Targeting Internal Anatomy in Real-Time During Radiotherapy

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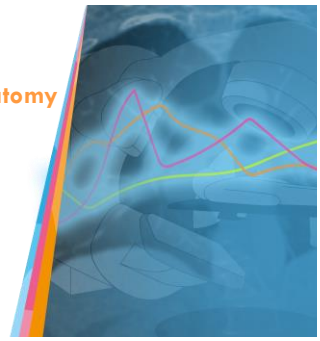


Disclosures

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

- **Patents:** 30+ 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

Definition: Targeting Internal Anatomy in Real-Time during Radiotherapy is …

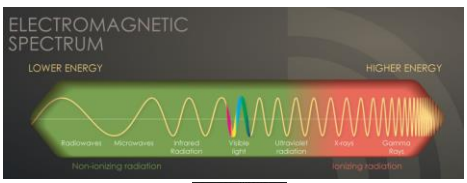
"The use of physical principles continuously during treatment to find the position of targets that cannot be observed with visual or surface imaging systems."

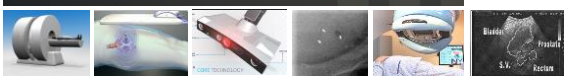
Targets are **intrinsic,** e.g. x-ray visible peripheral lung tumors, or **extrinsic,** e.g. implanted markers.

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

AAPM Task Group 199: Implanted Target surrogates for radiation treatment verification

Charge

Review applications of target surrogates in radiation therapy

Address patient complication, marker migration, deformation, and radiographic properties of markers

Recommend best practice for physicist involvement

Provide guidelines for specific treatment sites, such as prostate, lung, liver, pancreas, and breast

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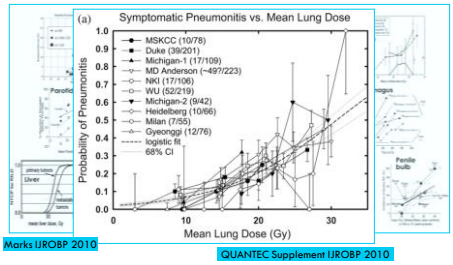
Clinical Benefit of Improved IGRT

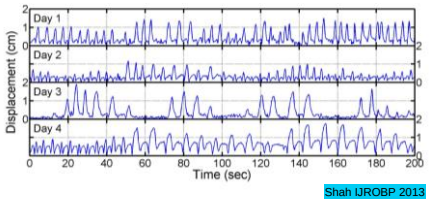


Marks IJROBP 2010

QUANTEC Supplement IJROBP 2010

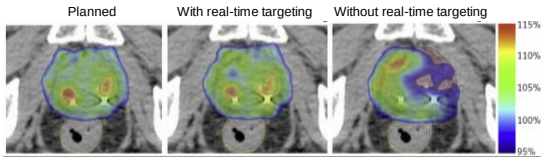
Tumor motion varies from breath to breath and day to day

- Calypso-measured lung tumor motion



Shah IJROBP 2013

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



Colvill IJROBP 2015

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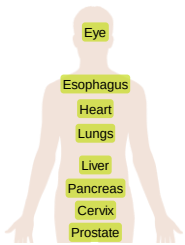
Marker-based real-time targeting



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, Zhifeng Mu, Jong Park, Gopinath Kuduvalli, and Calvin R. Maurer, Jr.

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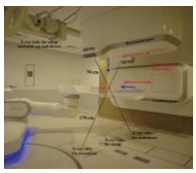
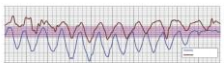
Markerless Tracking Clinical Implementation: Carbon ion therapy





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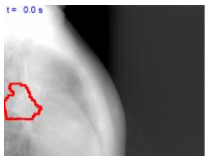
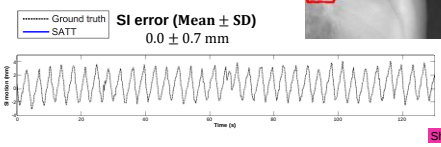
Markerless Tracking Clinical Implementation: Linac? Several R&D approaches





Shieh PMB 2017

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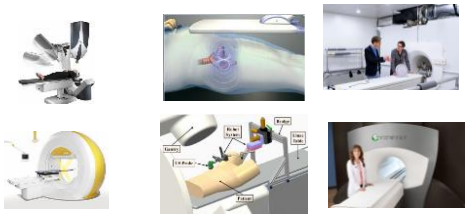
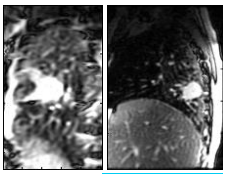
Clinical trajectory



MRI-guidance



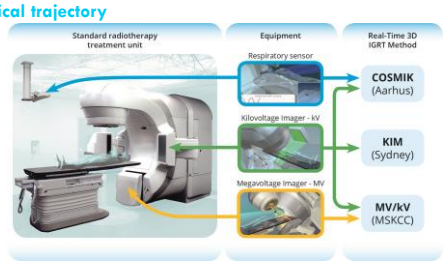
Courtesy Amit Sawant

Bjerre PMB 2013

Clinical trajectory

Keall *et al.* IJROBP 2018

Clinical trajectory



Keall *et al.* IJROBP 2018

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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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