Newer Radiotherapy Techniques- SRS/ SRT, Gamma knife/ X-knife, Cyber knife

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Definitions

"Stereo": Greek: Solid or 3 dimensional "tact" Latin: To touch: Greek "taxic" an arrangement

Stereotactic: 3 dimensional arrangement to touch

Stereotactic Radiosurgery (SRS): Stereotactically directed conformal radiation in a single fraction

Stereotactic Radiation Therapy (SRT): Stereotactically directed conformal radiation in multiple fractions

Fractionated Stereotactic Radiosurgery (FSR): Stereotactically directed conformal radiation in 2-5 fractions

Goals & Principles of Stereotactic Radiation

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- Rapid fall off outside the target volume
- Conformality of prescribed dose to the target volume
- Impeccable repositioning accuracy

To achieve these goals, multiple convergent non coplanar beams are used to deliver radiation to a precisely defined target

Stereotactic immobilization must be used to allow treatment reproducibility, repositioning, and the use of minimal margins around the target

Goals & Principles of Stereotactic Radiation

- The volume of non target tissue that receives a significant dose is strongly dependent on the size of the target and the conformity of the isodose to the target
- As the volume of the target increases the volume of the non target tissue that receives a significant radiation dose increases
- The use of multiple isocentres can increase conformality but at the expense of dose inhomogeneity with in the target
- The importance of dose fractionation in conventional irradiation applies to stereotactic irradiation

Key Requirements for Stereotactic Radiation

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Requirement	Rationale
Small Target/Volume	Reducing the volume of normal and target tissue irradiated to high doses improves tolerance
Sharply defined target	Can be treated with little or no extra margin of surrounding normal tissue
Accurate radiation delivery	No margin of normal tissue needed for set up error and/or reduced chance of under dosing the target
High conformality	Reduces the treatment volume to match the target volume
Sensitive structure excluded from target	Dose limiting structures should be able to be defined and excluded from the target volume to limit risk of injury

SRS vs SRT

	RADIOSURGERY	RADIOTHERAPY
Dose per Fraction	6-30 Gy	1.8-2 Gy
Number of Fractions	1-5	30-33
Number of radiation beams	150-200	5-10
Targeting accuracy	<1 mm	3-20 mm
Clinical Intent	Tumor ablation	Tumor control

Indications for Stereotactic Radiation

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	INDICATIONS	CONTRAINDICATIONS
SRS	Benign brain tumors Malignant brain tumors Brain metastasis AVM's Trigeminal neuralgia	Lesions involved with or intrinsic to critical structures viz. optic apparatus, brain stem Lesions >3 cm
SRT	Benign and malignant brain tumors	None
FSR	Benign brain tumors Malignant brain tumors Brain metastasis	Size limitation

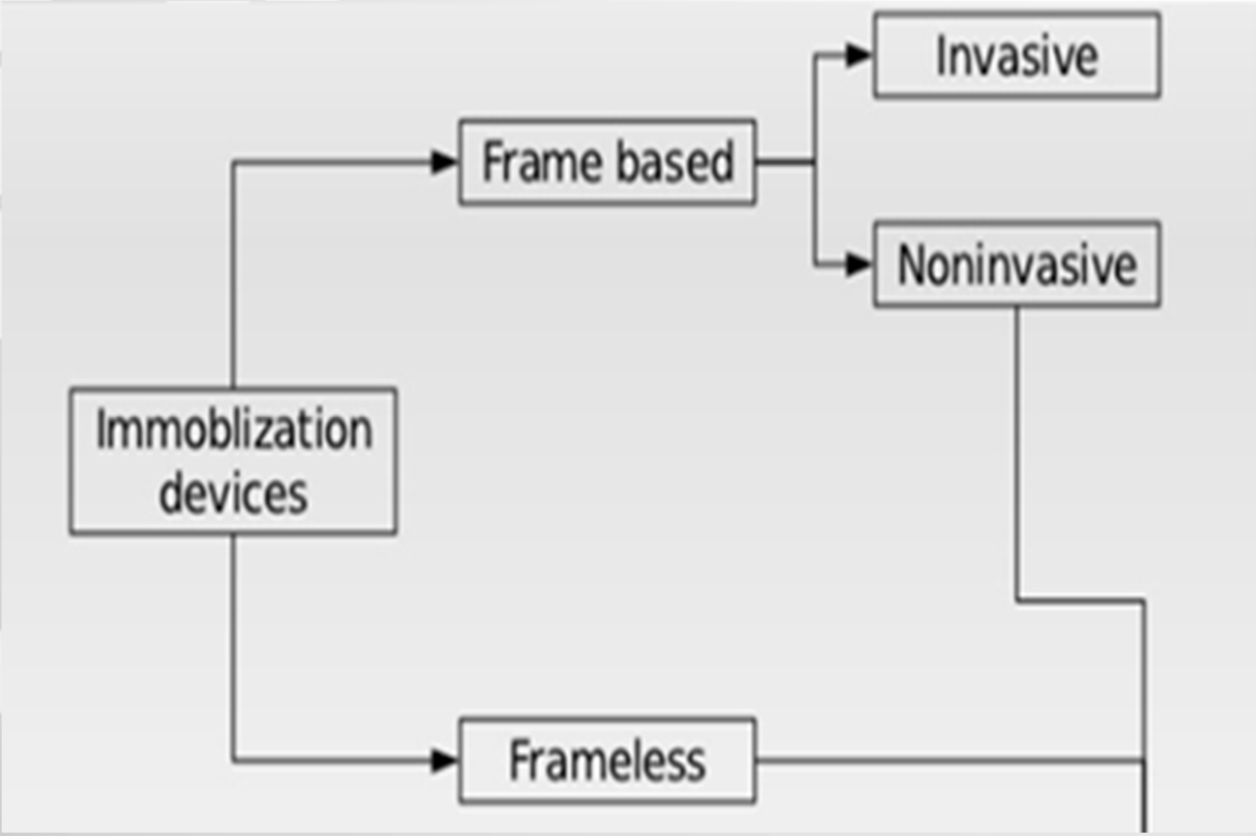
History of Stereotaxy

Year	Author	Location	Event
1951	Leksell	Stockholm (Karolinksa)	Invention of "Stereotactic Radiosurgery" using rotating orthovoltage unit
1967	Leksell	Stockholm	Invention of Gammaknife using cobalt-60 sources
1982	Betti Colombo	Buenos Aires Vicenza	Independent development of a system adapting LINACs for radiosurgery
1986	Lutz/ Winston	JCRT	Development of LINAC based SRS based on common stereotactic frame
1987	Lundsford	Pittsburgh	First Gammaknife installed in the US
1992	Loeffler/ Alexander	Boston	First commercially built dedicated SRS LINAC (Varian-SRS)
1994	Adler	Stanford	First clinical use of prototype of Cyberknife
1996	Hukku	Apollo Delhi	Dedicated LA for SRS/SRT

Radiobiological Considerations

- Before SRS became popular in late 80's, most radiation oncologists believed that fractionating radiotherapy lessens the relative risk of injury to normal tissue compared with tumor
- Laboratory studies on limited cell cultures and clinical experience with conventionally fractionated RT supported this
- Around the same time SRS allowed clinicians to administer high single doses of radiation to intracranial targets with relative safety
- Laboratory studies suggest that the radiation response for the high dose single fractions used is predominantly related to the supporting endothelial cells supported by pathology studies which also support vascular response

Stereotactic Frames



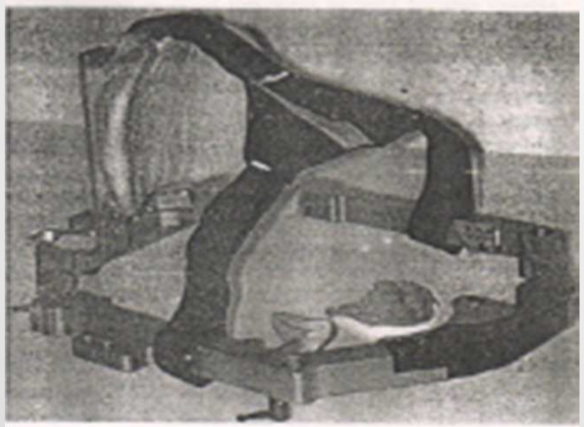
Stereotactic Frames

- SRS started with a rigid application of a stereotactic frame, a localizer, and an image data set derived from either CT, MRI, or angiography.
- With a fixed relationship between the patient's head and the fiducial localizers , any intracranial target can be reached with an optimal trajectory and great accuracy.
- The standard cerebral stereotactic systems should have a mechanical accuracy below 1 mm
- Within a Cartesian coordinate system, the x- and y-axes refer to a medial-lateral and anterior-posterior location, respectively, whereas the z-axis refers to a base-vertex location. Many methods have been outlined to determine the z-axis, but the most popular method uses posts with an "N" shape configuration where the position of the oblique rod relative to the vertical rods defines the z plane of the slice

Stereotactic Frames

- For radiosurgery of cranial lesions, the frame is neurologically fixed on to the patients skull

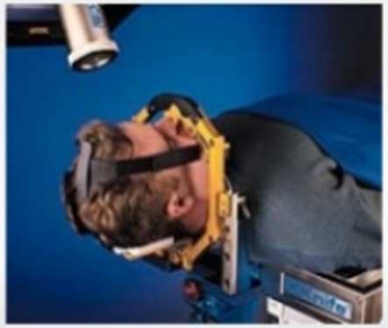
- For SRT the head is fixed non invasively in a relocatable thermoplastic mask attached on to a sterotactic frame



GTC relocatable non invasive head ring for SRT

Type of Frames

- Leksell Frame
- GTC System (Gill-Thomas-Cosman): Relocatable
- TLC System (Tarbell-Loeffler-Cosman): Pediatric
- BrainLab System
- Novalis Frame



Gill Thomas Cosman System

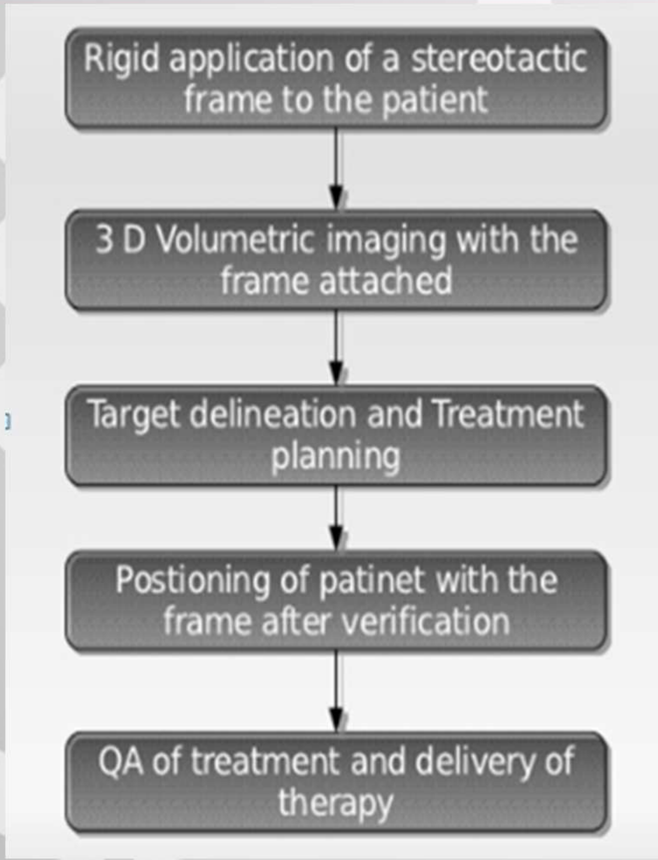
TLC System

BraiLAB Frame

Leksell Frame

Optical Surface Monitoring

Steps of a Stereotactic Procedure



- Outpatient procedure
- Head Ring is placed in the outpatient area
- Head ring has a dual purpose

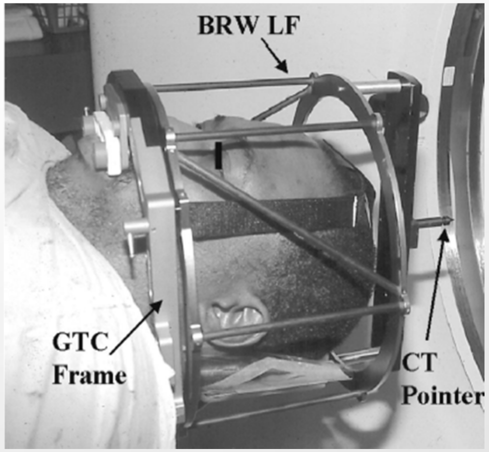
To establish the spatial relationship between the head ring and the target, which then will be used in treatment planning

Used to immobilize the patient during treatment

Simulation & Imaging

Imaging

- CT localizer is attached to the head ring which then is attached to CT couch
- CT localizer defines a Cartesian coordinate system in such a way that any point within the brain can be referenced with a unique set of coordinates related to the localizer
- Thin sliced high resolution CT scan is done
- MRI images are obtained stereotactically if required
- Simulation in treatment position
- Cover target and all OAR’s
- 5-10 cm superior and inferior of treatment borders
- Tomographic slice thickness 1-3 mm



Steps of a Stereotactic Procedure

Treatment Planning

- CT images are transferred to the TPS
- MRI images are also transferred if MRI is done
- Fusion of CT/MRI/DSA
- Target volume and OAR's are defined
- Isocentre placement, collimator selection, field definition, dose optimization and analysis, and plan evaluation is performed

Treatment Planning

- GTV/CTV considered identical
- Dose prescription specified at lower isodose with small or no margins for penumbra
- Restricting entrance dose to <30% of cumulative dose and avoiding beam overlaps to prevent acute skin reactions
- Increased number of beams yield better conformity but not practical (Cyberknife and VMAT overcome this issue)

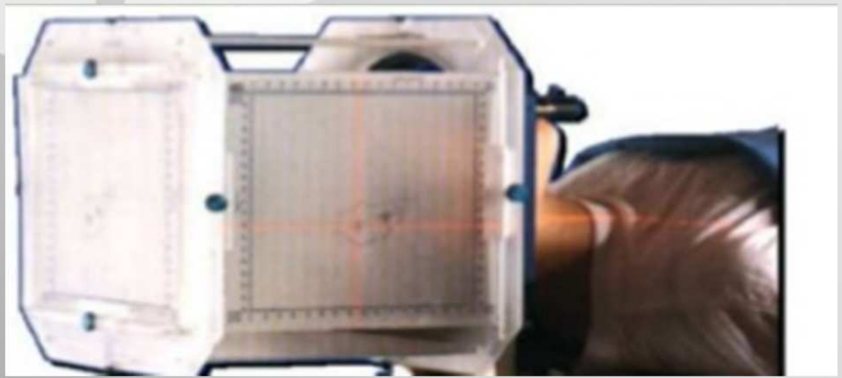
Steps of a Stereotactic Procedure

QA/Treatment Setup

- Stereotactic treatment components including the collimators are set up
- Verification for isocentre alignment, positioning, coordinate at the isocentre, alignment of the room lasers, transfer of the target coordinate alignment to the patient set up.
- Film test to assess and determine the mechanical isocentre accuracy

Treatment Delivery

- Stereotactic head ring on the patient is attached to the couch
- Alignment is done with lasers
- Treatment delivered
- Head ring removed



The XKnife® Depth Helmet for checking that the head ring position has not changed between the time of CT scanning and treatment..

Dose Selection

- Of extreme importance as it correlates with local control and complications
- For SRT, acute and long term complications are rare because of conventional dose and fractionation and stereotactic techniques
- Selection of SRT/SRS, and dose requires a thorough knowledge of neuroanatomy and individual disease process
- General guidelines for SRS dose selection are

a) Size of the lesion
b) Location of the lesion
c) Type of the lesion
d) Neighboring critical structures
e) Preexisting neurological symptoms/Comorbidities/Previous Surgery and/or RT

Complications of Stereotactic Treatment

- There are a range of immediate potential side-effects, affecting about one third of patients, though these are typically moderate and short term
- There is potential for late effects ranging from neurological impairment to death
- There is a risk of radiation-induced cancer resulting from intracranial treatments

Kulik C et al: Int J Radiat Oncol Biol Phys 2002;53: 1038–50

Neurocognitive Function Impairment after SRT

- 22 children and young adults with benign and low grade brain tumors treated with Stereotactic Conformal radiotherapy with specialized BrainLAB relocatable mask based stereotactic frame
- GTV with 5 mm margin to generate CTV and 2 mm for PTV
- Dose 54 Gy/30 fractions with PTV coverage by >95% and not exceeding 105%
- Neurocognitive evaluation before treatment and 6 and 24 months after treatment showed that the neuropsychological impairment existing before start of treatment did not worsen post treatment

Jalali et al: Int J Rad Oncol Biol Phys: 66;4

Side Effects of Radiosurgery

GENERAL

Nausea, Vomiting, Dizziness, Headaches, Hair loss, Anxiety, Facial pain.

EDEMA/HYDROCEPHALUS

- New motor deficits, including edema-induced ataxia, facial weakness, shunt placement for symptomatic hydrocephalus, and delayed seizures.
- Peritumorous imaging changes on MRI seen in 23.6% patients. 10% are symptomatic who recover on steroids.
- Attributable to vasogenic oedema. Pretreatment oedema, sagittal sinus occlusion, radiation doses above 6 Gy per fraction, and pre SRS neurological deficit significant risk factors for oedema development after radiation therapy.

Chang et al: J Neurol Neurosurg Psychiatry 2003;74:226-230
doi:10.1136/jnnp.74.2.226

Side Effects of Radiosurgery

CRANIAL NERVES

- Optic Pathway: Dose >8-10 Gy/1#. Important issues include, previous conventional radiation therapy, pre-existing anterior visual pathway dysfunction secondary to previous surgery or tumour compression, treatment plans based on computed tomography rather than MRI, large tumour volume, and treatment isocentres within 5 mm of the anterior visual pathways.

- Other Cranial nerves: A dose of <16 Gy to the cavernous sinus had no cranial nerve deficits

Side Effects of Radiosurgery

RADIONECROSIS

- Symptoms may be similar to the symptoms of tumor regrowth or stroke. Only 10% patients are symptomatic
- Brain volumes irradiated at 10 and 12 Gy are the most important independent predictive factors of brain necrosis
- For V10 Gy >12.6 cm^3 and V12 Gy > 10.9cm^3 the rate of radionecrosis is 47% (p=0.0001)
- Lesions with V12 Gy >8.5 cm^3 carries a risk of 10% and should be considered for treatment of lesions located in or close to eloquent areas

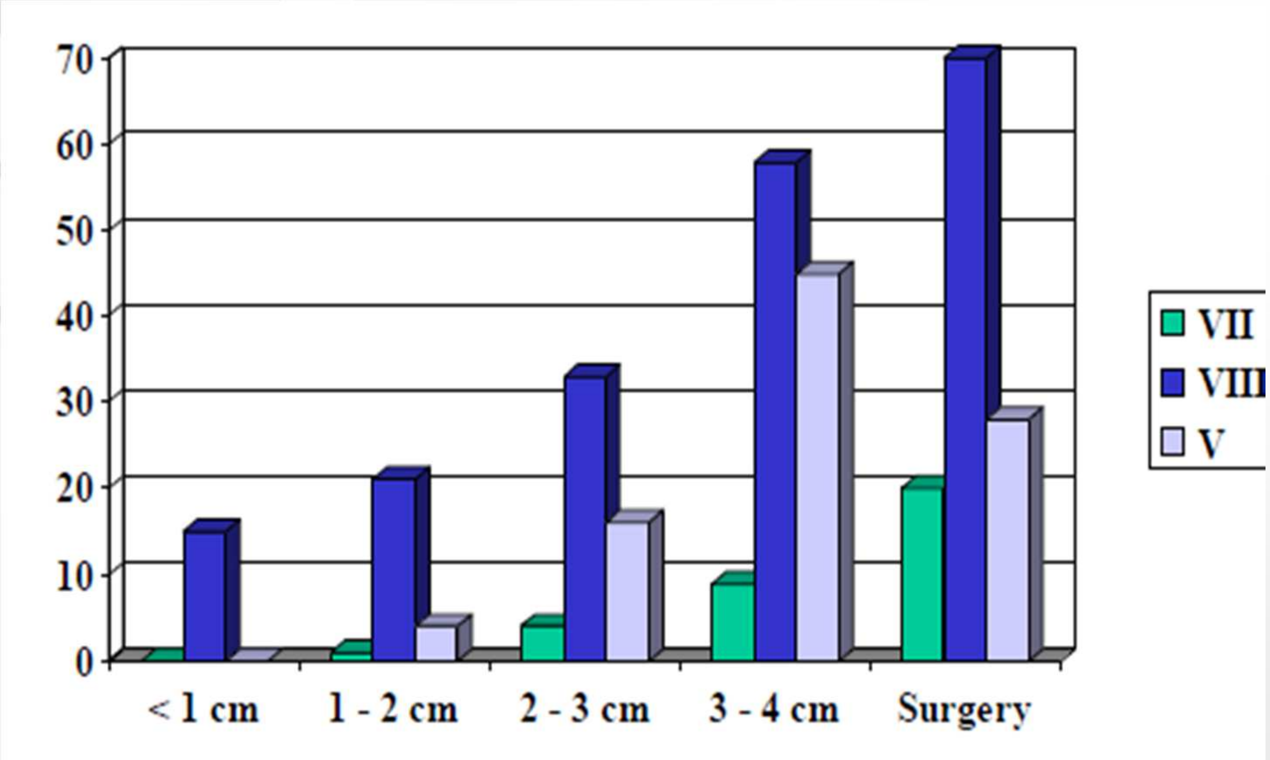
Minniti et al: Radiat Oncol: 2011: 6: 48

Published Complications on SRT/SRS

Study	Treatment/number of pt	5 year LC rate (%)	5-year hearing preservation rate (%)	5-year facial nerve preservation rate (%)	5-year trigeminal nerve preservation rate (%)
Andrew *et al.*, 2004 [10]	SRS/69	98	33	98	95
	CSRT/56	97	81	98	93
Meijer *et al.*, 2003 [7]	SRS/49	100	75	93	92
	HSRT/80	94	61	97	98
Comb *et al.*, 2010 [8]	SRS/30	96	70	83	93
	CSRT/175	96	78	98	97
Kopp *et al.*, 2010 [9]	SRS/68	97.9	79	100	87
	CSRT/47	98.5	85	100	100
Our study	SRS/39	95	75	98	100
	HSRT/79	100	87	97	99
	CSRT/28	95	63	100	100

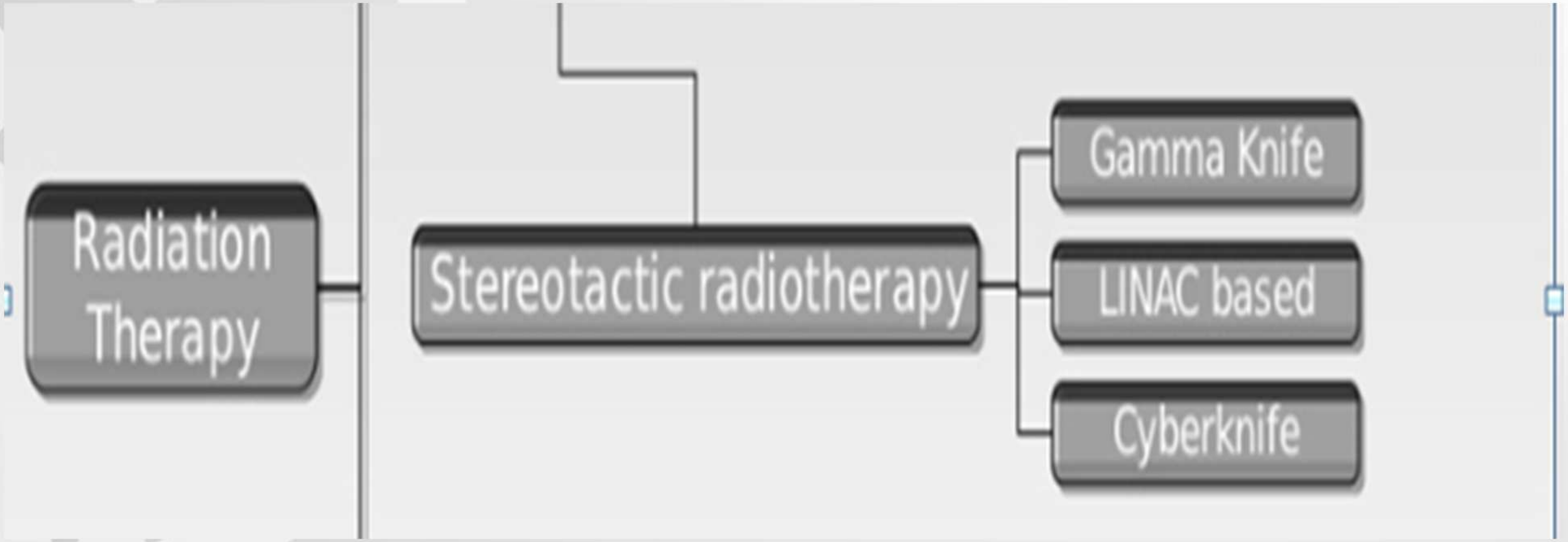
SRS = stereotactic radiosurgery, HSRT = stereotactic radiotherapy, hypofraction, CSRT = stereotactic radiotherapy, conventional fraction, LC = local control.

Published Complications on SRT/SRS

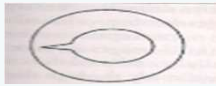
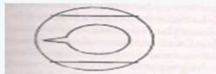
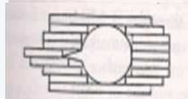
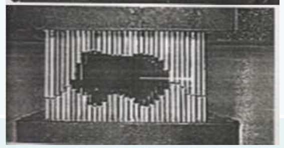


Iwai et al: Neurosurgery:2003:53:287
Regis et al: J Neurosurg: 2002:97:1091

Stereotactic Irradiation Systems



Stereotactic Irradiation Systems

System	Beam Shaping Techniques
Gamma Knife	Multiple circular collimators 
Linac	Fixed circular collimator  Circ Coll with jaws  mMLC   
CyberKnife	Fixed collimators  IRIS 
Protons	Fixed collimator 

Gamma Knife

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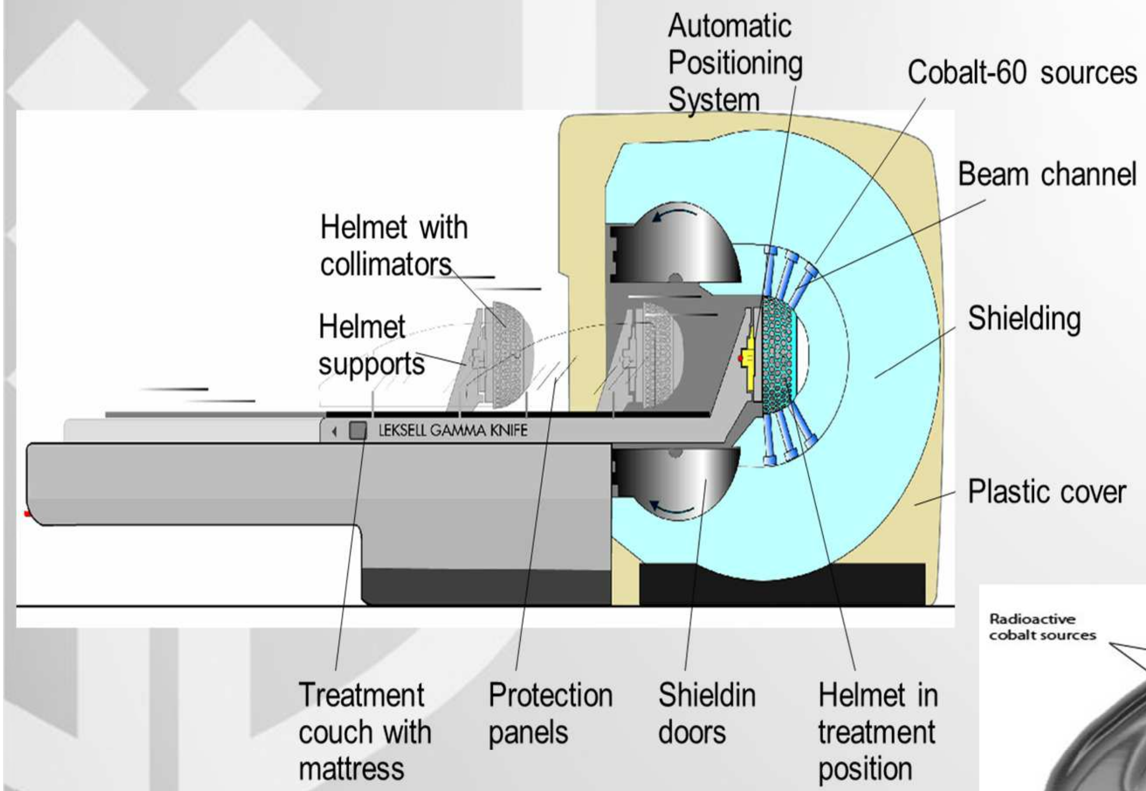
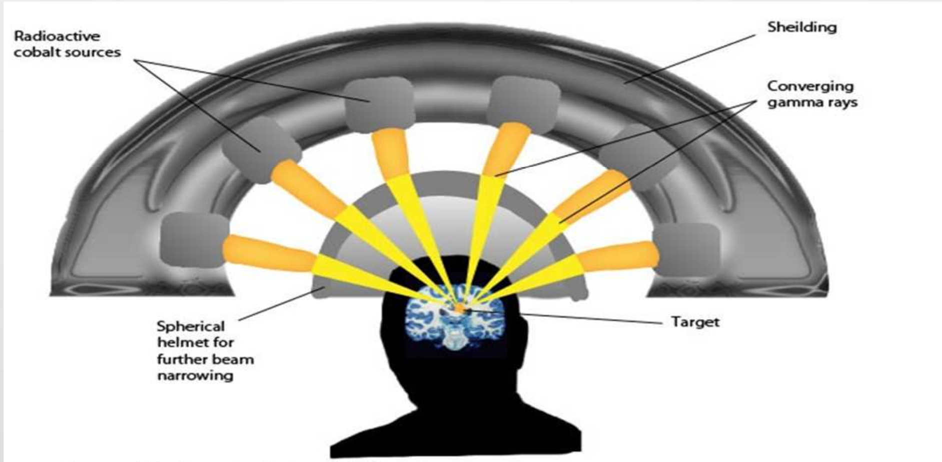


- Designed to provide an overall treatment accuracy of 0.3 mm
- 3 basic components
  - Spherical source housing
  - 4 types of collimator helmets
  - Couch with electronic controls
- 201 Co^{60} sources (30 Ci)
- Unit Center Point 40 cm
- Dose Rate 300 cGy/min



Stereotaxic Radiosurgery - Gamma Knife Concept
Multiple radiation beams converge on target tumor, delivering high-dose radiation to the tumor, but little to surrounding tissues. It is a single treatment and to ensure proper patient positioning and immobility, a positioning frame is secured to the patient's skull, then attached to the radiation source. Treatment lasts 45 to 60 minutes.

Gamma Knife

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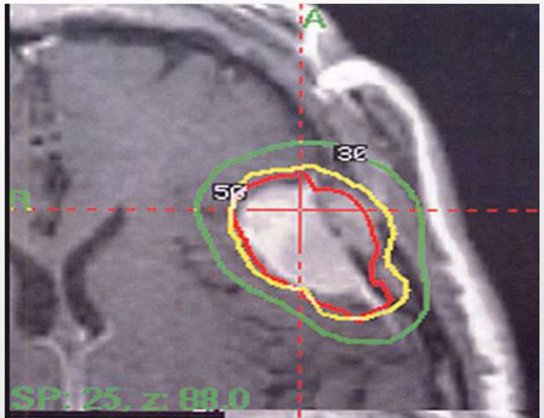
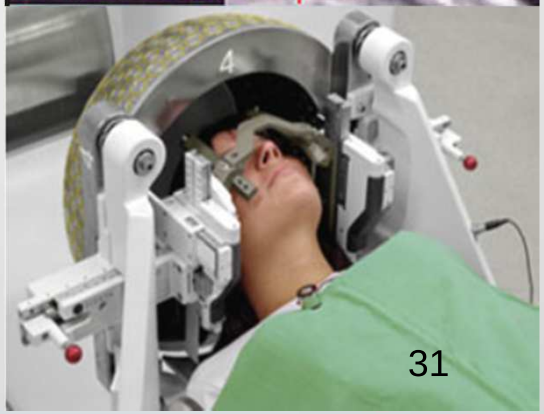
- Radiation from 192-201 cobalt sources (approx 30 curies) is finely collimated
- The rays all meet at the one point
- The size of the point target is adjusted by changing collimator helmets. Four interchangeable outer collimator with beam dia 4-18mm are used varying the target volume. Individual collimators may be blocked to conform to the target
- A stereotactic frame is attached to the patient
- Multiple target isocenters are used to create a treatment plan in 3 dimensions that fits the lesion shape. Target size of 3-18mm

Gamma Knife

PERFEXION 2006

- Unlimited access to cranial volume
- Full automation and one-push button approach
- Outstanding patient & staff comfort
- Best in class radiation protection for patient and staff
- Leksell GammaPlan® PFX™ with PC platform enables remote planning, multiusers and patient database access.





Gamma Knife

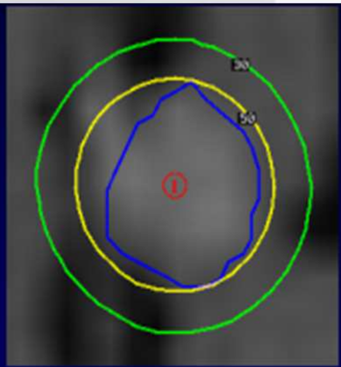
ADVANTAGES

- Over 30 years of clinical use with a large number of studies published in the medical literature
- Very high targeting precision
- Multiple targets in the brain are easily treated during a single treatment session

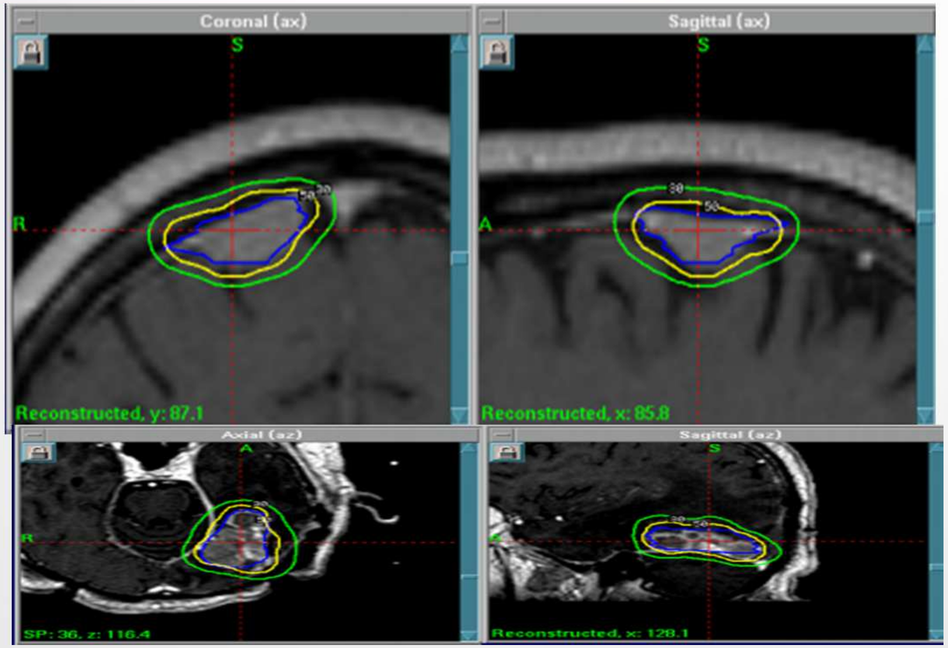
DISADVANTAGES

- The basic design limits use to the brain only
- The procedure for radiation targeting requires the placement of a somewhat painful stereotactic head frame
- It can be difficult to treat patients with lesions located in certain areas (e.g. the periphery) of the brain
- It cannot be used for staged radiosurgery
- Large target(s) with complicated shapes require treatment plans with multiple isocentres increasing complexity and treatment time
- Co sources decay, increasing treatment time and cost to replace after 5 years

Gamma Knife Weaknesses



- For small spherical lesions, the planning is straightforward.
- For example, here a single 8mm shot covered the target (6mm in diameter).

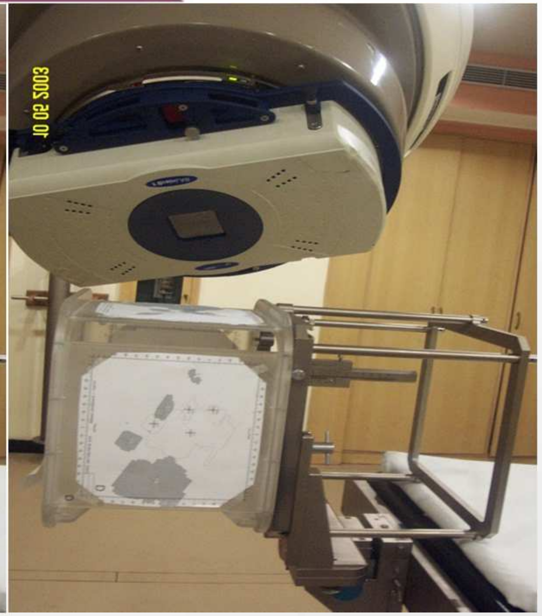


Rotating Gamma System

- Developed in China
- Uses 30 Co-60 sources in revolving hemispherical shell
- The secondary collimator is a co-axial hemispheric shell with six groups of five different collimators to produce spherical treatment volumes of different diameter

Linac Based Radiosurgery





Linac Based Radiosurgery

- Can treat target volumes of 40-50mm
- Accuracy not as high as other techniques
- Variety of beam techniques available
- Capable of SRS and SRT and SBRT

Linac Based Radiosurgery

ADVANTAGES

- More commonplace technology in hospitals
- With invasive stereotactic frame, precision targeting for brain tumors that approaches, but does not equal, that of the Gamma Knife or CyberKnife.
- The capacity to more accurately target extracranial (non-brain) tumors than standard radiation therapy
- An ability to deliver fractionated intracranial or extracranial treatment

DISADVANTAGES

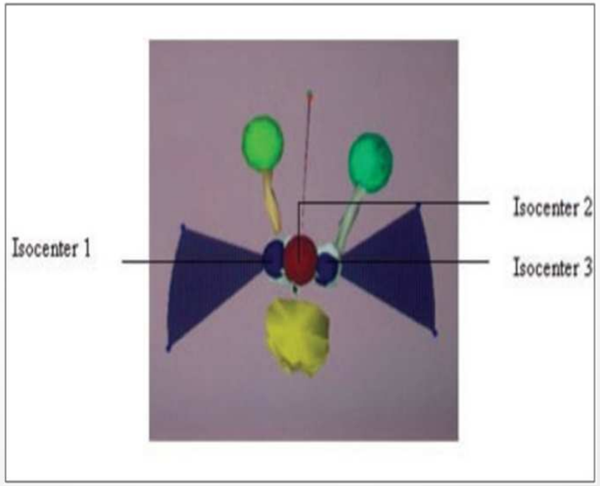
- The need for an invasive head frame (similar to the Gamma Knife) to assure treatment accuracy when used for brain radiosurgery (single fraction)
- Less treatment accuracy when multiple fractions are used to treat areas of the brain where the use of an invasive head frame is impractical
- A significantly lesser degree of targeting accuracy when treating extracranial tumors compared to brain radiosurgery
- Treatment accuracy is degraded further when the target moves during radiation delivery from either natural breathing or patient movement

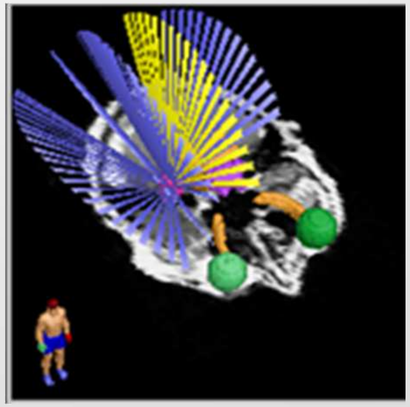
Linac Based Radiosurgery

BEAM SHAPING

Arcs with circular collimation:

- Patient is stationary while gantry moves through a given arc
- Multiple non coplanar arcs of uniform intensity are used
- Each arc given in a specific couch position with start/stop angle
- All arcs converge in the target
- Number of arcs depend on size, location, and shape of lesion
- Normally 3-6 arcs are used for each isocentre
- Multiple isocentres may be required for large lesions
- Fixed circular collimators of 4-50 mm are used
- Highly conformal for spherical and elliptical tumors
- Less conformal than fixed fields for irregular targets





Linac Based Radiosurgery

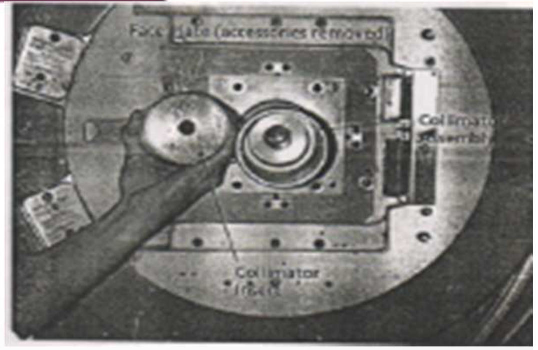
BEAM SHAPING

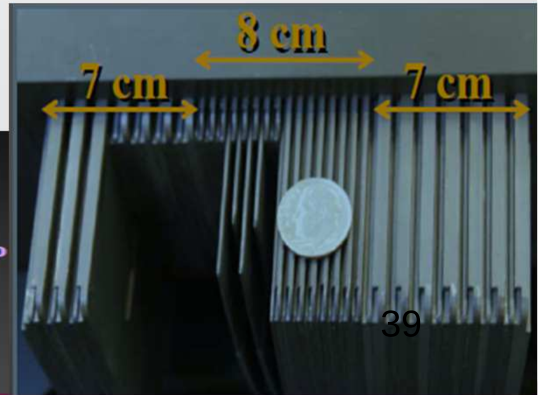
Fixed Static Field

- Position of patient and gantry are fixed
- Fixed, shaped and non coplanar fields used
- All fields have a same isocentre and uniform intensity
- Shaping done by custom made collimators
- MLC's and mMLC's can also be used which give better dose distribution

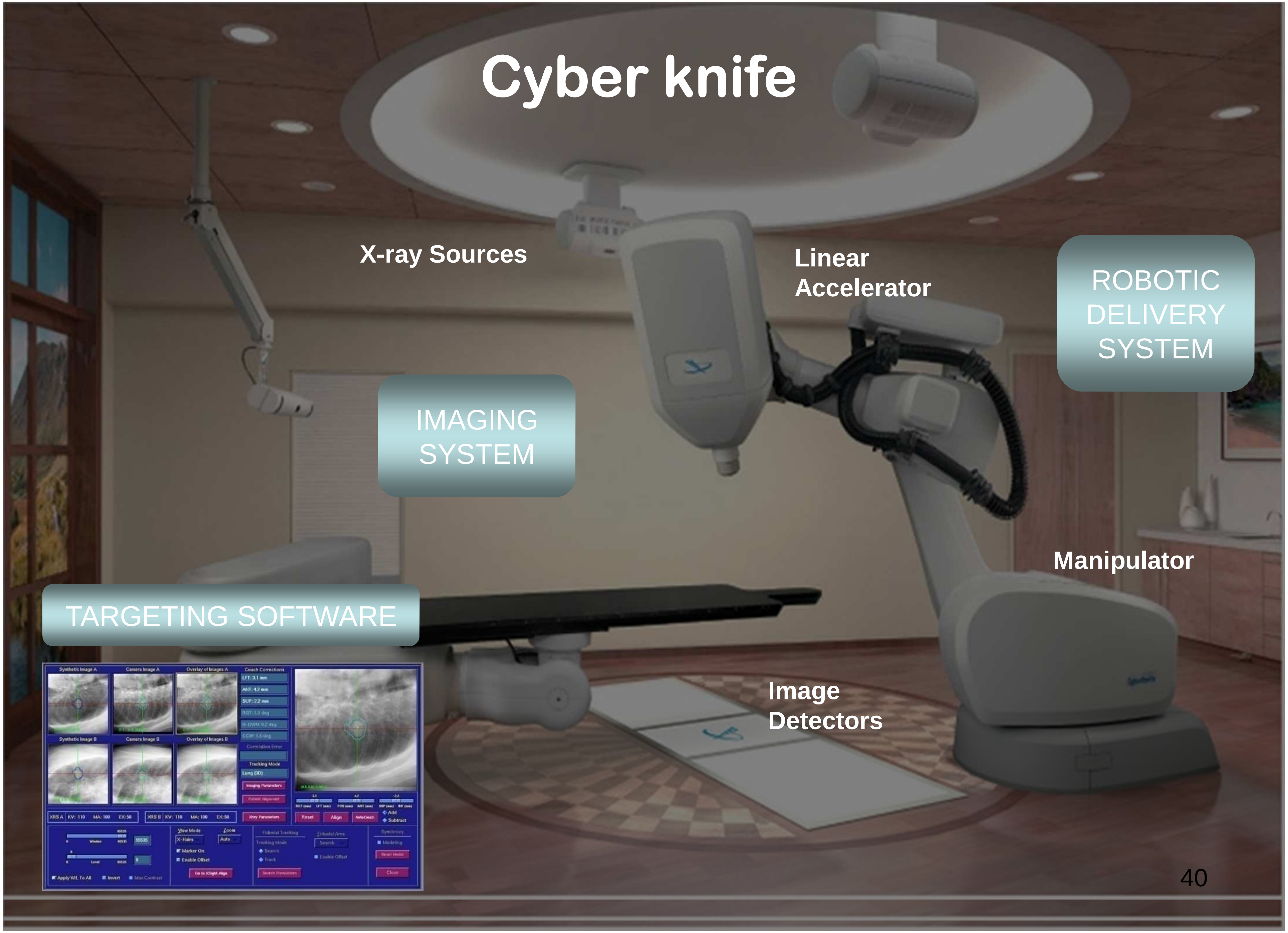
Arcs with Dynamic mMLC collimation

- Both the couch and gantry move, the collimator leaves are in continuous motion as the arc is traversed
- Single isocentre is needed even for irregular targets



Cyber knife


X-ray Sources
Linear Accelerator
ROBOTIC DELIVERY SYSTEM
IMAGING SYSTEM
Manipulator
TARGETING SOFTWARE
Image Detectors

CyberKnife

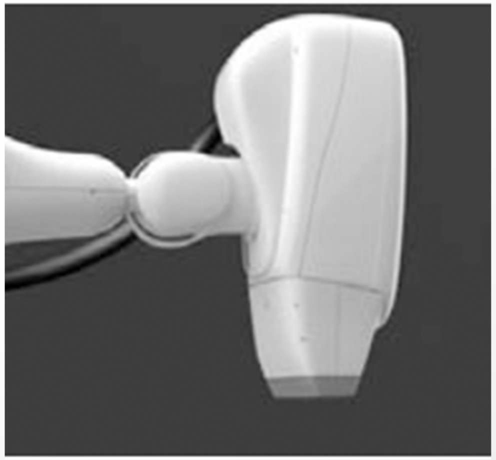
ADVANTAGES

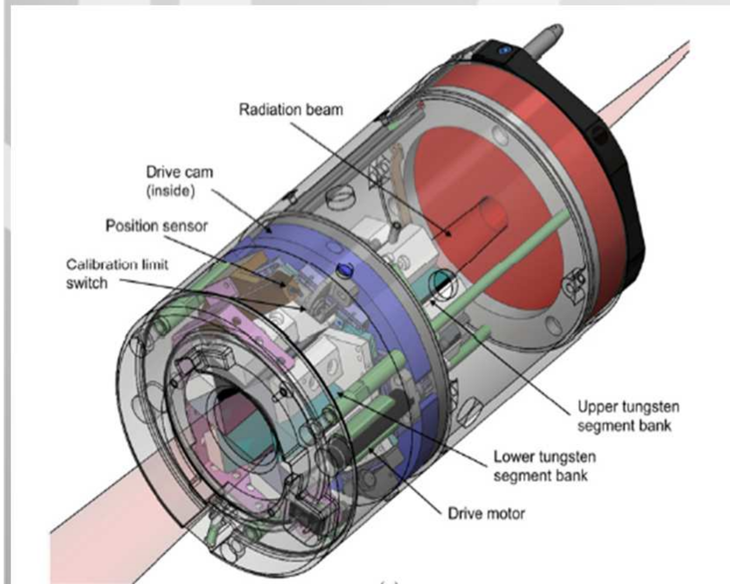
- No invasive head frame or other rigid immobilization device is required
- The ability to perform radiosurgery (1-5 fractions) on targets throughout the body, not just the brain
- Precise targeting (within 1 mm) of selected lesions in the brain and body
- A unique ability to provide real time monitoring of the treated target throughout treatment using an advanced image-guidance system
- A unique ability to correct during treatment for target motion (e.g. due to small patient movements). **Real time imaging possible**
- The capacity to easily perform staged radiosurgery

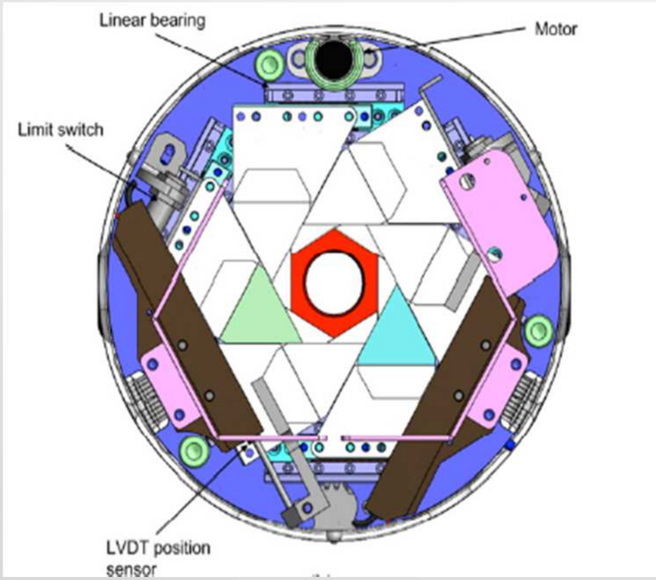
DISADVANTAGES

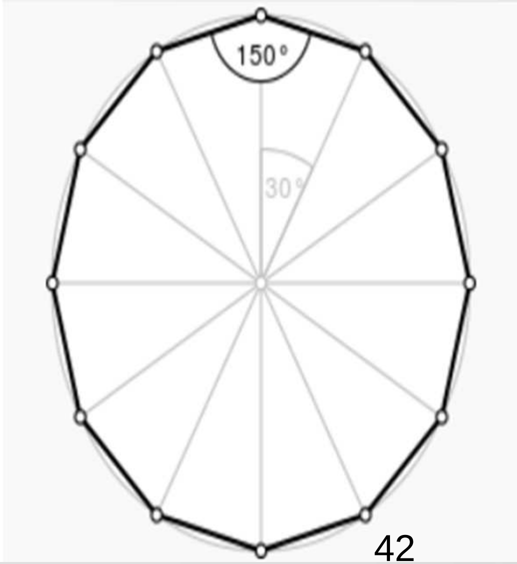
- The need for placement of fiducials for some indications
- Compared to other radiosurgical devices, treatment takes longer when multiple tumors are ablated during the same treatment session.
- No posterior beams below couch are possible
- Prolonged planning time/Treatment times

CyberKnife




Radiation beam
Drive cam (inside)
Position sensor
Calibration limit switch
Upper tungsten segment bank
Lower tungsten segment bank
Drive motor


Linear bearing
Motor
Limit switch
LVDT position sensor

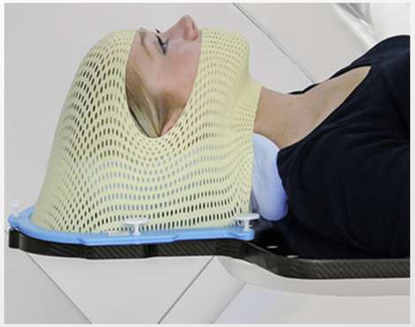

150°
30°

Frameless

- In frame-based RS, the accuracy of treatment delivery is determined solely by connecting a rigid frame to the patient which is anchored to the patient's skull.
- CyberKnife is the only RS device that does not require a frame
- Using a frameless system, a CT scan can be carried out on any day prior to treatment. The treatment planning can also be carried out at leisure. This allows the clinical staff to plan many patients at the same time, devoting as much time as is necessary for complicated cases
- Pediatric cases or patients with fragile heads because of prior brain surgery cannot be treated using a frame based system

Frameless

- Immobilization is done by a thermoplastic mask which cannot completely eliminate intrafraction movement
- This necessitates two approaches: a) An image registration for the initial set up with subsequent tracking and correction for intrafraction movements b) a user X-ray acquisition procedure to guarantee the global 1-2 mm error
- The 2D-3D registration method implemented in the CK VSI system has an accurate initial set up with constant adjustment for patient movement during image guided intracranial radiosurgery. The registration error is <0.5 mm



Imaging/Localization/Alignment

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- The method is called 6D or skull based tracking.
- The X-ray camera images are compared to a library of computer generated images of the patient anatomy. Digitally Reconstructed Radiographs (or DRR's) and a computer algorithm determines what motion corrections have to be given to the robot because of patient movement.
- This imaging system allows the CyberKnife to deliver radiation with an accuracy of 0.5mm without using mechanical clamps attached to the patient's skull.
- This method is referred to as 6D because corrections are made for the 3 translational motions (X,Y and Z) and three rotational motions.

Imaging/Localization/Alignment

- Image acquisition, target localization, and alignment corrections are repeated continuously during the delivery. X-ray images acquired in real time.

- The robot compensates for changes on the basis of most recently acquired image pair.

- Selection of imaging interval is based on the stability of the target position during the fraction. It is usually between 15-60 seconds (machine has a range of 5-150 seconds)

- CK VSI can correct translations of upto +/- 10 mm, in the 3 axes and rotation of upto +/- 1 degree in the ROLL and UP axes, +/- 3 degree in the CW axes.

GK and CK: Head to Head

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	Gamma Knife	CyberKnife
First Installation	1968	1994 (FDA approval 2001)
US Installations Total Installations	125 500+	151 280+
Patients Treated Publications	5,00,000 2000	1,00,000 700
Frame Fractionation Peripheral Lesions	Needed Not Possible Difficult to treat	Frameless Possible Possible

Accuray & Elekta websites

ACCURACY

	GAMMA KNIFE	CYBERKNIFE
Accuracy of Treatment Delivery	<0.5 mm	<0.5 mm
Error in real time image capture	----	0.5 mm
Errors in couch or robot positioning	-----	0.5 mm
Inaccuracy in head frame	0.5—1.7 mm	------
TOTAL ACCURACY	**1.0---2.2 mm**	**1.5 mm**

Clinical accuracy for spine 0.61mm: Ho et al: Neurosurgery 60,2007

Clinical Results & Dose to surrounding brain

GK has a better radiobiological effect on hypoxic cells

Presumption:

Dose inhomogeneity of the GK is advantageous by minimizing local tumor recurrences because the necrotic or hypoxic core of metastases harboring particularly radio-resistant tumor cells is receiving a very high dose of radiation . CK dose is more homogeneous potentially give rise to a higher local recurrence rate in tumors with a radio-resistant core when compared to the GK

Result

- The minimum tumor dose was significantly lower in the CK group as compared to the GK group. However the absolute numerical difference in this dose parameter was small (around 1 Gy or 5%).
- No impact on the clinical outcome and the quality of the treatment results

Wowra et al, Neurooncology, January 2009

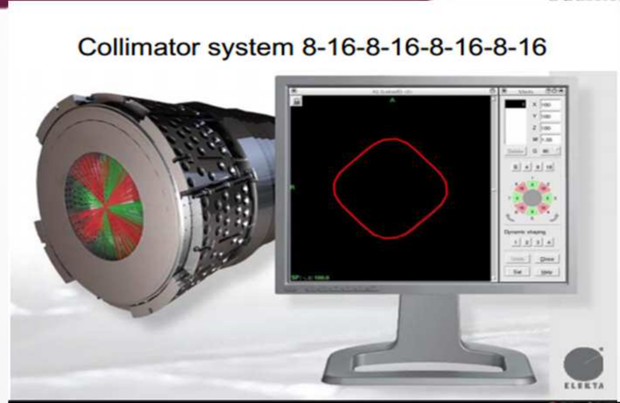
Perfexion: Changes to match CK

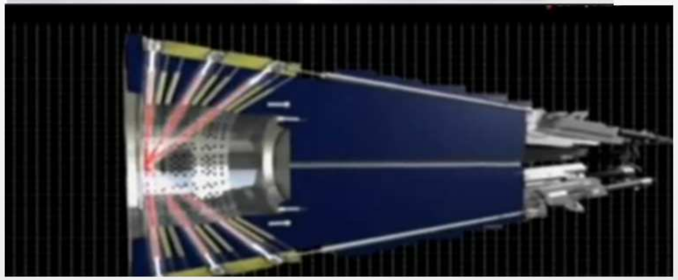
- Beam shaping was not possible earlier, so they brought a new collimator with 192 Co sources
- 4/8/16 mm focus with robotically adjusted inbuilt collimators
- To improve patient comfort, throughput, and extended anatomical reach
- Extended Anatomical Reach

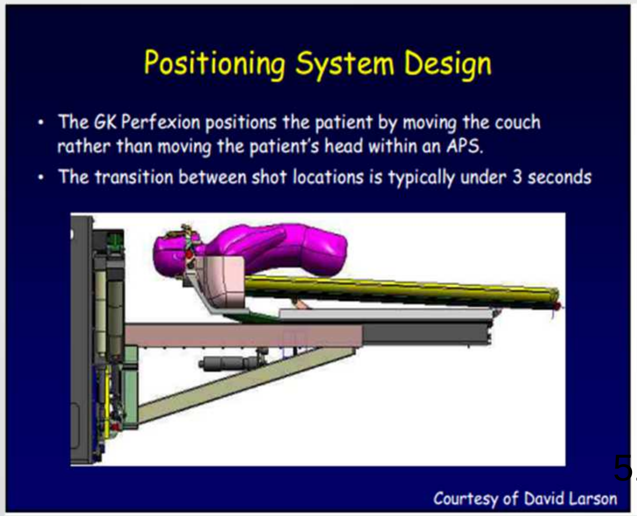
  Peripheral Lesions

  Cervical Spine

  PNS/Orbit







Complications

Acoustic Schwannoma: GK vs CK

Single Fraction RS with GK versus Fractionated RS with CK

Dose	**GK** **CK**	16 Gy (50% isodose) 14-16Gy 18-21 Gy
Tumor Control	**GK** **CK**	98% 98%
Surgical Salvage	**GK** **CK**	2.5 % in 4 years NA
Hearing Loss	**GK** **CK**	49% 26%
Facial Palsy	**GK** **CK**	21% 4% (Transient)
Trigeminal Nerve problems	**GK** **CK**	27% 0%

Kondziolka et al:N Engl J Med 1998; 339:1426-1433November 12, 1998 (Gammaknife)
Chang et al: 2005 (CyberKnife)

Conclusion

- Differences in treatment related parameters between GK and CK had no impact on the clinical outcome and the quality of the treatment results after RS
- Radiosurgical dose can be better tailored to the target with the CK than with the GK. This result, a **more homogeneous dose distribution, and a lower peripheral dose represent an advantage of the CK** in regard of the radiation protection
- This result clearly is in favor of the reproducibility of the treatment principle of RS if appropriate technology is used and the physical and clinical QA criteria are respected

Summary

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	Gamma Knife	Cyber Knife
Precision & Accuracy	1.0-2.2 mm	1.1 +/- 0.3 mm
Reproducibility	Excellent	Excellent
Immobilization	Invasive Frame	Frameless
Patient Comfort	Moderate	Very Good
Time taken for Treatment	15 mts to 3 hours (1 day)	40-90 minutes(1-5 days)
Time taken for planning	2-3 hours	6-8 hours
Machine flexibility	Only Cranial	Cranial & Extracranial
Machine Cost	4.5-5.0 million USD	4.5-5.0 million USD
Issue of radioactivity	Replacement & Disposal	None

CK vs Linac Based Radiosurgery

- **CyberKnife®**: Targeting Error **0.44 ± 0.12 mm**
- **Novalis:** Targeting Error **1.36 +/- 0.11 mm**
- **Elekta Synergy S**: 3D positioning errors combining translational and rotational setup error: **5.2 +/- 2.2 mm**

- There were statistically significant differences in organs at risk (OAR) doses

- Patients planned with the CyberKnife system had superior OAR (cochlea and mesial temporal lobe) sparing compared with those planned with the Linac-based system

Antypas C., et al. Phys Med Biol. 2008 Sep 7;53(17).
Dutta et al: J Neurooncol: 2012: 106: 637-42

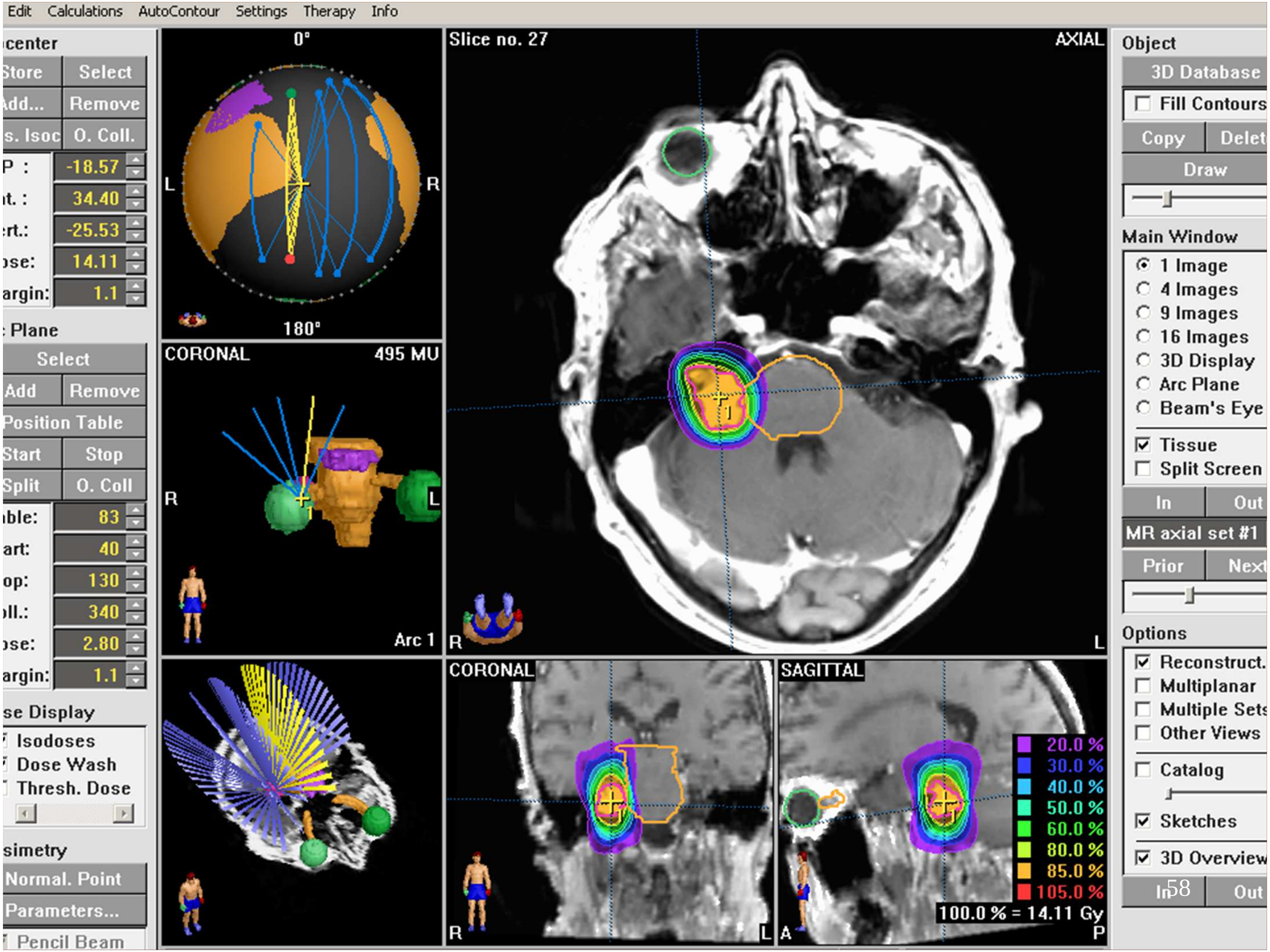
Gamma Knife vs CyberKnife vs X-Knife

- Each delivery system has its strengths and weaknesses. The characteristics of each system including work envelope, dose gradients, positional accuracy, mechanical accuracy, computational precision etc.

- The manufacturers of the various systems would like everyone to believe that theirs is the best system for all cases.

- Getting one of these systems does not immediately make one an expert in stereotactic radiosurgery any more than purchasing a scalpel makes one a surgeon.

- Experienced use and selection of the appropriate instruments by a trained radiation oncologist allows delivery of the best type of stereotactic radiosurgery in each case



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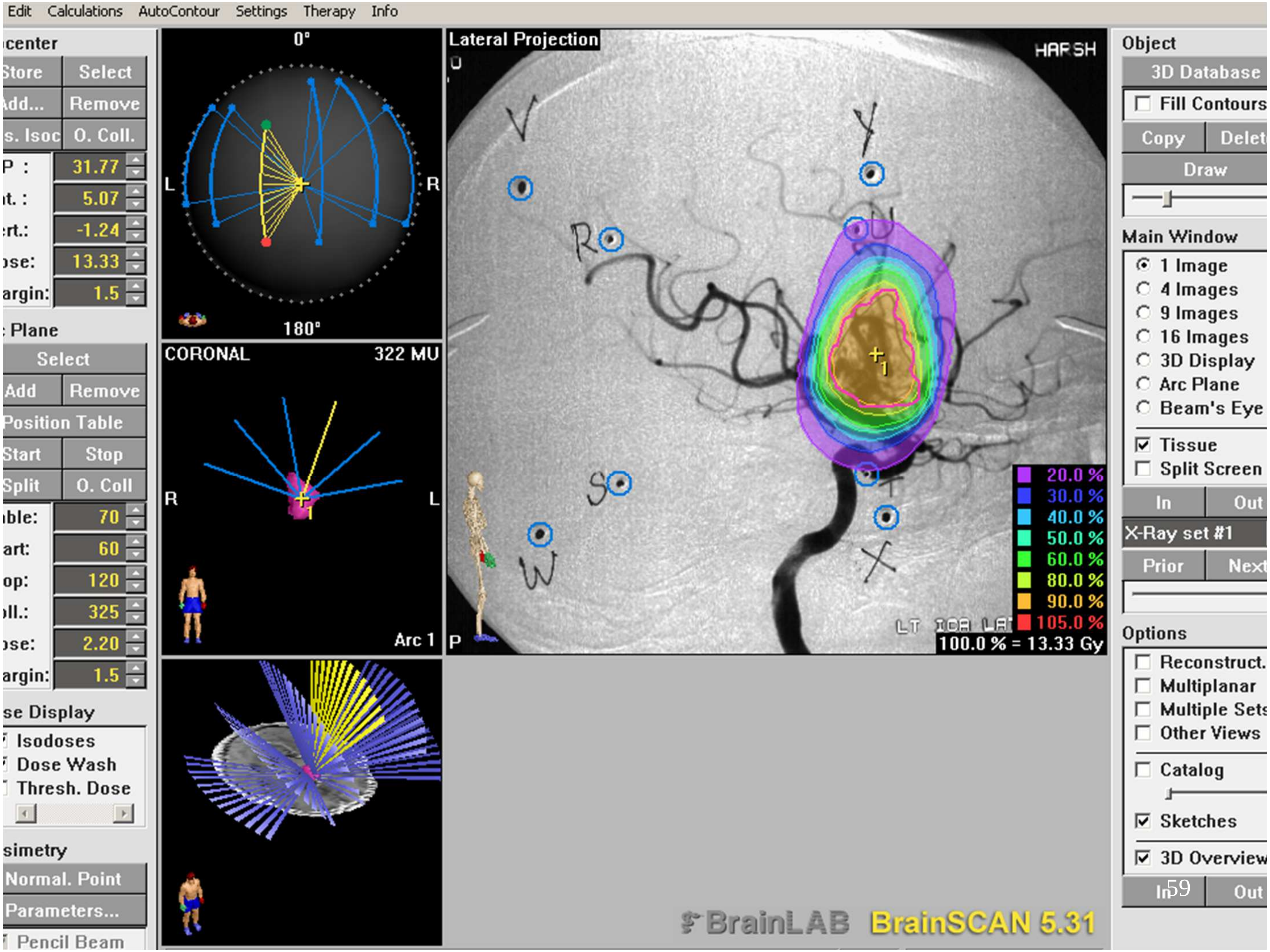
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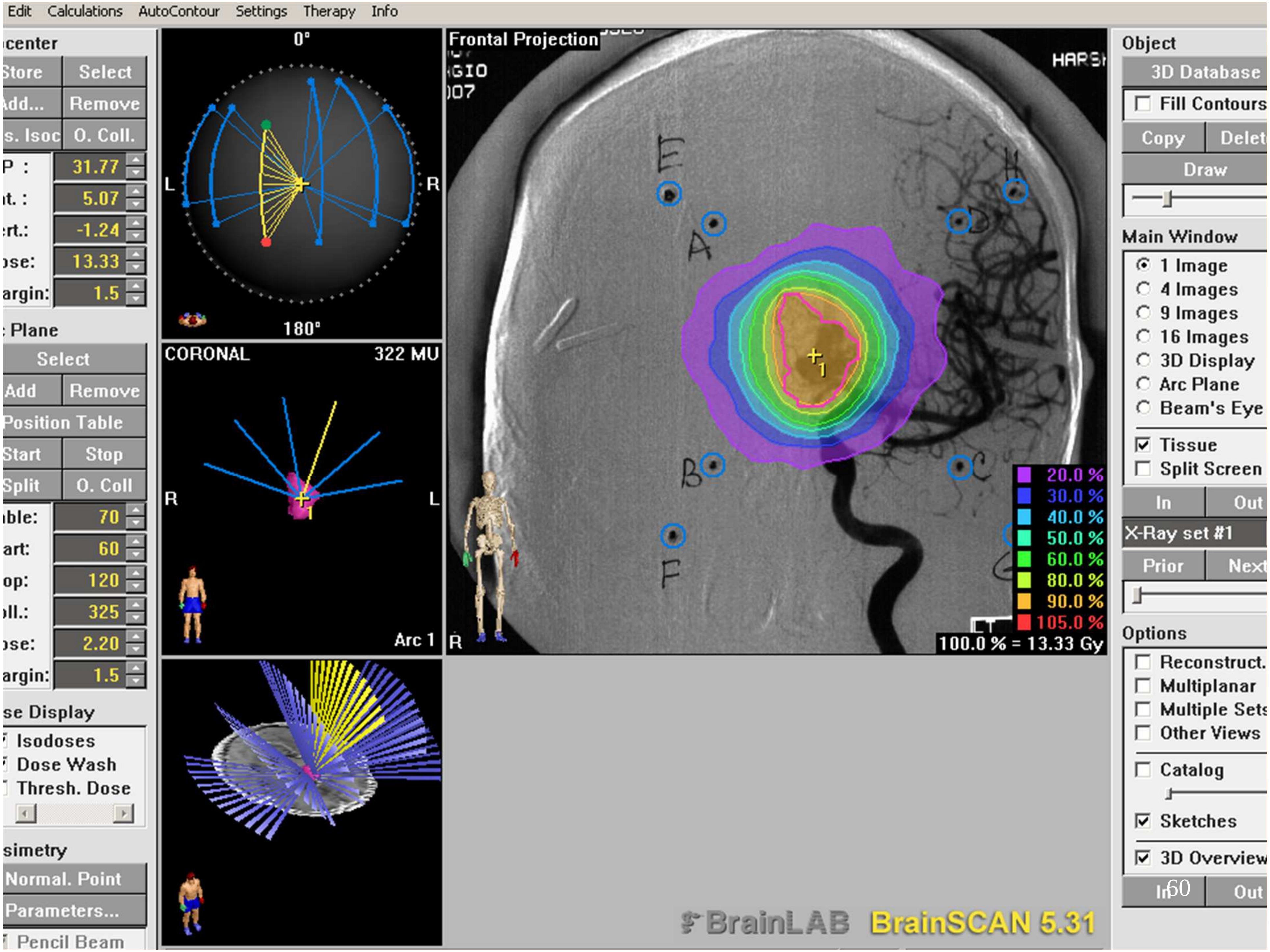

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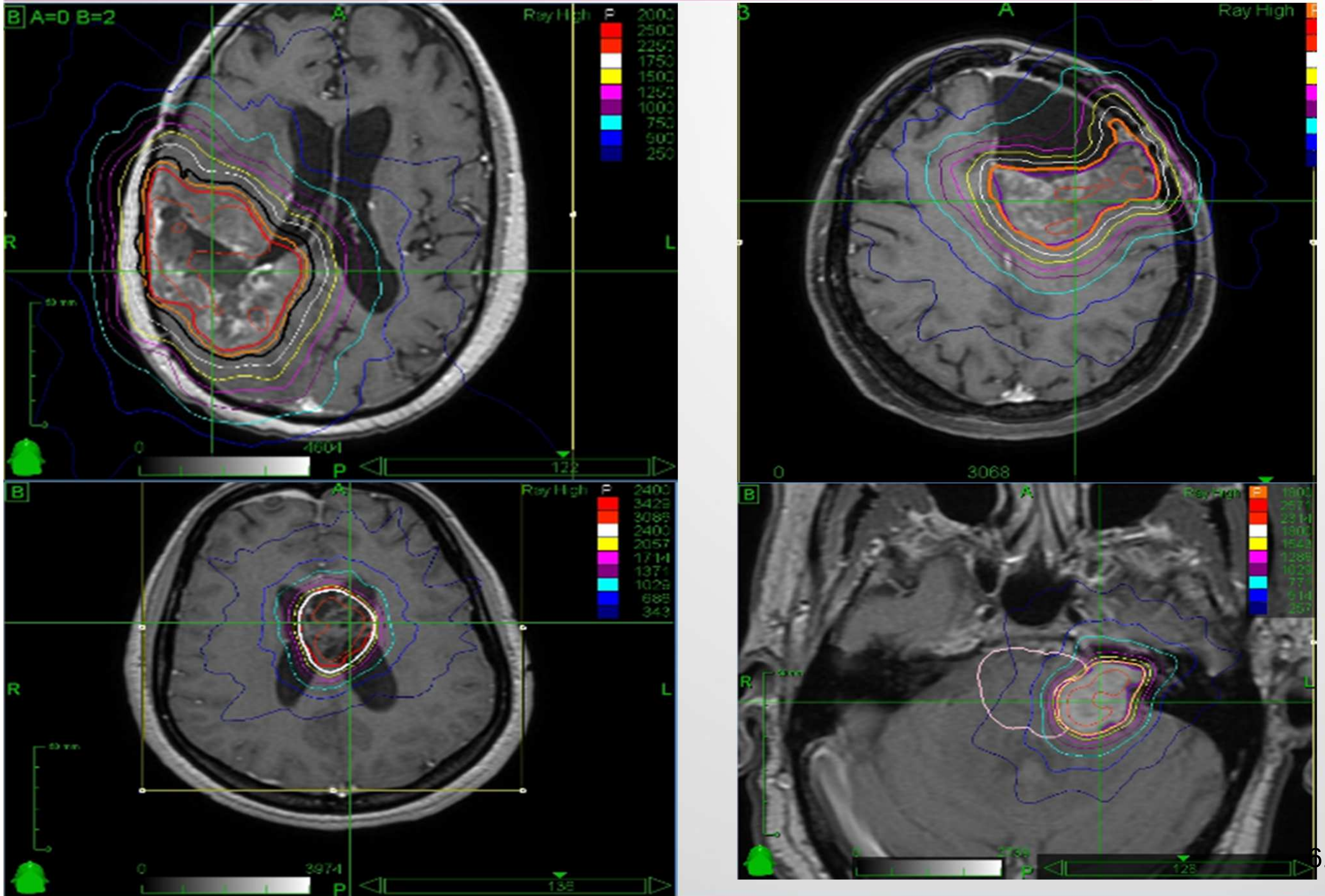

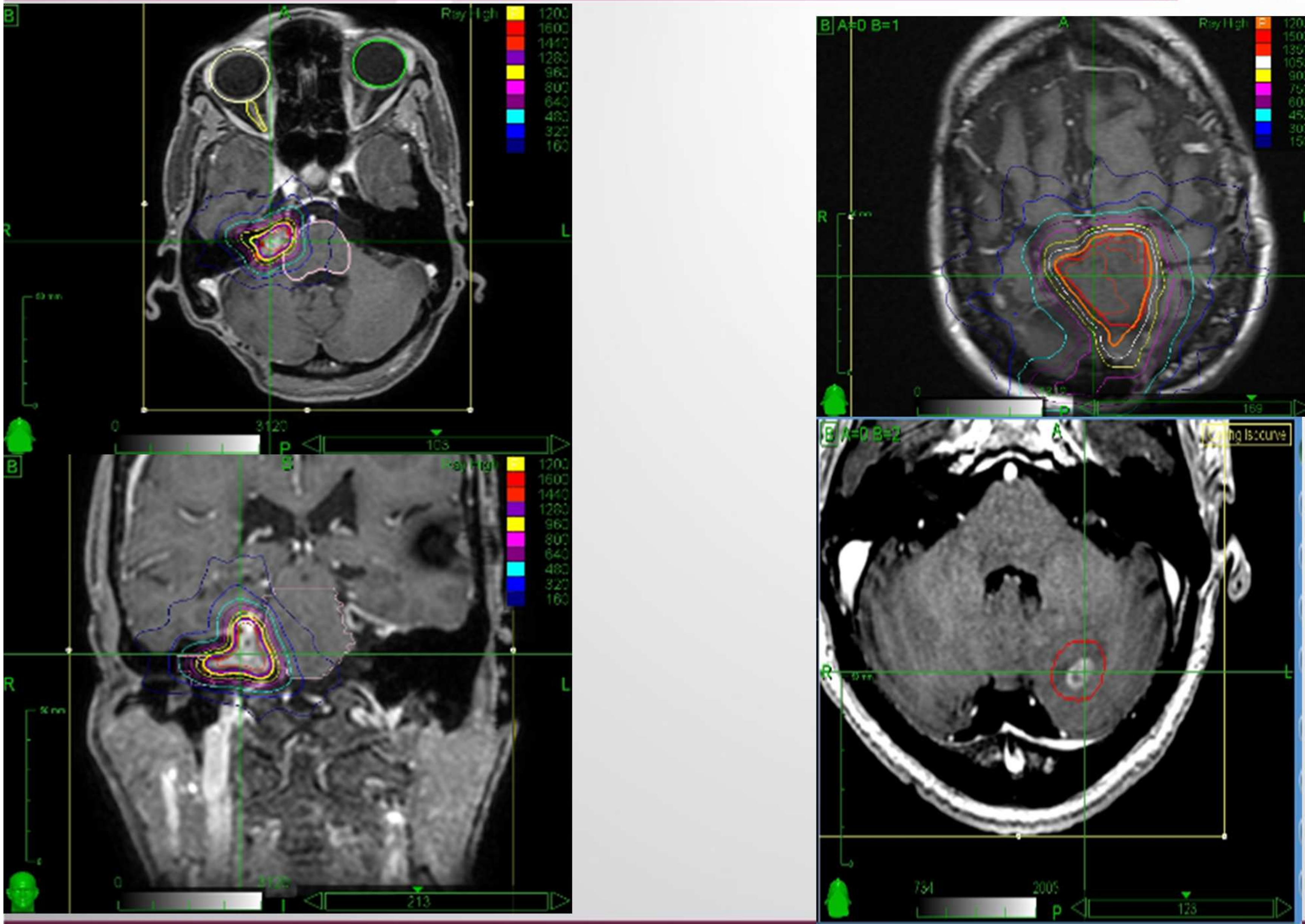

Future of Radiosurgery

Adler, John R. Jr MD: Neurosurgery 2013 - Volume 72 - p A8–A11

After emerging from and transforming the practice of neurosurgery, stereotactic radiosurgery is increasingly affecting all surgical disciplines.

The first generation of frame-based devices limited radiosurgery treatment to lesions of the brain where the rigidity of the skull provided adequate skeletal fixation

In an effort to surmount such anatomic limitations, robotic radiosurgery was developed.

After almost 2 decades of existence, the technology and clinical application of image-guided robotic radiosurgery have evolved considerably, and today a range of treatments with such technology have become commonplace.

Nevertheless, the timeless allure of a truly noninvasive, yet highly effective, therapy promises that further refinements in robotic radiosurgery will be forthcoming well into the future.

Future of Radiosurgery

Adler, John R. Jr MD: Neurosurgery 2013 - Volume 72 - p A8–A11

Going forward, this balance of skills will change.

The tools of noninvasive surgery, as manifested by radiosurgery, allow far less manual manipulation.

However, to enable the next stage of the evolution of surgery, robotic systems will assume even greater control of all mechanical processes, thereby automating the entire process of radiosurgery.

Although surgeons will remain critical to the process of comprehensive pretreatment planning, once properly programmed, robots will be the end effectors within radiosurgery.

In doing so, robots will constitute a metaphorical extension of the surgeon's hands and thereby remind future generations of the manual origins of surgery.