Principles and Practice of Stereotactic Radiosurgery (SRS) and Stereotactic Radiotherapy (SRT) in Intracranial Lesions

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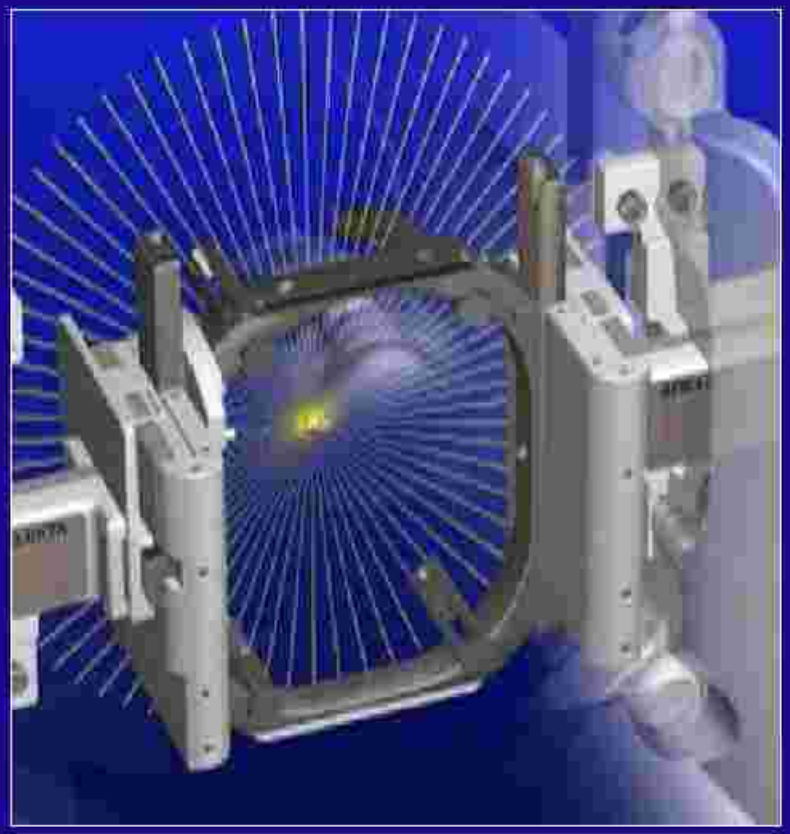
Stereotactic Radiotherapy

The delivery of multiple fractionated doses of radiation to a definitive target volume sparing normal structure (both intra as well as extra-cranial)

Stereotactic Radiosurgery



The delivery of a single, high dose of irradiation to a small and critically located intracranial volume, sparing normal structure

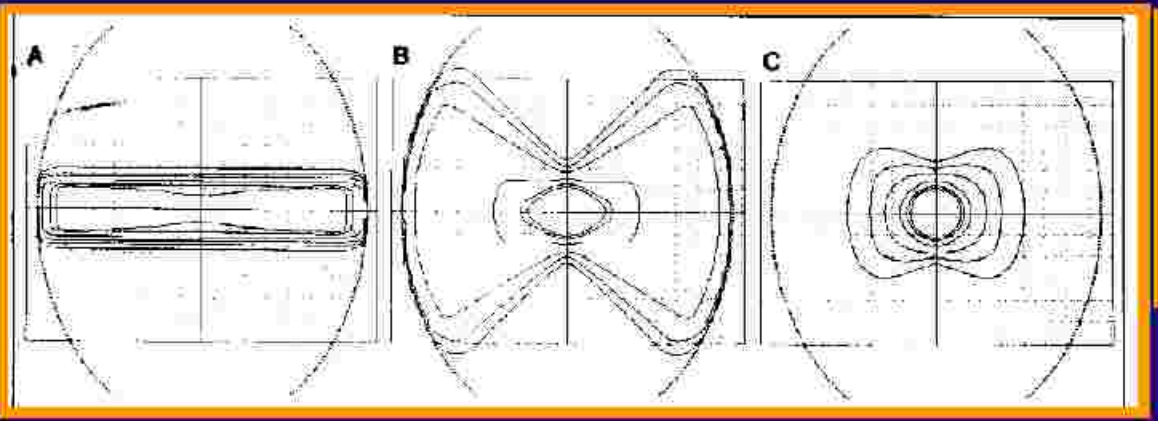
Conventional and Stereotactic setup

- ***Conventional***
  - coplanar setup
  - large volumes
  - less no. of fields
  - target volume delineation
  - positional accuracy ± 5 mm
  - Optical field, SSD indicator
  - Marking on patient's skin

- ***Stereotactic***
  - non-coplanar setup
  - small volumes
  - more no. of fields
  - precise delineation
  - positional accuracy ± 1 mm
  - Target volumes precisely delineated
  - Margins not necessary
  - Normal cells within the target negligible

Co-planar .vs. Non-coplanar beams

- tolerance of normal tissue depends upon both the dose and volume of the tissue irradiated
- normal tissue irradiation can be minimized through stereotactic definition of target and sharply focused, multiple, non-coplanar beams



A. Parallel opposed beams

B. Coplanar arcs (bilateral 100°)

C. Non-coplanar beams

Advantages

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

Quality of Life

- Minimally invasive
- Less trauma
- Faster recovery
- Minimal hospitalization
- Fewer complications
- Documented efficacy

Clinical Outcome

- Documented scientific data shows better or equal results compared with microsurgery
- Fewer complications
- Reproducible results
- Treatment solution for inoperable patients
- Combined treatment with microsurgery and endovascular techniques extend the capabilities

The Time Factor

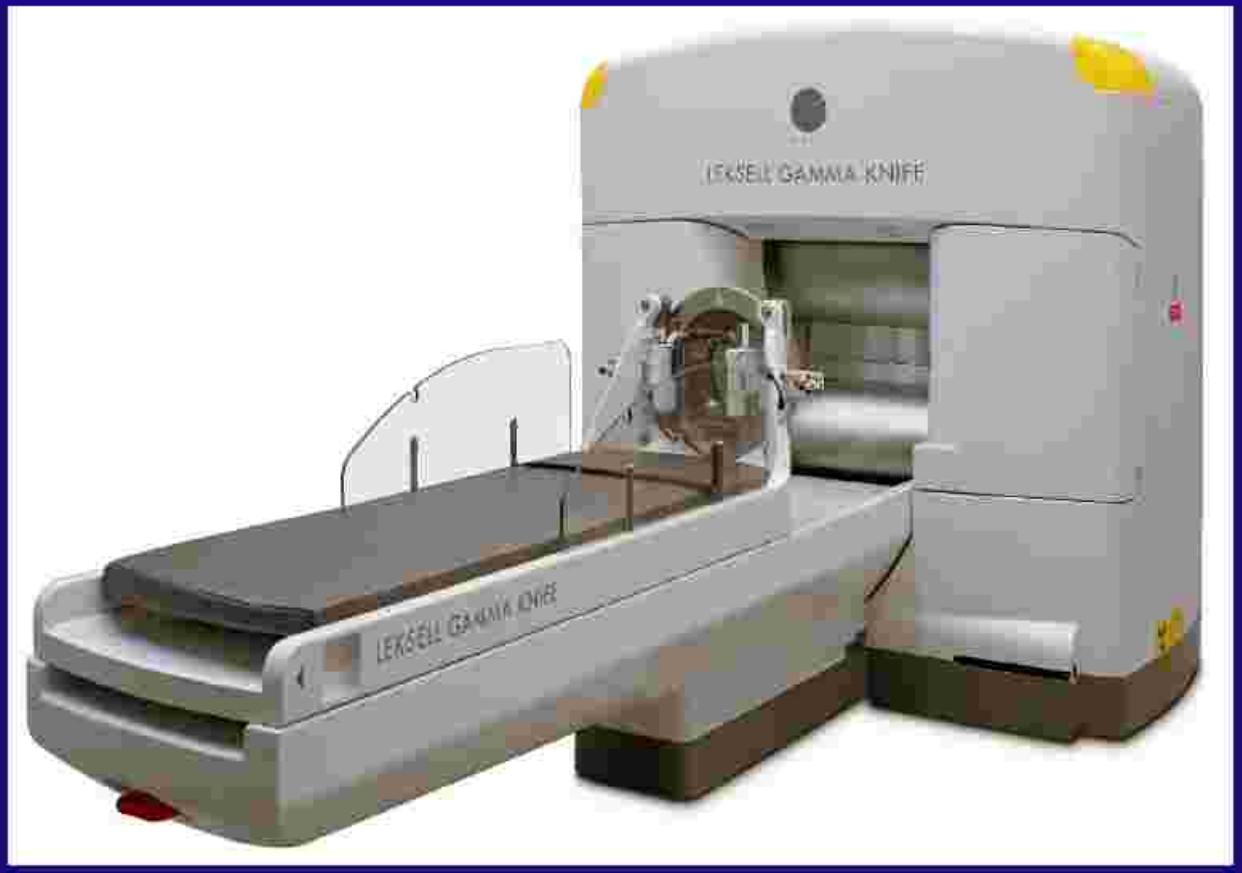
Treatment techniques & units

- charged particle beams - *cyclotrons & synchrotrons*
- gamma ray photons - ***Gamma Knife*** *& RGS*
- x-ray photons - *modified & dedicated linacs* ***(X-Knife), micro multi leaf collimator***
- neutrons have been used *unsuccessfully*

Gamma Knife … *the machine*

- 201 cobalt-60 radioactive sources
  - *cylindrical; 1 mm dia; 2 cm height; 30 Ci activity each*
- central ray from all the sources focused at a single point, within an accuracy of ***± 0.3 mm***
- dose distribution at this (sec. Collimator) point is in the form of a sphere
- helmets can shape the diameter of this ***'radiation sphere'*** to 4, 8, 14 and 18 mm
- ***plugging*** to alter the shape of this sphere
- minimal moving part (*couch in & out*)

Gamma Knife

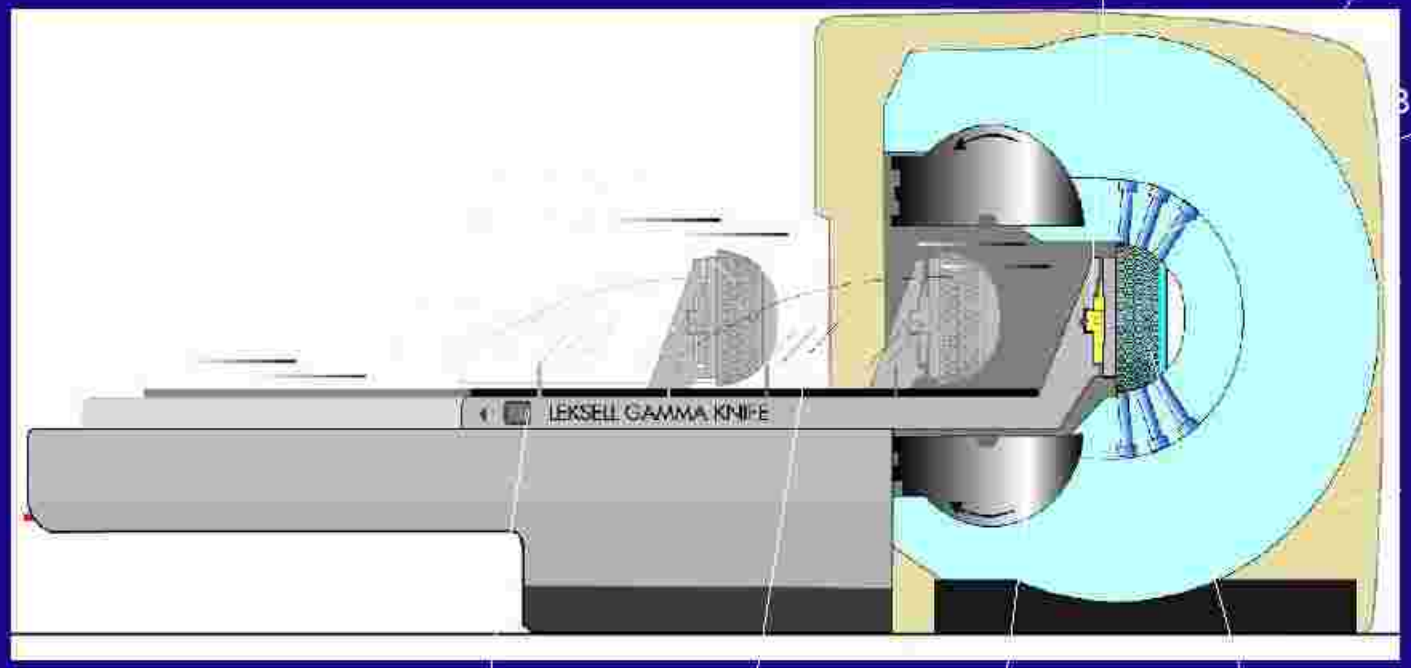


The man behind the machine ….

"The tools used by the surgeon must be adapted to the task and where the human brain is concerned they cannot be too refined."

Late Professor Lars Leksell

Leksell Gamma Knife



Automatic positioning system

Cobalt-60 sources

Beam channel

Shielding

Plastic cover

Treatment couch with mattress

Protection panels

Shielding doors

Helmet in treatment position

X-Knife

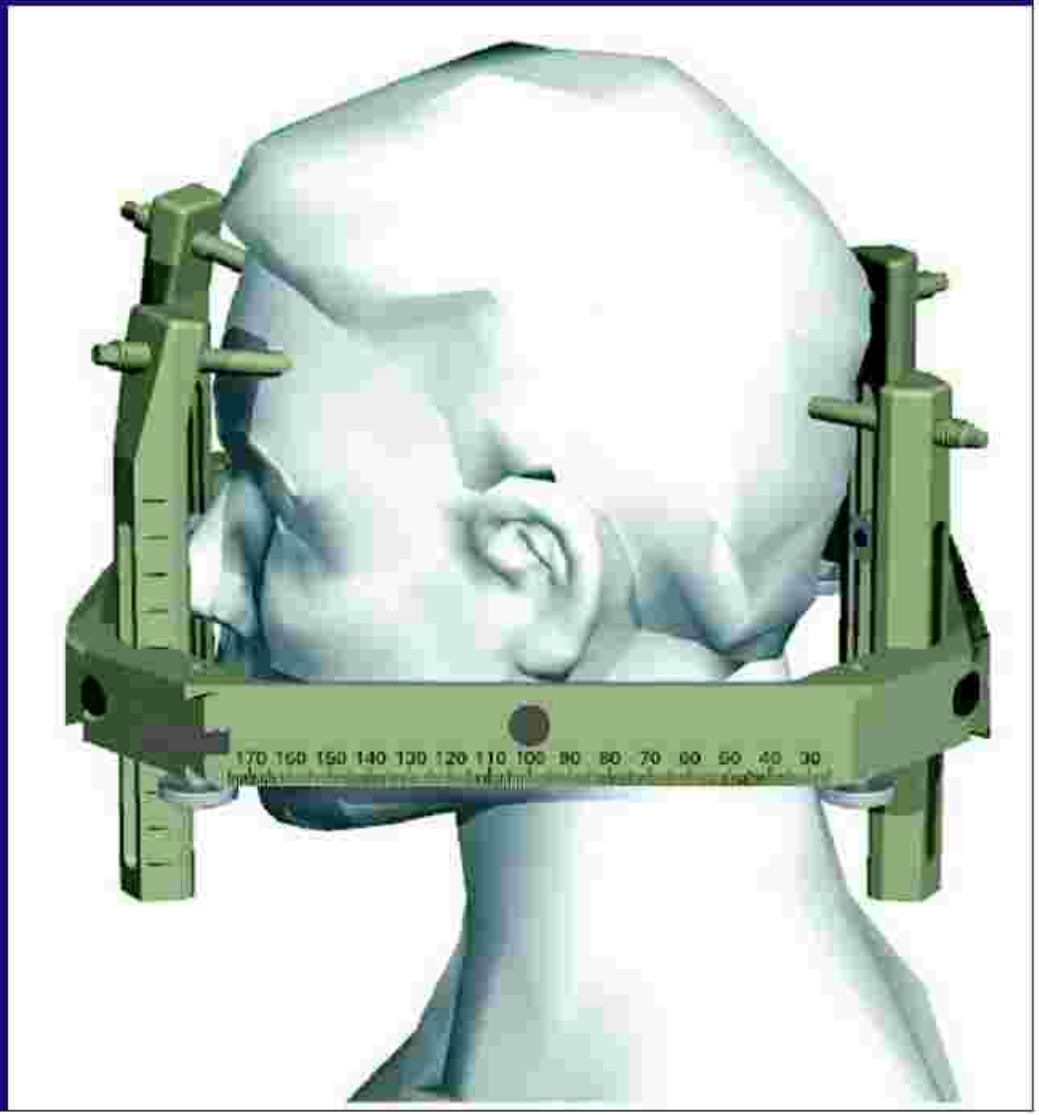
The Treatment Procedure

- Frame Fixation
- Diagnostic Imaging
- Image transfer
- Treatment planning
- Treatment

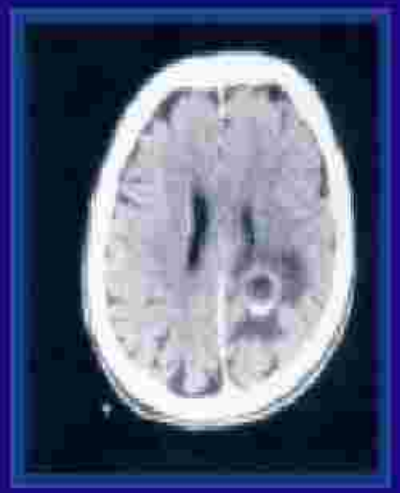
Why frame?

- helps us in defining the images in a coordinate system - ***fiducial points***
- accurate positioning of the patient at the time of treatment
  - **SRS frames**
    - Leksell frame ***in Gamma Knife***
    - BRW *(Brown-Roberts-Wells)* & CRW *(Cosman-Roberts-Wells)* ***in X-Knife***
  - relocatable frames for fractionated stereotactic irradiation ***(SRT)***
    - GTC *(Gill-Thomas-Cosman)*

Frame Fixation

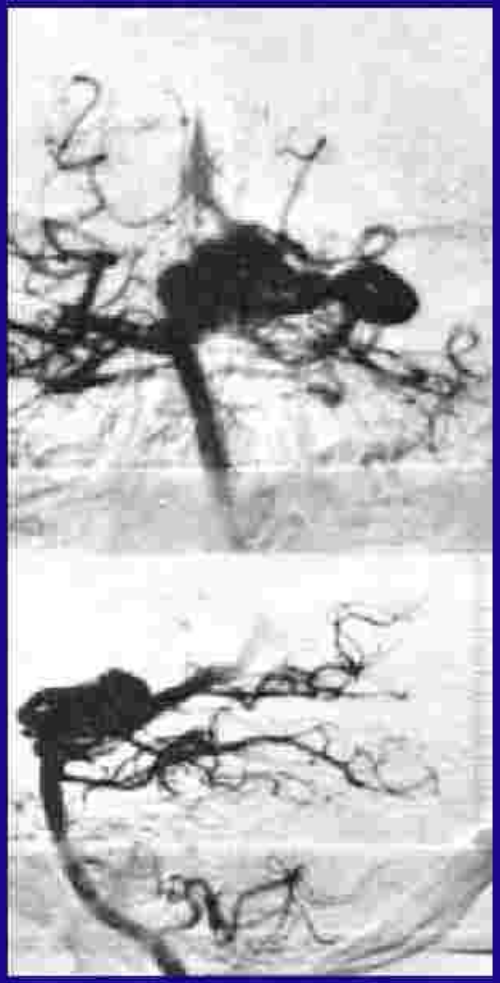


Diagnostic Imaging



CT scan

MRI



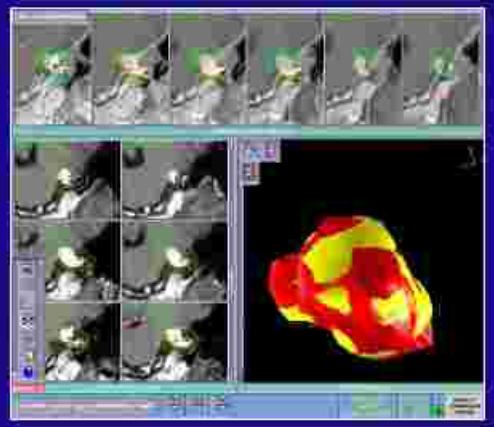
Angio

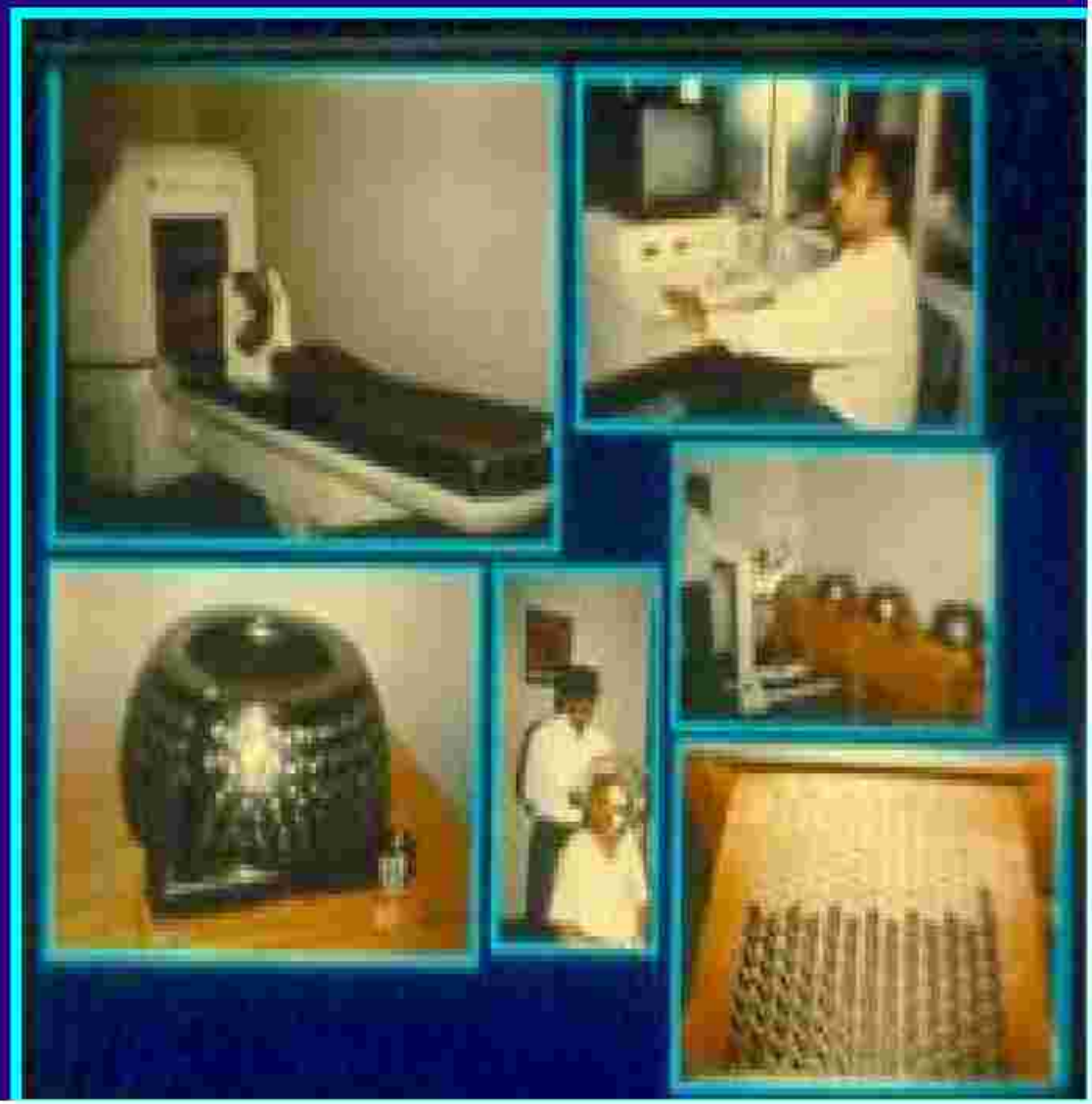
Image transfer

- Networking
  - Local area networking (LAN)
- PACS
  - to Gamma plan
  - to X-plan
    - Magneto Optical disc
    - DAC tape
    - Film scanner
    - CT, MR film

Treatment Planning

- Fast creation of optimal treatment plan
- User friendly software dedicated for Gamma Knife surgery

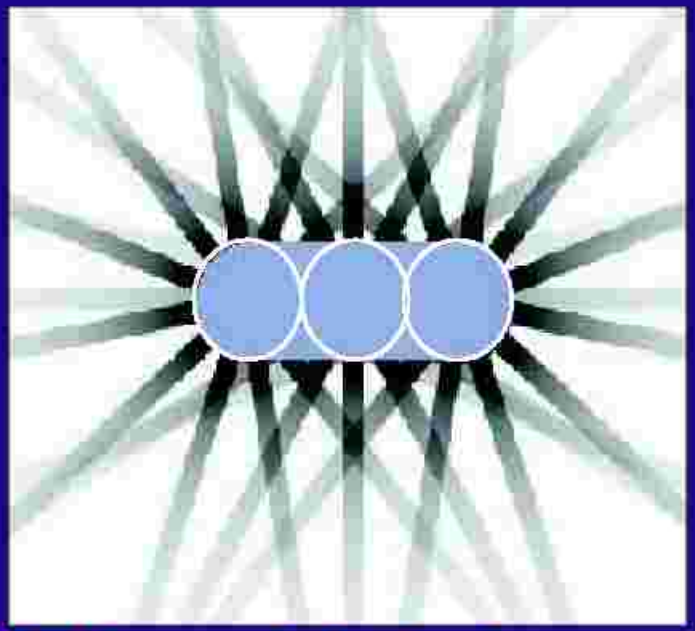




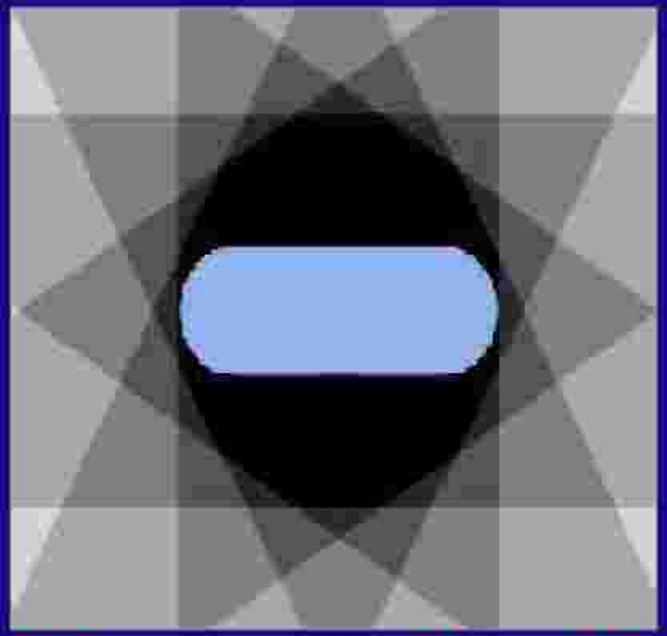
Treatment planning

- contouring of target and critical structures on image slices
- target contours on image slices constitute an empty sac three dimensionally
- fill up this sac with **'radiation spheres' (shots)** conformally
- x,y,z coordinates of the shots are given in the print out
- treatment time for every shot depends on the dose to be delivered
- position the patient for every shot and treat

Conformity of Dose to Target



With multiple isocenter



With conventional beams

Years of Clinical Experience

1968

The first prototype of Leksell Gamma Knife was installed in Stockholm, Sweden.

1999

Elekta refines the Art of radiosurgery by introducing Leksell Gamma Knife C.

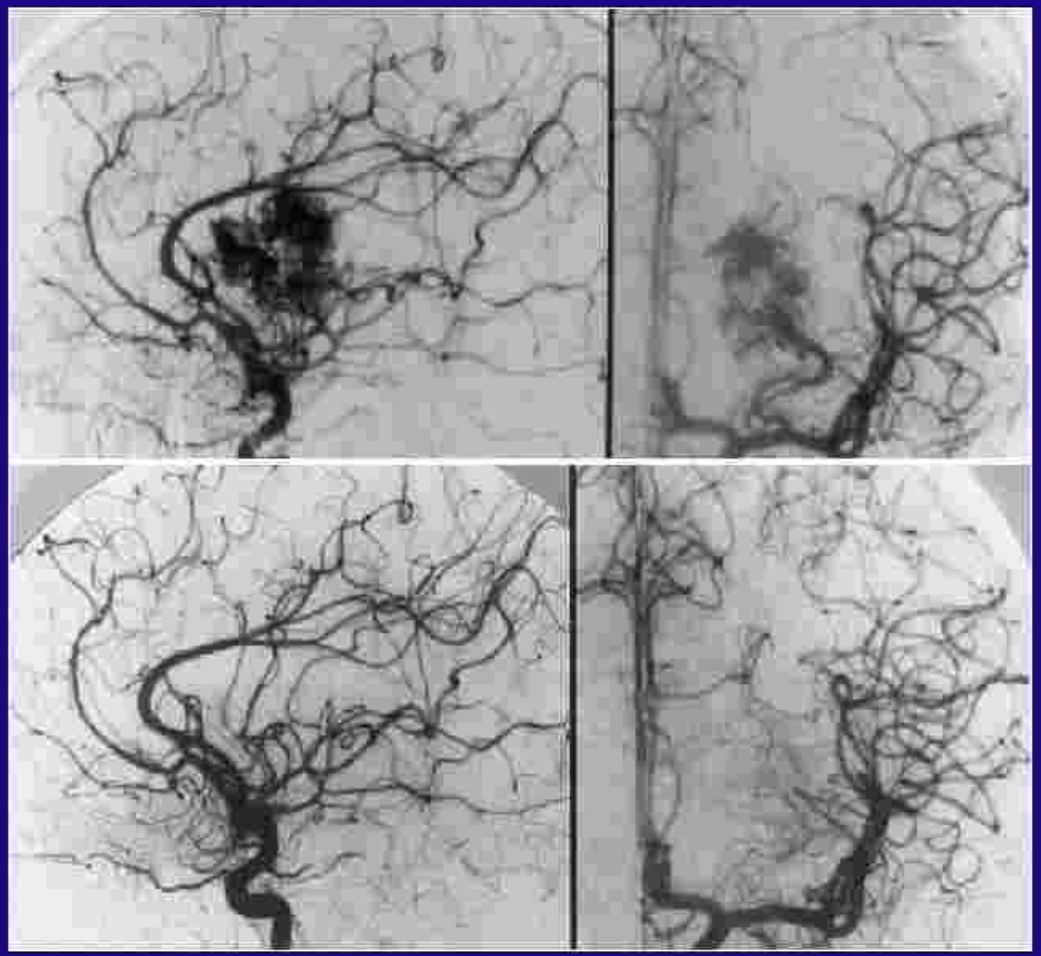
Treatment Indications

- **Tumors**
  - Meningioma
  - Pituitary
  - Acoustic
  - Metastatic
  - Glioma
- **Vascular**
  - AVM
- **Fuctional**
  - Trigeminal Neuralgia
- **Research Areas**
  - Movement Disorders
  - Intractable Pain
  - Epilepsy
  - Macular Degeneration
  - Uveal Melanoma

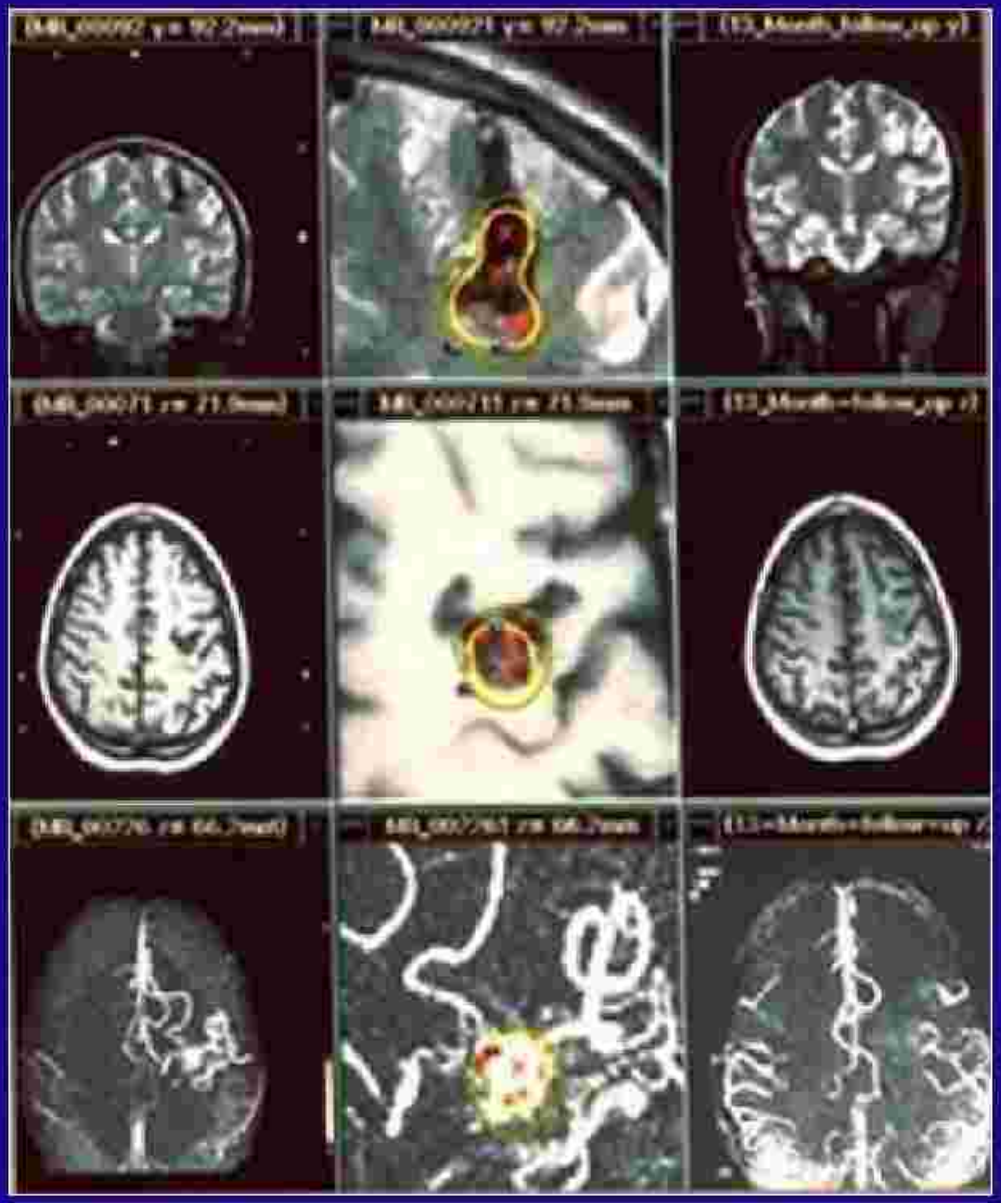
Arteriovenous Malformation

Pre Gamma Knife Surgery

2 years post Gamma Knife Surgery

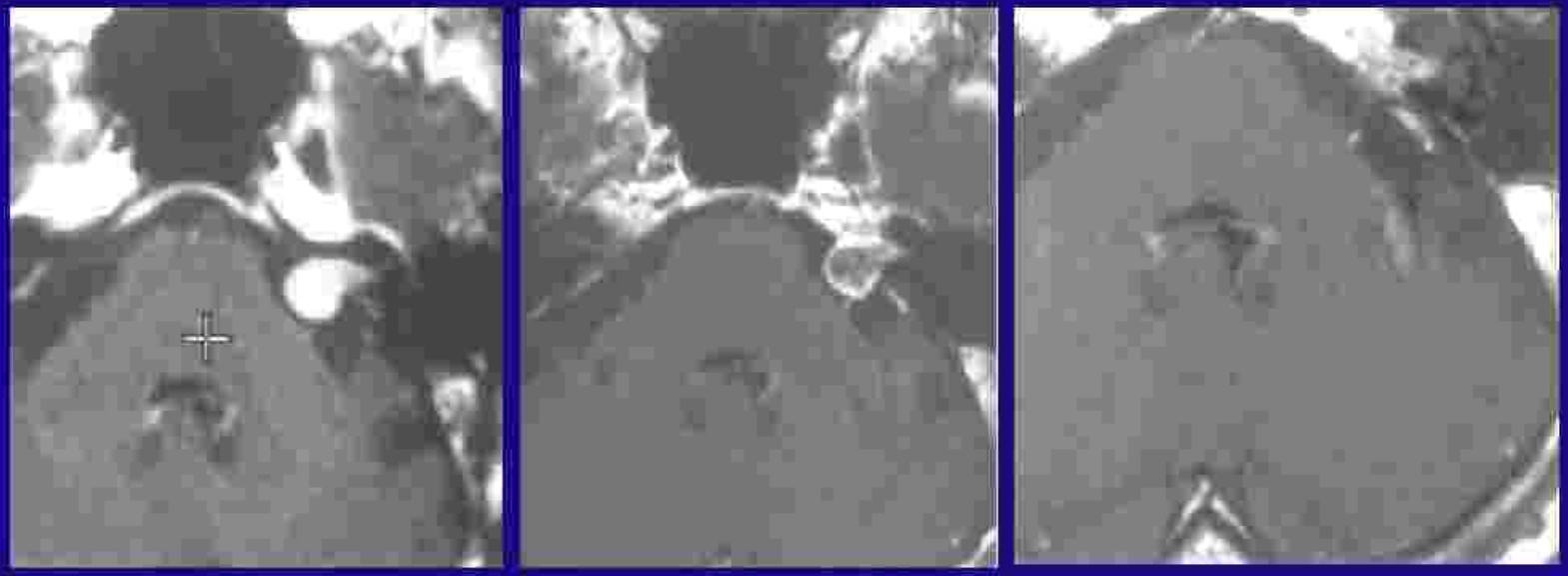


AVM



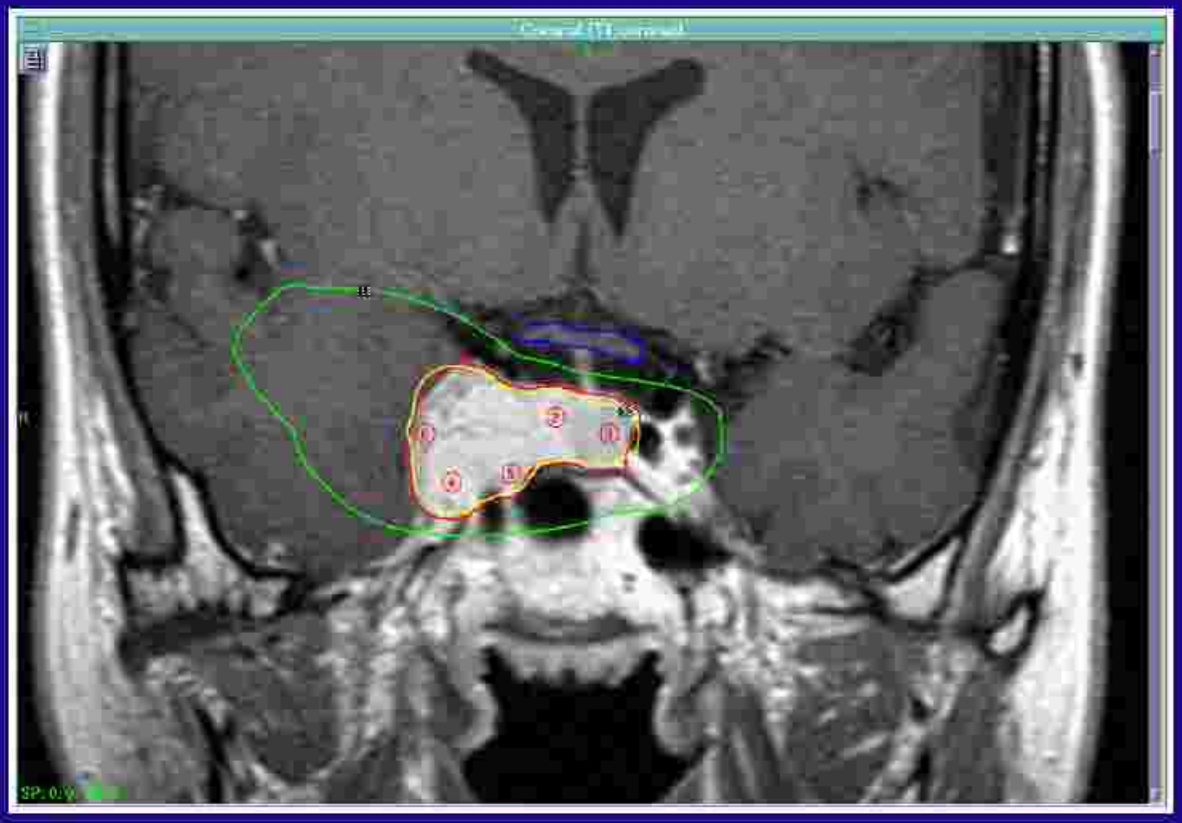
Pre Dose Plan 13 Months Post

Acoustic Neuroma



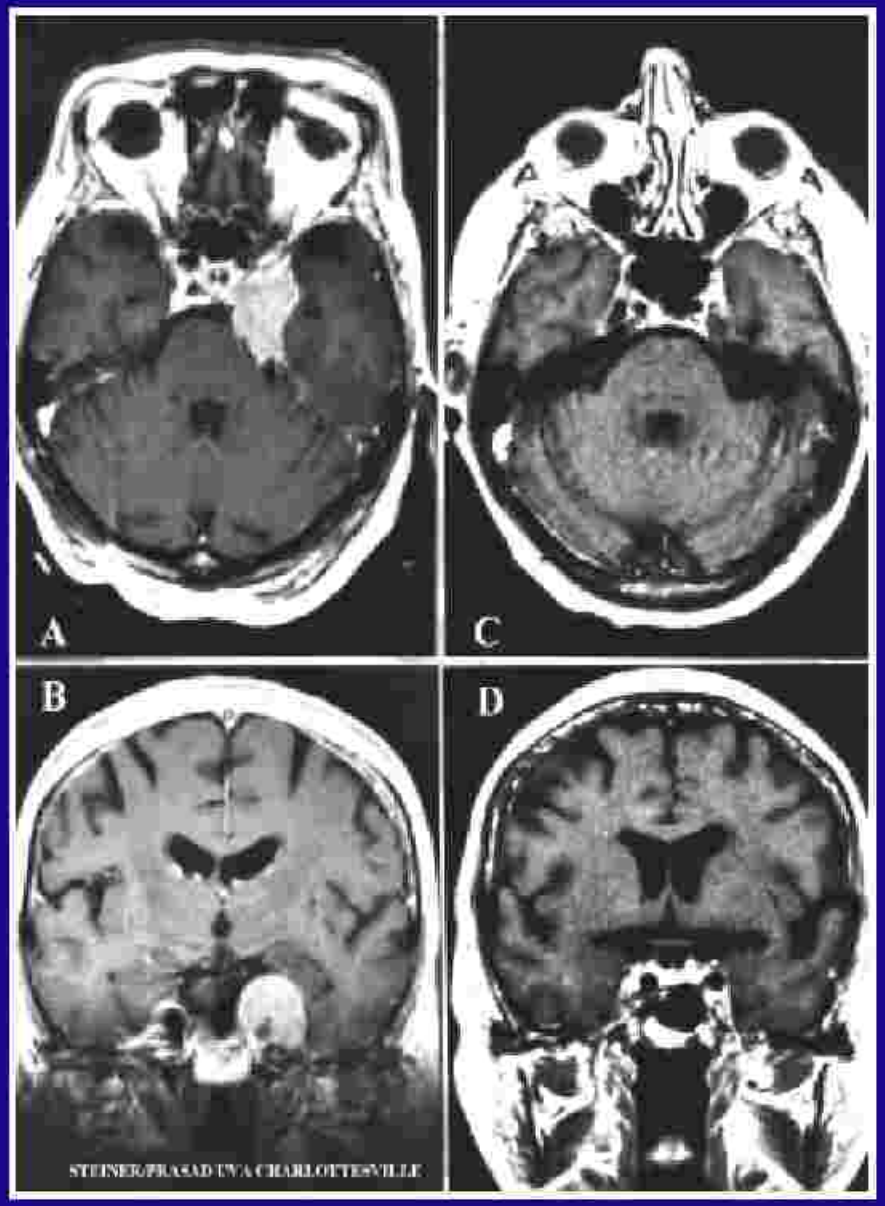
Pre | 6 months post | 2 years post

Meningioma



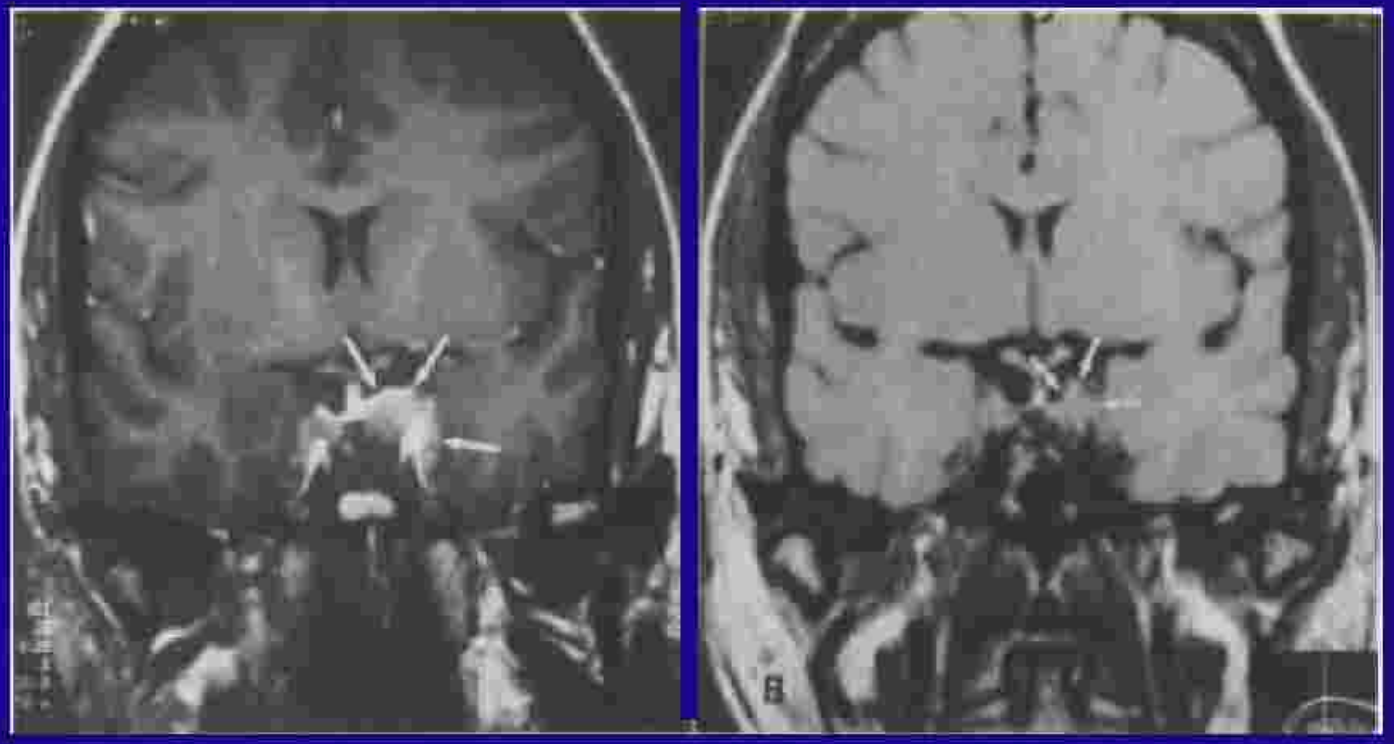
Dose plan with 6 isocenters
- minimizing dose to optic chiasm

Meningioma



2 years post

Pituitary Adenoma



Pre

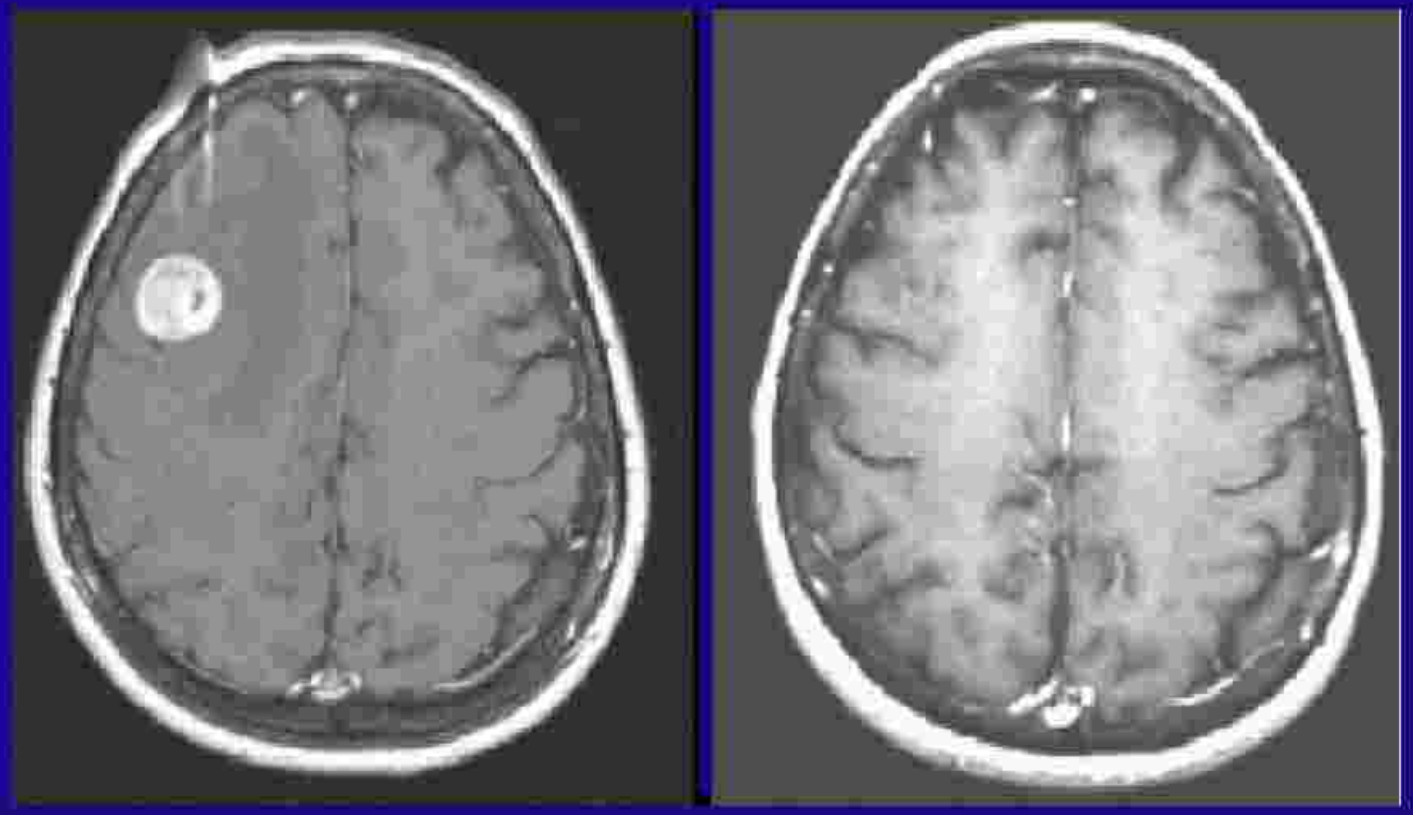
54 months post

Metastasis

Pre

2 months post

Metastasis

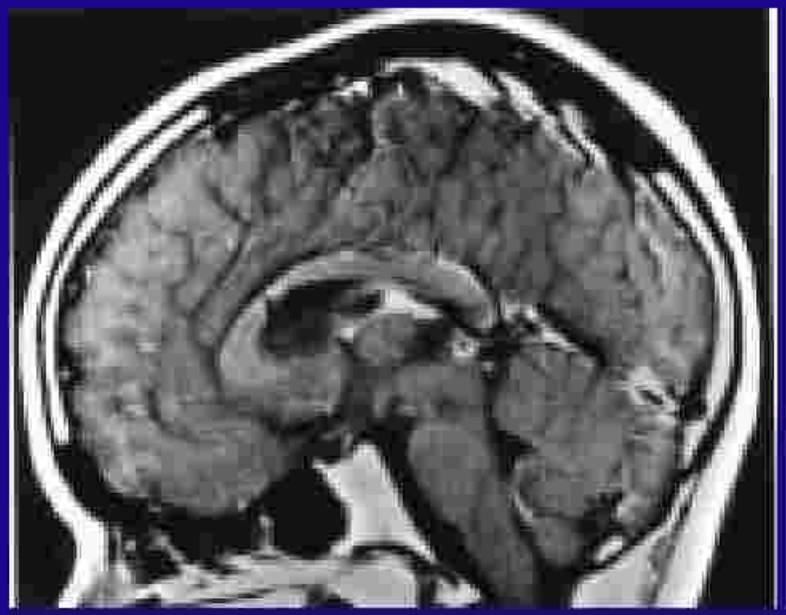


Pre

10 months post

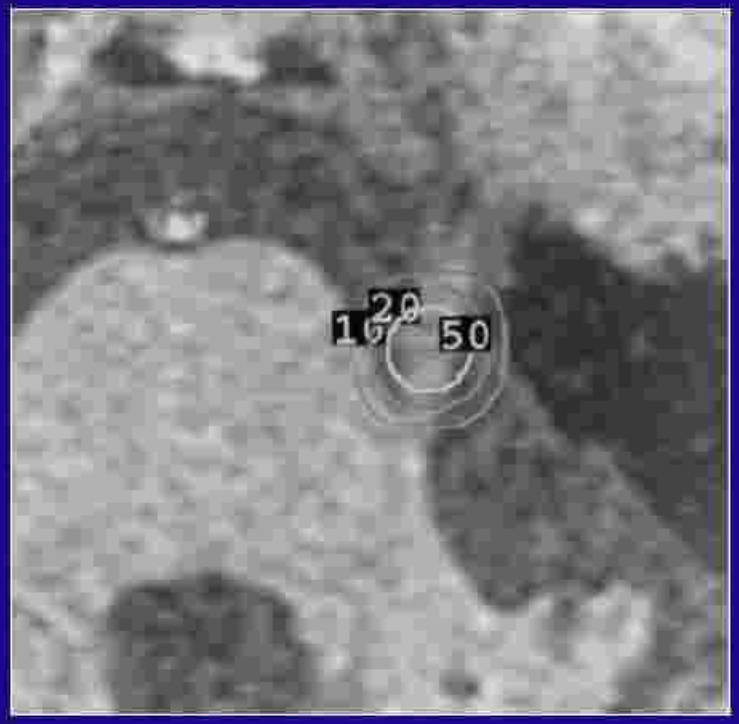
Astrocytoma

Pre



5 years post

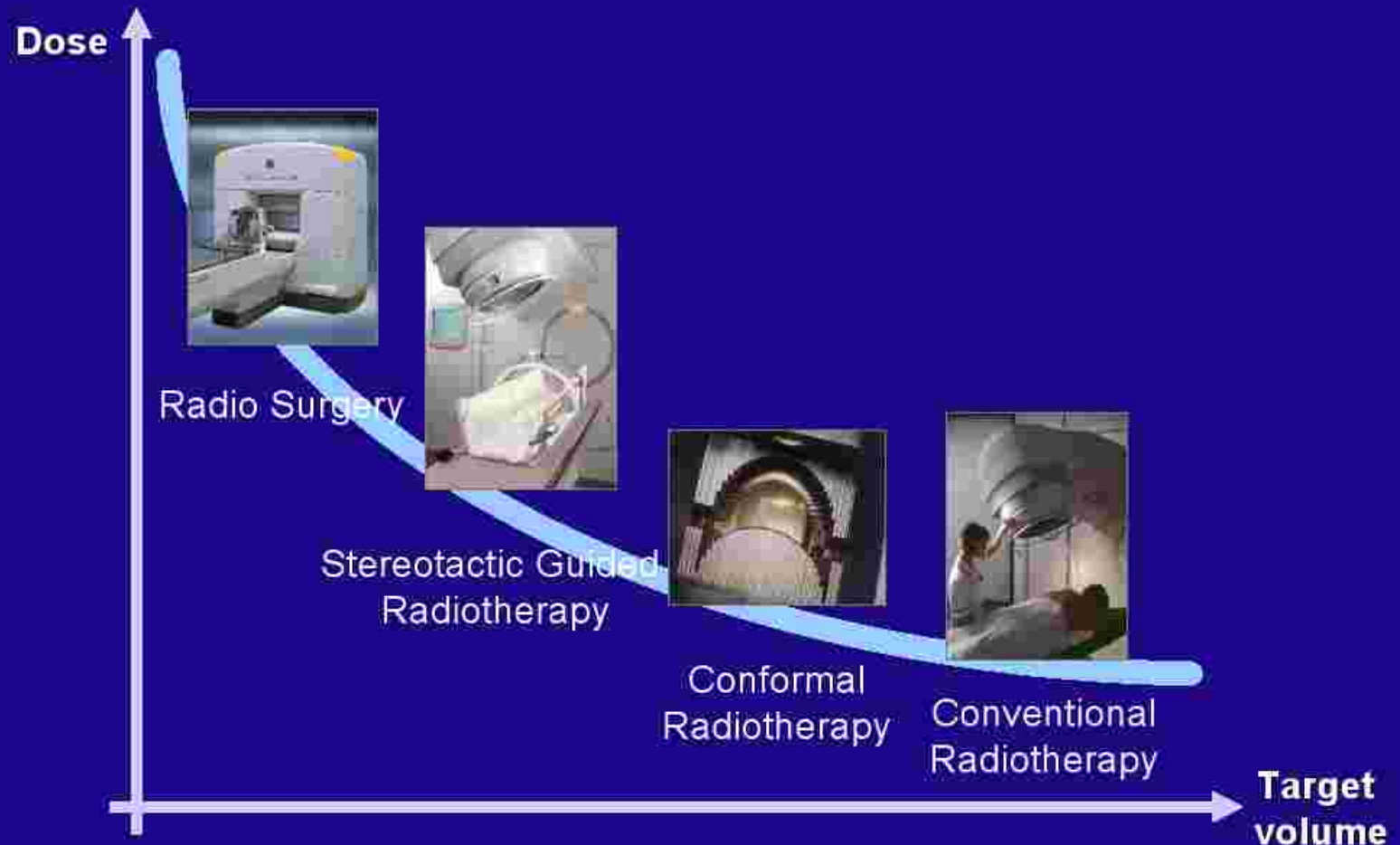
Trigeminal Neuralgia



Dose plan

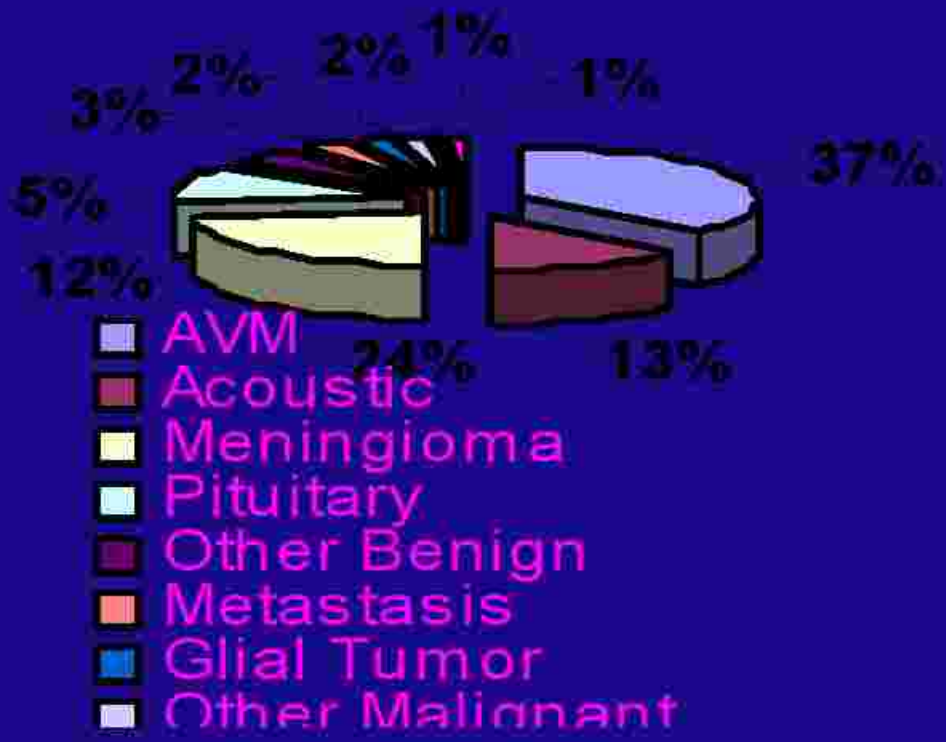
6 months post

Clinical Solutions



SRT/SRS at AIIMS ...

- Started on 27th May, 1997
- No. of patients treated till date: **1674**



X-Knife … *the machine*

- **installed on a modified / dedicated linac**
  - Floor Mounted System
  - ***Couch Mounted System***
- **collimators are modified**
  - tertiary collimators are add
  - circular; elliptical
  - mMLC (gradually replacing cone based radio-surgery system- *better isodose shaping*)

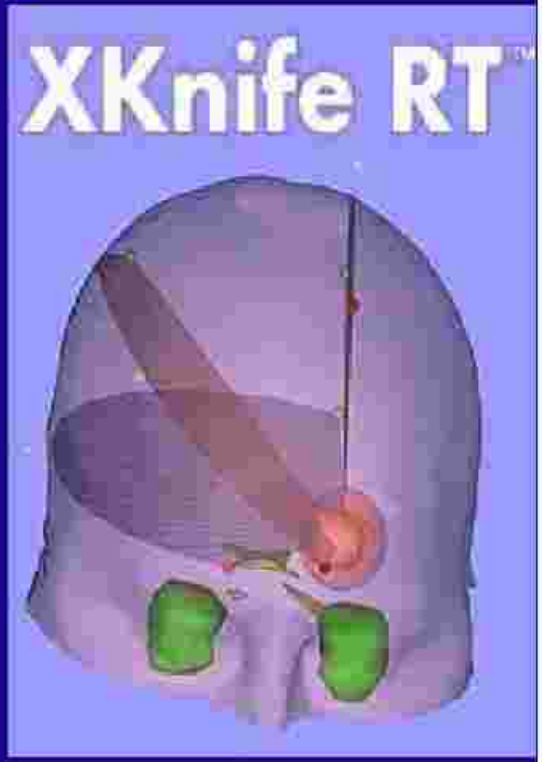
Linac treatment parameters

To be optimized to produce desired isodose.

- isocenter location
- collimator field size
- couch angle
- arc rotation interval
- weightage of each arc
- dose per isocenter

X-Knife planning steps

- **isocenter selection**
  - *place isocenter in target volume center*
  - *determine collimator size by covering target volume*
- **arc selection**
  - *Through BEV to avoid critical structures*
  - *Number of non-coplanar arcs (depends on collimator size)*
  - *couch / gantry restrictions to be considered*



QA for linac based SRS

Before every treatment

- lasers are aligned to point to isocenter
- lasers are then taken as the reference system for positioning the patient
  - *initial positioning*
  - *then, at every couch angle*
- Laser must fall on the reference line on the frame

positional accuracy better than ± 1 mm

Treatment Indications

- **Cranial**
  - **Tumors**
    - Pituitary
    - Meningioma
    - Craniopharyngioma
    - Acoustic
    - Metastatic
    - Glioma
  - **Vascular**
    - AVM
- **Extracranial**
  - **Primary lung tumors**
  - **Metastatic lung tumors**
  - **Liver metastases**
  - **Adrenal metastases**

Gamma Knife vs. X-Knife

- mechanical precision is far superior in Gamma Knife
  - Accuracy easily achievable (0.1mm- mechanical, 0.3mm- intersection of beams & 0.5mm overall)
  - only for cranial targets
- stereotactic procedures are quite similar, except
  - CT is a MUST for X-Knife; not so in Gamma Knife
  - skull contouring (total imaging in X-knife; partial imaging in Gamma Knife)

Stereotactic Bodyframe

- Stereotactic irradiation concept extended to extra-cranial sites also

In summary...

- SRS & SRT are *almost* the ultimate form of *Conformal Therapy (IMRT better for tumors encasing a normal structure)*
- *The dose distribution accuracy up to +/- 1mm (+/- 0.5 mm for Gamma Knife) not achieved by any other modality*
- *SRT preferred for targets adjacent to critical structures*
- *Immobilization by frame is the key*
- *SRT is achieved by re-locatable frames (non-invasive)*
- *Both SRT & SRS can be performed with Linac*

  (Only SRS possible with Gamma Knife)


Thank You