Accumulated Dose Comparison in SBRT for Lung Tumors Using Three Alignment Strategies

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Patient daily repositioning strategies

- Small margins are used for stereotactic body radiation therapy (SBRT) of the lung during treatment planning
- Accurate patient setup is required prior to dose delivery
- Commonly used patient setup methods
  - External marker / tattoo based
  - bony structure alignment (e.g. kV/MV-image)
  - soft tissue alignment (e.g. conventional CT, kV/MV CBCT)
- Which alignments do you trust if bony structure based alignment disagrees with soft tissue based alignment?

Purposes

- Taking SBRT of lung as an example, retrospectively calculated and compared the accumulated dose over the whole treatment course for three setup scenario:
  - Maker/tattoo based
  - Bony structure based
  - Soft tissue based

CT image acquiring

- Six patients underwent lung SBRT were selected for this study
- Patients were immobilized using a vacuum cushion (BodyFix) and CT scanned for treatment planning
- At each fraction, patients were re-scanned within their immobilization devices using conventional scanner
- They were moved to treatment table within their immobilization devices for radiotherapy

BodyFIX double-vacuum whole-body immobilization system

Treatment planning and dose estimation for each fraction

- Treatment plans were performed on free-breathing CT
- Homogeneity was used by following the RTOG 0236 protocol
- Plan normalization:
  - 60 Gy (3 Fx) prescribed to 85% isodose line
- PTV = ITV (union of GTVs) + 5 mm uniform margin
- Dose received at each Fx was estimated by:
  - assuming setup using **marker/tattoo, bony structure and soft tissue**
  - ISO center determined for each scenario
  - plan parameters copied onto each daily conventional CT
  - dose recalculated with heterogeneity correction

Accumulated dose calculation

- Daily CT obtained at each fraction was registered to the simulation CT
  - B-Spline based deformable registration algorithm
- Registration field provided the trajectory of voxel motion over the treatment course
- The recalculated dose at each fraction was summed along voxel trajectories to generate the accumulated dose
- The accumulated dose = the total dose delivered to the patient

Patient information

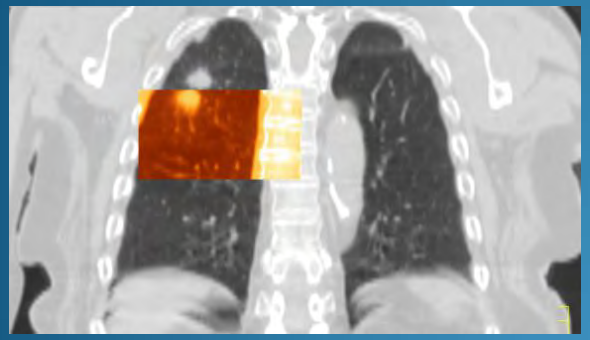
Patient	Vol. (cc)	Location	Vector motion (cm)
1	15.1	Left/upper	0.3
2	19.7	Right/upper	0.1
3	15.2	Right/upper	0.3
4	2.0	Left/upper	0.5
5	4.0	Right/upper	1.0
6	7.2	Left/upper	0.4

Tumor volume calculated on free breathing CT

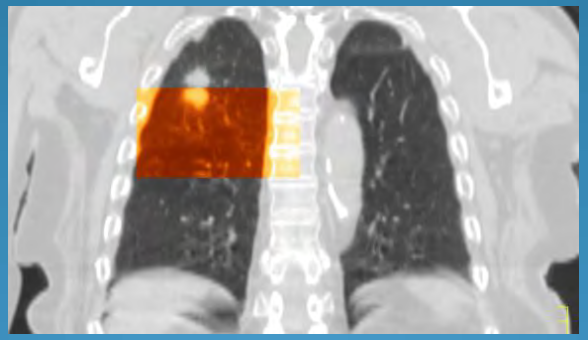
Alignments for a representative patient on fraction 1

The representative patient aligned using:

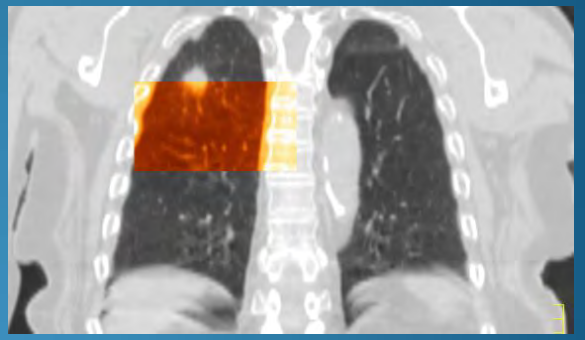
Markers/tattoos



bony structure



soft tissue

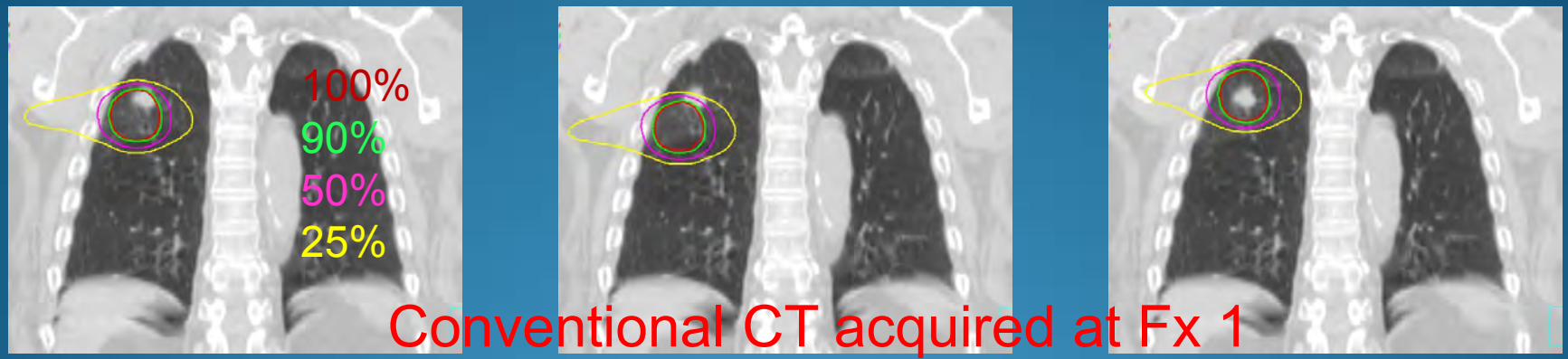


Grayscale – conventional CT scan at fraction 1
Thermal – simulation CT

Fraction 1 dose and mapped dose
for the representative patient

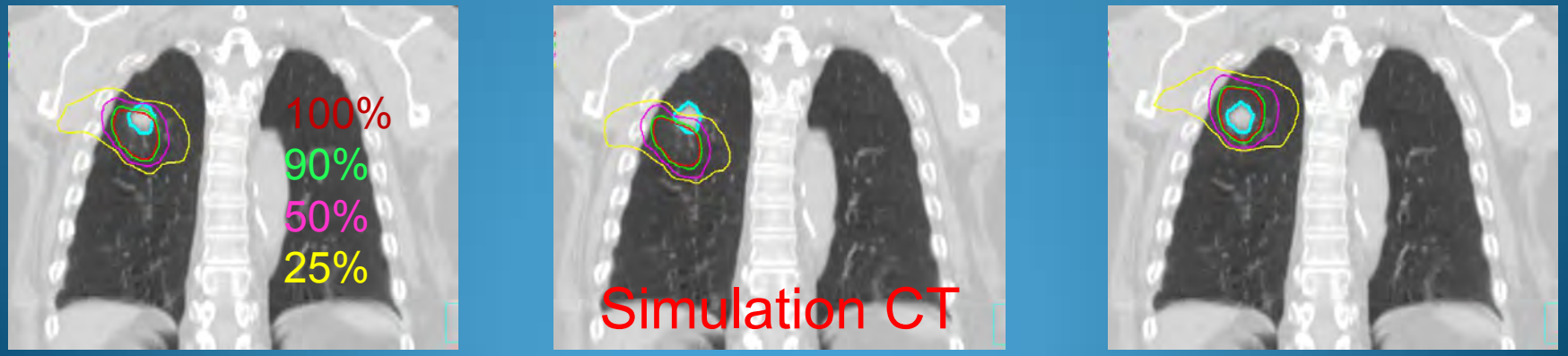
Dose received by the patient on fraction 1 if aligned by:

markers/tattoos | bony structure | soft tissue



Conventional CT acquired at Fx 1

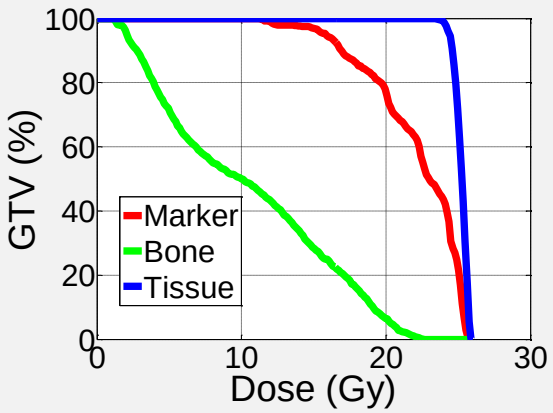
Dose mapped to simulation CT following deformable registration

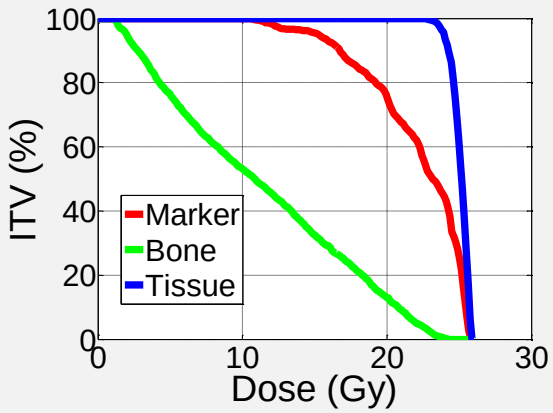


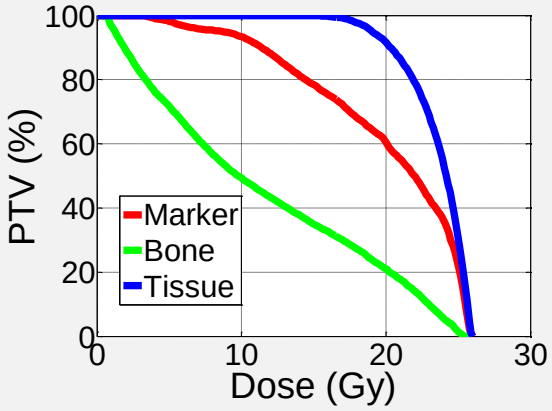
Simulation CT

DVH of fraction 1 dose estimated on simulation CT

for the representative patient



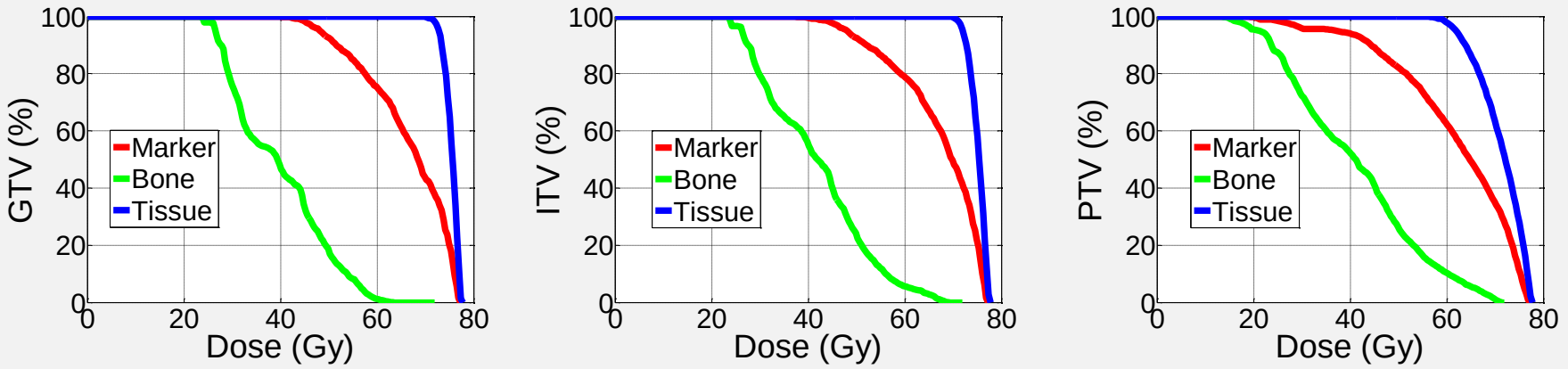




Prescription: 20 Gy/Fx for 3 Fx to 85% isodose line

DVH of accumulated dose over 3 Fx estimated on simulation CT

for the representative patient



Dose accumulated over 3 Fx =
total dose received by the patient

Prescription: 20 Gy/Fx for 3 Fx to 85% isodose line

Averaged tumor BED, NTD and coverage

averaged over 6 patients on accumulated dose

Alignment strategy	Marker / tattoo	Bony structure	Soft tissue
BED (Gy)	212.6±30.6	178.6±71.8	253.2±14.5
NTD (Gy)	190.8±25.9	148.9±59.8	211.0±12.1
V60 (%)	84.0±24.0	55.2±46.9	99.2±1.6
D100 (Gy)	53.4±9.1	4[illegible]	

V60 = percent volume receiving at least 60 Gy

D100 = dose received by 100% of volume

BED = biologically effective dose

NTD = normalized total dose delivered in 2 Gy/Fx

$$\mathrm{BED} = \mathrm{total\ dose} \times \left(1 + \boldsymbol{d}/\left(\alpha/\beta\right)\right)$$

$$\boldsymbol{d} = \mathrm{local\ dose\ per\ fraction}$$

$$\alpha/\beta = 10\,\mathrm{Gy\ for\ tumor}, 3\,\mathrm{Gy\ for\ lung}$$

$$\boldsymbol{NTD} = \boldsymbol{BED}/\left(1 + 2\boldsymbol{Gy}/\left(\alpha/\beta\right)\right)$$

Lung BED, NTD, mean dose and V20

BED, NTD mean lung dose and V20 averaged over 6 patients on accumulated dose

Alignment strategy	Marker	Bony structure	Soft tissue
BED (Gy)	7.0±2.9	6.9±2.7	6.9±3.0
NTD (Gy)	5.8±2.4	5.7±2.2	5.6±2.5
MLD (Gy)	3.6±1.6	3.7±1.4	3.5±1.6
V20 (%)	5.4±1.4	5.4±1.2	5.1±1.4

BED = biologically effective dose
NTD = normalized total dose delivered in 2 Gy/Fx
MLD = mean lung dose
V20 = percent of lung received at least 20 Gy

Conclusion

- Marker based and bony structure (kV/MV-image) based patient alignments are inaccurate for aligning patients in lung SBRT
- Soft tissue (e.g. conventional CT, CBCT) based alignment is necessary to match the prescribed dose delivered to the tumors