

Anatomical Adaptive Radiation Therapy

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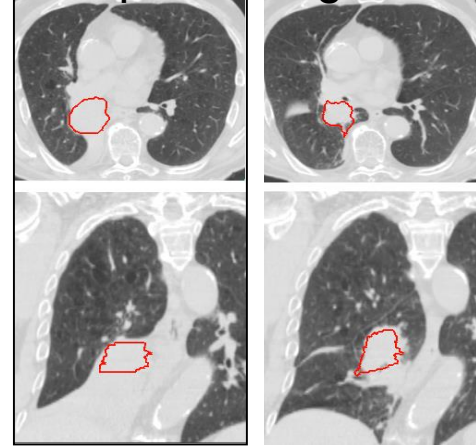
Disclosures

- **Employee:** Washington University
- **Research Grants:** AHA, NIH, Siemens, Varian Medical Systems, ViewRay
- **Speaking / consulting:** Varian

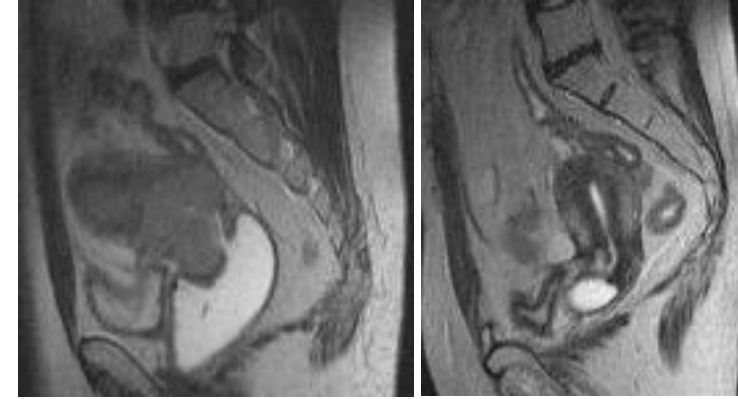
Anatomical Variability - Sources

- Musculoskeletal (articulation / swallowing)
- Motion (breathing, peristalsis, heartbeat)
- Disease progression / response
 - Primary
 - Secondary (pleural effusion)
- Other – immobilization / applicator

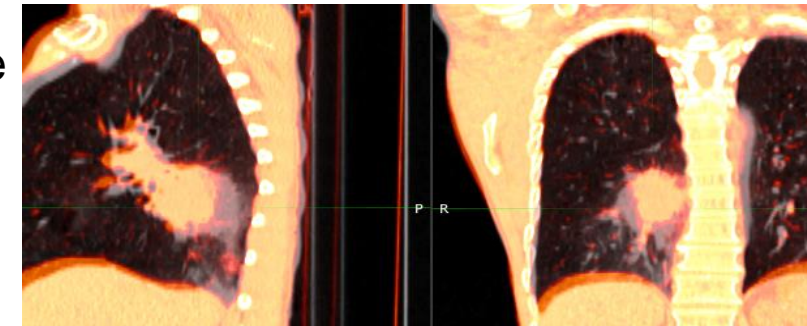
Collapsed Lung



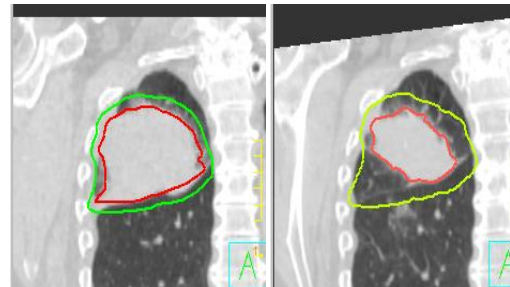
Organ motion



Multifactorial – breathing and response



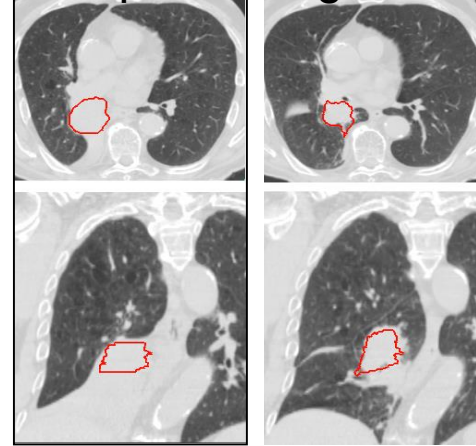
Tumor Growth / Response



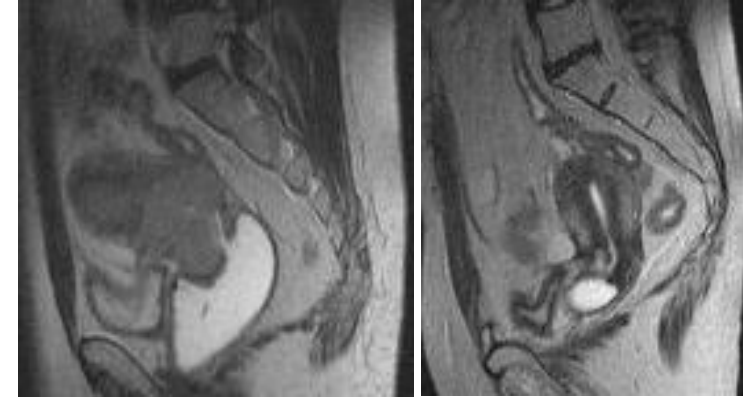
Anatomical Variability - Considerations

- Rigid / non-rigid
- Time scale
- Pattern
- Magnitude
- Affected tissues

Collapsed Lung

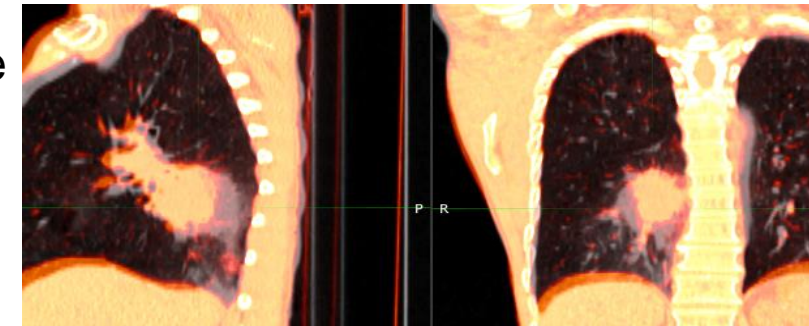
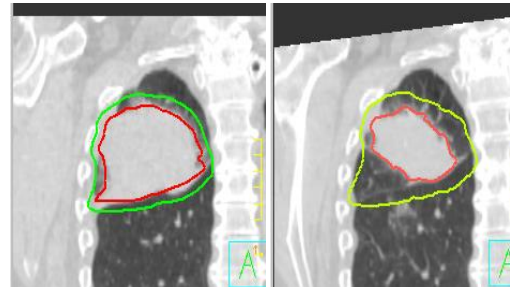


Organ motion



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Tumor Growth / Response



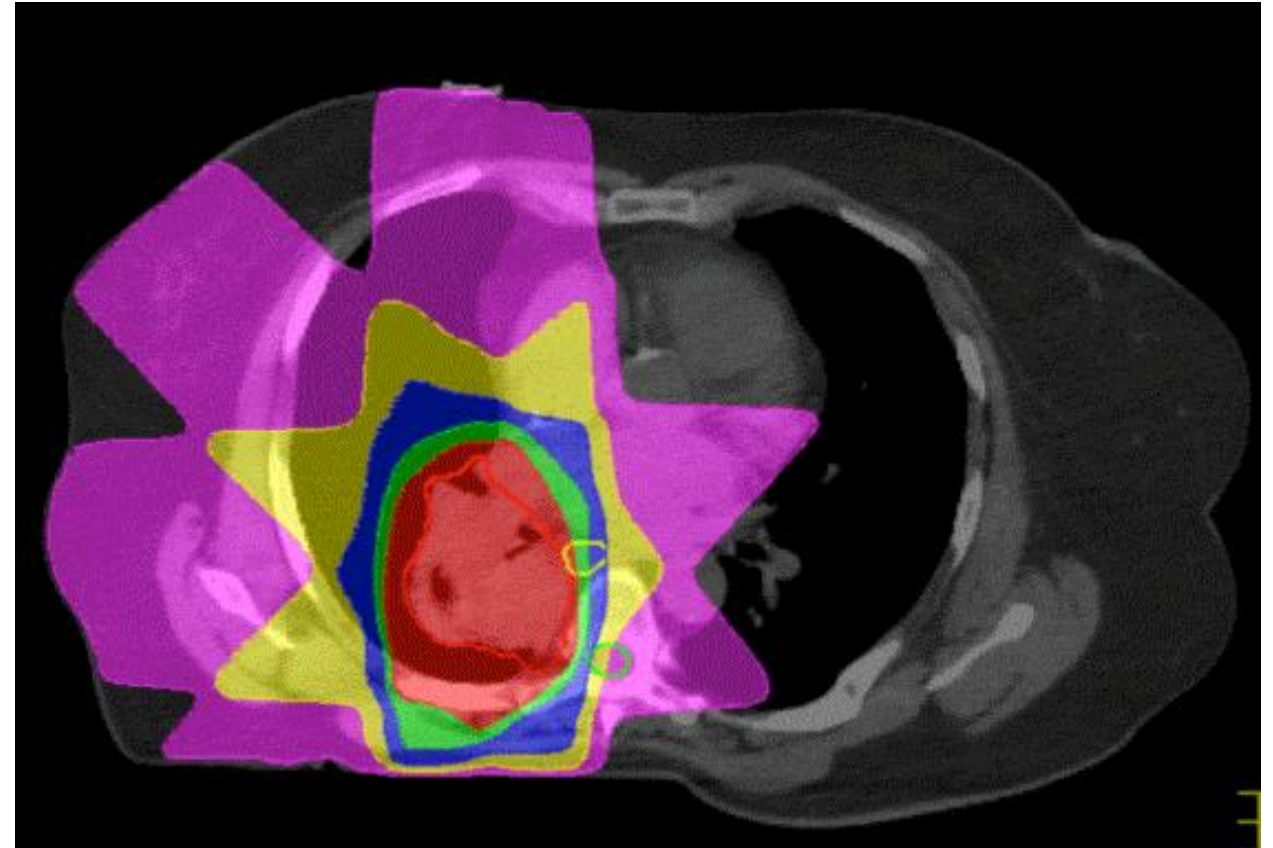
Anatomical Variability during RT

Geometric variability => target volume size

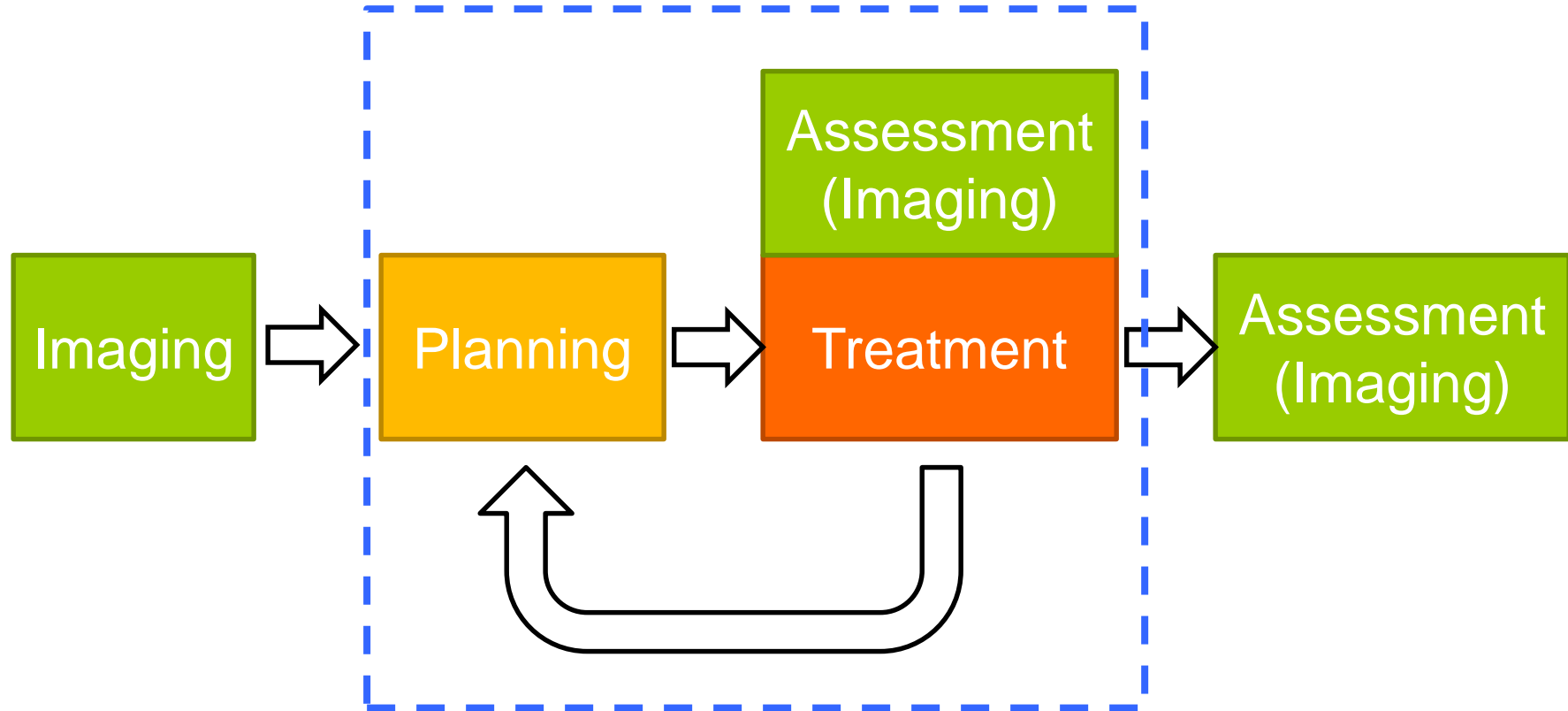
Geometric variability => uncertainty in normal tissue dose

Higher precision => less toxicity, better local control

Better estimates of delivered dose
=> better outcome models



Adaptive Radiation Therapy

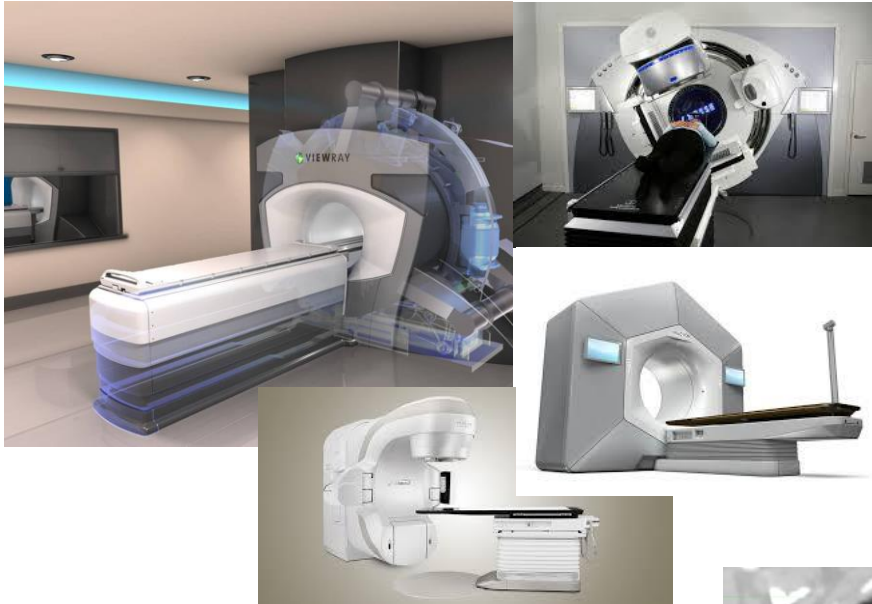


Quantify geometric variability

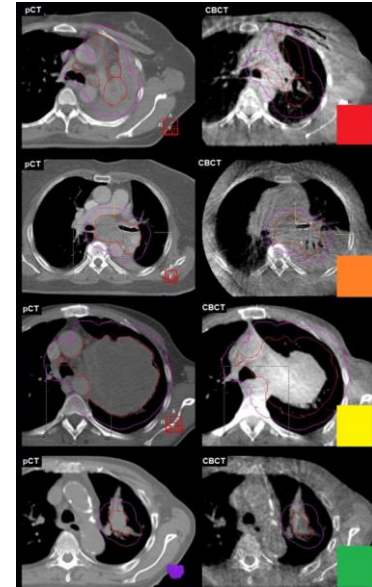
Correct what we can at time of treatment

Adapt the treatment plan to changes during therapy

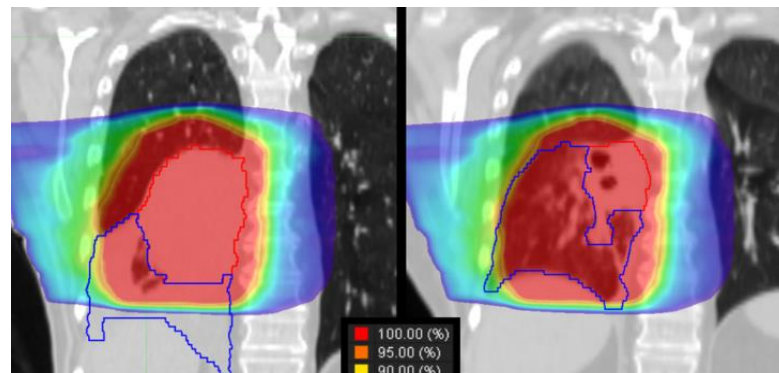
Enabling Technologies for Adaptive RT



Onboard Imaging



Decision Making

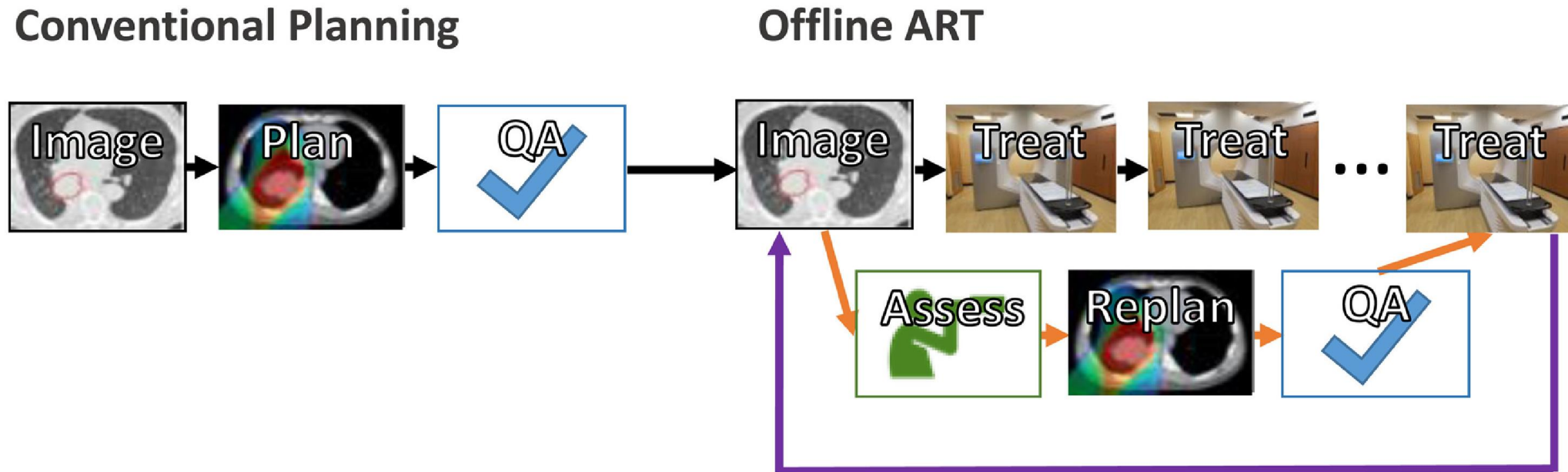


Replanning

Timescales of Adaptive RT

- Offline
- Online
- Realtime

Timescales of Adaptive RT - Offline



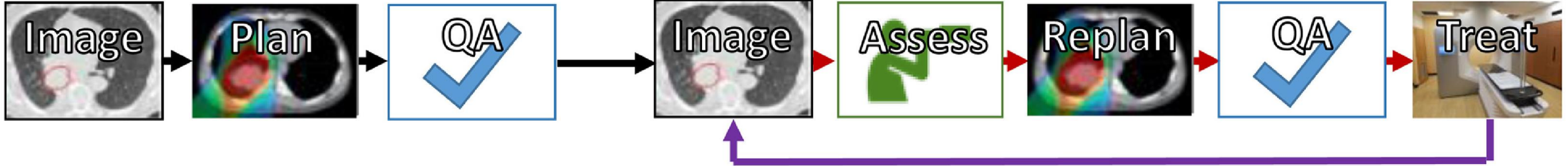
Treatments continue while adaptive process performed outside of treatment space

Timescales of Adaptive RT - Online

Conventional Planning

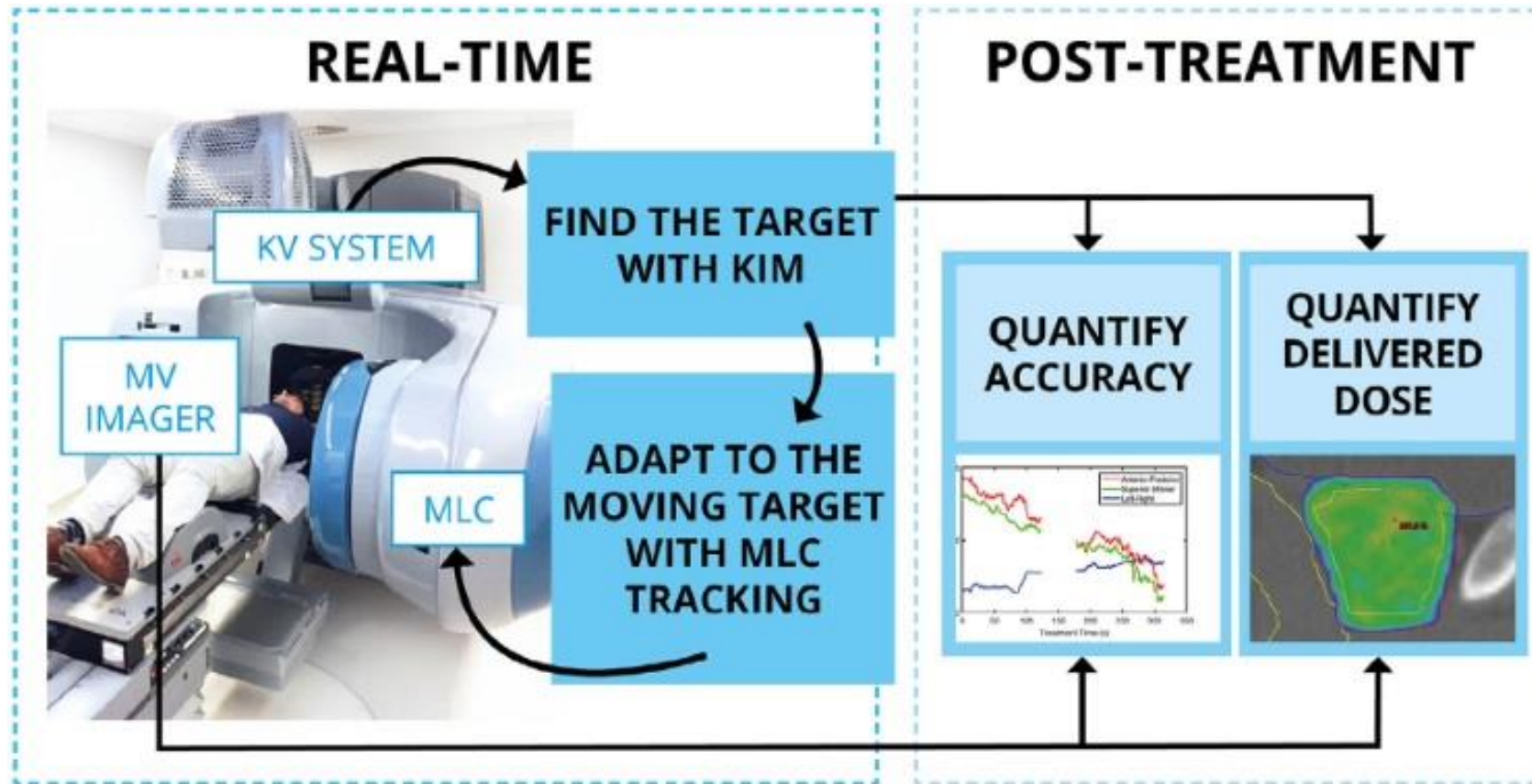


Online ART



Adaptive process performed while patient is on the treatment table, immediately prior to treatment

Timescales of Adaptive RT - Realtime



Adaptive process performed while patient is on the treatment table, continually during treatment

Timescales of Adaptive RT

Offline

- Economical
- Manages slow or singular changes
- Can use diagnostic images
- Can't manage daily change
- Typically more manual

Online

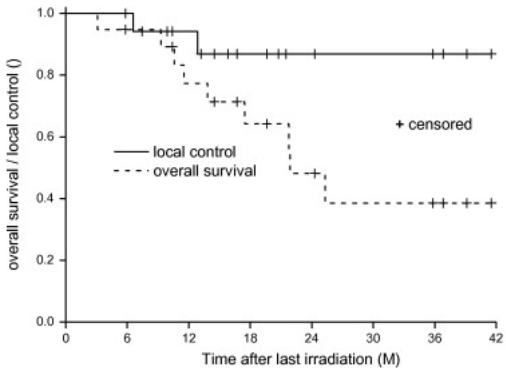
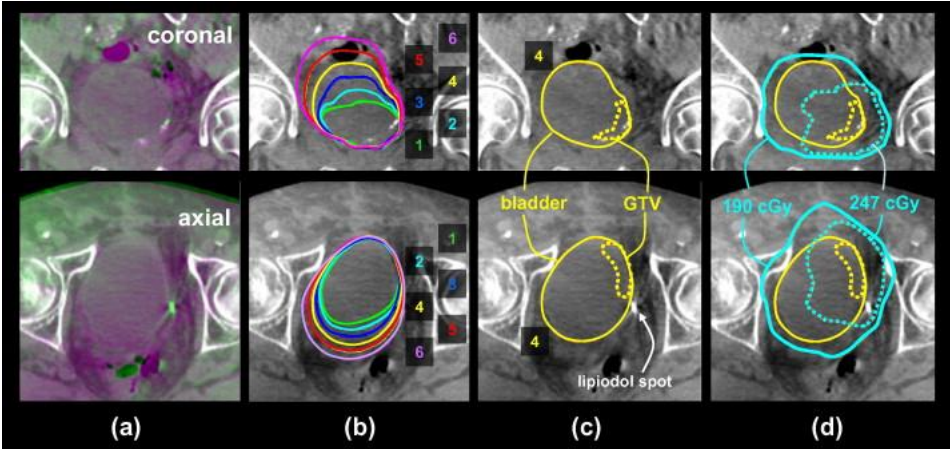
- Semi-automated toolset
- Typically single integrated system
- Most variabilities
- Risk of anatomical changes during / after replan
- Additional QA burden
- Requires intrafraction motion management

Realtime

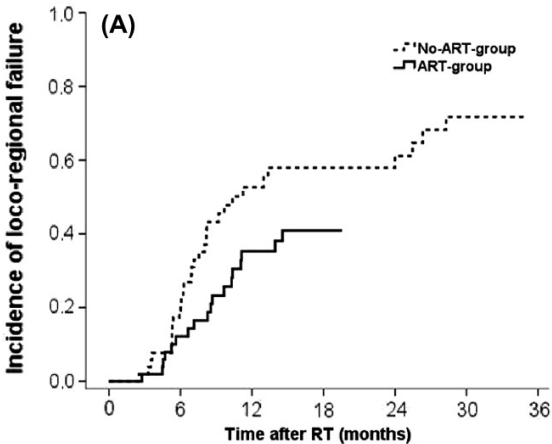
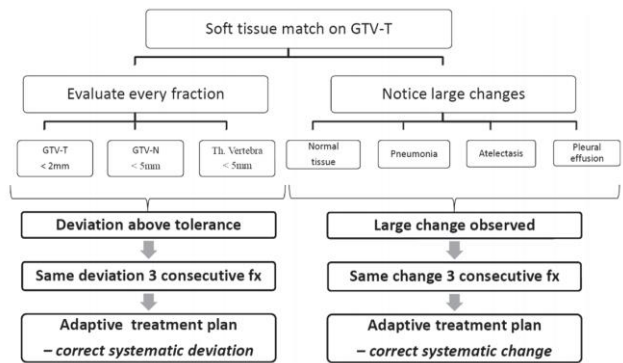
- Most responsive to high frequency changes
- Most direct, no need to model / manage other sources
- Requires most automation
- Less commercial availability
- Highest QA burden

Clinical Trials – Adaptive RT

Bladder Cancer – Hybrid Online/Offline – *Meijer Radiother Oncol 2012*

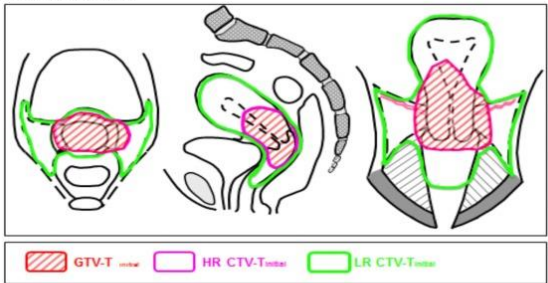


NSCLC – *Tvilum Acta Oncol 2015*

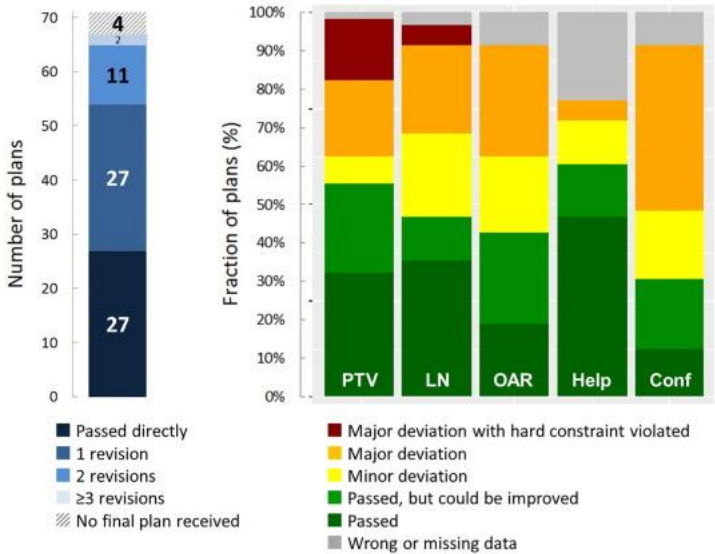
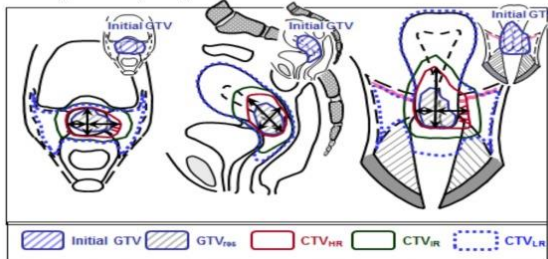


Cervical Cancer / IGABT EMBRACE-II

Panel A: Targets for EBRT



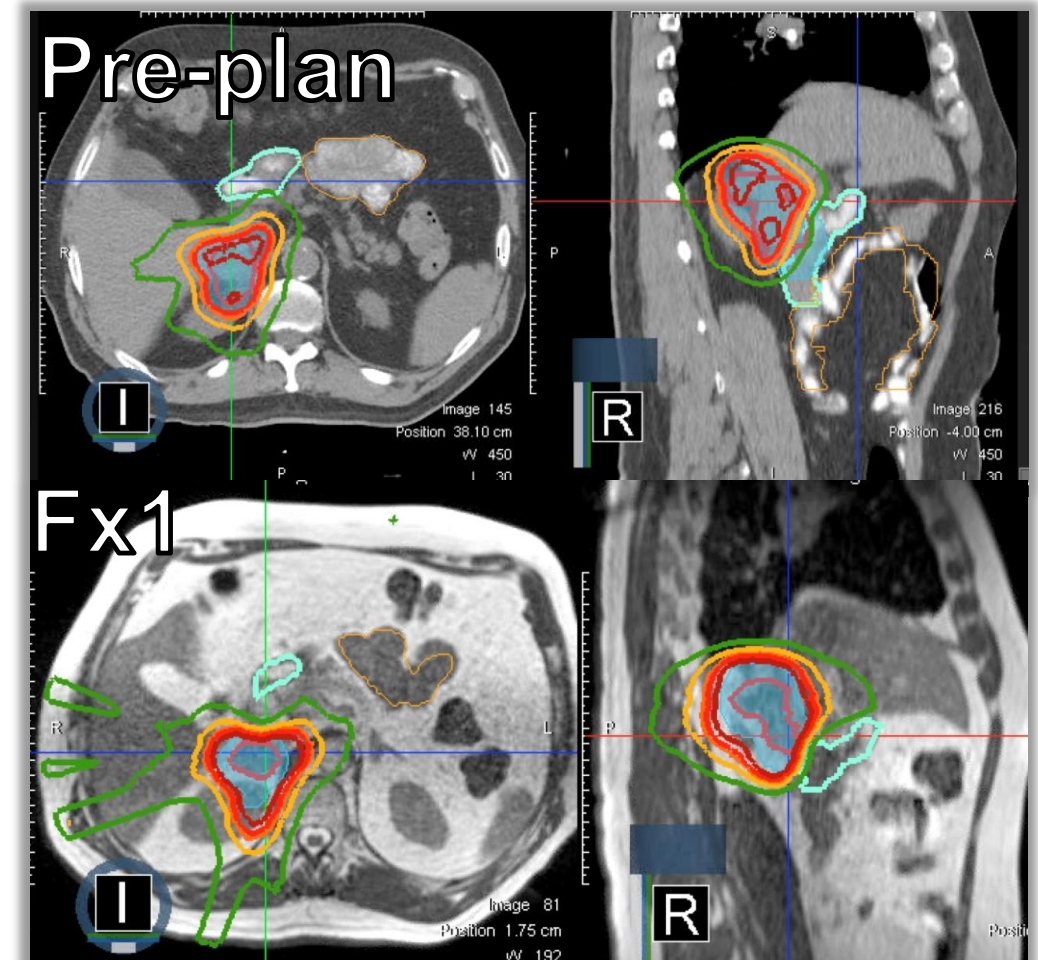
Panel B: Targets for brachytherapy



Seppenwoolde Radiother Oncol 2019

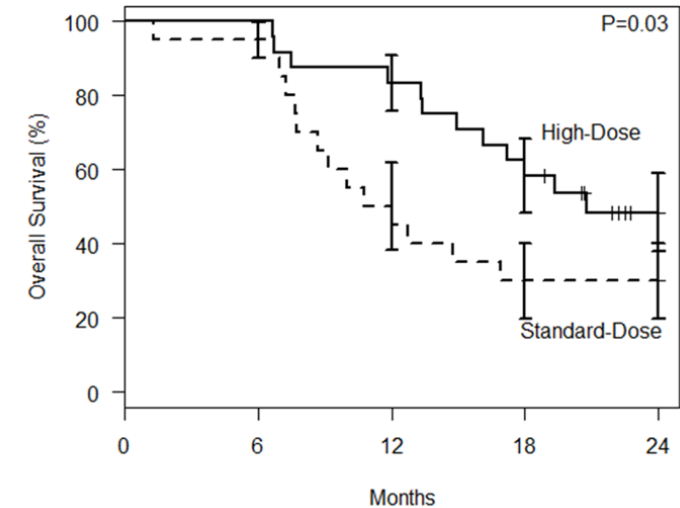
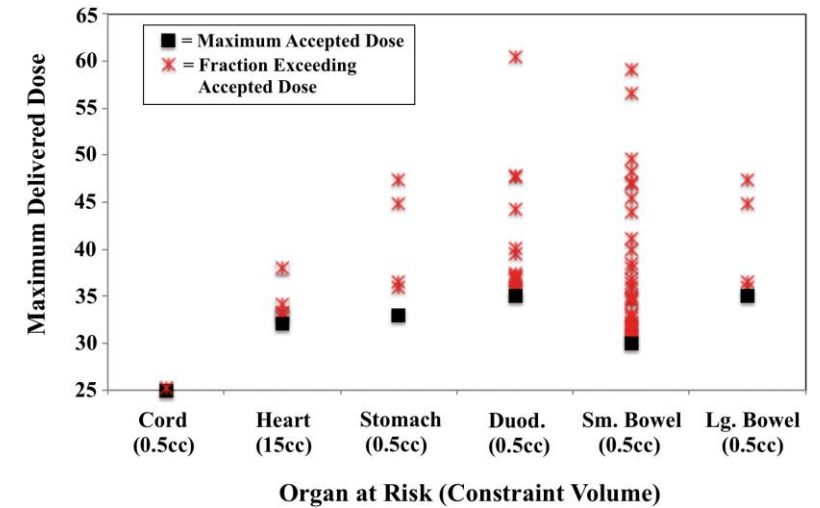
Phase I Trial - Stereotactic MR-Guided Online Adaptive RT (SMART)

- 20 patients with unresectable primary or oligometastatic disease of the liver (n = 10) & non-liver (n=10) abdomen planned for SBRT
- Prescription: 50Gy/5fx with SMART approach
- Isotoxicity approach, with dose escalation (or de-escalation) based on hard OAR constraints
- Breath hold or gating – managed by realtime cine MR



Phase I Trial - Stereotactic MR-Guided Online Adaptive RT (SMART)

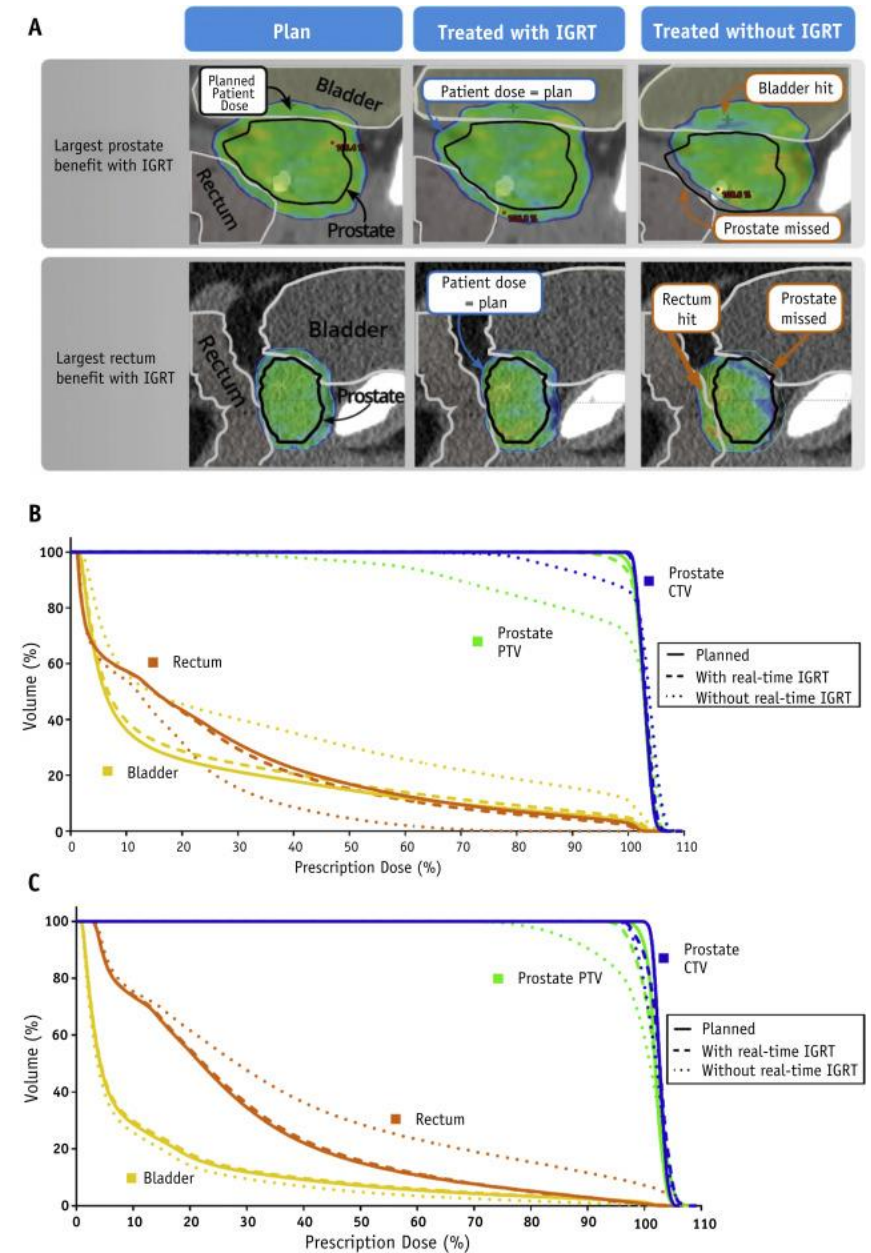
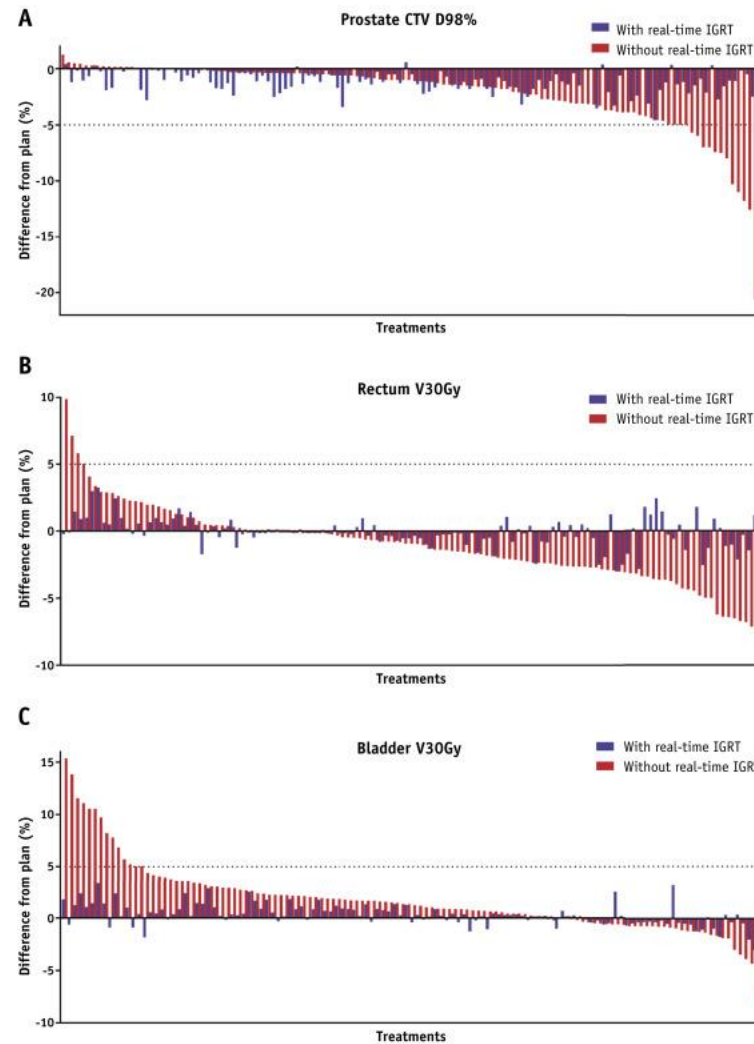
- 83% (79/95) fx adapted—all patients had ≥ 1
- Primarily (70/95 fx) to protect OARs after inter-fx motion
- 100% of OAR violations resolved with adaptive planning
- No **Grade 3+ toxicity** at median 11.8 mo f/u. Expected up to 30% based on prior reports accounting for motion (Hoyer, et al. 2005)



Realtime Adaptive – TROG

15.01 SPARK

- 48 prostate ca patients
- 88% patients > 1 correction
- CTV D98% within 5% with realtime IGRT
- No grade 3 toxicity
- Multi-vendor!



Adaptive RT – Needs Assessment

- Trials, trials trials!
- Automation and QA of automation
- Robust workflow models
- Training programs
- Tools for managing complex, multifactorial variability

Summary

- Anatomical variability can be managed in part by adaptive radiation therapy.
- Different types of adaptive RT for different time scales of variability.
- Work remains to produce clinical evidence, develop workflow and robustness, and manage complex changes.