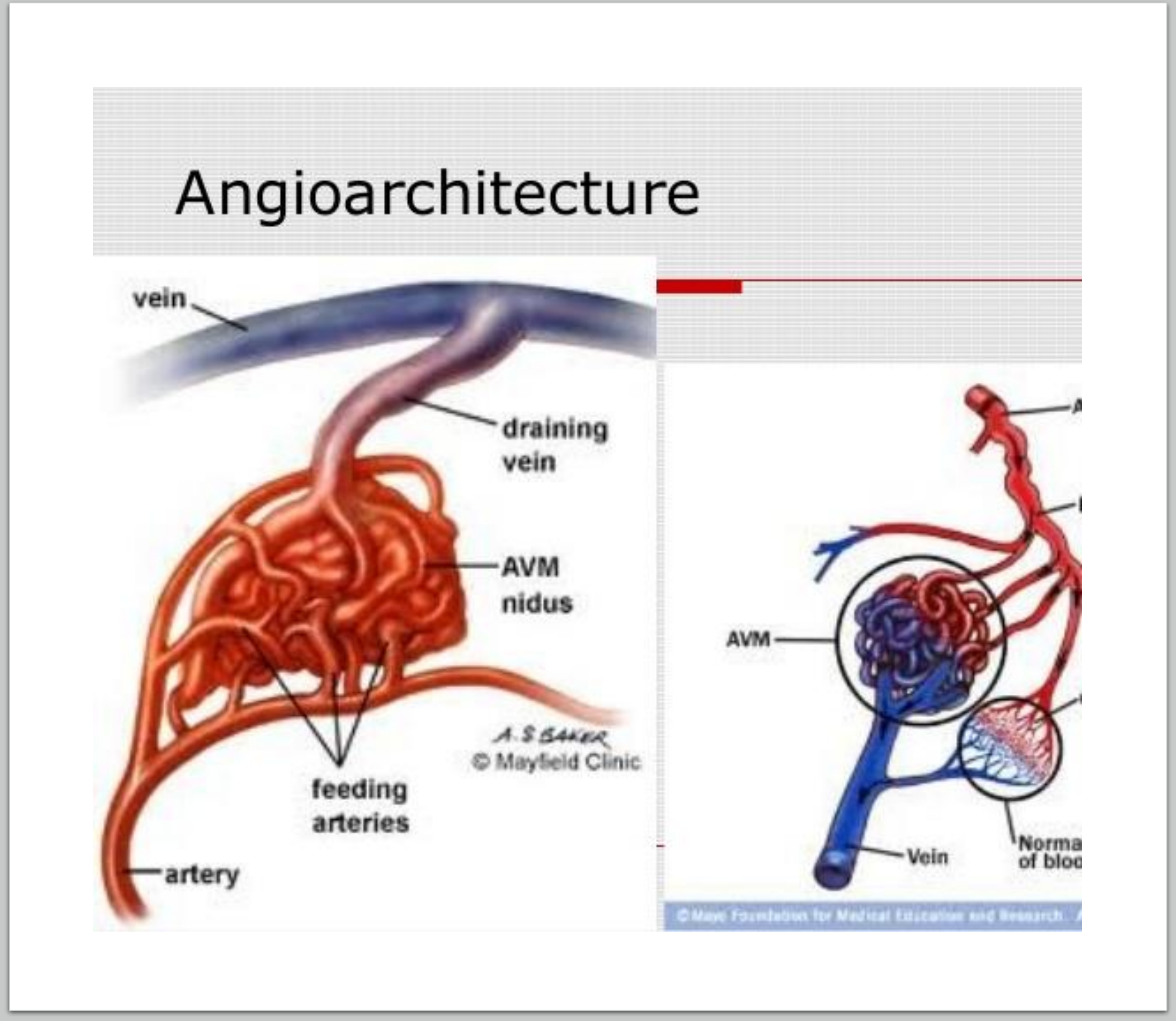

Angioarchitecture
vein
draining vein
AVM nidus
feeding arteries
artery
A. S BAKER
© Mayfield Clinic
AVM
Vein

AVM NIDUS

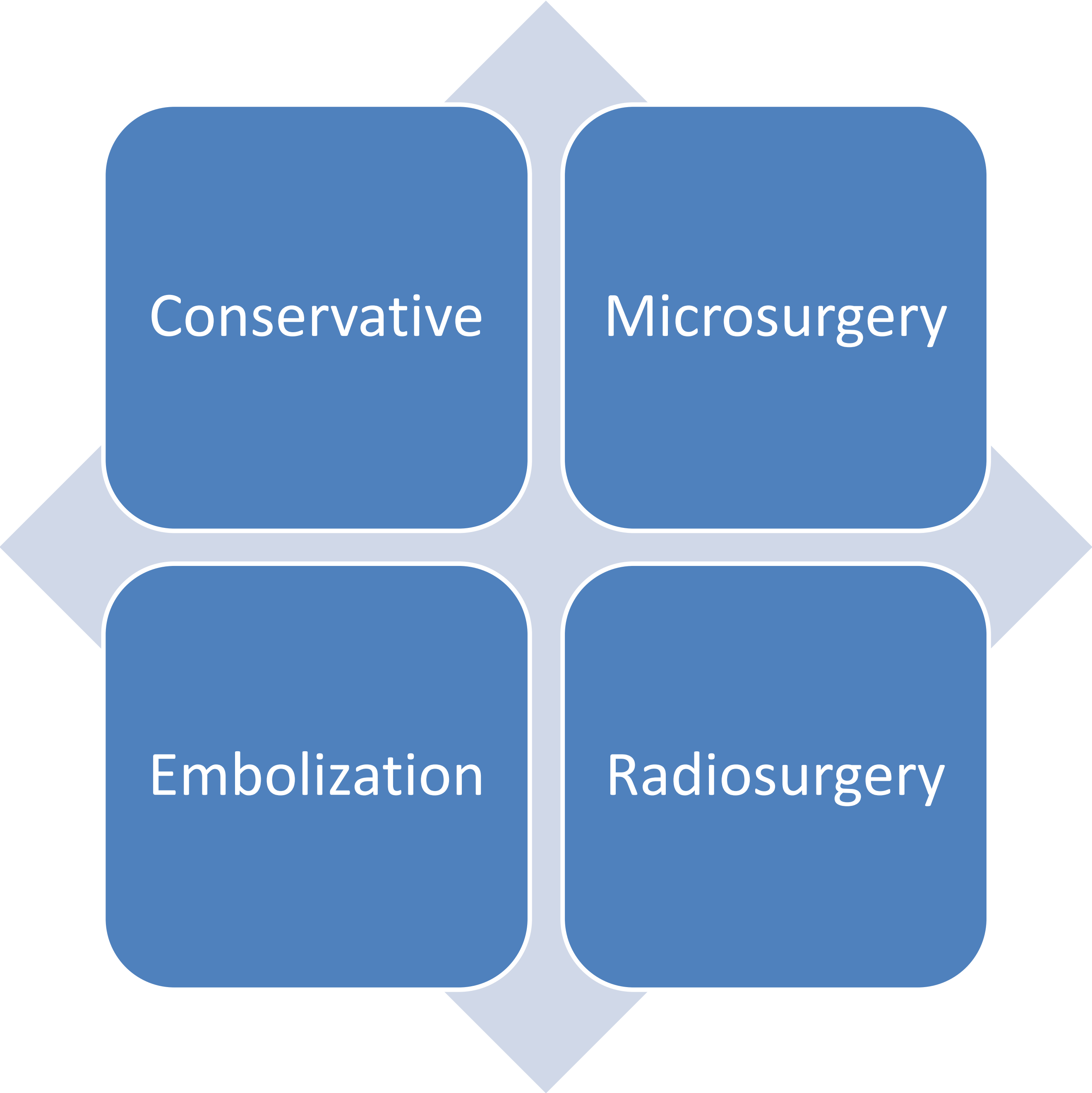
SPETZLER MARTIN GRADING AVM

Spetzler-Martin AVM Grading Scale	Points
Size	
0-3 cm	1
3.1-6.0 cm	2
> 6 cm	3
Location	
Noneloquent	0
Eloquent *	1
Deep venous drainage	
Not Present	0
Present	1
AVM Total Score	1-5

The Spetzler-Martin AVM Grading Scale is based on size, location, and venous drainage of intracerebral AV malformation. The score is calculated by adding the points for each category. The range is 1 to 5. The lower the score, the better the outcome.

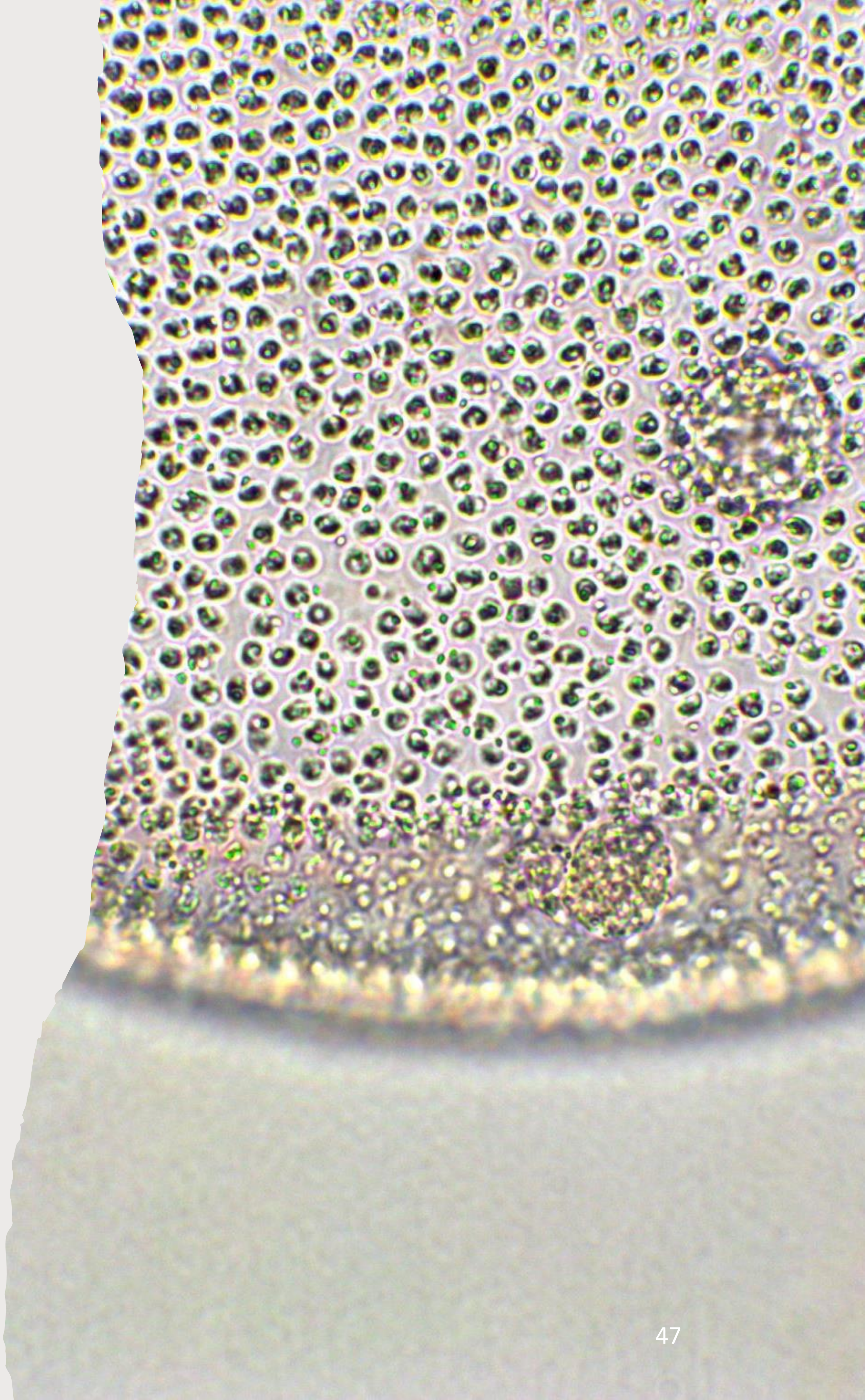
*__Eloquent locations__- areas of sensorimotor, language, visual, thalamus, hypothalamus, internal capsule, brain stem, cerebellar peduncles, and deep cerebellar nuclei

AVM MANAGEMENT



EMBOLIZATION

- Curative embolization
- Partial (staged embolization)
- Pre-op embolization
- Pre-radiosurgery embolization



CONSERVATIVE MX AVM

The AVM may be very extensive, located deeply with supply from deep perforating vessels which are not amenable for surgery or endovascular treatment.

→

Very old age would be consideration for conservative treatment.

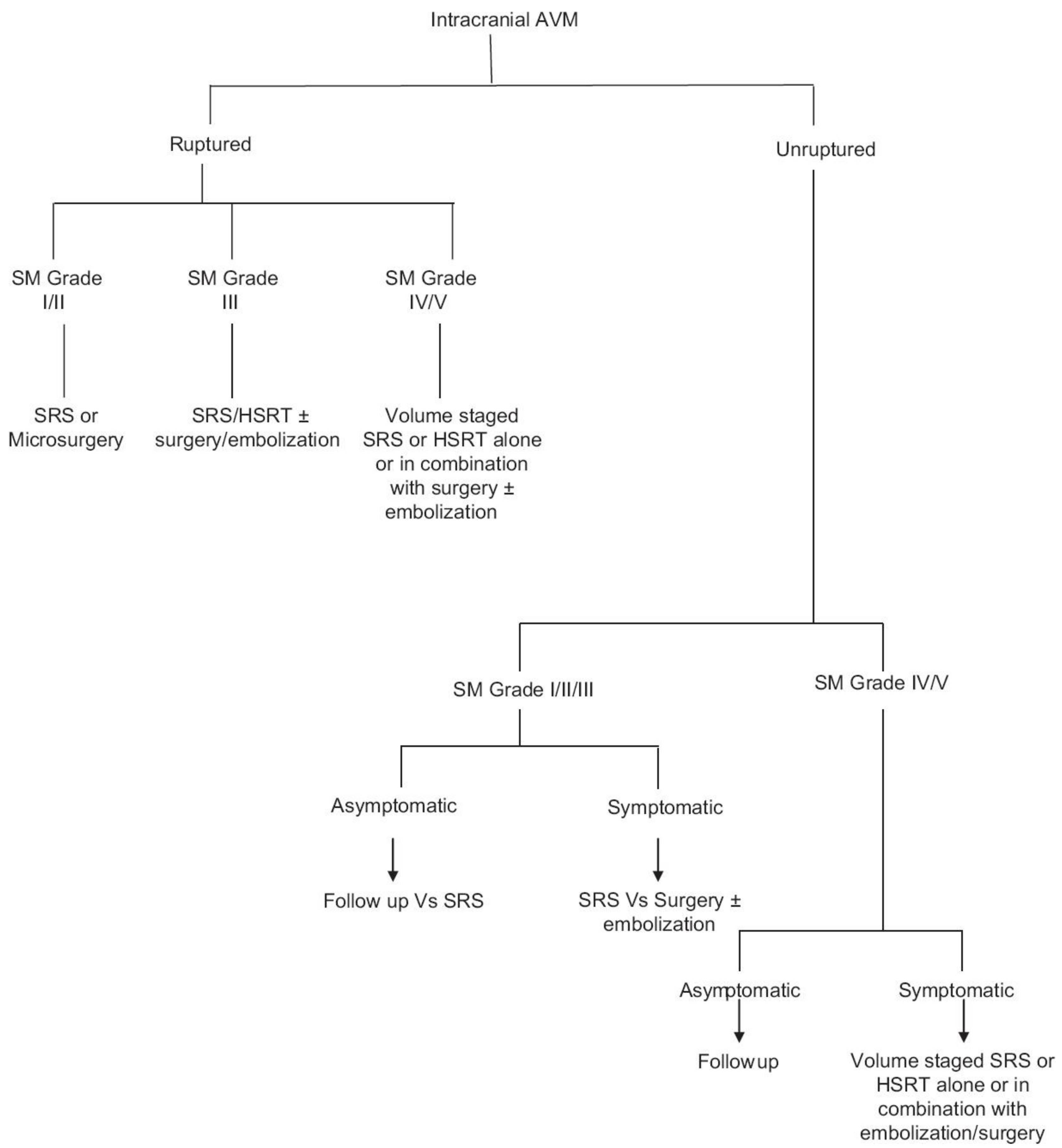
→

Obviously poor medical condition, such as advanced heart diseases, respiratory insufficiency or cancer with metastasis would be contraindication to a definitive AVM treatment

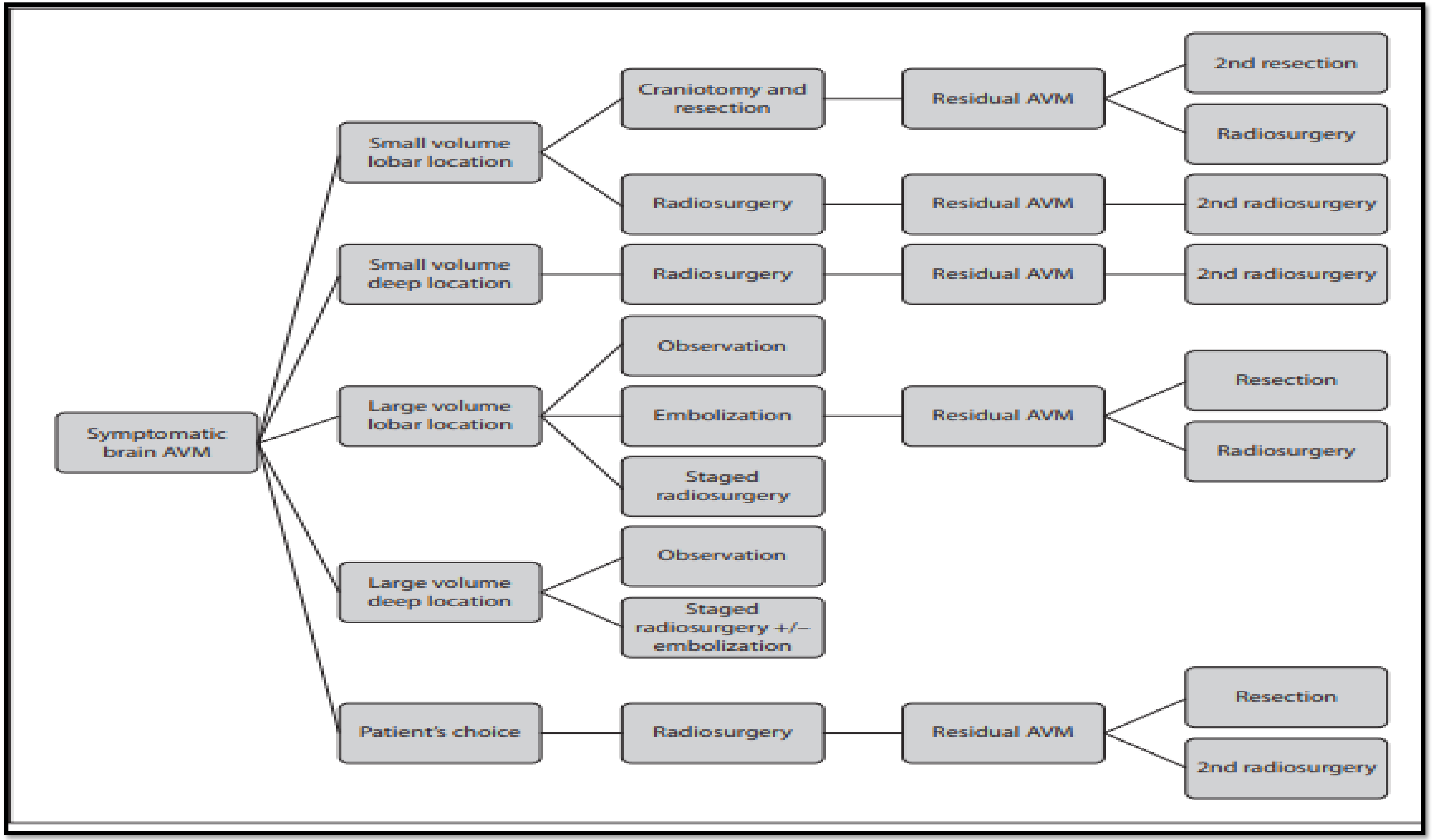
RADIOSURGERY

- Radiosurgery is an effective alternative treatment for selected AVM patients rather than microsurgery , especially in those with **surgically inaccessible lesions** with comorbidities which hinder surgical intervention or if microsurgery is not feasible.
- In terms of radiobiology, AVM are late responding **target within late reaction** of normal tissue.
- Following bleeding , part of nidus may be hidden or compressed by clots hence it is rational to wait till resolution of hematoma (**average 2-3 months**).

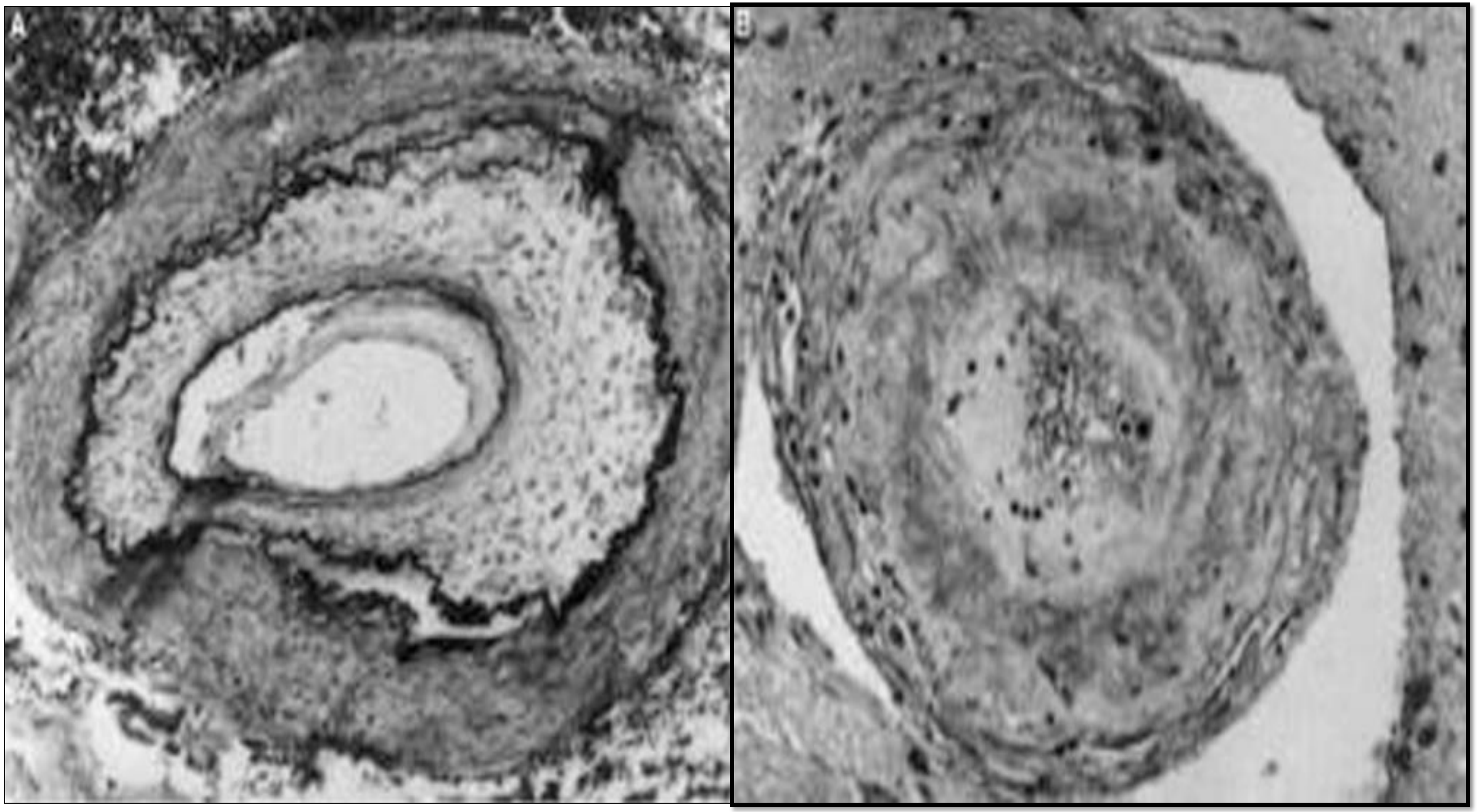
SPETZLER MARTIN GRADING AVM M_X



AVM M_X ALGORITHM-ISRS GUIDELINES



WHAT HAPPENES TO VESSELS



AVM-IMAGING

- DSA-DIGITAL SUBSTRACTION ANGIOGRAM
- MRI
  - 3DFSPGR CONTRAST- BETTER BRAIN VISUALIZATION
  - T2W GRADIENT ECHO- DETECT BLEED
- CECT-PLANNING

AVM- LITERTURE REVIEW

Author	Number of patients	Target volume	Dose (Gy) and number of fractions	Follow-up (months)*	Obliteration rate (%)	Annual hemorrhage rate after treatment (%)	Complications (%)
Hanakita (2014)[102]	65	10-20 cm^3	20 (Single)	60	76 (5 years)	1.9	3
Kim (2012)[97]	44	≥30 cm^3	13.9 (Repeat GKRS at an interval of 3 years)	109.4	34.1	6.8+	4.6
Sirin (2006)[95]	37	>15 ml	16 Gy (Volume-staged SRS, two sessions)	50	50	14+	8.1
Karlsson (2007)[98]	133	≥9 ml	Repeat radiosurgery		62	7	3
Lindvall (2015)[100]	24	≥10 cm^3	HSRT (6-7 Gy in five fractions)	35.2	69.6	NA	4.2
Blamek (2013)[99]	49	Mean volume 25.7 cm^3	HSRT (19.9 Gy in 2-4 fractions)	28.9	21 (at 3 years)	4.5	NA
Kano (2012)[103]	47	≥10 cm^3	16 Gy (Volume-staged SRS in two sessions)	47	28	4.3	13
Yamamoto (2012)[60]	20	≥10 cm^3	12-16 Gy (two-stage GKRS, 36 months apart)	105	65	9.7	6.5
Huang (2012)[104]	18	>15 ml	15 Gy (Volume-staged SRS in two to four stages)	NA	29 (5 years), 89 (10 years)	27.8+	NA

*Median/mean follow-up in months. +Percentage of patients who developed a bleed during follow-up (and not the annual hemorrhagic rate) was reported in these series

STAGED VOLUME RADIOSURGERAY

Large AVMs in a planned staged fashion was undertaken to limit the radiation exposure to the surrounding normal brain

At the first radiosurgical procedure, the total volume of the AVM is estimated and a dose plan calculated that covers 10 cm3 –15 cm3 , or one-half the nidus volume if the AVM is critically located (brainstem, thalamus, or basal ganglia).

At **6-month intervals thereafter**, radiosurgery was repeated to different portions of the AVM with the previous dose plan(s) being re-created utilizing intracranial landmarks to minimize radiation overlap

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0360-3016/00/$–see front matter

ELSEVIER

PII S0360-3016(00)00696-9

CLINICAL INVESTIGATION **Brain**

THE RATIONALE AND TECHNIQUE OF STAGED-VOLUME ARTERIOVENOUS MALFORMATION RADIOSURGERY

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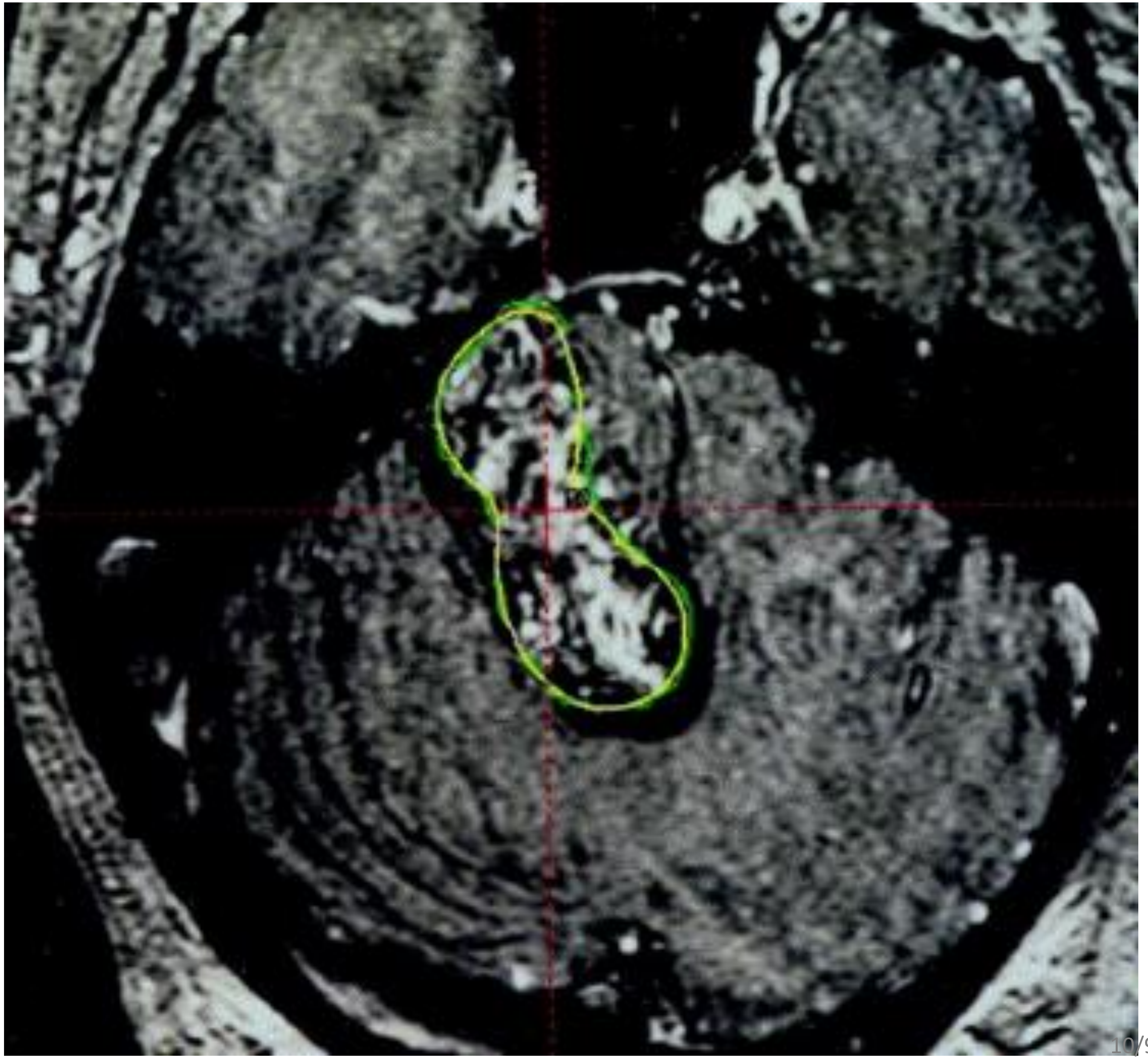
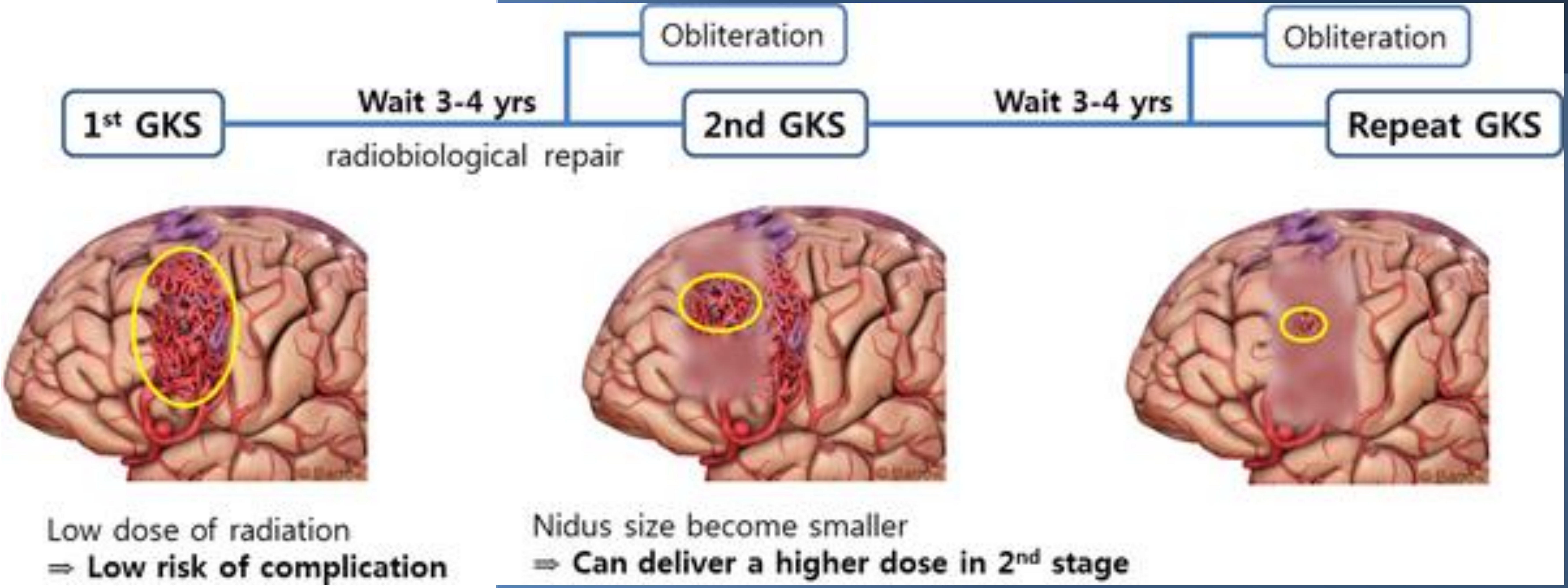
Purpose: Stereotactic radiosurgery is an effective management strategy for properly selected arteriovenous malformation (AVM) patients. However, the risk of postradiosurgical radiation-related injury generally limits this procedure to patients with AVMs of an average diameter of 3 cm or less. Radiosurgery of large AVMs in a planned staged fashion was undertaken to limit the radiation exposure to the surrounding normal brain.
Methods and Materials: Between April 1997 and December 1999, 10 patients with a median AVM volume of 17.4 cm^3 (range, 7.4–53.3 cm^3) underwent staged-volume radiosurgery (23 procedures). At the first radiosurgical procedure, the total volume of the AVM is estimated and a dose plan calculated that covers 10 cm^3–15 cm^3, or one-half the nidus volume if the AVM is critically located (brainstem, thalamus, or basal ganglia). At 6-month intervals thereafter, radiosurgery was repeated to different portions of the AVM with the previous dose plan(s) being re-created utilizing intracranial landmarks to minimize radiation overlap. Radiosurgical procedures were continued until the entire malformation has been irradiated.

POLLOCK ET AL/IJROBP

STAGED VOLUME




Obliteration
Obliteration
1st GKS
Wait 3-4 yrs
radiobiological repair
2nd GKS
Wait 3-4 yrs
Repeat GKS
Low dose of radiation
⇒ Low risk of complication
Nidus size become smaller
⇒ Can deliver a higher dose in 2nd stage


MENINGIOMAS

MENINGIOMAS

- Meningiomas are generally benign lesions that account for **15–20 %** of primary brain tumors, affect predominately middle- aged patients, and occur predominately in females
- The atypical and malignant meningiomas are characterized by **successive recurrences** and an aggressive behavior.
- Among all meningiomas, their **incidence varies** in the literature ranging from 4.7 to 7.1 % and 1.0 to 3.7 % for atypical and malignant, respectively

CASE SELECTION FOR MENINGIOMA

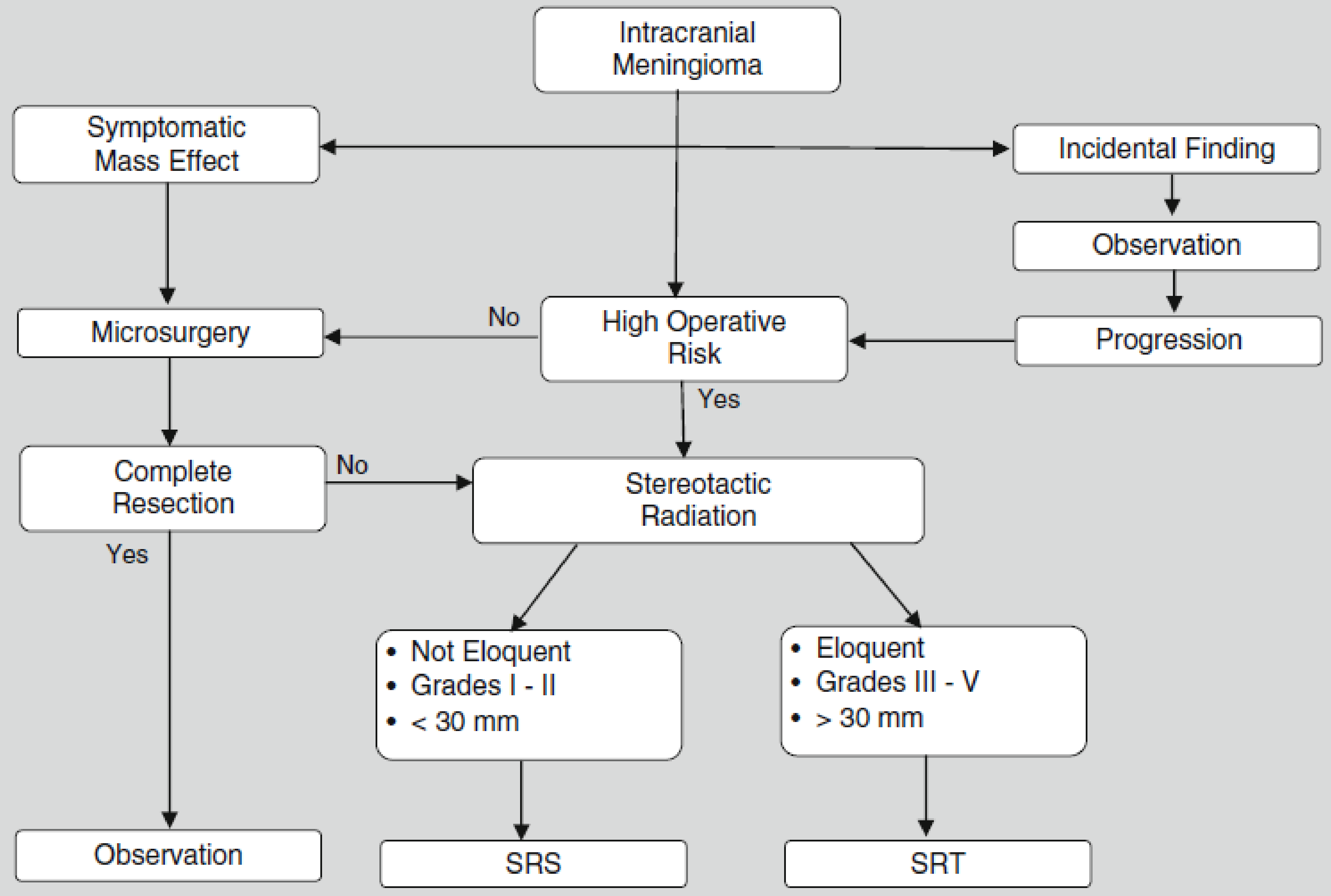


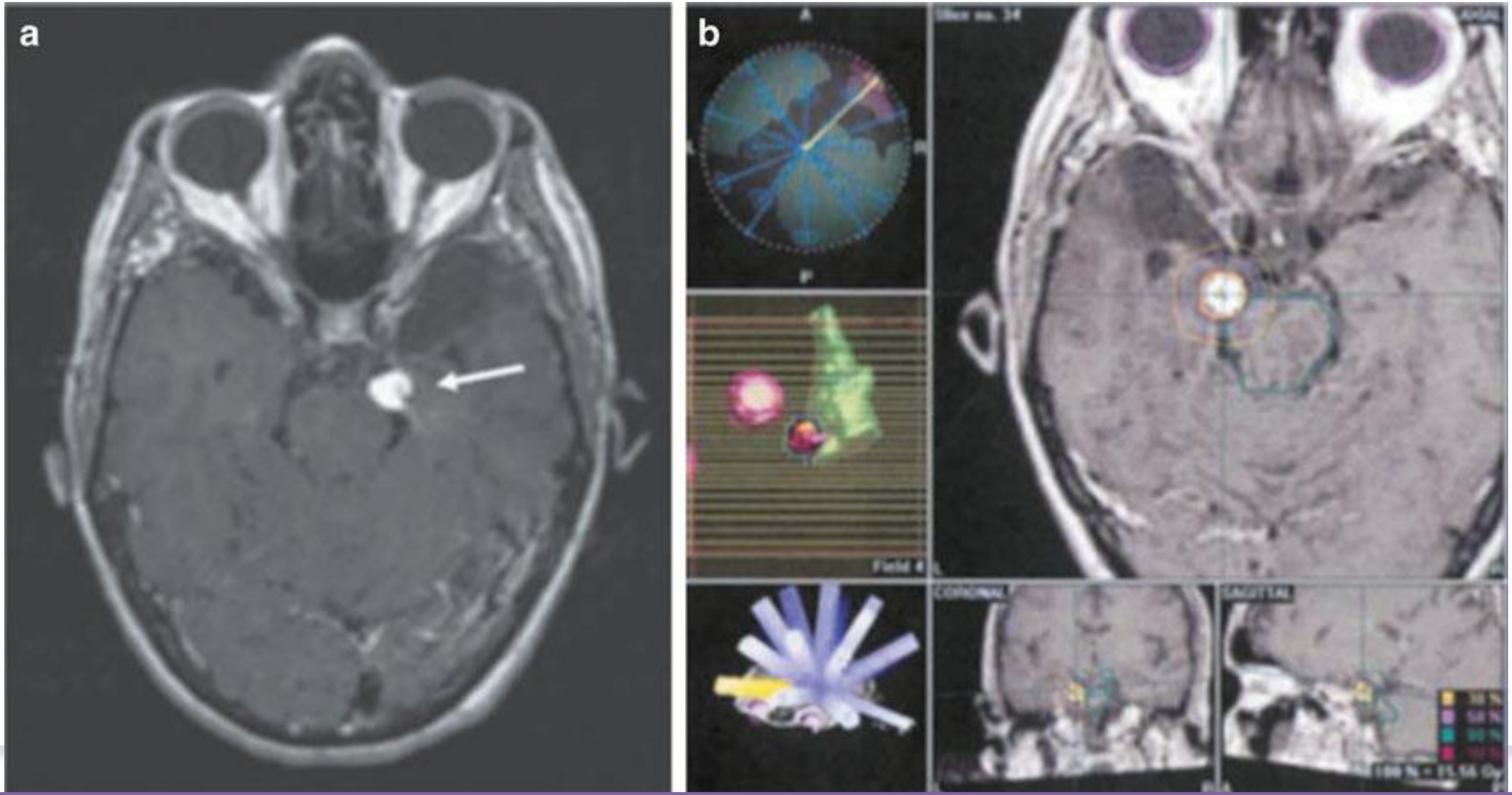
Fig. 20.16 Flowchart depicting selection criteria for stereotactic radiation of intracranial meningiomas used in our clinic

DOSE SELECTION

Table 20.5 Doses utilized in radiosurgery for intracranial meningiomas

Author, Year	Peripheral Dose	Variation (Gy)	Technique
Hakim, 1998 [46]	15	9–20	LINAC
Liscak, 1999 [59]	12	10–14	GK
Kondziolka, 1999 [51]	16	9–25	GK
Shafron, 1999 [47]	12.7	10–20	LINAC
Stafford, 2001 [54]	16	12–36	LINAC
Villavicencio, 2001 [114]	15	12–18.5	LINAC
Friedman, 2005 [115]	16	10–20	LINAC
Hasegawa, 2007 [116]	13	7.5–17	GK
Pollock, 2012 [117]	16	N/A	GK

N/A Not Available, *LINAC* Linear Accelerator, *GK* Gamma Knife


a
b
CORONAL
SAGITTAL

CONTROL RATES

Table 2
Literature review of aggressive meningiomas treated by SRS

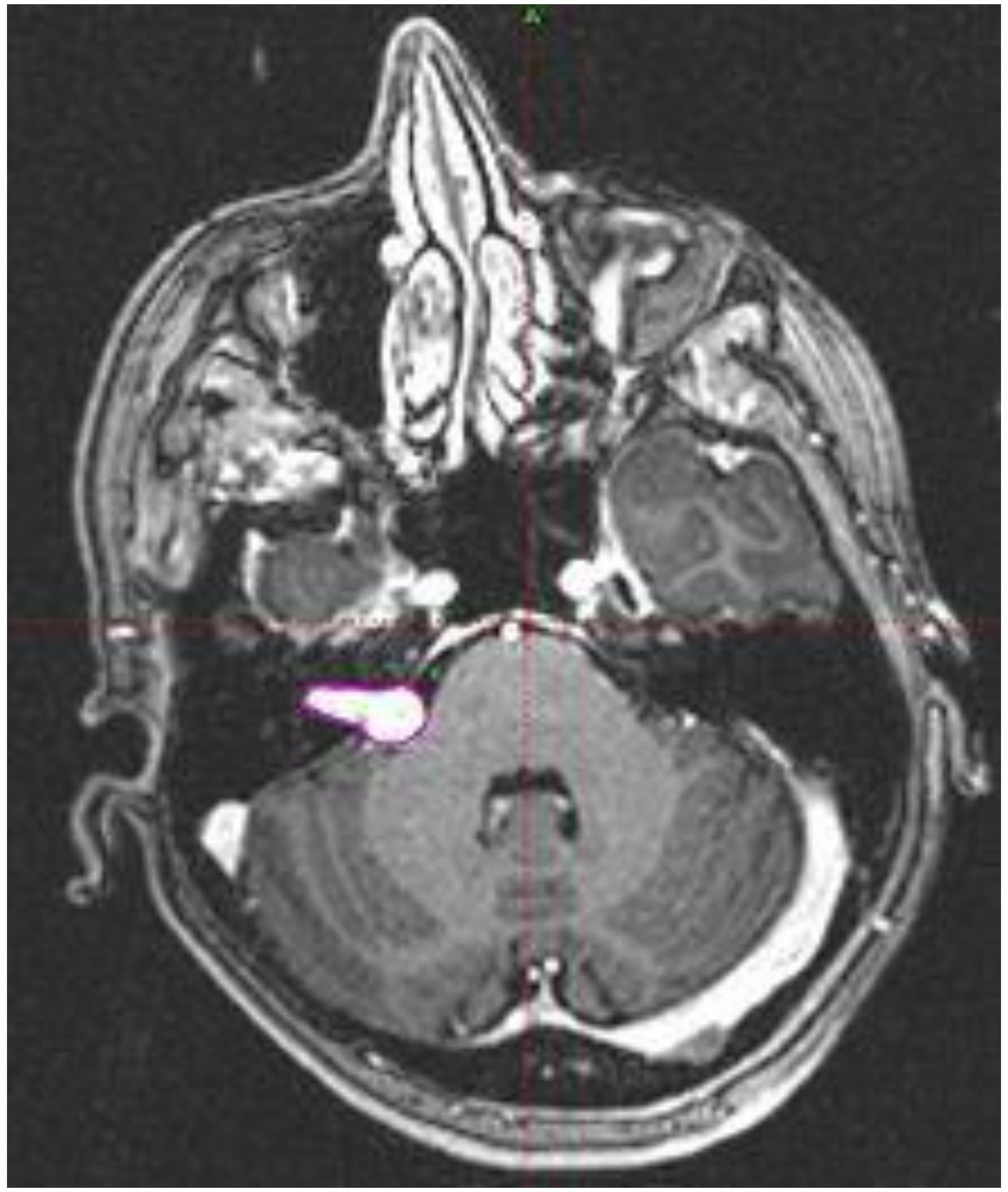
Author, Year	WHO Grade	Patient Number	Control Rate	PFS	Overall Survival
Ojemann et al,[85] 2000	3	19 (31)	—	26% at 5 y	40% at 5 y
Stafford et al,[78] 2001	2 3	13 9	68% at 5 y 0% at 5 y	—	76% at 5 y[a] 0% at 5 y[a]
Harris et al,[86] 2003	2 3	18 12	—	83% at 5 y 72% at 5 y	59% at 5, 10 y 59% at 5 y, 0% at 10 y
Huffmann et al,[87] 2005	2	15 (21)	93% at 6 mo	—	100% at 35 mo
Kondziolka et al,[46] 2008	2 3	54 29	50% at 2 y 17% at 15 mo	—	—
Attia et al,[88] 2012	2	24	75% at 1 y 51% at 2 y 44% at 5 y	40% at 2 y, 25% at 5 y	92% at 1 y, 67% at 2 y, 52% at 5 y
Mori et al,[89] 2013	2 3	19 (22) 4	74% at 1 y 54% at 2 y 34% at 3 y	—	—
Tamura et al,[90] 2013	2 3	9 7	29% at 40.5 mo	—	—
Ferraro et al,[12] 2014	2 3	31 4	—	95.7% at 1 y, 70.1% at 3 y 0% at 1, 3 y	92.4% at 1 y, 83.4% at 3 y 33% at 1, 3 y

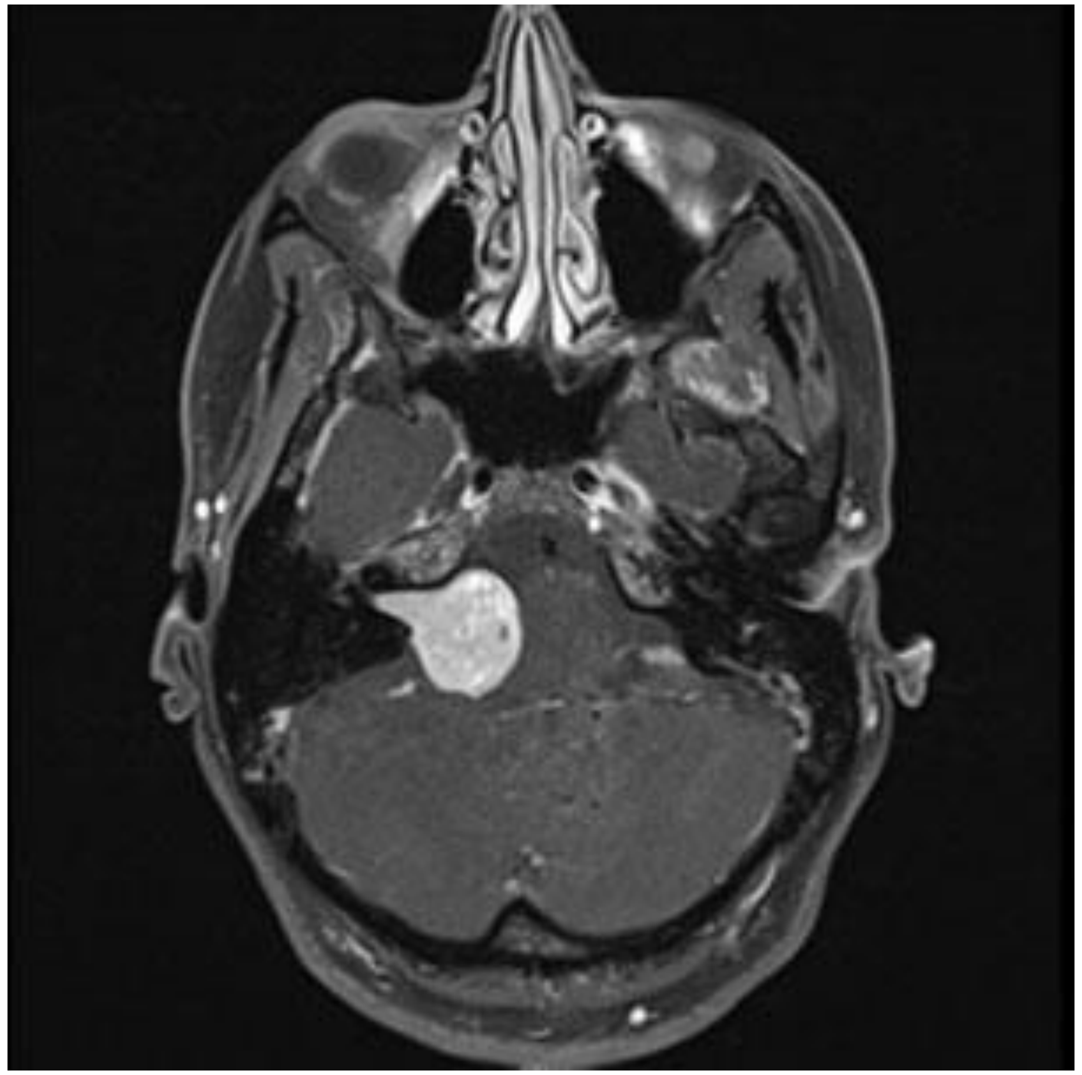
ACOUSTIC NEUROMA

ACOUSTIC NEUROMA

1. An **acoustic neuroma** is a noncancerous growth that develops on the eighth cranial nerve.
2. Also known as the **vestibulocochlear nerve**, it connects the inner ear with the brain and has two different parts.
3. One part is involved in transmitting sound; the other helps send balance information from the inner ear to the brain.

ICE CREAM CONE





BILATERAL ACOUSTIC NEUROMAS

ACOUSTIC NEUROMAS-s/s

Pretreatment symptoms [*n* (%)]		
Hearing loss	433 (87.3)	339 (88.0)
Vertigo	83 (16.7)	55 (14.3)
Facial paresthesia	86 (17.3)	74 (19.2)
Facial weakness	12 (2.4)	9 (2.3)
Dysphagia	2 (0.4)	2 (0.5)
Headache	43 (8.7)	31 (8.0)
Nausea	13 (2.6)	12 (3.1)
Otalgia	25 (5.0)	17 (4.4)
Ear fullness	85 (17.1)	68 (17.7)
Tinnitus	290 (58.5)	229 (59.5)
Gait imbalance	194 (39.1)	152 (39.5)
Dysgeusia	8 (1.6)	7 (1.8)
Facial twitching	21 (4.2)	13 (3.4)
Diplopia	5 (1.0)	2 (0.5)
Fatigue	3 (0.6)	3 (0.8)
Vomiting	7 (1.4)	7 (1.8)

ACOUSTIC NEUROMA- OPTIONS

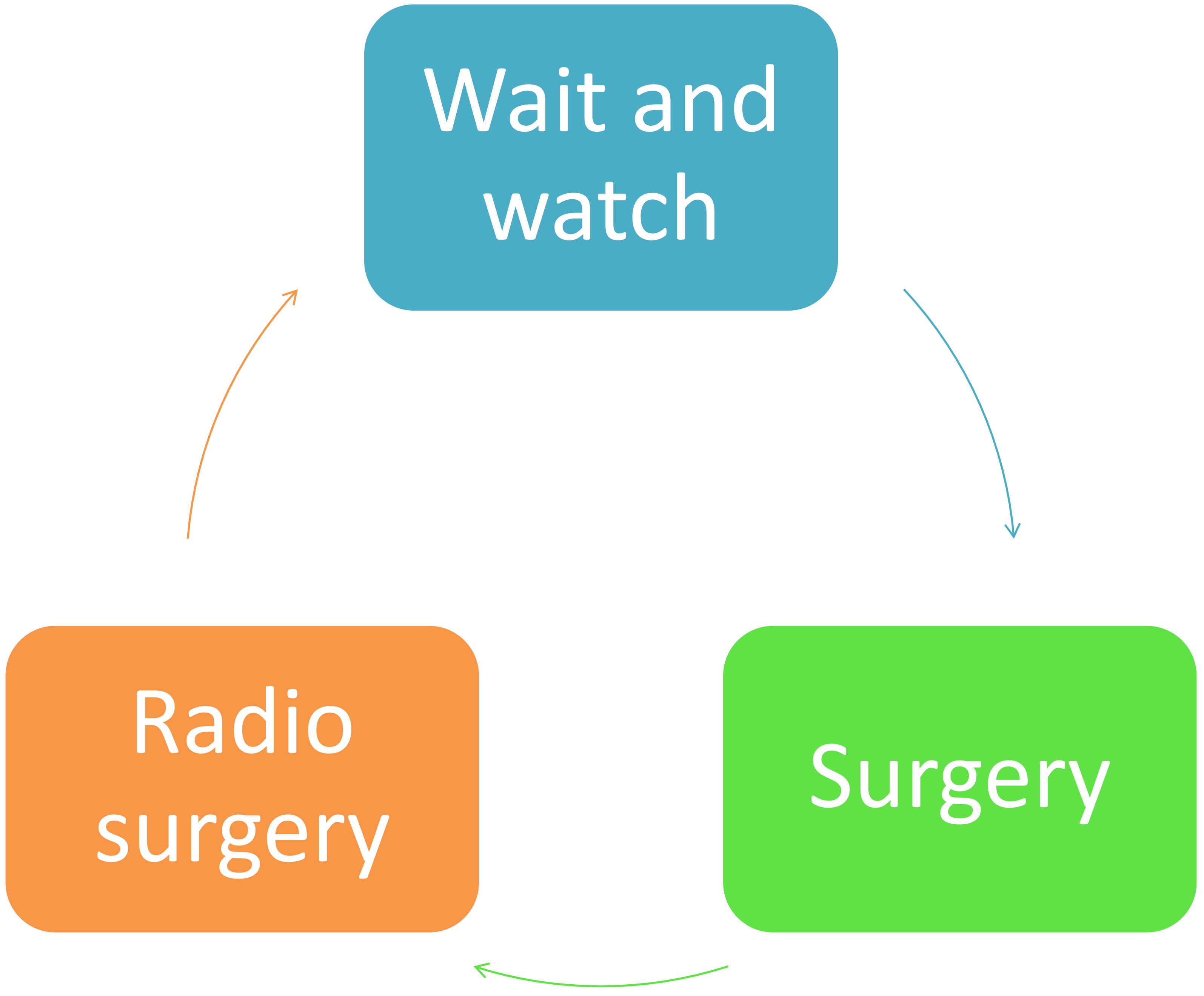
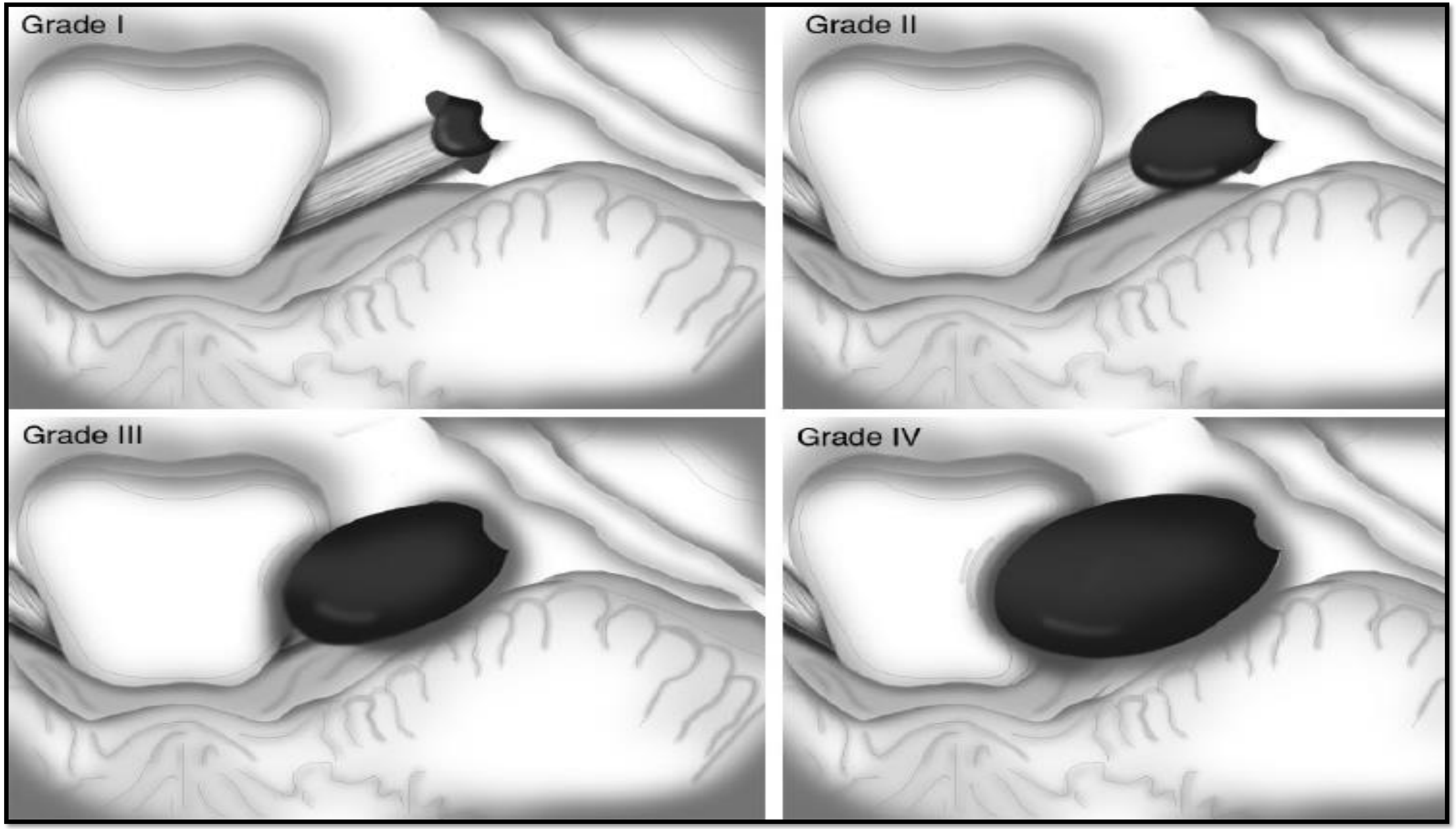


Table 23.3 Koos acoustic schwannoma tumor size grading criteria

Koos Grade I	Purely intracanalicular tumor limited to the internal auditory canal only
Koos Grade II	< 2 cm extracanalicular/CPA extension without brainstem compression
Koos Grade III	Extracanalicular/CPA extension >2 cm, with no brainstem compression
Koos Grade IV	Extracanalicular/CPA extension with any degree of brainstem compression

KOOS GRADING

KOOS GRADING



AUDIOMETRY

Table 23.1 Gardner-Robertson hearing (G-R) classification based on the poorer of either pure tone average (PTA) or speech discrimination score (SDS) class divisions [4]

G-R hearing class	Criteria
Class I (good)	PTA 0–30dB and/or SDS 70–100 %
Class II (serviceable/useful)	PTA 31–50dB and/or SDS 50–69 %
Class III (non-serviceable)	PTA 51–90dB and/or SDS 5–49 %
Class IV (poor)	PTA 91dB-max and/or SDS 1–4 %
Class V (none/deaf)	Untestable for PTA and/or SDS

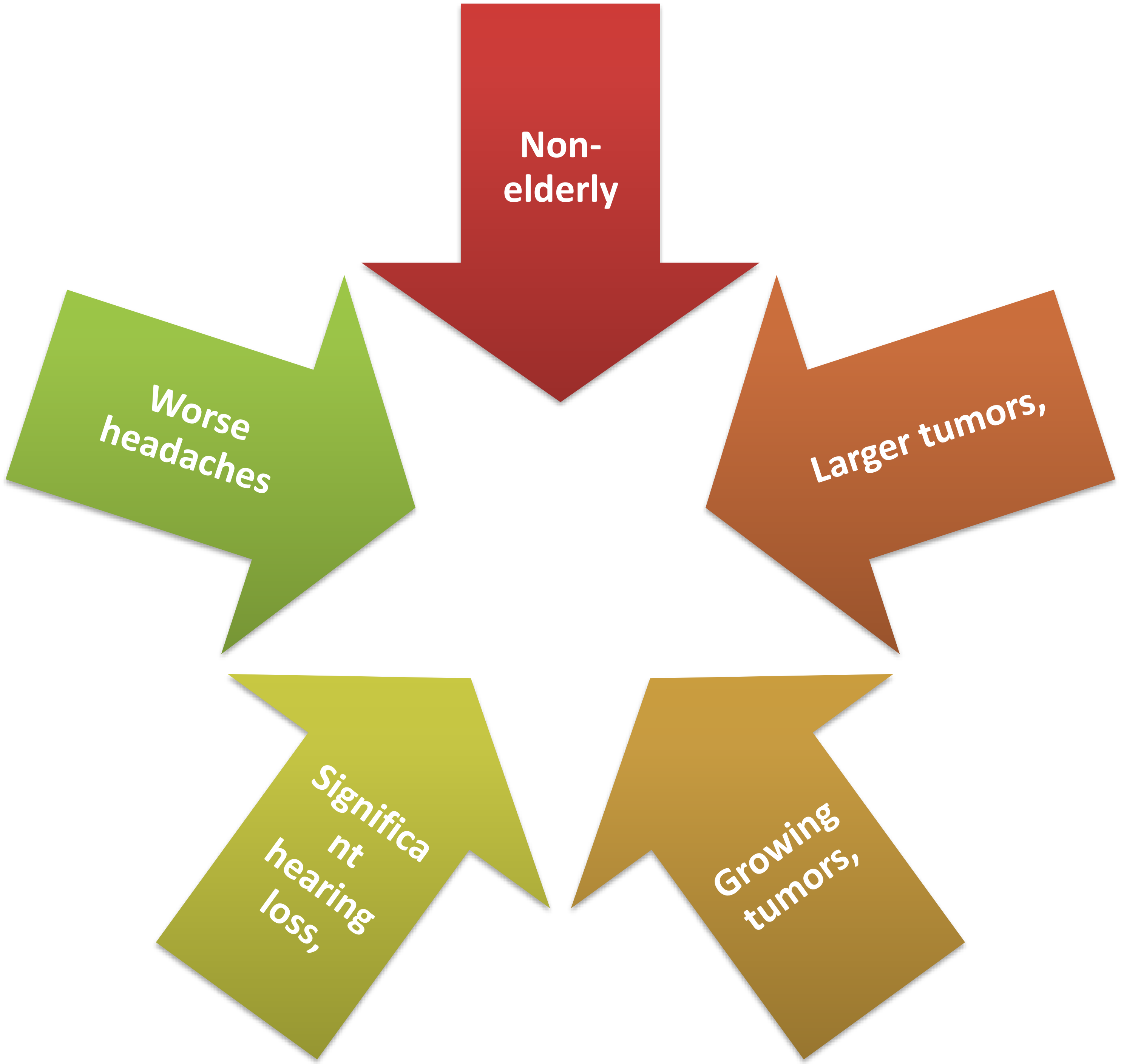
Table 23.2 House-Brackmann facial nerve grades [5]

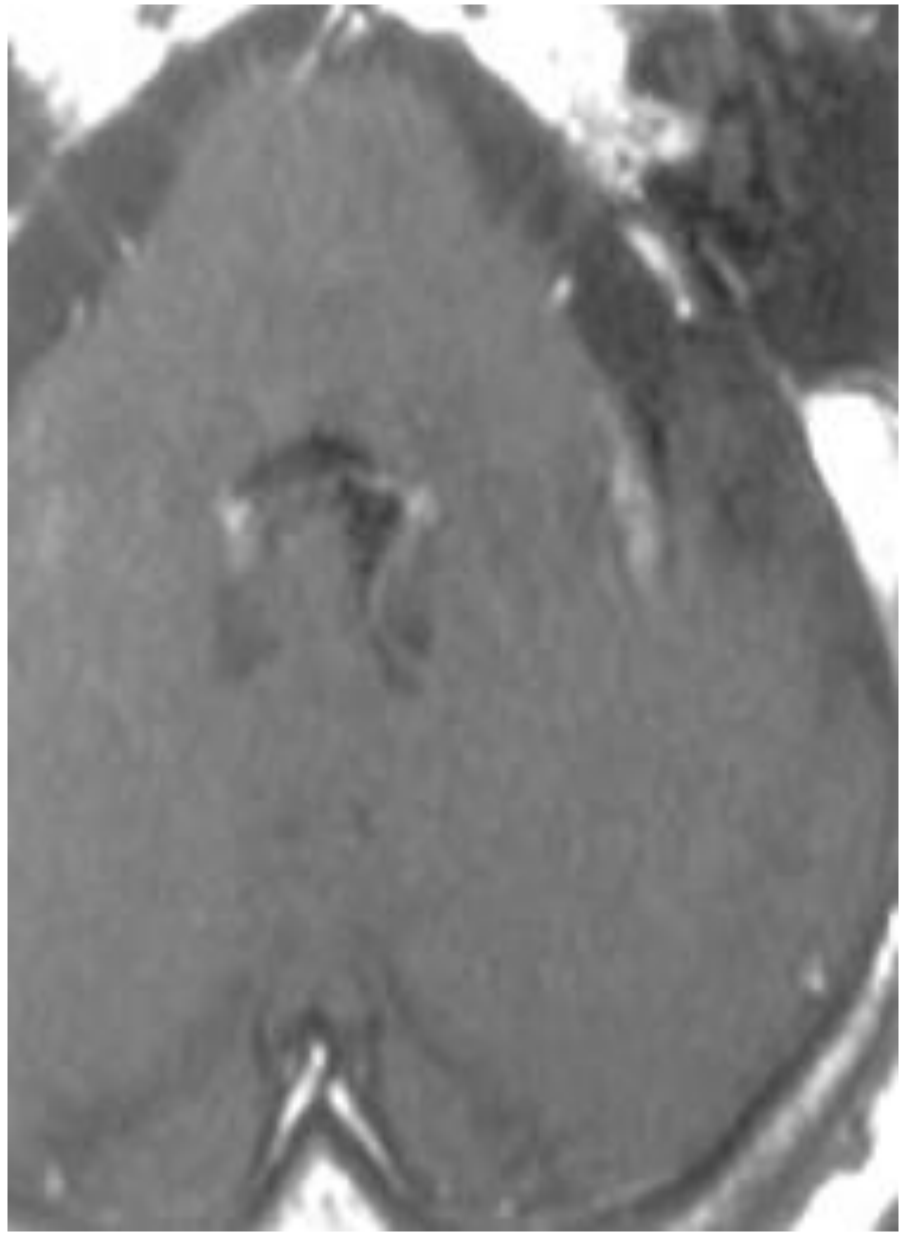
Grade 1	Normal facial function in all regions
Grade 2	Mild dysfunction: light weakness not obvious at rest
Grade 3	Moderate weakness that is obvious at rest but not disfiguring and with complete eyelid closure
Grade 4	Moderate to severe weakness: obvious disfiguring weakness with incomplete eyelid closure
Grade 5	Severe weakness: barely perceptible muscle movement with incomplete eyelid closure
Grade 6	Complete paralysis, no movement, loss of tone

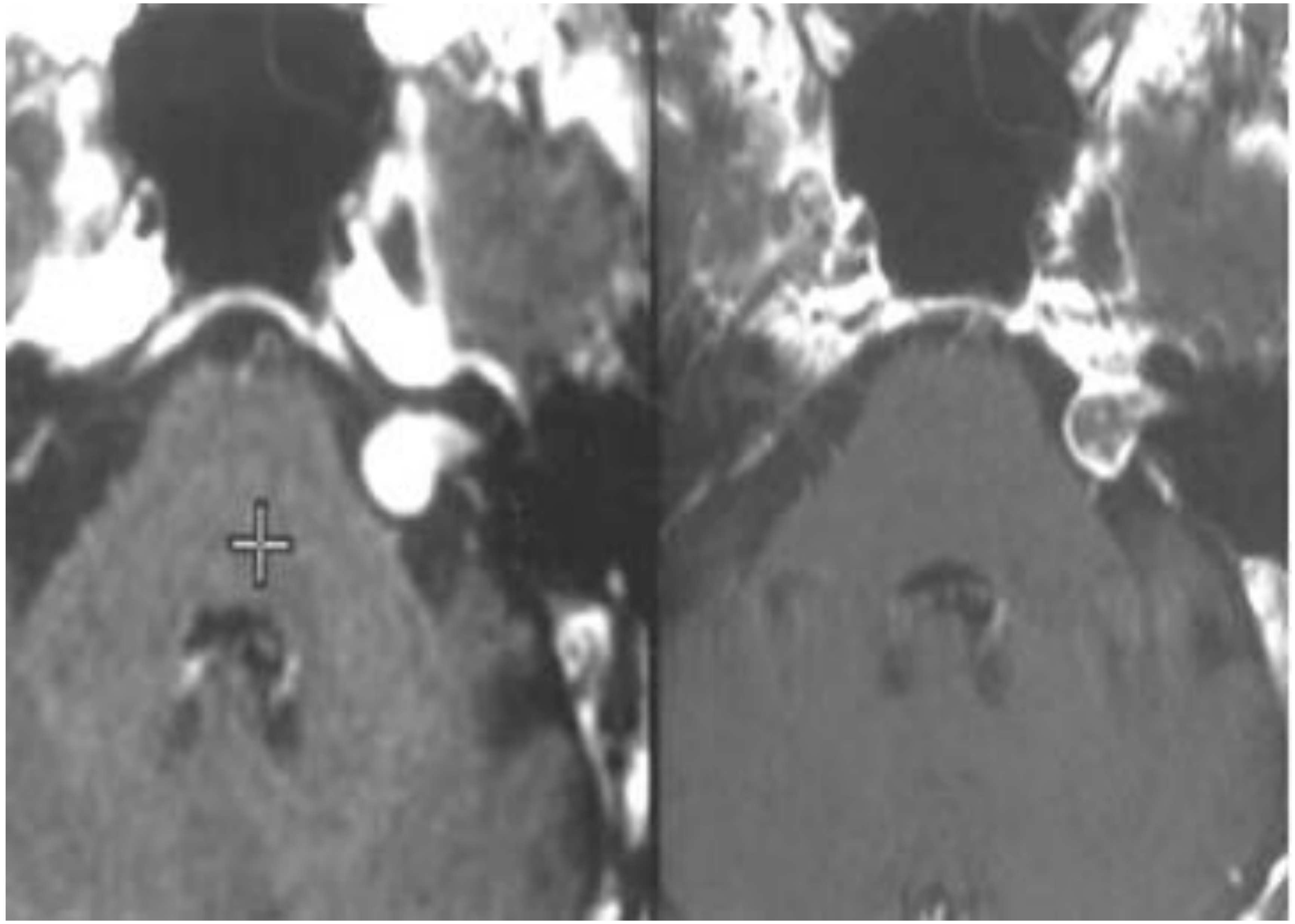
FACIAL PALSY GRADING

	Radiosurgery	Surgery	Observe
Size			
>2.5 cm	+	+++	0
1.5 to 2.5 cm	++	++	+
<1.5 cm	+++	++	++
Age			
<40	+	+++	0
40 to 60	++	++	+
>60	+++	+	+++
Hearing			
>50/50	+++	++	++
<50/50	++	++	+
Recurrent	+++	+	+

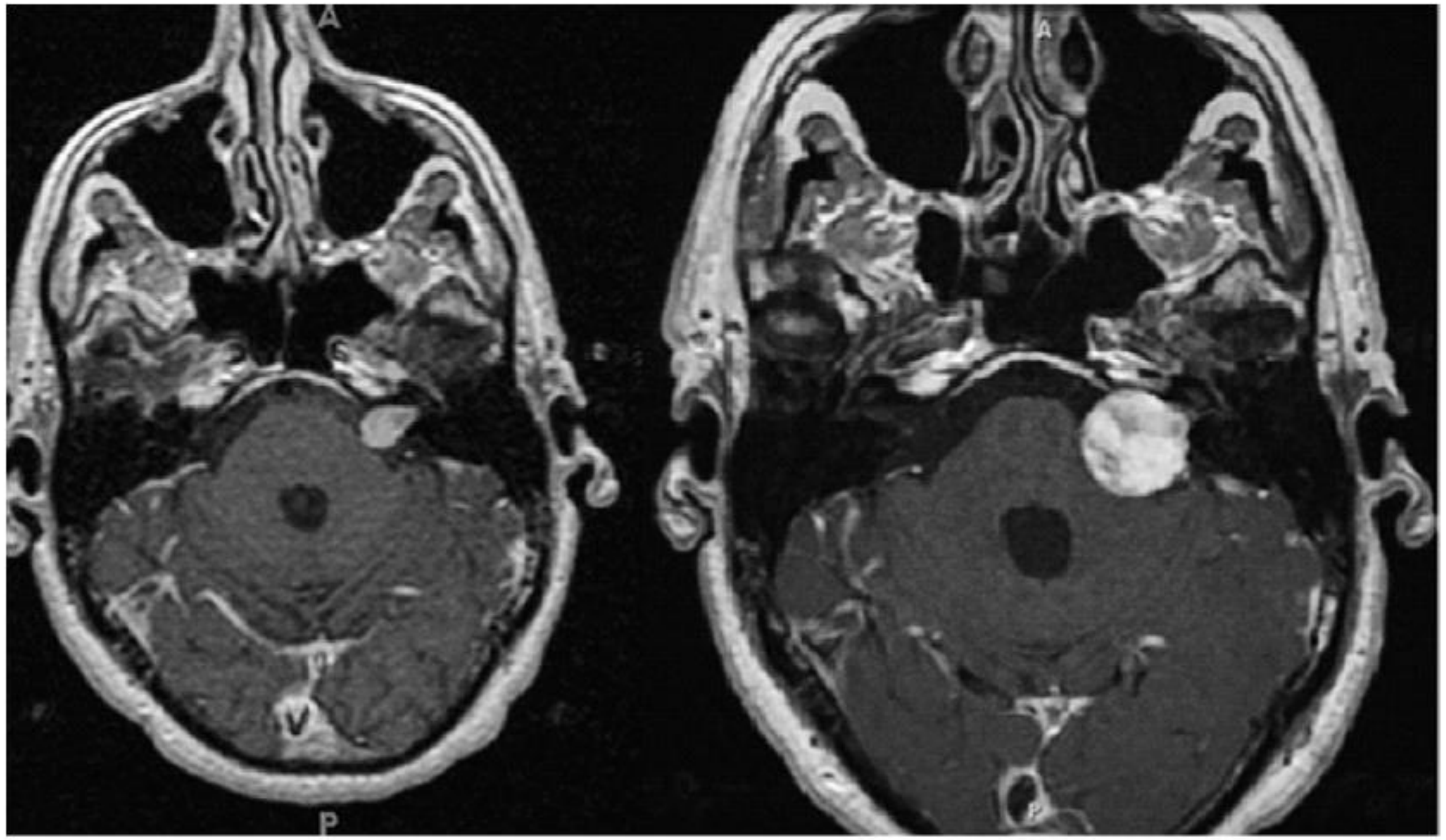
SURGICAL INTERVENTION







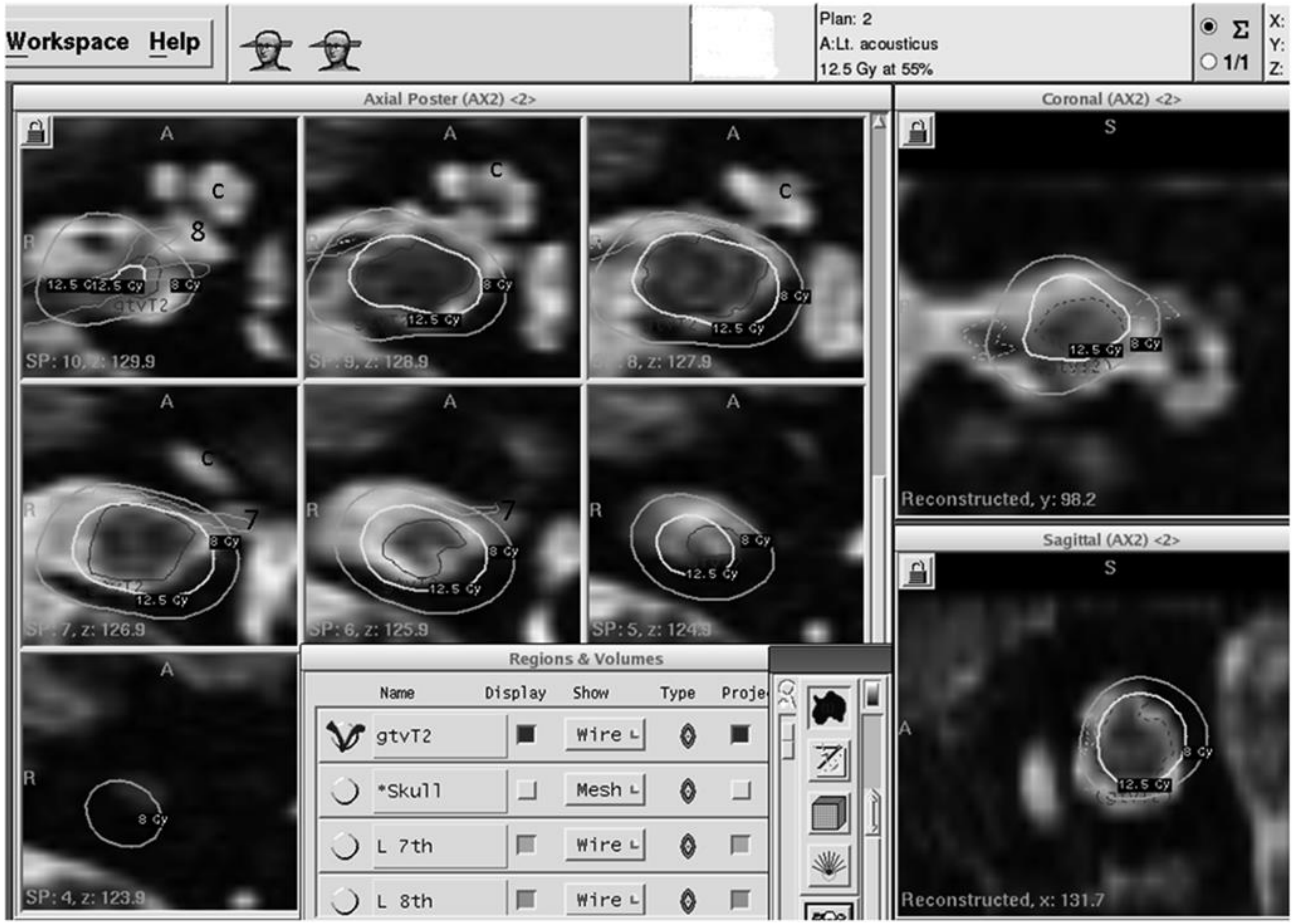
BEFORE-6M-2YEAR-POST SRS



a b

2. (a) Tumor in 65-year-old man at time of treatment (approximate baseline volume of 800 mm^3). (b) The same tumor 32 months of follow-up has undergone a 5-fold growth (approximate volume is 4080 mm^3). With ''freedom from ical intervention'' used as a criterion, this obvious radiologic failure would be considered a success.

RADIOLOGICAL PROGRESSION



DOSE DISTRIBUTION

CONTROL RATE

Long-term tumor control rates of acoustic schwannomas with radiosurgery vary from **90 % to 98 %** in different series.

Chopra et al reported long-term results with acoustic schwannoma radiosurgery to **12–13 Gy** for 216 patients at Pittsburgh With 98 % tumor control (freedom from resection) at 10 years

PITUITARY ADENOMAS

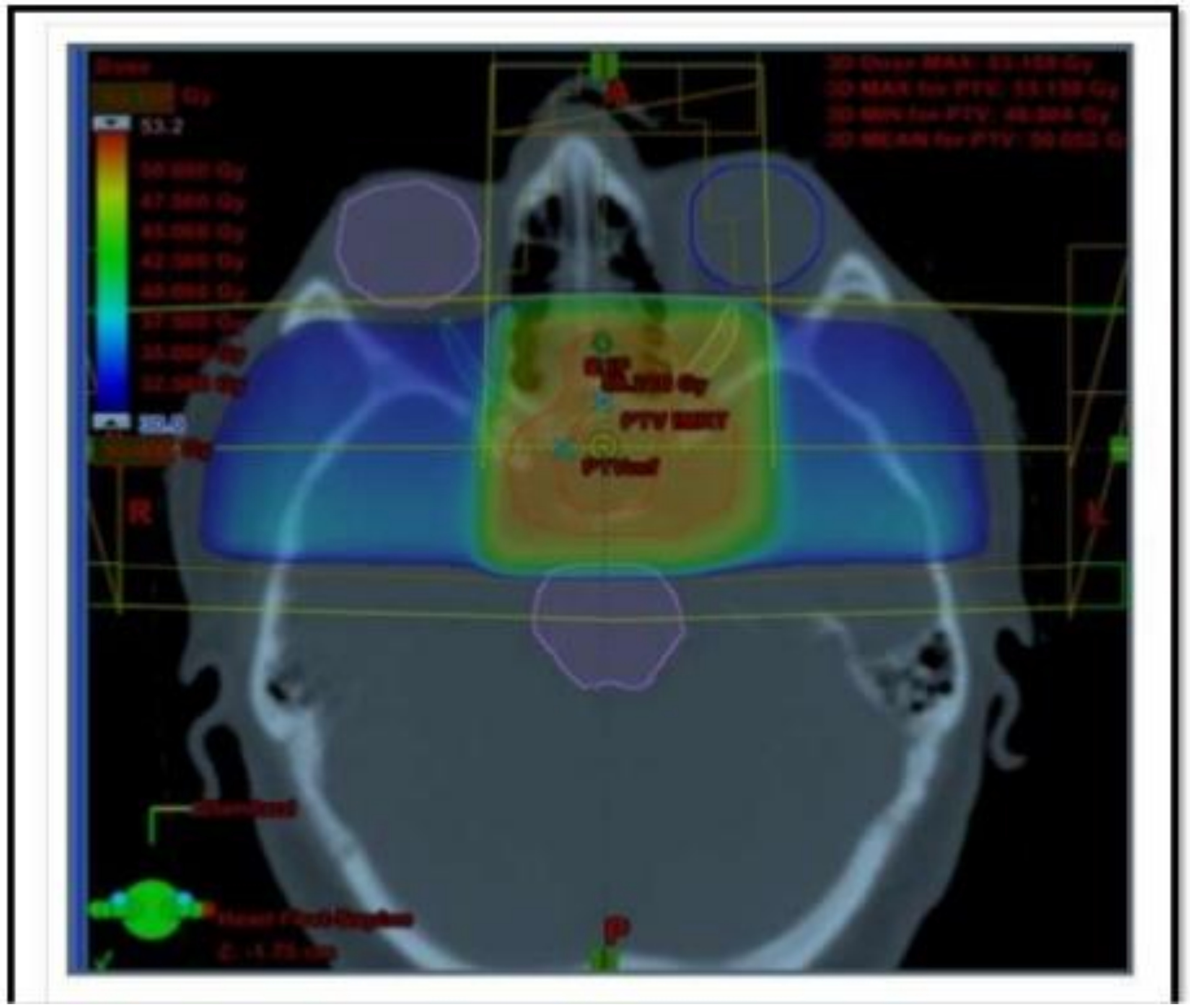
PITUITARY ADENOMAS

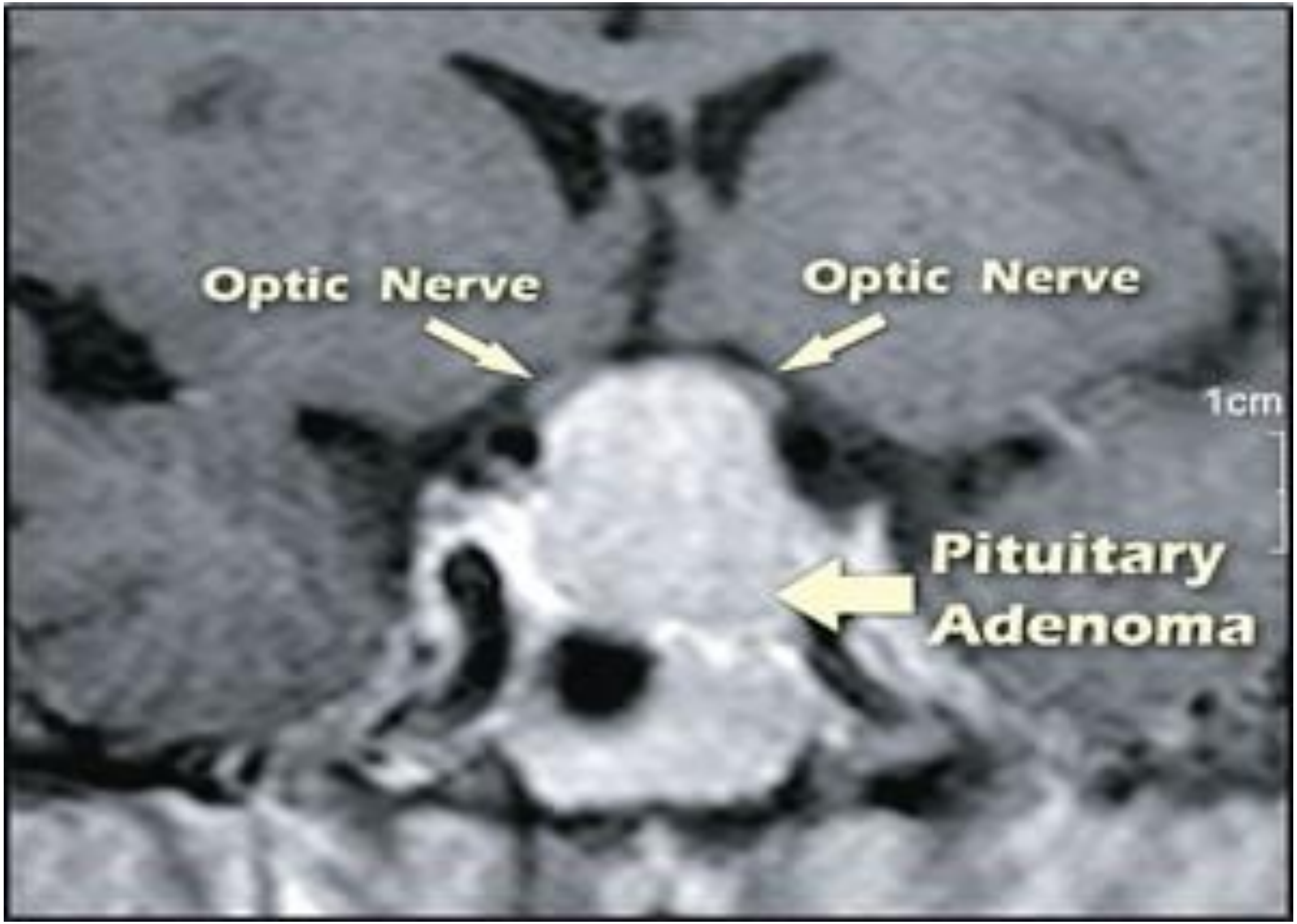
On the evidence available, no data support the superiority of SRS over FSRT for the treatment of patients with pituitary tumors.

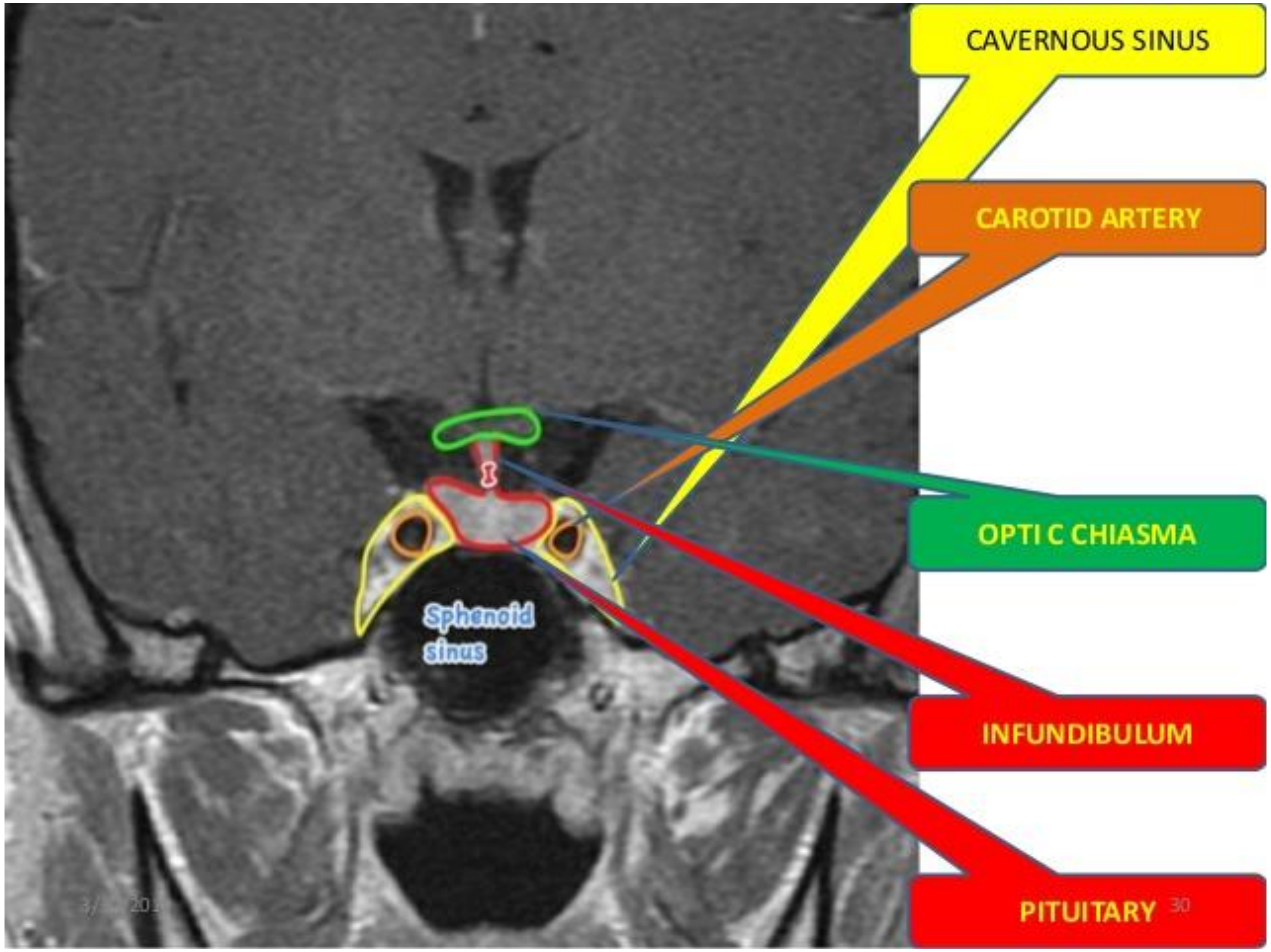
Dose and fractionation are usually chosen on the basis of the size and position of the pituitary adenoma.

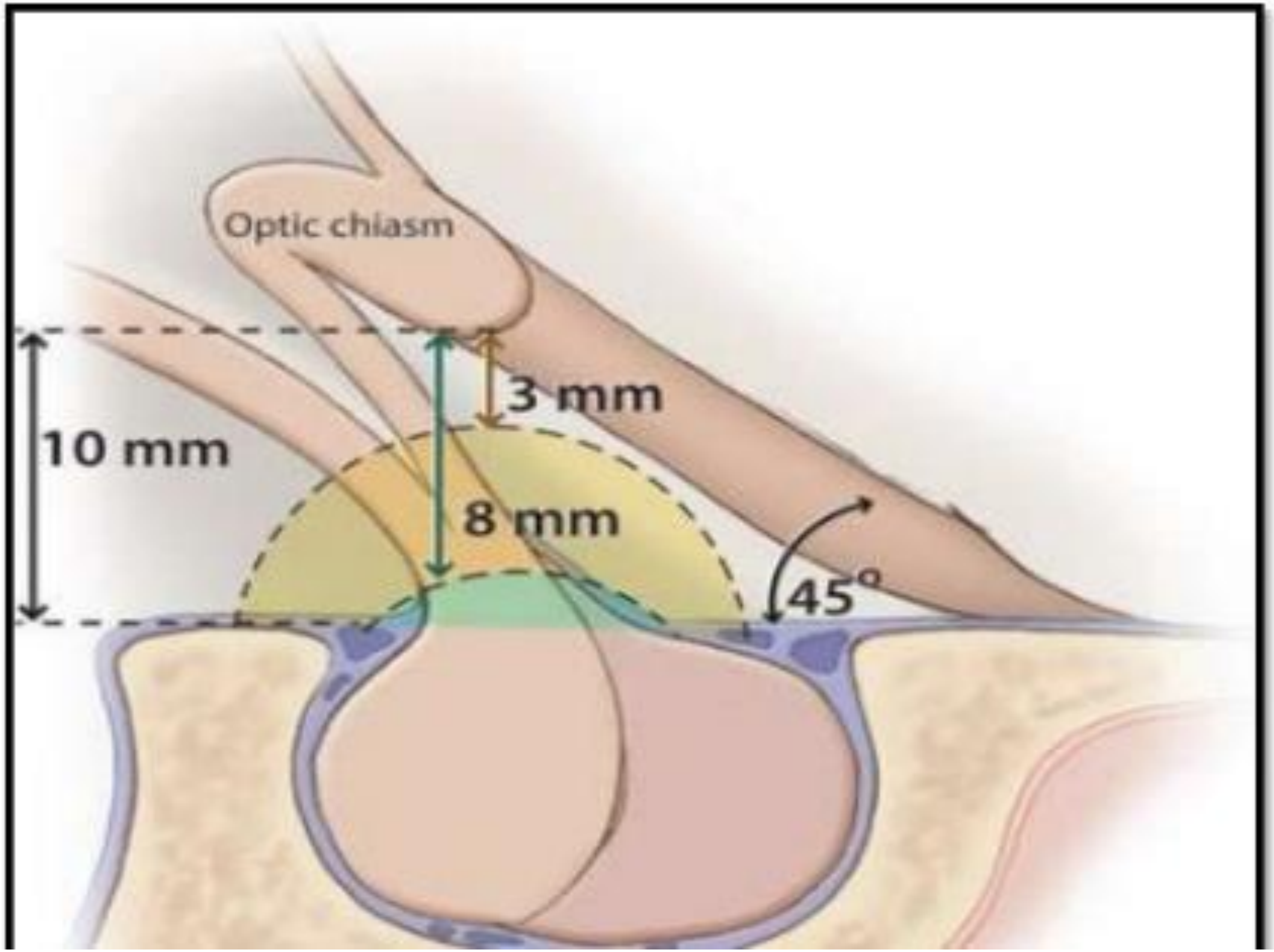
In current clinical practice, single-fraction SRS at doses of 16–25 Gy may represent a convenient approach to patients with a relatively small pituitary adenoma away from the optic chiasm, whereas FSRT is preferred over SRS for lesions >2.5–3 cm in size and/or involving the anterior optic pathway

CLASSICAL 2D PLAN



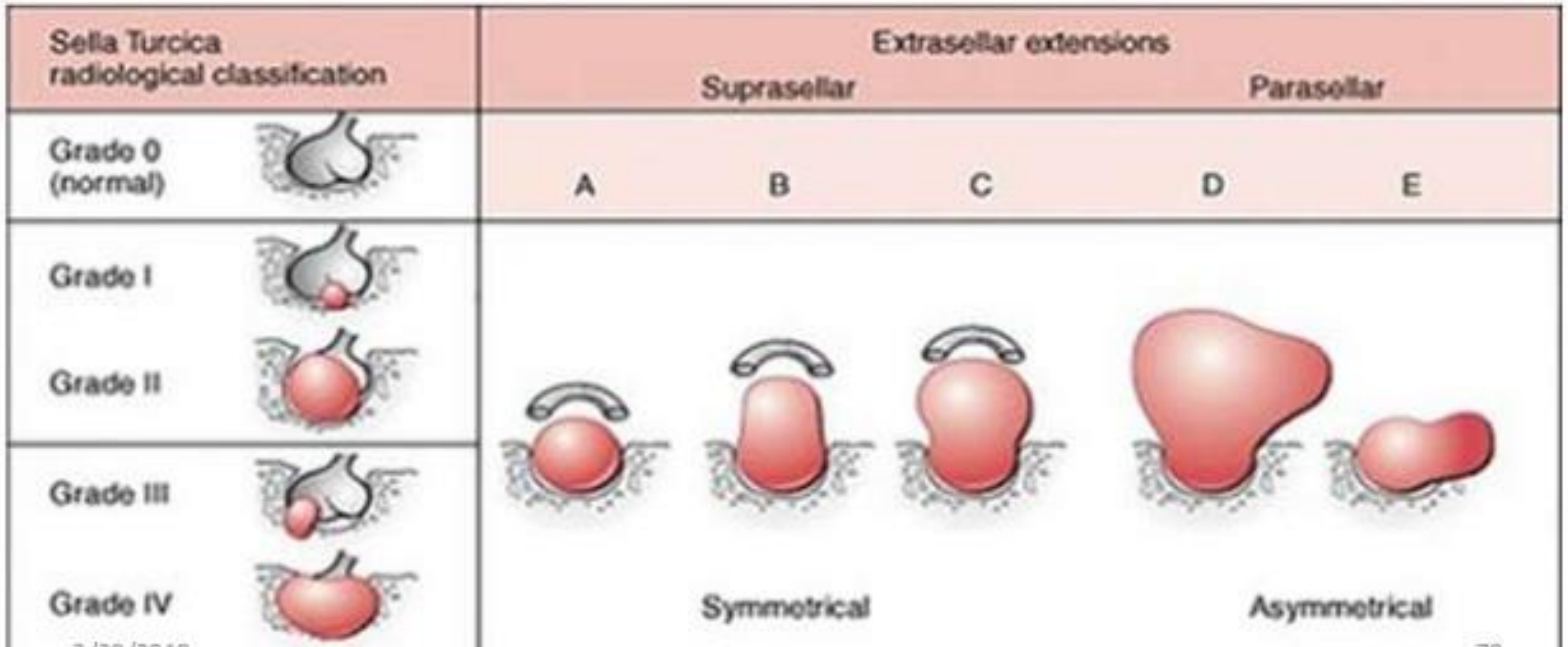

Optic Nerve
Optic Nerve
1cm
Pituitary
Adenoma


CAVERNOUS SINUS
CAROTID ARTERY
OPTI C CHIASMA
INFUNDIBULUM
PITUITARY
Sphenoid sinus
30


Optic chiasm
10 mm
3 mm
8 mm
45°

HARDY'S CLASSIFICATION

Hardy's classification of pituitary adenomas. Grades I and II are enclosed within the sella. Grades III and IV are invasive. Extrasellar classifications A, B, and C are increasing amounts of direct suprasellar adenomas. D is asymmetric extension, and E is lateral extension into the cavernous sinus. (Adapted from Hardy J, Somma M. 1979).



CONSIDERATION OF STEREOTAXY

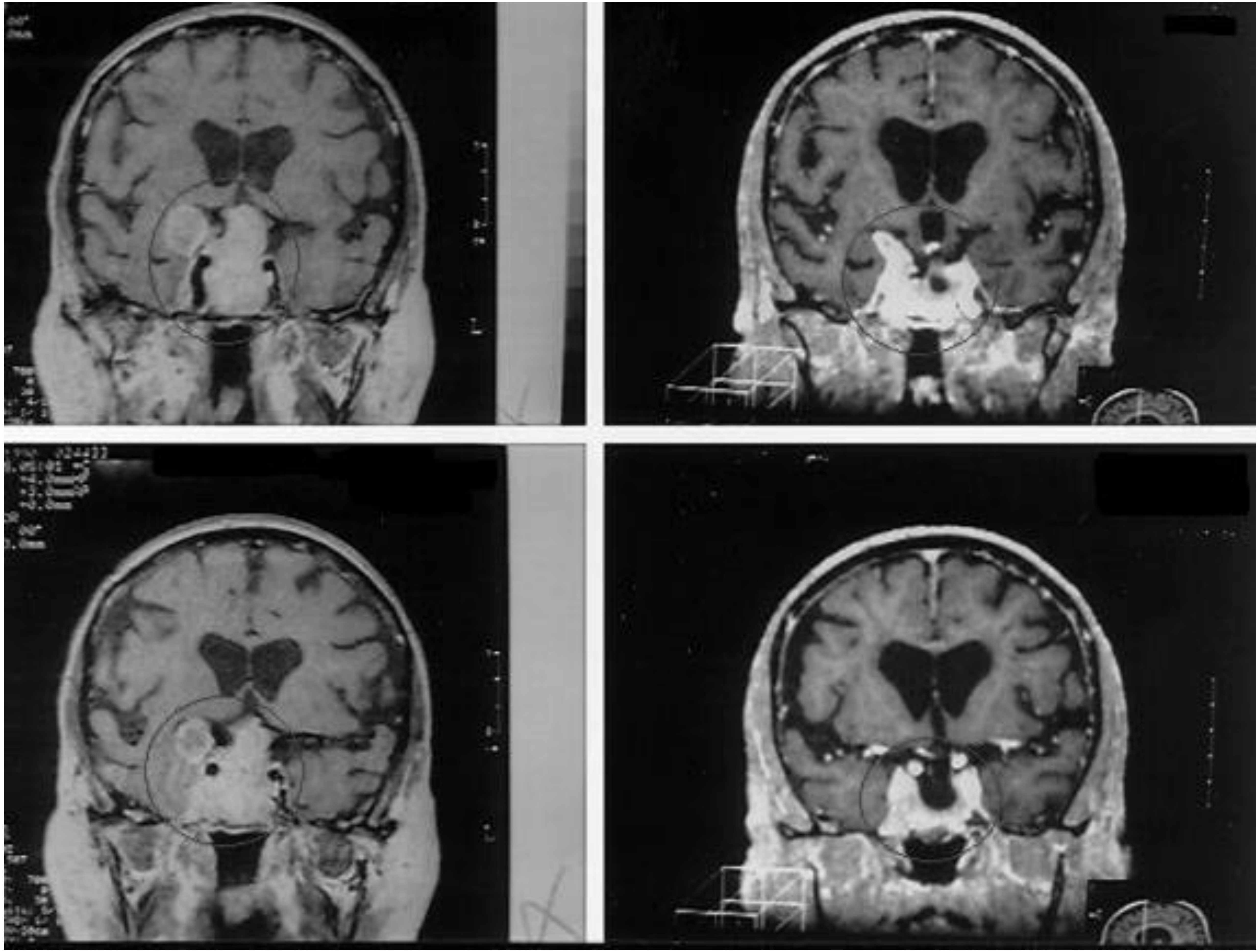
1. Commonly not practiced
    1. Conventional results are best
    2. Close proximity to chiasm
2. Functional tumors need higher dose16–25 Gy in a single fraction prescribed to at least the 50 % isodose line. Higher doses are preferred
3. Nonfunctional tumors: 14–16 Gy in a singlefraction prescribed to at least the 50 % isodose line,
4. Fractionated radiation therapy is recommended for tumors in close proximity to the optic chiasm (3 mm) or with marked extension into the cavernous sinus

FSRT FOR PITUITARY

- Stereotactic radiotherapy originally referred to radiotherapy treatment delivered to an intracranial target lesion that was located by stereotactic means in a patient immobilised in a neurosurgical stereotactic head frame. **The improved patient immobilisation, more accurate**
- Tumour target localisation using cross-sectional image for treatment planning, and high precision radiation treatment delivery to the tumour target, enabled a **reduction in the margins** around the radiotherapy target volume (the GTV to PTV margin), therefore achieving greater sparing of surrounding normal tissues than can be obtained with standard CRT techniques

SCRT VS SRT

- While SCRT is suitable for the treatment of all pituitary tumours, irrespective of size, shape or proximity to critical normal tissue structures,
- SRS is only suitable for treatment of small tumours away from the optic chiasm




CRANIOPHARYNGIOMA

RADIOSURGERY FOR CRANIOPHARYNGIOMA

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Purpose: To analyze the outcomes of gamma knife stereotactic radiosurgery (SRS) for residual or recurrent craniopharyngiomas and evaluate the factors that optimized the tumor control rates.
Methods and Materials: A total of 46 patients with craniopharyngiomas underwent 51 SRS procedures at University of Pittsburgh between 1988 and 2007. The median tumor volume was 1.0 cm^3 (range, 0.07–8.0). The median prescription dose delivered to the tumor margin was 13.0 Gy (range, 9–20). The median maximal dose was 26.0 Gy (range, 20–50). The mean follow-up time was 62.2 months (range, 12–232).
Results: The overall survival rate after SRS was 97.1% at 5 years. The 3- and 5-year progression-free survival rates (solid tumor control) were both 91.6%. The overall local control rate (for both solid tumor and cyst control) was

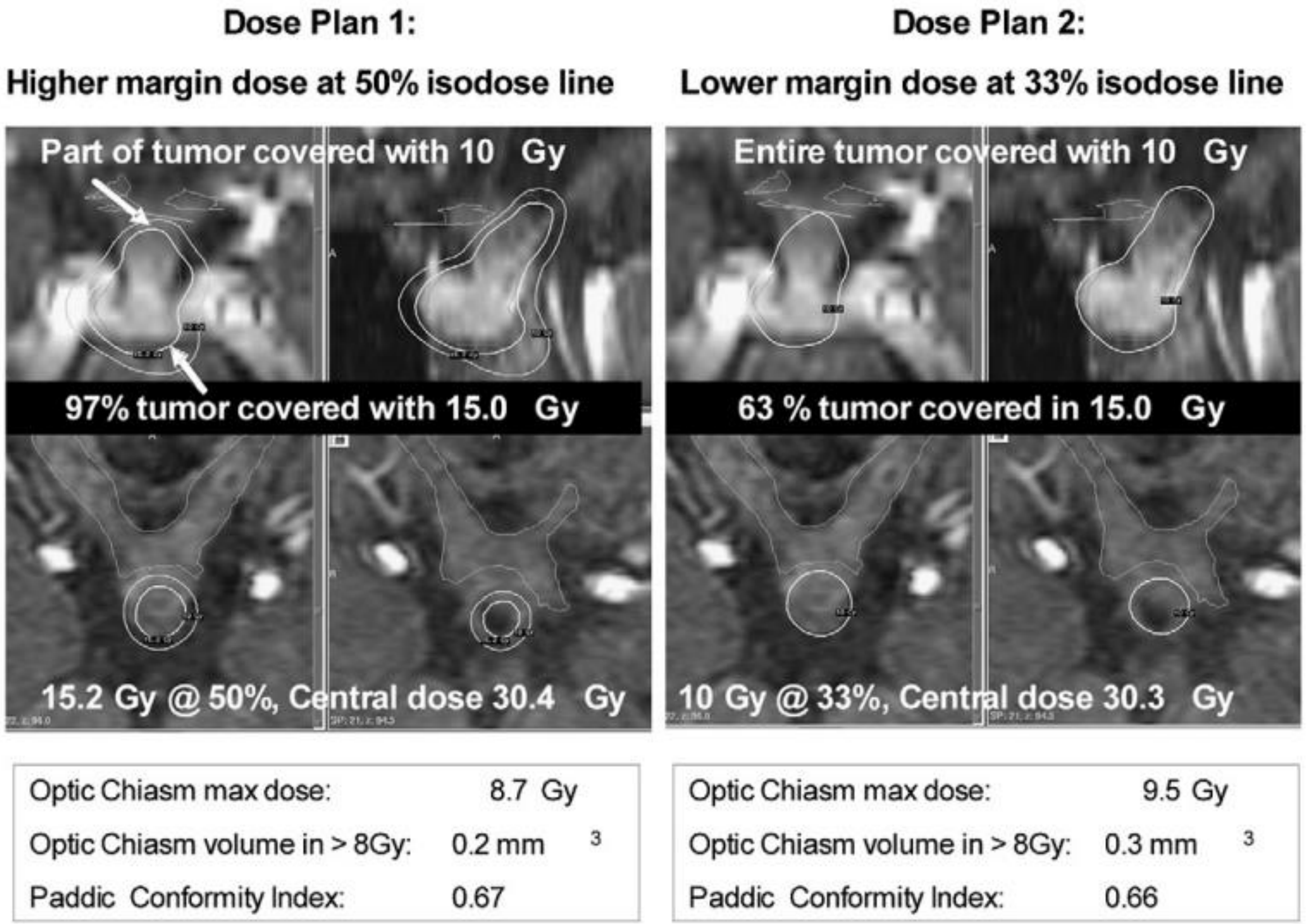


Fig. 1. Dosimetric comparison of two dose plans for craniopharyngioma radiosurgery. Plan 1 designed using greater margin dose prescribed to 50% isodose line. Plan 2 designed using lower margin dose prescribed to lower isodose line (33%). Plan 1 shows a comparable Paddick conformity index (5) and reduced optic chiasm dose fall-off.

TRIGEMINAL NEURALGIA

TRIGEMINAL NEURALGIA

TRIFACIAL NEURALGIA

TIC DOULOUREX

FOTHERGILLS DISEASE

TRIGEMINAL NEURALGIA

Nearly 80 to 90% of all TN cases are caused by a neurovascular conflict involving the trigeminal nerve and an artery.

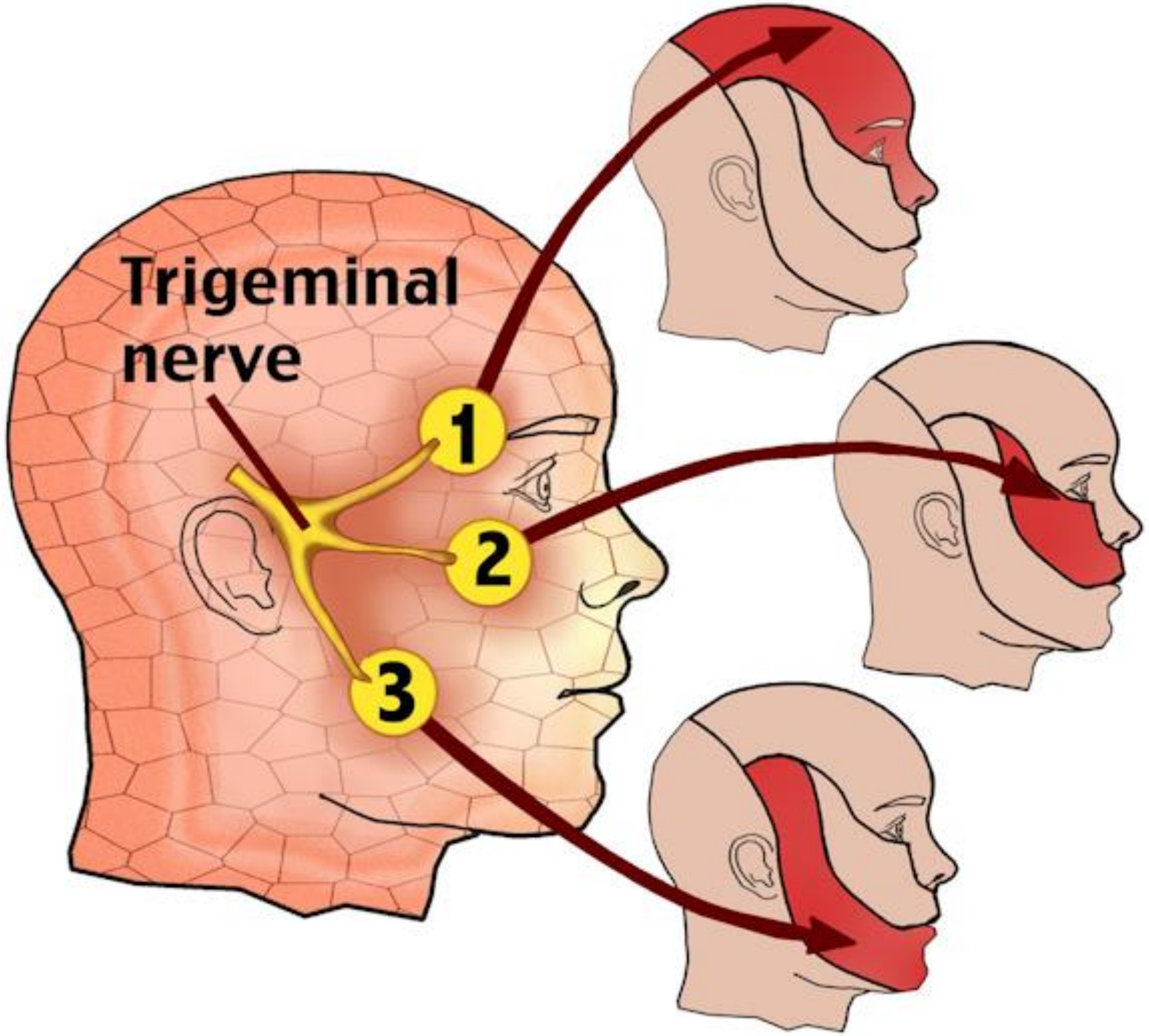
↓

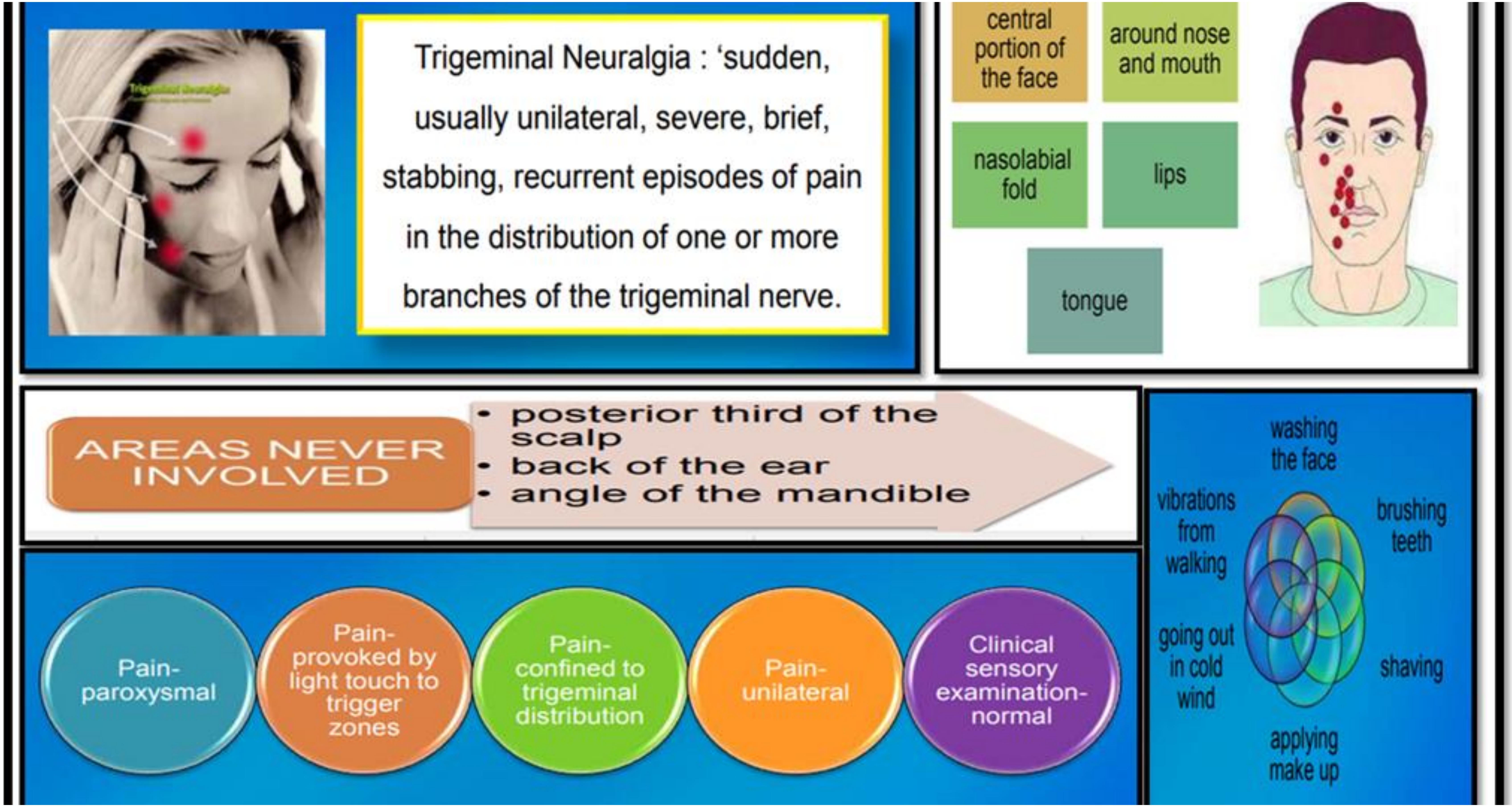
Another widely accepted cause of TN is mechanical compression of the trigeminal nerve root, usually within a few millimeters of entry into the pons—the root entry zone (REZ)

↓

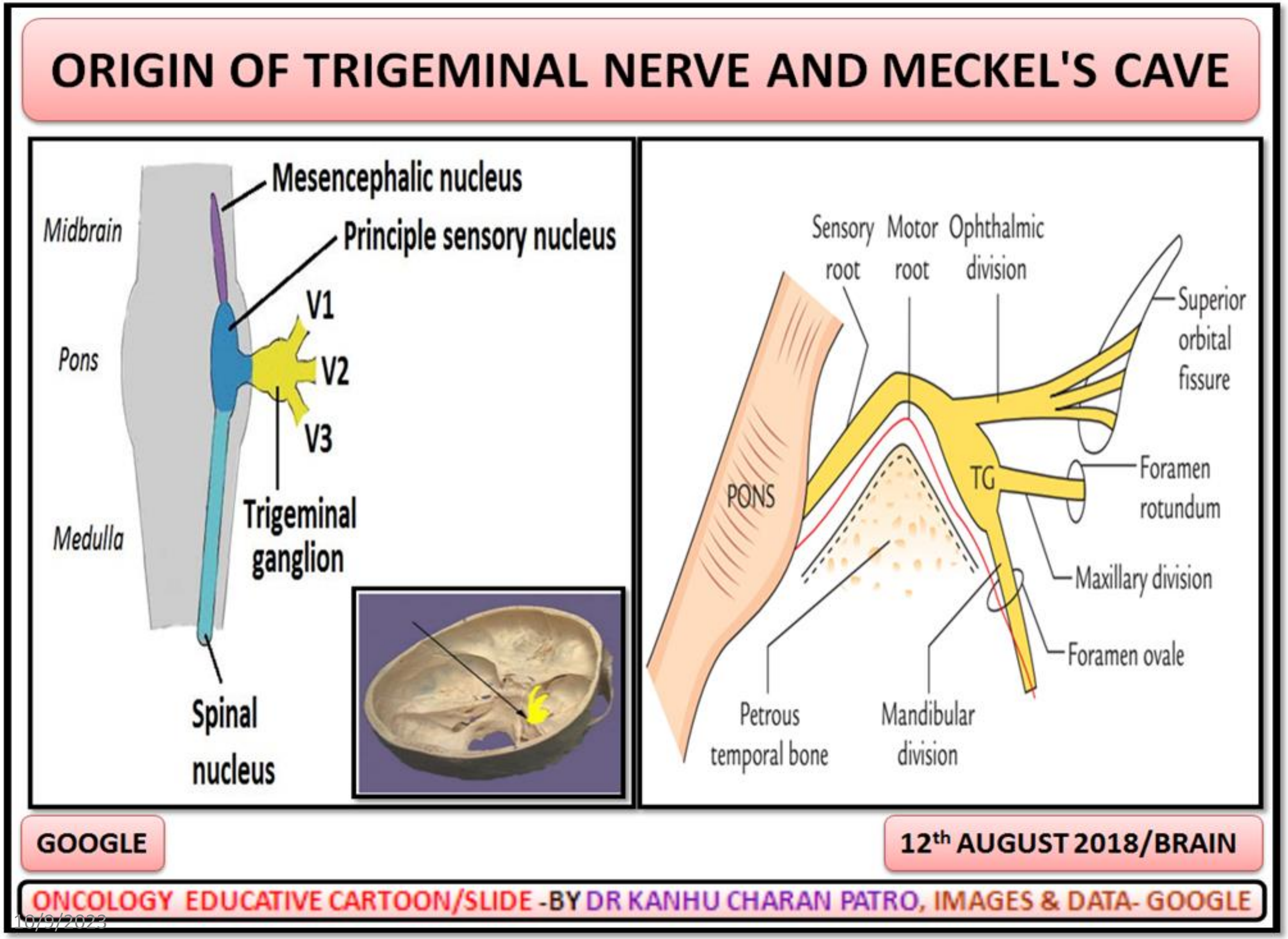
NERVE ROOT IRRITATION	
Arterial compression	Demyelination


I'm having a
PAIN ATTACK
in my face
and
CAN'T TALK NOW
PLEASE
1. Do NOT touch me
2. Do NOT move me
3. Don't ask questions
4. Just let me be
I know what to do.
The attack will pass.
It is NOT dangerous or contagious.
I have Trigeminal Neuralgia,
The pain is higher than worst
migraine and toothache combined.

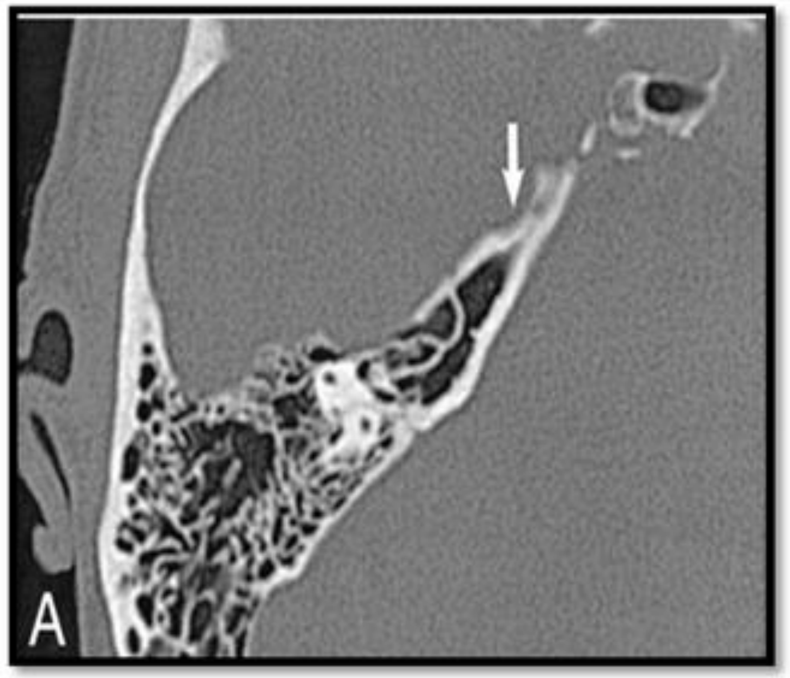

Trigeminal nerve
1
2
3

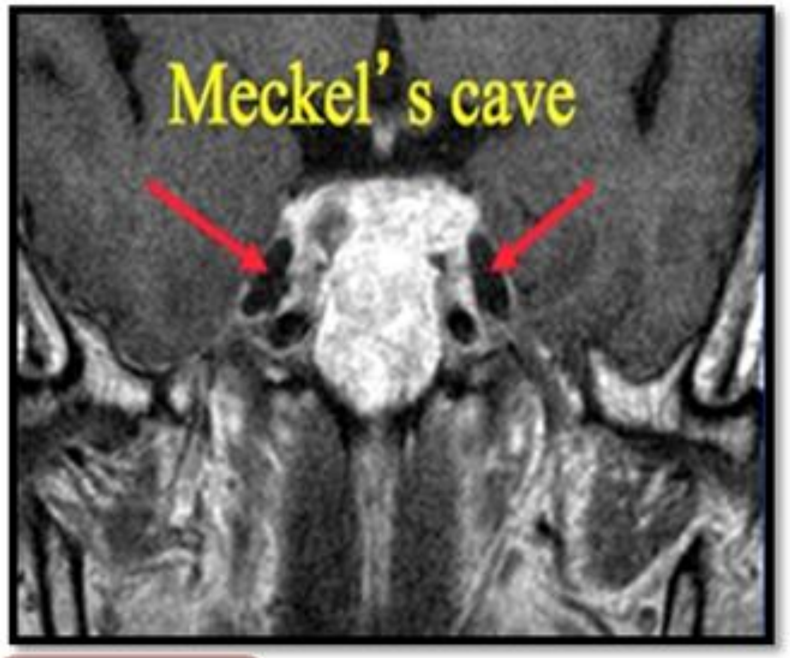


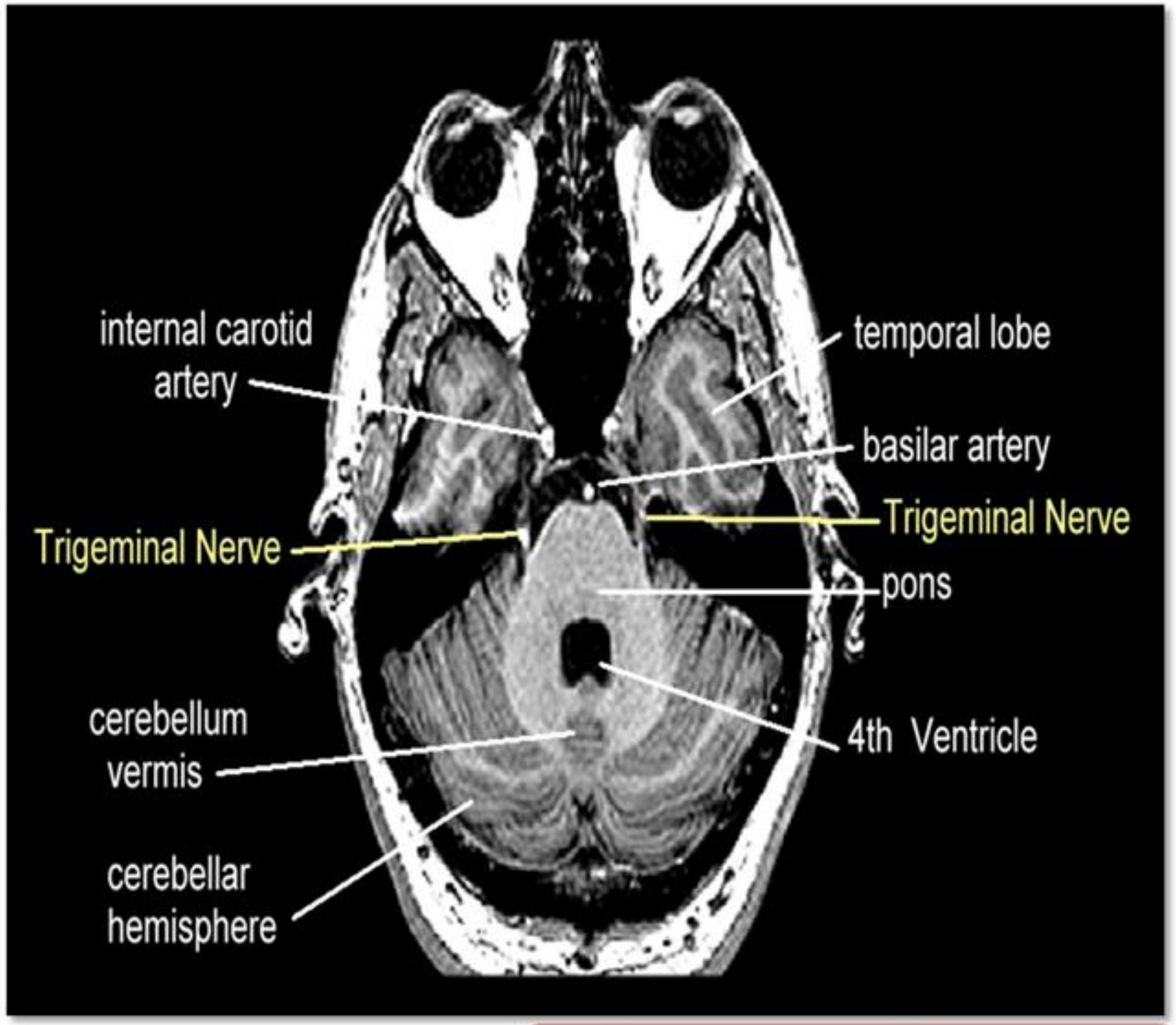
Trigeminal Neuralgia : 'sudden, usually unilateral, severe, brief, stabbing, recurrent episodes of pain in the distribution of one or more branches of the trigeminal nerve.
central portion of the face
around nose and mouth
nasolabial fold
lips
tongue
AREAS NEVER INVOLVED
• posterior third of the scalp
• back of the ear
• angle of the mandible
Pain- paroxysmal
Pain- provoked by light touch to trigger zones
Pain- confined to trigeminal distribution
Pain- unilateral
Clinical sensory examination- normal
washing the face
brushing teeth
shaving
applying make up
going out in cold wind
vibrations from walking


ORIGIN OF TRIGEMINAL NERVE AND MECKEL'S CAVE
Mesencephalic nucleus
Principle sensory nucleus
Midbrain
Pons
Medulla
V1
V2
V3
Trigeminal ganglion
Spinal nucleus
Sensory root
Motor root
Ophthalmic division
Superior orbital fissure
Foramen rotundum
Maxillary division
Foramen ovale
PONS
TG
Petrous temporal bone
Mandibular division
GOOGLE
12th AUGUST 2018/BRAIN
ONCOLOGY EDUCATIVE CARTOON/SLIDE -BY DR KANHU CHARAN PATRO, IMAGES & DATA- GOOGLE

IMAGING OF TRIGEMINAL NERVE



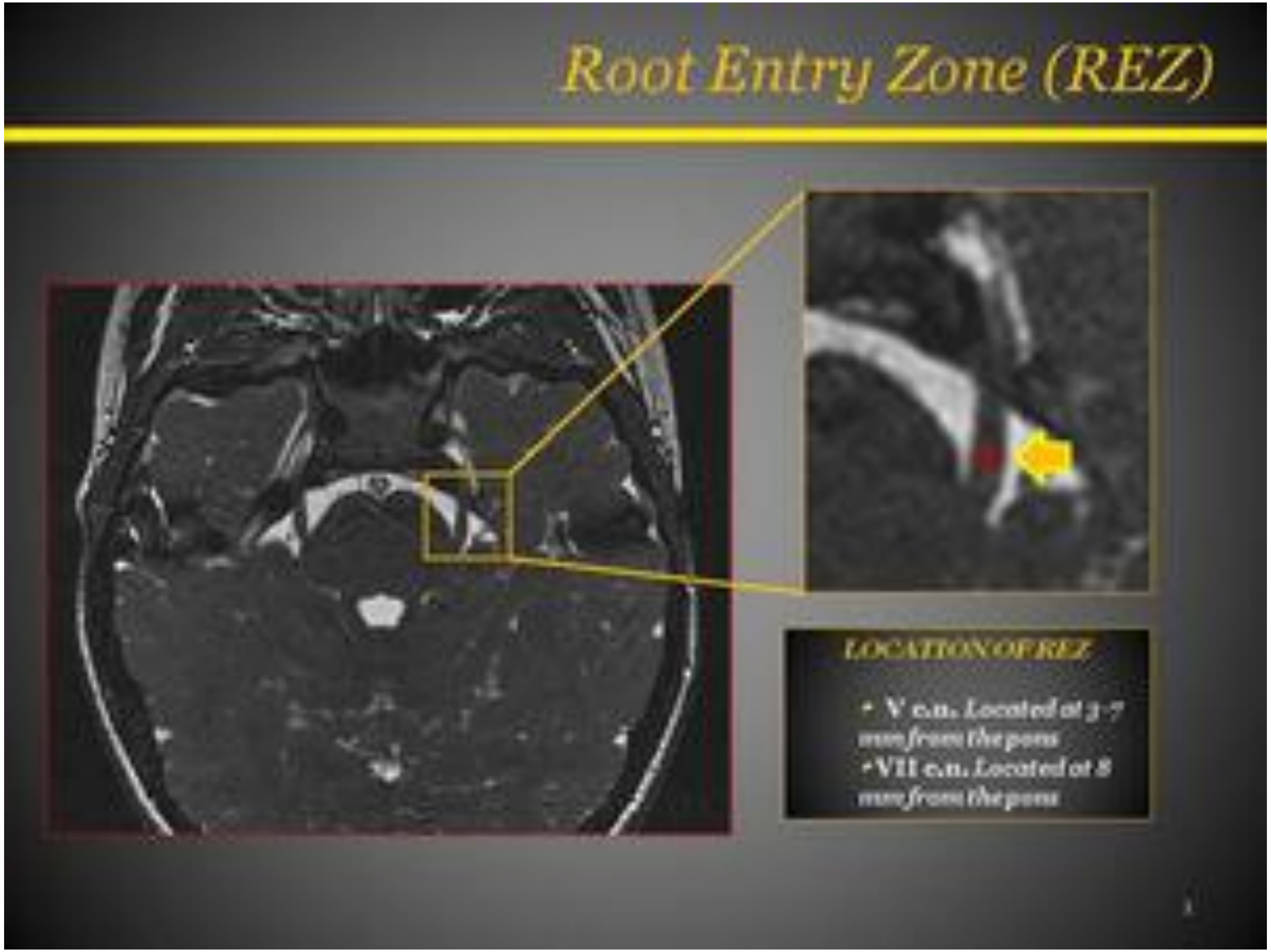




GOOGLE

13th AUGUST 2018/STEROTAXY

ONCOLOGY EDUCATIVE CARTOON/SLIDE -BY DR KANHU CHARAN PATRO, IMAGES & DATA- GOOGLE



THE NEUROVASCULAR CONFLICT

OPTIONS OF TREATMENT TN

1. Medications
2. Percutaneous radiofrequency rhizotomy , glycerol injection
3. Balloon compression
4. microvascular decompression (MVD)
5. Stereotactic radiosurgery (SRS)
6. Among these available techniques, SRS has emerged as the least-invasive procedure, resulting in a significant pain relief with minimal side effects

ALGORITHM

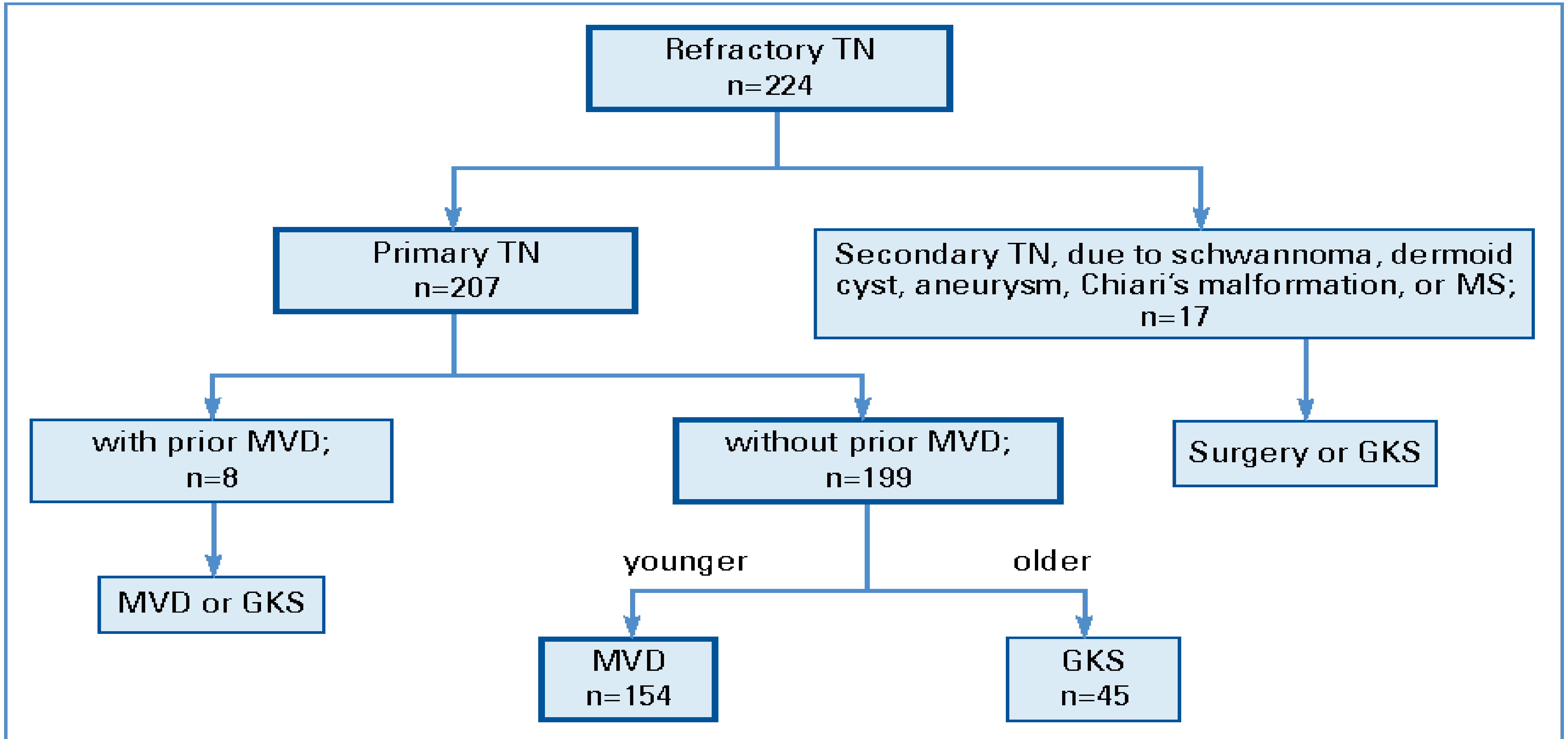
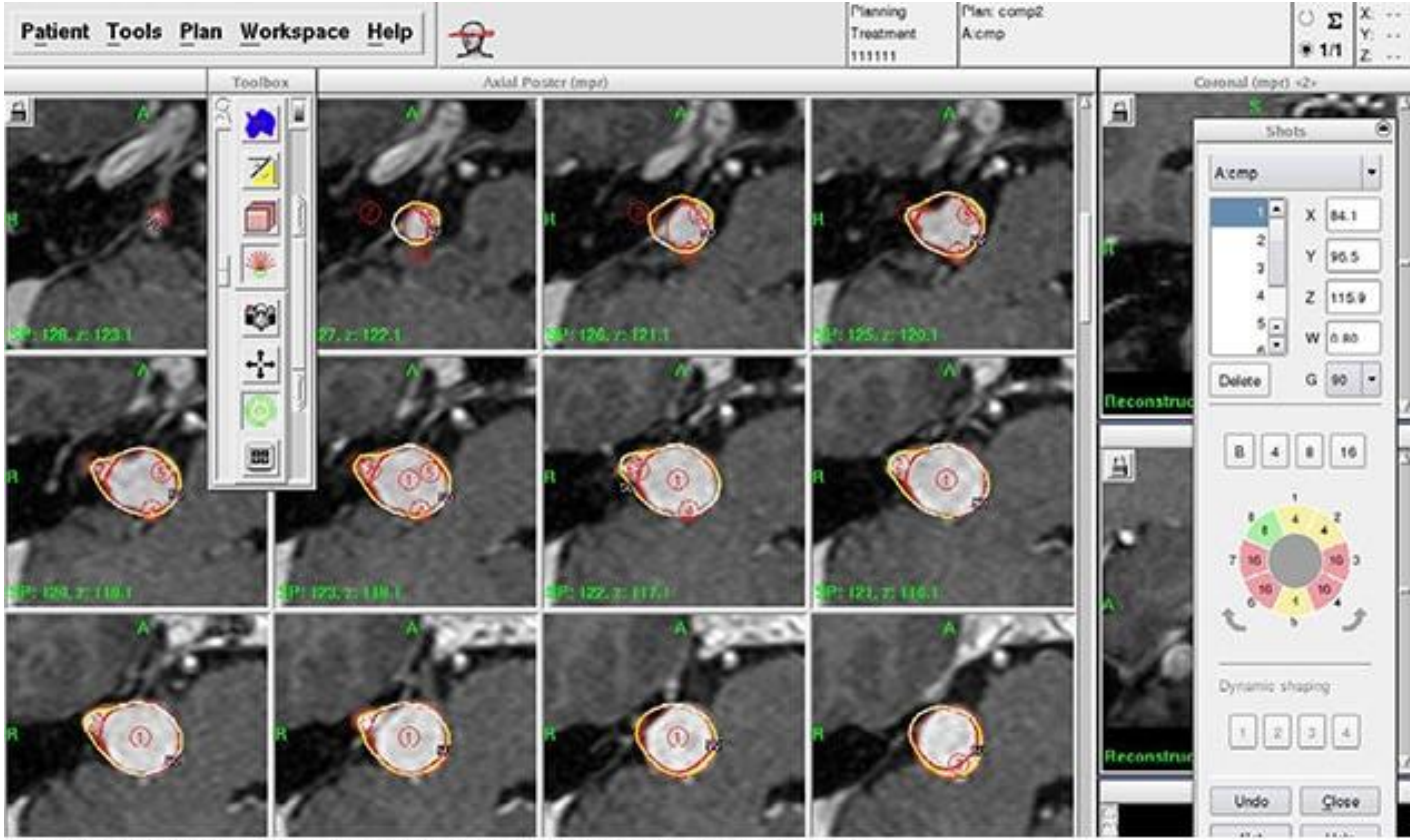


Figure 1 Flow diagram showing the included and excluded criteria of this cohort. GKS, gamma knife


Patient Tools Plan Workspace Help
Planning
Treatment
111111
Plan: comp2
A:cmp
Toolbox
Axial Poster (mpr)
Coronal (mpr) <2>
Shots
A:cmp
X 84.1
Y 96.5
Z 115.9
W 0.80
G 90
Delete
B 4 8 16
Dynamic shaping
1 2 3 4
Undo
Close

LITERATURE REVIEW-TG SRS

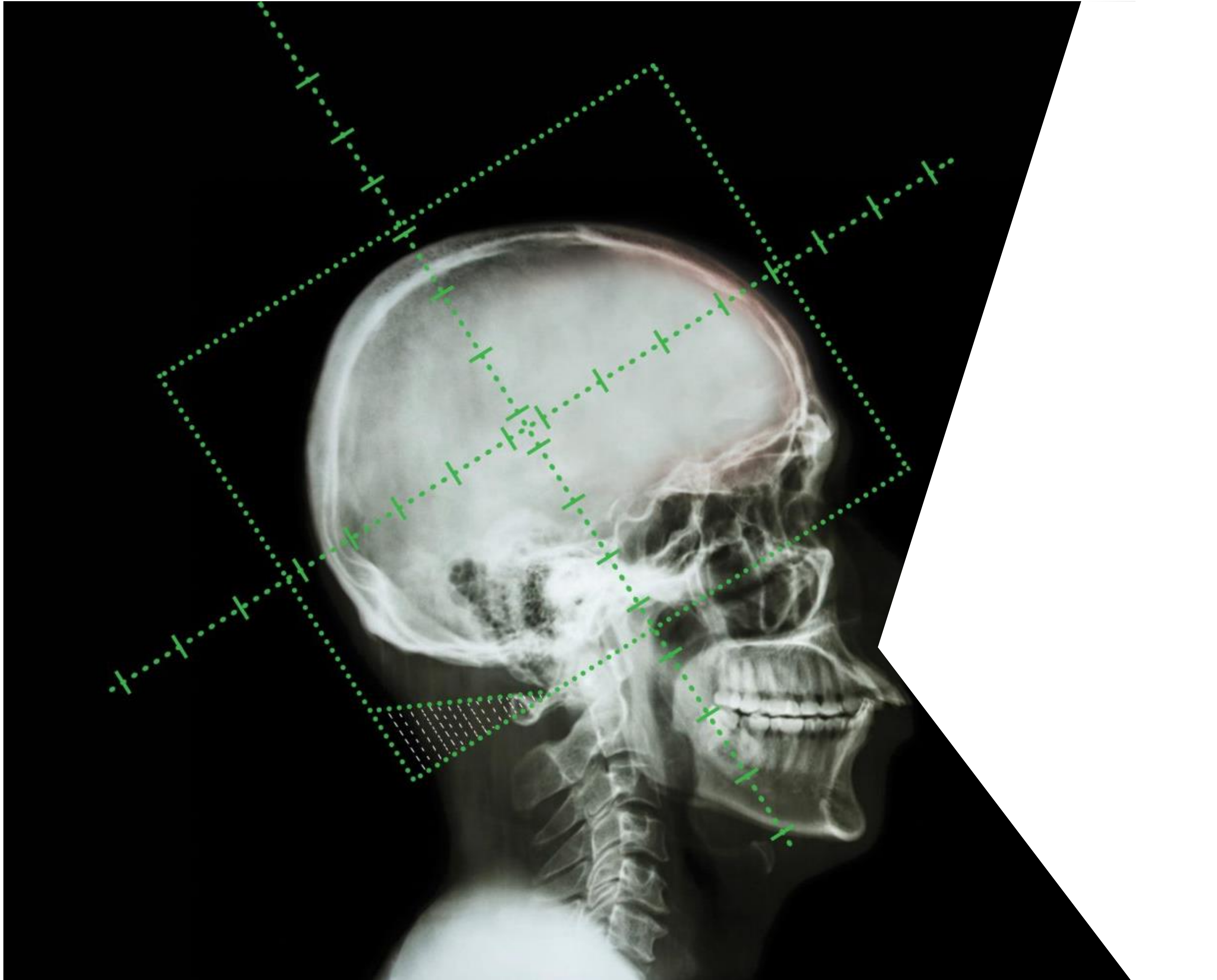
Overview of the recent clinical literature on SRS for trigeminal neuralgia

Author	Institution	Year	# Patients	Dose (Gy)	% Success	% Relapse
Goss[18]	Los Angeles Medical Center, Los Angeles	2003	25	90	100 at 18 months	32 at 8 months
Smith[15]	David Geffen School of Medicine, Los Angeles	2003	41	70 - 90	87 at 23 months	25 at 7 months
Frighetto[13]	David Geffen School of Medicine, Los Angeles	2004	17	90	95 at 21 months	23 at 8 months
Chen[14]	Los Angeles Medical Center, Los Angeles	2004	32	85 - 90	78 at 8 months	N/A
Gorgulho[22]	David Geffen School of Medicine, Los Angeles	2006	37	70 - 90	67 at 13 months	10 at 7 months
Pusztaszeri[21]	Centre Hospitalier Universitaire Vaudois, Lausanne	2007	17	50 - 56	100 at 12 months	29 at 8 months
Chen[16]	Los Angeles Medical Center, Los Angeles	2008	82	85 - 90	85 at 18 months	19 at 18 months
Zahra[17]	Baylor College of Medicine, Houston	2009	20	80 - 90	95 at 14 months	N/A

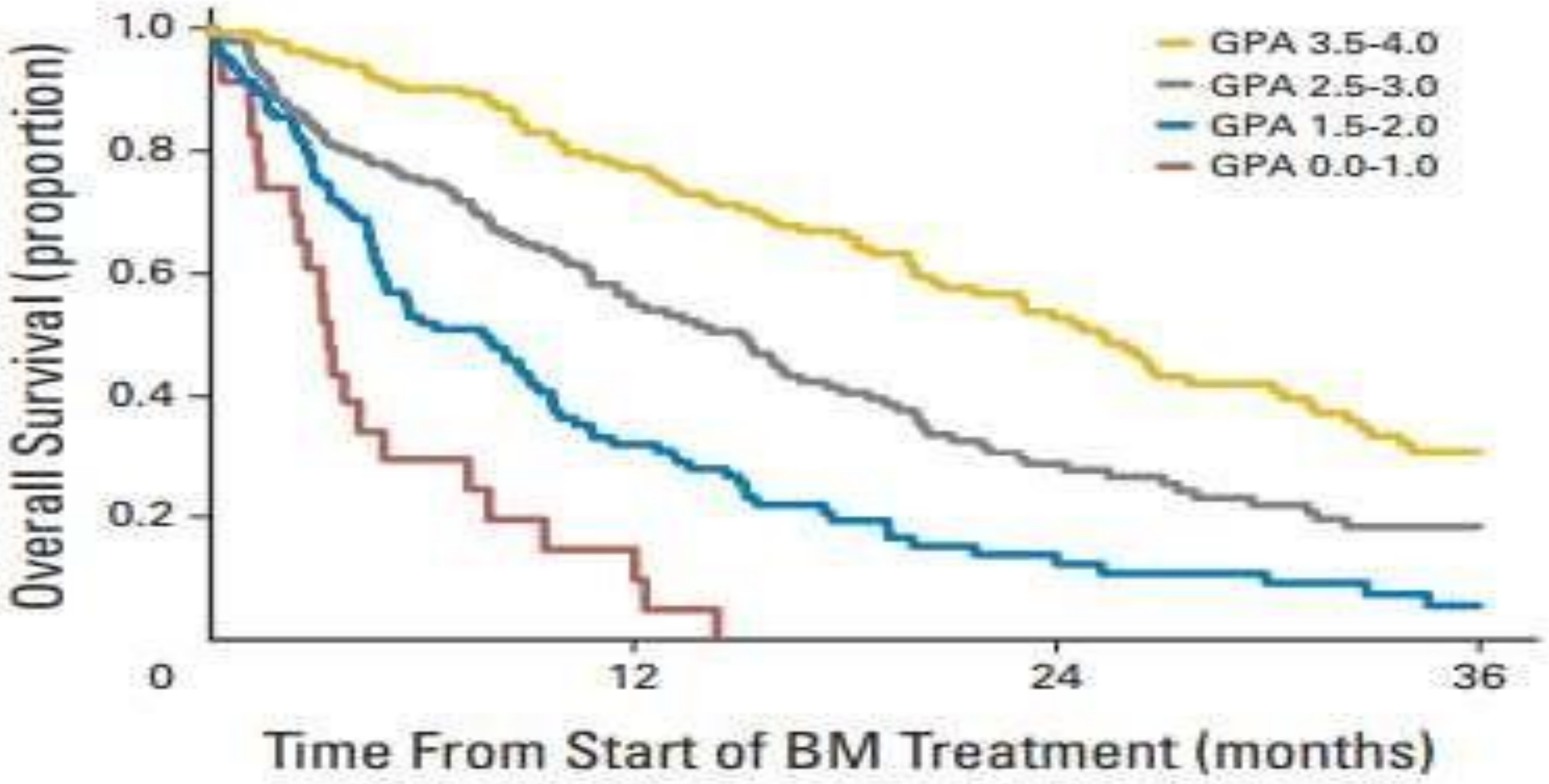
BRAIN METASTASIS

WHOLE BRAIN RADIOTHERAPY

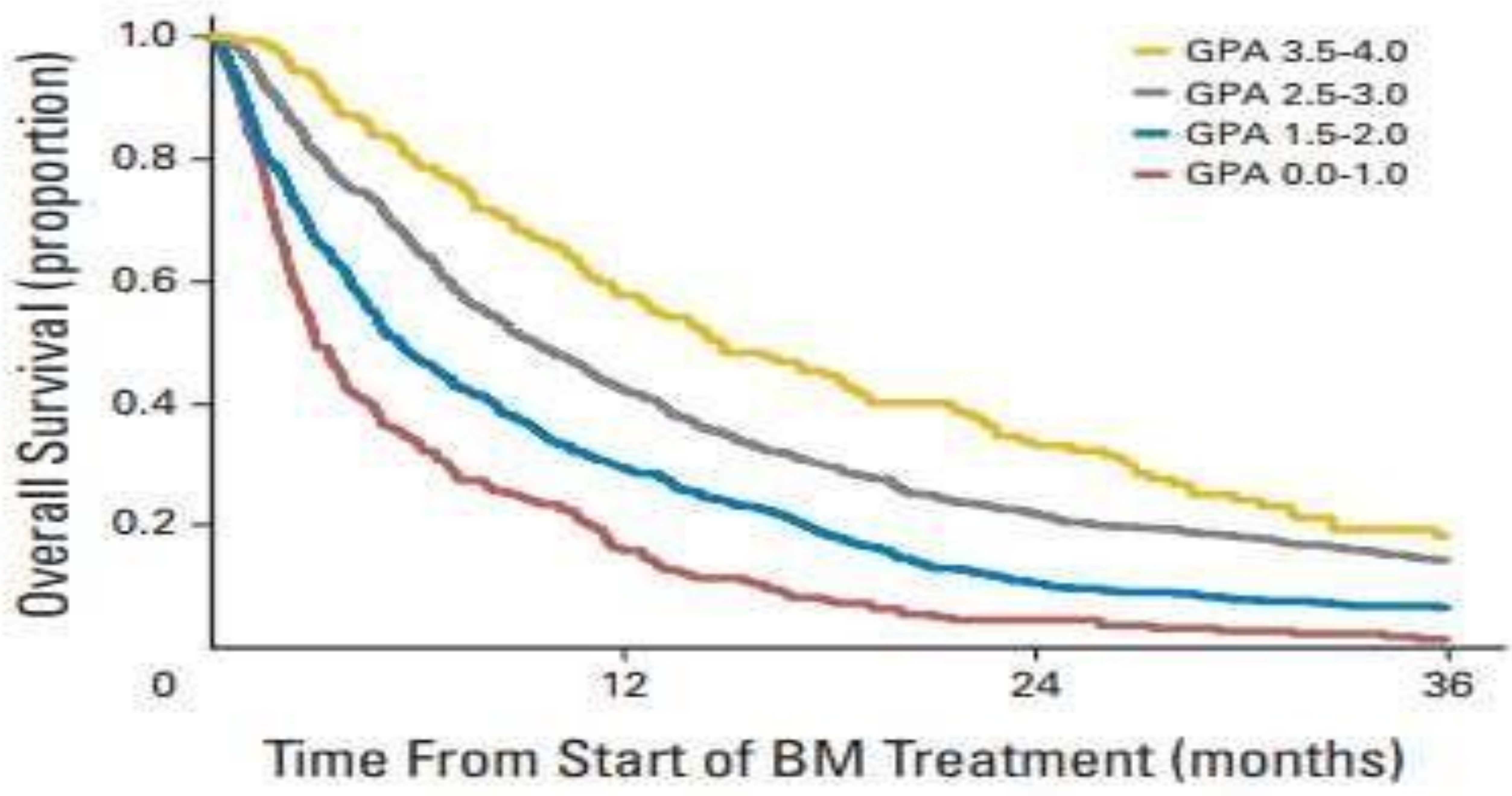
- LONG TERM SURVIVOURS
- COGNITIVE DECLINE
- QOL POOR

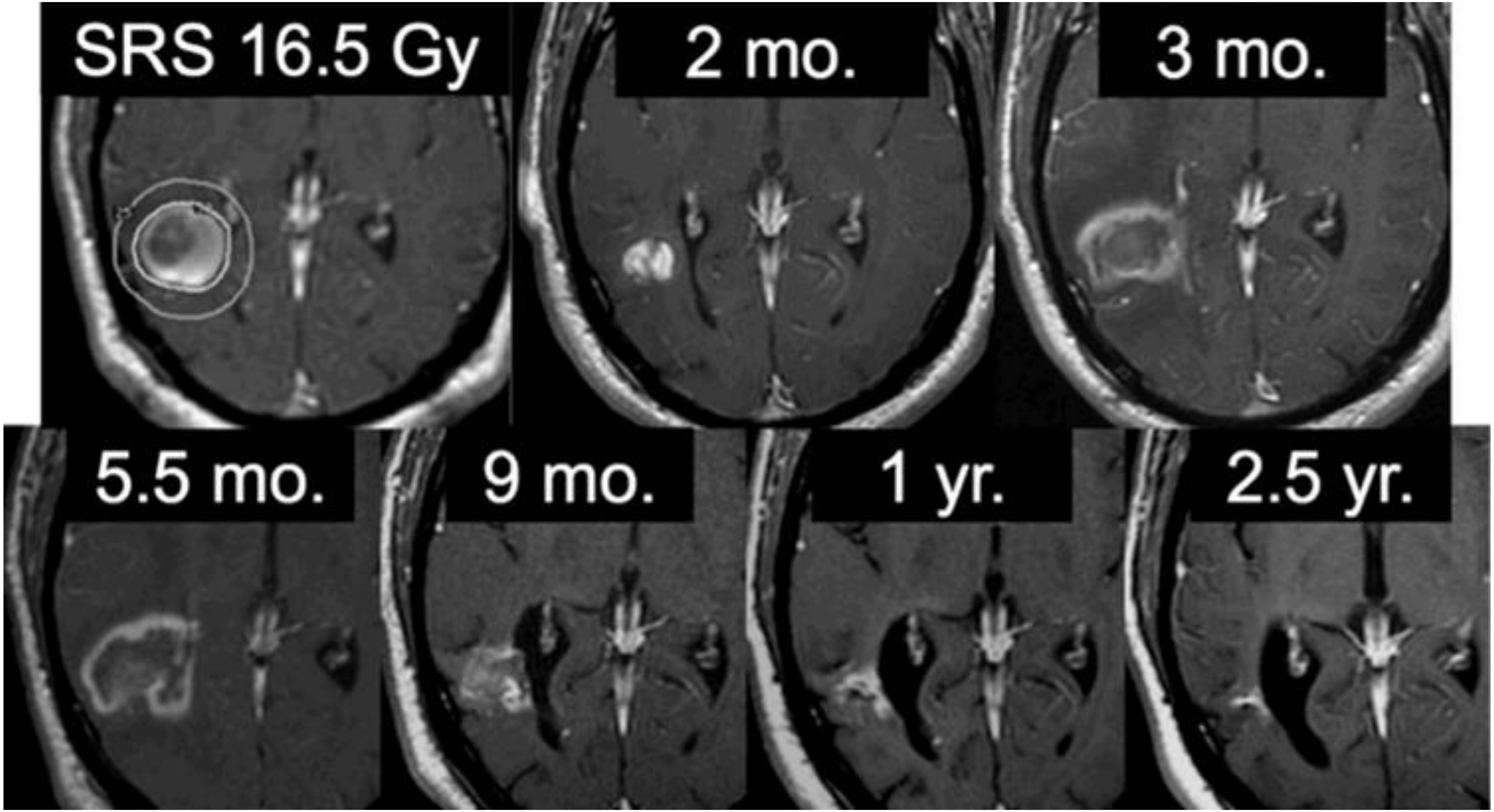


BRAIN METS WITH BREAST CANCER



BRAIN METS WITH LUNG CANCER





SRS 16.5 Gy
2 mo.
3 mo.
5.5 mo.
9 mo.
1 yr.
2.5 yr.

NCCN GIUDELINES BRAIN METS

Limited number (1 – 3) and stable systemic disease then surgery or radiosurgery or whole brain (with RS favored over whole brain) .

Multiple (>3) then whole brain or radiosurgery (consider RS if good performance and low overall tumor burden).

PITUITARY ADENOMAS

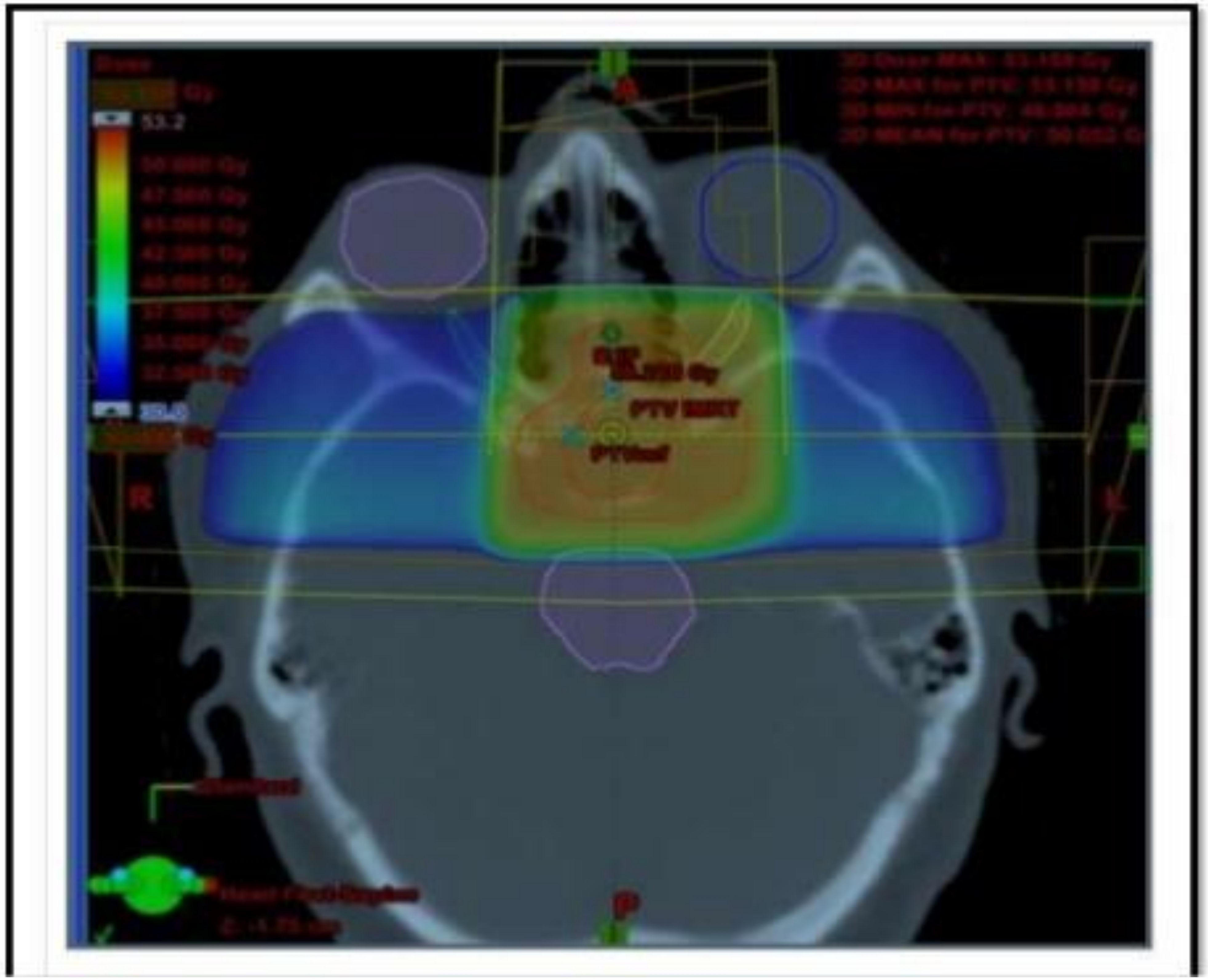
PITUITARY ADENOMAS

On the evidence available**, no data support the superiority of SRS over FSRT** for the treatment of patients with pituitary tumors.

Dose and fractionation are usually chosen on the basis of the size and **position of the pituitary adenoma.**

In current clinical practice, single-fraction SRS at doses of 16–25 Gy may represent a convenient approach to patients with a relatively small pituitary adenoma away from the optic chiasm, whereas FSRT is preferred over **SRS for lesions >2.5–3 cm in size and/or involving the** anterior optic pathway

CLASSICAL 2D PLAN



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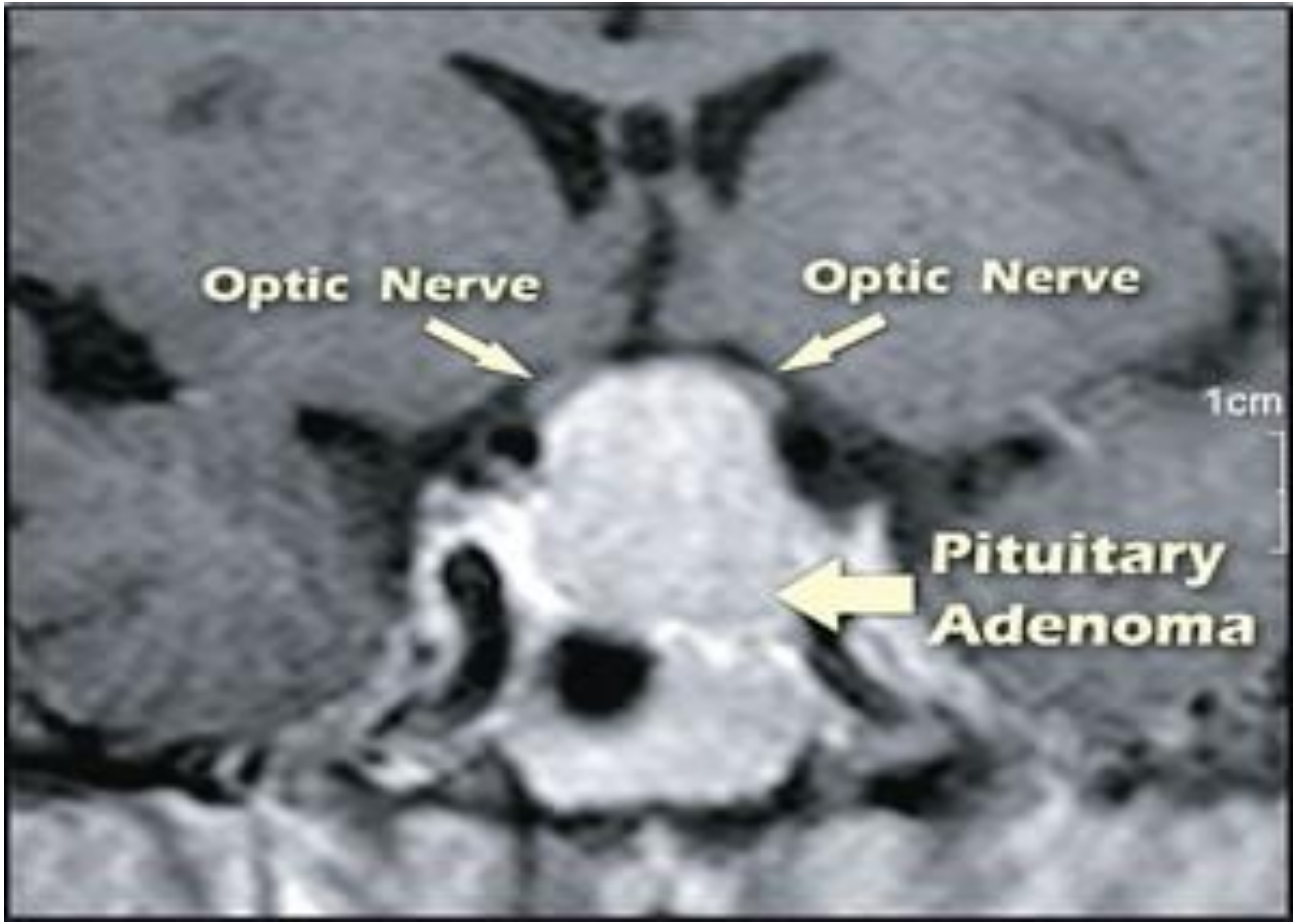
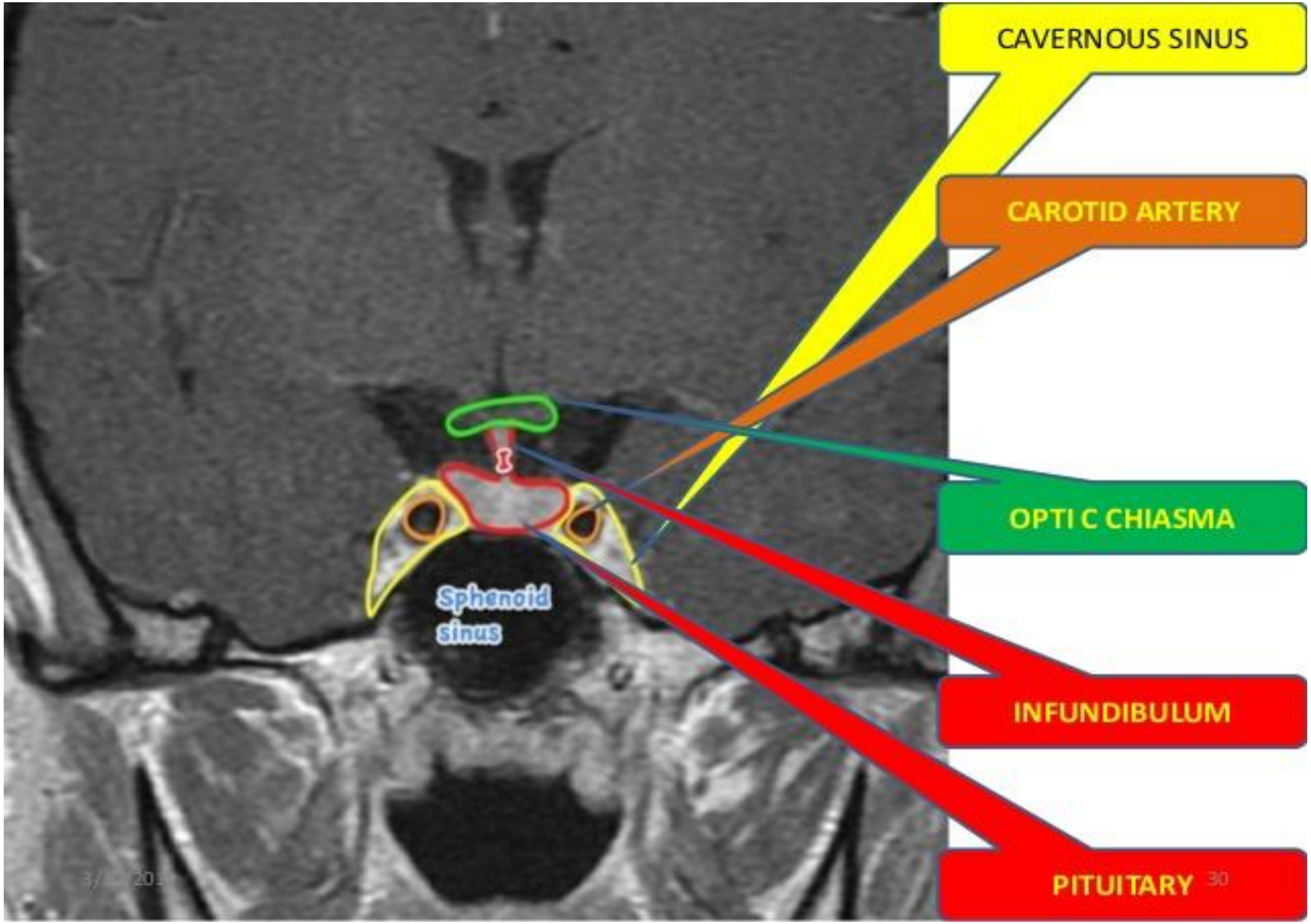
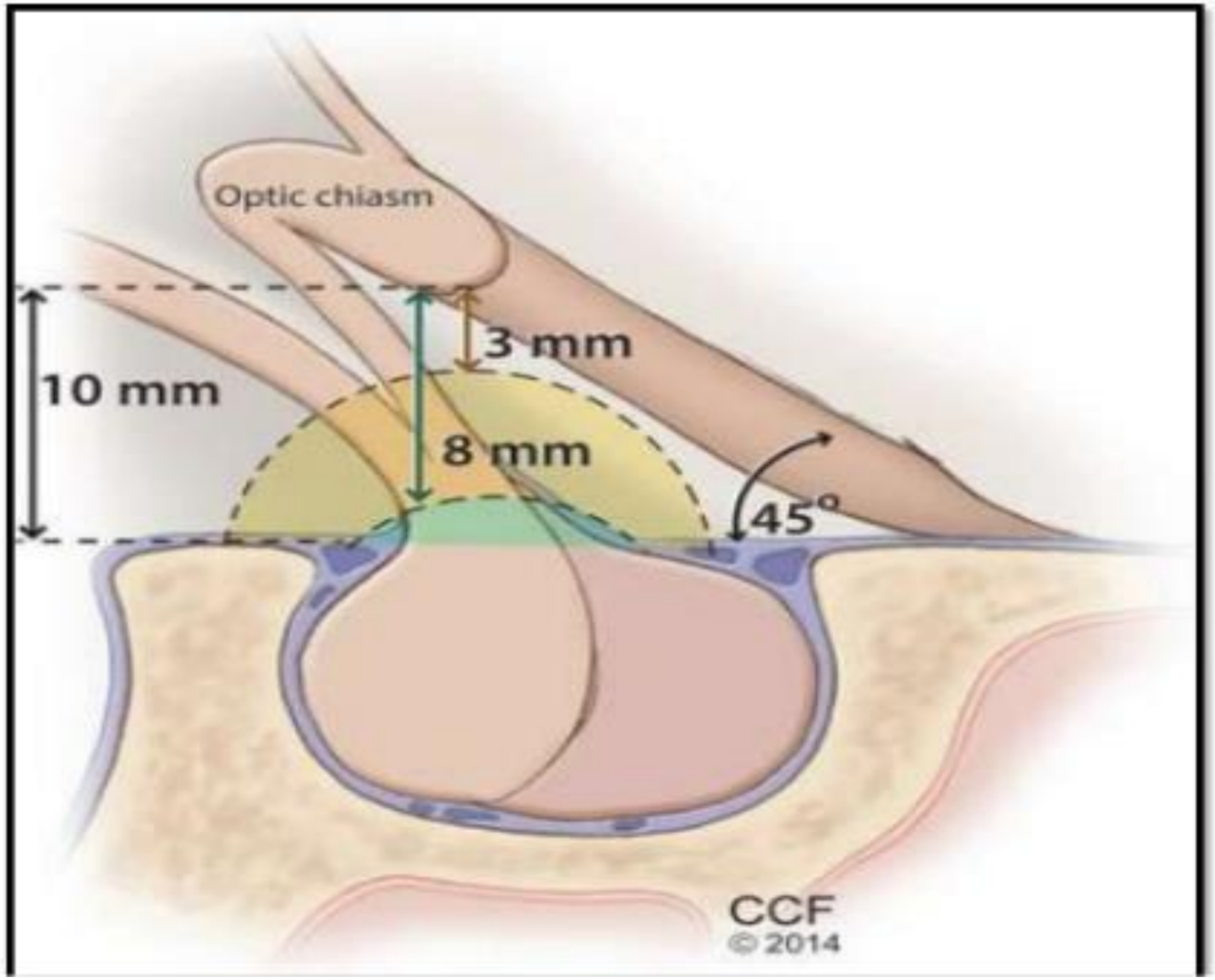

Optic Nerve
Optic Nerve
1cm
Pituitary
Adenoma


CAVERNOUS SINUS
CAROTID ARTERY
Sphenoid sinus
OPTI C CHIASMA
INFUNDIBULUM
PITUITARY
30

THE DISTANCE



3/30/2019

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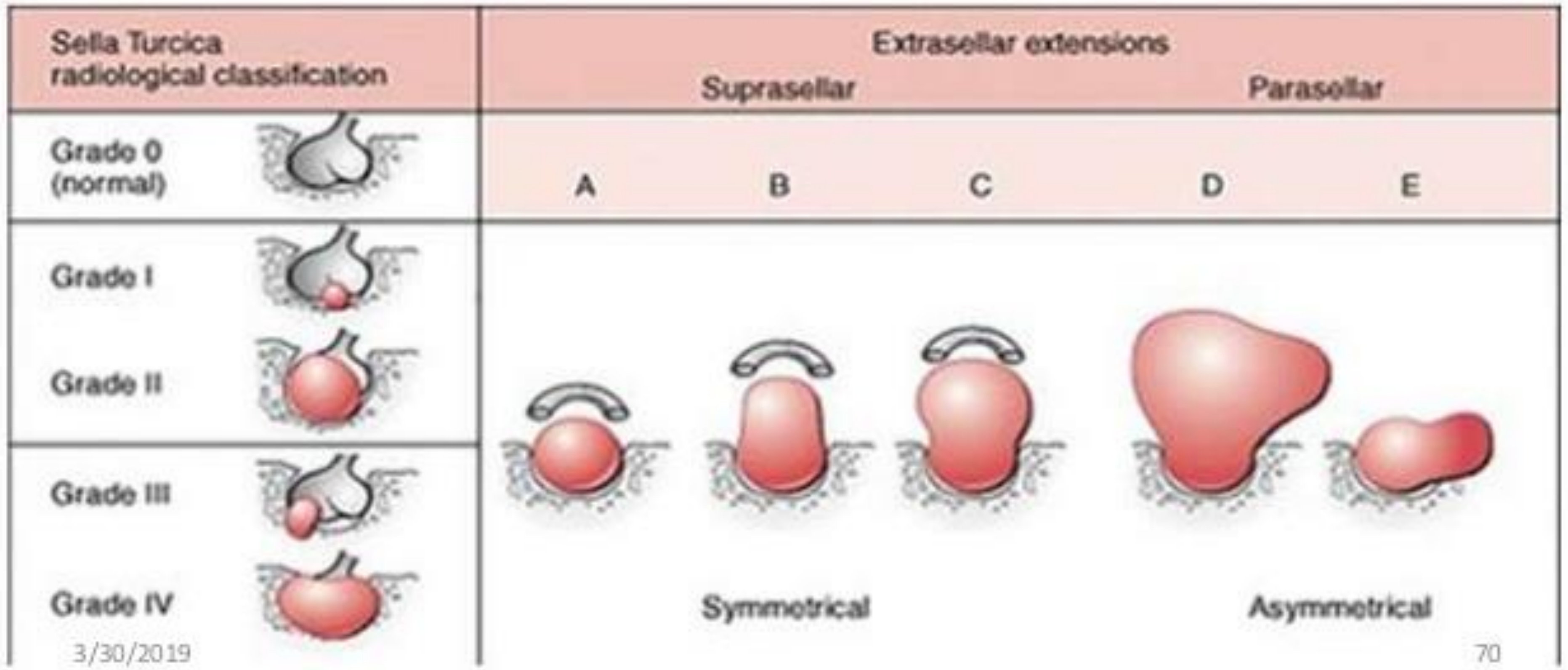
HARDY'S CLASSIFICATION

Hardy's classification of pituitary adenomas. Grades I and II are enclosed within the sella. Grades III and IV are invasive. Extrasellar classifications A, B, and C are increasing amounts of direct suprasellar adenomas. D is asymmetric extension, and E is lateral extension into the cavernous sinus. (Adapted from Hardy J, Somma M. 1979).



CONSIDERATION OF STEREOTAXY

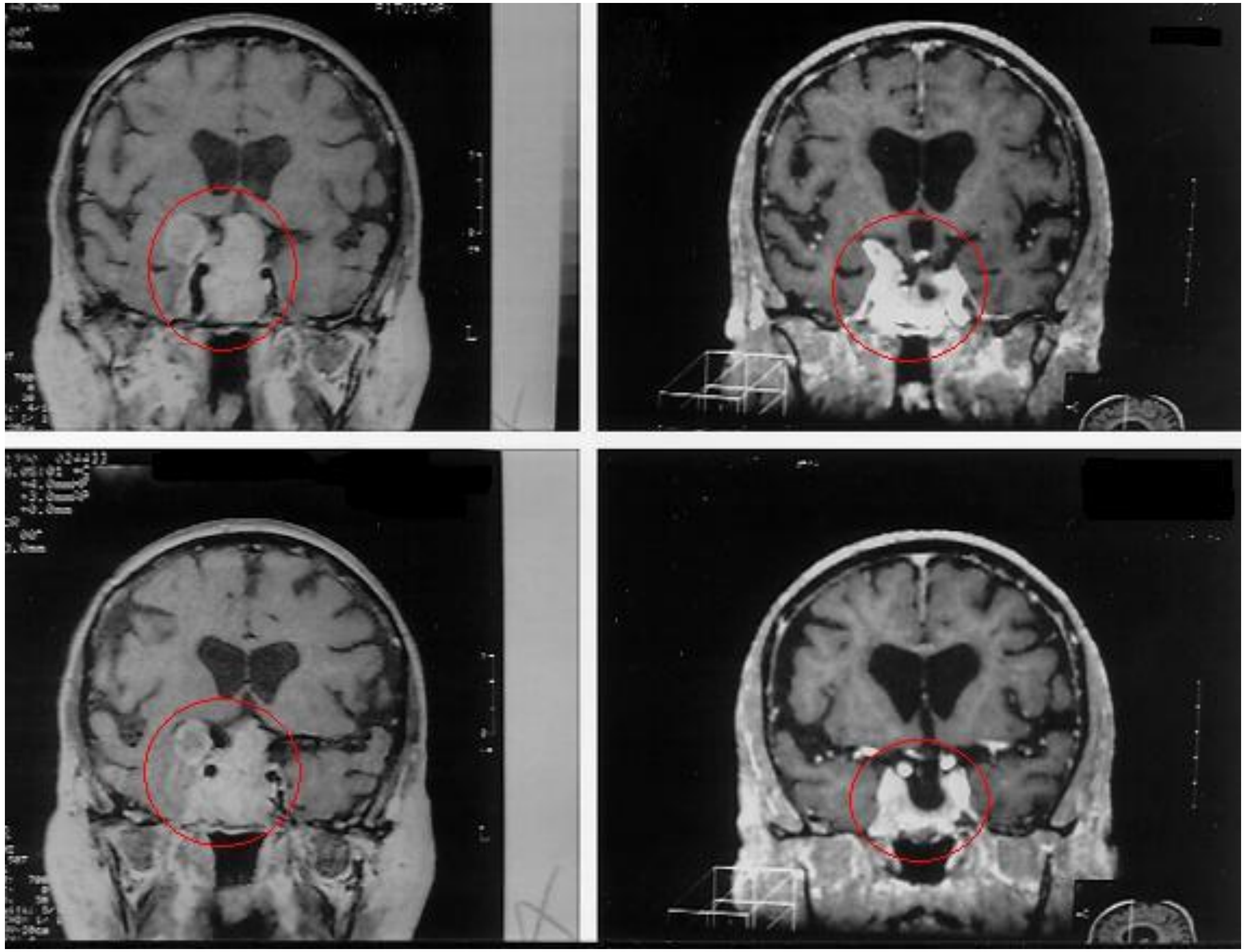
1. Commonly not practiced
    1. Conventional results are best
    2. Close proximity to chiasm
2. Functional tumors need higher dose16–25 Gy in a single fraction prescribed to at least the 50 % isodose line. Higher doses are preferred
3. Nonfunctional tumors: 14–16 Gy in a singlefraction prescribed to at least the 50 % isodose line,
4. Fractionated radiation therapy is recommended for tumors in close proximity to the optic chiasm (3 mm) or with marked extension into the cavernous sinus

FSRT FOR PITUITARY

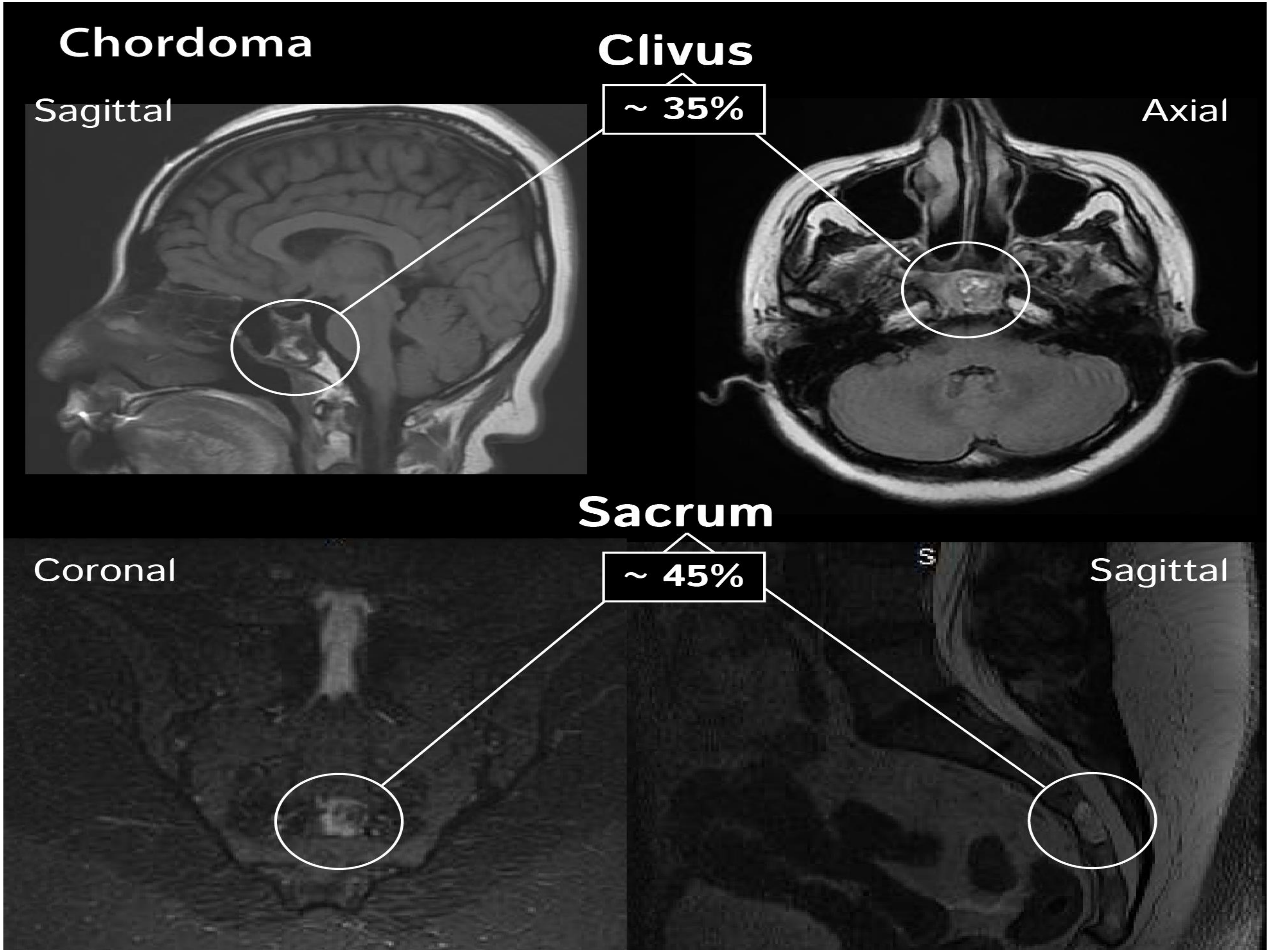
- Stereotactic radiotherapy originally referred to radiotherapy treatment delivered to an intracranial target lesion that was located by stereotactic means in a patient immobilised in a neurosurgical stereotactic head frame. **The improved patient immobilisation, more accurate**
- Tumour target localisation using cross-sectional image for treatment planning, and high precision radiation treatment delivery to the tumour target, enabled a **reduction in the margins** around the radiotherapy target volume (the GTV to PTV margin), therefore achieving greater sparing of surrounding normal tissues than can be obtained with standard CRT techniques

SCRT VS SRT

- While SCRT is suitable for the treatment of all pituitary tumours, irrespective of size, shape or proximity to critical normal tissue structures,
- SRS is only suitable for treatment of small tumours away from the optic chiasm




CHORDOMA


Chordoma
Clivus
~ 35%
Sagittal
Axial
Sacrum
~ 45%
Coronal
Sagittal
S

CHORDOMA CASE SELECTION

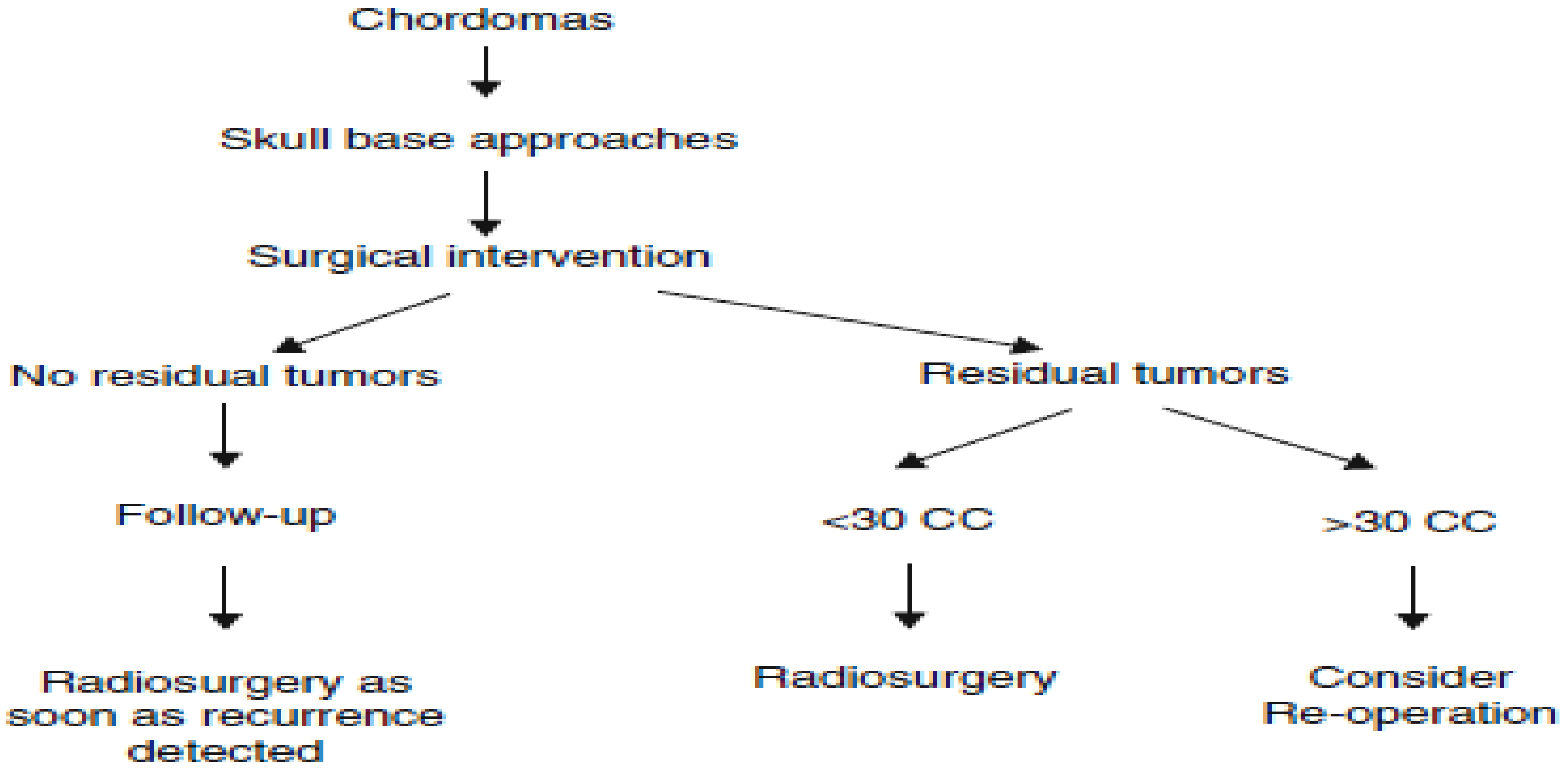


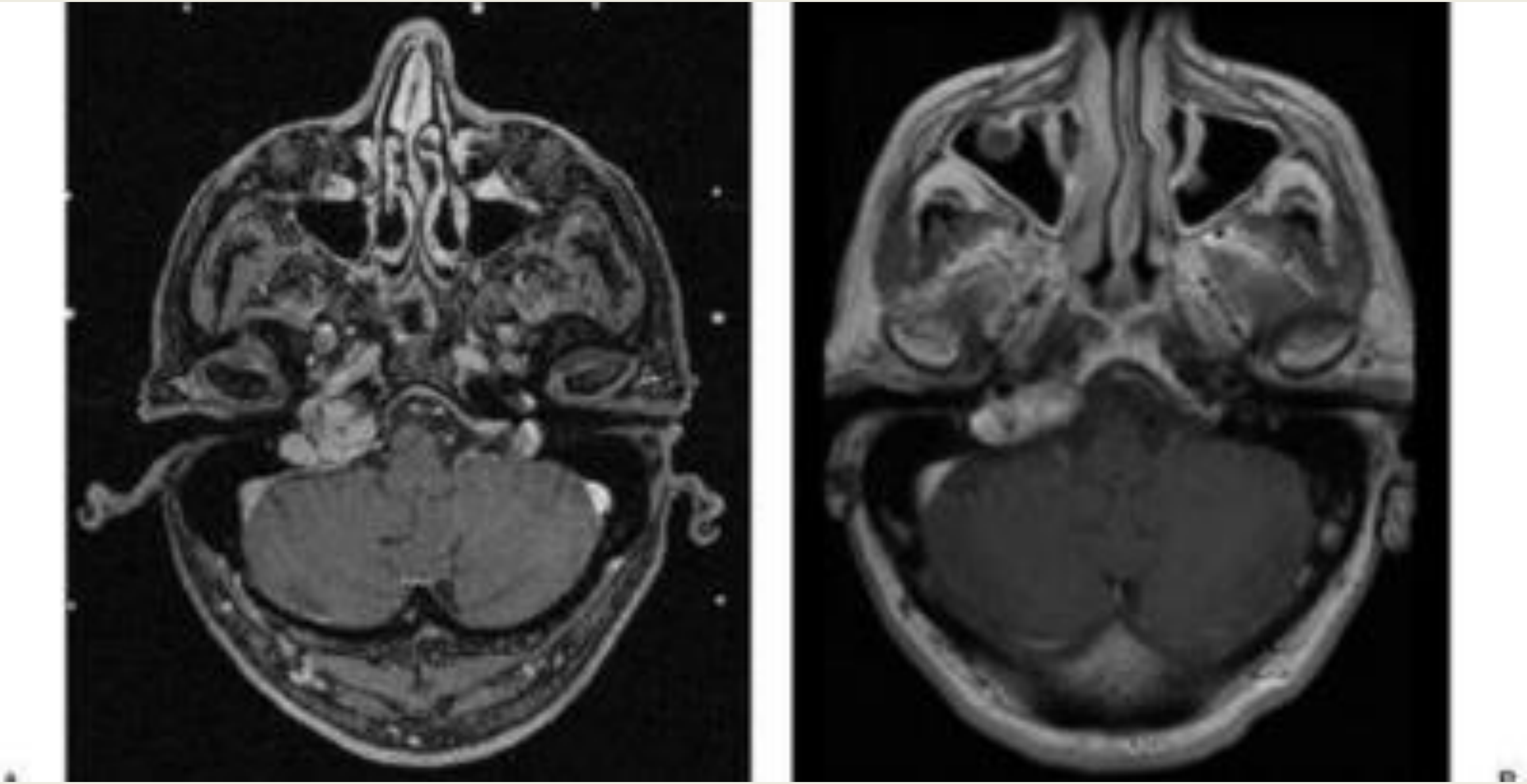
Fig. 38.1 Radiosurgical management algorithm for skull base chordomas according to Pamir et al. [83]. Should re-operation not be possible, high-dose particle beam therapy or IMRT should be recommended

CHORDMA SERIES

Table 38.5 Radiosurgical literature on chordoma and chondrosarcoma

Author	N	Median follow-up (range)	Median peripheral dose in Gy (range)	Local control* (%)	Morbidity	Comments
Krishnan et al. [107]		4.8 years (0.8–11.4)	15 (10–20)			
Chordoma	25			32‡	34 % (all with combined EBRT)	
Chondrosarcoma	4			100		
Feigl et al. [82]		17 months (6–36)†	17 (14–18)†			
Chordoma	3			33	Cranial nerve deficits, headaches, diplopia	
Chondrosarcoma	10			100		
Pamir et al. [89]		23.3 months (NA)†	NA	29	NA	
Chordoma	7					
Chang et al. [108]§		4 years (1–9)†	19.4 (18–24)†			
Chordoma	10			80‡	None	
Hauptman et al. [85]	5	4.5 years	15.5 (to 90 % isodose line)	60	Cranial neuropathy, visual deficits	
Koga et al. [84]	14	65 months (12–167)	15 (10–20)			Local relapse in all cases of Radiosurgery after fractionated xRT, Marginal doses of >16 Gy crucial
Chordoma	10	40.5 (12–167) months	13.7 (10–20)	15	1 transient visual deficit	
Chondrosarcoma	4	20 (45–145) months	15.5 (12–20)	100	1 transient visual deficit	
Martin et al. [109]		7.7 years (2–17)	16.5 (10–25)			
Chordoma	18	88 months		62.9‡	1 transient effect	
Chondrosarcoma	10	88 months		80‡		
Hasegawa et al. [110]		59 months (1–172)	14 (9–20)	80‡	1 worsening of facial numbness	Under 20 mL volume sig. better LC, at least 15 Gy marginal dose required
Chordoma	30			0.72		
Chondrosarcoma	7					

GLOMUS JUGULARAE



GLOMUS JUGULARAE

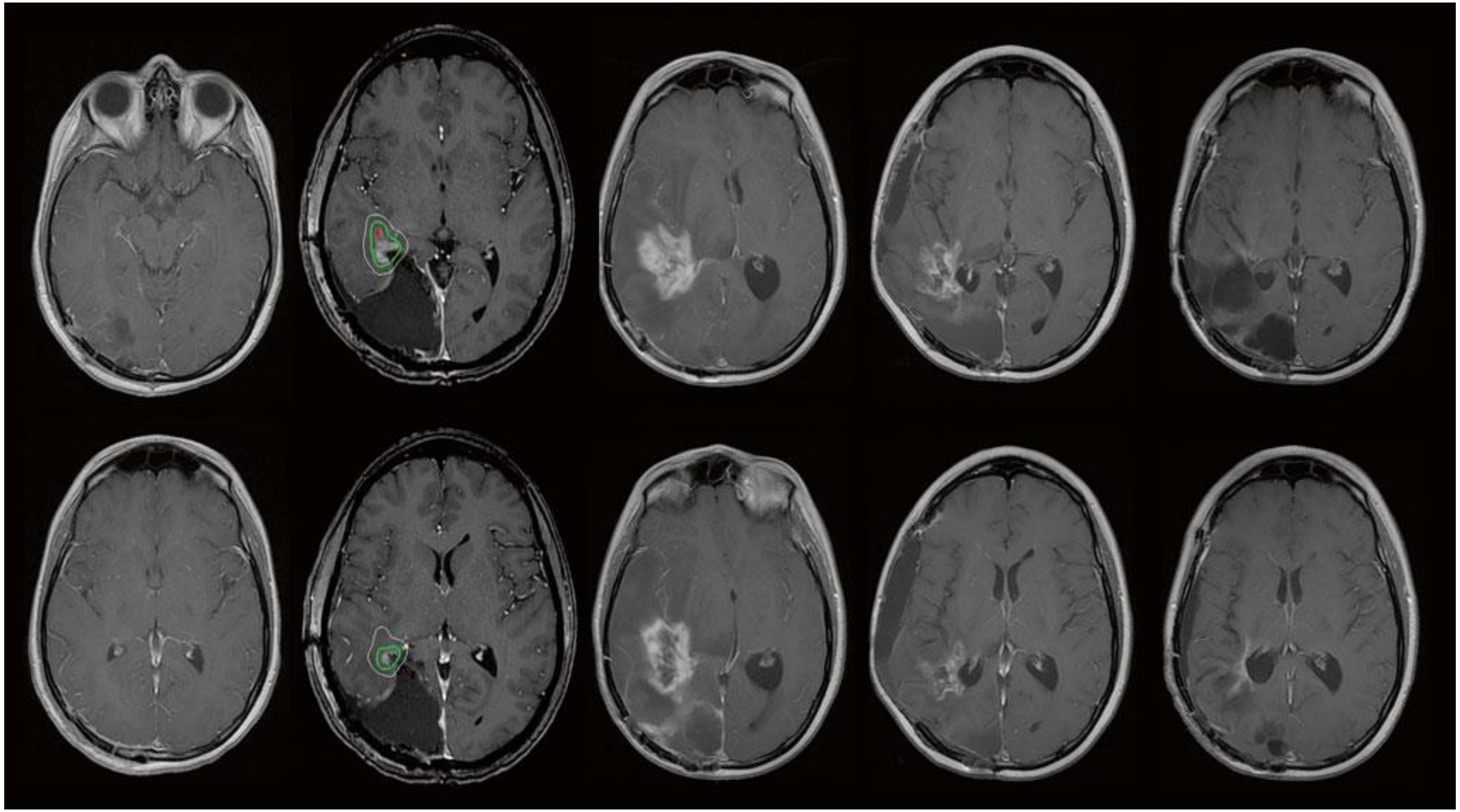
Table 38.6 Side effects of radiosurgery

Author	*N*	Median follow-up (range)	Median peripheral dose (range)	Local control[a]	Morbidity	Comments
Jordan et al. [82]	8	27 months (9.7–102)[b]	16.3 Gy (12–20)[b]	1	Acute vertigo (1 patient)	
Foote et al. [89]	25	37 months (11–118)	15 Gy (12–18)	1	Late vertigo (1 patient)	8 decreased in size
Eustacchio et al. [111]	19	7 years (1.5–10)	14 Gy (12–20)	0.95	None	
Maarouf et al. [83]	12	4 years (0.8–9)	15 Gy (11–20)	1	Moderate facial palsy (1 patient)	8 decreased in size
Liscak et al. [88]	52	24 months (4–70)	16.5 Gy (10–30)	1	Tinnitus (2 patients)	Tumor size decreased in 40 %
Gottfried et al. [112][c]	142	39.4 months[b]		0.98	8.5 % morbidity	
Pollock et al. [113]	42	44 (6–149 months)	14.9[b](	0.98	15 % new deficits (4× hearing loss, 2× vocal cord paralysis, temporary imbalance/vertigo ×1	
Hurmuz et al. [96]	14	39 months (7–60)	25 (18–30) (in 1–5 fractions)	1	None	Tumor regression in 6

[a]Crude local control rates
[b]Mean values
[c]Literature review

GLIOMA RECURRENCE

GLIOMA RECURRENCE-REIRRADIATION



18 Gy SRS salvage

Clinical Article

J Korean Neurosurg Soc 61 (4) : 516-524, 2018
https://doi.org/10.3340/jkns.2017.0259
pISSN 2005-3711 eISSN 1598-7876

Efficacy of Gamma Knife Radiosurgery for Recurrent High-Grade Gliomas with Limited Tumor Volume

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Objective : This study aims to determine whether gamma knife radiosurgery (GKR) improves survival in patients with recurrent high-grade gliomas.

Methods : Twenty nine patients with recurrent high-grade glioma underwent 38 GKR. The male-to-female ratio was 10 : 19, and the median age was 53.8 years (range, 20–75). GKR was performed in 11 cases of recurrent anaplastic oligodendrogliomas, five anaplastic astrocytomas, and 22 glioblastomas. The median prescription dose was 16 Gy (range, 10–24), and the median target volume was 7.0 mL (range, 1.1–15.7). Of the 29 patients, 13 (44.8%) received concurrent chemotherapy. We retrospectively analyzed the progression-free survival (PFS) and overall survival (OS) after GKR depending on the Eastern Cooperative Oncology Group (ECOG) performance status (PS), pathology, concurrent chemotherapy, radiation dose, and target tumor volume.

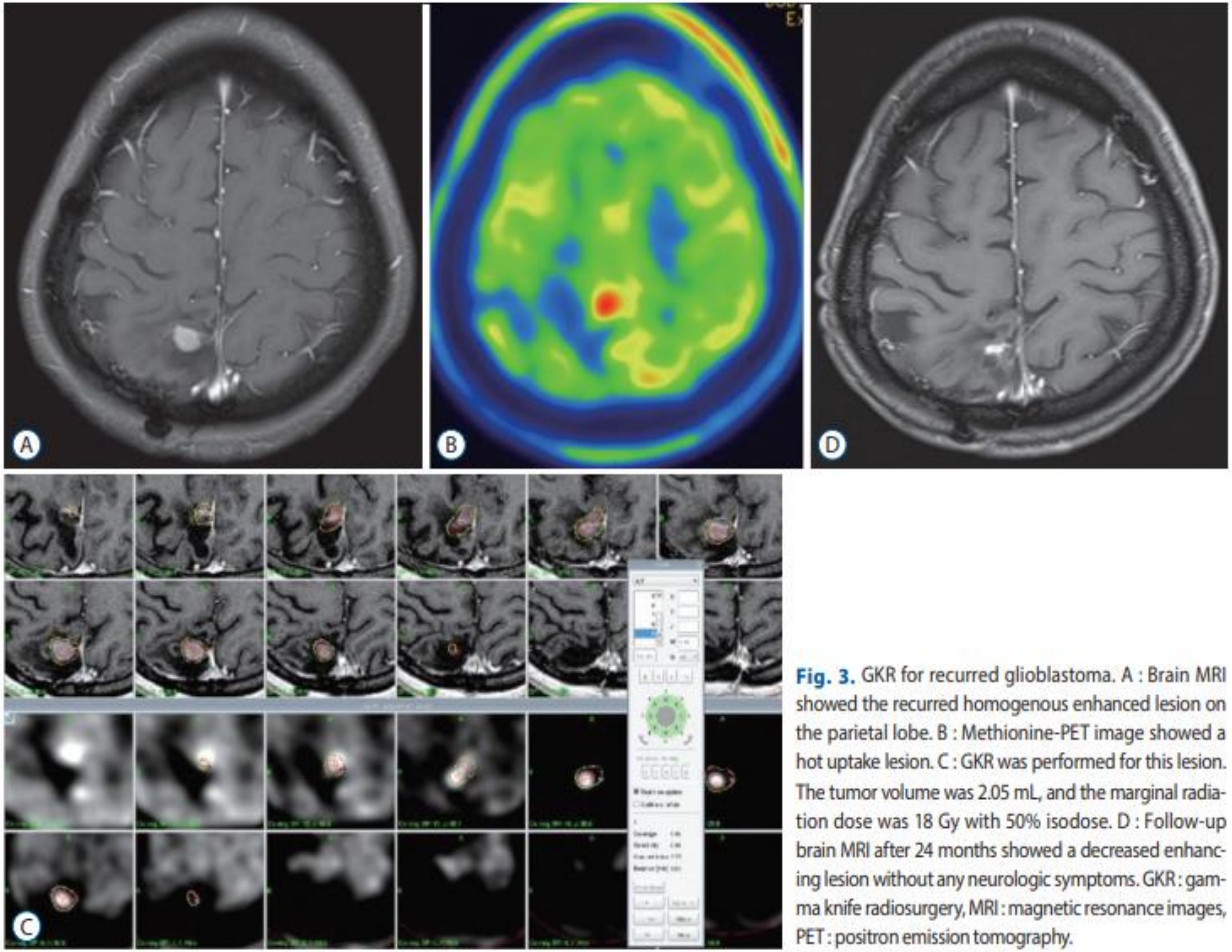


Fig. 3. GKR for recurred glioblastoma. A : Brain MRI showed the recurred homogenous enhanced lesion on the parietal lobe. B : Methionine-PET image showed a hot uptake lesion. C : GKR was performed for this lesion. The tumor volume was 2.05 mL, and the marginal radiation dose was 18 Gy with 50% isodose. D : Follow-up brain MRI after 24 months showed a decreased enhancing lesion without any neurologic symptoms. GKR : gamma knife radiosurgery, MRI : magnetic resonance images, PET : positron emission tomography.

CNS -SRS RADIATION DOSES

DISEASE		DOSE
AVM-[Chang TC/IJROBP/2012]		12-24Gy
ACOUSTIC NEUROMA-[Steve Braunstein/Cancer Manag Res/2018]		12Gy
PITUITARY ADENOMA [Gi. Minniti/Rep Pract Oncol Radiother/2016]	FUNCTIONAL	16-25Gy
	NON FUNCTIONAL	15-16Gy
BRAIN METASTASIS-[RTOG 9505]	2cm	24Gy
	2.1 – 3cm	18Gy
	3.1 - 4cm	15Gy
TRIGEMINAL NEURALGIA-[Pokhrel D/J Appl Clin Med Phys./2017]		80-90Gy
MENINGIOMA-[POLLOCK BE/NEUROSURGERY/2012]		15-16Gy
GLOMUS JUGULARAE-[Faycal El Majdoub/PLOS/2015]		15-16Gy
CHORDOMA-[Juan J. Martin/JNS/2007]		15-16Gy
REIRRADIATION GLIOMA-[Young-Jun Cheon/J Korean Neurosurg/2018]		12-24Gy
CRANIOPHARYNGIOMA-[Tatsuya Kobayashi/Nagoya J Med Sci/2015]		13-20Gy

LITERATURE COLLECTION

29th JULY 2019/STEREOTAXY

ONCOLOGY EDUCATIVE CARTOON/SLIDE -BY DR KANHU CHARAN PATRO, IMAGES & DATA- GOOGLE

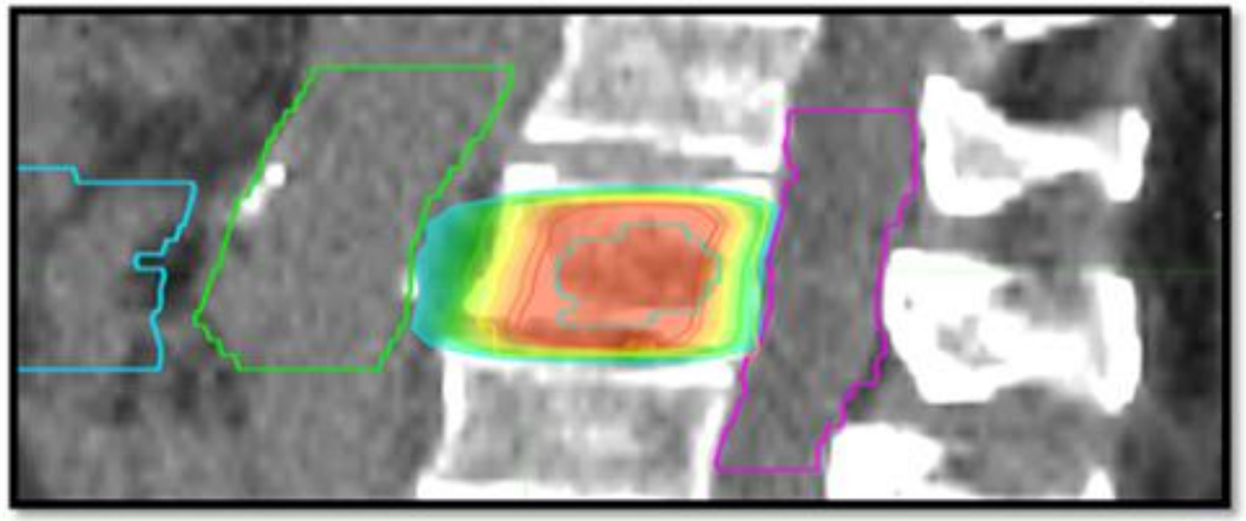
SBRT FOR VERTEBRAL HEMANGIOMA

12 Gy single dose Stereotactic Body Radiotherapy seem to be very effective in the management of symptomatic vertebral hemangioma

2002 to 2006 /13 patients

12 Gy with at least 6 coplanar or non-coplanar beams limiting the maximal dose to medulla to 8 Gy

2 cervical, 7 dorsal and 5 lumbar vertebrae, no one had medullar compression and no bleeding history



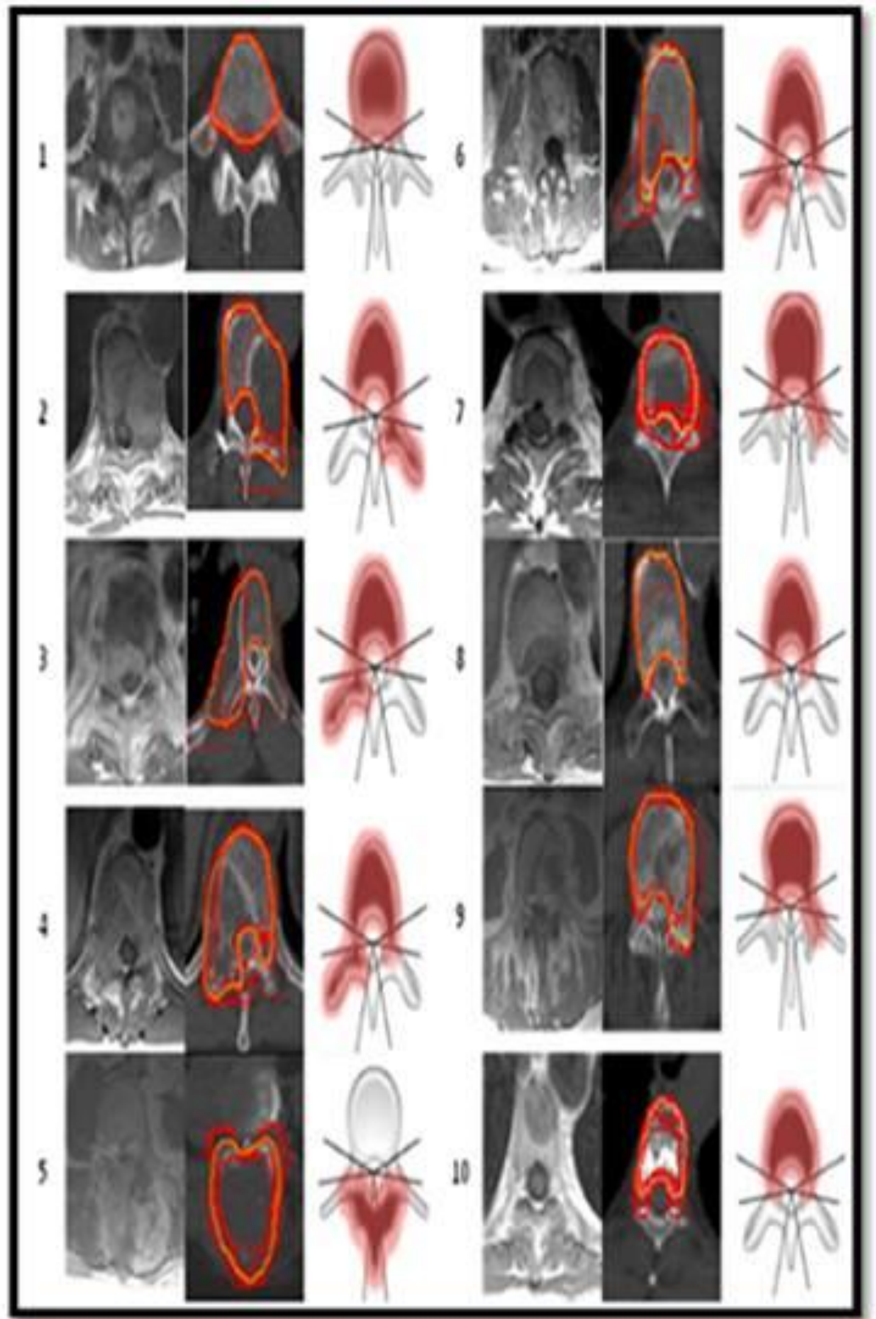
At this moment 10 patients (76,9%) and 11 localitations (78,5%) are with complete pain remission

L. Larrea/ijrobp/Supplement, 2007

4th JULY 2018/BENIGN

ONCOLOGY EDUCATIVE CARTOON/SLIDE -BY DR KANHU CHARAN PATRO, IMAGES & DATA- GOOGLE

VOLUME FOR SPINAL SBRT-ISRC RECOMMENDATIONS



1. GTV include the complete extent of the gross metastatic tumor using all available clinical information and imaging modalities, including MRI, CT, myelography, plain films, & pet,
2. CTV should include abnormal marrow signal suspicious for microscopic invasion and an adjacent normal bony expansion to account for subclinical tumor spread.
3. No epidural CTV expansion is recommended without epidural disease.
4. As a general rule, the entire vertebral body, pedicle, transverse process, lamina, or spinous process was included in the CTV if any portion of these regions contained the GTV. Additionally, the next adjacent normal marrow space was typically included in the bony CTV.
5. Circumferential CTVs encircling the cord should be used only when the vertebral body, bilateral pedicles lamina, & spinous process are all involved or there is extensive metastatic disease along the circumference of the epidural space.
6. NO PTV

BRETT W. COX/IJROBP/2012

13TH MARCH 2017/SPINAL SBRT

ONCOLOGY EDUCATIVE CARTOON/SLIDE -BY DR KANHU CHARAN PATRO, IMAGES & DATA- GOOGLE


Breast
Head/Neck
Intracranial
Pancreas
Lung
Liver
Spine
Prostate

THANK YOU