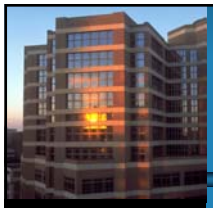

IMRT for Lung Cancer?

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MD ANDERSON
CANCER CENTER

Thanks

- Kenneth Forster, Ph.D.
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General XRT Principles

- The most radioresistant tumor cell is the one that is out of the field
- The worst complication is a local recurrence (unless you kill the patient with your treatment)

Conclusions
IMRT for lung cancer

- DON'T! Until.....
  - Tumor motion can be taken into account
  - Dose calculation algorithms are better
  - The effects of low doses to large volumes of lung are better understood.

Conclusions
IMRT for lung cancer

- In the meantime....
  - Outline GTV as best as possible
  - Construct CTVs based on the literature
  - Construct PTVs based on measured tumor motion and known set-up uncertainty.

Problems with lung cancer

- Tumors biologically aggressive
  - Large tumors
  - Metastases
  - Inherently aggressive
- Surrounded by critical normal structures
  - lung, esophagus, heart
- Tumors move

Problems with target definition

- GTV - tumor we see
  - GTV_1 (primary) and GTV_2 (nodes)
  - Windowing/leveling
  - Atelectasis
  - I.V. Contrast
- CTV - tumor we don't see
  - How do tumors invade?

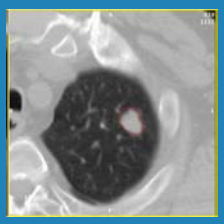
Problems with target definition

- PTV
  - Setup Uncertainty
  - Motion
    - 2D vs 3D motion measurement
    - ITV approach
    - Gating
- Don't forget block edge!

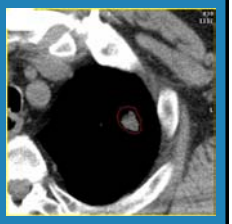
Tumor volumes for 3D-CRT
GTV

- The tumor that you can see
  - GTV_1 for primary
  - GTV_2 for involved LN
- Primary must be outlined on pulmonary windows
- LN on mediastinal windows

Effect of Window/Level

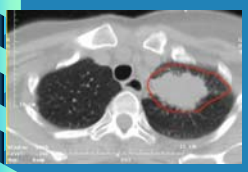


Lung Window
(W1000/L-300)

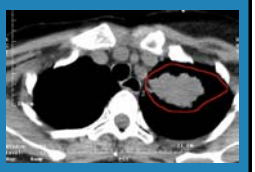


Mediastinal Window
(W340/L25)

Effect of Window/Level

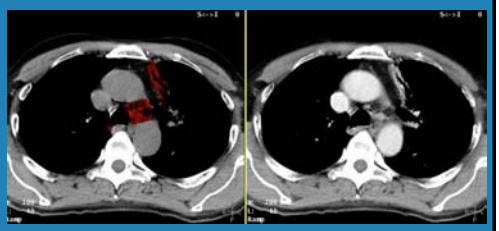


Lung Window
(W1000/L-300)



Mediastinal Window
(W340/L25)

GTV
I.V. Contrast



GTV
PET-CT

- FDG-PET scanning helps with GTV
  - metabolic activity
- Staging ~30% NSCLC upstaged (MacManus)
- Can reduce contour variation (Caldwell)
- Can dramatically affect radiation planning
- BUT: PET very bad at edges!
- Be wary of stage migration - PET staged patients have MS=31 months!

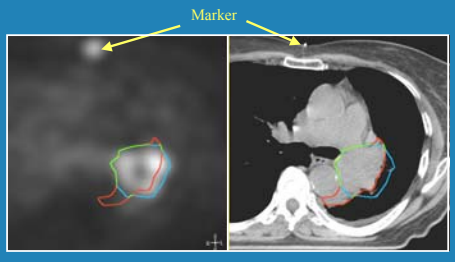
Tumor volumes for 3D-CRT
CTV_2 PET

- PET (14) vs. CT (29) meta-analysis

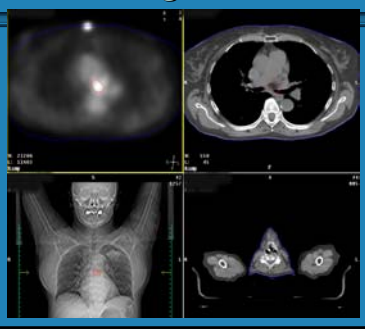
	PET	CT
Sensitivity	.79	.60
Specificity	.91	.77
Positive PV	90%	50%
Negative PV	93%	85%

Dwamena, et al., Radiology 213:530, 1999

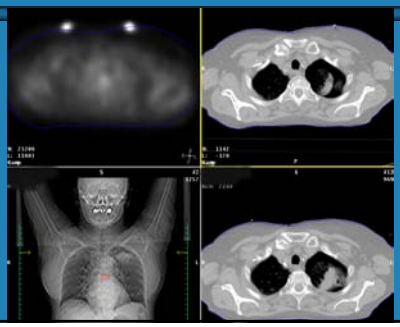
GTV
Atelectasis/PET



CT-then-PET Registration

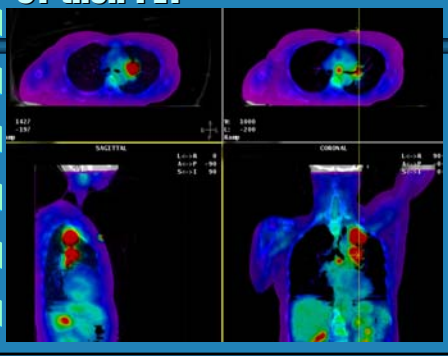


CT-then-PET Registration

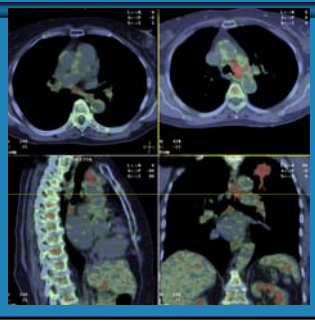


CT-then-PET Registration

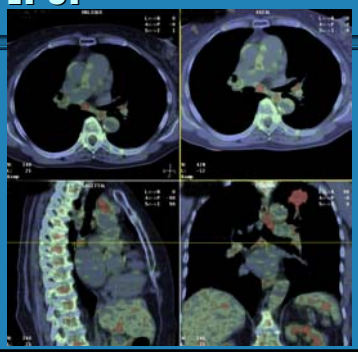
CT-then-PET



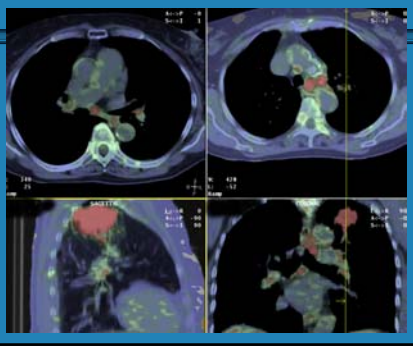
PET-CT



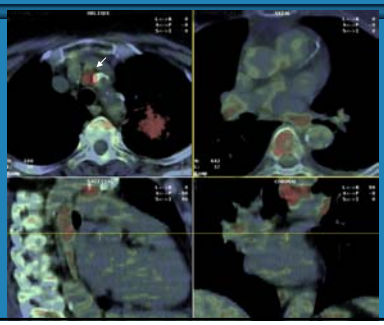
PET-CT



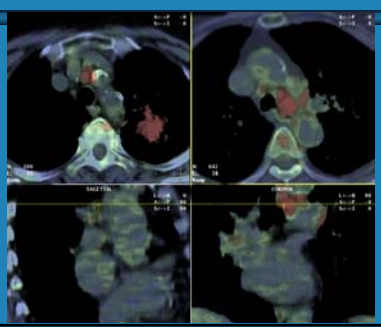
PET-CT



PET-CT



PET-CT



PET-CT
Proposed guidelines

- Atelectasis
  - SUV>2.5 with 1 cm margin - still GTV!
  - Not across anatomic boundaries
- Nodes
  - Use to identify nodes on scan
  - Don't draw GTV on PET!!!
  - If no nodes in PET positive area
    - check registration, then use clinical judgement

Tumor volumes for 3D-CRT
CTV

- Where the tumor might be
- CTV_1
  - microscopic extension of primary
- CTV_2
  - microscopic nodal disease

Tumor volumes for 3D-CRT
CTV_1

- 354 slides from 70 patients
- Adeno 2.48 $\pm$ 2.55 (0-12mm)
- Squam 1.09 $\pm$ 2.00 (0-13mm)

- Therefore 8mm and 6mm margin
- Would have missed 5/176 and 4/178
- Caveat: lungs not inflated before fixation

Giraud et al., IJROBP 48:1015, 2000

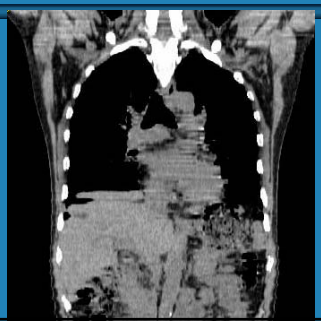
Tumor volumes for 3D-CRT
CTV_2

- Where the tumor might be
- CTV_2
  - microscopic nodal disease
  - ?????

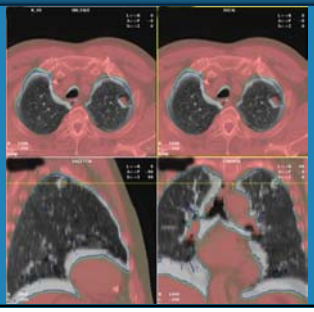
PTV
Setup Uncertainty

- Our observations
  - symmetrical
  - 1 s.d. = 3.5mm
  - more immobilization better (alpha cradle and wing board)
    - (1 s.d. = 5mm with just alpha cradle)

PTV
Motion



PTV
Motion

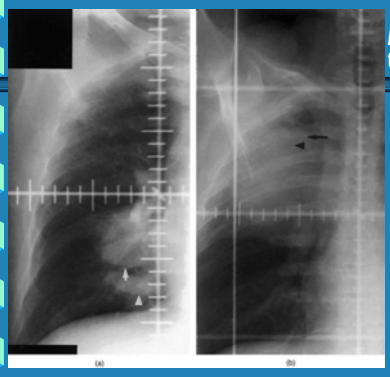


PTV
Motion

- Tumor motion not predictable
  - size, location, PFT
- Motion is complex
  - hysteresis
- Patients breath differently day-to-day
- Patients breath differently at start and end
- Normal tissues move too

PTV
Tumor motion

- 2D vs 3D
  - 22 patients studied on double exposure CXR
  - SI tumor motion 4.5±5.0 (0-22mm)
    - 12 moved, 10 did not



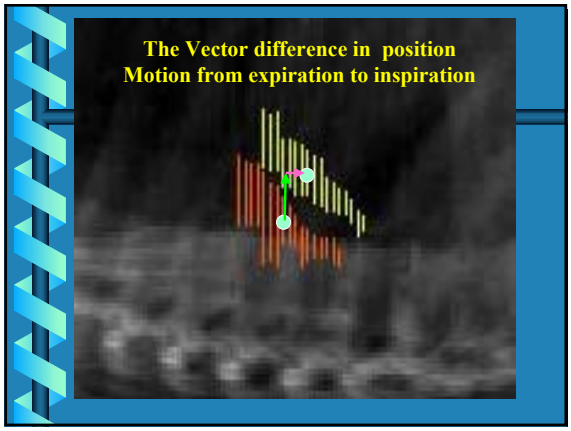
Arrows denote tumor motion

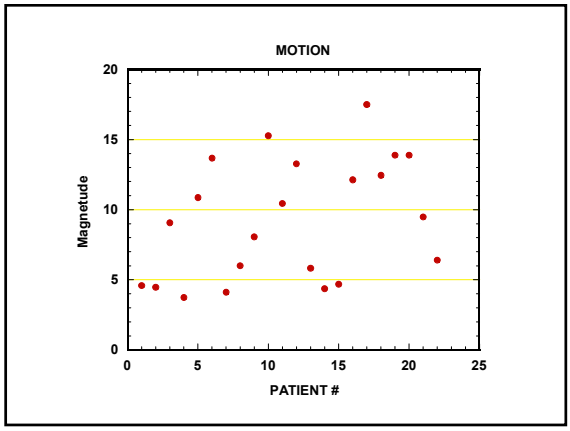
SI tumor motion was not predictable

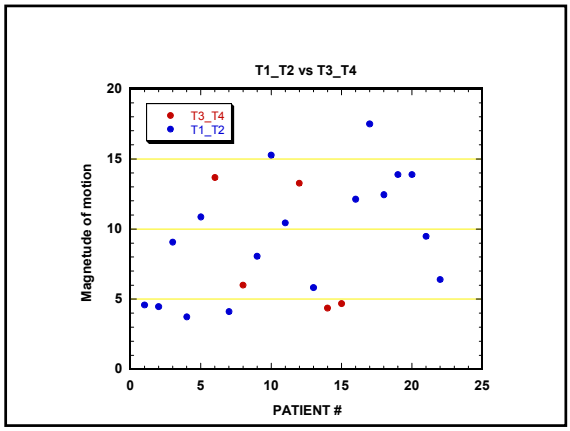
Parameter	Mean ± standard deviation	p^a
Tumor size (cm)	5.5 ± 3.1 (1.5–12)	0.78
Central vs. peripheral motion	7/11 vs. 5/11	0.81
Lower vs. upper + middle motion	4/5 vs. 8/17	0.30
Rib motion (mm)	7.3 ± 3.2 (2–15)	0.87
FeV_1	1.8 ± 1.2 (0.53–5.33)	0.91
DLCO	14.0 ± 4.5 (7.8–21.9)	0.99
TLC	6.5 ± 1.2 (3.3–8.0)	0.59

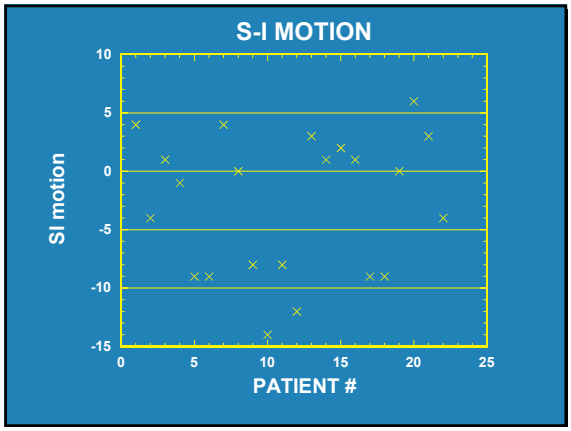
Determine Extent of Organ Motion

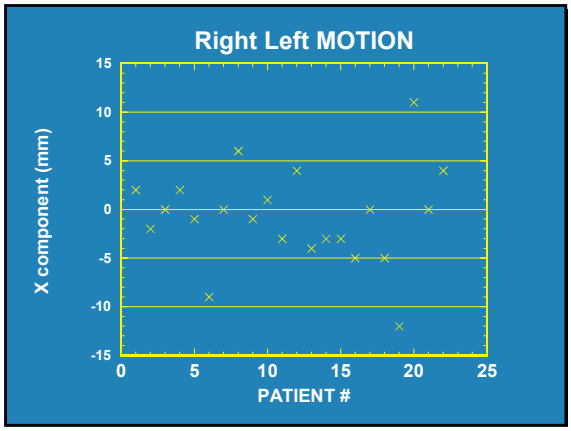
- Protocol ID00-202 (CS-PI, KF-CT, HL-MRI)
- CT arm of this protocol
  - Acquire CT image sets at fixed levels of inspiration: DIBH (60% Vc), 100% TV, end expiration (0% TV)
  - The vector difference in tumor centroid position between 100% and 0% TV should represent the motion during normal respiration

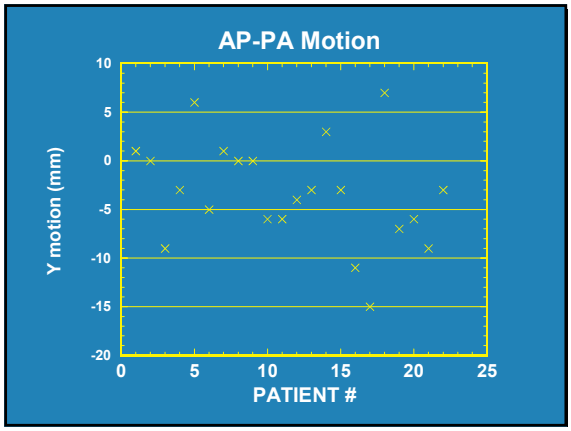

The Vector difference in position
Motion from expiration to inspiration


MOTION
Magnetude
PATIENT #

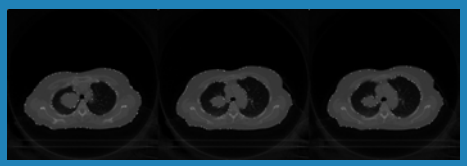

T1_T2 vs T3_T4
T3_T4
T1_T2
Magnetude of motion
PATIENT #


S-I MOTION
SI motion
PATIENT #


Right Left MOTION
X component (mm)
PATIENT #

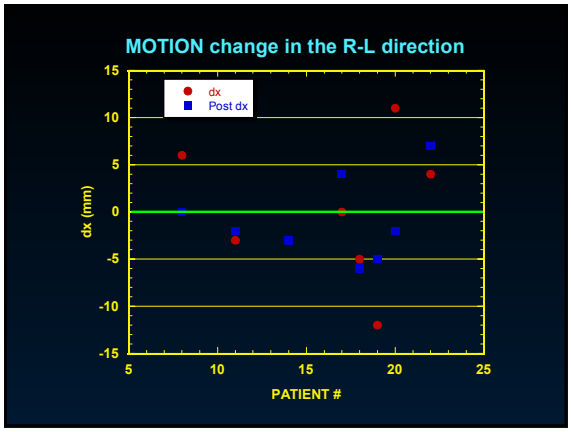

AP-PA Motion
Y motion (mm)
PATIENT #

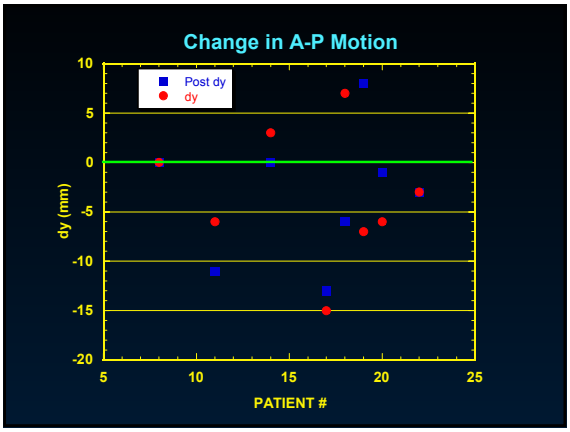
Lung tumors aren't bricks

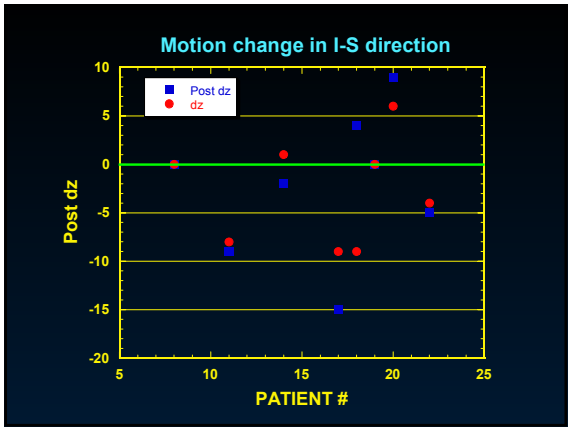


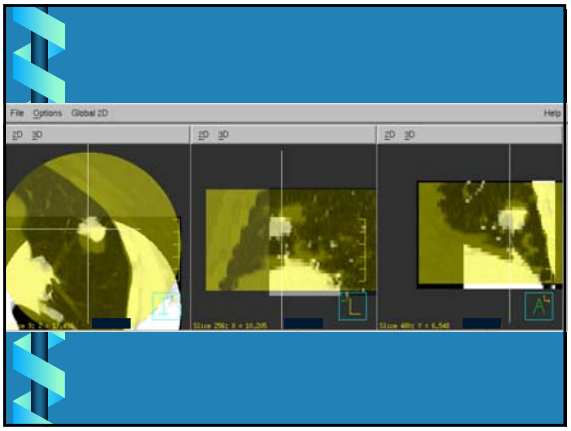
What variables predict for motion?

	Mean	STD
T1/T2	9.5	4.2
T3/T4	8.4	4.7
Upper	7.8	3.6
Lower	12.9	3.9
Free	12.4	3.4
Attached	7.8	3.9





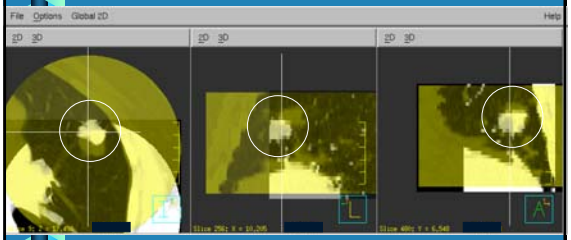




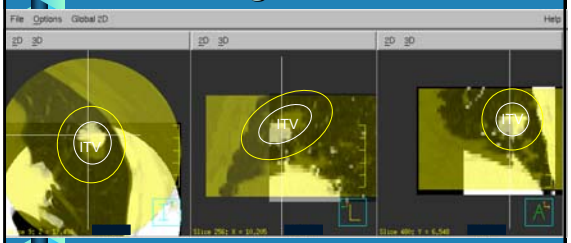
Tumor volumes for 3D-CRT
ITV

- ICRU 62
  - ITV = CTV + IM
  - ITV + SM (setup margin) = PTV

Internal Target Volume

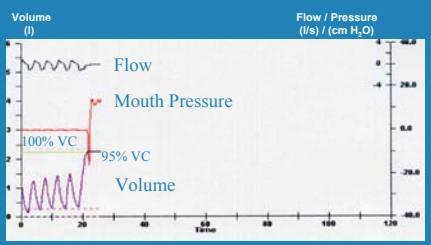


Internal Target Volume



How do we determine ITV?

- Gating device (long acquisition times)
- Use a spirometer system
  - Acquire CT scans at shallow breathing
  - Acquire CT about lesion at
    - 60% VC
    - 30% VC
    - 0% Tidal volume



Gating

- Why gate treatment?
- We can treat tumor with ITV, so……
- Gating is to reduce irradiation of lung!!

Treatment planning

- CT data sets and contours transferred to Pinnacle
- CTVs generated by uniform 0.8 cm expansion of GTVs
- Define ITV to be envelope of CTV 0 and CTV 100

Treatment planning

- PTV ITV generated by uniform 1.0 cm expansion of ITV -- setup uncertainty, motion uncertainty
- PTV 0.7 generated by uniform 0.7 cm expansion of CTV 0 - setup uncertainty, no gating uncertainty

Treatment planning
PTV ITV plan

- AP/PA + obliques
- Isocenter at PTV ITV center
- 1 cm margin around PTV ITV
- AP/PA to deliver 44 Gy to 93% of isocenter dose
- Obliques to deliver 16 Gy to 93% of isocenter dose

Treatment planning
PTV 0.7 plan

- AP/PA + obliques
- Isocenter at PTV 0.7 center
- 1 cm margin around PTV 0.7
- AP/PA to deliver 44 Gy to 93% of isocenter dose
- Obliques to deliver 16 Gy to 93% of isocenter dose

Dose calculations

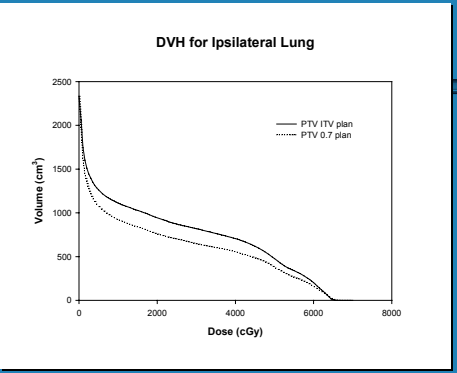
- All calculations done on free-breathing data set
- Ideally, compute PTV ITV plan on free-breathing data set, PTV 0.7
- CT data sets acquired at different times
- Somewhat different geometries

Dose calculations

- Keep comparisons uniform by using same data set
- Set uniform densities:
  - ITV = 0.7
  - Lung = 0.3

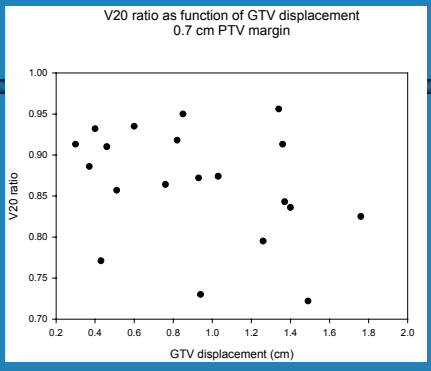
Assess potential lung morbidity

- Compute DVH for total lung
- Record V20 for total lung
- Record mean total lung dose



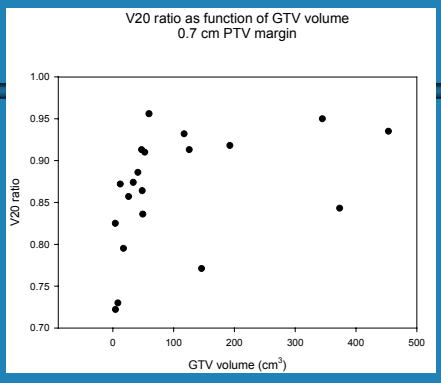
Data analysis

- Compute GTV excursion
  - center of circumscribing box
- Compute V20 ratios and mean dose ratios between gated and ITV plans
  - PTV 0.7 and PTV ITV plans



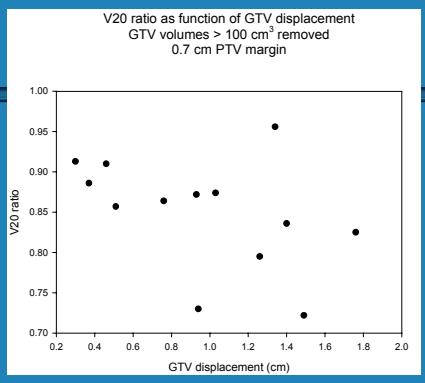
Results

- Does not appear to be correlation between GTV displacement and V20 ratio for 0.7 cm PTV margin
- But – look at V20 ratio as function of GTV volume



Results

- For 5 out of 7 cases where GTV volume > 100 cm^3, V20 ratio greater than 0.95 – little benefit to be gained by gating
- Remove cases for which GTV volume > 100 cm^3 from analysis



Conclusions

- Gating can reduce the amount of irradiated uninvolved lung
  - For GTV < 100 cm^3
  - For GTVs that exhibit significant excursion (1 cm?)
  - Provided there is little uncertainty as to the location of the tumor during gating

Tumor volumes for 3D-CRT
PTV motion

- A variety of techniques used.
  - Spirometry (ABC vs DIBH)
  - Chest wall motion
- They are time consuming
- Until this issue is resolved, use ITV

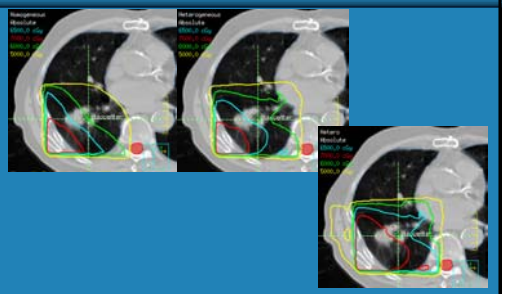
ITV

- Advantages
  - Do not miss tumor!
  - No special equipment or techniques
- Disadvantages
  - May treat slightly more volume
  - Dosimetry not quite correct

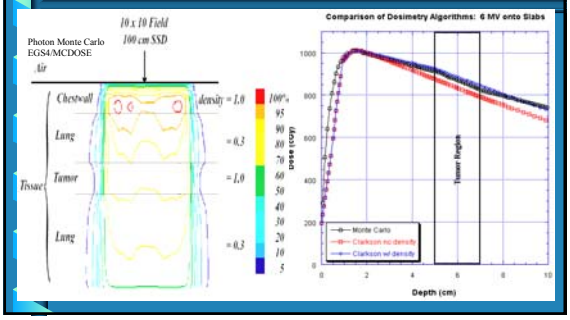
A word about heterogeneity

- It is safe to use heterogeneity corrections
  - isocenter dose about the same
  - better target volume coverage
- If you don't use heterogeneity corrections
  - 14/30 pts delivered less than 90% of the prescription dose to PTV
  - tempted to use >10MV beams

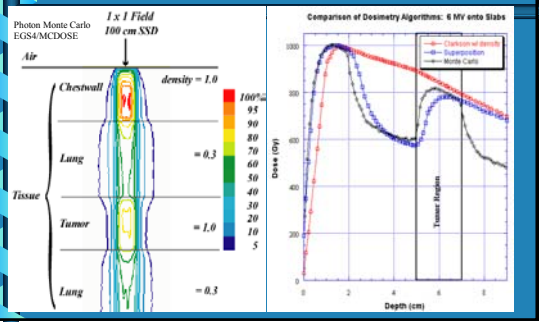
A word about heterogeneity

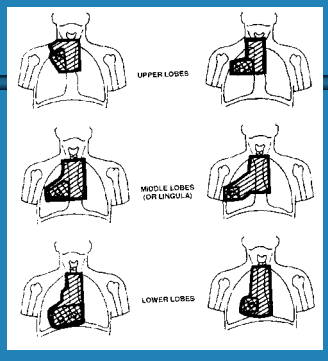


Comparison of Dosimetry Algorithms: 6 MV Broad Beam Broad Target

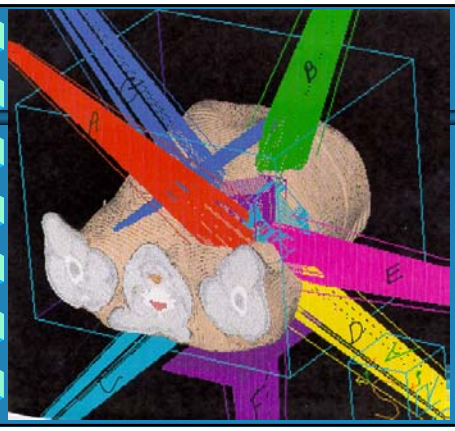


Comparison of Dosimetry Algorithms: 6 MV IMRT Beamlet Broad Target

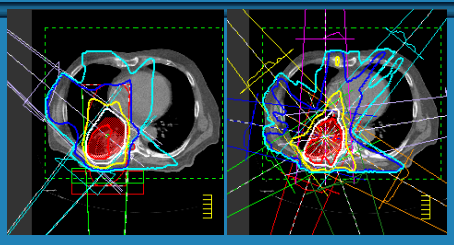




Perez and Brady, 1997

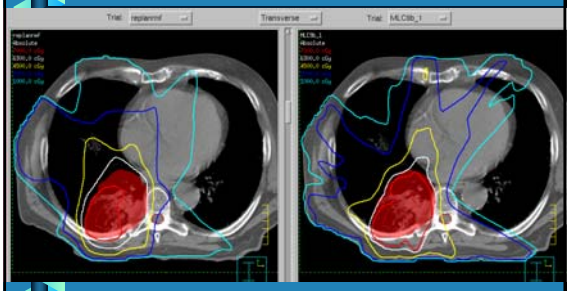


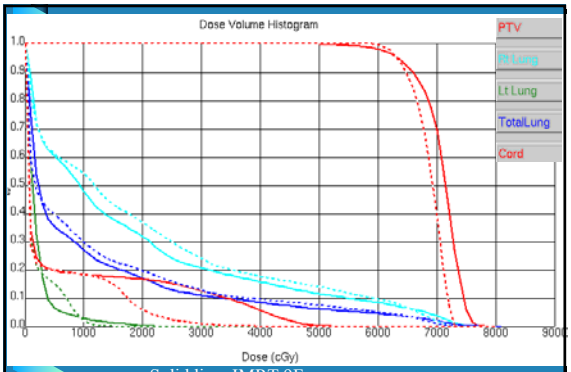
Lung IMRT (primary)



Wedge-Pair Conventional

6MV 9-Field





Solid line: IMRT 9F
Dashed line: Conventional

Conclusions
IMRT for lung cancer

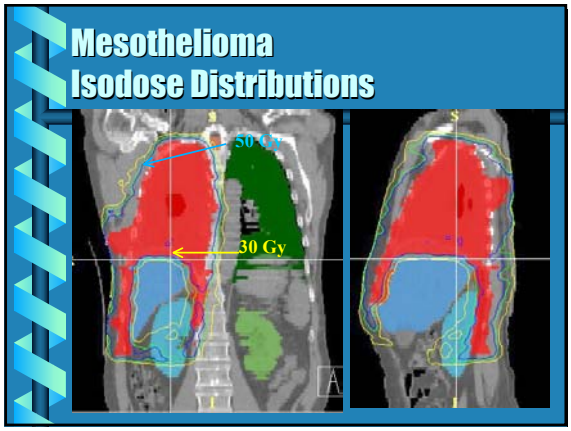
- DON'T! Until.....
  - Tumor motion can be taken into account
  - Dose calculation algorithms are better
  - The effects of low doses to large volumes of lung are better understood.

Conclusions
IMRT for lung cancer

- In the meantime....
  - Outline GTV as best as possible
  - Construct CTVs based on the literature
  - Construct PTVs based on measured tumor motion and known set-up uncertainty.

Conclusions
IMRT for thoracic tumors

- Where are we planning IMRT?
  - Mesothelioma
  - Superior sulcus
  - Esophagus


Mesothelioma
Isodose Distributions
50 Gy
30 Gy