Auto-segmentation using Biomechanical Models

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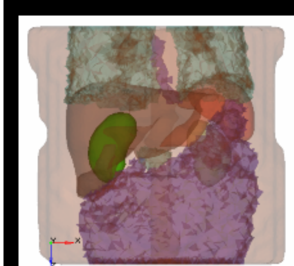
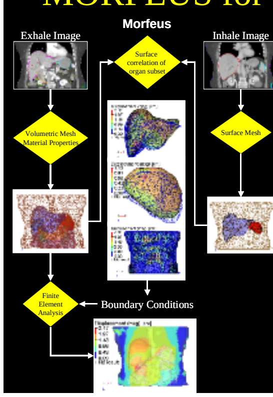
Biomechanical Models for Deformable Registration



- Include biomechanical properties of tissues
- Enable complex surface interfaces
- Little dependence on image intensity
- Proven accuracy

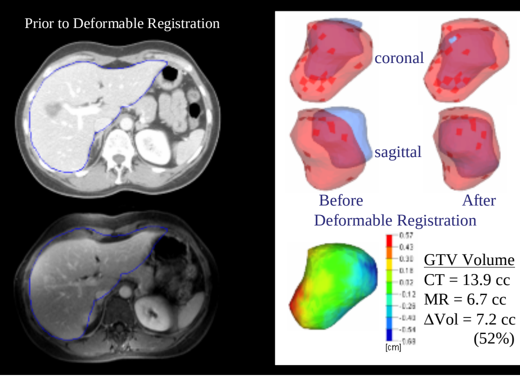
MORFEUS for Auto-Segmentation



- Enables propagation of contours using a smaller subset of contours
- Accuracy of propagation of structures independent of image contrast

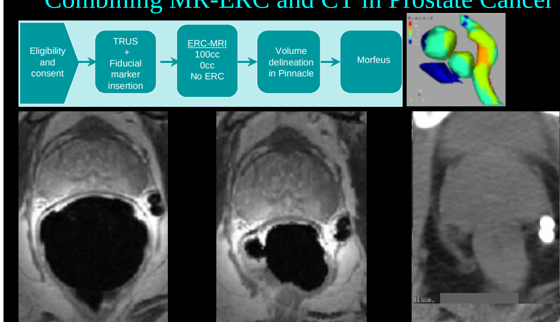
Use well defined contours to auto-segment uncertain structures

Warning! What are you propagating?



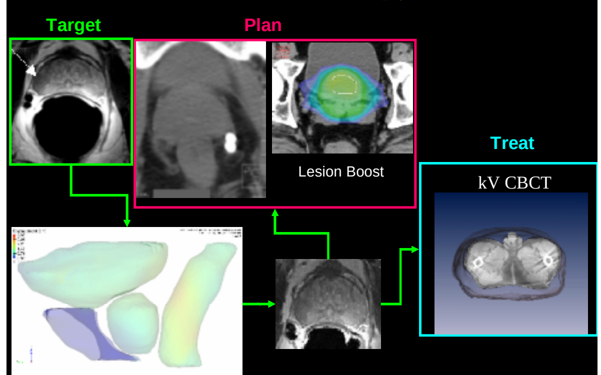
Accurate Target Definition

Combining MR-ERC and CT in Prostate Cancer

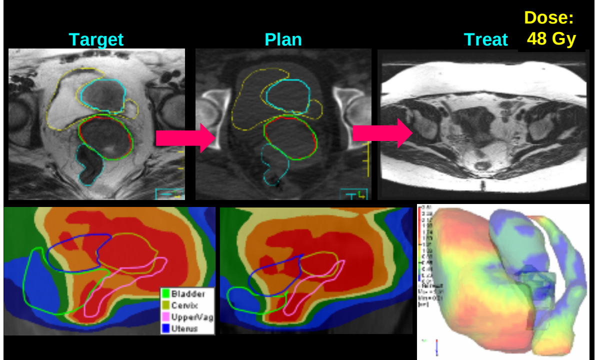


100cc ERC Primary Image | **Deformed Image** | **Actual No coil Image**

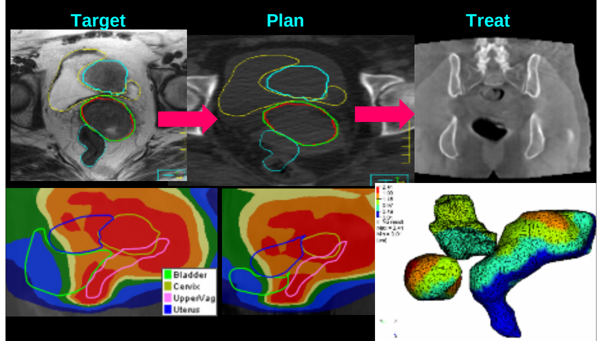
Prostate Therapy



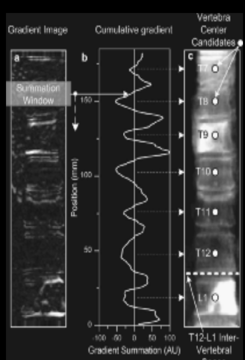
Cervix Therapy



Cervix Therapy



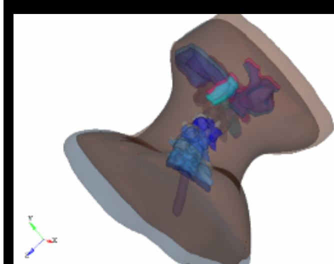
H&N Applications



- Combining intensity based auto-segmentation with biomechanical models
- Using single point identification – auto-segmentation of VBs

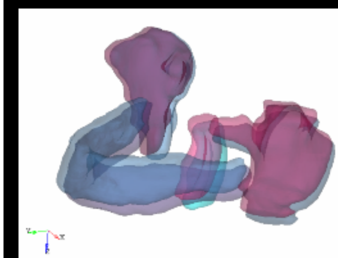
D Létourneau, et. al. Med Phys 35(1) 2008

H&N Applications



- Combining intensity based auto-segmentation with biomechanical models
- Using single point identification – auto-segmentation of VBs

H&N Applications



Surface Accuracy: abs mean
< 2mm (parotids)
< 1mm (tumor)

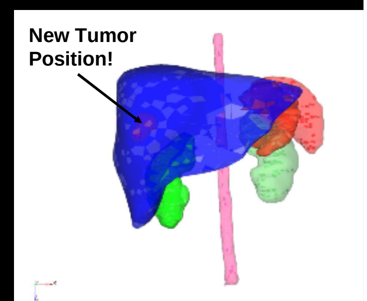
- Combining intensity based auto-segmentation with biomechanical models
- Using single point identification – auto-segmentation of VBs

Precision Image-Guidance

Planning CT [w contrast]

CBCT [w/o contrast]

Resolve Geometric discrepancies

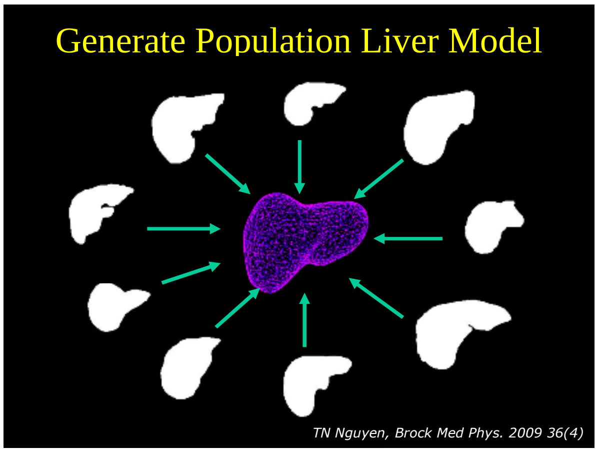


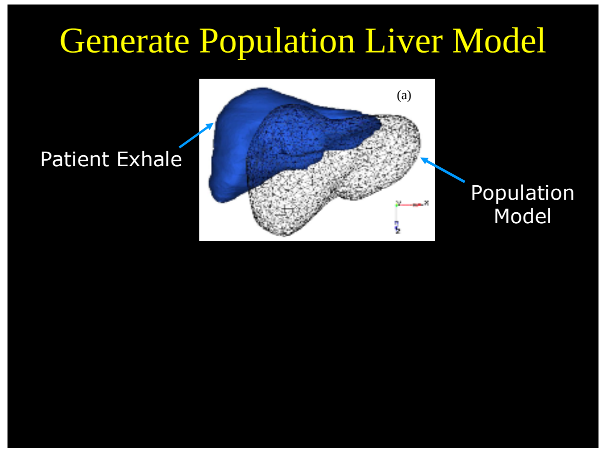
Accurate Tumor Guidance
12 Liver Patients: 6 Fx Each
Rigid Reg → Deformable Reg

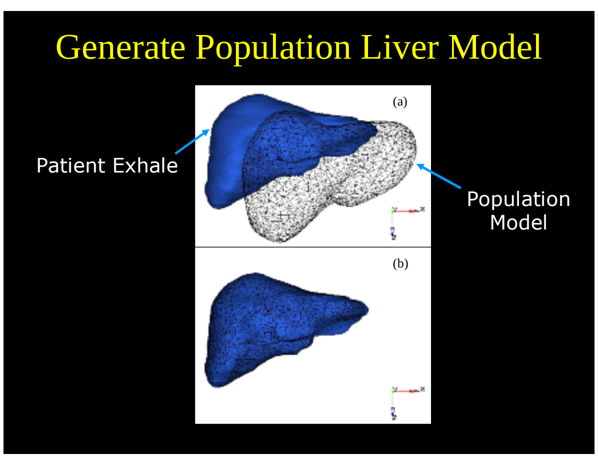
Δ Tumor	dLR	dAP	dSI	abs(dLR)	abs(dAP)	abs(dSI)
AVG	-0.04	-0.01	0.01	0.08	0.10	0.10
SD	0.10	0.15	0.20	0.07	0.11	0.17
Max	0.27	0.43	0.97	**0.34**	**0.65**	**0.97**
Min	-0.34	-0.65	-0.70	0.00	0.00	0.00
Median	-0.03	0.01	0.00	0.05	0.06	0.04

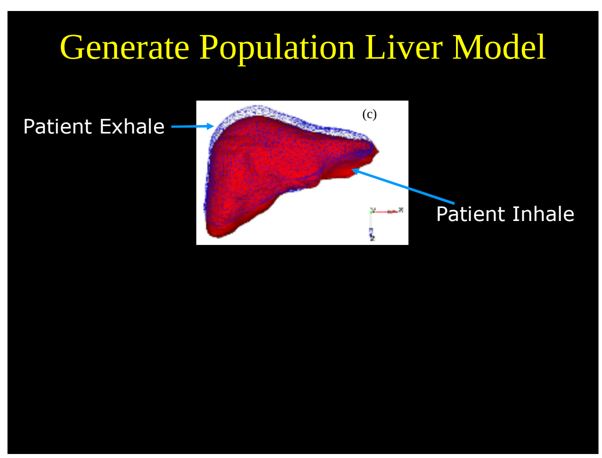
- 33% (4/12) Patients had at least 1 Fx with a ΔCOM of > 3 mm in one direction
- 15% of Fx had a ΔCOM of > 3 mm in 1 dir.

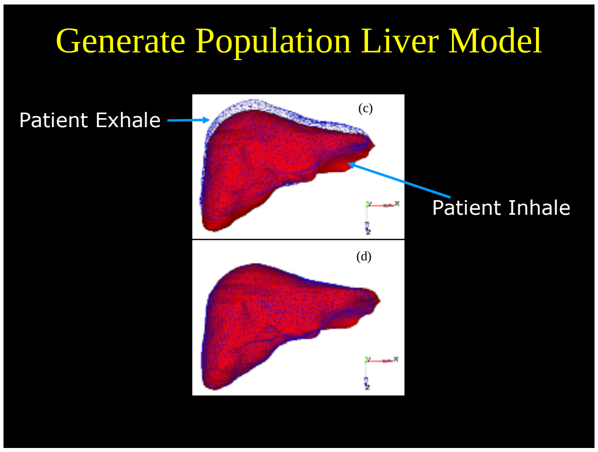
Use models and limited image information to auto-segment structures

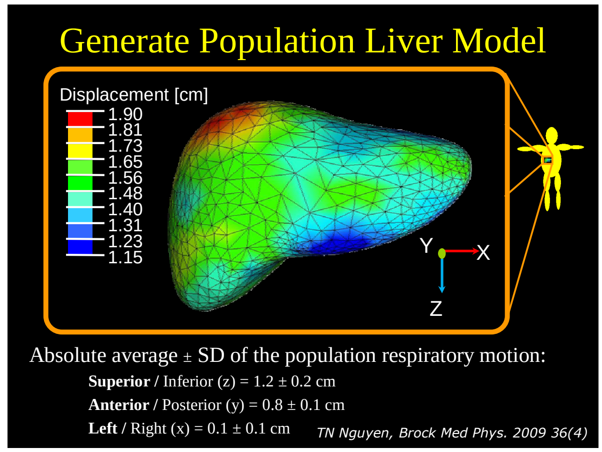

Generate Population Liver Model
TN Nguyen, Brock Med Phys. 2009 36(4)

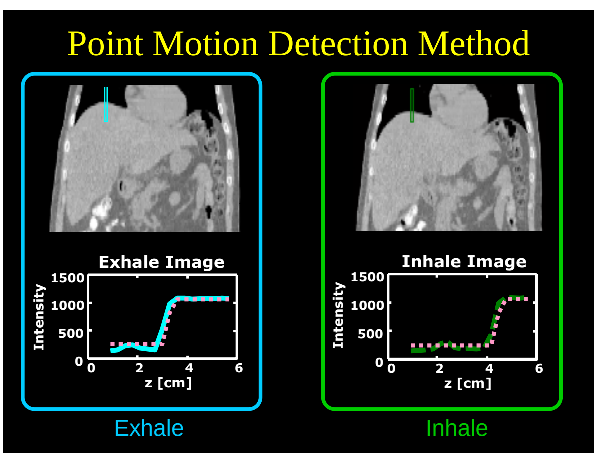

Generate Population Liver Model
(a)
Patient Exhale
Population Model

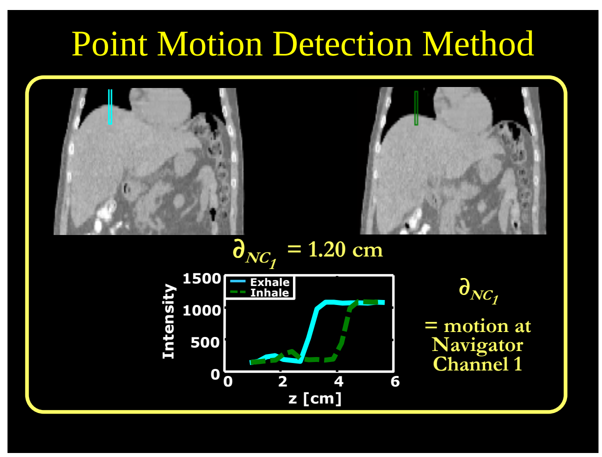

Generate Population Liver Model
(a)
Patient Exhale
Population Model
(b)


Generate Population Liver Model
(c)
Patient Exhale
Patient Inhale

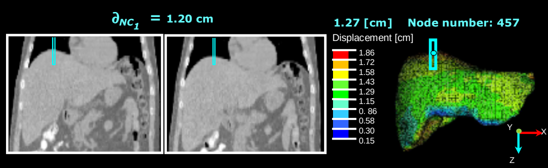

Generate Population Liver Model
Patient Exhale
(c)
Patient Inhale
(d)


Generate Population Liver Model
Displacement [cm]
1.90
1.81
1.73
1.65
1.56
1.48
1.40
1.31
1.23
1.15
Y
X
Z
Absolute average ± SD of the population respiratory motion:
Superior / Inferior (z) = 1.2 ± 0.2 cm
Anterior / Posterior (y) = 0.8 ± 0.1 cm
Left / Right (x) = 0.1 ± 0.1 cm
TN Nguyen, Brock Med Phys. 2009 36(4)


Point Motion Detection Method
Exhale Image
Intensity
1500
1000
500
0
0
2
4
6
z [cm]
Inhale Image
Intensity
1500
1000
500
0
0
2
4
6
z [cm]
Exhale
Inhale


Point Motion Detection Method
∂_{NC_1} = 1.20 cm
Exhale
Inhale
Intensity
1500
1000
500
0
0
2
4
6
z [cm]
∂_{NC_1}
= motion at Navigator Channel 1

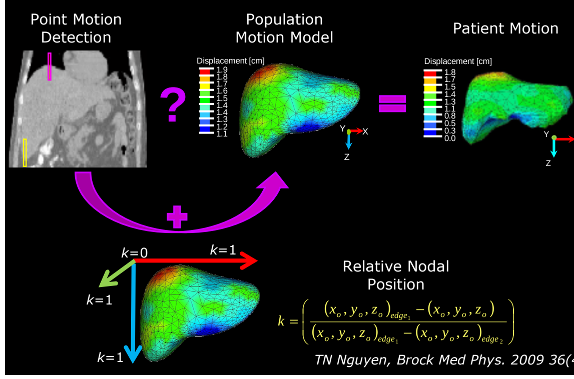
Results: Motion Detection Accuracy



	Mean [cm]	SD [cm]	Max [cm]	Min [cm]
Superior Dome	0.10	0.09	0.31	0.01
Inferior Tip	0.11	0.04	0.20	0.04
Anterior	0.11	0.07	0.21	0.01
Posterior	0.10	0.07	0.26	0.00

N = # of Patients = 13

Adaptation



$$k=\left(\frac{(x_o,y_o,z_o)_{edge_1}-(x_o,y_o,z_o)}{(x_o,y_o,z_o)_{edge_1}-(x_o,y_o,z_o)_{edge_2}}\right)$$

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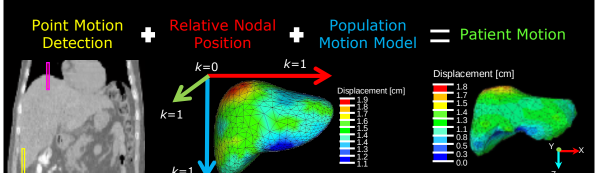
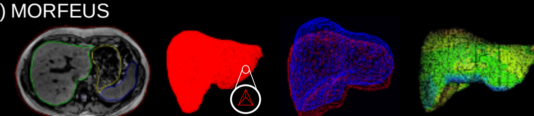
Adaptation



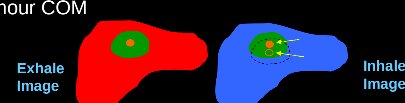
$$\partial(x_o,y_o,z_o)=\Delta(x_o,y_o,z_o)\left[\left(\frac{\partial_{NC_1}}{\Delta_{NC_1}}\right)(1-k)+\left(\frac{\partial_{NC_2}}{\Delta_{NC_2}}\right)(k)\right]$$

Accuracy Metrics

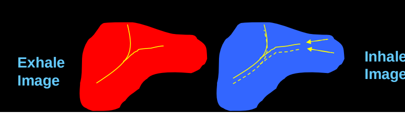
1) MORFEUS



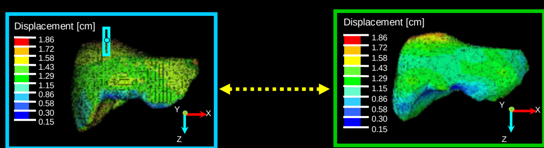
2) Tumour COM



3) Blood vessel Bifurcation



Results: Adapted Motion Accuracy



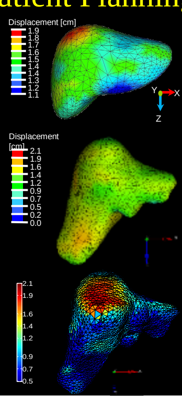
Error = Patient Full 4D Deformable Motion Model - Navigator-refined Patient Motion Model

Results: Motion Detection Accuracy

N = # of Patients, n = # Samples

	SI	AP	LR	Vector
	Mean [cm]	Mean [cm]	Mean [cm]	Mean [cm]
Bifurcations (*N*=3, *n*=16)	0.26	0.13	0.15	0.33
Tumour COM (*N*=7, *n*=14)				
MORFEUS tumour COM	0.19	0.15	0.20	0.33
Image tumour COM	0.14	0.13	0.21	0.29
MORFEUS (*N*=13)	0.25	0.24	0.23	0.43

Patient Planning Model → Tx Model

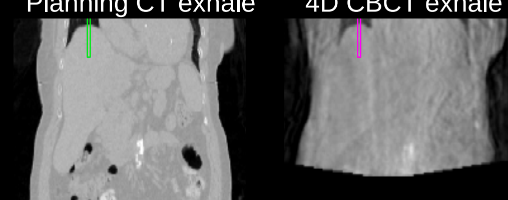


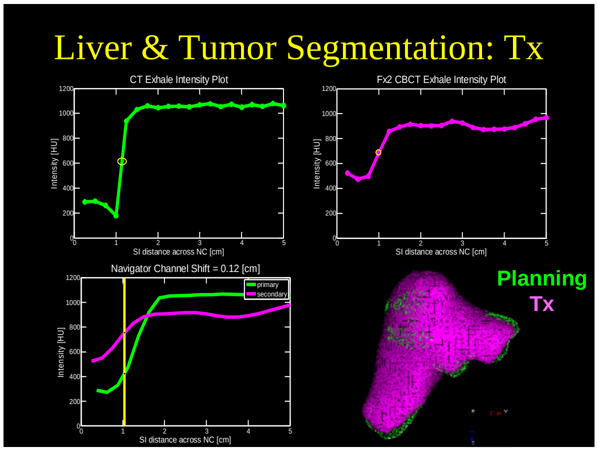
- Population Model
- Patient specific planning model
- Propagate contours onto Tx (4D CBCT) images

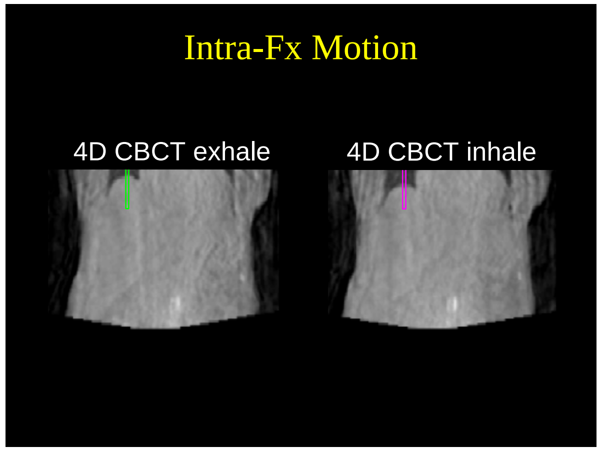
Liver & Tumor Segmentation: Tx

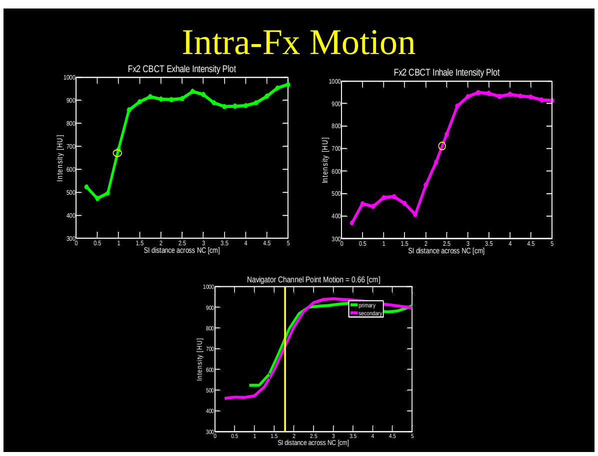
Planning CT exhale

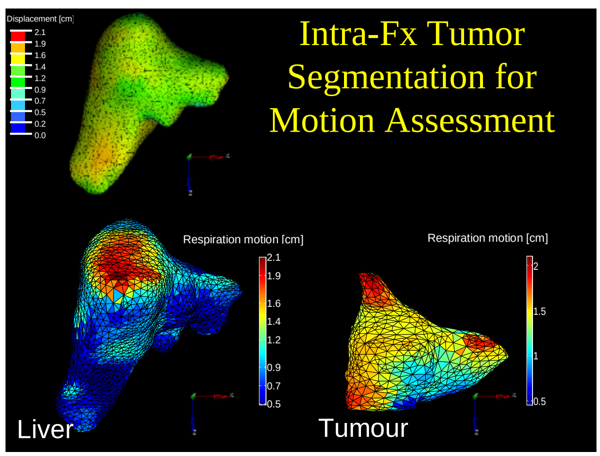
4D CBCT exhale




Liver & Tumor Segmentation: Tx
CT Exhale Intensity Plot
Fx2 CBCT Exhale Intensity Plot
Intensity [HU]
SI distance across NC [cm]
Navigator Channel Shift = 0.12 [cm]
primary
secondary
Planning
Tx


Intra-Fx Motion
4D CBCT exhale
4D CBCT inhale


Intra-Fx Motion
Fx2 CBCT Exhale Intensity Plot
Fx2 CBCT Inhale Intensity Plot
Intensity [HU]
SI distance across NC [cm]
Navigator Channel Point Motion = 0.66 [cm]
primary
secondary


Displacement [cm]
Intra-Fx Tumor Segmentation for Motion Assessment
Respiration motion [cm]
Respiration motion [cm]
Liver
Tumour

Accuracy of Adaptation

Absolute accuracy of Inter-Fx motion [cm]

	LR	AP	SI	Vector
Mean	0.15	0.16	0.15	0.14
SD	0.11	0.10	0.09	0.10

Absolute accuracy of Intra-Fx motion [cm]

	LR	AP	SI	Vector
Mean	0.14	0.15	0.18	0.17
SD	0.10	0.08	0.09	0.10

Summary

- Must be careful what contours we propagate
- Biomechanical models can assist in accurate propagation of structures lacking significant intensity variation
- Combination of intensity-based segmentation of more easily discernable structures and biomechanical models can improve segmentation
- Use of limited intensity information and population (or patient specific models) can enable automated biomechanical-model based segmentation