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Prostate SBRT: Adaptive Radiotherapy and Treatment Personalization

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Agenda

- What oART changes (and what it doesn't).
- Key dosimetric and workflow evidence (MR + CBCT).
- Clinical outcomes: SBRT benchmarks + MIRAGE toxicity benefits.
- Personalization: PSMA-PET response-adaptation, risk-adapted margins, digital twins.
- Safety, QA, and what we don't know yet

Why Prostate SBRT?

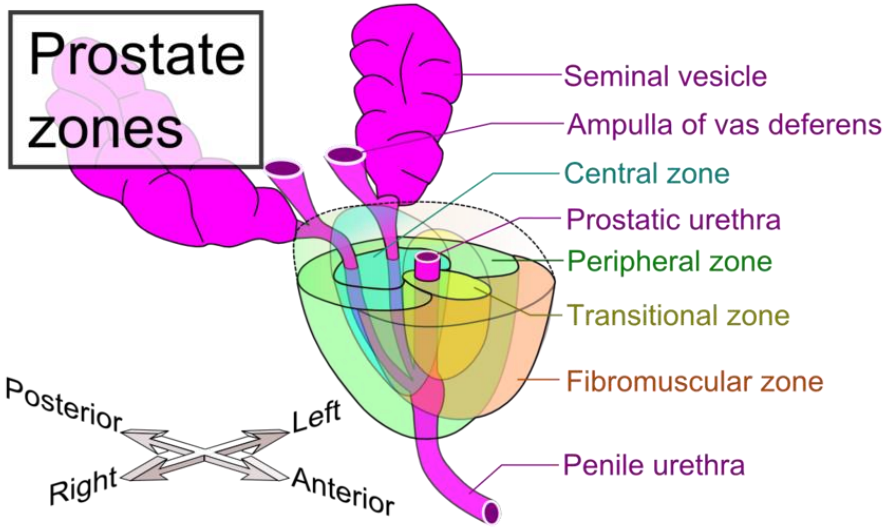
- Low alpha/beta ratio
- Biologic rationale for hypofractionation
- Short treatment course

SBRT: Typically 36.25–40 Gy in 5 fractions for localized disease

PACE-B trial (NEJM 2024) as the benchmark for 5-fraction SBRT.
van As et al., N Engl J Med 2024 — PACE-B SBRT vs conventional RT.

Why adaptive & personalized SBRT?

- SBRT compresses weeks of dose into 5 fractions → smallgeometric errors matter.
- Daily bladder/rectum filling changes prostate distortion and motion.
- Interfraction variation can break PTV coverage or OAR constraints in a meaningful fraction of sessions
- Online adaptation aims to **restore the intended plan on "anatomy of the day."**
- Personalization goes beyond geometry: margin-risk adaptation + biology-driven boosts (e.g., PSMA-PET)



Hall et al. "Adaptive MR-guided SBRT for prostate"
Casillas et al. review of MR/CT oART

Anatomy is compact—but neighbors are dose-limiting (rectum, bladder, urethra).

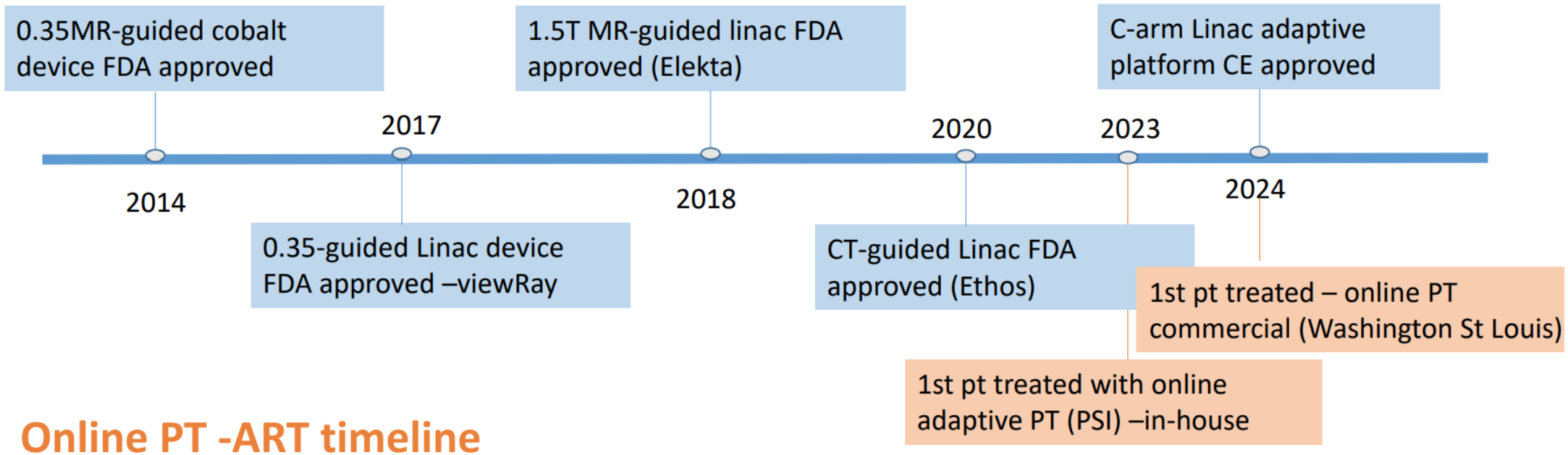
Big picture

Where are we with oART?

What has happened in the field in the last few years?

Field is rapidly evolving

Online ART technology timeline



Online PT -ART timeline

Parallel advances include MR-guided photon therapy, CBCT-guided photon therapy, and adaptive **proton therapy (PT)** workflows. **PSMA-PET response-adaptive SBRT reported in 2025**

Clinical Rationale for oART

1. Improve Efficacy

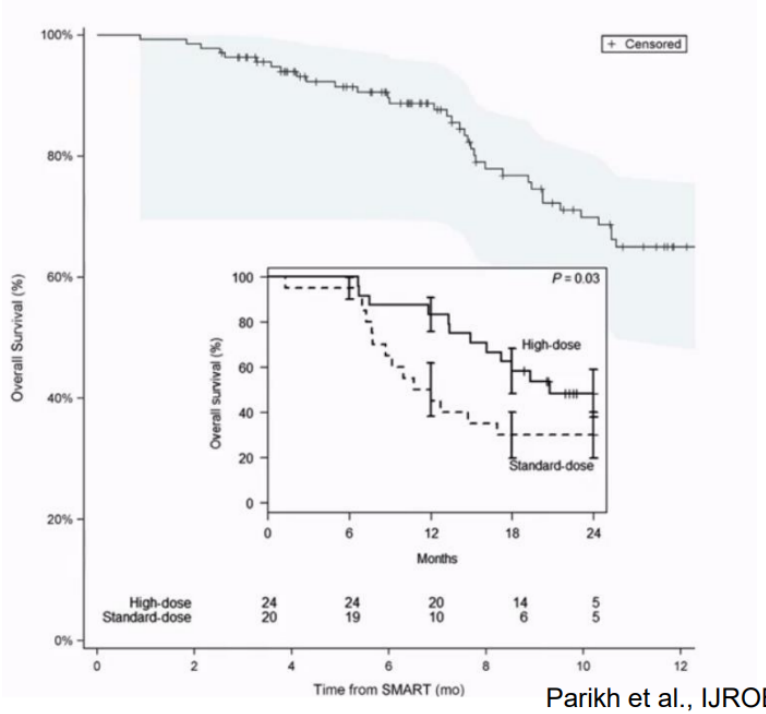
- Dose escalation

- Guarantee target coverage when tumors change position/shape

- Improve target coverage (for favorable anatomy)

Phase 1 trial 50Gy/5fx abdominal tumours - Henke 2024 Radioth Oncol

SMART trial for non operable pancreatic cancer (Dose escalation)



Parikh et al., IJROBP, 2023

136 patients recruited 2019-2022

No acute Grade>3 GI toxicity

1y overall survival =65% (vs 25% standard dose)

Clinical Rationale for oART

2. Reduce Toxicity

- Reduce OAR dose - Margin reduction

- Reduce OAR dose – account for anatomical changes

Reduction of toxicity in cervical cancer
Branco et al J Appl Clin Med Phys 2023

DARTBOARD trial (1mm vs 5mm PTV)

	IGRT				DART				
Toxicity	**None**	**G1**	**G2**	**G3**	**None**	**G1**	**G2**	**G3**	***P***
Acute									
Dermatitis	0	18 (69%)	8 (31%)	0	4 (17%)	18 (75%)	2 (8%)	0	.01
Mucositis	0	2 (8%)	16 (62%)	8 (31%)	0	6 (25%)	15 (63%)	3 (12%)	.13
Dysphagia	0	5 (19%)	16 (62%)	5 (19%)	2 (8%)	4 (17%)	16 (67%)	2 (8%)	.20
Late									
Xerostomia	10 (43%)	13 (57%)	0	0	13 (54%)	11 (46%)	0	0	.48
Soft-tissue necrosis	18 (78%)	0	3 (13%)	1 (4%)	21 (87%)	0	3 (13%)	0	.53
Dysphagia	13 (57%)	7 (30%)	0	3 (13%)	17 (71%)	5 (21%)	1 (4%)	1 (4%)	.39

Sher J Natl Cancer Inst 2025

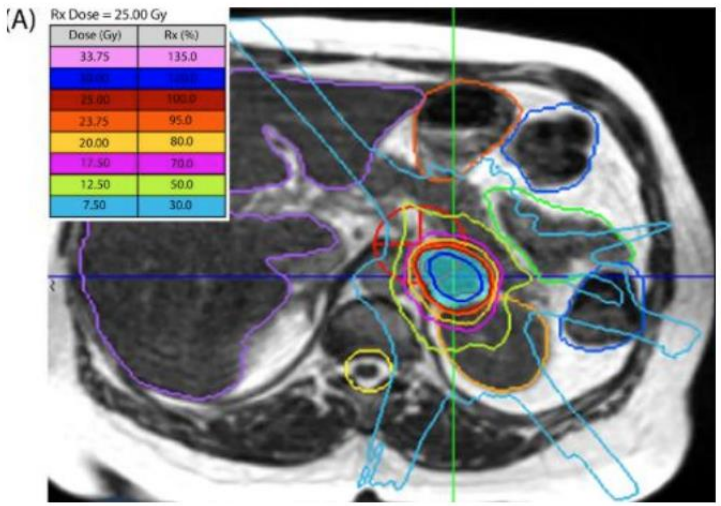
50pt H&N - No local failure
Dosimetric improvement - Limited NTCP benefit

Clinical Rationale for oART

3. Improve efficient use of resources/reduce cost—

- Hypofractionation (↘ #fraction)

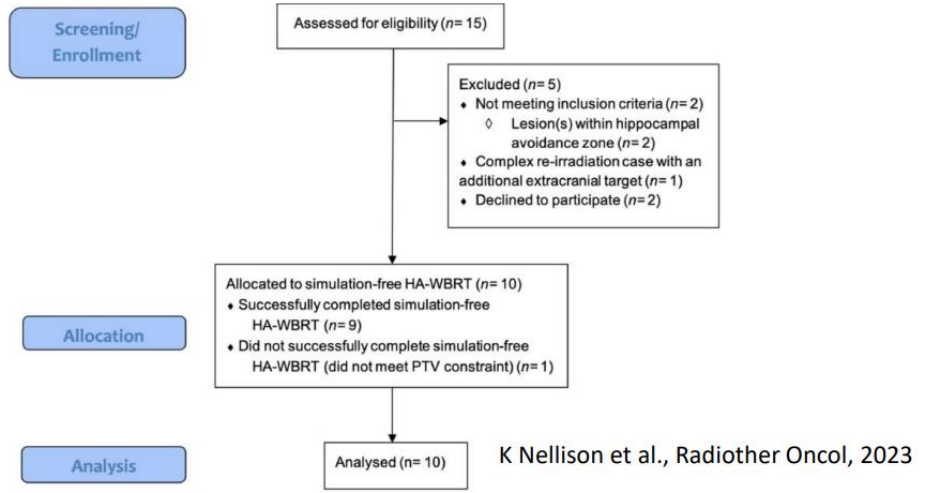
SMART ONE Trial



10.1016/j.ijrobp.2025.03.030 Choung IJROBP 2025

Single-fraction 25Gy (MRgRT-SBRT)
30pt
3pt with Gr3 acute toxicity.
No grade 5 or late grade ≥3 toxicities reported

- Avoid/reduce need of pre-treatment simulation (direct-to-unit /simulation free workflow)



K Nellison et al., Radiother Oncol, 2023

10pt whole brain radiation therapy. Hippocampi avoidance – 30Gy
Patient on treatment couch 41min [34-70min]
Simulation free plan comparable to simulation-based plan

Anatomic & Motion Challenges

- Daily prostate motion
- Bladder and rectal filling
- Intrafraction motion
- oART responds by daily re-optimization (adapt-to-shape) on MR or CBCT platforms

Dose-limiting neighbors

- Rectum
- Bladder
- Urethra

Key lever: reduce high-dose spill while maintaining target coverage.

- Adaptive RT reviews; Poon et al. (MRgSBRT prostate) for motion and need for adaptive routines.
- Nicosia et al. (MR vs VMAT daily dosimetric variation)

Online Adaptive Radiotherapy (oART)

- Daily re-optimization
- Adapt-to-shape workflows
- MRI- and CT-guided platforms

What is online adaptive radiotherapy (oART)?

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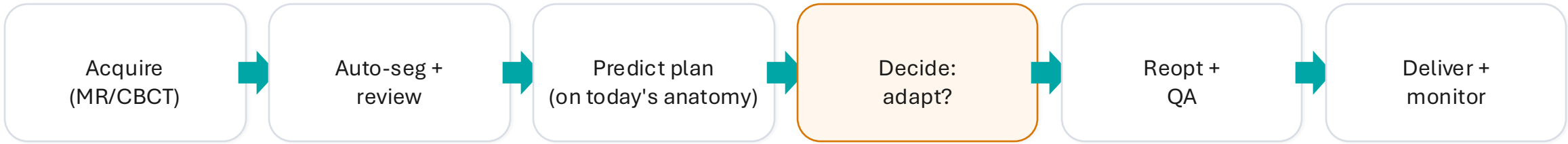
Two common strategies

- Adapt-to-position: update shifts/rotations (fast).
- Adapt-to-shape: recontour + reoptimize plan to new anatomy (more powerful).

What "online" means

- Image on couch (MR or CBCT).
- Same-day segmentation + plan evaluation.
- Reoptimization + QA before delivery.



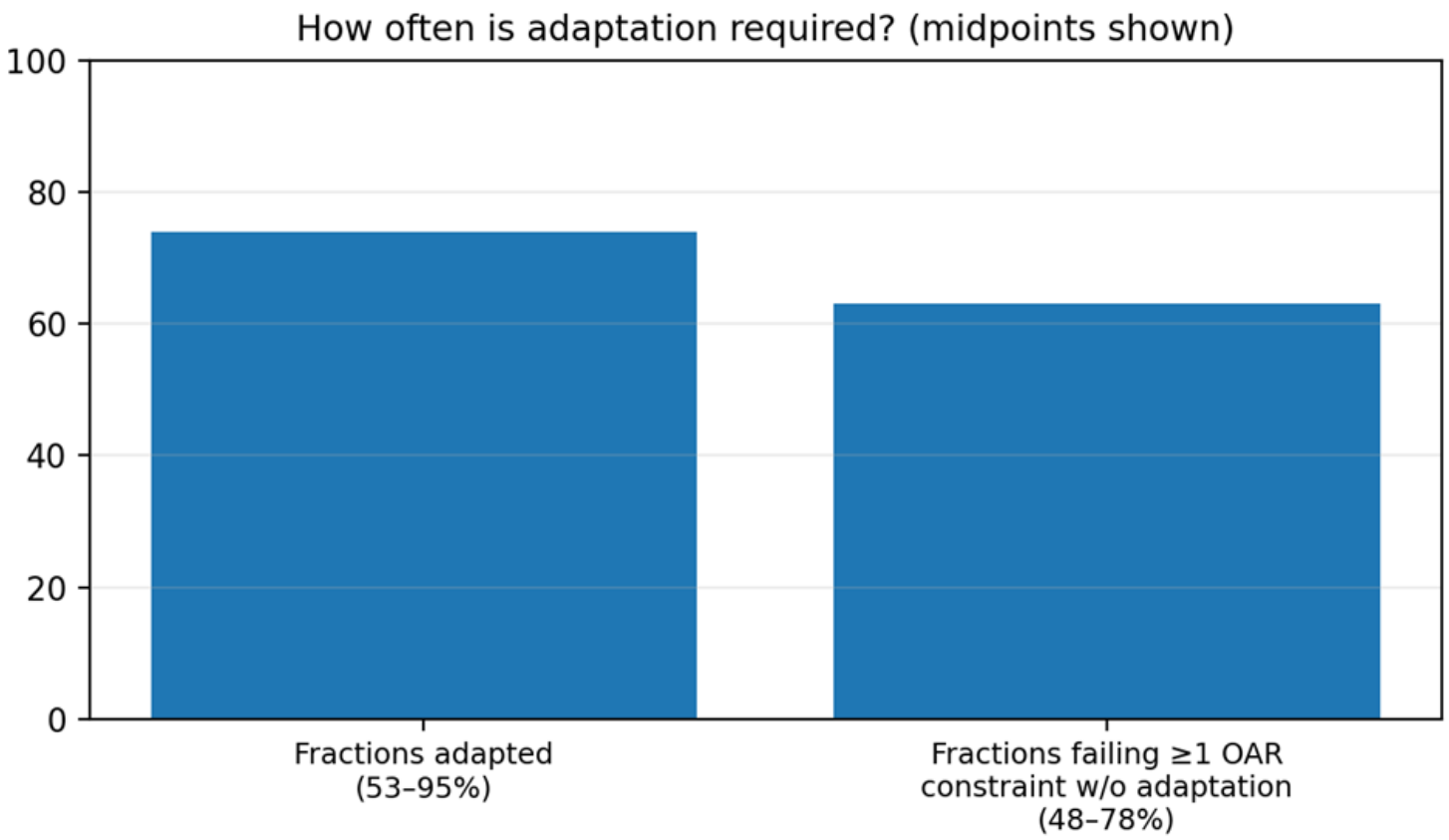
Two strategies

- Adapt-to-position: update shifts/rotations (fast)
- Adapt-to-shape: recontour + reoptimize to new anatomy (more powerful)

Key decision: adapt only when coverage/constraints drift beyond thresholds.

Ugurluer 2020, Poon 2021

How Often Is Adaptation Required?



Across MR- and CBCT-guided series, a majority of fractions benefit from re-optimization.

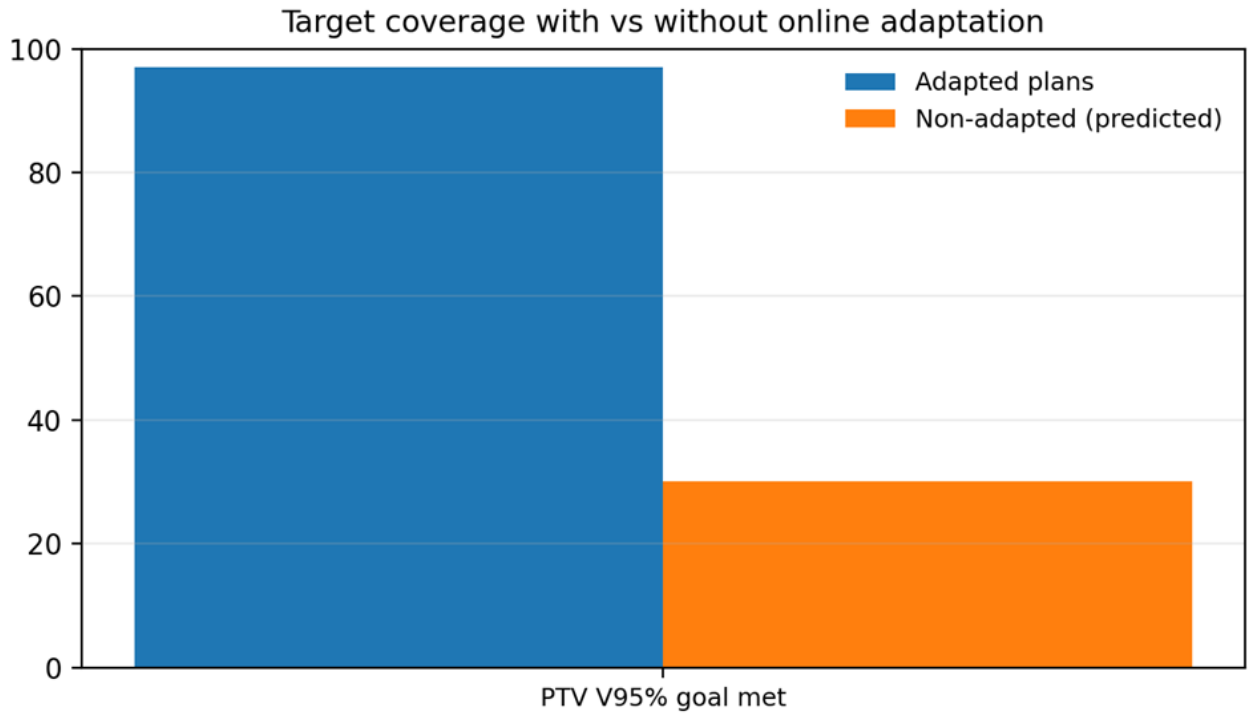
Without adaptation, many fractions violate ≥1 OAR constraint (rectum/bladder/urethra).

Operational message: you need staffing + QA capacity for frequent adaptation—not just occasional "rescue" replans.

Fink et al, Wurschi et al, Preziosi et al

Dosimetric Benefit: Target Coverage Improvements

- PTV V95% goal met in ~95–100% of adapted fractions vs ~18–41% if the original plan is delivered on today anatomy.
- Typical mean improvements: +4.5–11.8% PTV coverage; +1.4–2.9% CTV coverage.
- Practical: adaptation is most valuable on “bad anatomy” days (rectum/bladder changes, rotations).



Fink et al, Perziosi et al)

Dosimetric Benefit: Organ-at-Risk Sparing

Examples shown reflect dosimetric improvements reported across MR-guided SBRT, CBCT-based online adaptation, and PSMA-PET response-adaptive SBRT.

Rectal D0.035cc ↓ up to 12 Gy

Bladder wall D0.035cc ↓ ~10 Gy

PSMA-PET response-adaptive SBRT (Li 2025)

Urethra 59% –> 93% meet constraints

MR-guided SBRT (Fink SMILE)

Constraint violations ↓ 79–93%

CBCT-based oART, (Eckl)

- Adaptive replanning reduces high-dose spill to rectum/bladder while restoring target coverage.
- Urethra constraint achievement improved in MR-guided oART series (e.g., 59% → 93% meeting goals).
- When planning time is non-trivial, consider intrafraction verification (MR cine or a second CBCT).

MRI-Guided Adaptive SBRT

- Superior soft-tissue contrast
- Real-time motion tracking
- Enables margin reduction

Fink CA et al., “Dosimetric Benefit of Online Treatment Plan Adaptation in Stereotactic Ultrahypofractionated MR-guided Radiotherapy for Localized Prostate Cancer,” Front Oncol 2023/2024.

MR-guided oART: dosimetric gains

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Fractions adapted

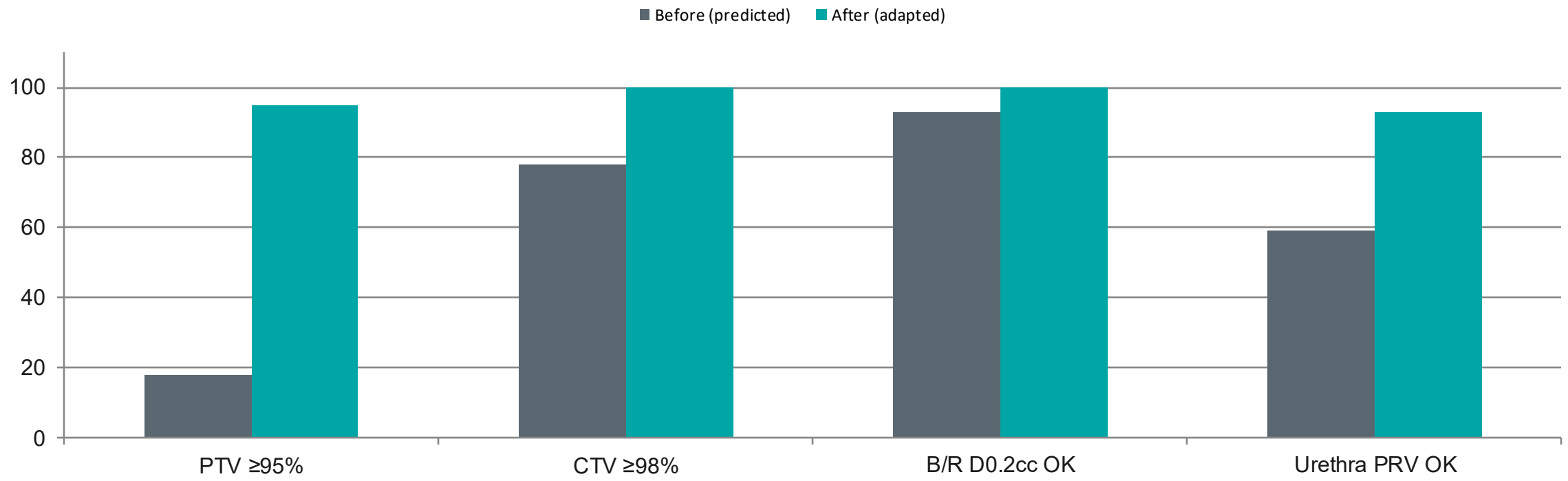
95% (152/160)

Mean coverage gain

+4.5% PTV | +1.4% CTV

Constraint adherence

Urethra 59% → 93%



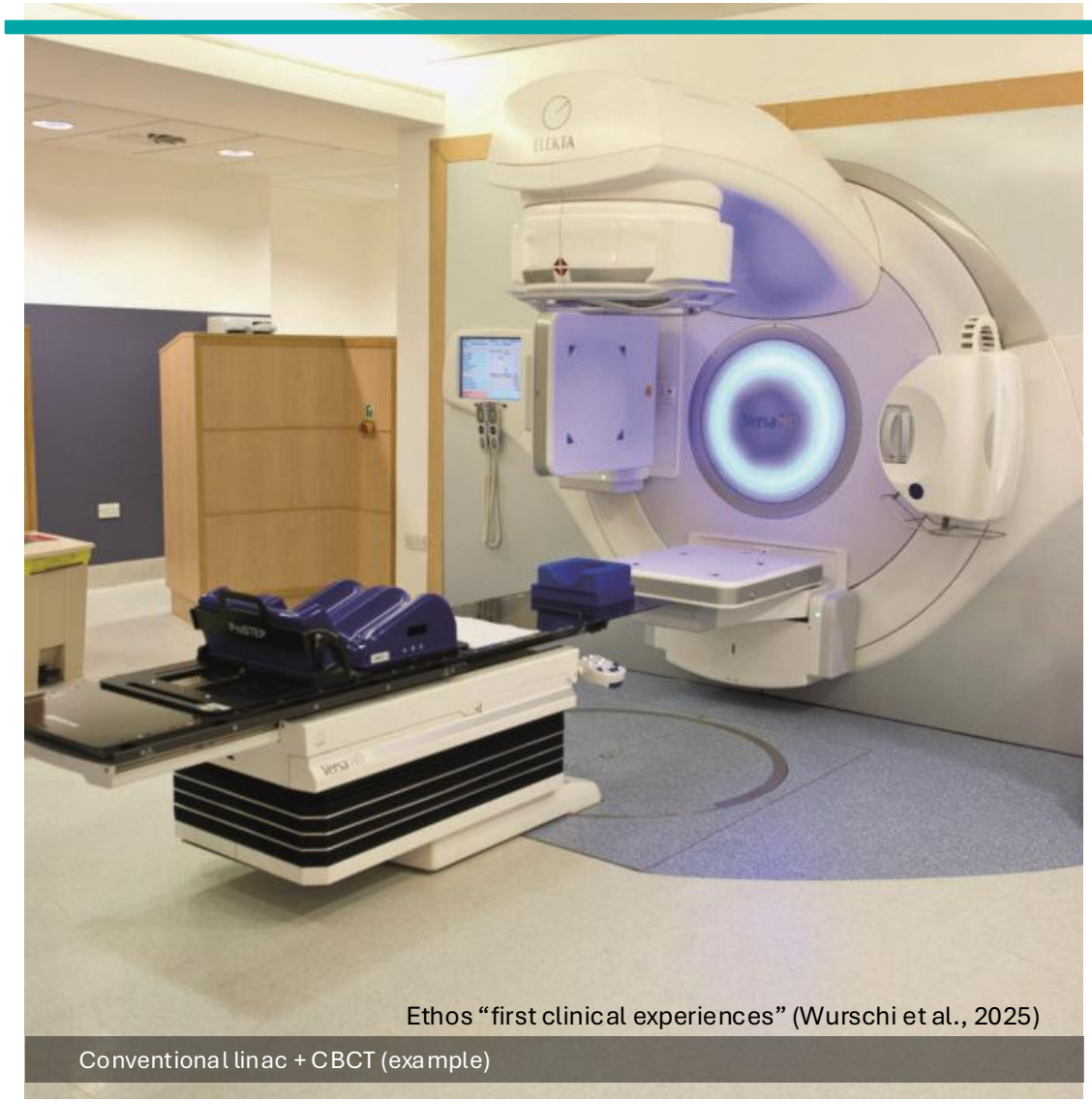
Fink et al., Frontiers in Oncology 2024

Percent of fractions meeting prespecified goals

CT-Guided Adaptive SBRT

- AI-driven auto-segmentation
- Median treatment time 25–32 min
- Scalable alternative

CBCT-guided oART: feasibility in ultra-hypofractionation



Ethos “first clinical experiences” (Wurschi et al., 2025)

Conventional linac + CBCT (example)

Key feasibility signals (n=7; 35 fractions)

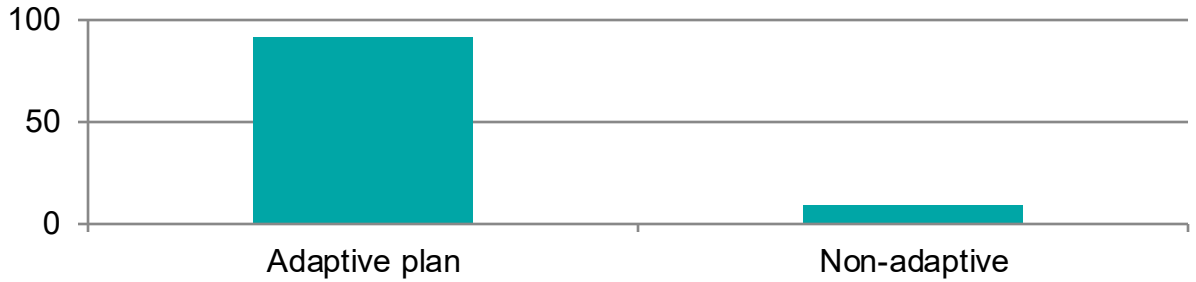
- Adaptive plan applied in 32/35 fractions (91.4%).
- Mean treatment time ~30 minutes per fraction.
- Target coverage improved (e.g., PTV D98%); OAR improvements more modest in this small series.
- A second CBCT recommended to compensate for intrafraction motion during planning.

Adaptive used

91.4%

Mean time / fx

30:17 min



Speed matters: adaptation on a standard linac

Concept: generate synthetic CT (sCT) from CBCT → fast plan modification

CBCT → sCT (DL) → SAM / SWO → Full reopt

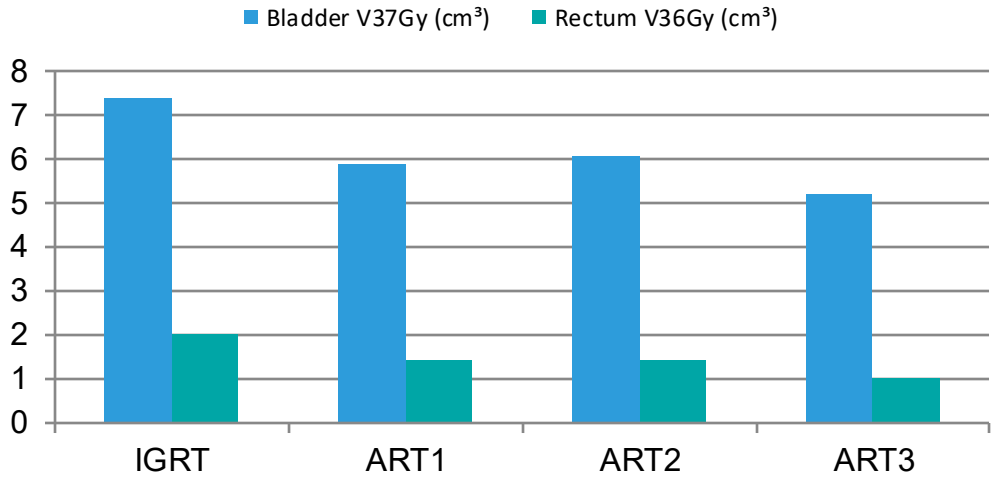
Avg. adaptation time

2.6 min (ART1)

Fast-adapt approaches represent selected workflows and are not equivalent to full adapt-to-shape re-optimization

Constraint violations

↓ 79–93%



Example: daily adaptation reduces high-dose volumes to bladder/rectum (means).

Eckl M et al., "Dosimetric Benefits of Daily Treatment Plan Adaptation for Prostate Cancer Stereotactic Body Radiotherapy," Radiation Oncology 2021

Workflow efficiency (what to budget per fraction)

Modern AI-integrated oART workflows can fit into ~25–32 minutes for prostate-only cases; complex cases may run longer (up to ~50+ minutes).

Segmentation + plan generation are the biggest time drivers—automation reduces variability with experience.

Offline or “fast-adapt” approaches (e.g., segment aperture morphing / fast reoptimization) can compress adaptation to a few minutes in some implementations ~2.6 min

.

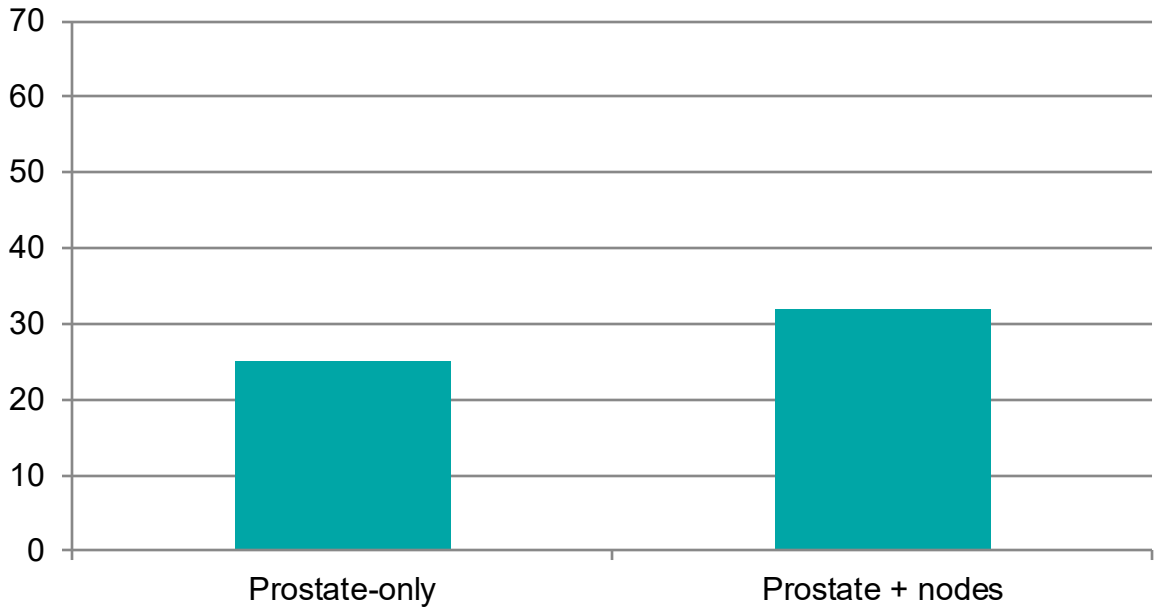
Step	Typical time
Imaging & setup	3–5 min
Auto-segmentation + review	5–8 min
Plan adaptation / optimization	6–10 min
Online QA & approval	3–5 min
Beam delivery	5–7 min
Total (typical)	**~25–32 min**

Preziosi et al, Wurschi et al, Alongi et al

Operational budgeting: aim for a consistent ~30 min slot for prostate-only oART

Workflow efficiency: AI-driven oART can fit clinic schedules

Median total time per session (end-to-end)



Preziosi et al., Radiation Oncology 2025 — AI-driven Ethos oART prostate.

Reported ranges

- Prostate-only: 14–34 min
- Prostate + nodes: 18–68 min
- Automation primarily helps segmentation + plan generation steps.

Operational takeaway

If your clinic can reliably allocate ~30 minutes per fraction for prostate-only cases, oART becomes practical—and variability shrinks with experience + automation.

Platforms: MR-guided vs CBCT-guided oART

MR-guided

- Superior soft-tissue contrast
- Real-time intrafraction tracking
- Enables tighter margins (e.g., 2 mm)
- Strong randomized toxicity signal (MIRAGE)

Best fit

- When shrinking margins or adding focal boosts
- Targets near mobile bowel (nodes / post-op bed)

CBCT-guided (standard linac)

- Scalable hardware footprint
- AI auto-segmentation + fast workflows
- Typical session ~25–32 min for prostate-only
- Intrafraction motion management may require re-imaging

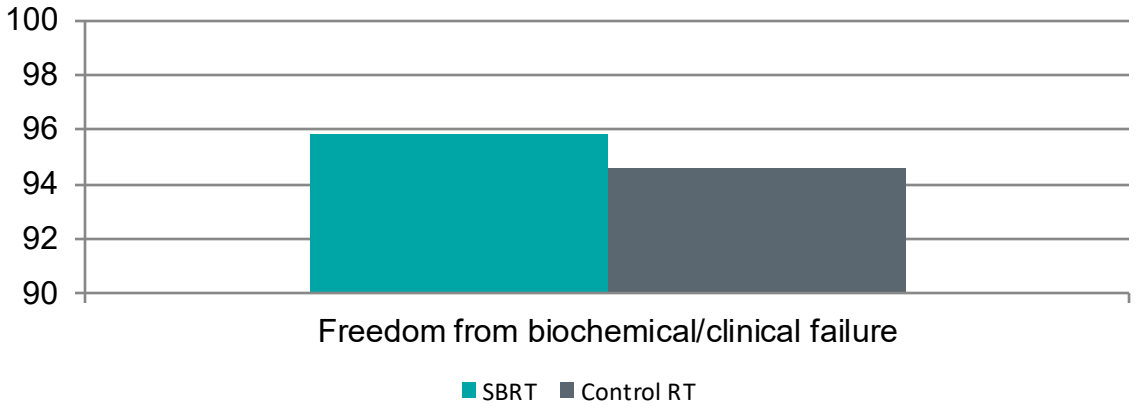
Best fit

- Broad adoption / throughput constraints
- When MR access is limited but oART benefits are desired

Fink et al, Wurschi et al, Preziosi et al

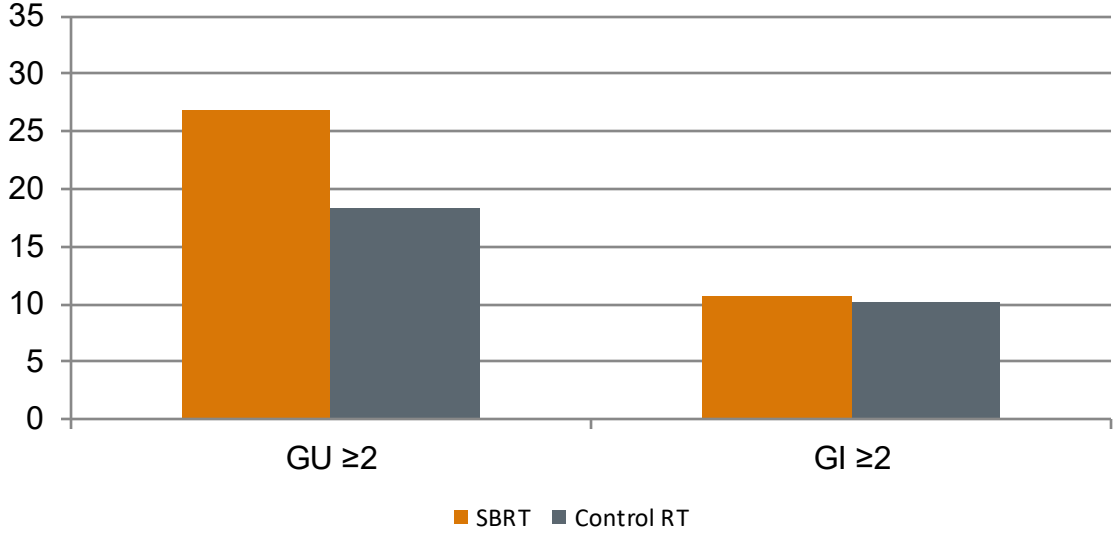
Clinical benchmark: SBRT is durable

Efficacy (5-year)



Noninferior: HR 0.73 (90% CI 0.48–1.12)

Late toxicity (5-year cumulative incidence)



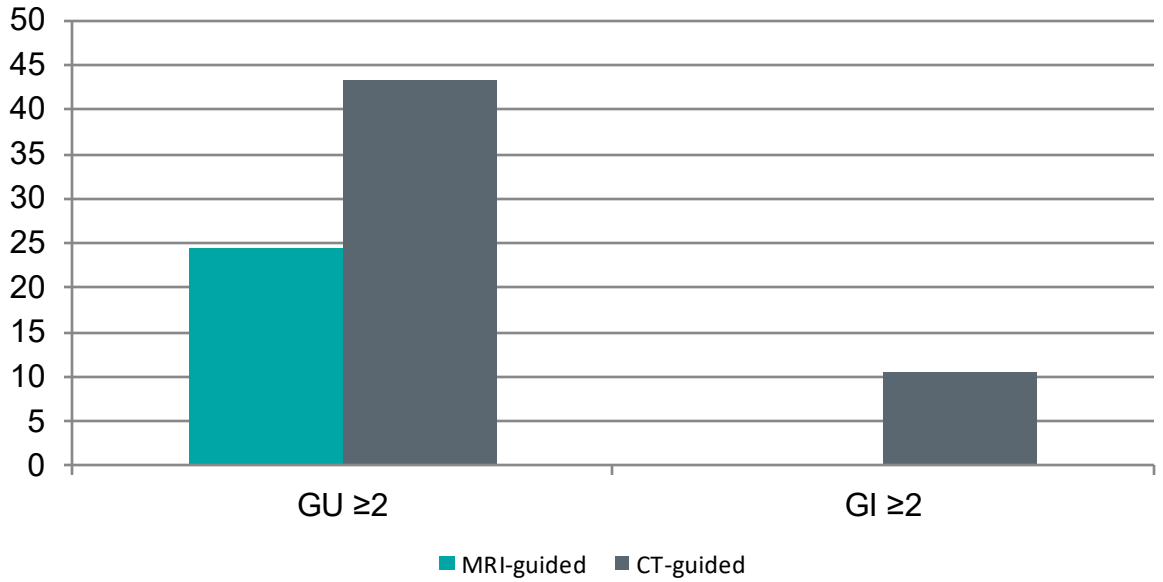
Disease control is excellent—next gains are toxicity reduction and enabling personalization (e.g., focal boosts).
When counseling: SBRT shortens treatment from 20–39 fractions to 5 with comparable control.

So what's left to improve?

SBRT already controls disease well. Adaptive workflows are most compelling where they can (a) reduce toxicity, (b) enable safe margin reduction, or (c) support focal dose escalation without paying an OAR penalty.

van As et al., "Phase 3 Trial of Stereotactic Body Radiotherapy in Localized Prostate Cancer," N Engl J Med 2024

Randomized evidence: MRI guidance reduces acute toxicity



Acute physician-scored toxicity (grade ≥2)

Patient-reported outcomes (1 month)

- IPSS worsening ≥15 points: 6.8% (MRI) vs 19.4% (CT)
- EPIC-26 bowel decline ≥12 points: 25% (MRI) vs 50% (CT)
- Absolute reductions in acute grade ≥2 toxicity: GU −19.0%, GI−10.5%.
- Mechanism: MRI guidance enabled smaller PTV margins (2 mm vs 4 mm).

Bottom line

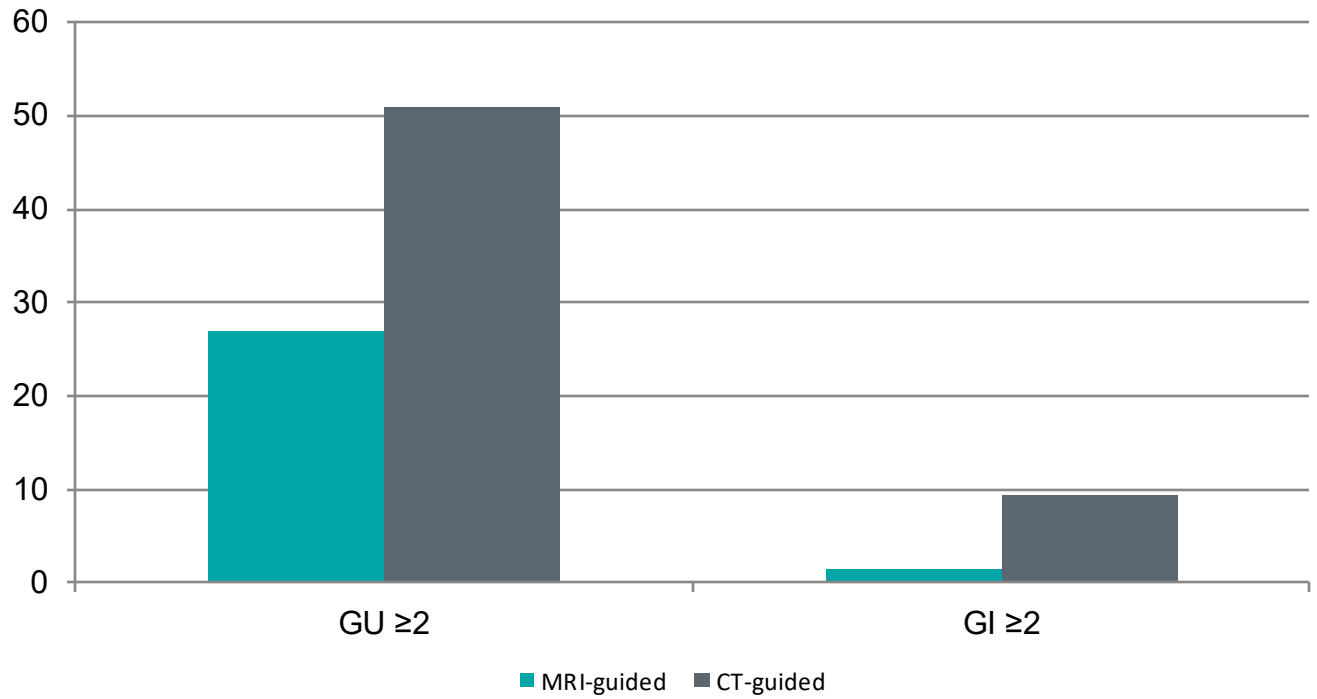
In a randomized trial, MRI guidance materially reduced acute GU/GI toxicity and early symptom burden.

MIRAGE was not an online adaptive trial; it demonstrated that MRI guidance enables aggressive margin reduction, which is the primary driver of toxicity reduction in prostate SBRT.

Kishan et al., "Magnetic Resonance Imaging–Guided vs Computed Tomography–Guided SBRT for Prostate Cancer (MIRAGE)," JAMA Oncol 2023

MIRAGE: benefits persist at 2 years (late toxicity)

Cumulative incidence of late grade ≥2 toxicity at 2 years



Interpretation

- Late GU signal is the key differentiator in prostate SBRT; MRI guidance roughly halves it at 2 years.
- Late GI toxicity is low overall, but still improved with MRI guidance.
- These results come from aggressive margin reduction enabled by MRI tracking/visualization.

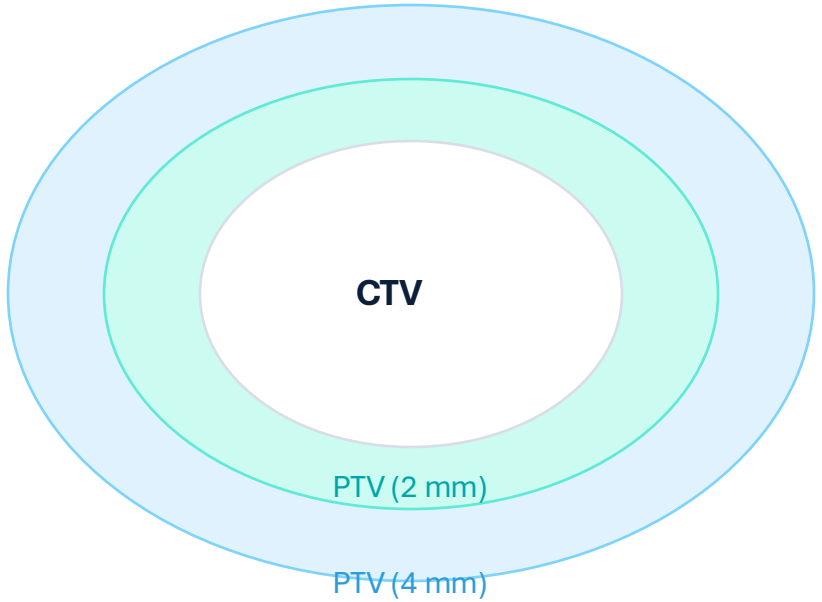
Kishan et al., MIRAGE 2-year outcomes, European Urology 2025

Important nuance

MIRAGE tested MRI guidance for margin reduction (2 mm vs 4 mm) — not mandatory online replanning. Online adaptation may add another layer of robustness when anatomy is unfavorable.

Mechanism: what drives toxicity reduction?

Primary driver: margin reduction enabled by MRI visualization and motion management (not mandatory online replanning). Online adaptation provides added robustness on unfavorable anatomy days



What's doing the work?

- Margin reduction: biggest proven driver of toxicity benefit (enabled by visualization + intrafraction monitoring).
- Online adaptation: adds robustness on unfavorable anatomy days (coverage drift, urethra/rectum constraints).
- Practical: pair tighter margins with reliable motion management + fast re-optimization + QA.

Practical implication

If a platform can reliably support (1) intrafraction monitoring and (2) fast reoptimization, clinics can consider narrower margins and/or safe focal escalation.

- MIRAGE trial
- Courtney et al., post-hoc dosimetric analysis (MR vs reduced-margin CT SBRT).

Clinical outcomes

SBRT benchmark + what MR guidance adds?

Reduced toxicity via margin reduction with daily adaptation providing robustness on unfavorable anatomy days

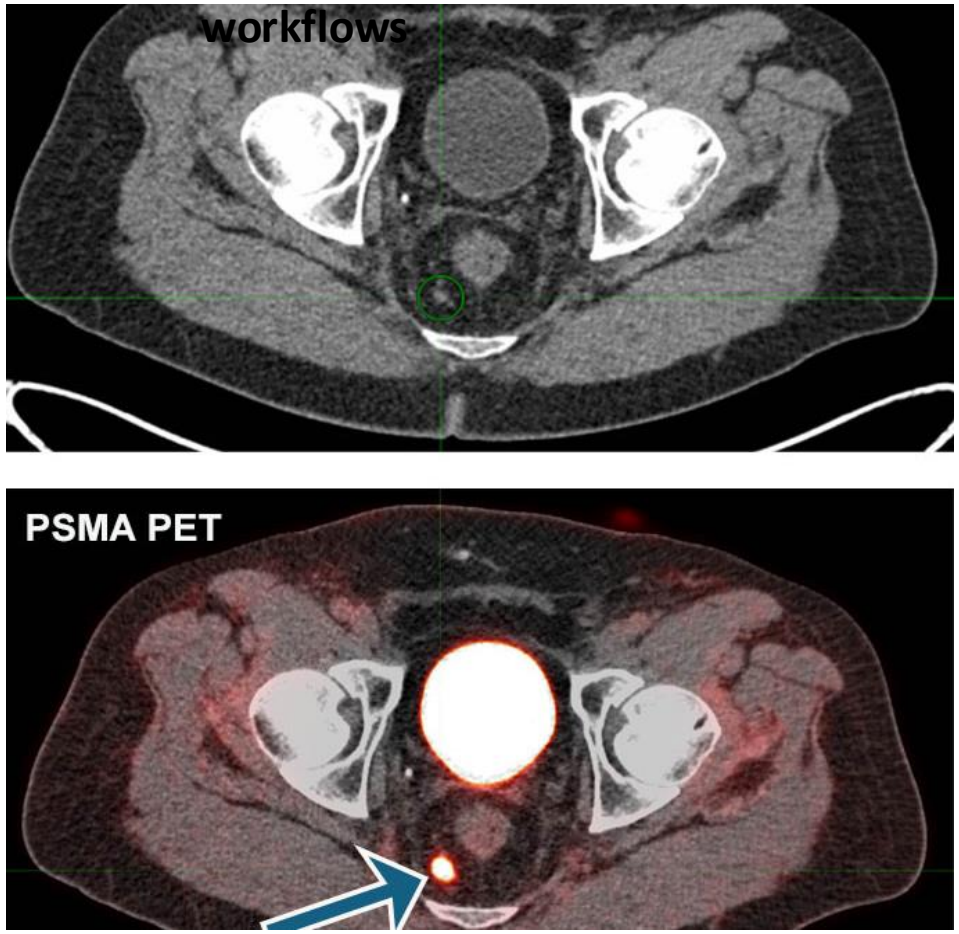
Outcome (≥ Grade 2)	CT-guided SBRT	MR-guided SBRT
Acute GU	~41%	**22%**
Acute GI	~10.5%	**0%**
2-yr Late GU	**51%**	**27%**
2-yr Late GI	**9.5%**	**1.4%**

Treatment personalization

Geometry → Biology → Uncertainty

Personalization: PSMA-PET response-adaptive microboosting

High-risk prostate cancer treated with 5-fraction SBRT/SABR using adaptive workflows

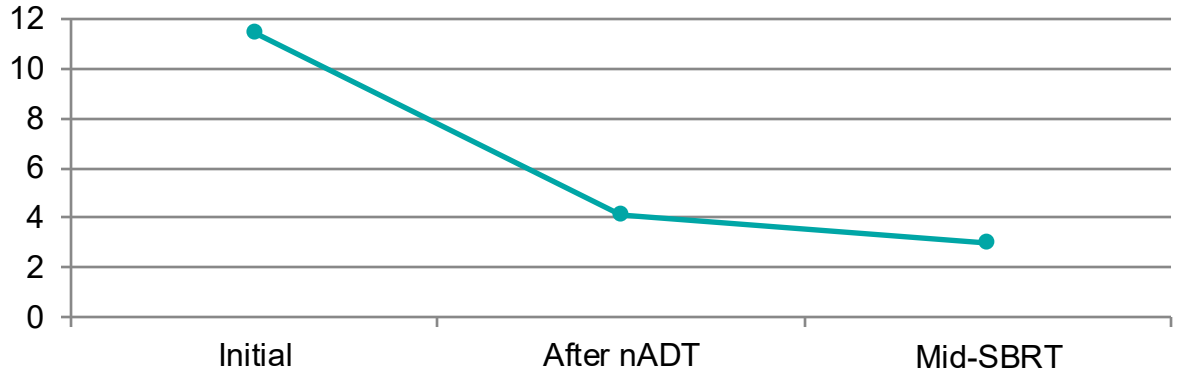


Response-adaptive dominant intraprostatic lesion (DIL) boosting during prostate SBRT

Li et al., Cancers (MDPI) 2025

Response-based boost adaptation (pilot feasibility)

- Sequential PSMA-PET after neoadjuvant ADT and mid-treatment refines boost volumes.
- Mean dominant intraprostatic lesion (DIL) volume shrank 11.4 cc → 4.1 cc → 3.0 cc.
- OAR doses dropped meaningfully while maintaining coverage (e.g., rectal wall D0.035cc ↓ up to 12 Gy).



Rectal wall D0.035cc

↓ up to 12 Gy

Bladder wall D0.035cc

52.3 → 42.9 Gy

Example: PSMA PET detects small lesions missed by CT

PSMA-PET response-adaptive microboosting (concept)

Goal: escalate dose to dominant intraprostatic lesion (DIL) while protecting urethra/rectum/bladder.

Sequential PSMA-PET (after neoadjuvant ADT and mid-treatment) can shrink/refine boost volumes.

Reported example: mean DIL volume 11.4 cc → 4.1 cc → 3.0 cc, enabling OAR dose reductions while maintaining target coverage.

11.4 → 3.0 cc

Mean DIL volume change
(with response adaptation)

≤12 Gy

Rectal wall
D0.035cc ↓

52.3 → 42.9 Gy

Bladder wall dose
(example)

Implementation and workflow

- Response-adapted DIL volumes were incorporated via hybrid offline → online adaptation without major workflow delays.
- Feasible on routine adaptive systems (MR-Linac and CBCT-guided ART), providing **biologically personalized focal boosting** while maintaining daily adaptive planning.

Li R et al., “Clinical Implementation of PSMA-PET Guided Tumor Response-Based Boost Adaptation in Online Adaptive Radiotherapy for High-Risk Prostate Cancer,” Cancers 2025

Who benefits most?

Use adaptation where it changes decisions

Patient factors

- Baseline LUTS (higher IPSS)
- Large gland / median lobe
- IBD history / prior TURP (case-by-case)
- Anticoagulation/avoiding fiducials

Target factors

- Seminal vesicle involvement
- Pelvic nodes near bowel
- Focal boosts (DIL)
- Re-irradiation / narrow therapeutic window

System factors

- Real-time intrafraction monitoring
- Reliable adaptive planning + QA
- Throughput (time slot) + staffing
- Contouring/auto-seg performance

Risk-adapted margins + “adapt when it matters”

Rule of thumb: prioritize adaptation when you’re trying to shrink margins or add a focal boost.

Poon et al., MRgSBRT outcomes; Nicosia et al.; Fink; Wurschi.

Personalization frontier: plan libraries & digital twins

Plan libraries (pre-computed options)

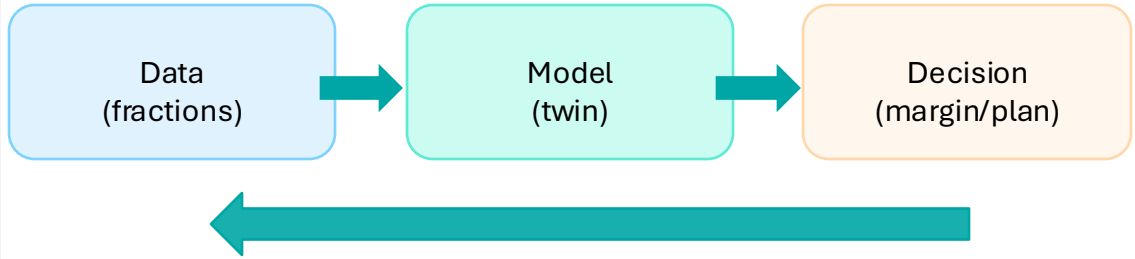
- Generate motion-informed plans ahead of time.
- Select the best plan on the day using scoring metrics.
- Can reduce online compute time while keeping robustness.

Still early—but these approaches aim to make personalization scalable.

Shah et al., knowledge-based plan library-guided adaptive proton SABR for prostate

Digital twin (patient-specific model)

- Learn patient-specific setup uncertainty from prior fractions.
- Predict which margin/plan will remain robust.
- Supports individualized margins and faster plan selection (especially in proton SBRT).



Faster decisions, patient-specific uncertainty

Chang et al., CBCT + digital twin concept for adaptive proton therapy.

Safety & QA in oART

oART introduces new failure modes → build a “QA habit” into the workflow

What must be true before you scale

Minimum checklist

- Image quality check (MR/CBCT) and anatomy suitability (bladder/rectum) artifacts.
- Contour review focus region (around PTV) + critical OARs (rectum, bladder, urethra).
- Plan comparison: predicted vs adapted (coverage + constraints tradeoffs).
- Independent dose calculation / secondary check before beam-on.
- Intrafraction verification (e.g., second CBCT or MR cine) when planning time is non-trivial.
- Document: what adapted, why, and what constraints were traded.

Operational reality: throughput is a safety issue—don’t scale faster than your QA capacity.

Implementation: measure what matters

Suggested oART KPIs

Domain	Example metrics (track per fraction and per patient)
Target	PTV V95% / D98%; CTV coverage; hotspot control
OAR	Rectum/bladder high-dose metrics; urethra PRV constraint adherence
Process	Adaptation rate; time per step; frequency of re-imaging (e.g., 2nd CBCT)
Safety	Secondary check pass rate; contour edits; near-miss log
Patient	Acute symptoms (IPSS/EPIC); late GU/GI toxicity; QoL recovery trajectories

Tip: build a small "fraction audit" dataset—most insights come from a few dozen well-reviewed sessions.

Challenges in oART – moving beyond rigid anatomy

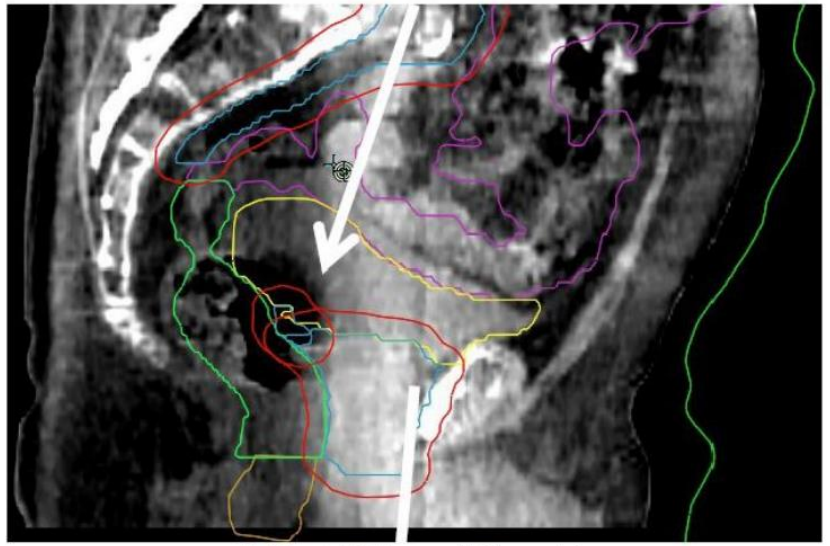
- Speed
- DIR

Challenges in oART – moving beyond rigid anatomy

i) speed of the process

- Prostate patient treated with ETHOS @PARTICLE (Leuven)
- Structures contoured on CBCT acquired before treatment
- They are projected on the CBCT acquired after treatment
- **Shift of the irradiated PTV** (seminal vescicles largely in the rectum) occurred **between PRE and POST treatment CBCT**

Gas bubble



E. Sterpin (KU Leuven/UCLouvain)

D Dechambre, X Geets (Clinique Universitaries Saint Luc)

Need a Fast Adaptation workflow!

Challenges in oART – moving beyond rigid anatomy

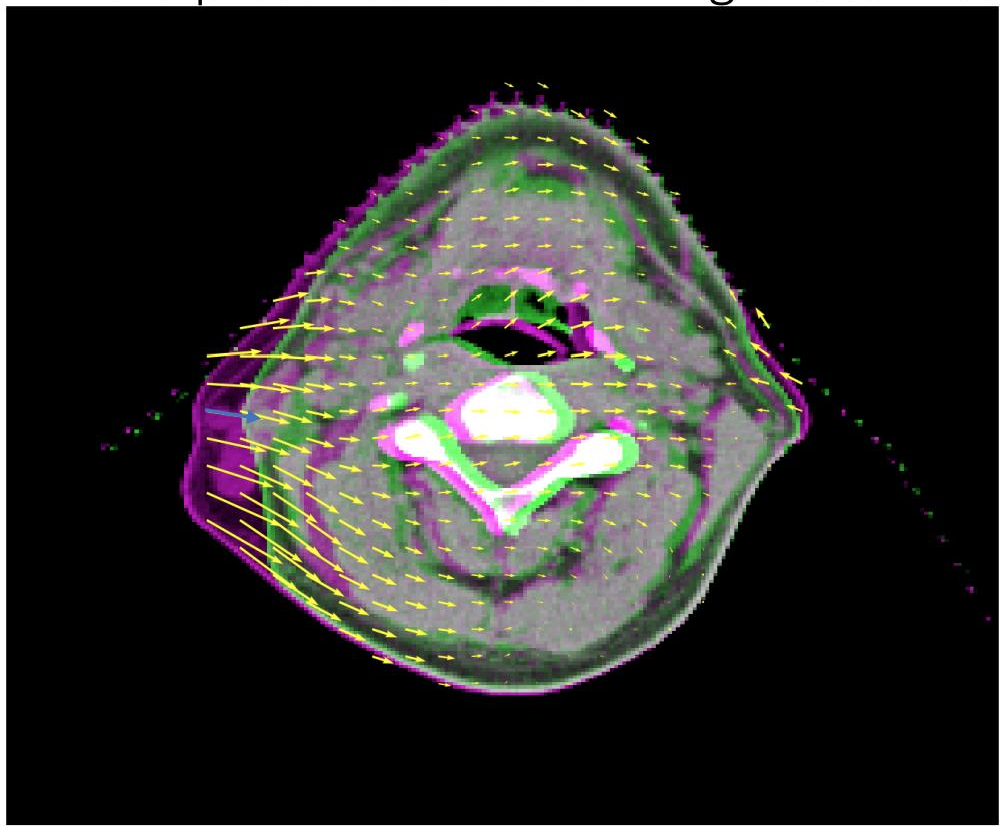
i) speed of the process

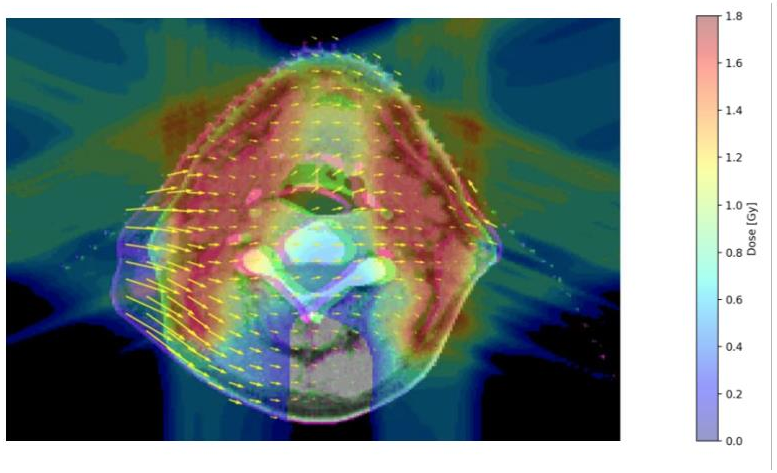
- Daily contours: bottleneck
  - Auto-contours are never 100%
  - What is the dosimetric impact of contouring uncertainties?
  - This can result in **potential** delivery uncertainties if unaccounted for
  - Need contour guidance QA tool?
    - For geometric accuracy
    - Dosimetric impact
    - Identify sensitive part of contour to be reviewed

Challenges in oART – moving beyond rigid anatomy

ii) The need for deformable image registration (DIR) to accumulate the dose

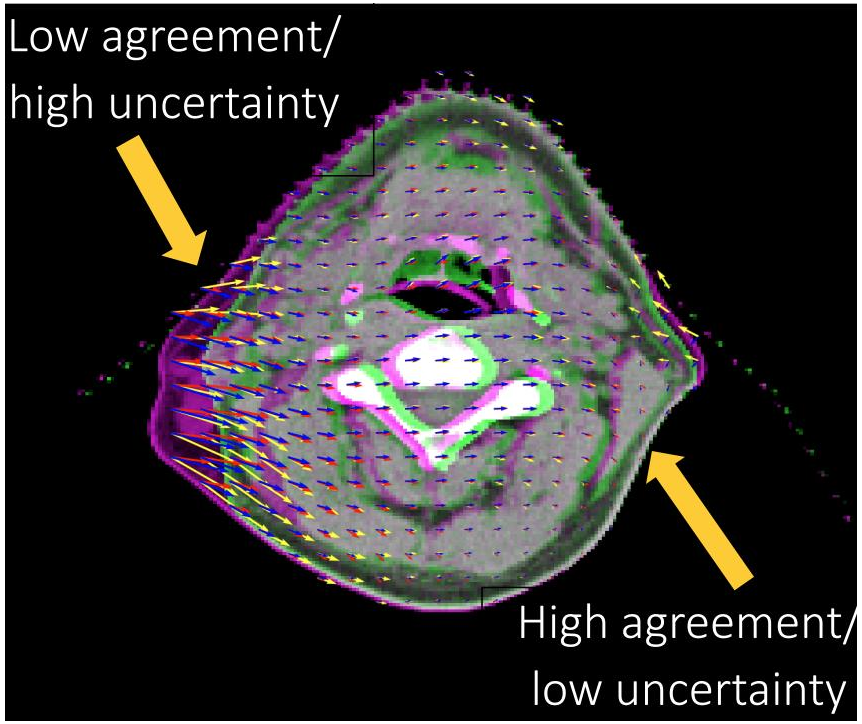
In the presence of deforming anatomies



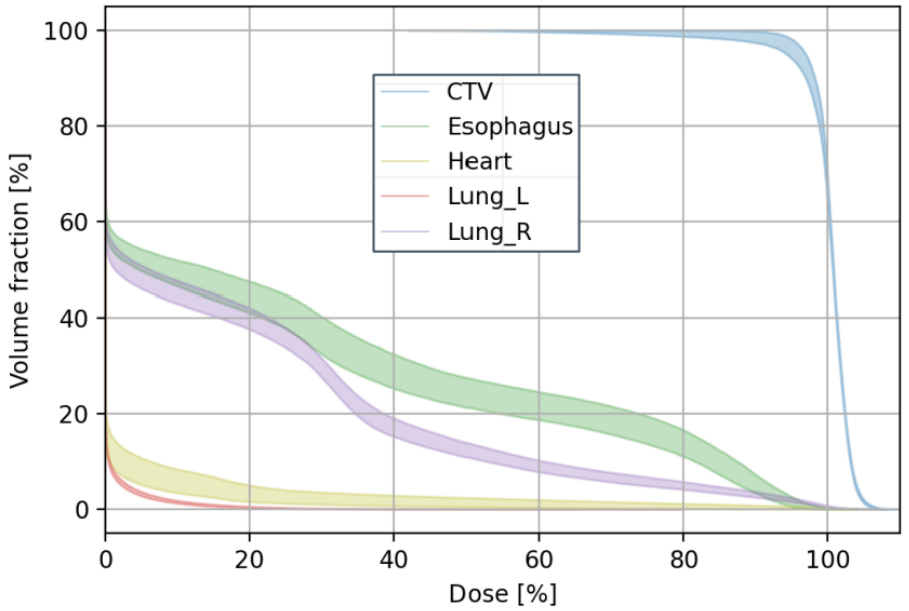


Challenges in oART – moving beyond rigid anatomy

ii) The need for deformable image registration (DIR) to accumulate the dose



- DIR is uncertain because of the many degrees of freedom
- Perfect DIR does not exist
- Need an uncertainty model to calculate dose accumulation uncertainty



Leveraging Mult-Platform Image Guidance for Prostate SBRT at LCI

Varian® TrueBeam™

Radixact™

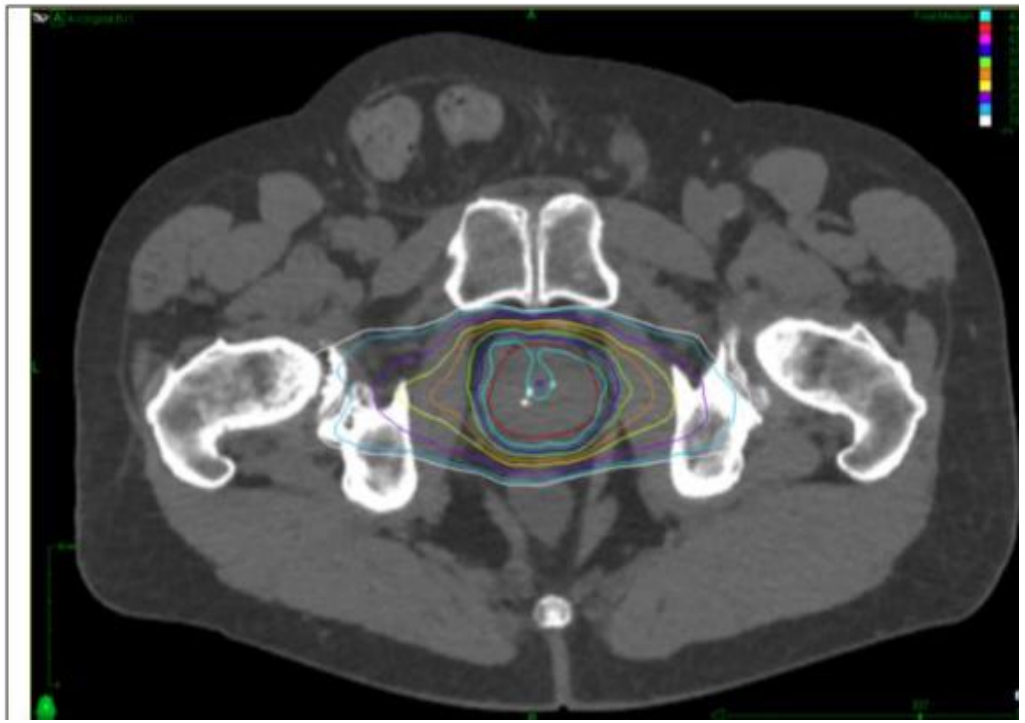
CyberKnife® M6™

ViewRay MRIdian

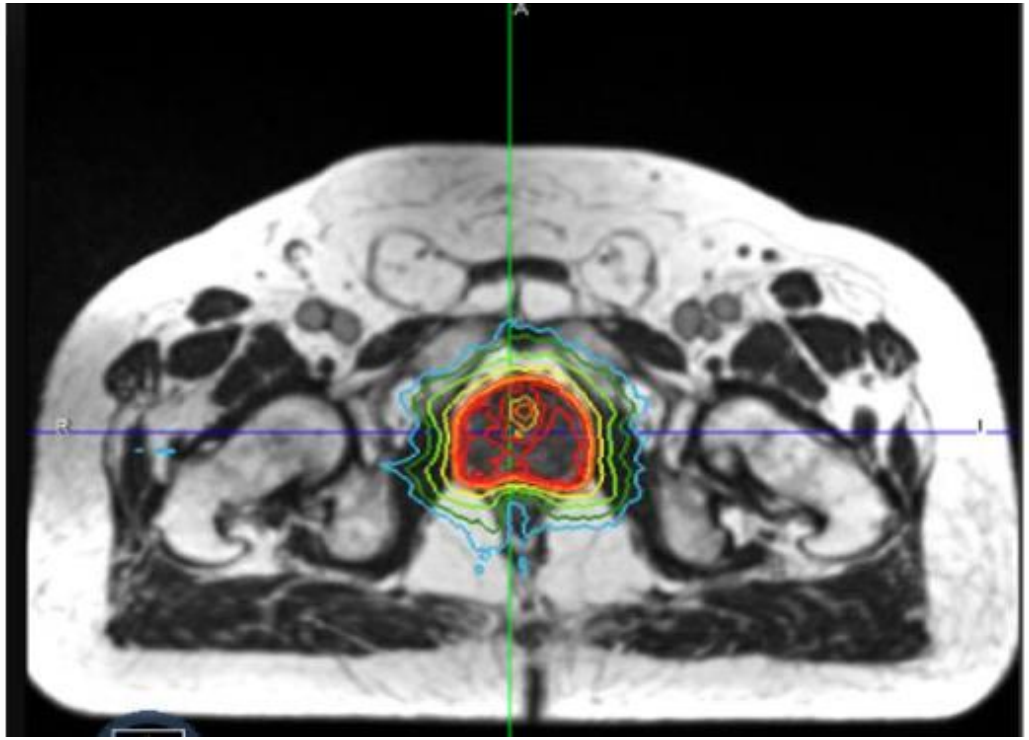
What's coming at LCI?

Single Room Proton Therapy System

ViewRay MR-LINAC and CyberKnife as primary platforms



CyberKnife



ViewRay MRIdian

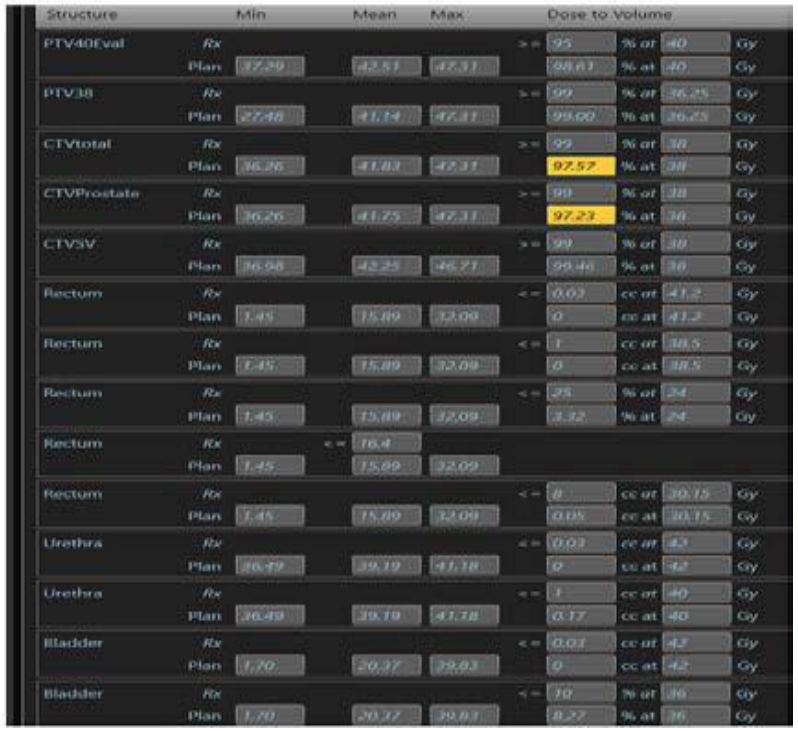
Patients with unilateral and Bilateral Prosthesis

Table 1 Treatment Planning Objectives and Dose Constraints for Prostate SBRT 40Gy in 5 fractions

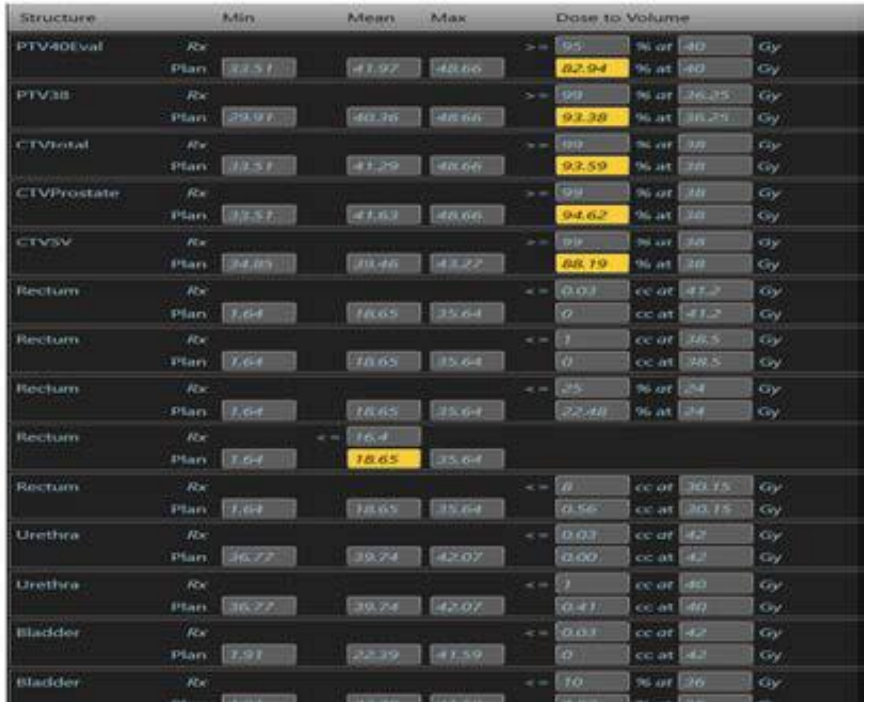
Structure	Dose–Volume Constraint
Prostate_40Gy	V40Gy ≥ 95%
PTV_36.25Gy	V36.25Gy ≥ 95%
Seminal Vesicles (proximal 1 cm)	V38Gy ≥ 95%
Bladder	D0.03cc ≤ 38 Gy
Bladder	D5cc ≤ 37.5 Gy
Rectum	D0.03cc ≤ 38 Gy
Rectum	D1cc ≤ 36 Gy
Rectum	D20cc ≤ 25 Gy
Urethra	D0.03cc ≤ 38.7 Gy
Sigmoid Colon	D0.03cc ≤ 33 Gy
Sigmoid Colon	D10cc ≤ 12.5 Gy
Penile Bulb	D0.03cc ≤ 50 Gy
Penile Bulb	D3cc ≤ 30 Gy
Femoral Heads	V30Gy ≤ 10%

Dose–volume metrics are reported as minimum target coverage (VxGy) or maximum dose to specified volumes (Dxcc).

Unilateral prosthesis: Meeting all dosimetric constraints



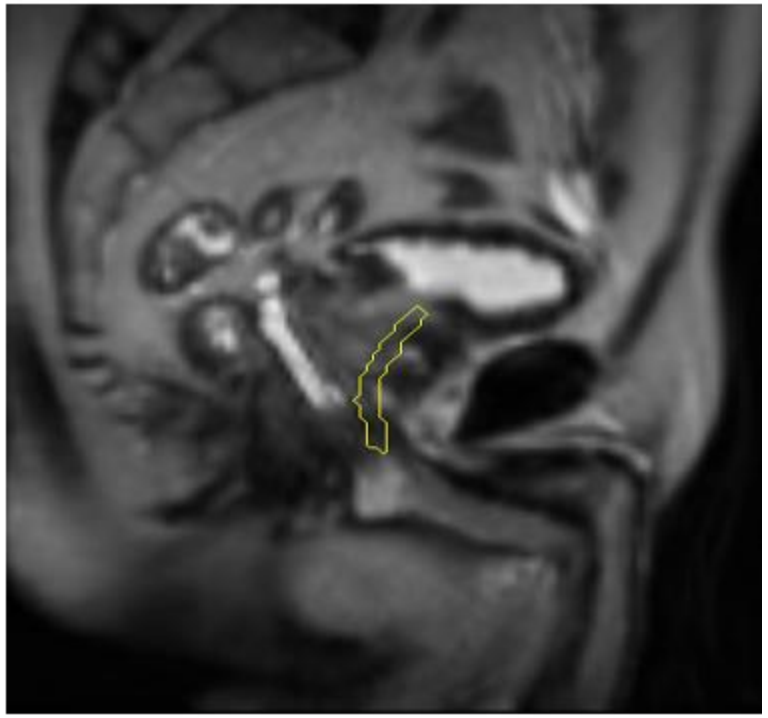
Bilateral prosthesis: Failing Target coverage and OARs dosimetric constraints



Post-Void Limited-Field T2 MRI in ViewRay MRIdian (0.35T): Improving Urethral Confidence in Prostate SBRT

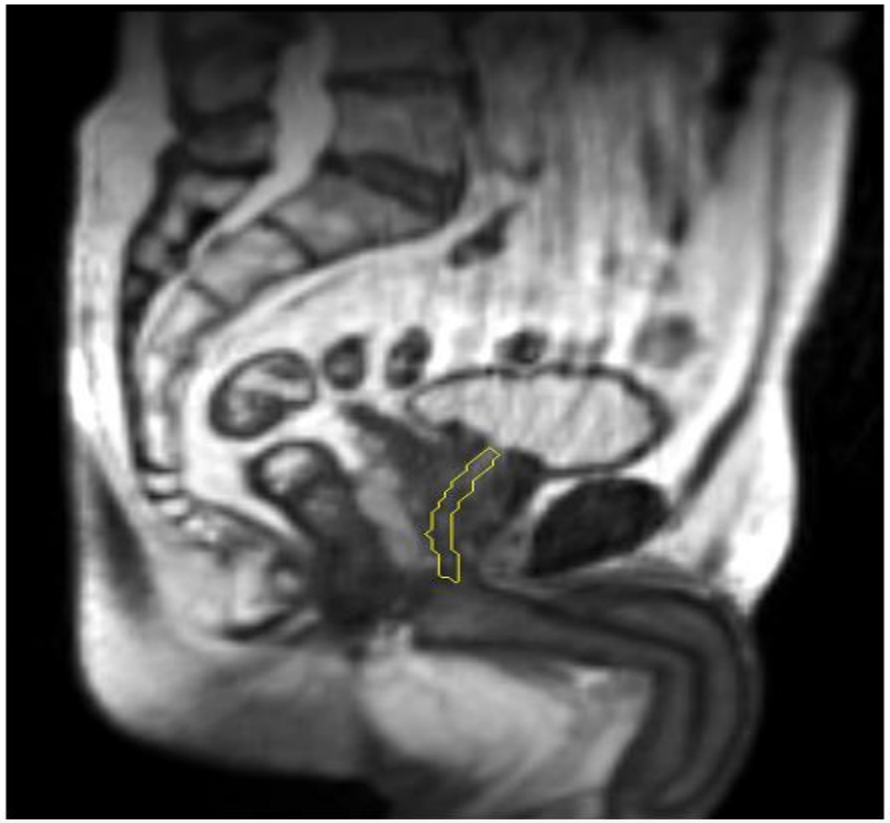
Sagittal View: Post-Void Limited FOV T2 Weighted

Images Acquired in 0.35T ViewRay MR -LINAC



Sagittal View: TRUFI planning Images

Acquired in 0.35T ViewRay MR -LINAC



Evidence gaps (and what to watch next)

What we know vs what we still need

- Randomized data: MRI guidance reduces acute and 2-year late toxicity (MIRAGE).
- Dosimetric data: online adaptation restores coverage/constraints when anatomy is unfavorable (MR and CBCT).
- Long-term comparative oncologic outcomes (MRI-guided/adaptive vs standard SBRT) are still immature; SBRT benchmark remains excellent (PACE-B).
- Key research need: multi-center, scalable workflows + patient selection + cost-effectiveness.
- Early programs (e.g., master protocols/registries) can speed device evaluation, but disease-control endpoints require time.

Watch list: MIRAGE longer follow-up • Master protocols/registries for safety • Faster contouring/QA automation • Response-adaptive boosts (PSMA-PET)

Watch list (examples)

- MIRAGE longer follow-up for efficacy endpoints (planned).
- Master SMART protocol pooled analyses for safety/feasibility across sites.
- Automation: faster/safer contouring + plan QA.
- Personalization: response-adaptive boost strategies (e.g., PSMA-PET microboost).

Key takeaways

- SBRT already provides excellent long-term control (PACE-B); the “next gains” are toxicity and personalization.
- oART is frequently needed and improves coverage + constraint adherence when anatomy drifts (MR and CBCT).
- MR-guided oART can be used in most fractions and materially improves coverage/constraint adherence when anatomy drifts (Fink/SMILE).
- CBCT-guided oART is feasible in ultra-hypofractionation with ~30-minute sessions in early experience (Wurschi).
- Randomized evidence: MRI guidance enabling smaller margins reduces acute and 2-year late GU/GI toxicity (MIRAGE).
- Personalization is moving from geometry to biology (PSMA-PET response-adaptive boosts) and modeling/patient specific uncertainty (plan libraries/digital twins).
- Scale safely: build a repeatable QA checklist and track KPIs per fraction.
- Online adaptive proton therapy *(early clinical feasibility but no prostate SBRT outcome data)*

Clinical Take-Home Messages

- Adaptive SBRT improves precision
- Clear toxicity & QoL benefits
- No concerning early signals for compromised oncologic control - Long-term comparative oncologic outcomes are maturing
- Online adaptive radiotherapy is an effective way to mitigate anatomical changes
- But an adaptive workflow is more than adaptation: it enables daily decision-making, potentially reducing margins, improving consistency of delivered dose, and opening the door to safe escalation and personalization
- Online adaptive proton therapy

THANK YOU

QUESTIONS