Klinik RADIOONKOLOGIE
Unispital Zürich
Direktor: Prof. Dr. M. Guckenberger

IGRT for SBRT and particle therapy

Matthias Guckenberger, MD

Outline

1. Rational for IGRT
2. Technologies for IGRT
3. Pitfalls and challenges in IGRT
4. Clinical evidence for IGRT

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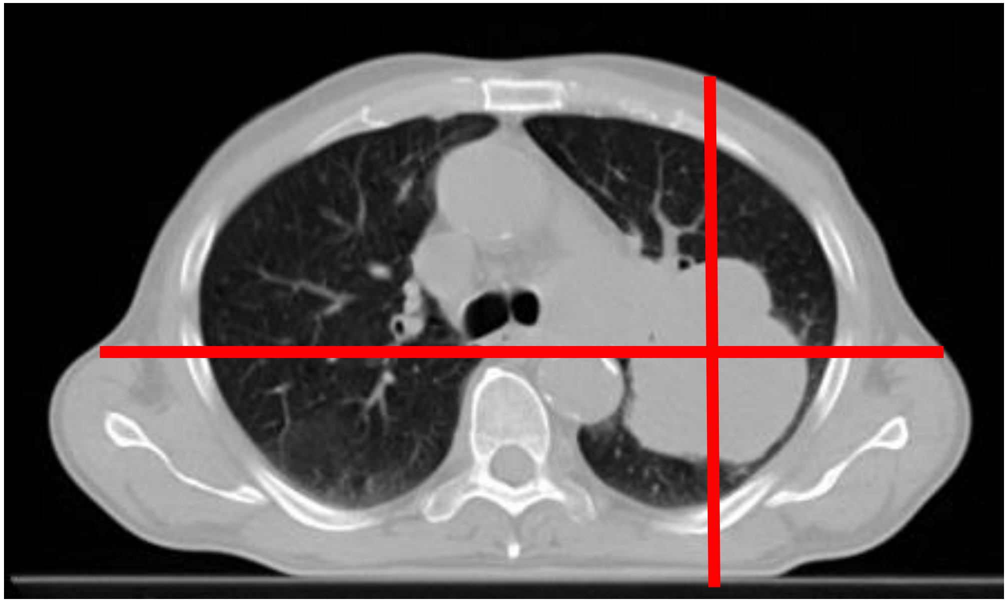
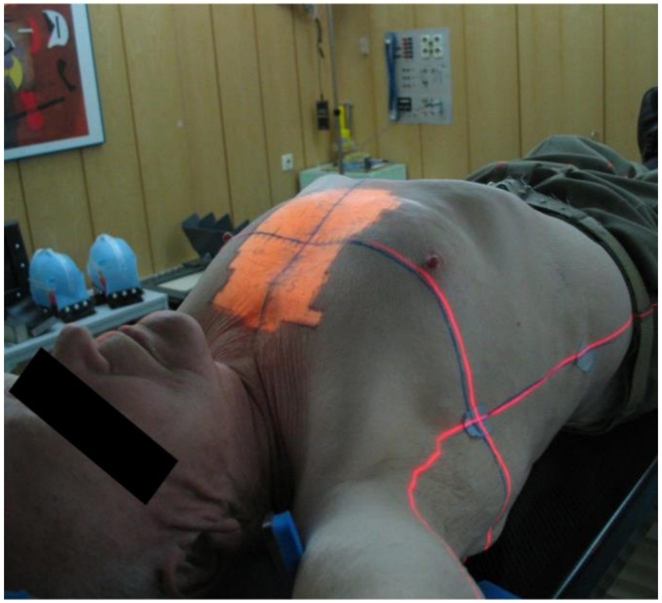
Traditional patient set-up: skin marks

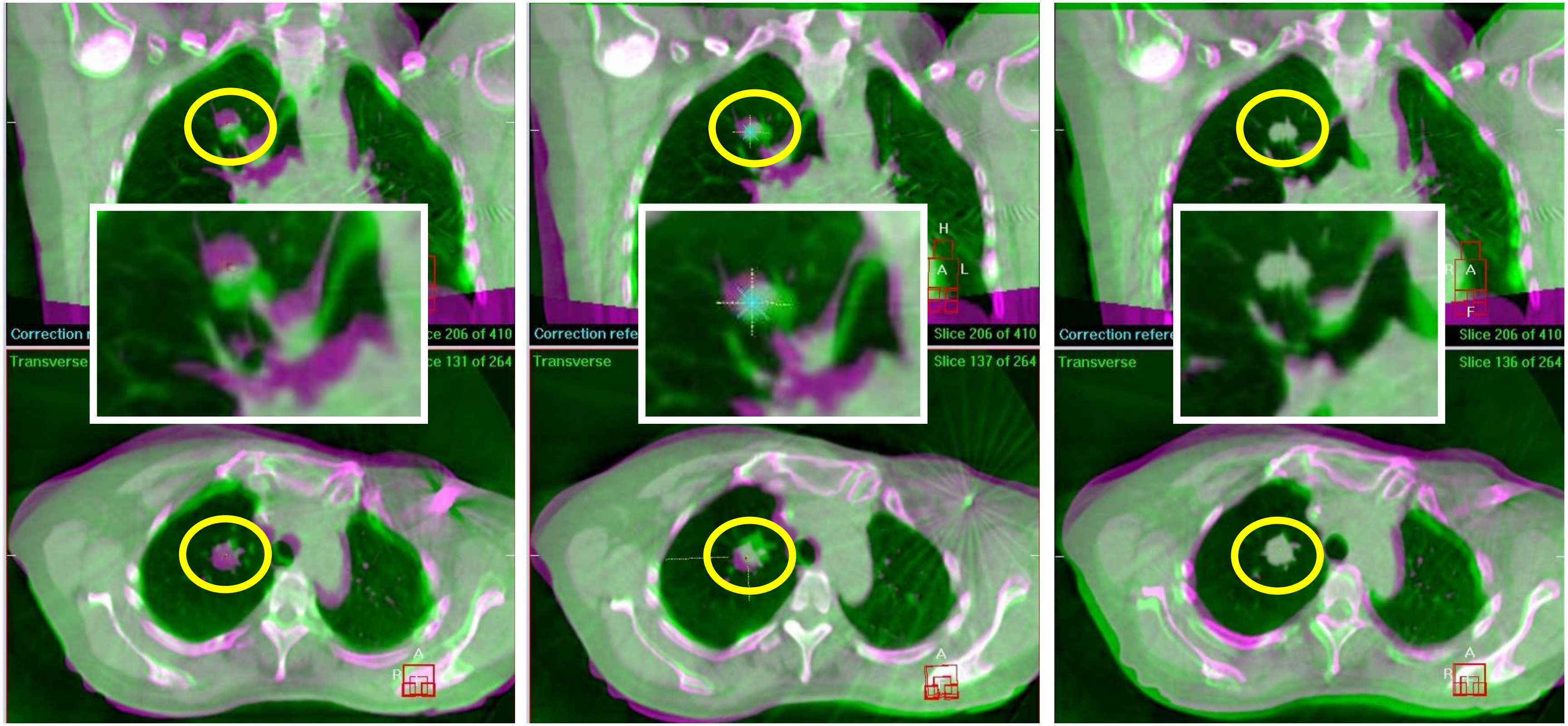




Constant relationship between skin marks and internal anatomy ?

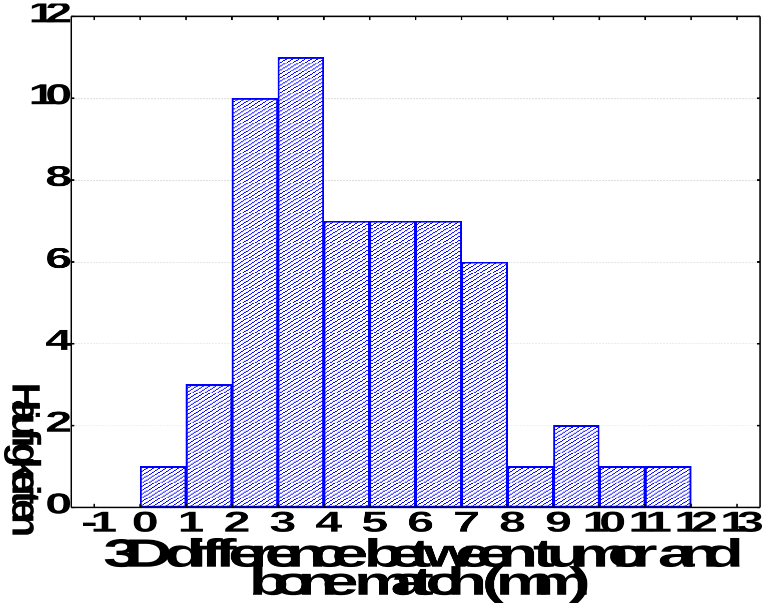
Inter-fractional base line shifts in lung SBRT

Patient positioning | **Bone set-up** | **Tumor set-up**



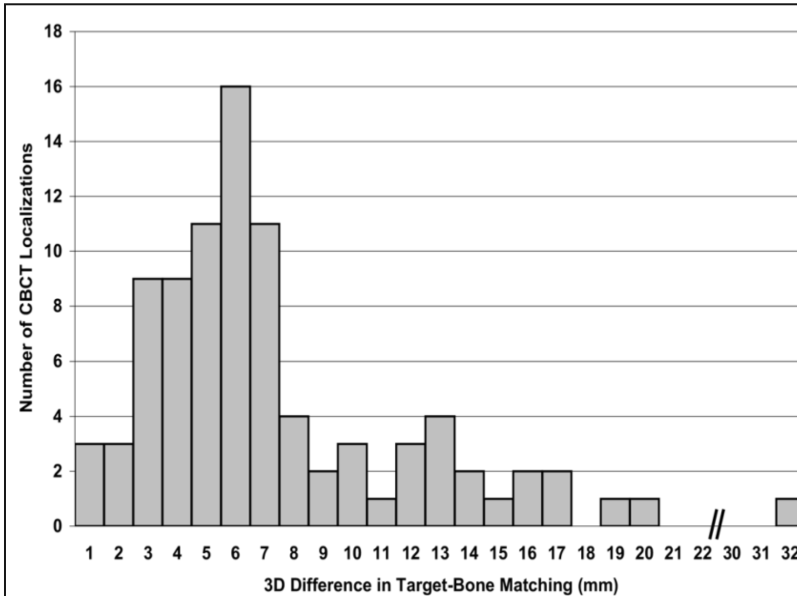
Base-line shifts independently from the bony anatomy

Inter-fractional base line shifts in lung SBRT



Mean: 5.3mm 90th percentile: 8mm

Guckenberger et al. 2006



Mean: 6.8mm 90th percentile: 13.9mm

Prudie et al. 2007

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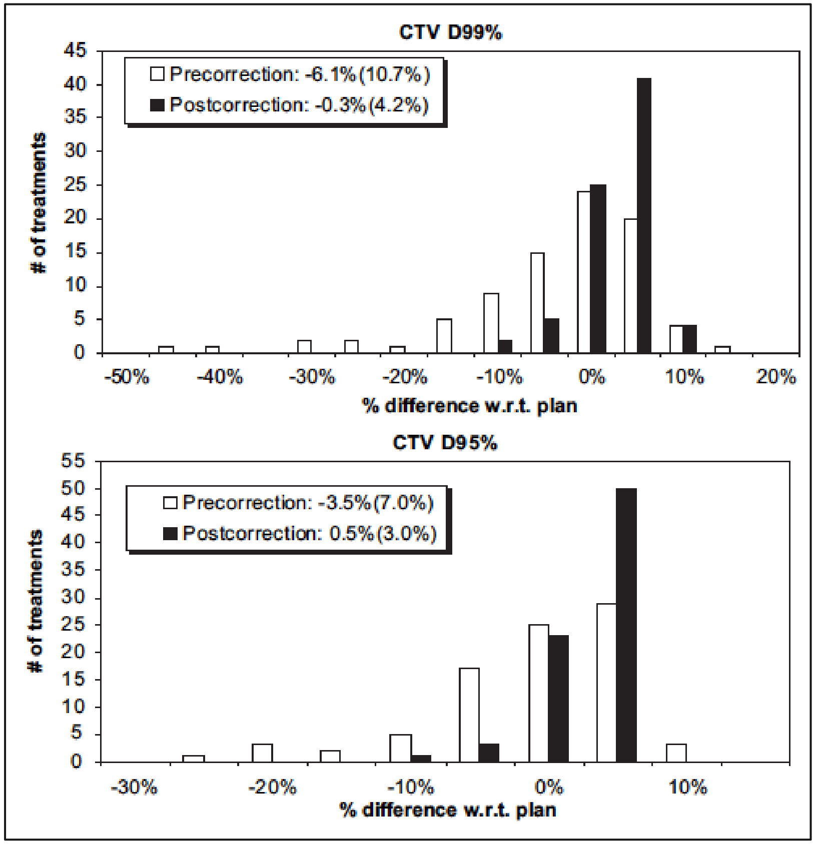
Dosimetric effects in "Photon" SBRT

Galerani IJROBP 2010



Dosimetric effects in lung SBRT

- ITV concept
- 5mm PTV margin

No IGRT

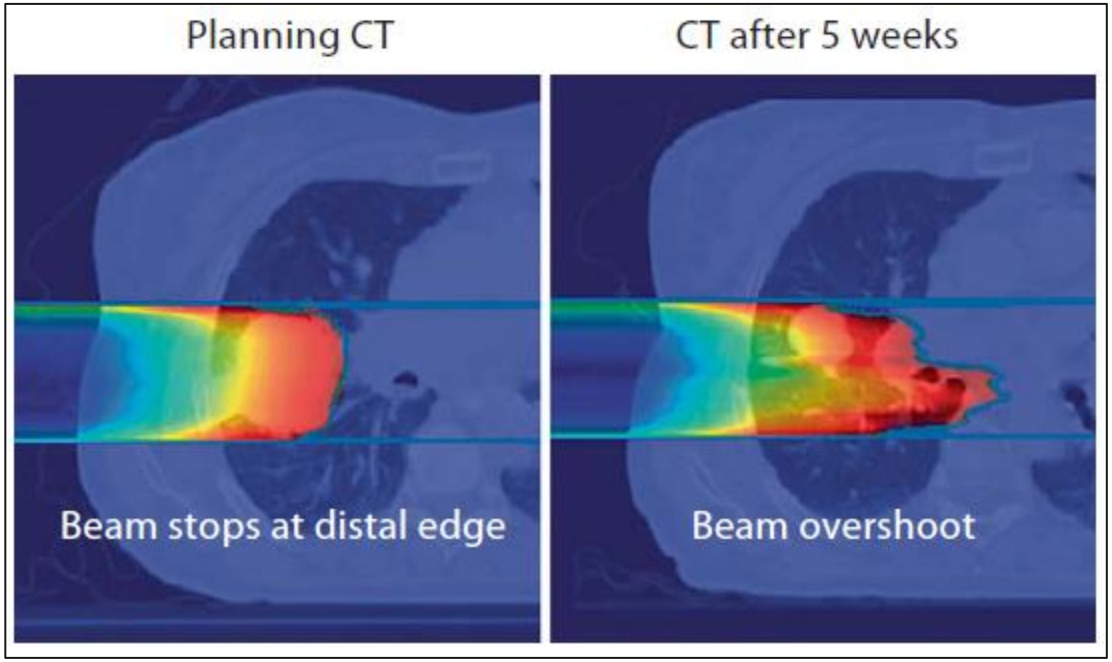
- Minimum CTV dose
  - 6% on average
  - -50% on maximum

IGRT

- No relevant dose loss

Dosimetric effects in "Proton" SBRT

Meyer 2011



Increased complexity in Proton SBRT to compensate
- Tumor volume / shape changes
- Breathing motion

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Technologies for in-room IGRT

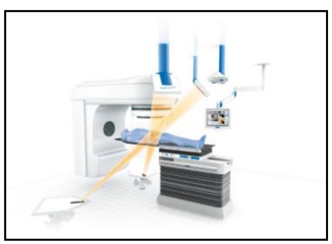
3D volume imaging

In-room CT

Cone-beam CT

MV CT

2D kV stereoscopic imaging



2D & 3D imaging

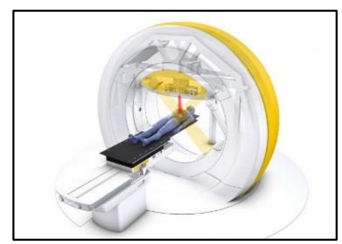
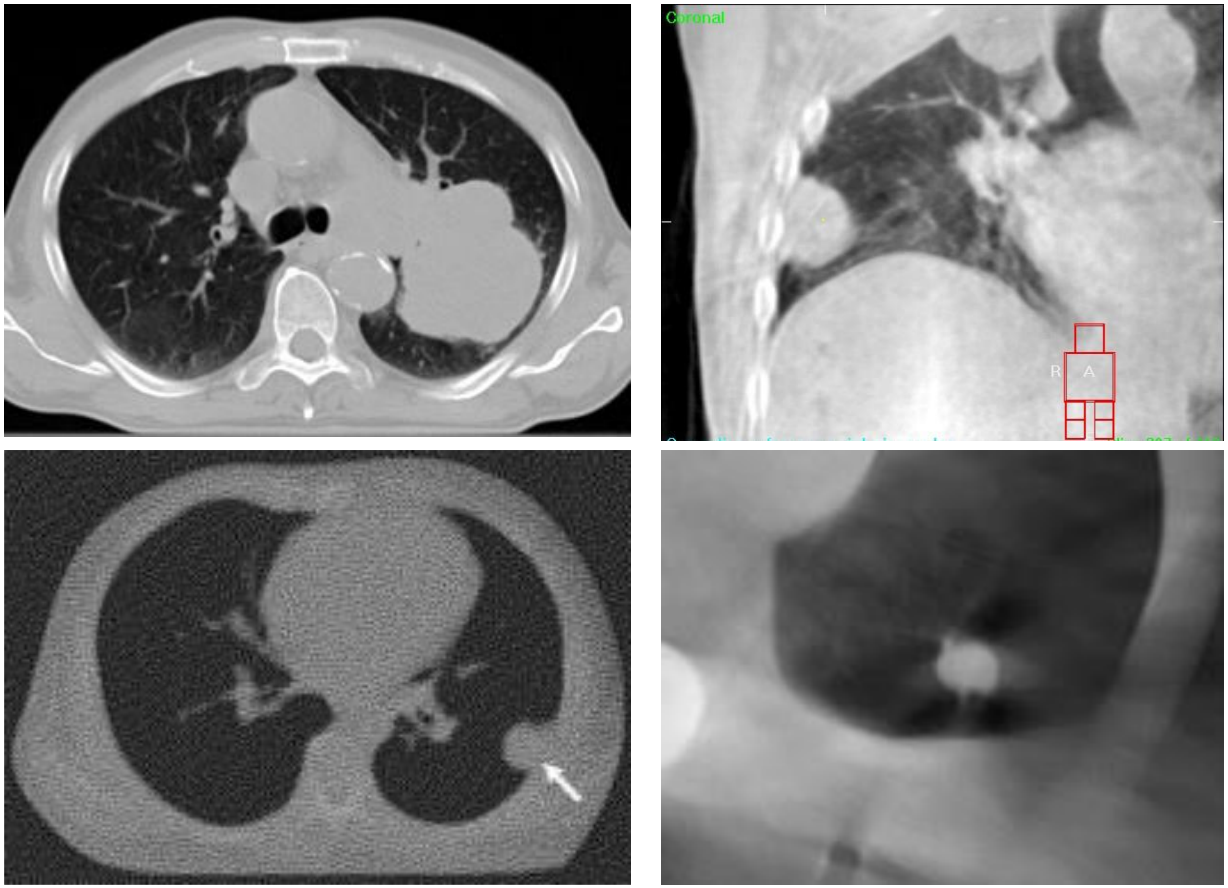


Image quality of in-room CT imaging

Helical

kV CBCT



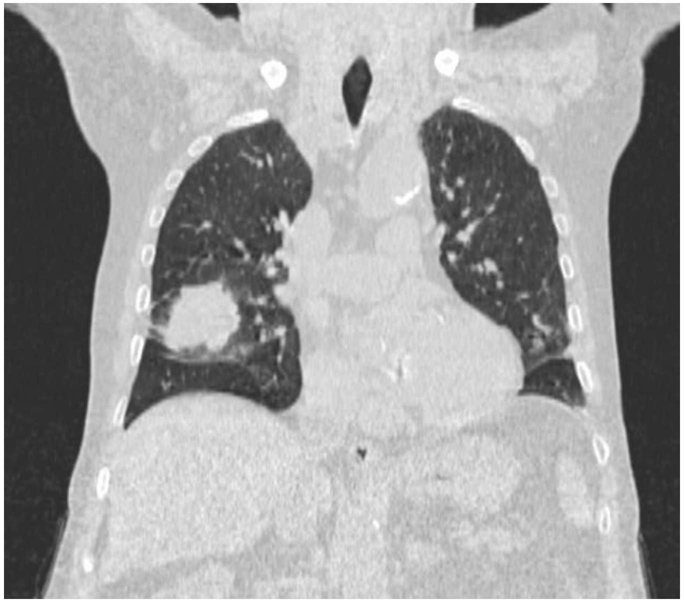
MV CT

kV/MV CBCT

- Intra-pulmonary targets clearly visible in all imaging modalities
- IQ for mediastinum suitable only in kV helical CT

Integration of 4th dimension into IGRT

Planning



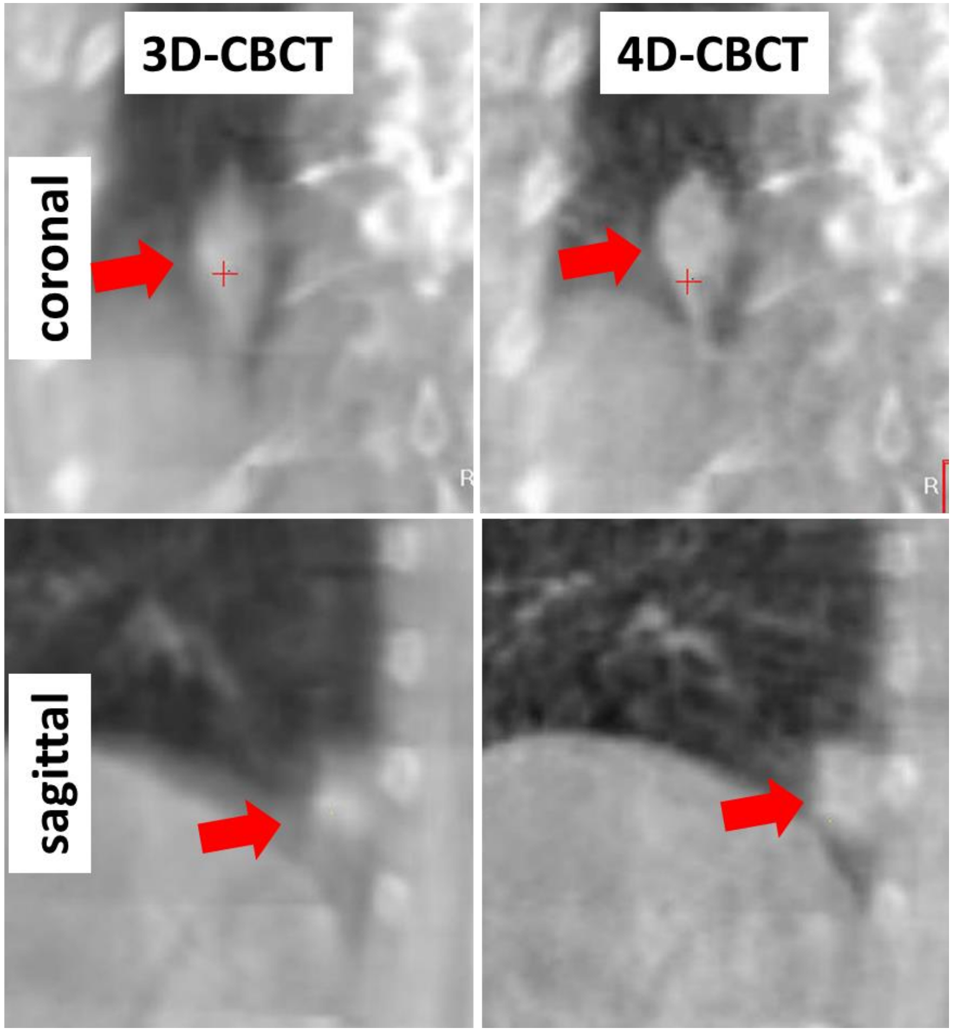
4D IGRT

Treatment

Respiration correlated CT

Respiration correlated CBCT

Where 4D CB-CT improves accuracy



Mobile tumors located immediatly superior the diaphragm

2D IGRT – implanted markers

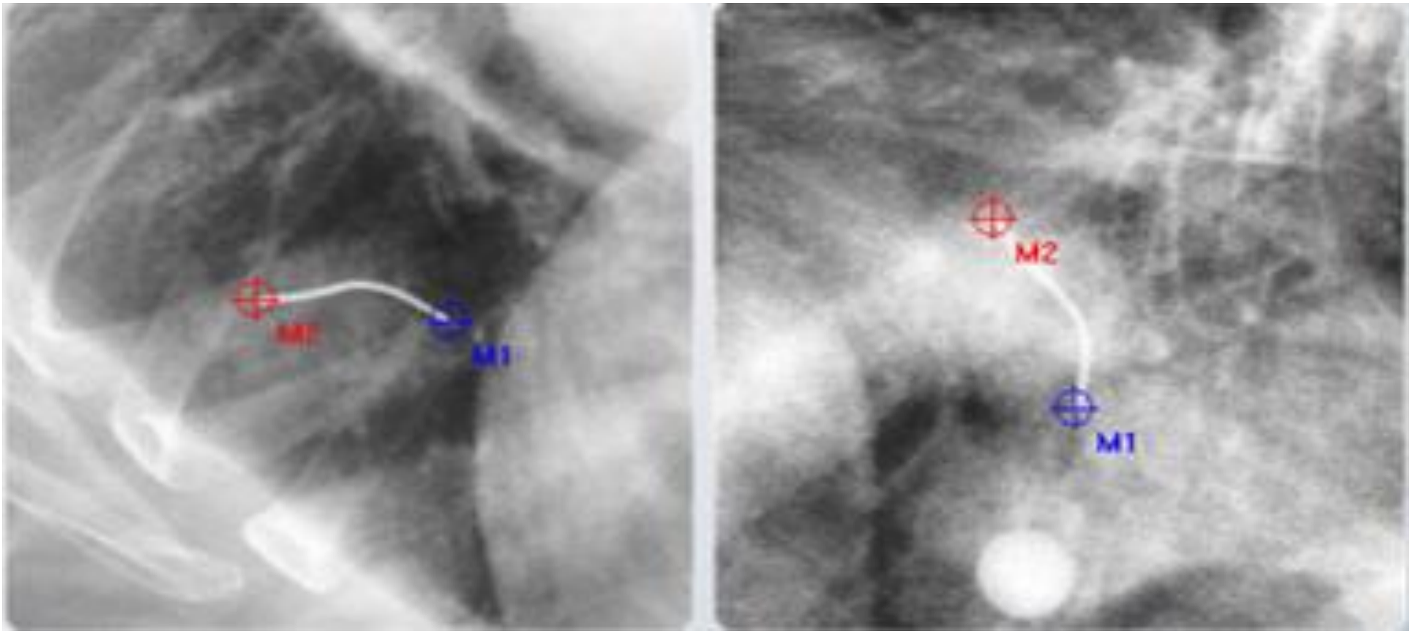


Image from
www.Brainlab.com

- Markers required: poor soft-tissue contrast
- Surrogate, not the target itself

2D IGRT – implanted markers

	Type of markers	Implantation method	Success rate
de May 2005	Coils	Transthoracic	100%
Kupelian 2007	Coils	Transthoracic Transbronchial	100% 100%
Bgagat 2010	Seeds	Transthoracic	81%
Hong 2011	Coils Seeds	Transthoracic	99.3% 85.3%

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2D IGRT – implanted markers

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Hong 2011	Coils **Seeds**	Transthoracic	99.3% **85.3%**

- Seeds: high marker migration rate

2D IGRT – implanted markers

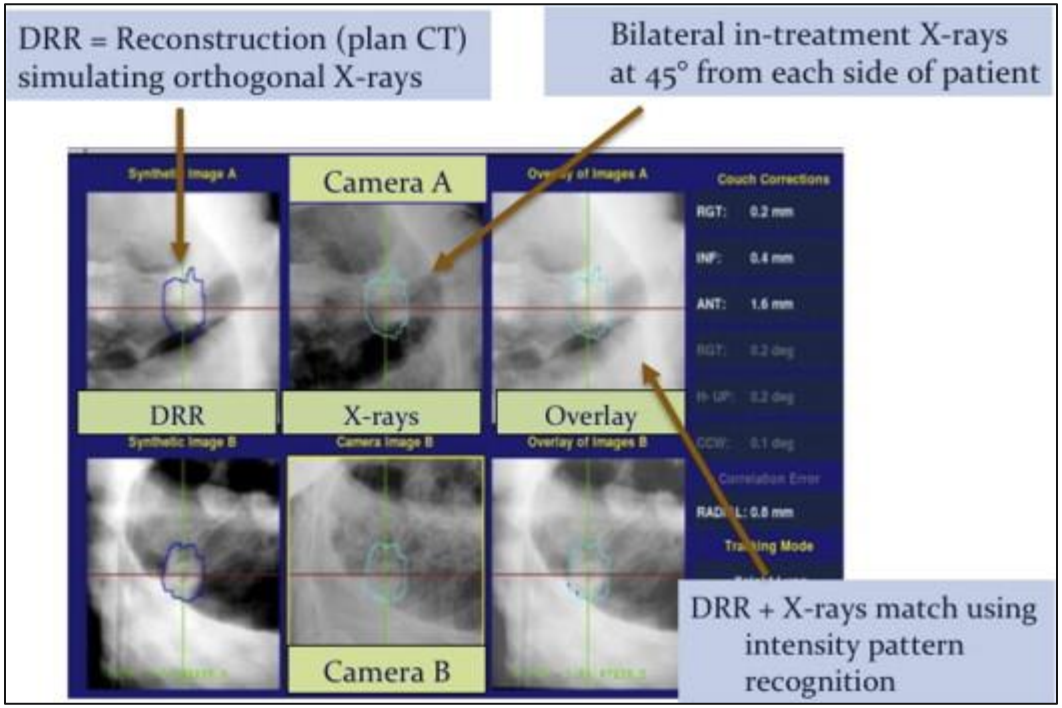
	Type of markers	Implantation method	Success rate	Pneumothorax	Chest tube
de May 2005	Coils	**Transthoracic**	100%		**1/10**
Kupelian 2007	Coils	**Transthoracic** Transbronchial	100% 100%	**8/15** 0/8	**6/15** 0/8
Bgagat 2010	Seeds	**Transthoracic**	81%	**18/28**	**6/28**
Hong 2011	Coils Seeds	**Transthoracic**	99.3% 85.3%	**23%** **54%**	**3%** **29%**

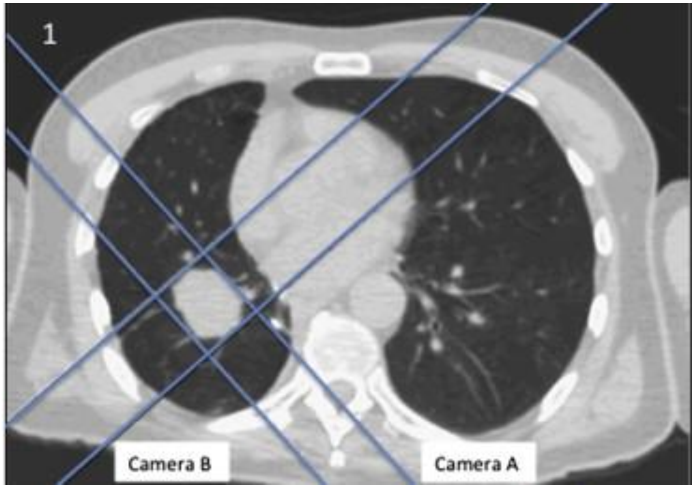
- Seeds: high marker migration rate
- Transthoracic approach: high rates of pneumothorax

➢ Transbronchial implantation of Coils

2D kV IGRT – markerless tracking

Bahig IJROBP 2013





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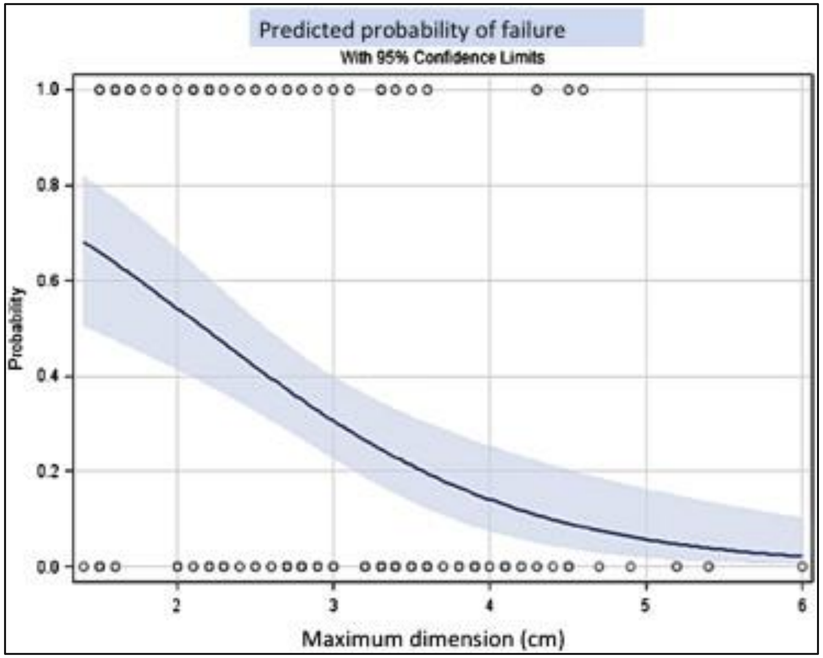
2D kV IGRT – markerless tracking

Target diameter

Bahig IJROBP 2013



"We recommend considering tumor tracking in all patients with tumors >3.5 cm based on >80% chance of adequate tumor visualization in this subgroup"

- Strategy in remaining 20% ?
- 95% success rate requires tumor diameter >5cm

Predictors for successfull markerless tracking

- Tumor size
- Volume
- Density

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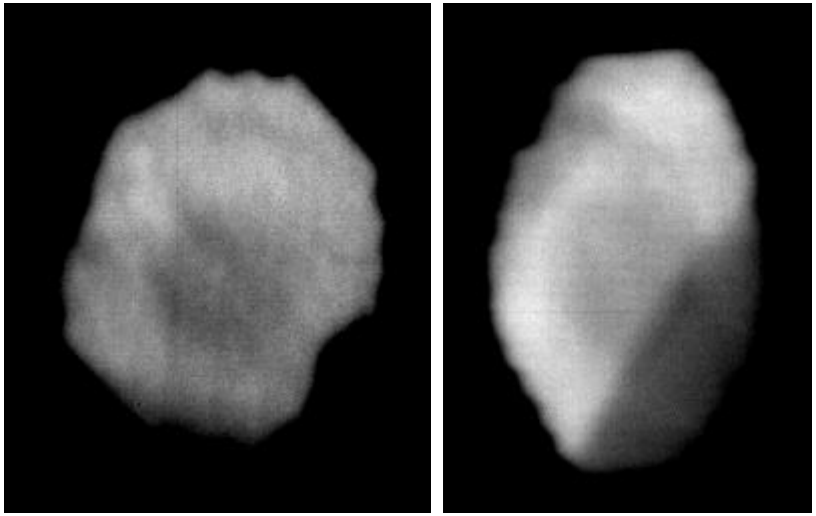
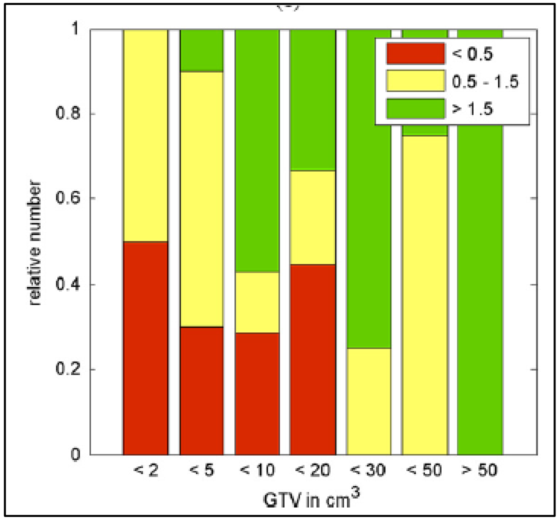
2D MV IGRT – markerless tracking

EPID for target monitoring during SBRT

Richter IJROBP 2010



Volume effect



Pros:

- Passive monitoring w/o additional irradiation dose or additional hardware

Cons:

- Successful in < 50% of SBRT cases
- Requires 3D-CRT

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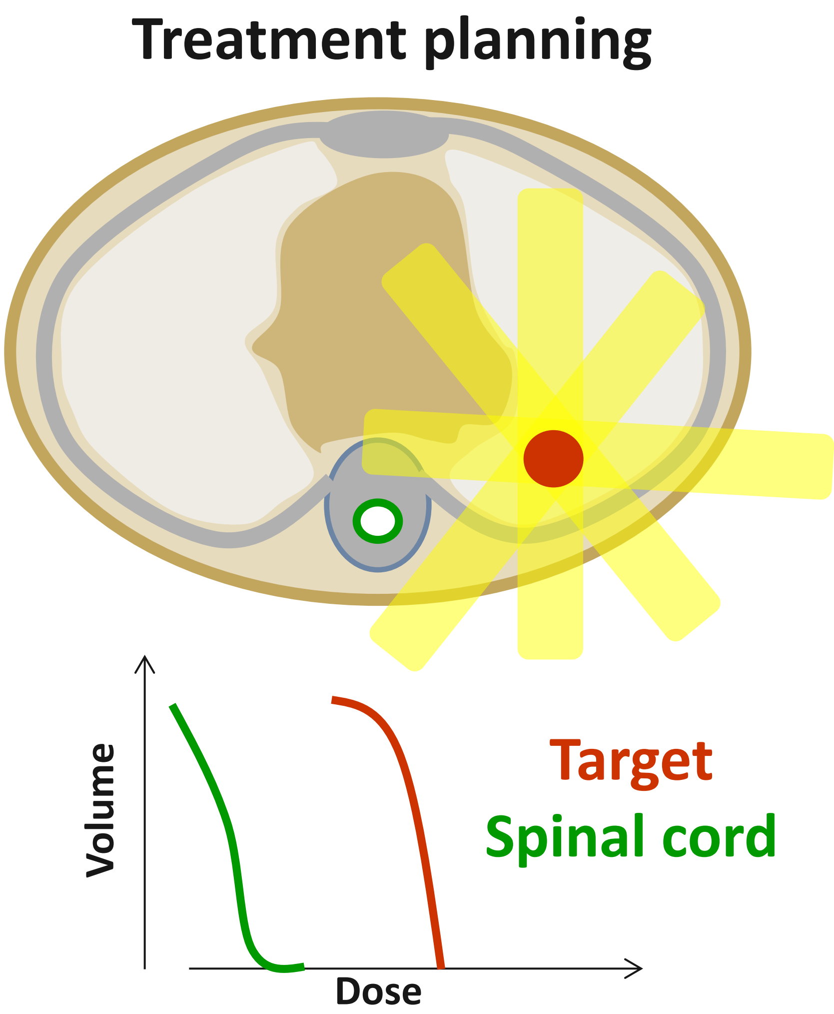
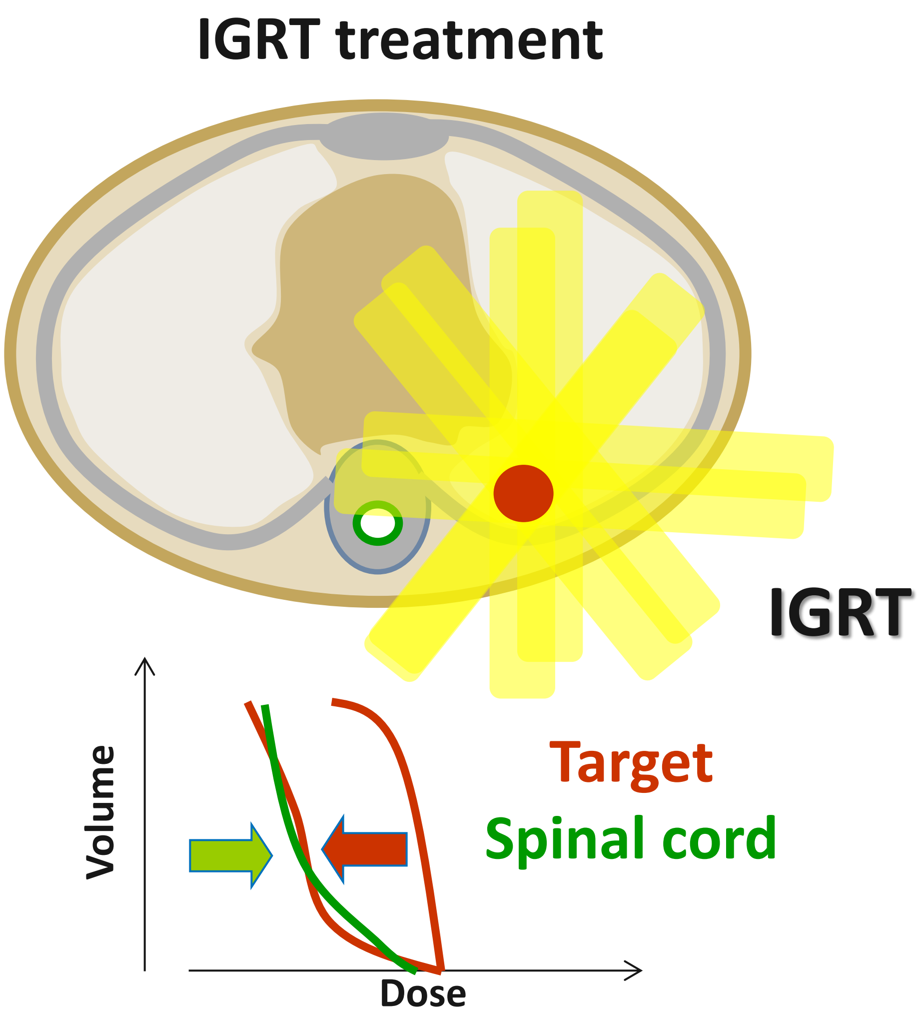
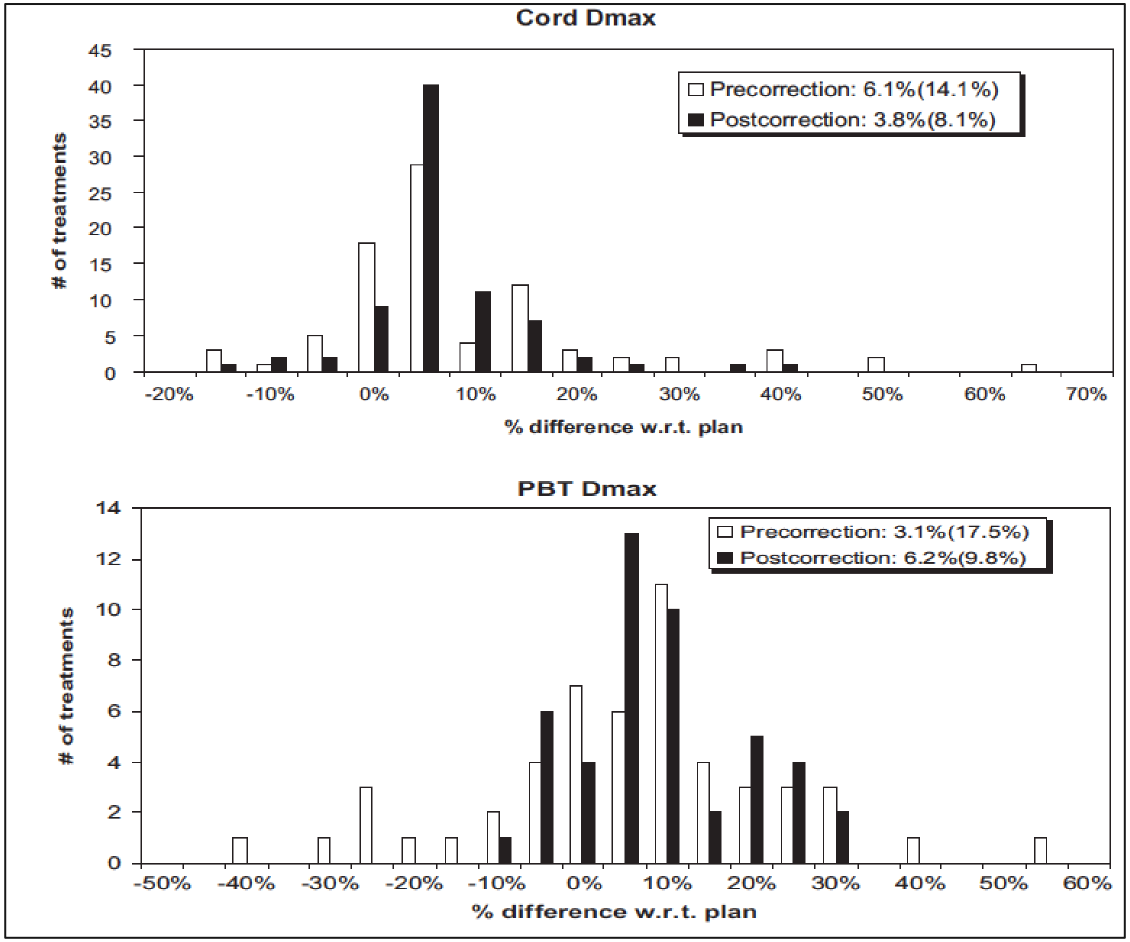
Non-rigid uncertainties in NSCLC





Dosimetric effects of base line shifts:
ORGANS AT RISK

Galerani IJROBP 2010



Dose variability

1 SD	No-IGRT
Cord	14.1%
Esophagus	6.5%
PBT	17.5%
Aorta	19.5%

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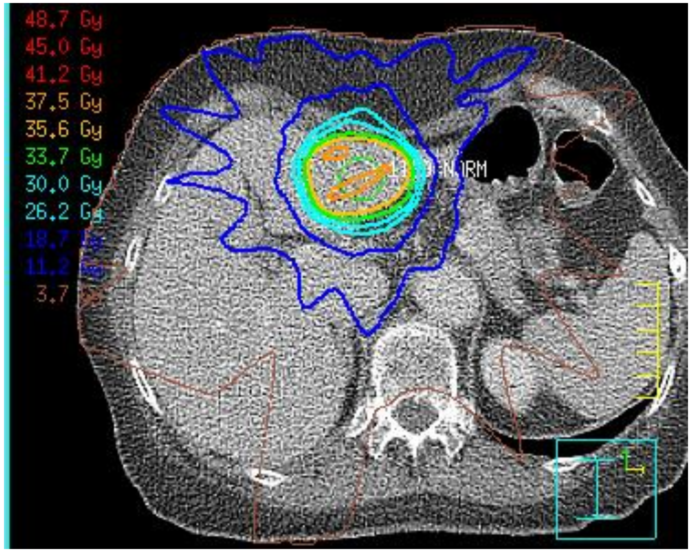
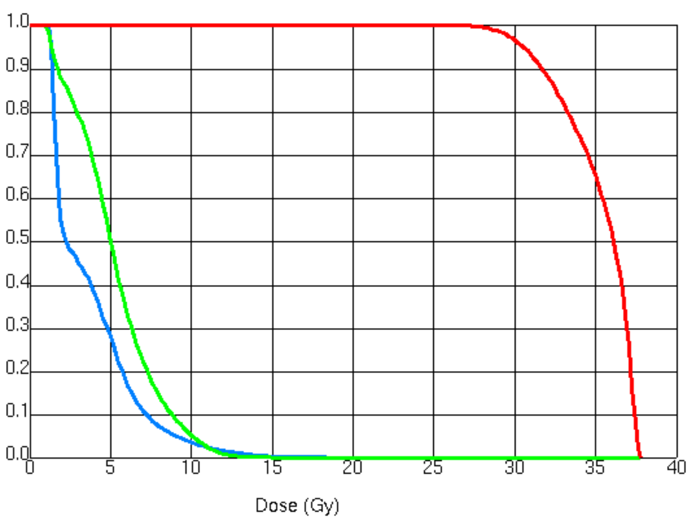
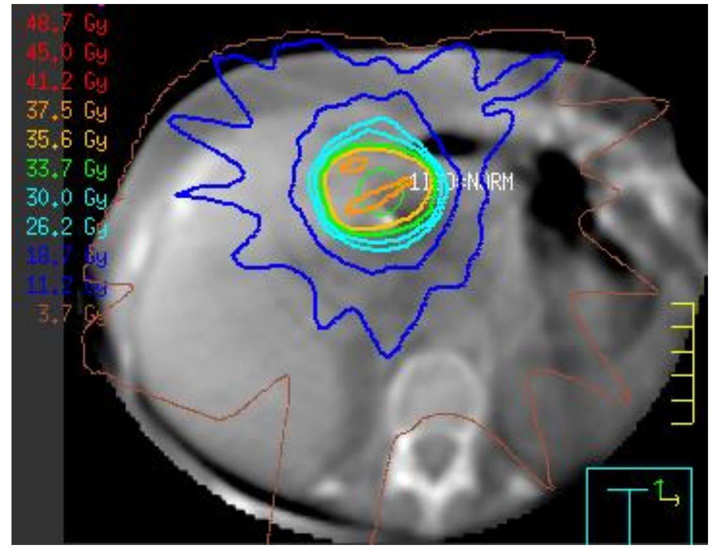
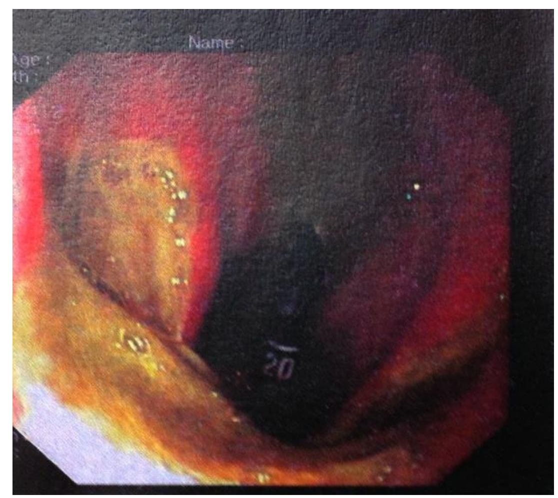
Clinical relevance of differential motion









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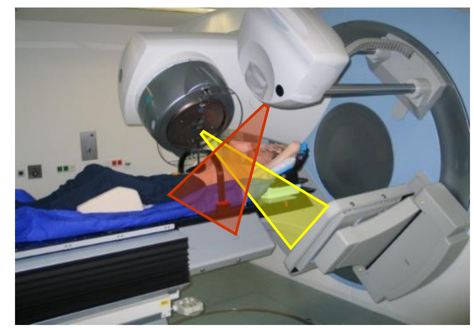
(Missing) Evidence in lung SBRT

Patterns of care and outcome in Germany and Austria:

n=582

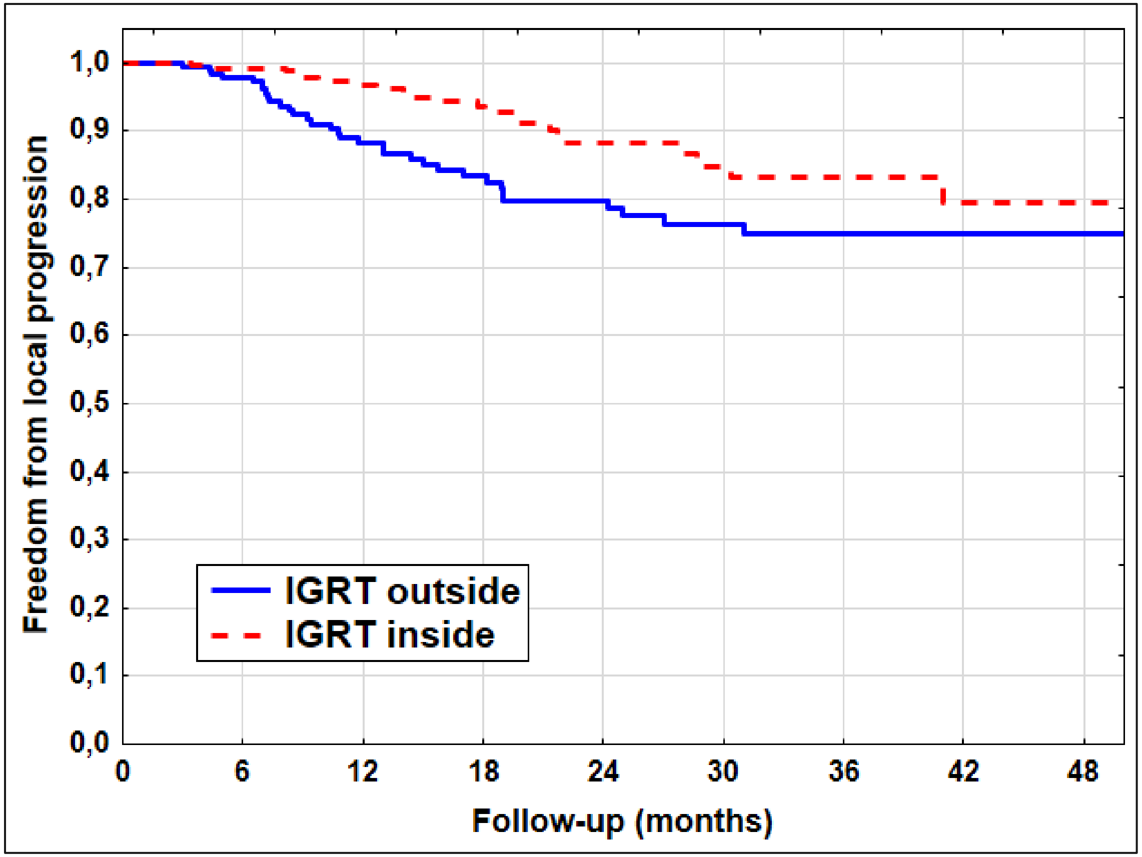


IGRT | SBF | IGRT outside | IGRT inside

1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

(Missing) Evidence in lung SBRT

Patterns of care and outcome in Germany and Austria



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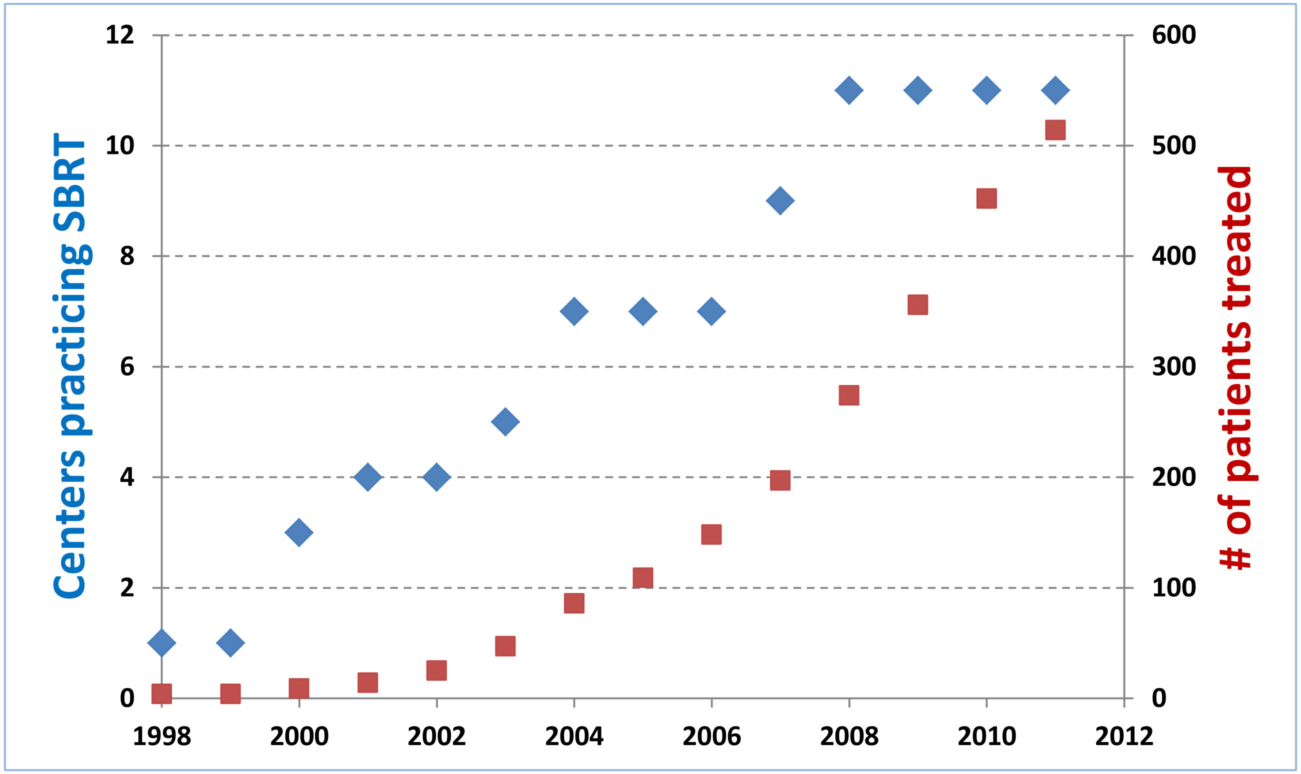
(Missing) Evidence in lung SBRT



Rapid adoption of SBRT at least partially result of IGRT:
- Confidence in high-dose per fraction radiotherapy
- Improved and streamlined work-flow

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CONCLUSIONS

- Image guidance broadly available on all modern linacs
- Major **benefit** of volumetric IGRT: 3D and 4D visualization of target and OARs
- Major **disadvantage** of volumetric IGRT: slow and limited usability for intra-fraction monitoring
- Both 2D and 3D imaging suitable for lung SBRT
- Integration of 4D breathing motion is essential

➢ Image guidance a mandatory QA procedure in SBRT