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Adaptive RT: Real-Time Tracking and Compensation with the Radixact

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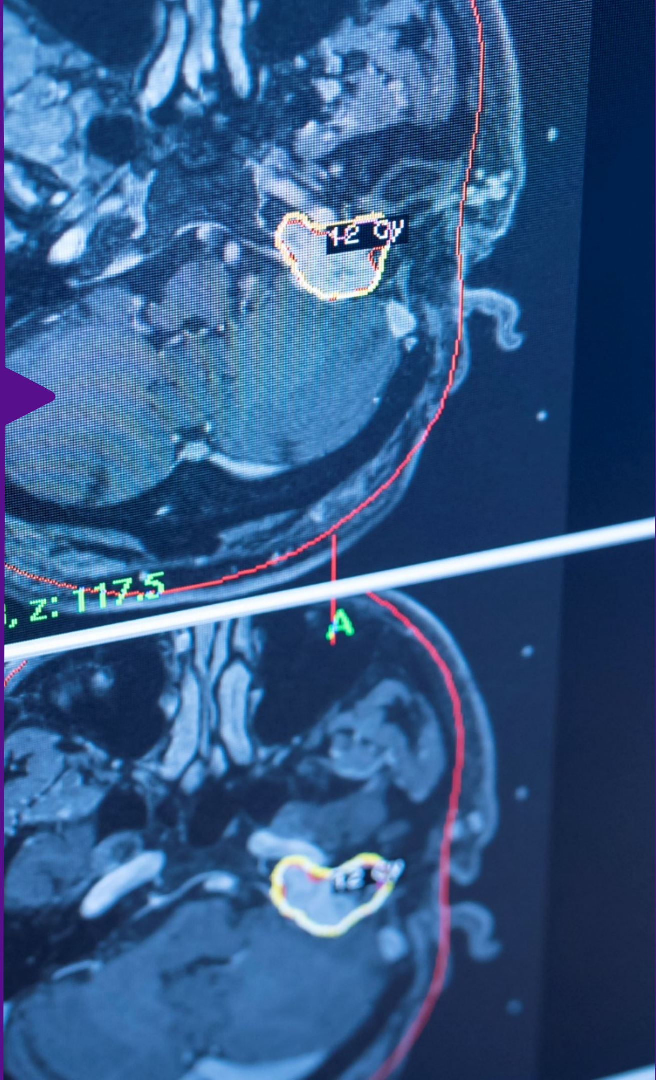


Disclosures

- I am receiving an honorarium from Accuray, Inc. for this presentation.

What is adaptive radiotherapy?

- First introduced by Yan et al. in 1997 in *PMB*:
  - “Adaptive radiation therapy is a closed-loop radiation treatment process where the treatment plan can be modified using a systematic feedback of measurements.”
  - “Adaptive radiation therapy intends to improve radiation treatment by systematically monitoring treatment variations and incorporating them to re-optimize the treatment plan…”
  - “In this process, field margin and treatment dose can be routinely customized to each individual patient to achieve a safe dose escalation.”
- In its initial conception, adaptive RT involved modification of the treatment plan itself to compensate for deformation of the patient’s anatomy. The goal was to adjust the treatment plan such that it took into account the state of the target volumes and the OARs at the start of a given fraction.

Traditional Adaptive Workflow

Image Patient → Deform Contours → Re-optimize Tx Plan On New Contours → Tx Patient

Is this sufficient for adaptive RT?

- Imaging, contouring, and re-optimization prior to delivery of each fraction is certainly better than relying on the imaging and state of the anatomy at simulation (and assuming a static state), as there may be changes to the anatomy which occurred over time.
  - The state of the patient’s anatomy at a the beginning of a given fraction may be very different from the snapshot taken at simulation.
- Imaging and contouring prior to delivery still only provides a snapshot of the patient’s anatomy at a given point in time.
- Is imaging/contouring/re-optimization prior to delivery of each fraction truly adaptive?

What happens during tx delivery?

Imaging/Contouring/Reoptimization Pre-Tx: Adaptation

→

Treatment Delivery: No Adaptation???

Expanding the Concept of Adaptive RT

- The historical definition of adaptive RT allows compensation for inter-fractional changes in patient anatomy.
- It does nothing to compensate for intra-fractional changes in patient anatomy.
  - Visceral motion.
  - Excursion with respiration.
  - Any other motion during tx.
- **Need to revise the understanding of adaptive RT to include methods for addressing both inter- and intra-fractional changes in patient anatomy.**

If you’re only imaging /contouring/reoptimizing prior to tx, but not correcting for changes during tx, you’re only solving 50% of the problem.

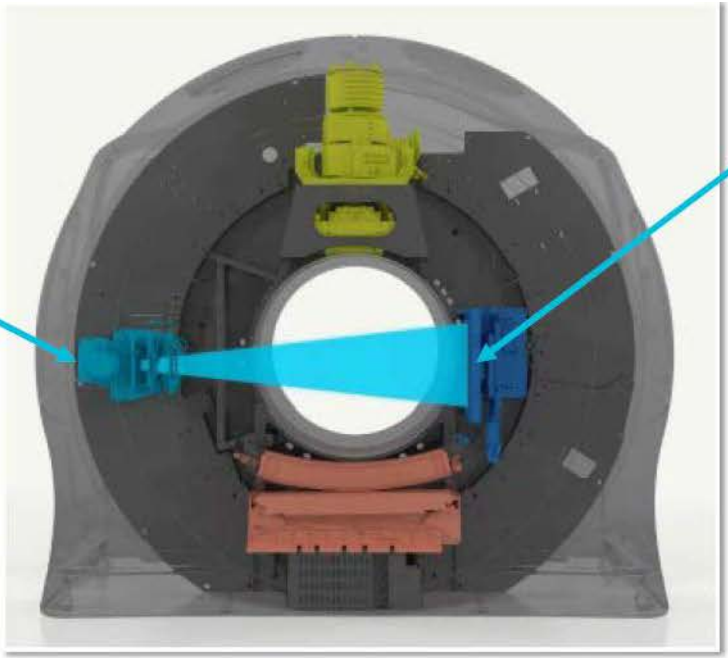
Compensating for Intra-Fractional Changes

- Image during treatment delivery.
- Detect motion of the target.
- Displace the dose distribution in real-time to compensate for the motion of the target.

Radixact® and CyberKnife® Allow For Real-Time Intra-fractional Motion Compensation: Track/Detect/Correct

ClearRT Imaging System

kV Tube

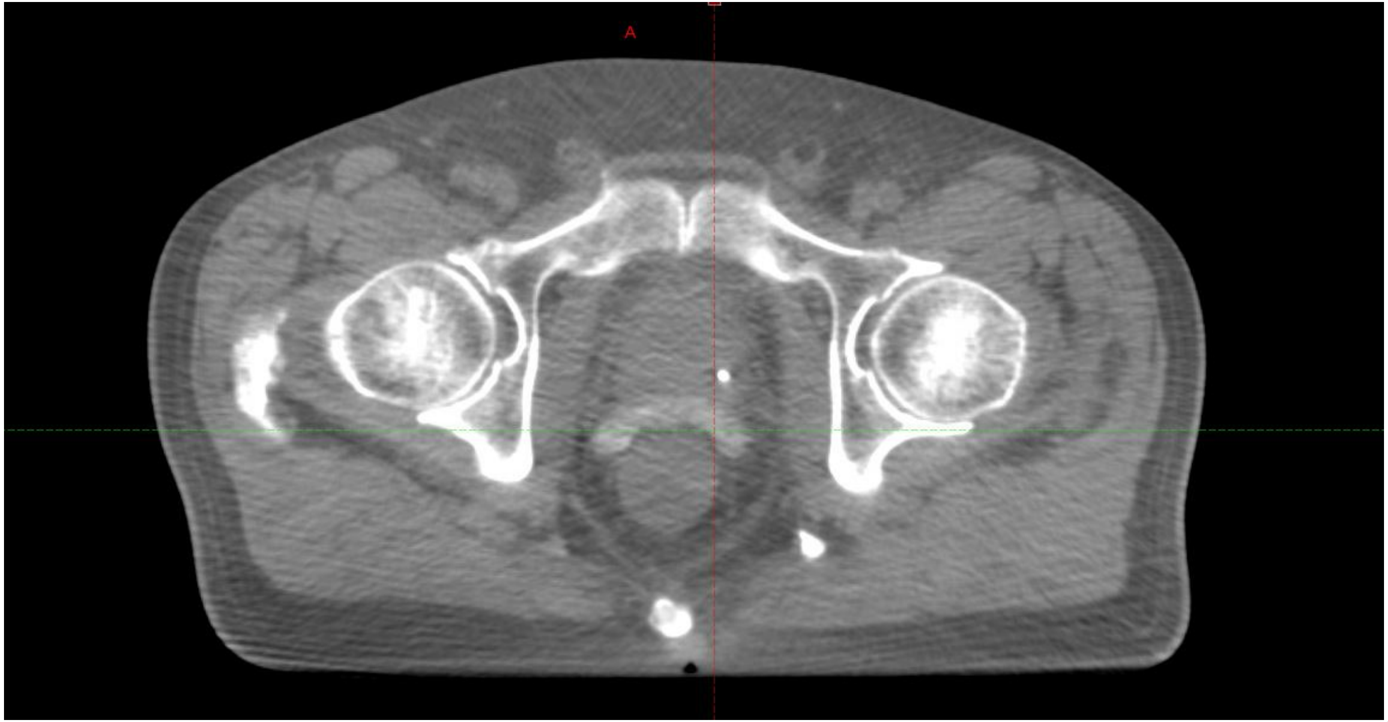


Radixact®

Flat Panel Detector:

- CsI: Ti
- 2880 x 2880 pixels
- 0.15 mm x 0.15 mm pixel size
  (pixels are binned into 0.9 mm x 0.9 mm clusters for generating ClearRT images)
- 43.2 cm x 43.2 cm active panel area
  (projects to 28.8 cm x 28.8 cm at isocenter)

Example ClearRT Image: Prostate (Treated at NYU Langone Hospital-Long Island)



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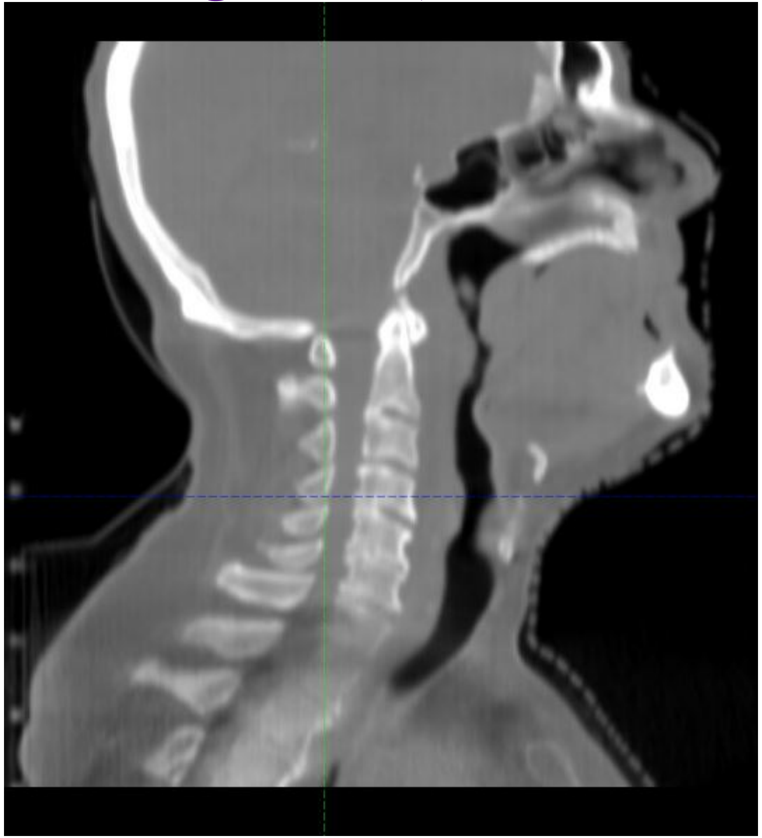
Example ClearRT Image: Head & Neck (Treated at NYU Langone Hospital-Long Island)



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Example ClearRT Image: Lung (Treated at NYU Langone Hospital-Long Island)

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Track/Detect/Correct > Gating

- This is NOT gating.
  - Gating simply shuts off the beam when the target excursion is larger than specified limits.
  - Requires larger margins.
- Track/Detect/Correct is real-time displacement of the dose distribution.
  - Beam stays on as compensation for target excursion occurs.
  - Margins can be smaller.

Track/Detect/Correct on the Radixact®

- Track targets of up to 8 cm length and motion up to ±2 cm.
- Tracking modes.
  - Fiducial.
    - Position model is generated to predict position of fiducials based on 2D radiographs.
  - Fiducial with respiratory.
    - Respiratory tracking uses external LEDs.
    - Correlation model is generated to predict position of fiducials based on the respiratory trace and 2D radiographs.
  - Lung with respiratory, i.e. fiducial-less lung tumor tracking.
- Target motion compensation.
  - Jaws correct for motion in IEC Y direction.
  - MLC sinogram shifted at each projection to correct for motion in IEC X and IEC Z axes.

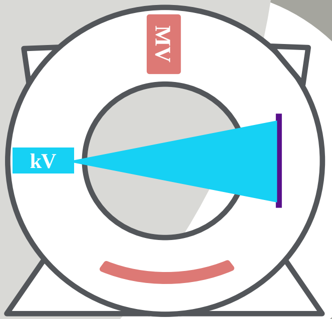
Track/Detect/Correct on the Radixact®

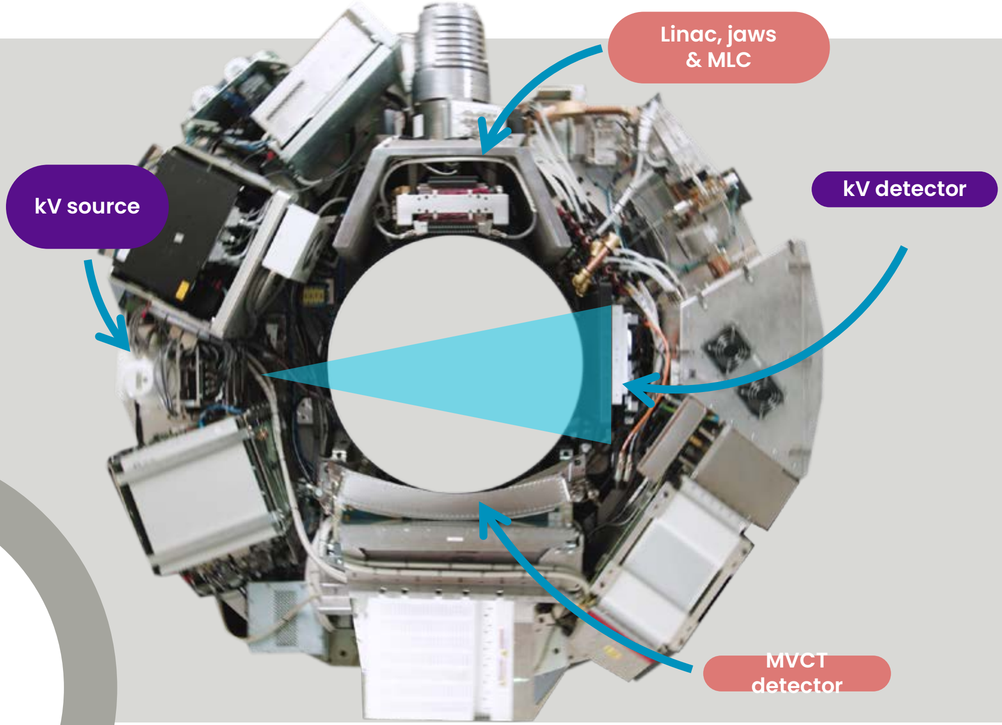
- Imaging angles selected during planning, but can be modified at the tx delivery console.
  - 2 to 6 angles.
- Imaging accomplished while the tx beam is on.

Hardware for Synchrony® for the Radixact® System

Current “motion management” for precise RT

- kV imaging enables in-treatment monitoring of target location
- External camera enables real-time monitoring of breathing cycle





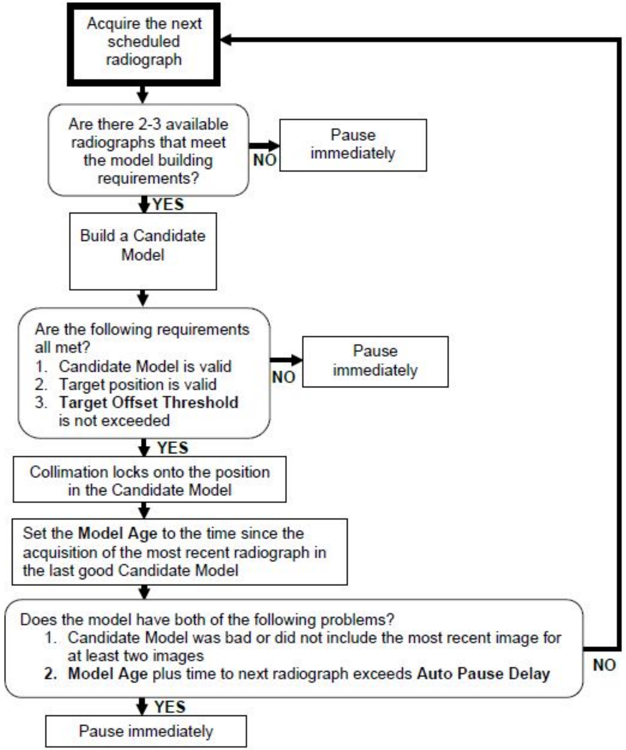
Tracking and Detecting

Enables continuous delivery and patient comfort

- kV imaging enables in-treatment monitoring of target location
- External camera enables real-time monitoring of breathing cycle

OPTICAL CAMERA

Non-Respiratory Tx



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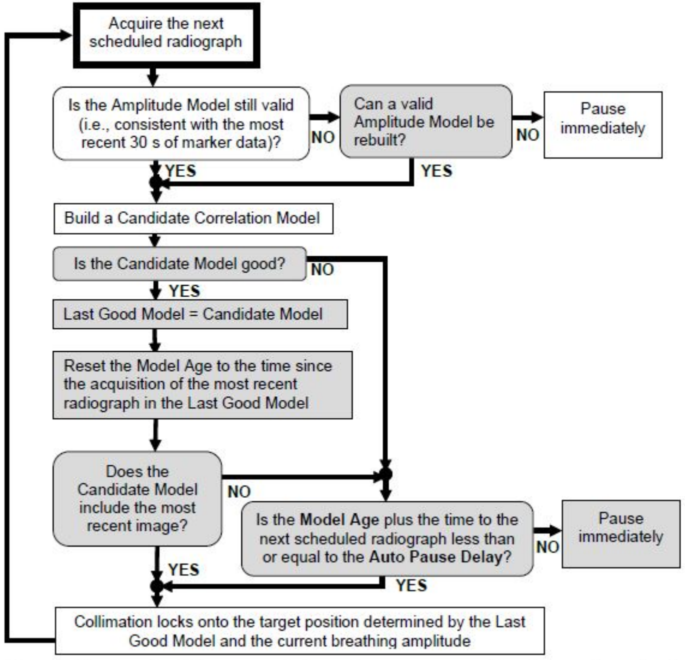
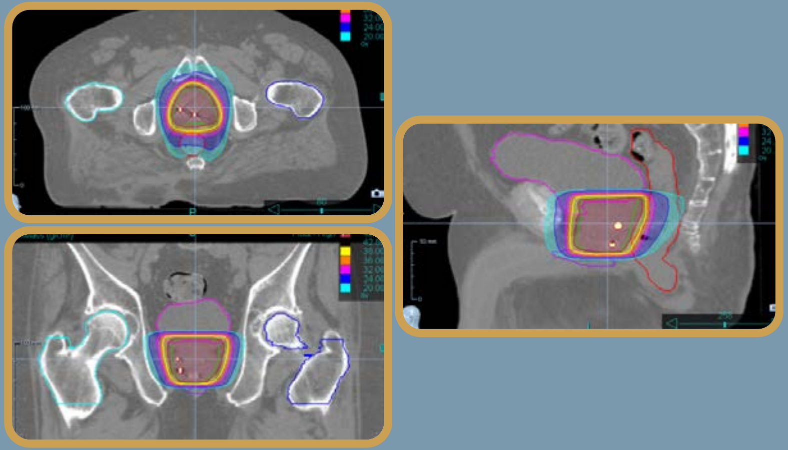
Respiratory Tx



PATIENT CASE HIGHLIGHTS:

Prostate SBRT with Fiducials

PATIENT INFORMATION



69 yo male with peak Gleason 3+4=7, 1 core, right mid-gland. Gleason 3+3=6 in 4 cores bilateral gland. 5 of 12 cores total

VOLUME	Gland confined tumor. 39 cc gland Bone scan benign. Peak PSA 9.41 ng/ml
TOTAL DOSE DOSE PER FRACTION	40 Gy 8 Gy in 5 fractions
SYNCHRONY® METHOD	Synchrony® Fiducial Tracking™
LHRH	Leuprolide injection 2 months prior to RT
PSA follow-up	Post-RT 2 months: 0.47 ng/ml 4 months: 0.22 ng/ml 8 months: <0.13 ng/ml

Patient image provided by Altru Health System, Grand Forks, ND, USA

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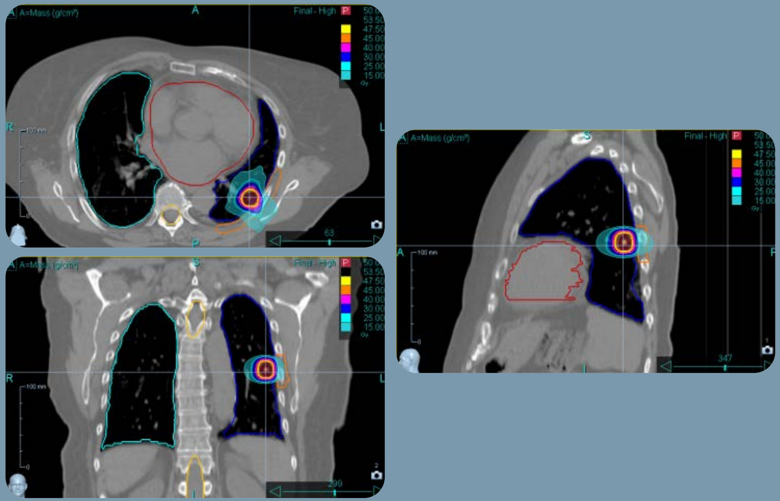
PATIENT CASE HIGHLIGHTS:

Fiducial-free SBRT Lung

PATIENT INFORMATION



63 yo female

Adenocarcinoma, grade 2 of 3

Patient image provided by Altru Health System, Grand Forks, ND, USA

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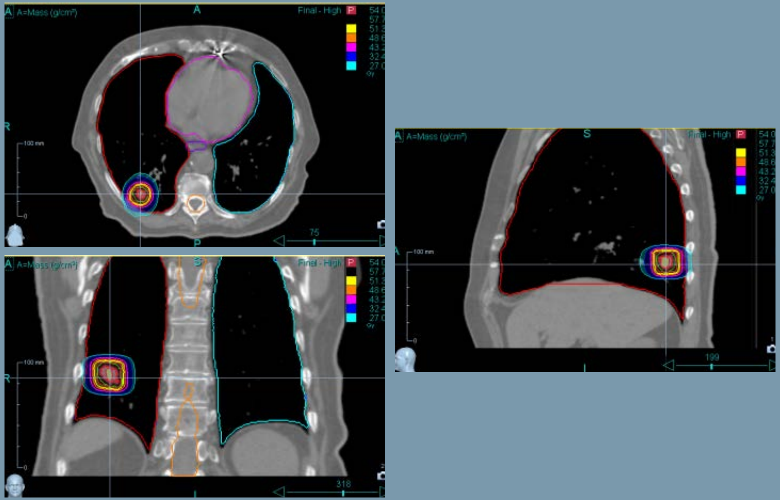
PATIENT CASE HIGHLIGHTS:

Fiducial-free SBRT Lung

PATIENT INFORMATION



80 yo male

Adenocarcinoma

SBRT: 54 Gy in 3 fractions

Every other day delivery

Patient image provided by Altru Health System, Grand Forks, ND, USA

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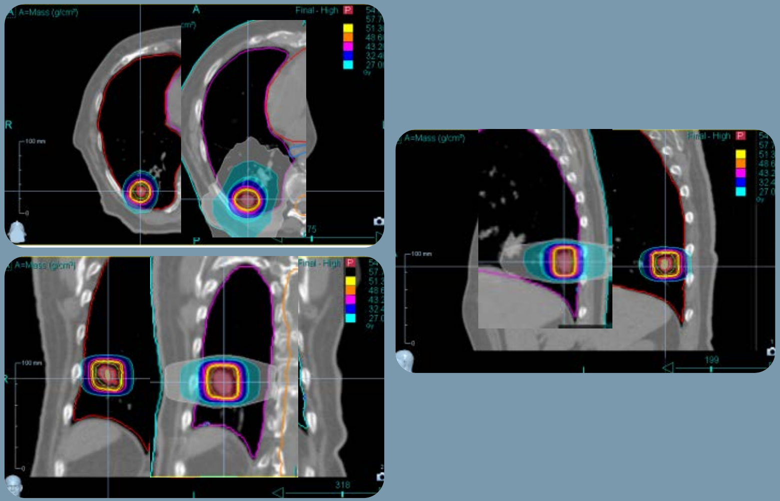
PATIENT CASE HIGHLIGHTS: Comparison of Synchrony® and ITV plans

Fiducial-free SBRT Lung

PATIENT INFORMATION



The amplitude of superior to inferior
motion determines the amount of
lung tissue saved
by Synchrony®

Higher motion = more tissue spared

Patient image provided by Altru Health System, Grand Forks, ND, USA

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Thank You