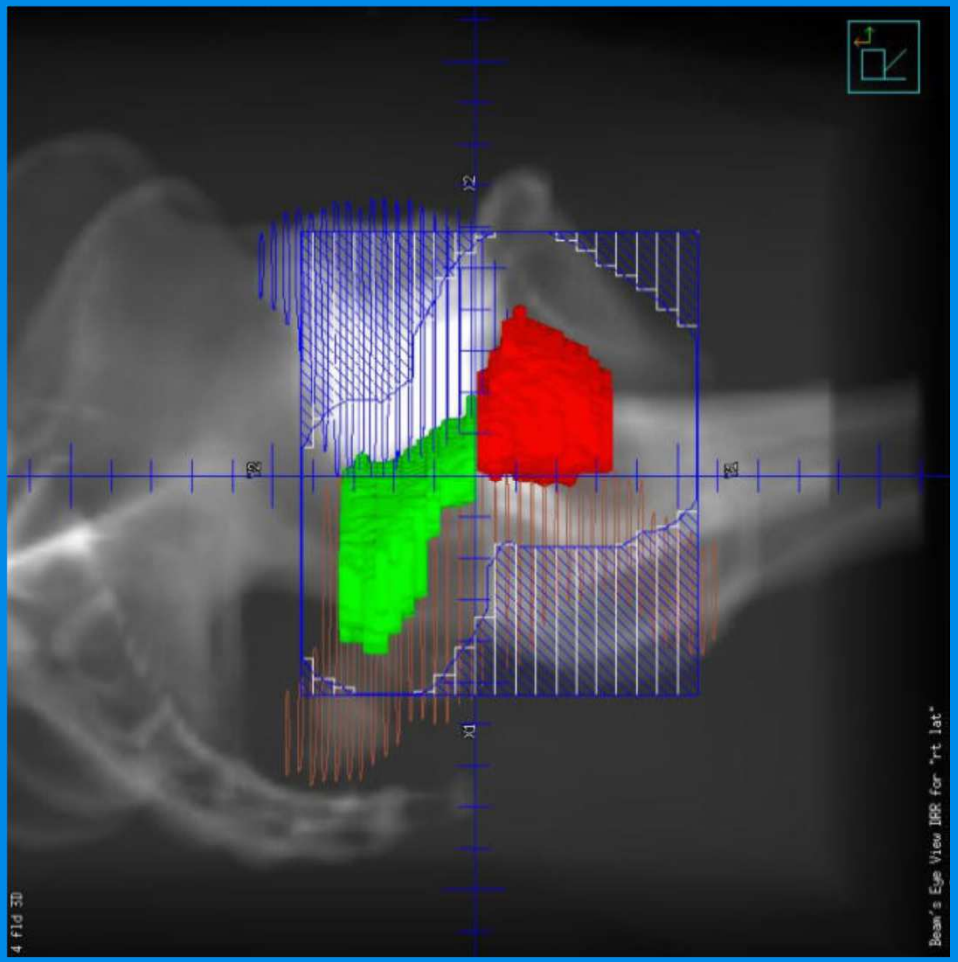
Stereotactic Body Radiotherapy (SBRT) for Lung Cancer

Dr. A. K. Bansal,
Medical Physicist,
Dept. of Radiotherapy,
AIIMS, N. Delhi

Evolution of Technology

- 1970's: Cobalt-60, treatment guided by surgical anatomy and plain radiographs. Doses calculated from depth-dose charts.
- 1980's: Cross-sectional imaging (CT) available to guide treatment delivery.
- 1990-1995: 3D conformal radiotherapy planning systems capable of showing Beam's Eye View
- Followed by SRT/IMRT/IGRT.

Evolution of Technology



Stereotactic Radiotherapy (SRT)

- Initially used only for cancers and disorders in the brain.

- SRS

  - Single fraction is used to "kill" everything within the defined target, i.e. radiosurgery.

- SRT with multiple fractions has become alternative choice to resection for stage I/II patients who are medically in-operable or those decline surgery

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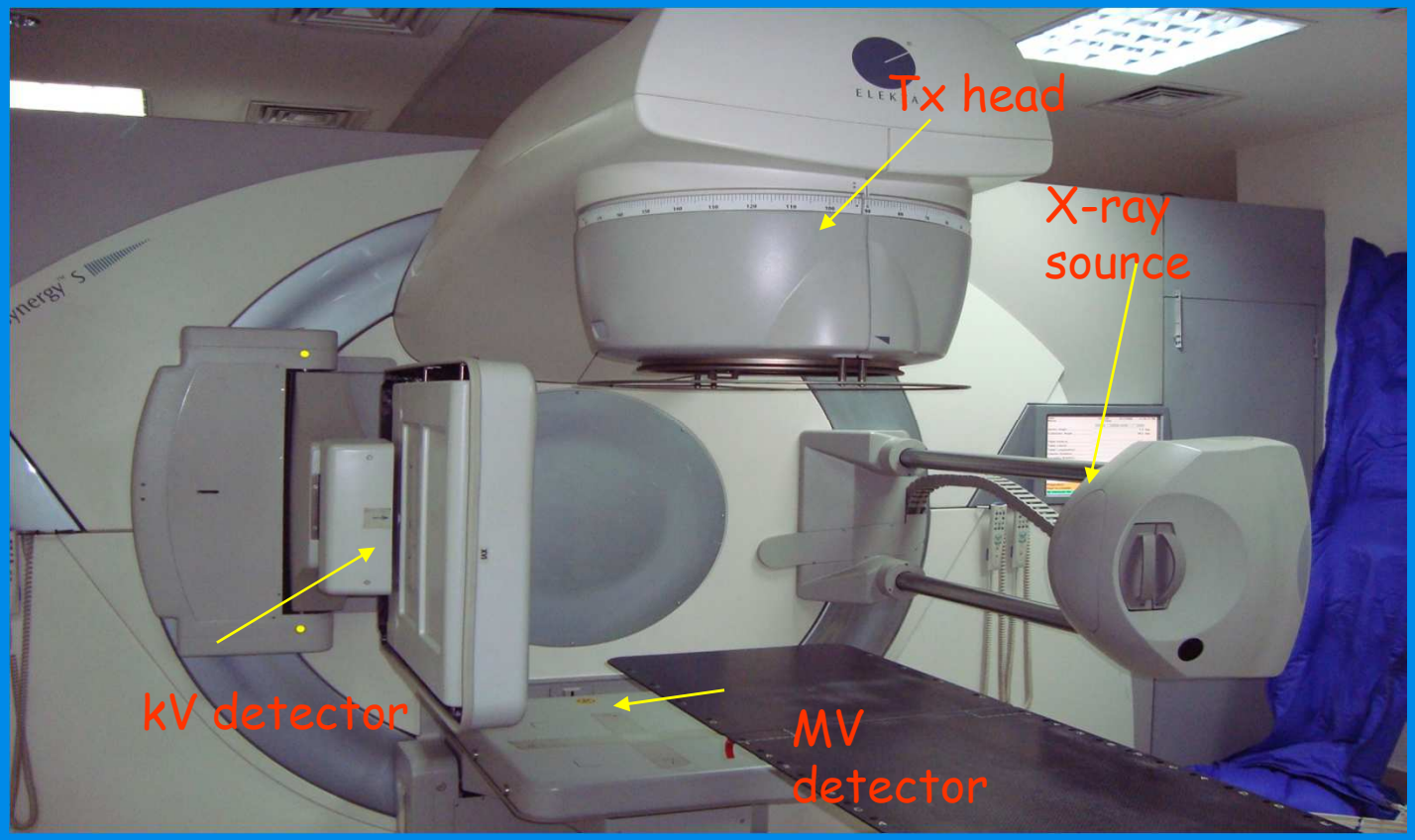
- Stereotactic Body Radiotherapy (SBRT) uses similar concepts to treat cancers outside of the brain.

SRT Machines

- **Synergy-S** is a modified linac that delivers streotactic treatments through setup and monitoring with a kV imager.



CyberKnife

CyberKnife is a dedicated SRT machine that is not designed to provide conventional radiotherapy . Small, precise beams and long treatment delivery times.

Tomotherapy

Tomotherapy is a linac that images and delivers treatment through a rotational gantry (like CT). Provides image guidance with every treatment and it can simultaneously treat multiple targets quickly.

IGRT: Image-Guided RT

- Daily targeting of internal structures instead of skin marks or bony landmarks.
- Synergy-S, Trilogy and Tomotherapy are technologies that provide daily "CT-like images" that are matched to planning CT images for positioning.
- New standard for state-of-the-art radiotherapy

Image-guided Therapy: Principles

- Image guidance ensures that relative positions of isocenter and target are the same during treatment and in treatment plan

- This potentially allows:
  - ✓ **Reduced treatment margins**
  - ✓ **Increased dose**
  - ✓ **Reduced complications**
  - ✓ **Avoid misses**

Stereotactic Body Radiotherapy(SBRT)

- Relatively new treatment concept
- Concept derived from brain radiosurgery
- Few fractions/high doses/steep gradients
- Radiosurgery enables the delivery of a small number of large dose fractions to minimize tumor repopulation
- Goal is tumor ablation

Stereotactic Body Radiotherapy(SBRT)

To provide safe and effective SBRT, following are the requirements:

- Secure patient immobilization with customized body mould with or without external frame with fiducial reference markers
- Accurate tumor re-localization using IGRT or other equivalent methods

Stereotactic Body Radiotherapy (SBRT)

- Frame based vs frameless SBRT

- At one time frame based SRT was essential with external fiducial markers

- With modern image guidance like CBCT/MVCT on treatment couch, it is not essential to use SRT frame

- Large vacuum bag on three sides of patient create a cast providing uniform support for treatment

SBRT - hypothesis

- High-dose focused radiation may provide high probability of local tumor control when surgical approaches are not indicated
  - Medical inoperability

- Improved therapeutic ratio over fractionated RT courses

- High dose focused radiation promises similar tumor control where limited surgical approaches are standard of care
  - Stage 1 NSCLC
  - Lung metastases
  - HCC
  - Liver metastases
  - Spinal tumors

The rationale for SBRT
Primary lung tumors

Historical perspective

- Standard doses for RT of lung cancer are 60 to 66 Gy over 6 to 7 weeks
  - For early and advanced stage disease
  - 30 to 50% in-field local failure rate in advanced disease
  - 30% to 69% local failure rate for early stage disease
  - Local failure is associated with distant metastases and death
- Conventional RT frequently fails to achieve cure for early stage lung cancer

The rationale for SBRT
Primary lung tumors

Attempts to improve outcomes after RT

- **Radiation dose escalation**
  - **Martel et al. estimate that 84 Gy would improve local progression free survival (>30 months)**

    Martel et al., Lung Cancer 1999

- **- Phase 1 studies confirm the feasibility of radiation dose escalation**
  - Hayman et al., JCO 2001
  - Narayan et al., Lung Cancer 2004
  - **Increased late pulmonary toxicity (grade 3 and higher)**

- **About 15% at doses between 71 and 80 Gy**
  - Maguire et al., JCO 2001
  - RTOG 9311, Bradley et al. IJROBP 2003 abstract
  - Langendijk et al., IJROBP 2002 (QOL assessment)

Radiobiological rationale for SBRT Primary lung tumors

- The biological equivalent dose (BED_{10}) of 100 Gy is required to offer local control of lesions ≤ 4 cm.
- By delivering the BED_{10} of 100 Gy to the PTV, high local control rates with low complications are possible.
- In a retrospective multi-institutional review, delivering a BED < 100 resulted in a 27% local failure rate compared to 8% local failure with a BED > 100 Gy. Survival with doses less than 100 BED was 70% versus 88% with BED > 100 ($p < 0.05$)
- (Onishi et al. 2004).

Radiobiological rationale for SBRT Primary lung tumors

- BED_{10} of 100 Gy can be delivered safely via several different dose regimens including

- 12 Gy × 4 or 10 Gy × 5.

- Doses higher than 20 Gy × 3 are not recommended especially when treating central lesions

  (Timmerman et al. 2006)

SBRT – critical considerations

- Dose
- Dose prescription
- Dose planning
- Dose schedule
- Target and PTV concept
- Normal organ tolerances/RTOG
- Criteria for dose delivery

SBRT - dose

- Early German and Japanese single dose trials
  - Japan 15 to 25 Gy
  - Germany 19 to 26 Gy
- IU dose escalation trial
  - 24 to 66 Gy
- RTOG trial dose
  - 3x20 Gy
- Alternate protocols
  - OHSU/U Wisconsin 5x12 Gy
- Dose delivery
  - -2 fractions/week
  - -3 fractions /week
  - -5 fractions/week

SBRT- The Treatment

- Many fractionation schedules have been used, but the "winning" regimens…
- 20 Gy x 3 = 60 Gy
- 12 Gy x 4 = 48 Gy (near sensitive structures)

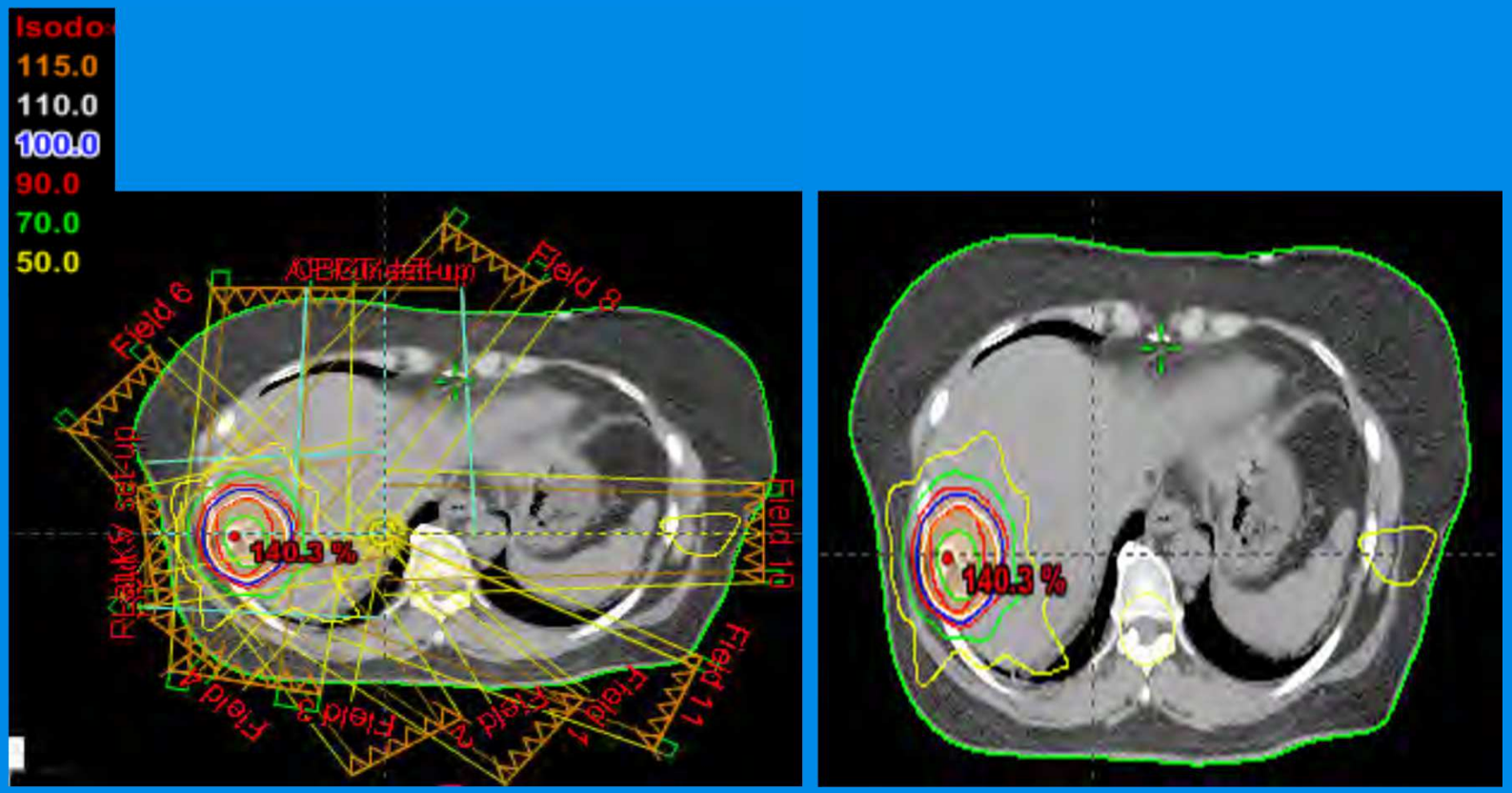
Dose prescription

- "Conventional approach"
  - Homogeneous dose prescription
  - RTOG 0436
- PD encompasses the PTV
- Min dose 90%, max dose 120%
- "Ablative intent"
  - Heterogeneous dose prescription
  - PD encompasses 95+% of PTV (PD around 80%)
  - Maximum dose should approach 150%
  - Ablative intent may afford steeper dose gradients

Dose planning

- Modality
  - 3D-CRT
  - Arcs (fixed or dynamic)
  - IMRT
- Number of fields
  - RTOG minimum of 5 fields
  - More fields? How many?

Dose planning.....



SBRT- The Simulation

- 4D-CT simulation is performed (3D plus motion). Provides images at each phase of respiration.
- Abdominal pressure plate added (when needed) to limit respiratory motion
- Gating can be utilized in excessive organ motion

Target volume considerations

- SBRT – target volume definition in the absence of 4DCT capabilities

- Free breathing scan

  - Potentially multiple free breathing scans

- GTV is visible tumor

- PTV is GTV + 5 mm axial/10 mm craniocaudal

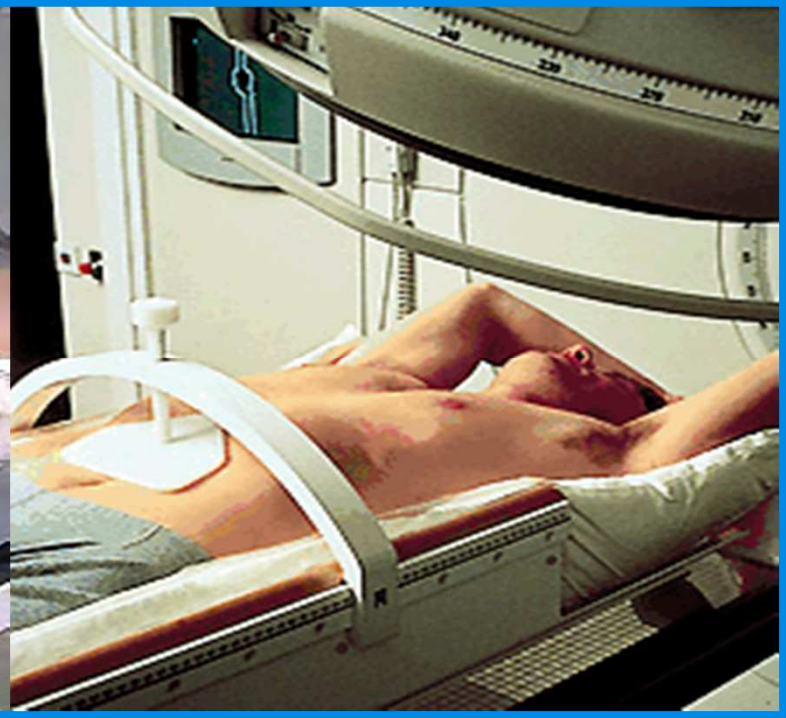
- With 4DCT maximum intensity projection (MIP) used for planning

Patient Immobilization

Medical Intelligence
BodyFIX

Blue bag with abdominal compression plate

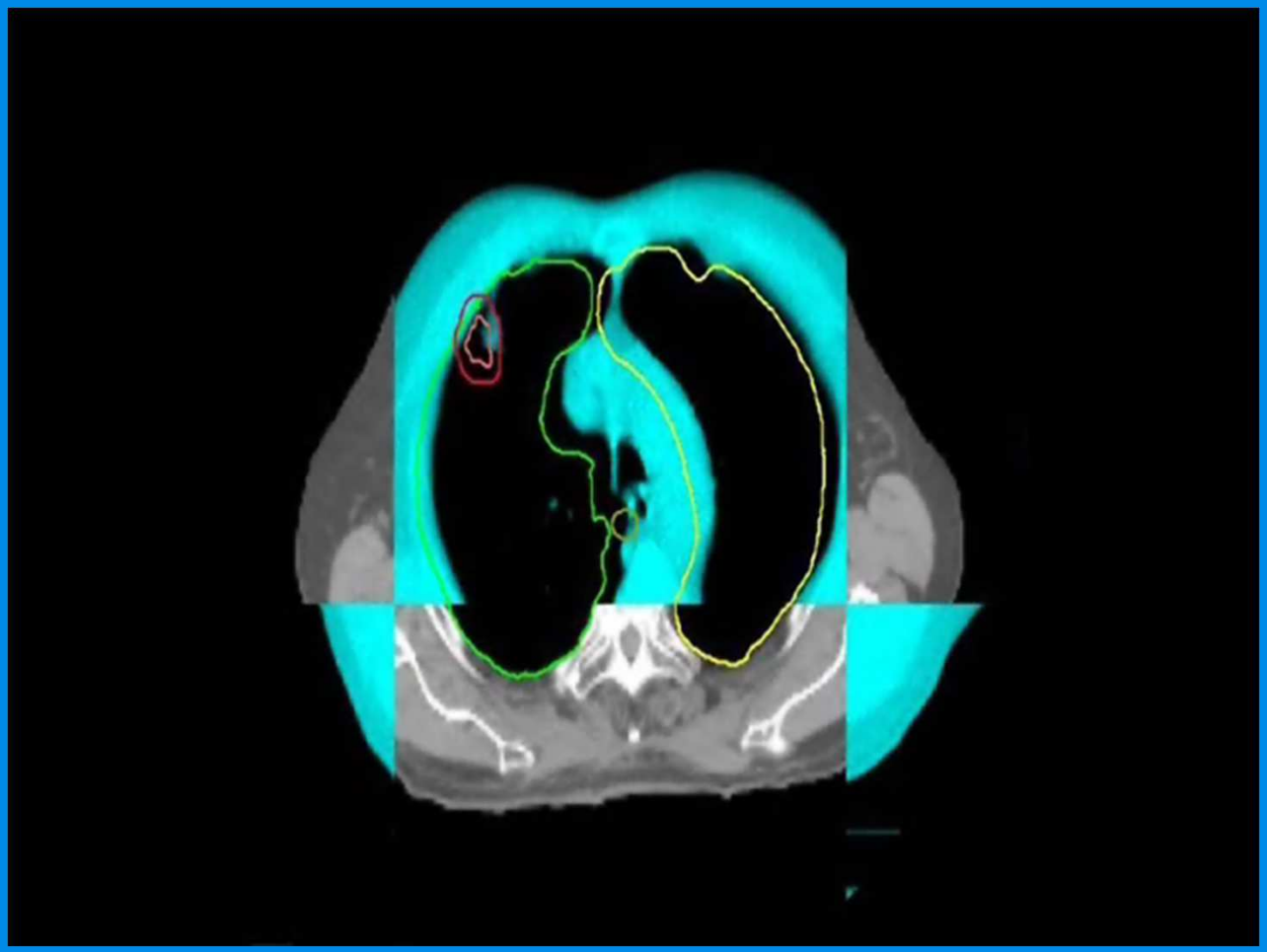
Elekta Stereotactic Body Frame



SBRT Delivery

- Image-guidance
- Positional adjustment
- Positional monitoring
- Gating/motion management

CBCT & Planning CT registration



SBRT outcomes for Stage I Non-small Cell Lung Cancer

Institution	# Patients	Local Control
Yamanishi, Japan	257	92%
Japan	131	96%
Aarhus(Denmark)	89	89%
Wash U	70	83%
Indiana U(protocol)	70	88%
Cleveland Clinic	94	97%
Amsterdam	206	97%

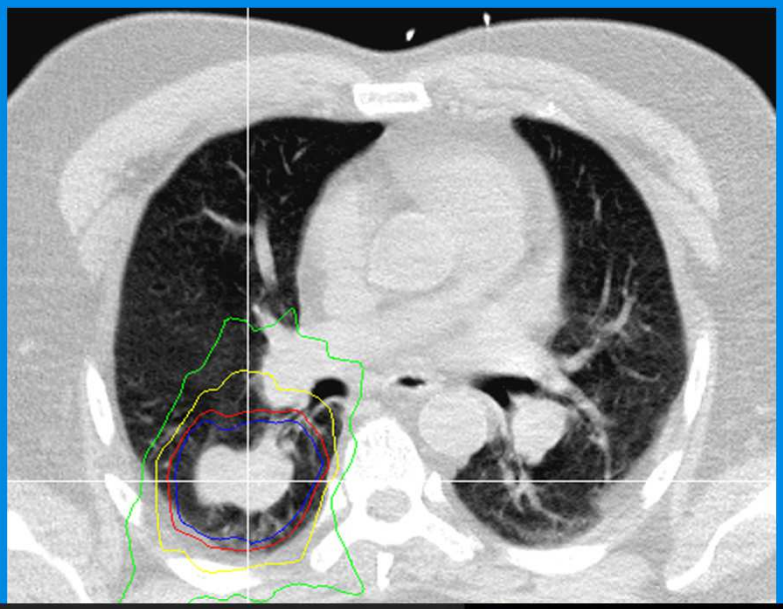
Outcomes

- T2 N0 M0 NSCLC. For selected patients, outcomes appear equivalent to surgery. Local control rates were of greater than 90% at 2-year follow-up, with only 3% serious morbidity

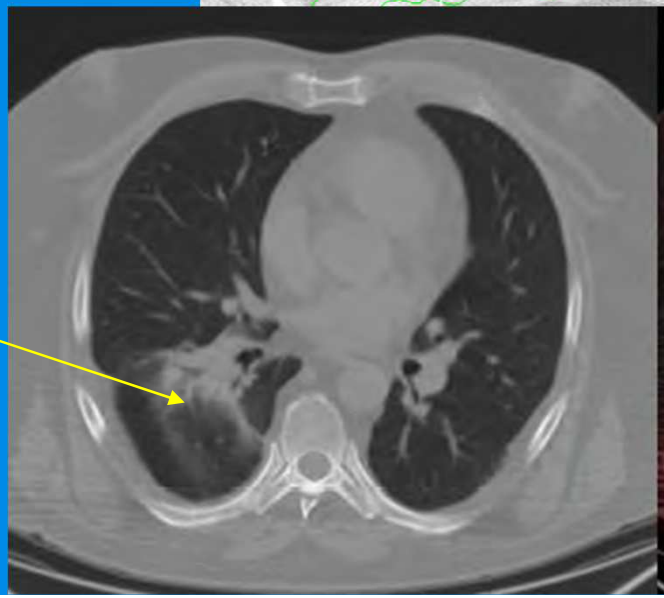
- Five year survival for medically operable patients who refused surgery was 88%

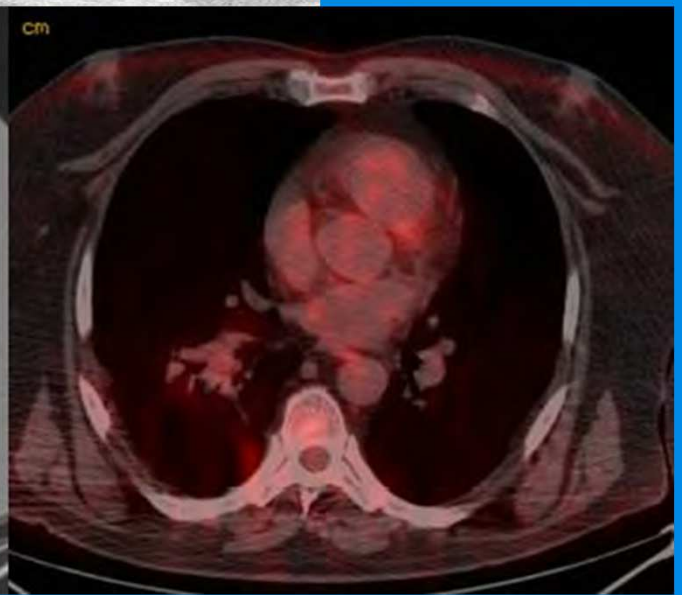
Onishi et al. 2004,2007

Outcomes



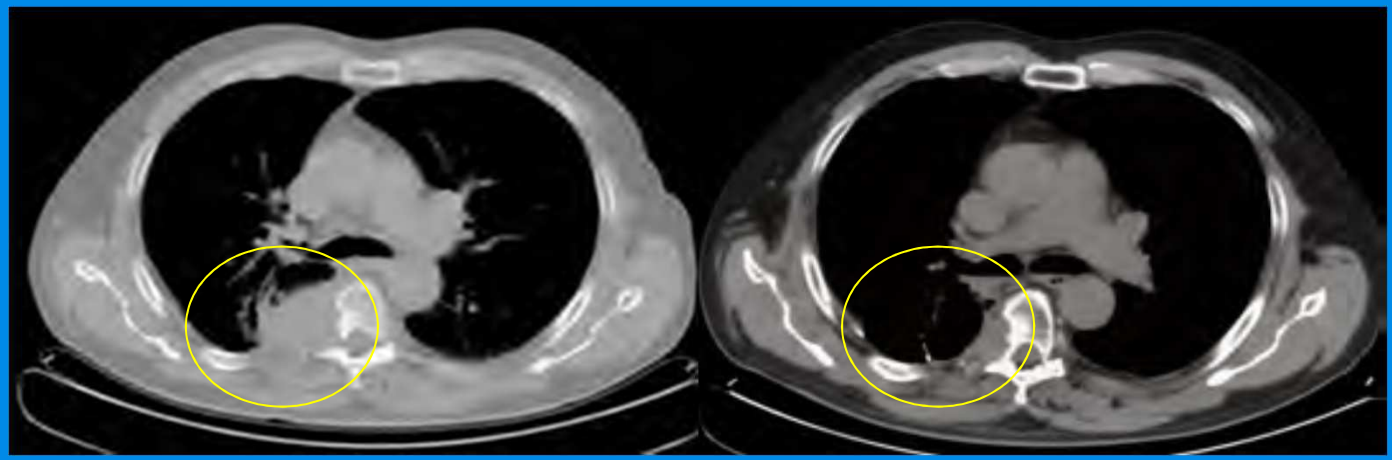
Follow-up PET scan





Follow-up scan

Outcomes



SBRT- Complications

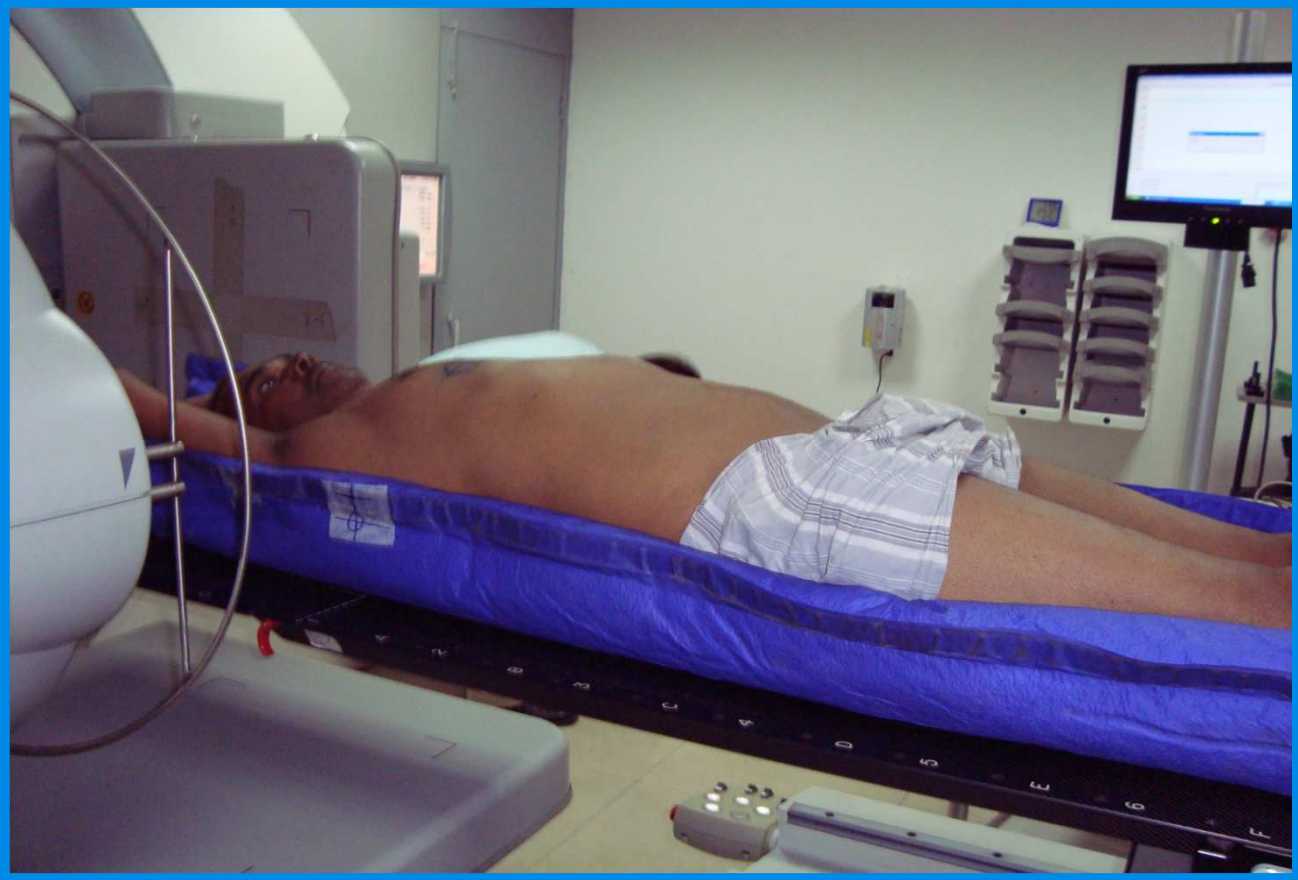
- Normal tissue tolerance is not yet clearly defined for hypo-fractionated irradiation to the intrathoracic tissues, bone, and soft-tissue.
- Acute morbidity induced by radiosurgery is rare.
- Late complications may occur one year or more after surgery, and may include fistula, bleeding, fibrosis, pneumonitis, pneumonia, brachial plexopathy for apical lesions and liver toxicity for basal lesions (Onishi et al. 2007).
- Rib fracture and soft tissue fibrosis are also possible with stereotactic radiosurgery.

SBRT AT AIIMS

- 59 yr old gentleman
- NSCLC
- T2 N0 M0
- Lesion Size 4X4 CM
- Peripherally Located Lesion in Rt Upper Lobe
- Medically in-operable due to COPD

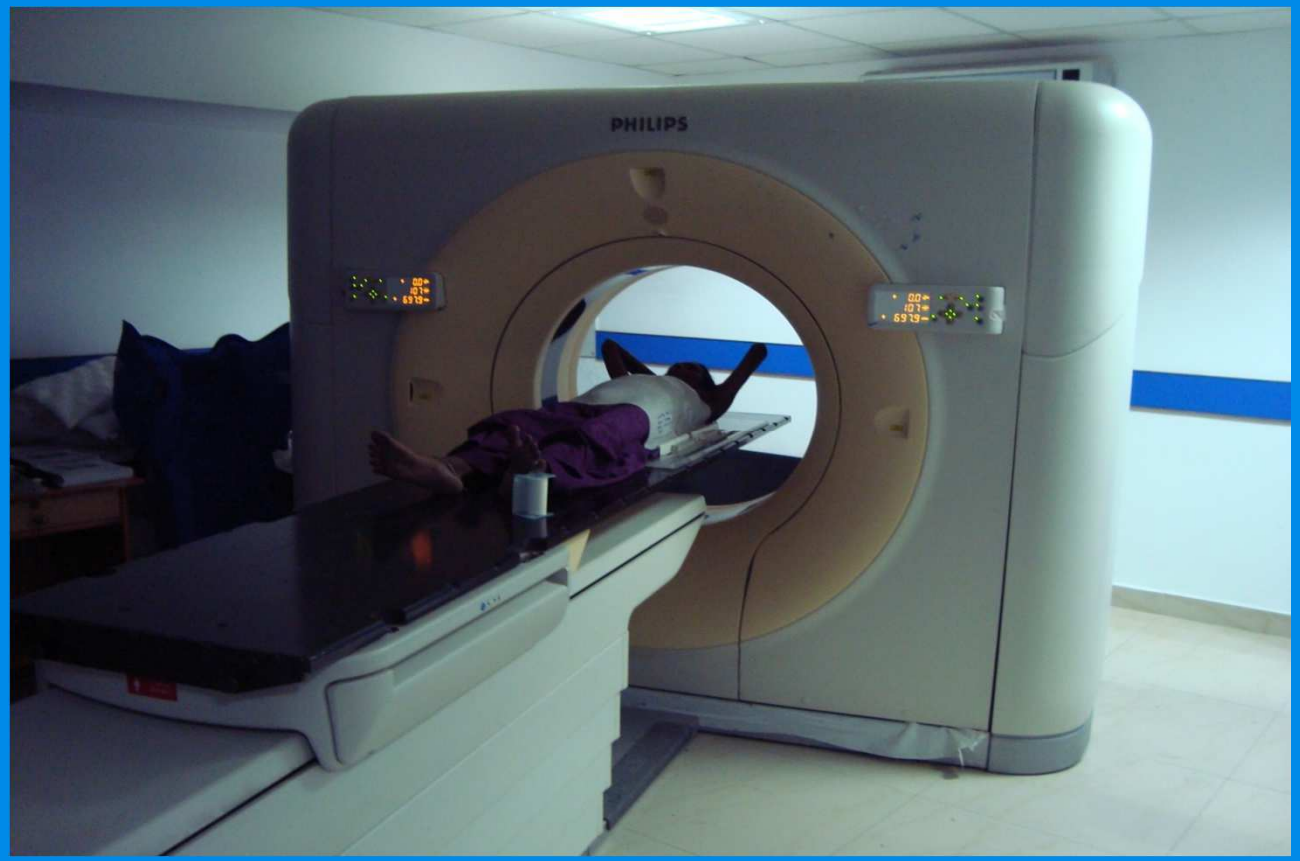
SBRT AT AIIMS

- Immobilization
  - Blue Bag-Body Fix



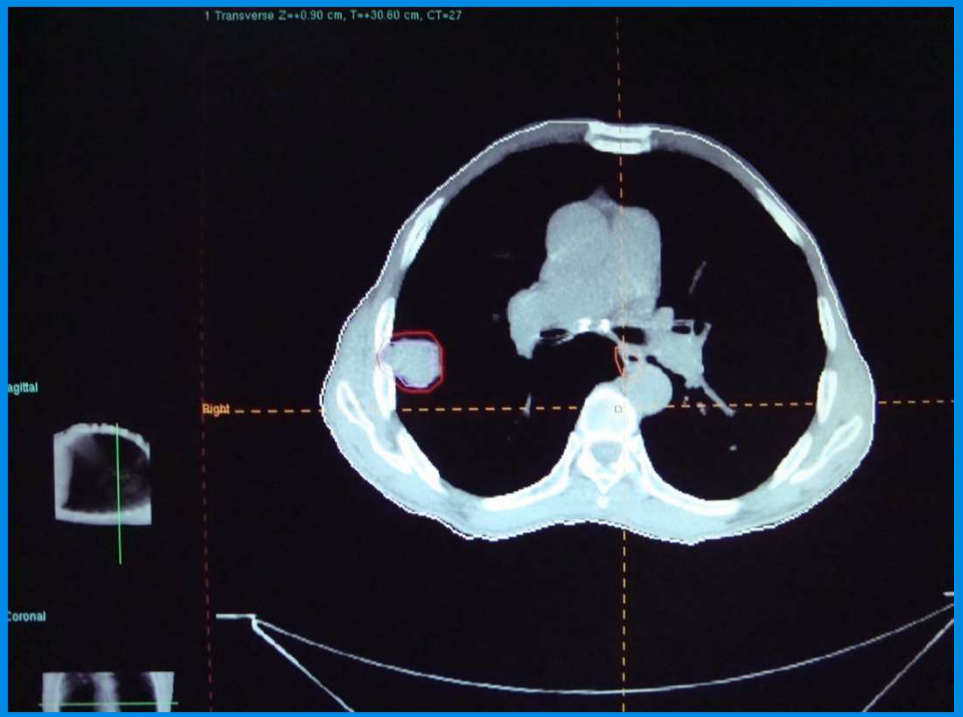
Imaging

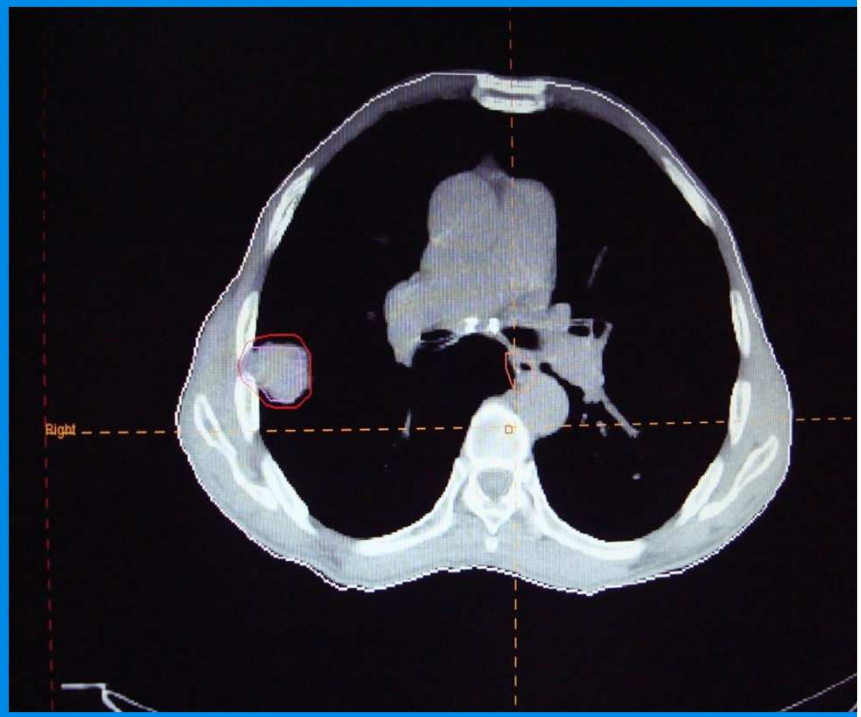
- PHILIPS 4DCT AT AIIMS



Planning for SBRT

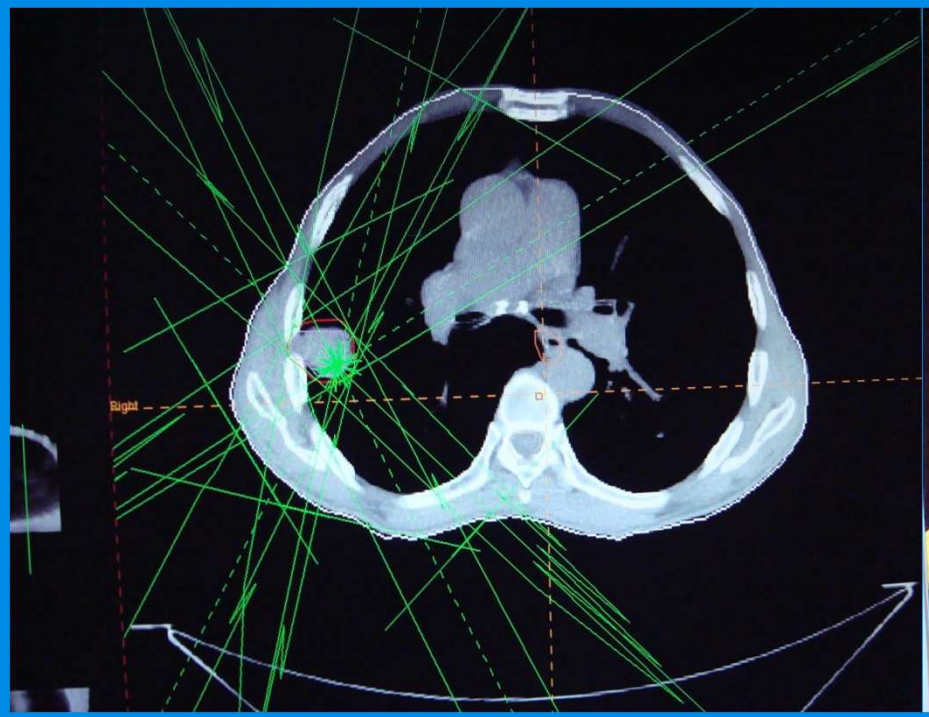
- Contouring on MIP images

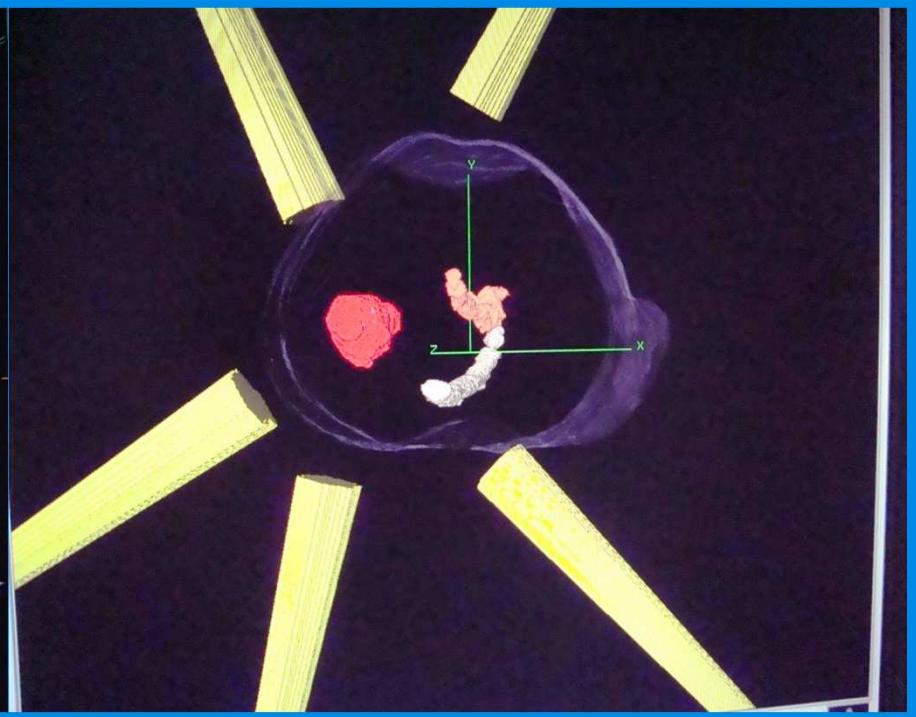




Planning for SBRT.....

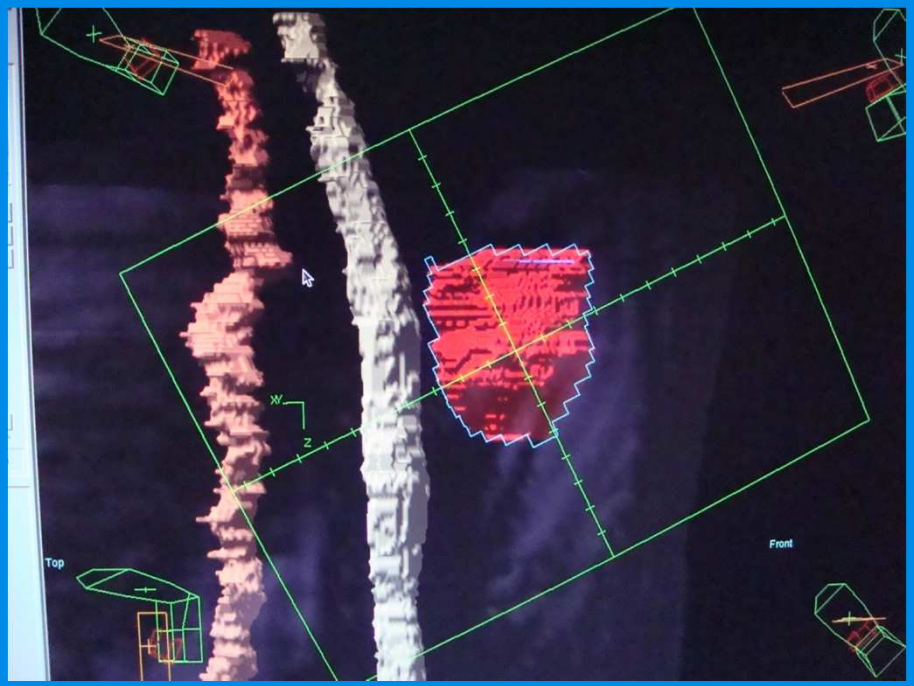
- 3D-CRT Planning
- Beam placement

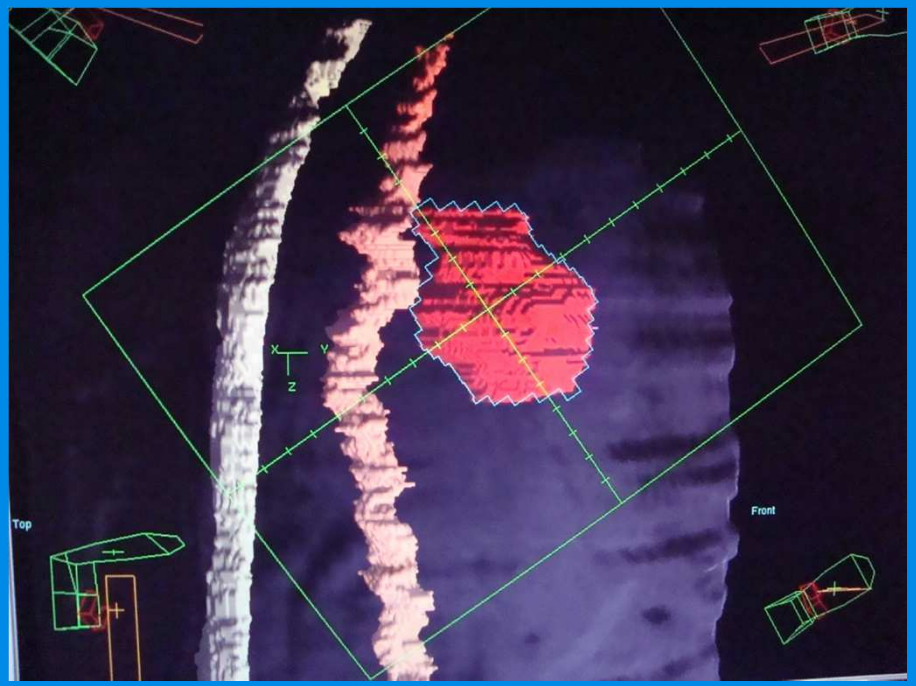




Planning for SBRT….

- 3D-CRT Planning
- BEV (Beam eye view)

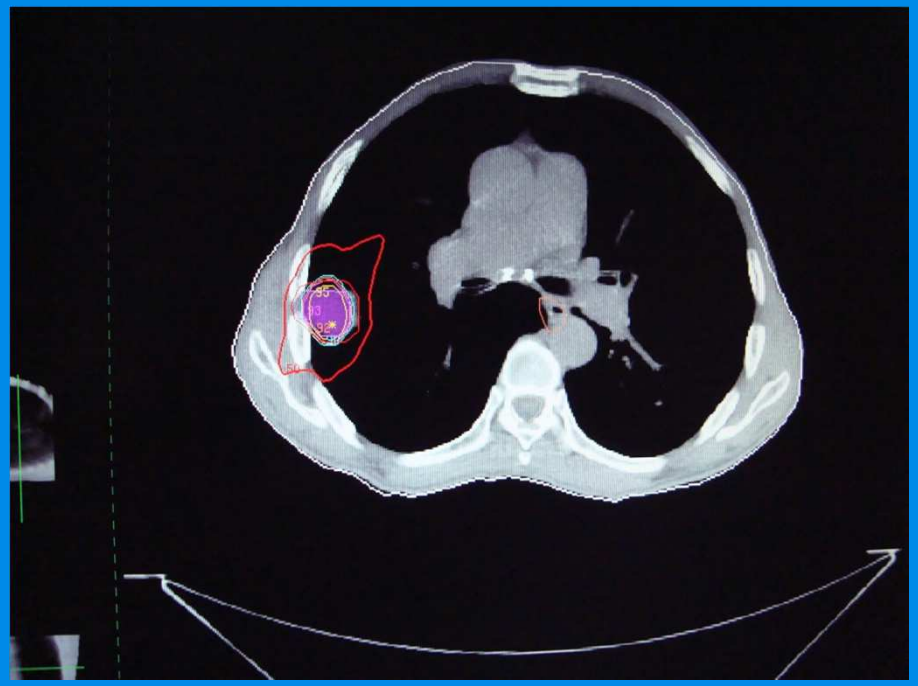


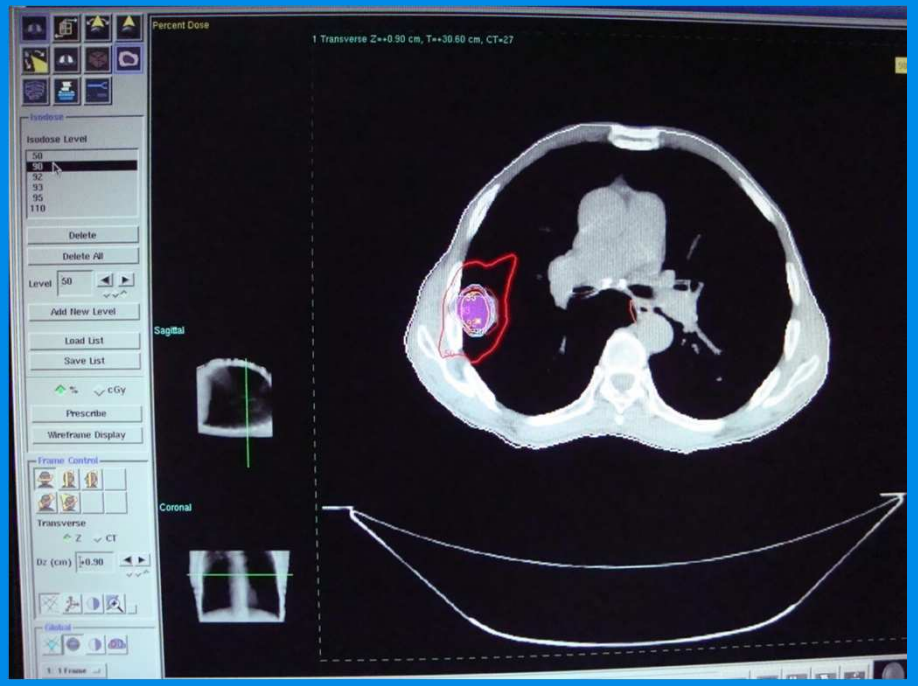


Planning for SBRT….

- Planning

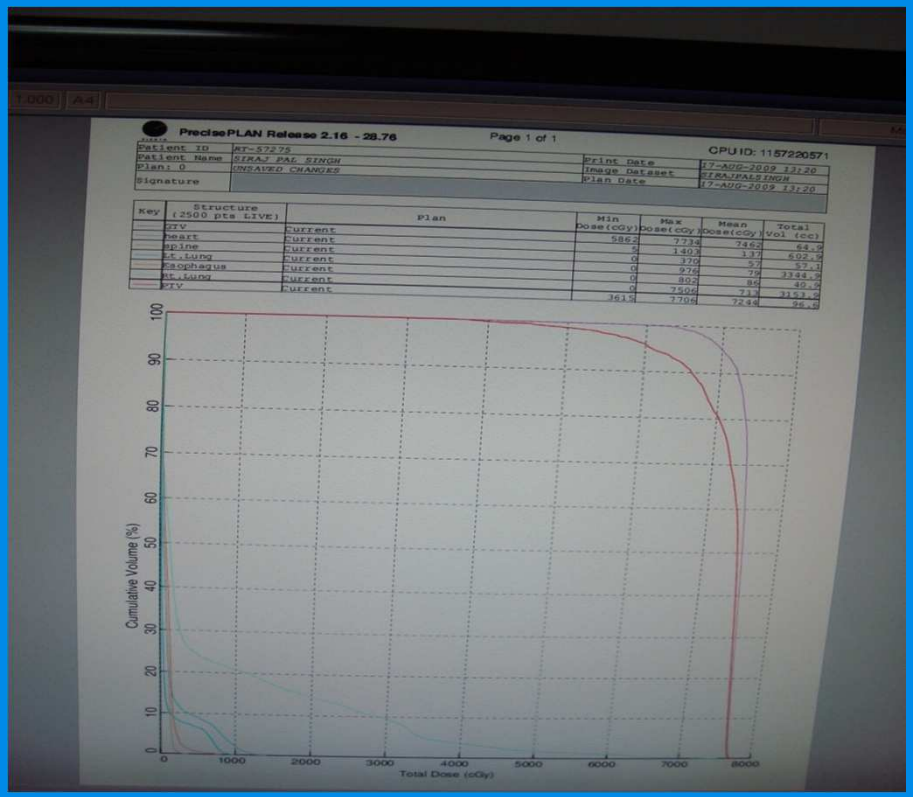
- Isodose display

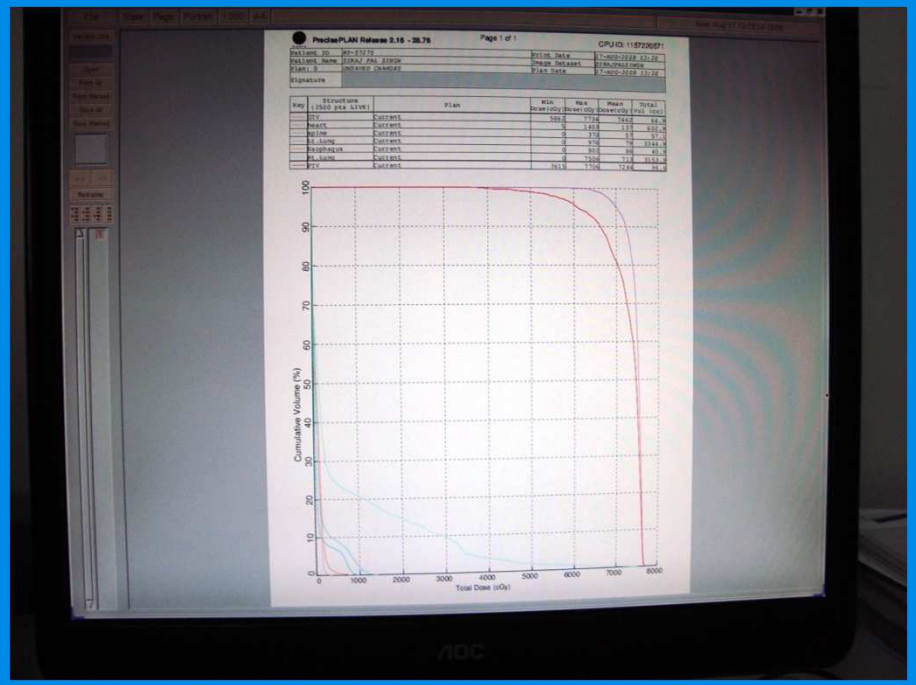




Planning for SBRT....

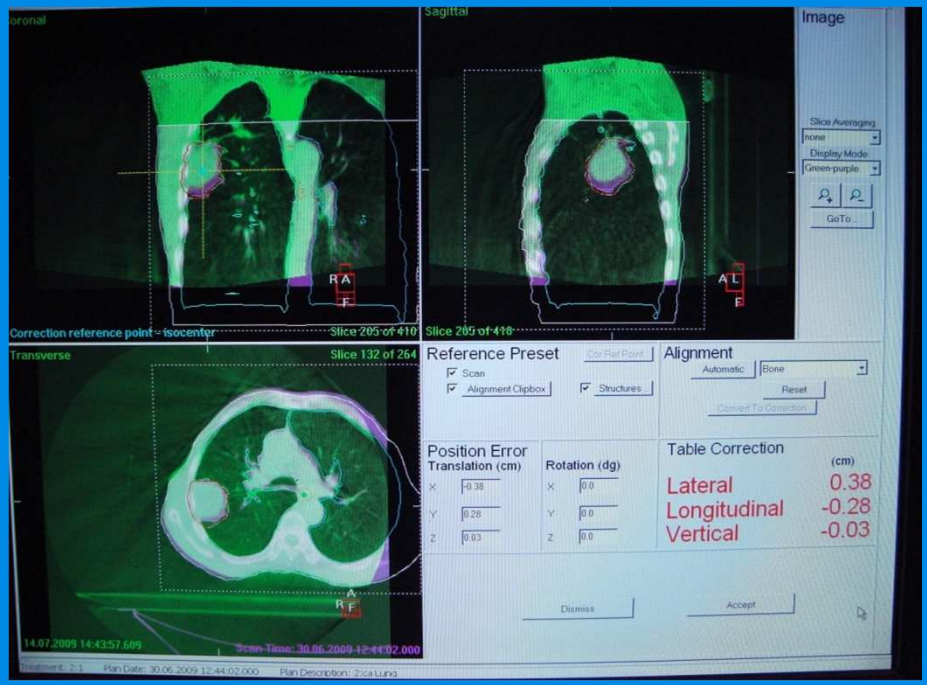
- Planning
- DVH





IGRT

- Set-up verification with CBCT (XVI)

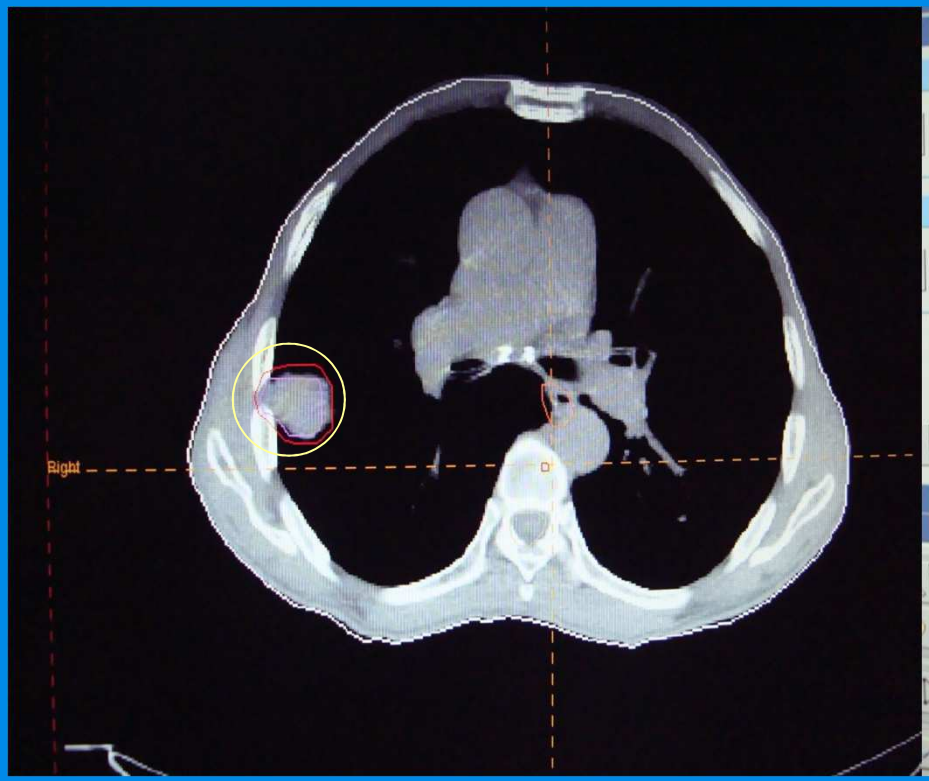


Treatment Delevery

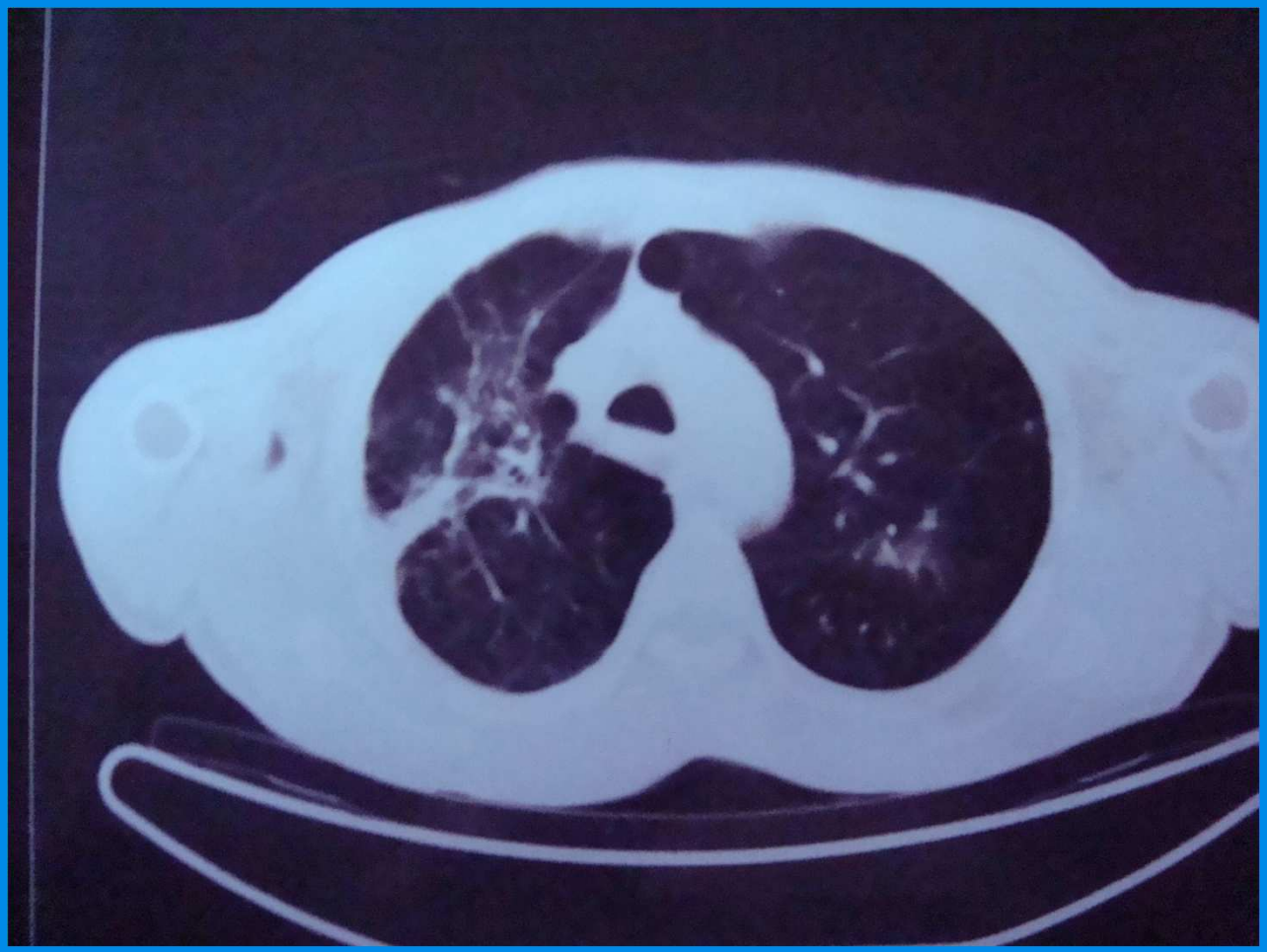
- Treatment on Synergy-S

Response

- After three weeks



PET CT after six weeks



PET CT after six weeks

Summary

- SBRT is std of care for medically in-operable lung (T1/T2,N0,M0)
- Highly effective and time efficient
- Most common sites: lung, liver, spine
- Useful for recurrent tumors in previously irradiated fields
- Tumor control is seen in 80-90% of metastases treatment, but survival is not impacted


Thanks