Targeting Internal Anatomy in Real-Time During Radiotherapy

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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.

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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
- ...
Targeting Internal Anatomy in Real-Time during Radiotherapy

The Pioneers in 1998

- Real-time fluoroscopy 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

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

Tumor motion varies from breath to breath and day to day

- Calypso-measured lung tumor motion

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

- Eye
- Esophagus
- Heart
- Lungs
- Liver
- Pancreas
- Cervix
- Prostate

Targeting Internal Anatomy in Real-Time during Radiotherapy

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 Robust 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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SI error (Mean ± SD) 0.0 ± 0.7 mm

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Clinical trajectory
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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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