In-Room Patient/Beam Adaptation - Future Roadmap

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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?

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
- ...

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Technologies for Real-Time Internal Anatomy Targeting
Targeting Internal Anatomy in Real-Time during Radiotherapy

The Pioneers in 1998

- Real-time fluoroscopic imaging of gold markers with gating
- Markers inserted into/near the tumor 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

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Tumor motion varies from breath to breath and day to day

- Calypso-measured lung tumor motion

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

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Marker-based real-time targeting

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**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 >1.5 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

Markerless Tracking Clinical Implementation:
Carbon ion therapy

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

Markerless Tracking Clinical Implementation:
Linac? Several R&D approaches
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Can we locate targets with sub-mm accuracy in real time... On every linac?
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What do these two things have in common?

They're both being revolutionized by AI.

They're both getting safer.
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

They use a fundamental cognitive process
See > Think > Act
It’s time for real-time

See > Think > Act

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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