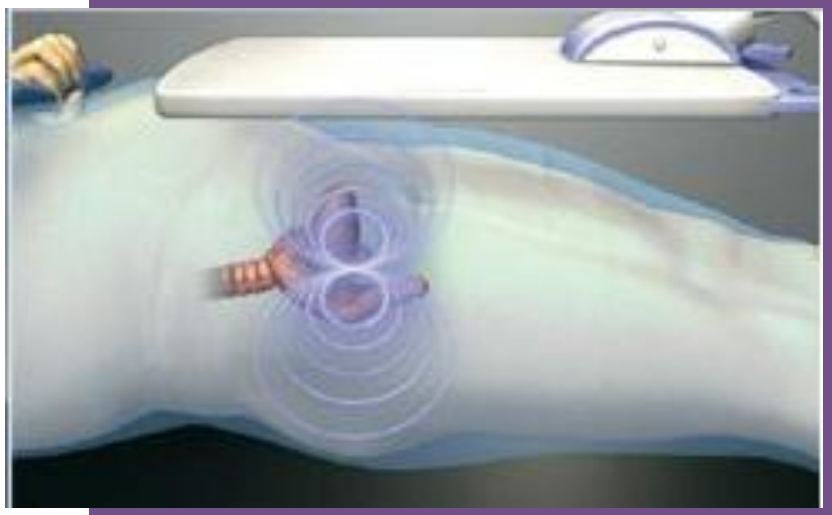
Electromagnetic Tracking in Cancer Radiotherapy



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Disclosures

- **Patents:** Awarded and pending
- **Licenses:** Nano-X, Respiratory Innovations, Standard Imaging, Varian
- **Grants:** Philips (Co-Investigator), Varian (Co-I)
- **Ownership:** Cancer Research Innovations, Nano-X, Respiratory Innovations

http://sydney.edu.au/medicine/radiation-physics/about-us/disclosures.php

Physics

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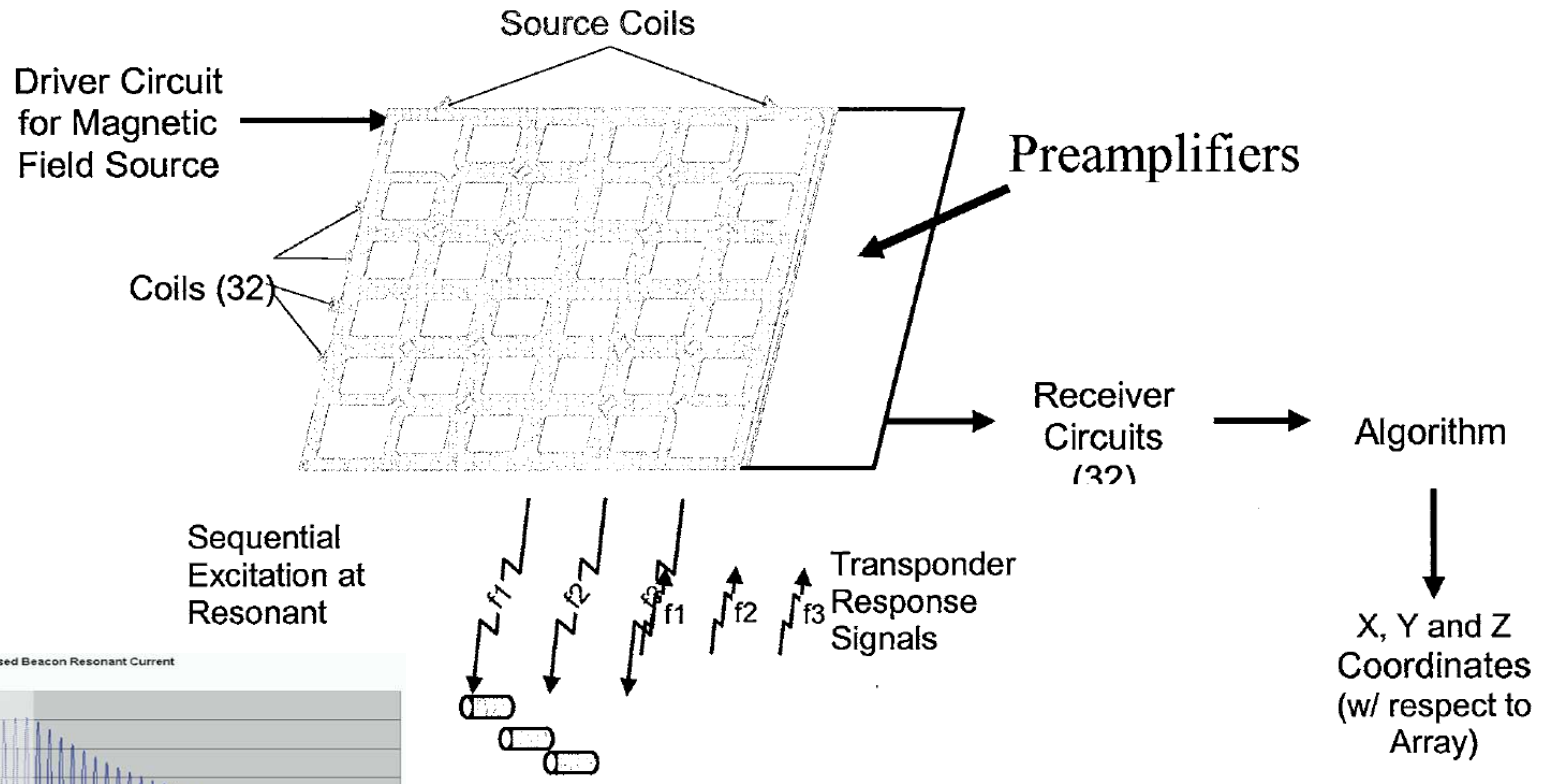
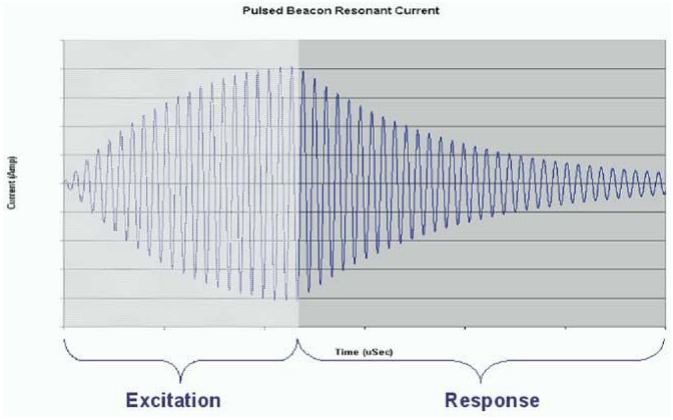
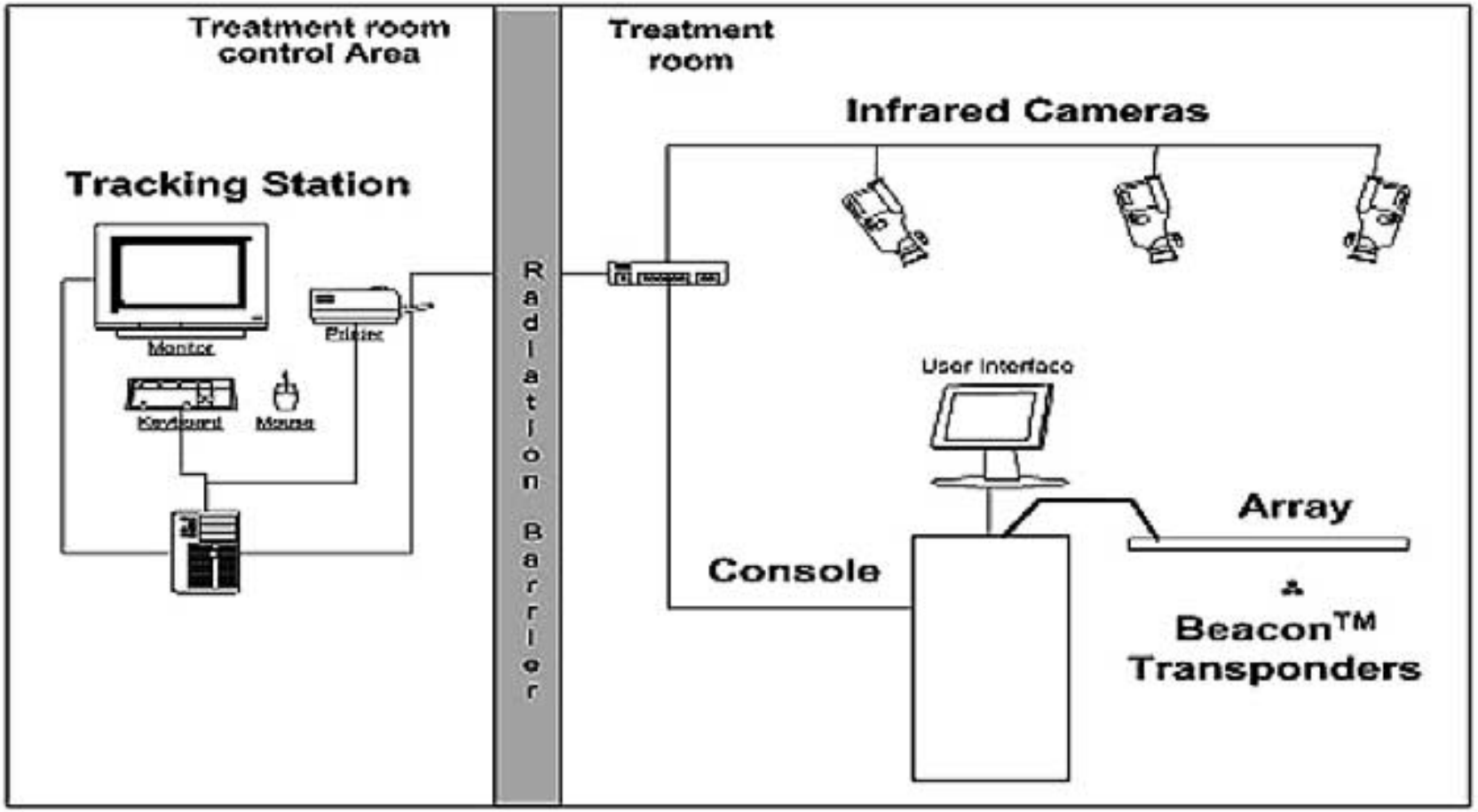
Physics





Balter IJROBP 2005



Balter IJROBP 2005

SAM Question

The location signal from electromagnetic positioning systems is determined from:

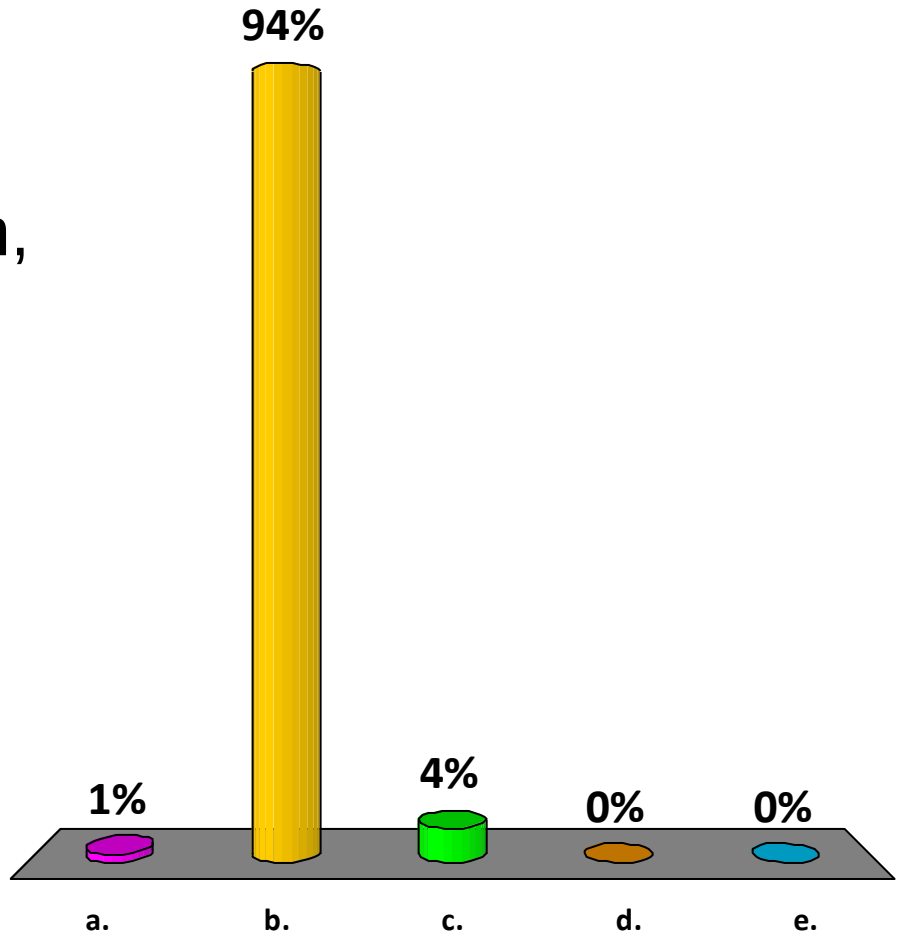
a. Feldkamp-Davis-Kress reconstruction

b. Electromagnetic excitation, response, localization

c. Electromagnetic transmission tomography

d. X-ray transmission tomography

e. Gravitation wave interferometry



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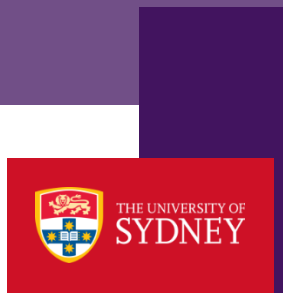
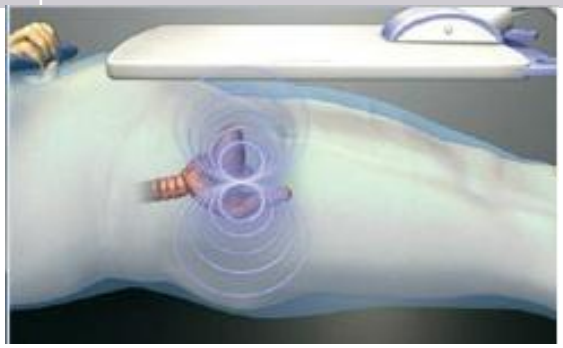
Balter, James M., J. Nelson Wright, Laurence J. Newell, Barry Friemel, Steven Dimmer, Yuki Cheng, John Wong, Edward Vertatschitsch, and Timothy P. Mate. "Accuracy of a wireless localization system for radiotherapy." *International Journal of Radiation Oncology* Biology* Physics* 61, no. 3 (2005): 933-937.

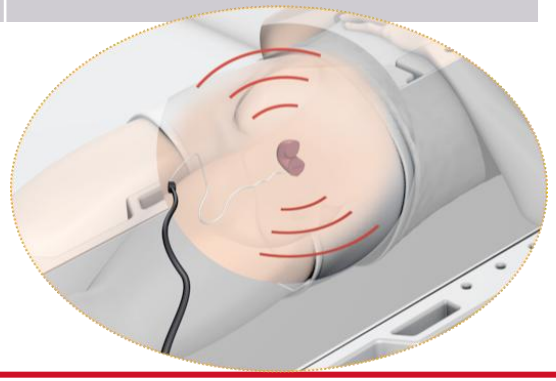
Technology



Technology

Technology	Calypso	RayPilot
Company	Varian	MicroPos
Array	Above patient	In couch
Wired	No (Permanent)	Yes (removable)
Beacons	3	1
Clinical since	~2005	2010
Clinical sites	Prostate, lung, pancreas, liver, breast	Prostate, breast
Integrated with gating/tracking?	Yes	Yes





Commissioning and Quality Assurance

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Commissioning and Quality Assurance

Commissioning of the localization system should include:

1. Integration of peripheral equipment
2. Spatial reproducibility and drift
3. Static localization accuracy
4. Dynamic localization accuracy
5. Vendor recommended assessment
6. Documentation and SOP

Quality assurance for nonradiographic radiotherapy localization and positioning systems: Report of Task Group 147

+ Santanam Med Phys 2009

SAM Question

Commissioning of the localization system should include

8%
a. X-ray output constancy, Integration of peripheral equipment; Spatial reproducibility and drift

5%
b. X-ray output constancy, Photon beam profile constancy; Spatial reproducibility and drift

6%
c. Photon beam profile constancy; Spatial reproducibility and drift; Spatial localization accuracy

80%
d. Integration of peripheral equipment; Spatial reproducibility and drift; Spatial localization accuracy

2%
e. X-ray output constancy, Spatial reproducibility and drift; Spatial localization accuracy

SAM Question

- Commissioning of the localization system should include:

(a) X-ray output constancy, Integration of peripheral equipment; Spatial reproducibility and drift

(b) X-ray output constancy, Photon beam profile constancy; Spatial reproducibility and drift

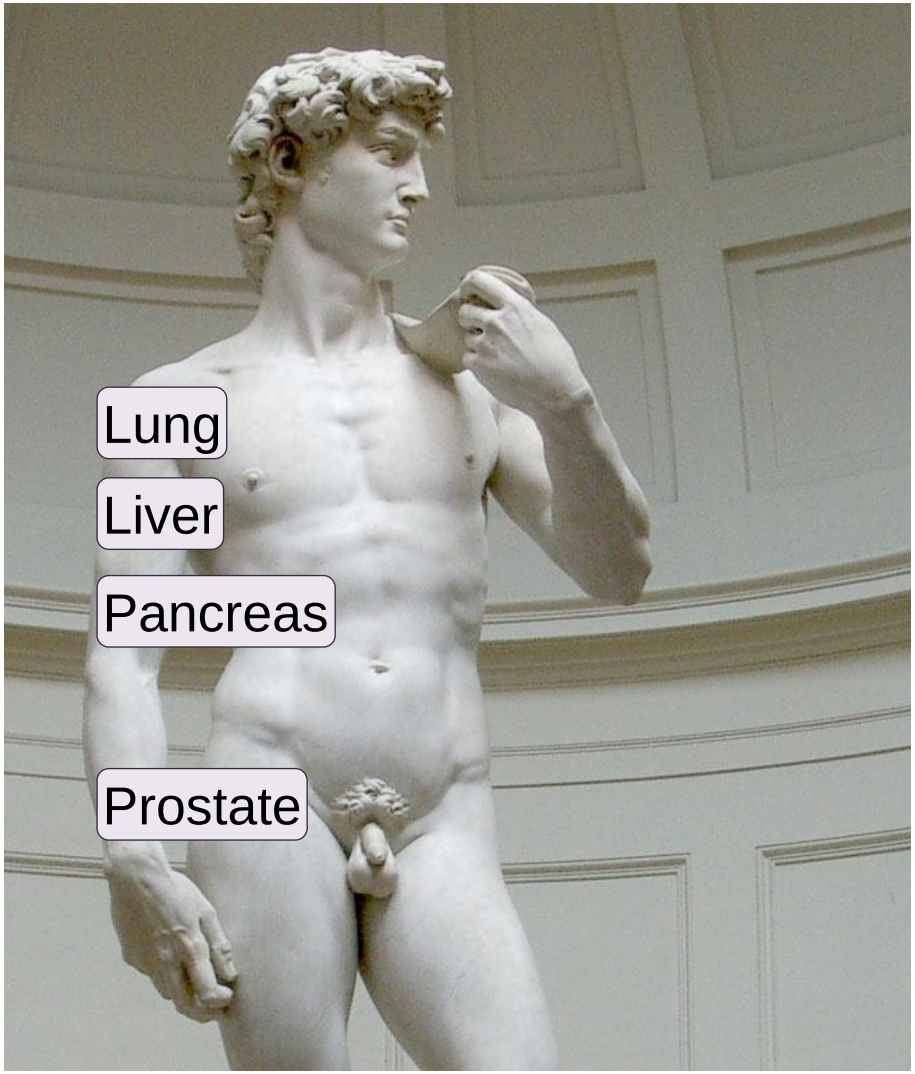
(c) Photon beam profile constancy; Spatial reproducibility and drift; Spatial localization accuracy

(d) Integration of peripheral equipment; Spatial reproducibility and drift; Spatial localization accuracy

Willoughby, Twyla, Joerg Lehmann, José A. Bencomo, Shirish K. Jani, Lakshmi Santanam, Anil Sethi, Timothy D. Solberg, Wolfgang A. Tomé, and Timothy J. Waldron. "Quality assurance for nonradiographic radiotherapy localization and positioning systems: Report of Task Group 147." *Medical physics* 39, no. 4 (2012): 1728-1747.

Clinical results

Clinical applications



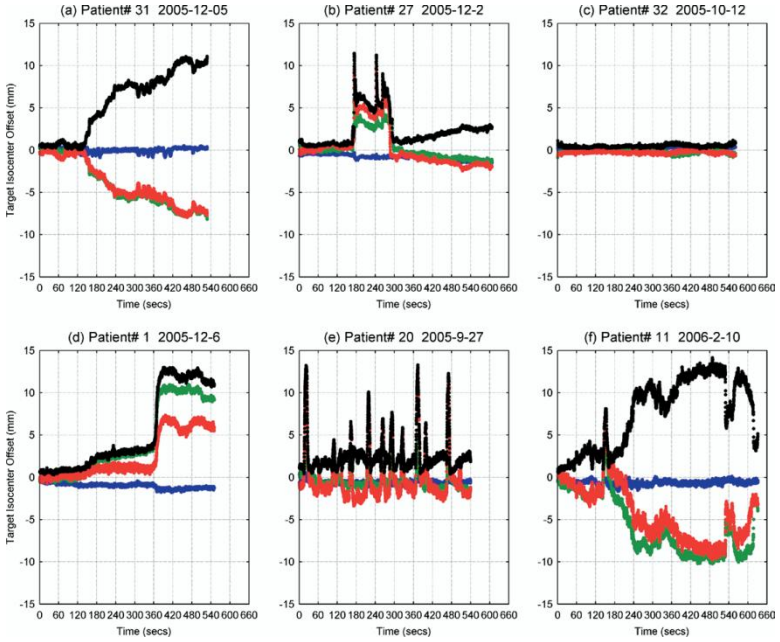
Prostate clinical results

CLINICAL INVESTIGATION **Prostate**

MULTI-INSTITUTIONAL CLINICAL EXPERIENCE WITH THE CALYPSO SYSTEM IN LOCALIZATION AND CONTINUOUS, REAL-TIME MONITORING OF THE PROSTATE GLAND DURING EXTERNAL RADIOTHERAPY

PATRICK KUPELIAN, M.D.,* TWYLA WILLOUGHBY, M.SC.,* ARUL MAHADEVAN, M.D.,† TOUFIK DJEMIL, PH.D.,† GEOFFREY WEINSTEIN, M.D.,‡ SHIRISH JANI, PH.D.,‡ CHARLES ENKE, M.D.,§ TIMOTHY SOLBERG, PH.D.,§ NICHOLAS FLORES, M.D.,¶ DAVID LIU, PH.D.,¶ DAVID BEYER, M.D.,¶ AND LISA LEVINE, PH.D.‖

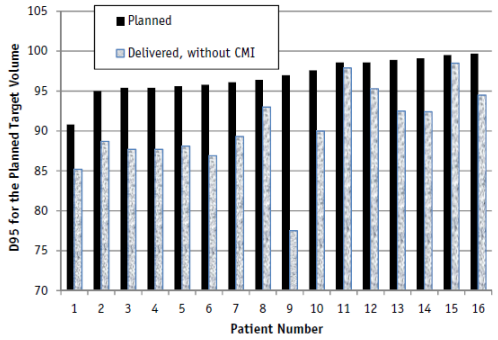
- 41 patients in 5 centres
- 3 EM transponders implanted
- “Clinically efficient and objective localization method”
- 1.9mm comparison with X-ray



Prostate gating clinical results

Conventional Fx

- 64 patients, 150 comparator group
- 3mm margins with gating
- Reduced bowel morbidity
- Less QoL reduction with gating



Sandler Urology 2010

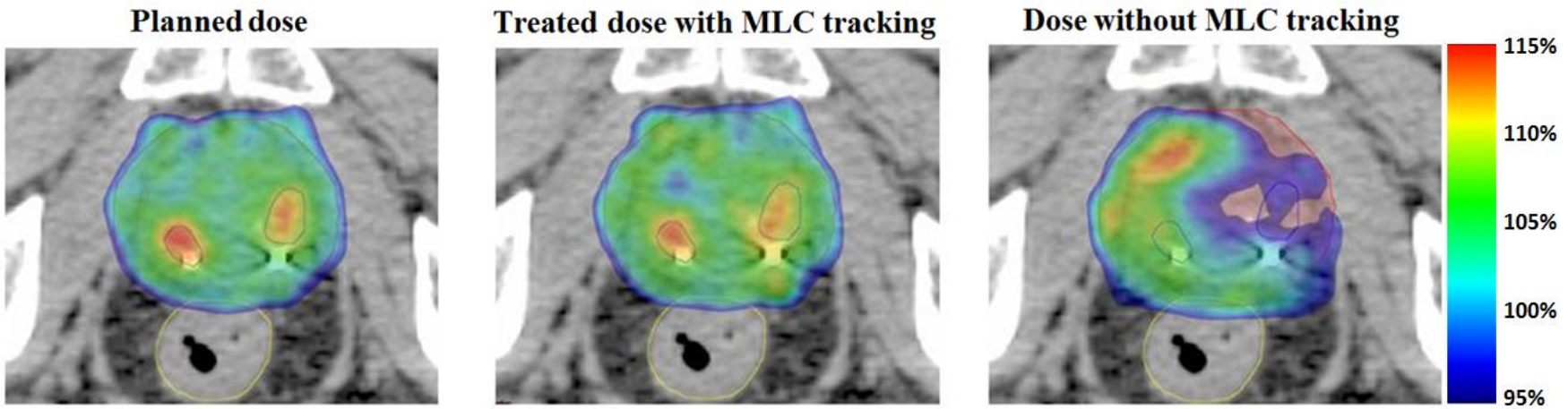
SBRT

- 89 patients
- 5/3mm margins with 2mm gating
- Estimation of delivered dose
- PTV coverage improved
- Without gating 10% of patients PTV D_{95} < 90%

Lovelock IJROBP 2015

Prostate tracking clinical results

- 28 patients, > 900 fractions
- Conventional & SBRT
- MLC tracking improves the consistency between the planned and delivered doses



Colvill IJROBP 2015

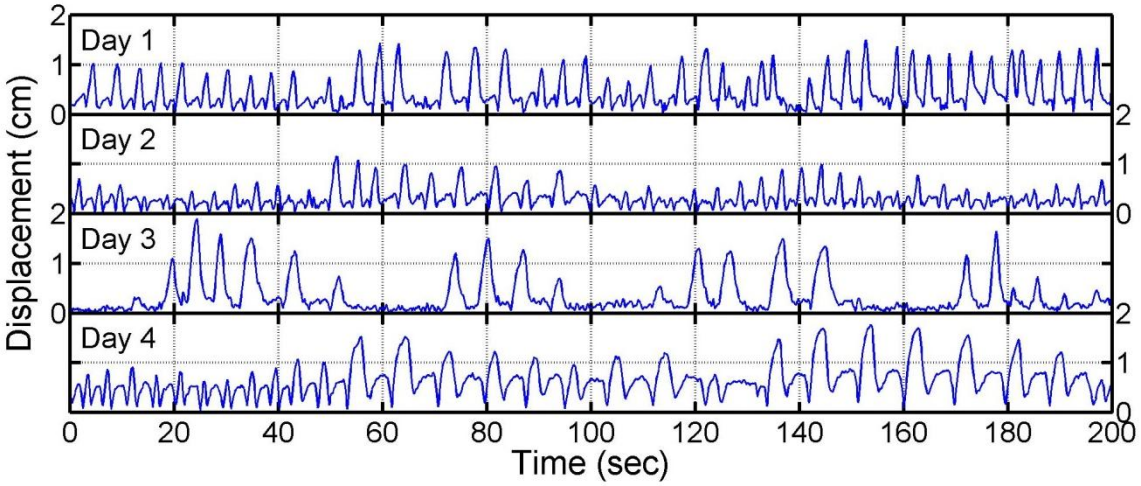
Calypso lung implantation study

- 50 patients bronchoscopic implantation of 3 transponders in/near tumor
- Anchored beacon technology
- 2 patients pneumothorax; resolved overnight
- 2 patients had transponder migration
- “Real-time localization and tracking of lung tumors is feasible and provides motion information that can be used for RT planning and delivery”

Tamm Eur. Resp. Soc 2013 (abstract)

Lung clinical results

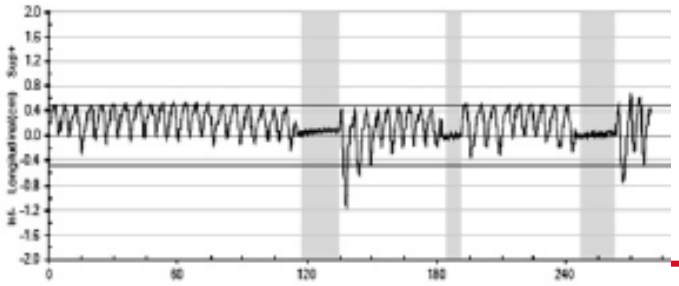
- 7 patients bronchoscopically implanted
- ≥1 transponder implanted in all patients; 13/14 stable
- “transponder implantation is achievable” “lung tumor motion exhibits large variations from fraction to fraction”



Shah IJROBP 2013

Pancreas clinical results

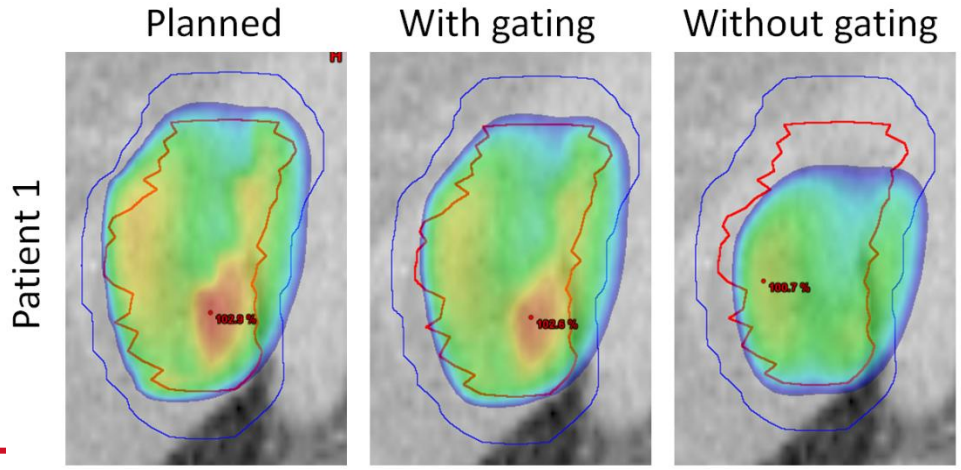
- 5 patients peri-tumorally implanted during laparoscopy
- Implantation well tolerated; one beacon expulsed
- Tracking successful; delivered with breath hold
- “EM transponder implantation appears to be safe and effective for monitoring inter- and intrafractional motion”

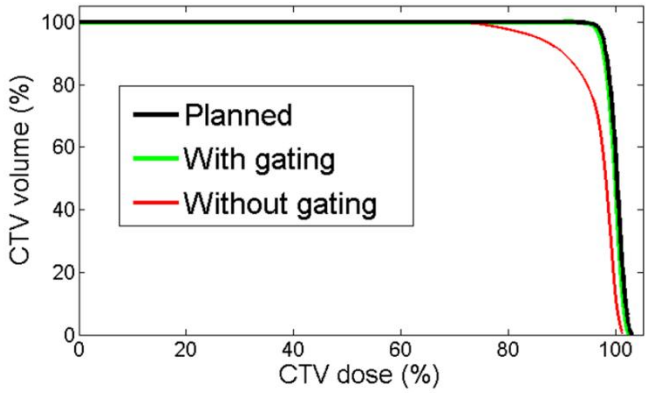


Shinohara IJROBP 2011

Liver clinical results

- 2 patients, 3 beacons percutaneously implanted near tumor under ultrasound guidance
- Implantation well tolerated; one beacon expulsed
- Treated with exhale gating >50% duty cycle
- 1/2 patients largely improved CTV coverage





Poulsen, Acta Oncologica, 2015

Limitations

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Limitations

- Cost – actual, space and time
- Need for implantation
- Marker size
- MRI artifacts
- X-ray interference (2-way)
- Limited operating range

Summary

Summary

- EM tracking has provided us with rich knowledge of the complexity and magnitude of target motion
- Real-time EM motion has driven developments in dose accumulation, gating and tracking to improve radiotherapy
- Future directions include miniaturization, further integration and extensions to other body sites

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Future directions

Future directions

- More body sites
- Smaller markers
- Panel in couch
- Rotation/deformation
- Real-time dose reconstruction/real-time replanning