In-Room Patient/Beam Adaptation - Future Roadmap

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Disclosures

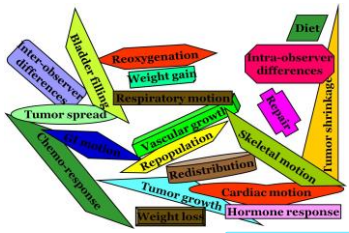
sydney.edu.au/medicine/image-x/about/disclosures

- **Patents:** Awarded patents and pending applications
- **Licenses:** Leo, Opus, Standard Imaging, Varian
- **Industry grants:** Siemens (PI), Varian (CI)
- **New entities:** Cancer Research Innovations (Partner), Leo (Founder), Opus (Founder), SeeTreat (Founder)

Outline

- **Introduction**
- Clinical benefits of real-time targeting
- Marker-based real-time targeting
- Markerless real-time targeting
- Clinical trajectory of real-time targeting
- Future outlook for real-time targeting

Why is better technology needed?

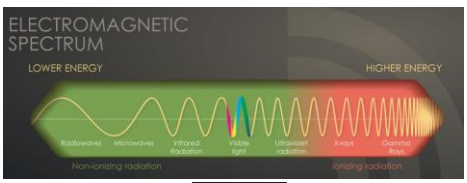


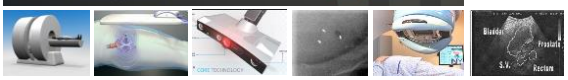
ASTRO, 4D RT Panel, 2003

Ideal Technology for Targeting Internal Anatomy in Real-Time during Radiotherapy

- Volumetric
- High spatial resolution
- High temporal resolution
- High fidelity
- Can transfer planning contour & dose information to & from
- Low latency
- High contrast
- No interference with delivery system
- Non-invasive
- No imaging dose
- Can optimize and compute dose on
- Reduces treatment time
- Cheap with low operational costs
- …

Technologies for Real-Time Internal Anatomy Targeting





Targeting Internal Anatomy in Real-Time during Radiotherapy
The Pioneers in 1998

Real-time tumour-tracking radiotherapy THE LANCET • Vol 353 • April 17, 1999
Hiroki Shirato, Shinichi Shimizu, Tadashi Shimizu, Takeshi Nishioka, Kazuo Miyasaka

- Real-time fluoro imaging of gold markers with gating
- Markers inserted into/near the tumour in 10 patients
- No complications or local relapses within a 6 month follow-up
- *"A real-time tumour-tracking system can improve the accuracy of radiotherapy and reduce the volume of normal tissue irradiated"*
- 2014 applied technology to proton therapy

Courtesy Prof Hiroki Shirato

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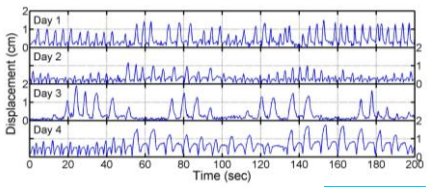
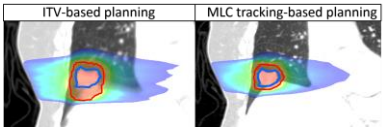
Tumor motion varies from breath to breath and day to day

› Calypso-measured lung tumor motion



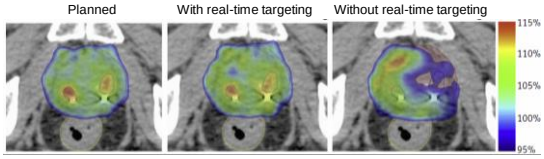
Shah IJROBP 2013

With real-time internal anatomy targeting
planned dose is less & planned dose is closer to delivered dose



Courtesy Vincent Caillet, Jeremy Booth

With real-time internal anatomy targeting
planned dose is closer to delivered dose



Colvill IJROBP 2015

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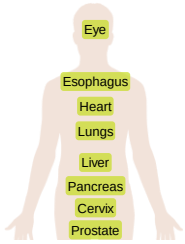
Marker-based real-time targeting



COSTS

- Marker $
- Implantation procedure $
- Procedure toxicity
- Anesthesia risk
- Increased hospital visit
- Increased time to treatment
- Radiation dose
- Mis-targeting if migration
- Variable marker-target motion

BENEFITS

- Improved tumor targeting
- Normal tissue sparing
- Reduced margins

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Markerless Tracking Clinical Implementation: CyberKnife Xsight Lung

- Tumor >15 mm diameter
- In lung periphery
- X-ray images not completely obstructed by spine
- Spine subtraction x-ray processing
- Block matching search
- Internal/external correlation model

Xsight Lung Tracking System: A Fiducial-Less Method for Respiratory Motion Tracking

Dongshan Fu, Robert Kahn, Bai Wang, Hongwu Wang, Zhiping Mu, Jong Park, Gopinath Kuduvalli, and Calvin R. Maurer, Jr.

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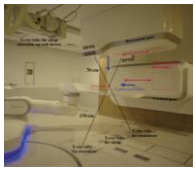
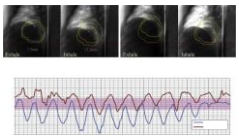
Markerless Tracking Clinical Implementation: Carbon ion therapy





- 10 lung and liver patients treated with markerless tumor tracking-driven gated carbon ion therapy

Mori *et al*. IJROBP 2016

QST National Institutes for Quantum and Radiological Science and Technology
National Institute of Radiological Sciences (NIRS)
(Radiological Science Research and Development Directorate)

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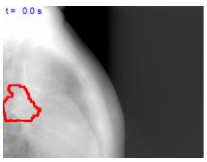
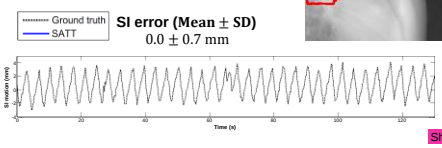
Markerless Tracking Clinical Implementation: Linac? Several R&D approaches





Shieh PMB 2017

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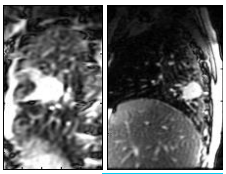
MRI-guidance



Courtesy Amit Sawant

Bjerre PMB 2013

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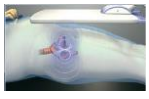
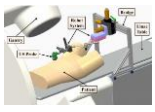
Clinical trajectory

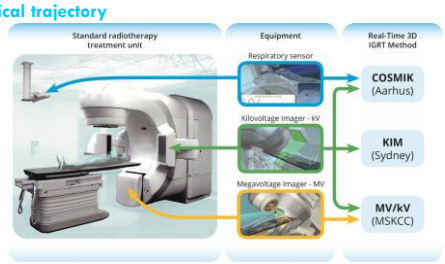




Clinical trajectory

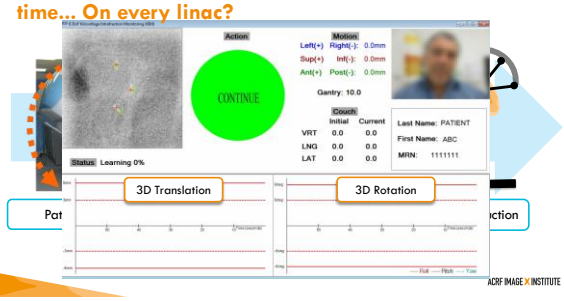
Keall *et al.* IJROBP 2018

Clinical trajectory



Keall *et al.* IJROBP 2018

Can we locate targets with sub-mm accuracy in real time… On every linac?



SPARK trial: Primary outcome – dosimetric improvement

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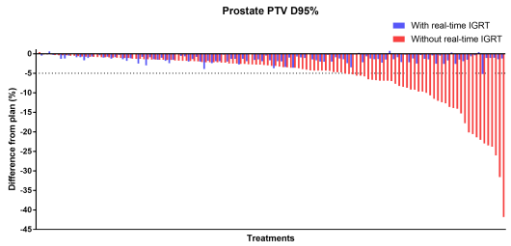
SPARK trial: Primary outcome – dosimetric improvement



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What do these two things have in common?

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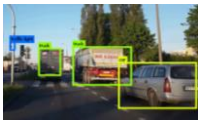
They're both being revolutionized by AI



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They're both getting safer.

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They use a fundamental cognitive process

See > Think > Act

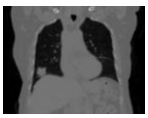
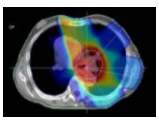
They use a fundamental cognitive process

See > Think > Act



They use a fundamental cognitive process

See > Think > Act


It's time for real-time

See > Think > Act

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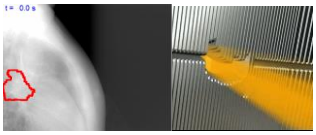
It's time for real-time

See > Think > Act



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Future Outlook

Targeting Internal Anatomy in Real-Time

1. Minority ⇨ Majority
2. Large markers ⇨ Small markers
3. Permanent markers ⇨ Temporary markers
4. Markers ⇨ No markers
5. 2D ⇨ 3D ⇨ 6DoF ⇨ Deformation
6. Outcomes ⇧ ⇨ Patient numbers ⇧

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