Image-Guidance for Breast Radiotherapy

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NKI-AVL

Disclosure

- Our department has research collaborations with:
  - Elekta Oncology Systems
  - Philips Radiation Oncology Systems
  - Ray Search Laboratories
- Our department licenses software to:
  - Elekta Oncology Systems

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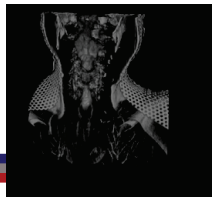
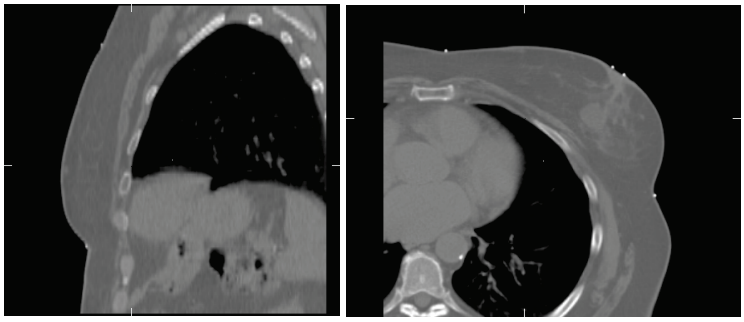


Content

- CBCT versus portal image analysis
- Geometrical Uncertainties in breast RT
- IGRT for deep inspiration breath-hold
- IGRT for pre-operative partial breast irradiation
- Adaptive RT for breast cancer

Cone Beam CT Guided Breast RT @ NKI-AvL

Geometrical Variability in Breast Radiotherapy



Protocol

- Patients are treated in 28 fractions with
- 50.7 Gy to the whole breast and 64.4 to the boost area
- Registration on bony anatomy
- Correction using a shrinking action level protocol with N=3 and initial action level α=9 mm

Image Registration

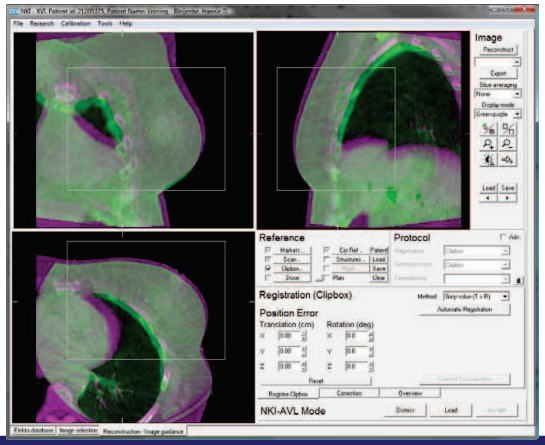
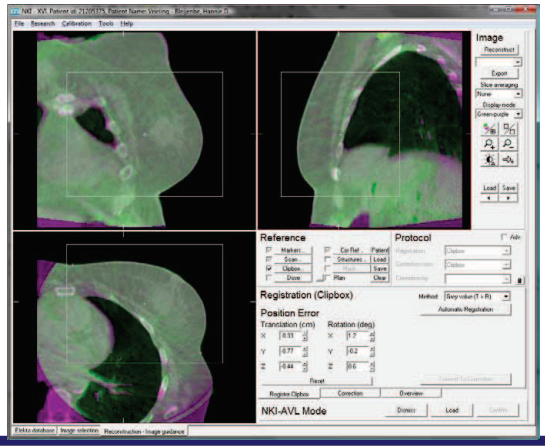
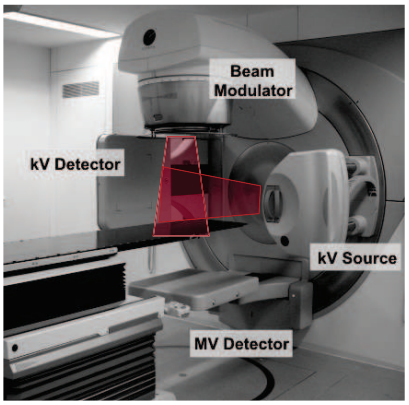


Image Registration



Cone Beam CT versus Portal Image Analysis

Introduction



Study

- 20 breast cancer patients, treated in a supine position
- CBCT scans were regularly acquired for a shrinking action level (SAL) setup correction protocol
- The EPID images were obtained during the same fraction from the opposing oblique treatment beams and manually registered to the DRRs in the 2D coordinate system of the EPID (U,V).
- For both EPID and CBCT the registrations were performed on the ribs

Study

- Analyze position variability based on CBCT in three orthogonal directions
  - Without corrections
  - For offline correction protocol (SAL)
- Compare portal image analysis with CBCT analysis in the EPID coordinate system (U,V)

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Bony Anatomy Position Variability CBCT

	No-correction			Offline		
	CC	LR	AP	CC	LR	AP
M (mm)	-1.1	-2.1	2.0	-0.5	-1.0	0.8
Σ (mm)	3.8	3.1	2.5	1.7	1.4	1.2
σ (mm)	2.8	2.2	2.6	3.1	2.3	3.0

Topolnjak et al. IJROBP 2010

Bony Anatomy Position Variability CBCT

	No-correction			Offline		
	CC	LR	AP	CC	LR	AP
M (mm)	-1.1	-2.1	2.0	-0.5	-1.0	0.8
Σ (mm)	3.8	3.1	2.5	1.7	1.4	1.2
σ (mm)	2.8	2.2	2.6	3.1	2.3	3.0
Margin	11.5	9.2	8.0	6.4	5.2	5.1

Margin=2.5Σ + 0.7σ

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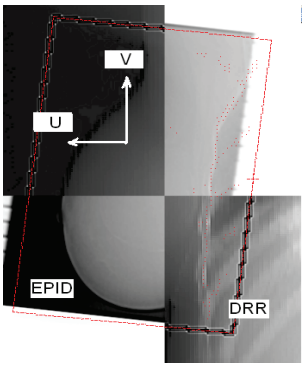
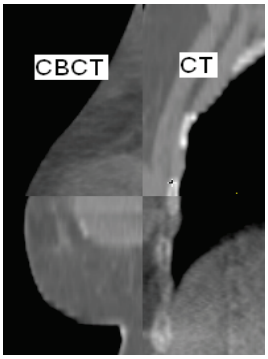
2D versus 3D imaging



Portal image – DRR fusion



CBCT-planning CT fusion

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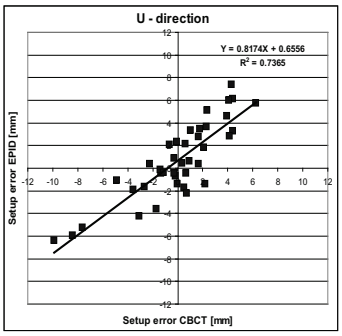
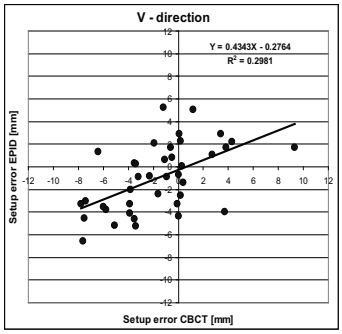
Correlation EPID - CBCT





R^2=0.74 R^2=0.30

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Geometrical Uncertainties for EPID

	Offline		Online	
	U	V	U	V
M (mm)	-0.9	-0.8	-0.8	-0.5
Σ (mm)	2.2	3.3	1.1	2.5
σ (mm)	2.9	2.9	2.0	3.0
Margin	7.7	10.3	4.0	8.2

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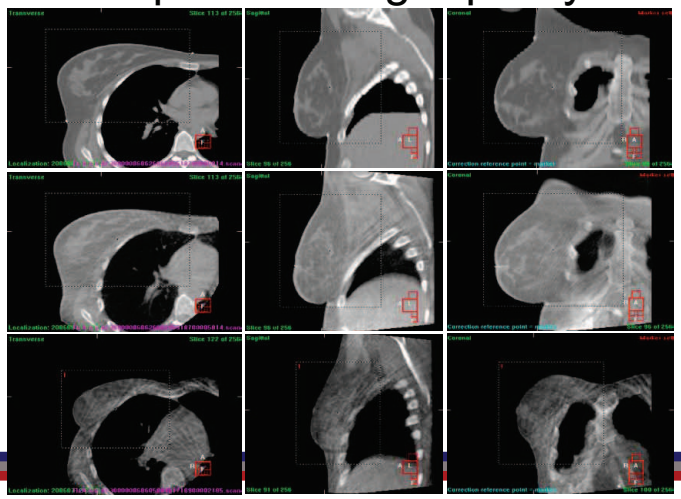
Geometrical Uncertainties for Tumor Bed Boost

Method

- 20 breast cancer patients
- Three registration methods:
  - Bony anatomy
  - Breast surface
  - Tumor bed
- Compare residual geometric uncertainties

Improved image quality



Boost position variability – Surrogate accuracy

	No-correction			Bone			Surface		
	CC	LR	AP	CC	LR	AP	CC	LR	AP
M (mm)	1.4	0.2	−3.1	0.5	−0.9	0.9	−0.4	1.0	−0.3
Σ (mm)	3.0	3.8	2.7	2.0	2.3	1.5	1.8	1.7	1.1
σ (mm)	2.6	3.2	2.9	1.8	2.3	1.9	1.7	1.6	1.6
Margin	8.3	10.6	7.7	5.6	6.5	4.5	5.1	4.8	3.3

Margin=2.5Σ + 0.3σ

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Relative Surface surrogate benefit

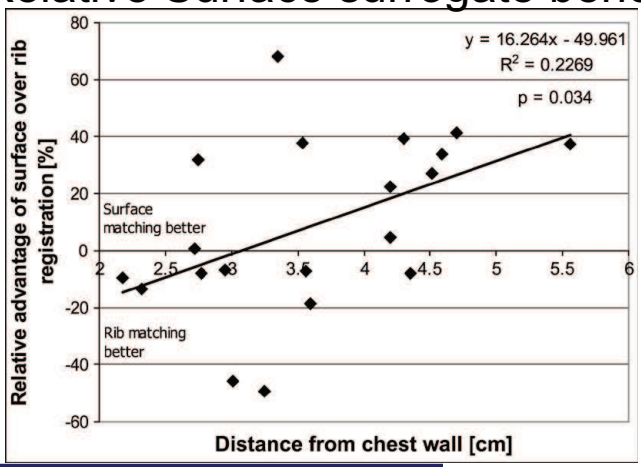

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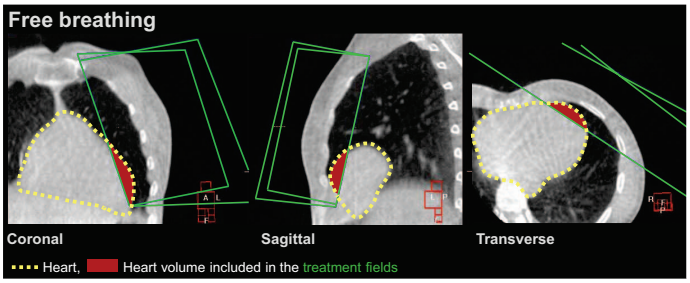
Image Guidance for Deep Inspiration Breath-hold

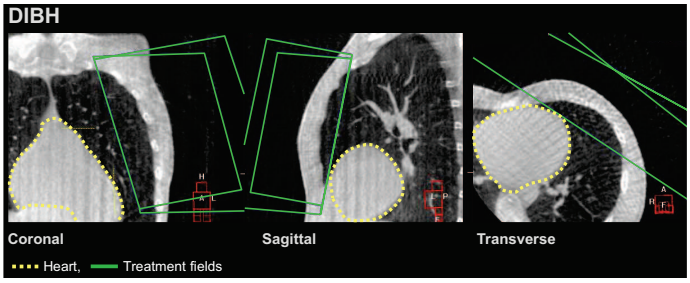
Introduction

- Left-sided breast cancer radiation
  - Increased risk for long term heart disease



Introduction

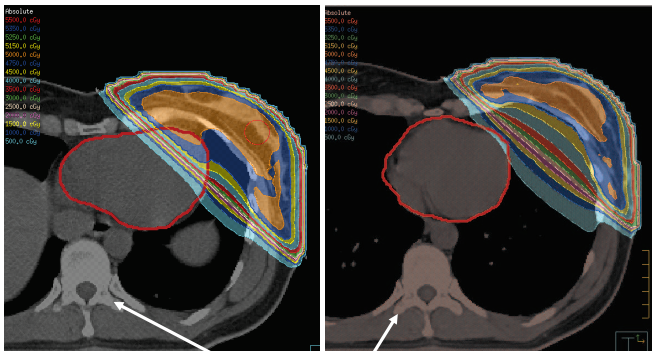
- To decrease the irradiated heart volume
  - Voluntary deep inspiration breath hold (DIBH)



Treatment planning

Free Breathing

Deep Inspiration Breath Hold

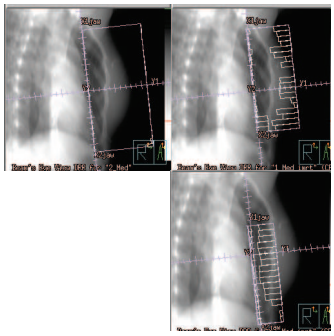


Same vertebra

Treatment planning

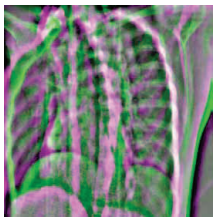
Planning:

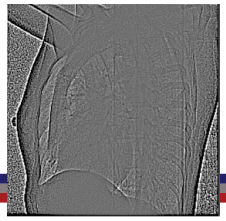
- IMRT plan
- Max.I 3 segments per beam
- 1 open en 2 IMRT segments



Patient set-up

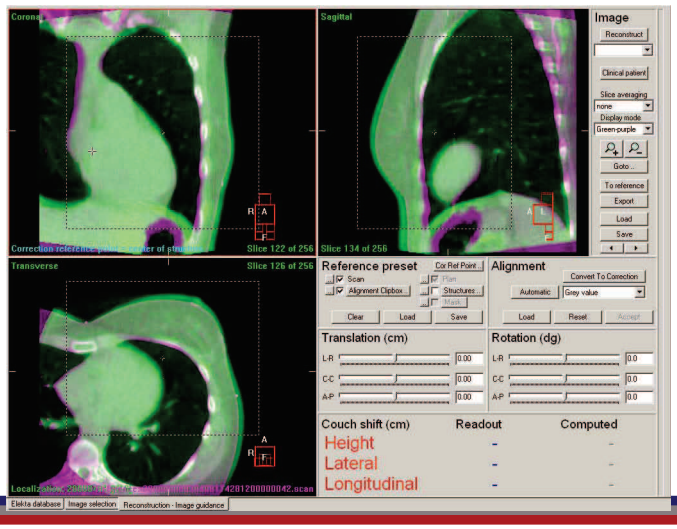
- Under kV fluoroscopy guided imaging the patient was instructed for 2 deep in- and expirations before the DIBH position was taken.
- During the DIBH position a CBCT was performed (30 sec.)



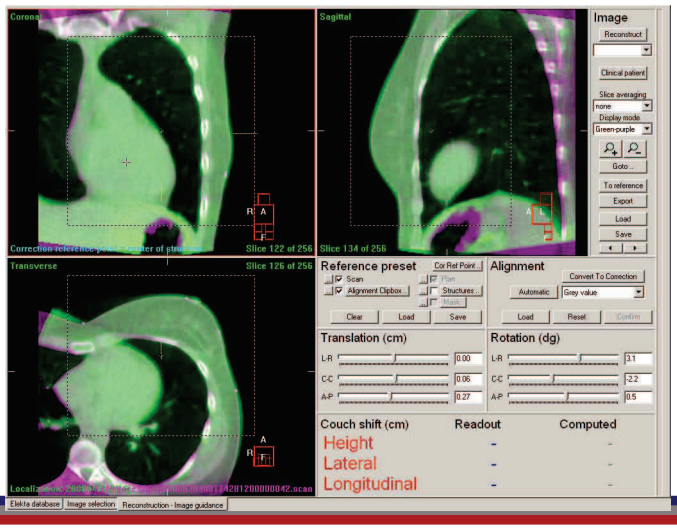


Free breathing vs Breath hold CBCT

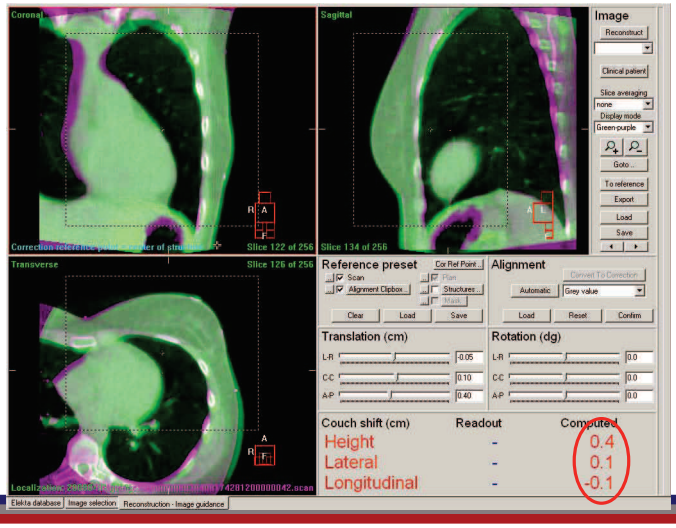
CBCT before registration



CBCT after registration



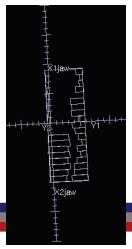
CBCT after registration



Procedure: step V - irradiation

- During the first part of the second DIBH, the medial segments were given and guided by kV fluoroscopy imaging (green).

Segment 1



Segment 2

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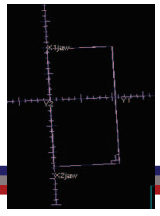
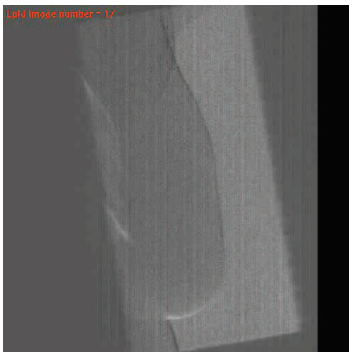
Procedure: step VI - irradiation

- Hereafter, the open medial fields were given and registered by online EPID images.
- This procedure was repeated for the lateral fields during the third DIBH.

Open field





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Post Correction Residual Error

- Open field treatment portal used for image registration

	Inter-fraction		Intra-fraction	
	U	V	U	V
M (mm)	0.3	-1.3	-0.4	-0.2
Σ (mm)	1.4	1.6	0.8	0.3
σ (mm)	1.6	1.8	1.1	0.8

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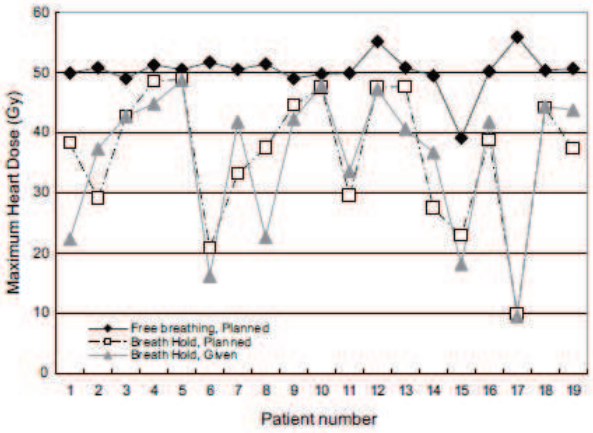
Heart Dose



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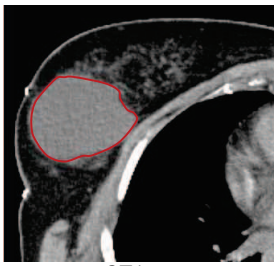
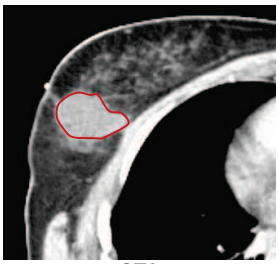
Adaptive RT for breast cancer

Dosimetric Impact of Seroma Reduction on Boost Planning Volume

- Seroma reduction during RT



CT1 scan



CT2 scan

CT1: initial planning CT obtained before whole-breast irradiation
CT2: second CT obtained during a patient's RT course

Dosimetric Impact of Seroma Reduction on Boost Planning Volume

- Retrospective comparison between three different boost RT delivery and planning techniques:
  - SEQ: a sequential boost plan
  - SIB: a simultaneous integrated boost plan
  - SIB-ART: a SIB adaptive radiation therapy plan

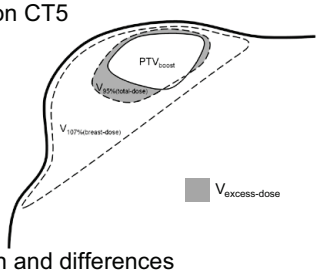
	SEQ	SIB	SIB-ART	
Whole breast	CT1 25x2Gy	CT1 28x1.81Gy	CT1 15x1.81Gy	CT2 13x1.81Gy
Boost	CT3 8x2Gy	CT1 28x0.49Gy	CT1 15x0.49Gy	CT2 13x0.49Gy

Dosimetric Impact of Seroma Reduction on Boost Planning Volume

- 21 Patients
- Seroma volume reduction:
  - Significant total reduction during RT (p<0.001, one sample t test)
  - Mean (Range): 62 (38~85)%
  - 77% of total reduction in first three weeks of RT
- Evaluation on CT scans used for planning:
  - Target coverage: relative volume of TV_{breast} and PTV_{boost} receiving ≥95% of the prescribed dose
  - $V_{excess\text{-}dose}$: undesired volume (outside PTV_{boost}) receiving ≥95% of the total dose

Dosimetric Impact of Seroma Reduction on Boost Planning Volume

- Evaluation of total dose distributions on CT5
  - Target coverage
  - $V_{excess\text{-}dose}$
  - $V_{107\%(breast\text{-}dose)}$
  - $V_{95\%(total\text{-}dose)}$
  - HD_{max}: maximum physical heart dose
  - LD_{mean}: mean physical lung dose



- Correlation seroma volume / reduction and differences between the treatment plans for
  - $V_{excess\text{-}dose}$
  - $V_{107\%(breast\text{-}dose)}$
  - $V_{95\%(total\text{-}dose)}$

Dosimetric Impact of Seroma Reduction on Boost Planning Volume

Variable		mean			Friedman	Wilcoxon
		SEQ	SIB	SIB-ART	*p*	
$V_{107\%(breast\text{-}dose)}$ (cm^3)		584.5	536.8	485.5	<0.001	SIB-ART<SIB<SEQ
$V_{95\%(total\text{-}dose)}$ (cm^3)		273.6	289.4	234.2	<0.001	SIB-ART<SEQ<SIB
$V_{excess\text{-}dose}$ (cm^3) *Planning*		134.4	58.3	36.1	<0.001	SIB-ART<SIB<SEQ
$V_{excess\text{-}dose}$ (cm^3) *CT3*		134.4	150.1	95.0	<0.001	SIB-ART<SEQ<SIB
HD_{max}* (Gy)	Left	39.9	36.9	35.8	0.001	SIB-ART<SIB<SEQ
LD_{mean}* (Gy)		4.2	4.6	4.5	0.001	SEQ<SIB-ART<SIB

Summary

- Considerable geometrical uncertainties limit the precision in breast RT
- Image guided correction strategies effectively manage setup errors
- Adaptive RT has the potential to account for shape and volume changes