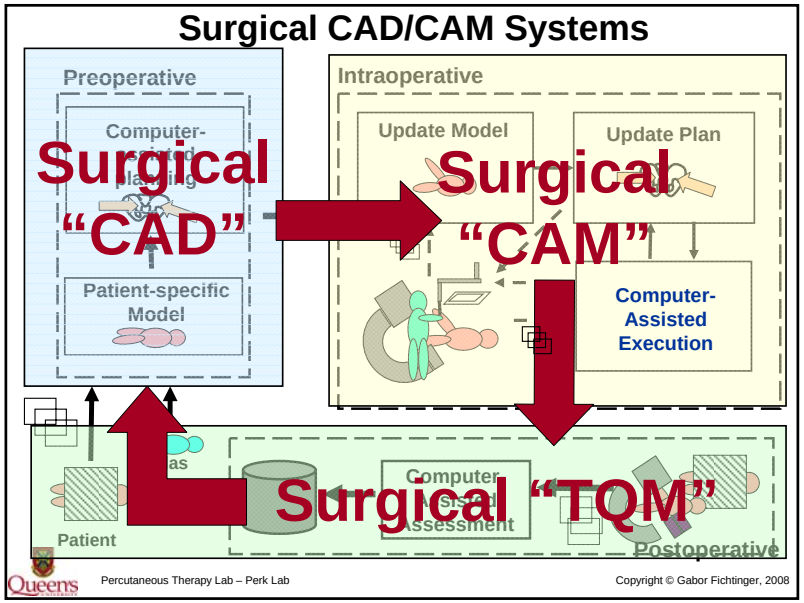
Brain Tumor Radiosurgery

Surgical CAD/CAM Systems



Brain Tumors Are

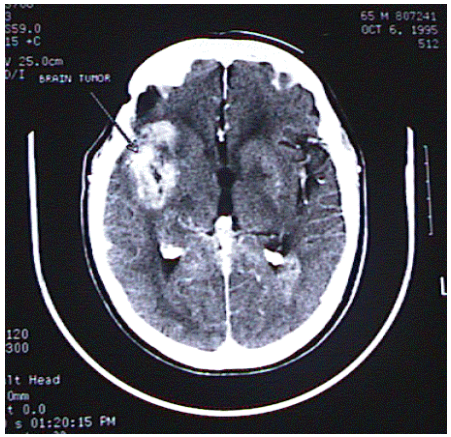
- The leading cause of death from childhood cancers among persons up to 19 years
- The second leading cause of cancer-related deaths in males ages 20-39
- The fifth leading cause of cancer-related deaths in women ages 20-39

Incidence of Brain Tumors
in the US in 2005

- Total new cases of primary brain/CNS tumors (malignant and non-malignant):
  - 200,000 metastatic
  - 43,800 primary
- They occur in 10-15% of people with cancer.
- Primary brain tumors generally do not metastasize to other parts of the body.

Brain Tumors

Some are lethally aggressive (glioblastoma multiforme)

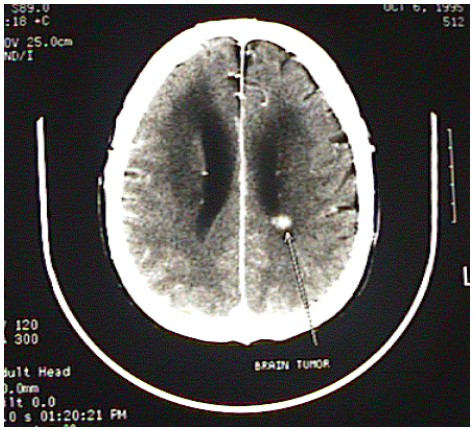


Brain Tumors

Some are inoperable – too big, intrusive, etc..

Brain Tumors

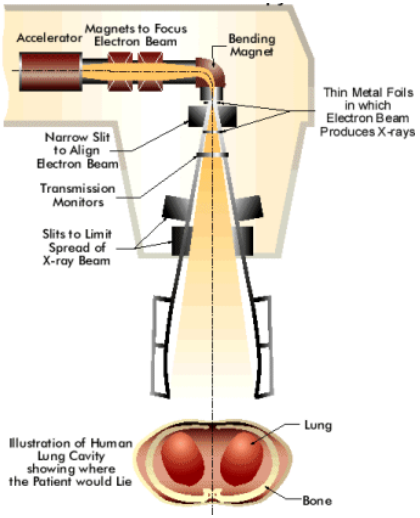
Some are inoperable (too deep, metastatic, etc.)



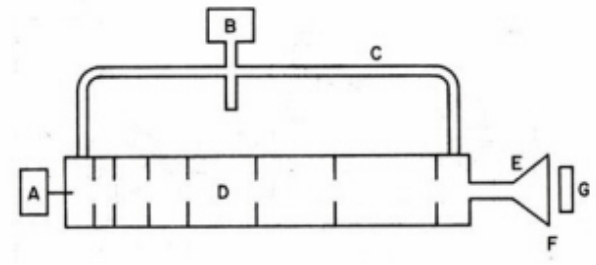
Radiosurgery

Blasting out tumors with high energy (25 MeV) X-ray

Medical Linear Accelerator



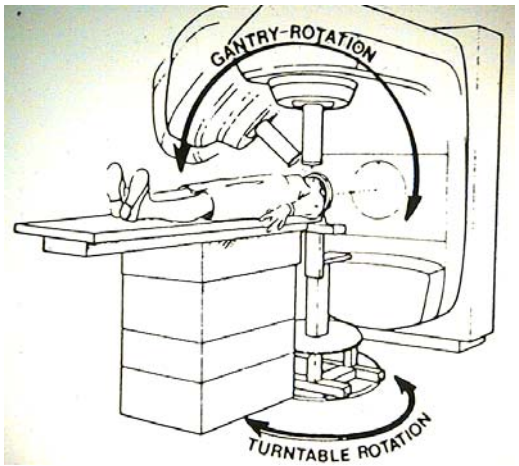
Linear Accelerator



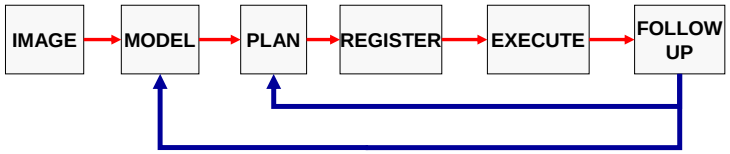
Linear accelerator (LINAC) for electrons. A klystron (B) connected to a waveguide (C) generates traveling microwaves in the evacuated accelerator tube (D). Electrons are injected in bunches by source (A) and are accelerated by the traveling microwaves. The pulsed electron beam is spread by a scanning coil (E), exits through a thin window (F) and irradiates the target (G). (Adapted from O'Donnell and Sangster.)

Multiple Beams

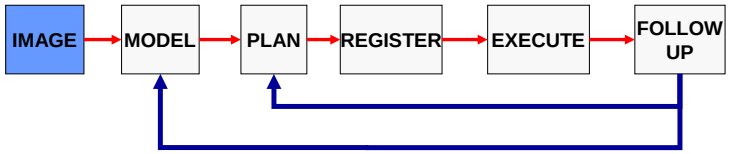
Linac Motions



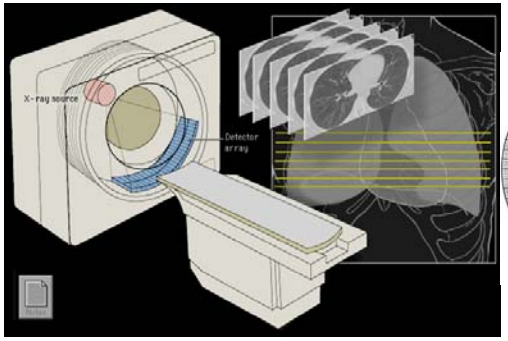
Radiosurgery CAD/CAM

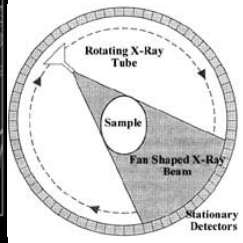


Radiosurgery CAD/CAM

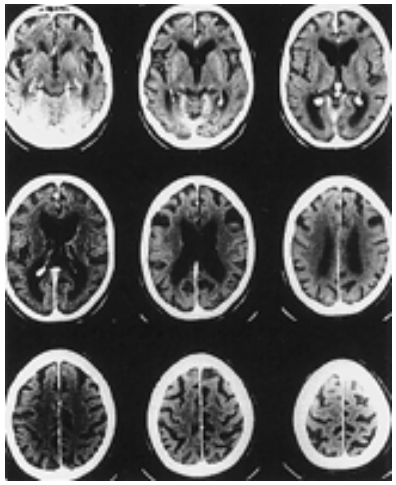


Computed Tomography (CT)



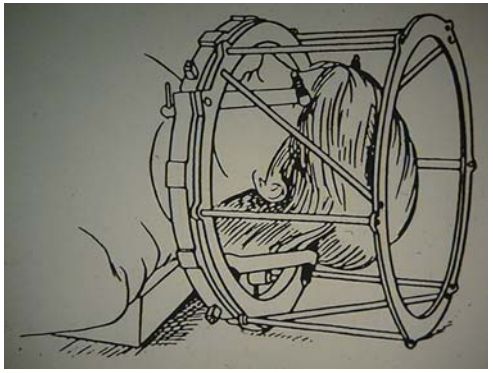


Computed Tomography – Images



Head-ring Attachment

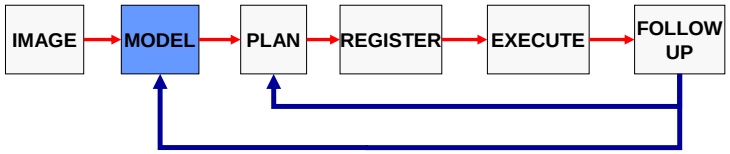
Patient in Localization Frame



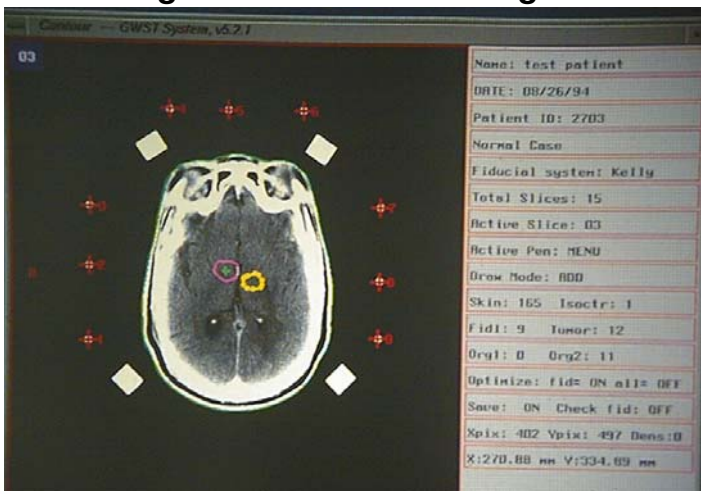
Relocatable Headrest

CT Imaging

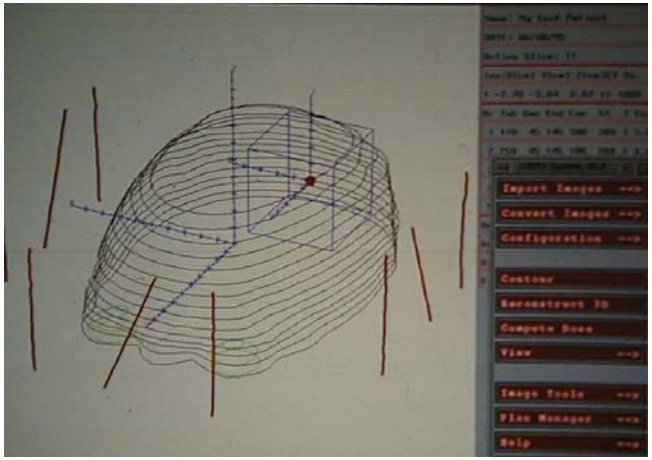
Radiosurgery CAD/CAM



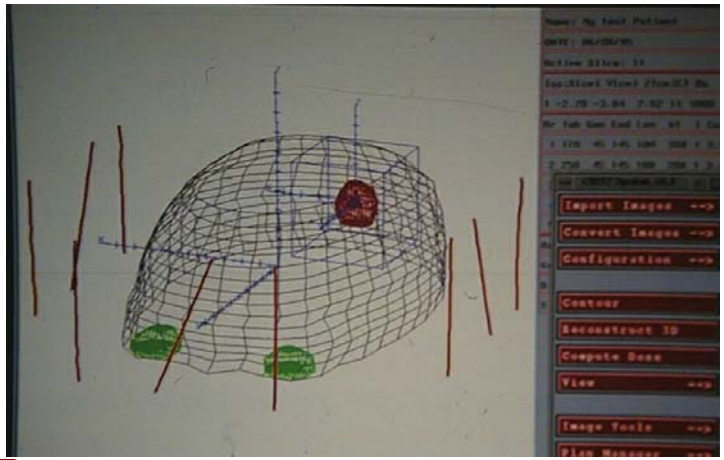
Segmentation of CT image



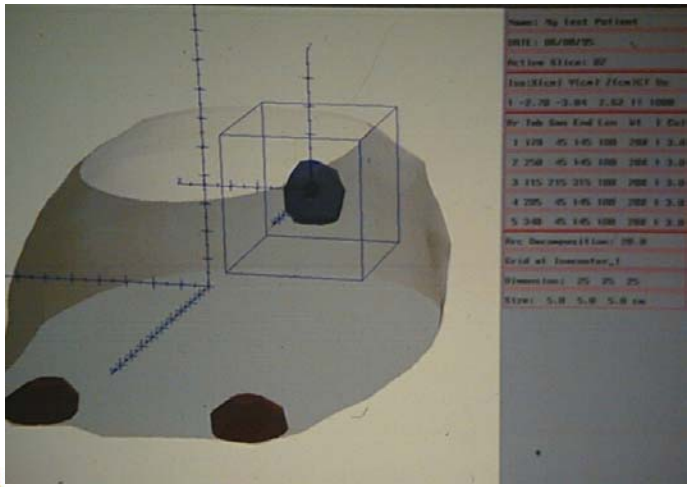
3D reconstruction



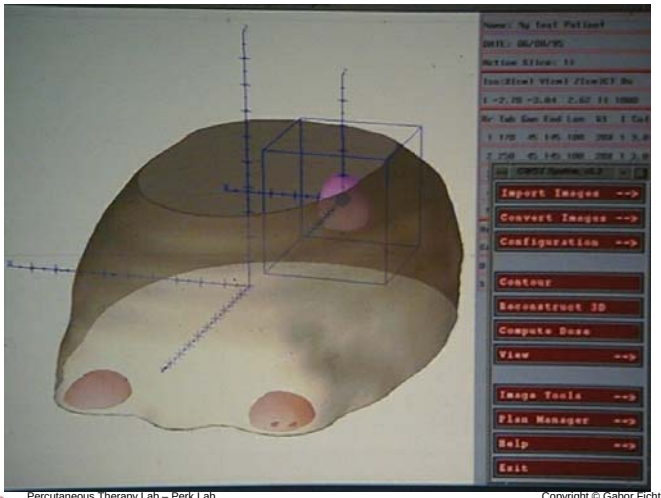
3D Reconstruction



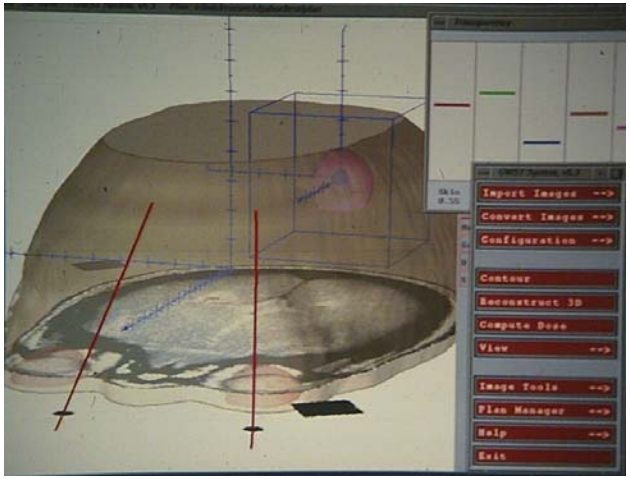
3D Reconstruction



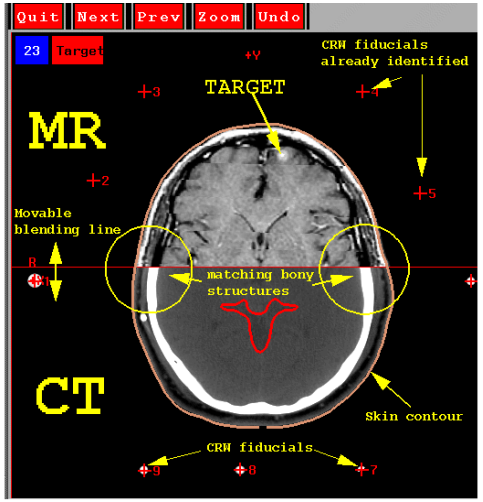
3D Reconstruction



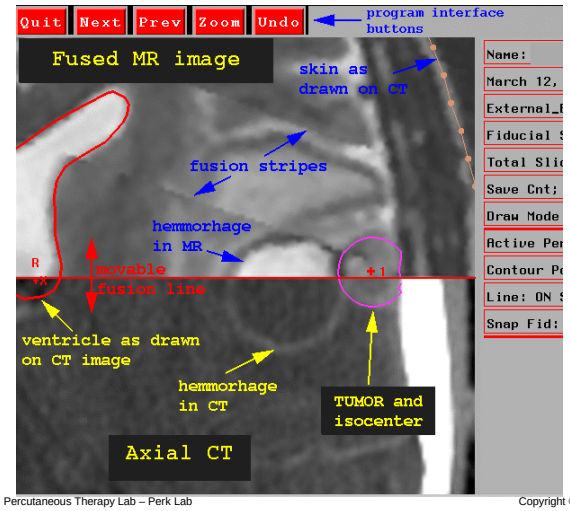
3D Reconstruction



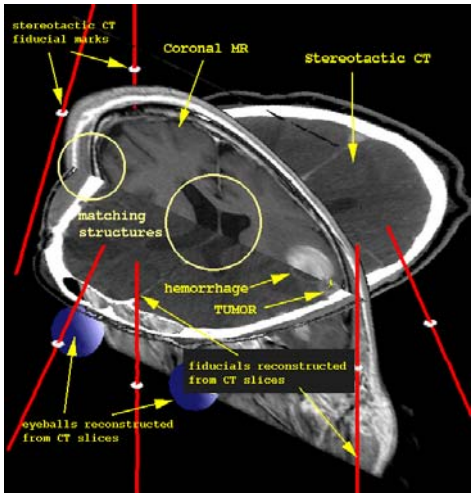
Data Fusion



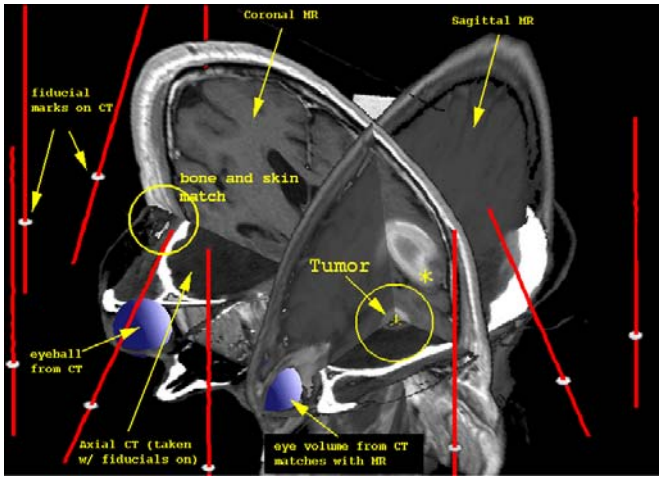
Data Fusion



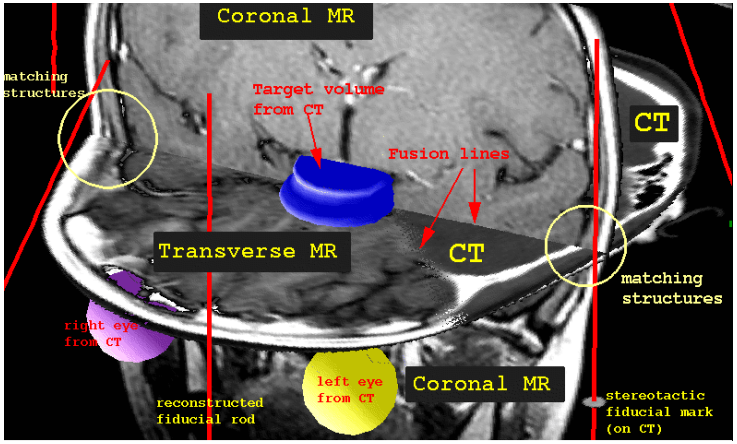
3D Target Visualization



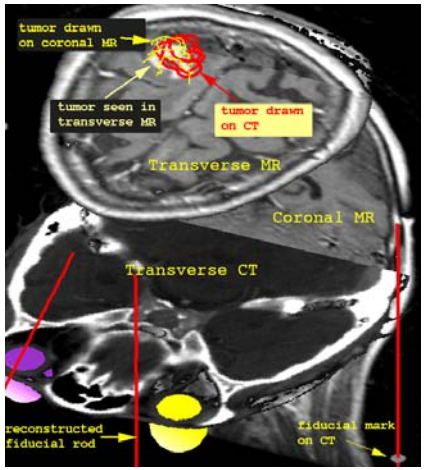
3D Target Visualization



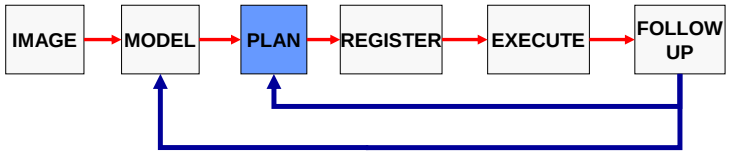
3D Target Visualization



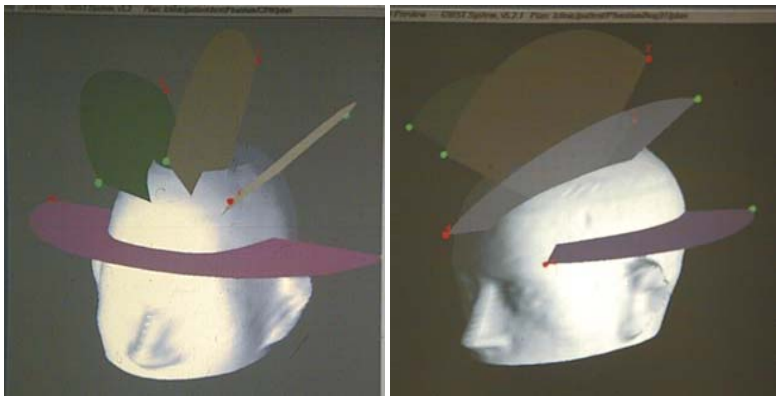
Target Volume in CT and MRI



Radiosurgery CAD/CAM

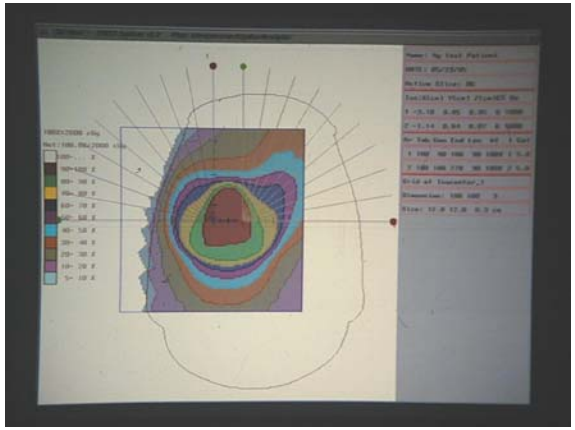


Arc Therapy

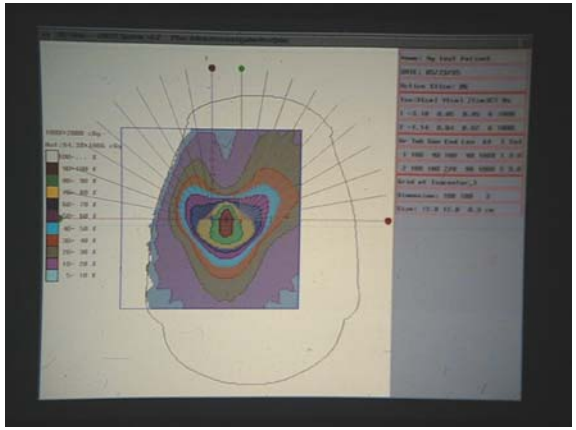


Arc Design

Dose from two isocenters

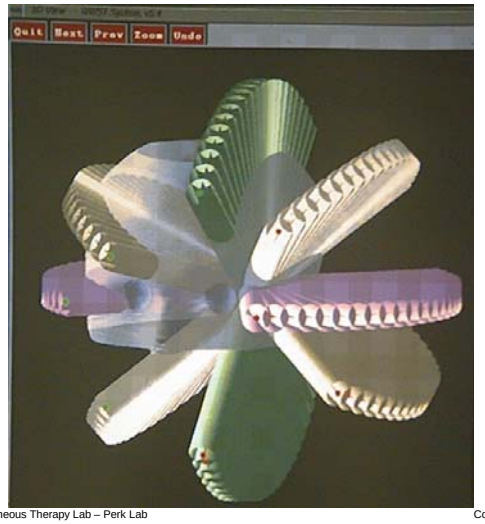


Dose from two isocenters

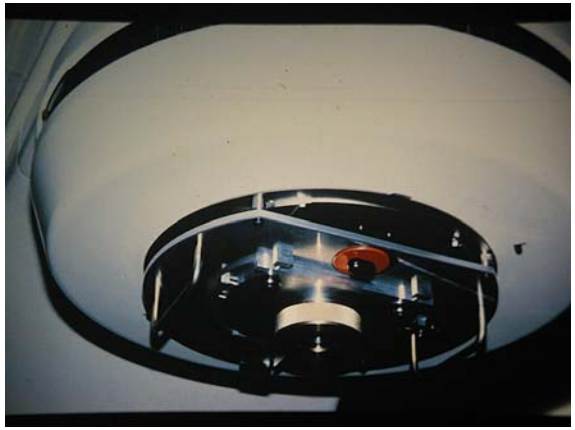


"Thick" Pencil Beams

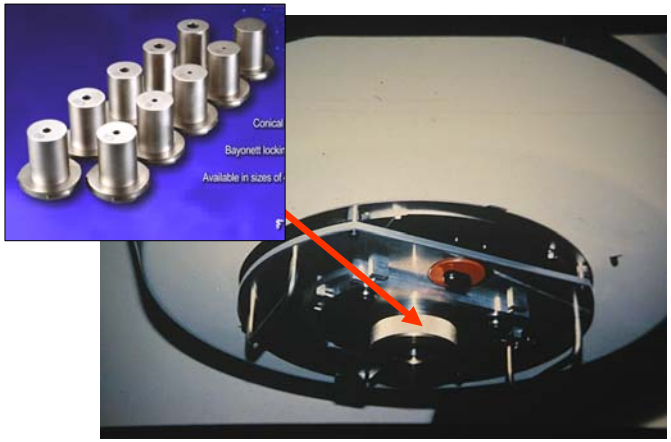
Entry & Exit Beams



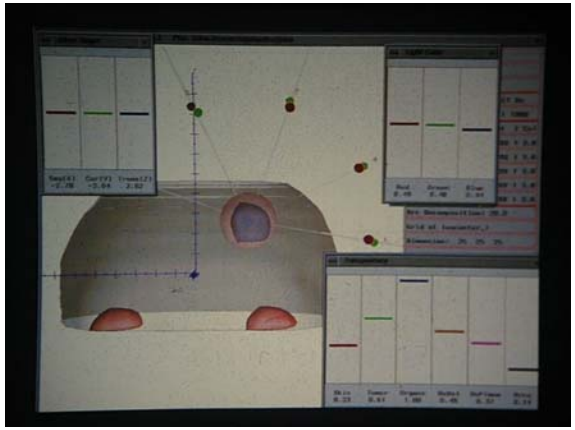
Linear Accelerator Gun



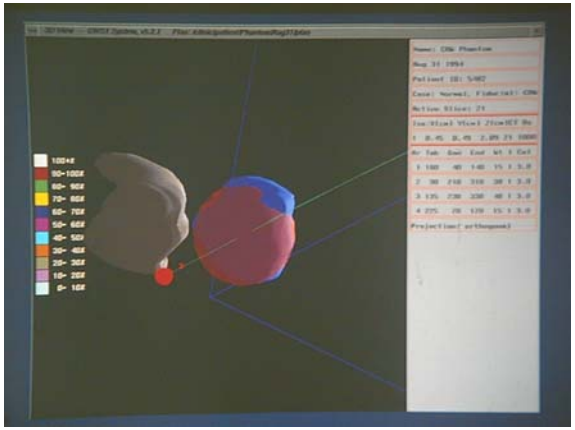
Beam Collimation



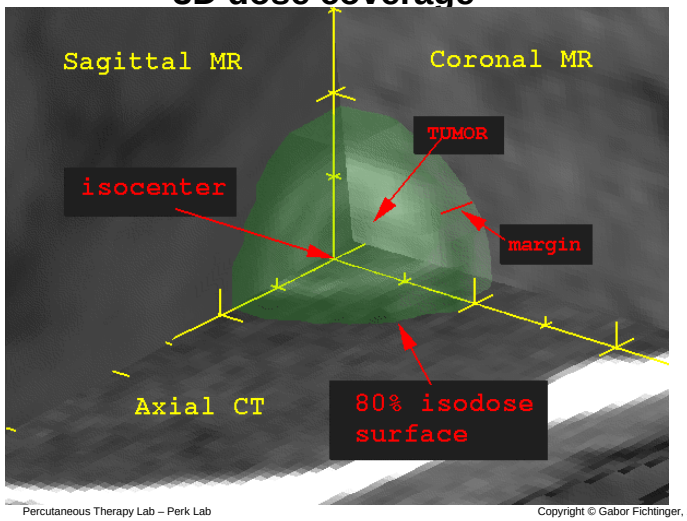
Check collimator size



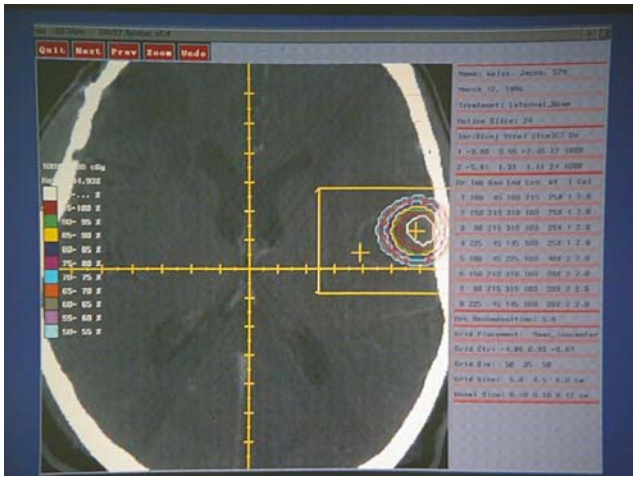
Beam's eye view



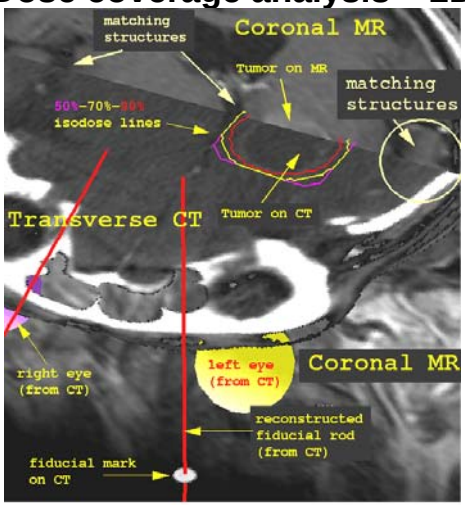
3D dose coverage



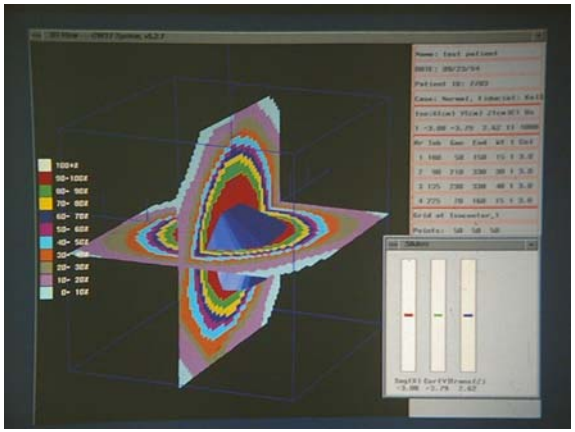
2D dose overlay on CT



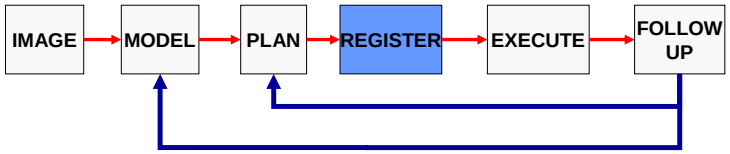
Dose coverage analysis – 2D



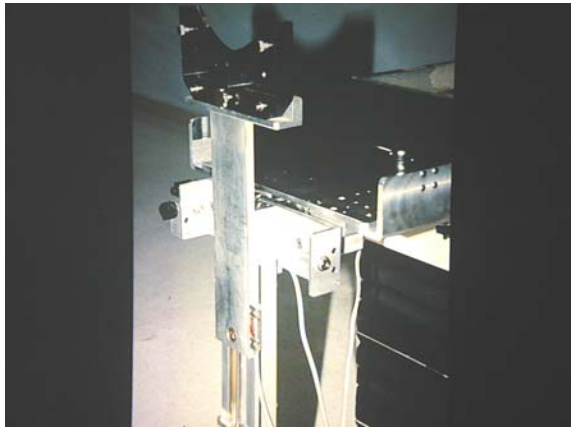
Dose coverage analysis – 2D



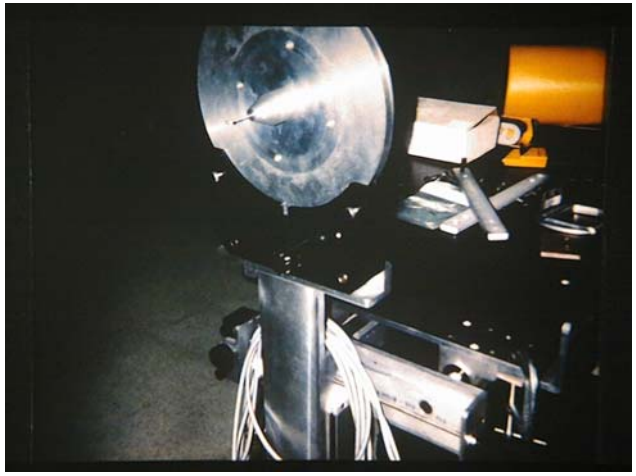
Radiosurgery CAD/CAM



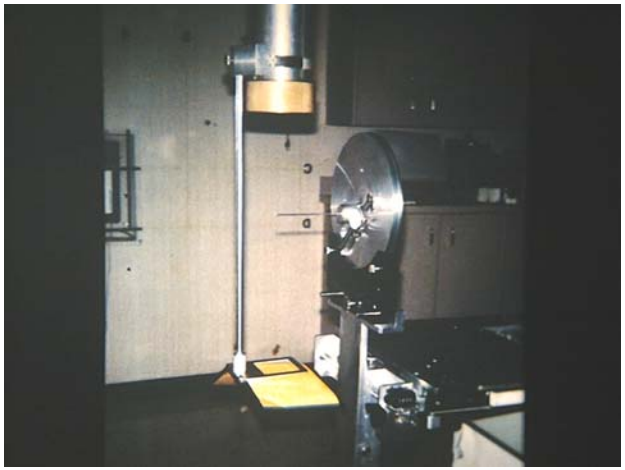
Head-holder on linac table



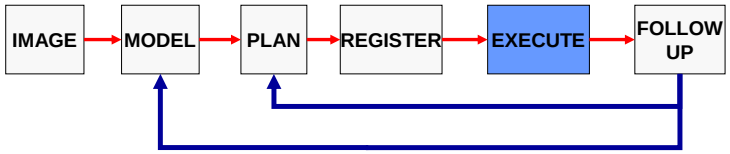
Linac target phantom



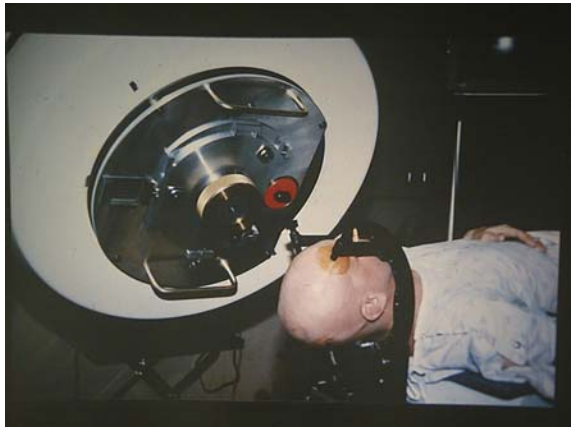
Target phantom x-rays



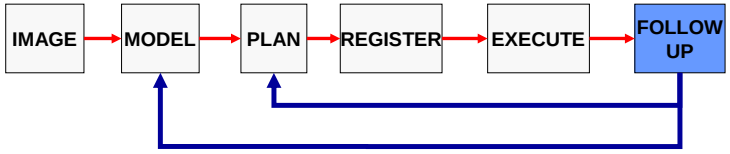
Radiosurgery CAD/CAM



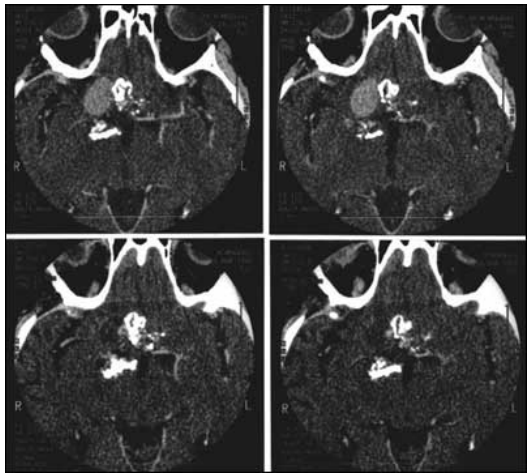
Run dry, then deliver the dose



Radiosurgery CAD/CAM



Follow-up CT (3,6,12,24 mo)



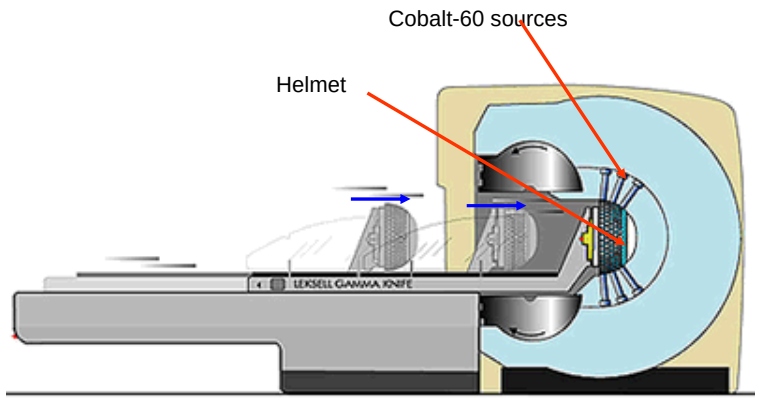
The Ultimate Reward…

Ten years after treatment for a malignant pineoblastoma

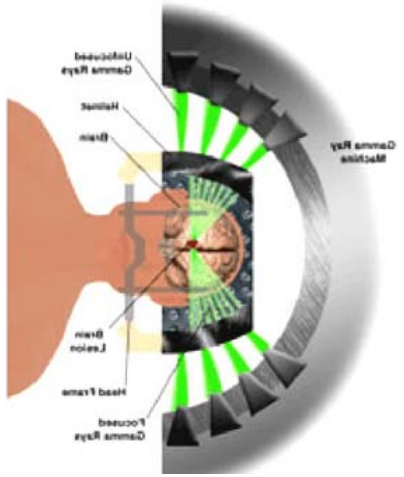
Gamma Knife

Gamma Knife – close-up

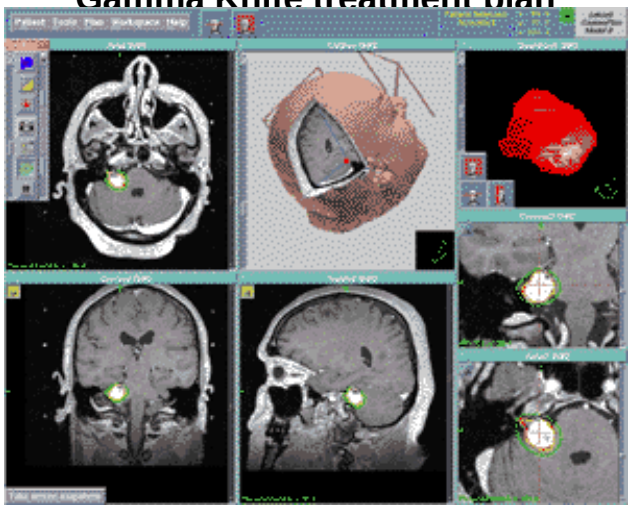
Gamma Knife – inside



Gamma Knife – inside



Gamma Knife treatment plan



Linac versus Gamma Knife

Linac: Multiple use
Gamma Knife: Intracranial neurosurgery only

Linac: moving table, gantry and collimator
Gamma Knife: all static

Linac: X-ray on demand (X-ray generator)
Gamma Knife: beam “always on” ($Cobalt^{60}$ source) – therapeutic beamtime is low, source replacement $0.5M in every five years, longer treatments are needed as Co^{60} source decays.

Linac versus Gamma Knife

Linac: Multiple use
Gamma Knife: Intracranial neurosurgery only

Linac: moving table, gantry and collimator
Gamma Knife: all static

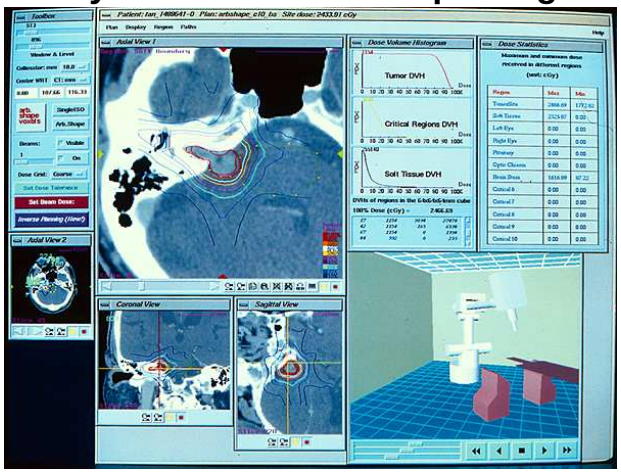
Linac: X-ray on demand (X-ray generator)
Gamma Knife: beam “always on” (Cobalt-60 source)

Cyberknife = Robot arm + Linac

CyberKnife patient fixation

CyberKnife fluoro image guidance

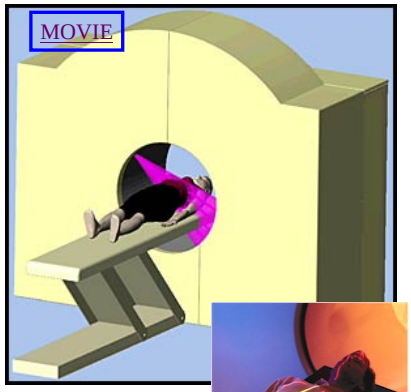
CyberKnife treatment planing

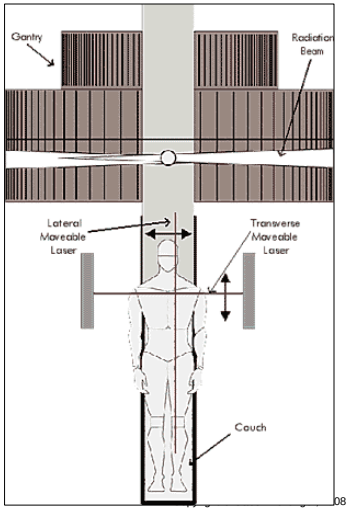


CyberKnife- summary

- a compact 6-MV linear accelerator
- mounted on a 6DOF computer-controlled robotic arm
- intra-op X-ray image guidance
- no need for rigid stereotactic frame.

Yet another new way: Tomotherapy





Pros and Cons

Pros:

- Sophistication
  - High dose conformity
- Simplicity
  - No simulator
  - No separate treatment planning computers
  - No block cutting & compensator molding
  - No portal imaging systems.
- Safety
  - No bream shaping blocks
  - No dual e/X-ray mode
  - No beam stopper
  - No scatter

Cons:

- Reduced case portfolio
  - No electron beams
  - No 10+ MEV beams
  - Only one beam energy
- Only transverse beams
- Not so good CT (beams are too “hard”)