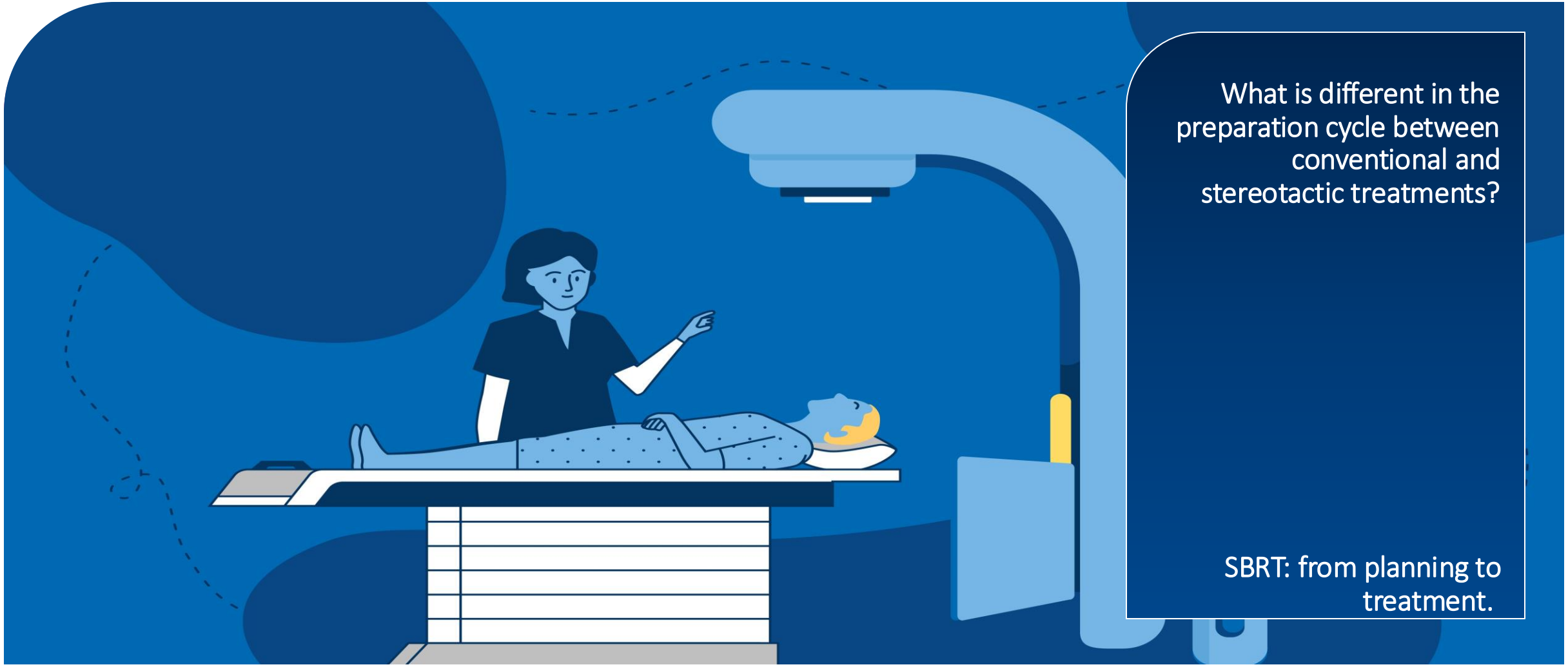

What is different in the preparation cycle between conventional and stereotactic treatments?

SBRT: from planning to treatment.

H.U.B
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B-STRO 2025
RTT PMC

01

INTRODUCTION

INTRODUCTION

Summary

01
Objectives

02
Radiobiology and Physics

03
Clinical Aspects

OBJECTIVES

- Present SBRT: principles, indications, and limitations
- Radiobiological and dosimetric comparison vs conventional RT
- Physical constraints and SBRT planning
- Site-specific applications (institutional schemes >5 Gy/fx)
- Re-irradiation & palliation,
- Practical role of RTTs in the SBRT workflow

02

RADIOBIOLOGY AND PHYSICS

Why does SBRT work?

- High dose per fraction (1–5 fx) → specific biological effects (high BED)
- Vascular damage + endothelial apoptosis + microenvironmental changes
- Potential immunomodulatory effect
- **Clinical outcome**: strong local control if OARs are protected

LQ Model, BED, and High-Dose Limits

- **BED** = n·d × (1 + d / (α/β)) — comparative tool
- Reliable for conventional fractionation; caution for d > 10–15 Gy
- Alternative models available (modified LQ, USC) — BED remains a practical and widely used reference

LQ Model, BED, and High-Dose Limits

Alpha/beta (α/β) ratio is defined in radiobiology as a measure of intrinsic radiosensitivity of a specific tissue, measured in Gy, and often considered as being 3 Gy for late-responding normal tissues and 10 Gy for rapidly proliferating carcinomas (Fowler, 1989). In the linear quadratic model, a widely accepted model to describe radiation cell killing, α and β are two constants representing two processes of radiation induced cell death, and their ratio represents a measure of the relative importance of the two processes (Astrahan, 2008).

Stereotactic body radiation therapy (SBRT) on renal cell carcinoma, an overview of technical aspects, biological rationale and current literature

G. Francolini [a], B. Detti [a], G. Ingrosso [b], I. Desideri [a], C. Becherini [a], G. Carta [a], D. Pezzulla [a], G. Caramia [a], L. Dominici [a], V. Maragna [a], M.A. Teriaca [a], M. Bottero [b], L. Livi [a]

LQ Model, BED, and High-Dose Limits

- **α/β** = tissue sensitivity to fractionation (in Gy)
- **High α/β (~10 Gy)**: most tumors and early-responding tissues — little sensitivity to fraction size
- **Low α/β (≈ 2–3 Gy)**: late-responding normal tissues (spinal cord, rectum) — very sensitive to fraction size
- **Prostate α/β ≈ 1.5 Gy**: exceptionally low, favoring hypofractionation

- **Lung (α/β = 10)**: 48 Gy / 4 fx → d = 12 Gy → BED_{10} = 105.6 Gy
- **Spinal cord (α/β = 2)**: 12 Gy / 1 fx → BED_2 = 84 Gy — extremely high, avoid
- **Prostate (α/β = 1.5)**: 36.25 Gy / 5 fx → d = 7.25 Gy → $BED_{1.5}$ ≈ 211.6 Gy — huge biological dose explaining success of hypofractionation

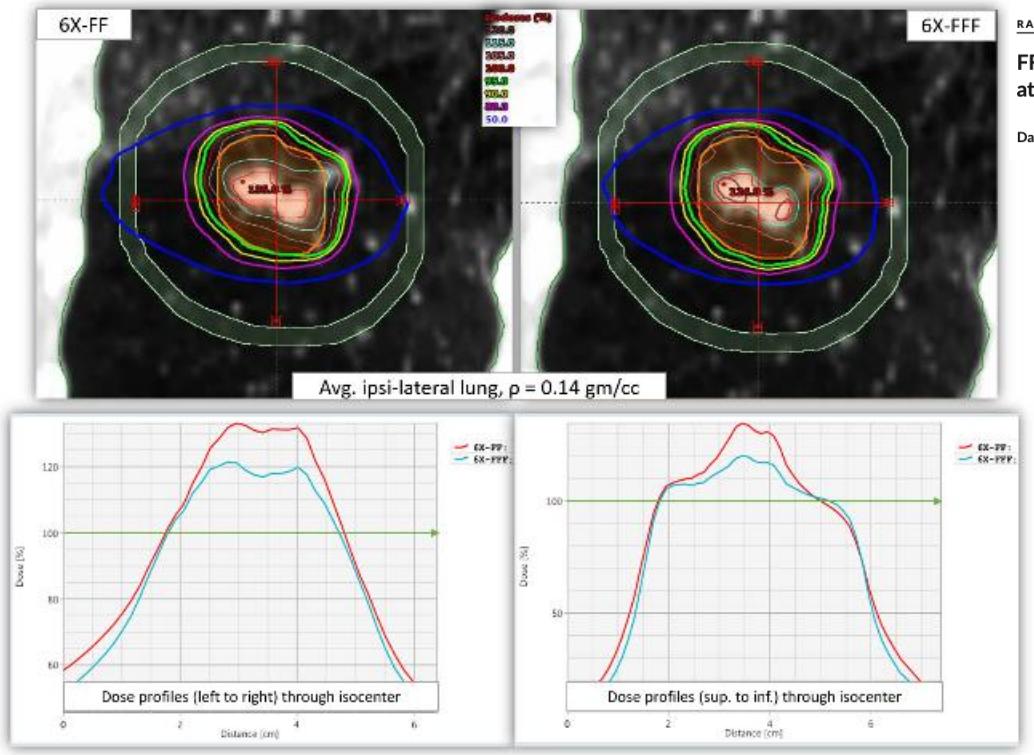
Physics & Planning

- Recommended algorithms: **Monte Carlo** / type-B (not recommended for lung)
- **Grid resolution** ≤ 2 mm
- Planning criteria: GTV/CTV/PTV coverage, conformity index, sharp dose gradient
- Reduced margins: typically 2–5 mm (can be < 2 mm with MRI guidance or tracking, or even no margin-free)
- VMAT/IMRT? — depending on site and technique

Beam Energy, Arcs & MU (key Trade-offs)

- **6 MV FFF beams** → higher dose rate, significantly reduced beam-on time; better OAR sparing for small/intermediate targets.
- **Flattened 6 MV (FF)** may be preferred for larger or off-axis targets where beam uniformity helps.
- **More arcs (1–3)**, including non-coplanar, improve conformity & reduce OAR dose; diminishing returns beyond ~3 arcs.
- More arcs usually mean **increased MU**, **longer delivery**, **higher complexity**.
- MU optimization (constraints, priorities) can reduce MU/Gy without losing plan quality.
- QA should benchmark **MU, beam-on time, dose fall-off** for each site, energy, and arc strategy.

Beam Energy, Arcs & MU (key Trade-offs)



RADIATION ONCOLOGY PHYSICS

WILEY

FFF-VMAT for SBRT of lung lesions: Improves dose coverage at tumor-lung interface compared to flattened beams

Damodar Pokhrel | Matthew Halfman | Lana Sanford

FIG. 3. Upper panel: Isodose distributions from 6X-FF (left) and 6X-FFF (right) plans in coronal views for patient #6 as shown in Figure 1. Lower panel: Corresponding radial dose profiles drawn through the isocenter. Bottom left shows the dose profiles from left to right and the bottom right shows the dose profiles from superior to inferior directions (within D2 cm). The green lines on each graph show that both plans were normalized to get 95% of the target to receive 100% of the prescription dose. For identical target coverage, the ITV and the out-of-field doses (intermediate dose-spillage and dose to the OAR) were higher with 6X-FF beams. ITV, Internal target volume; OAR, organs-at-risk.

Beam Energy, Arcs & MU (key Trade-offs)

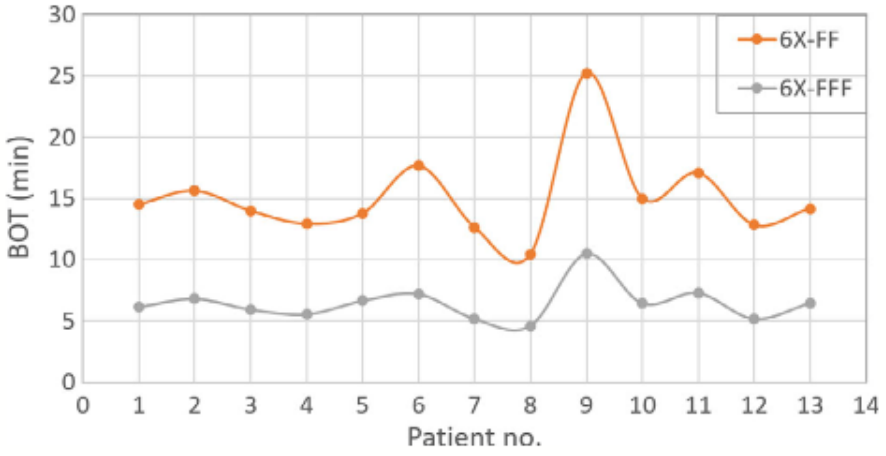


Fig. 4. Total BOT on a per-patient basis, for all 13-lung SBRT patients treated with a single dose of 30 Gy. The mean value of total BOT was 6.5 ± 1.5 min (with 6X-FFF) compared to 15.1 ± 3.6 min (with 6X-FF) showing an on average improvement by a factor of approximately 2.5. BOT, beam-on time; SBRT, stereotactic body radiation therapy.

RADIATION ONCOLOGY PHYSICS

WILEY

FFF-VMAT for SBRT of lung lesions: Improves dose coverage at tumor-lung interface compared to flattened beams

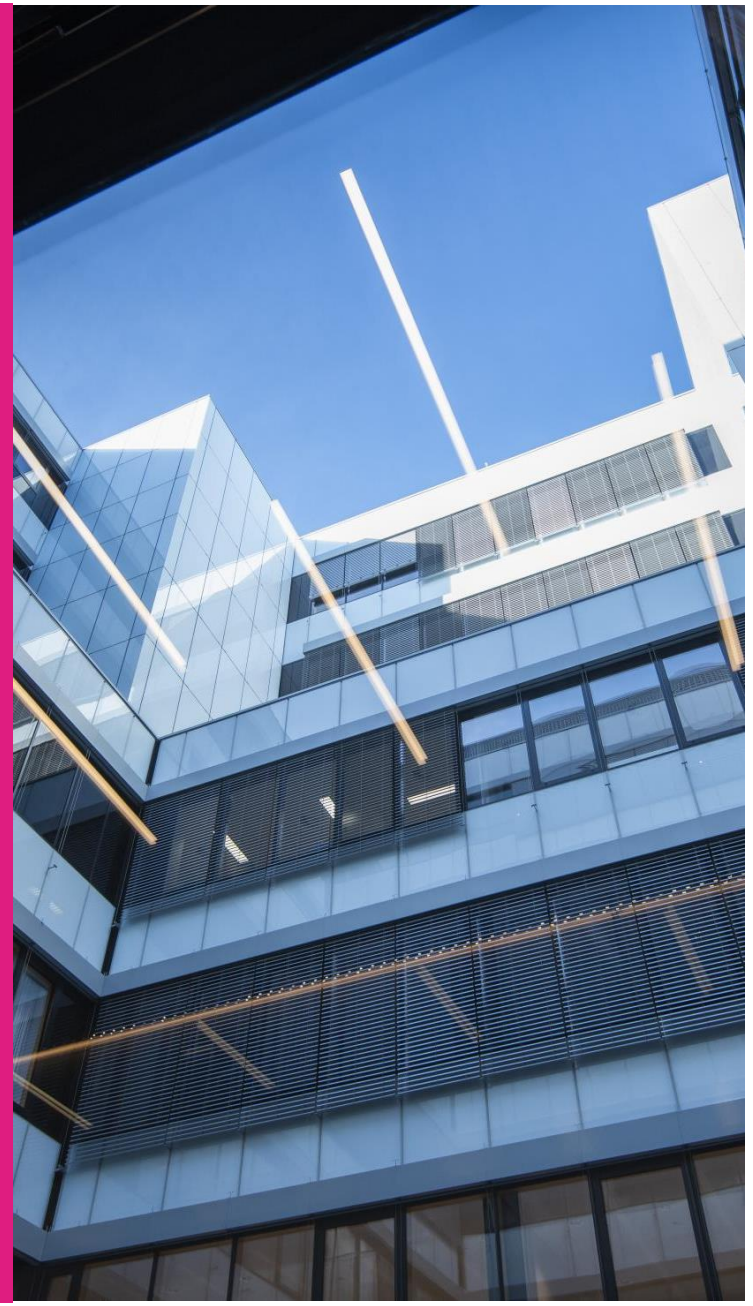
Damodar Pokhrel | Matthew Halfman | Lana Sanford

Beam Energy, Arcs & MU (key Trade-offs)

- **Single-arc VMAT**: faster, fewer MU, but may limit OAR sparing.
- **Dual- or triple-arc VMAT**: improved conformity and OAR protection; more MU and QA workload
- **Non-coplanar arcs**: useful for complex sites (liver, spine) to reduce dose to critical OARs.
- **Optimization strategies:** apply MU constraints; use of rings might help, for example.

03

CLINICAL ASPECTS



Treatment & Motion Management

- High dose, few fractions → need for reproducibility and motion control
- Tools: ITV, gating, breath-hold (DIBH), fiducials + tracking, SGRT, strict immobilization
- Pre-treatment verification and escalation procedures if anatomy changes (TLP)

CLINIC ASPECTS

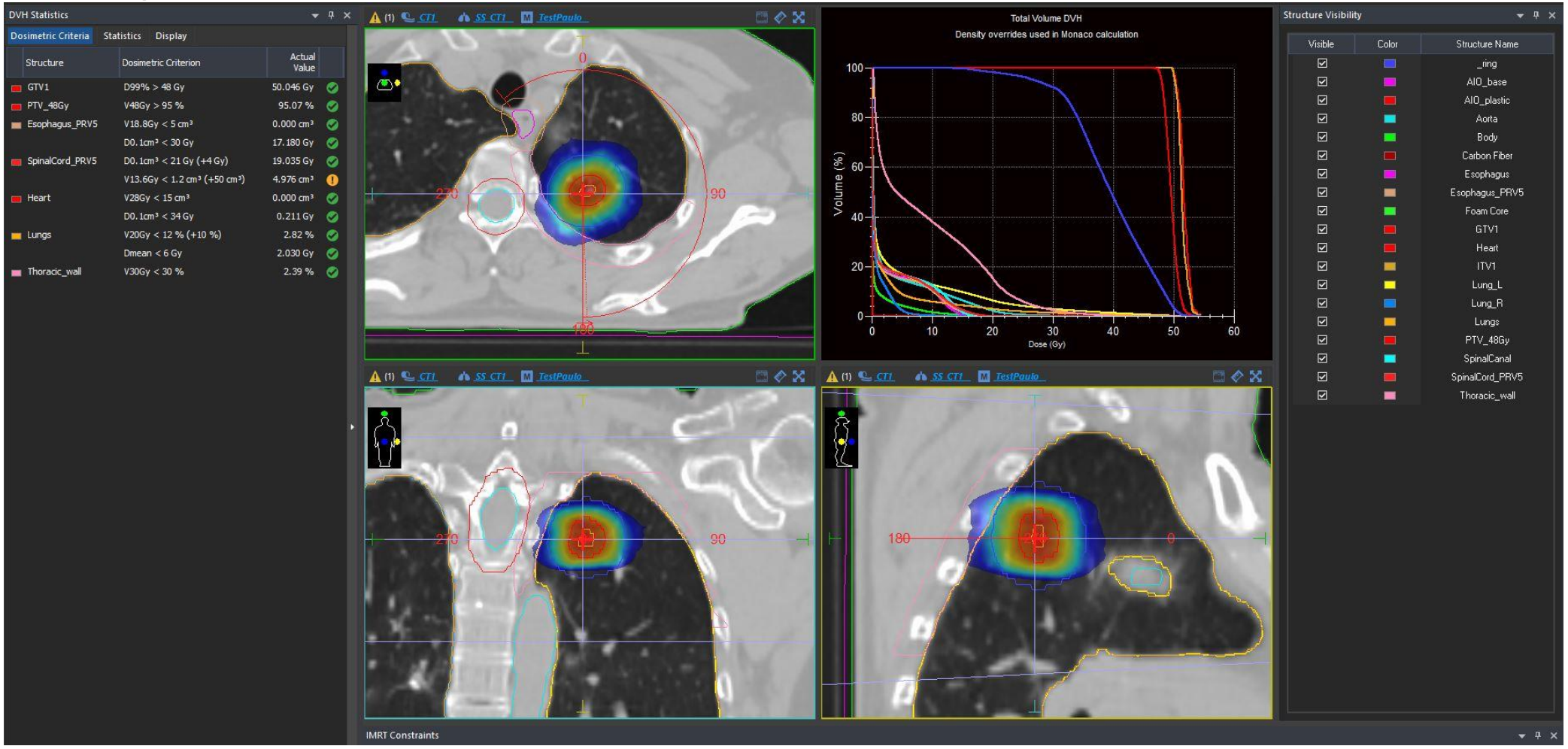
Lung

- **Indications:** Early-stage NSCLC, pulmonary oligometastases;
- **Institutional Schemes:** 48 Gy / 4 fx; 60 Gy / 8 fx; 60 Gy / 10 fx;
- **Simulation:** 4D-CT for respiratory motion; Motion strategy based on tumor size/location;
- **OARs:** proximal bronchi, heart, esophagus, chest wall;

CLINIC ASPECTS

Lung

- 48 Gy / 4 fx



OAR:

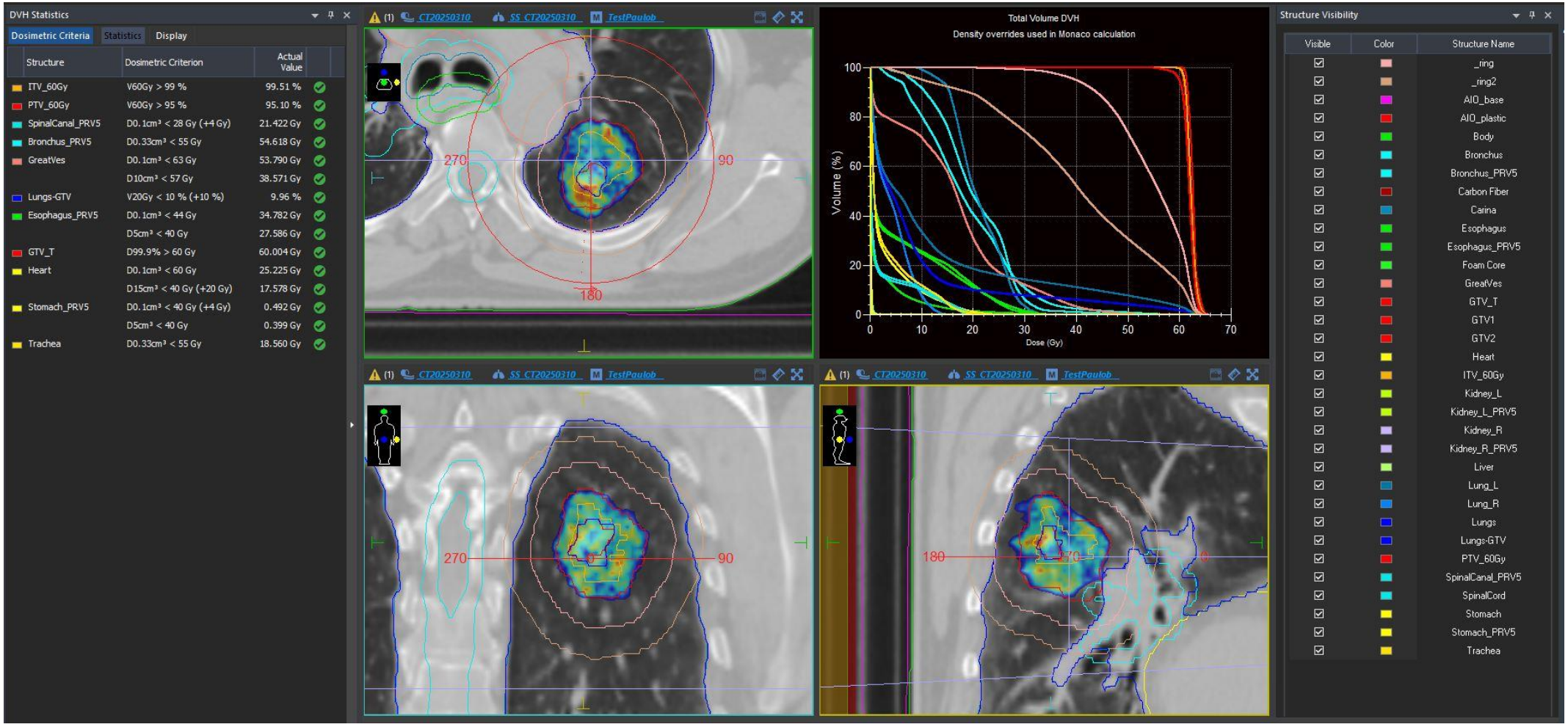
- proximal bronchi,
- heart,
- esophagus,
- chest wall;

Isodose ≥24 Gy

CLINIC ASPECTS

Lung

- 60 Gy / 8 fx



OAR:

- proximal bronchi,
- heart,
- esophagus,
- chest wall;

Isodose ≥60 Gy

CLINIC ASPECTS

Lung

- **48 Gy / 4 fx VS 60 Gy / 8 fx**

LungSBRT 48Gy/4fr

OAR	Mandatory	Optimal	Reference
Brachial Plexus	D0.1cc<27Gy	D3cc<23.6Gy	NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Bonchus PRV	D0.1cc<34.8Gy		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Chest Wall		V30Gy<30cc	Chang et al 2015 (https://doi.org/10.1097/JTO.0000000000000453)
Esophagus PRV	D0.1cc<30Gy V18.8Gy<5cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Great Vessels	V43Gy<10cc D0.1cc<48Gy		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Heart	D0.1cc<34Gy V28Gy<15cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Skin	D0.1cc<36Gy V30Gy<10cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051) Consensus Bordet
Spinal Canal PRV	D0.1cc<25Gy	D0.1cc<21Gy V13.6Gy < 1.2 cc	Grimm et al 2016 (?) NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Stomach	D0.1cc<27.2Gy V17.6Gy<10cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Lungs-GTV		Dmean<6Gy	NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051) Chang et al 2015 (https://doi.org/10.1097/JTO.0000000000000453) Lig et al 2014 (?)
Trachea PRV	D0.1cc<34.8Gy		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)

LungSBRT 60Gy/8fr

OAR	Mandatory	Optimal	Reference
Brachial Plexus	D0.1cc<38Gy	D0.1cc<27Gy	Rose et al 2017 (https://doi.org/10.1016/j.ejmp.2017.04.010) Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007)
Bonchus PRV	D0.33cc<55Gy		Chen et al 2019 (?) RTOG 0813 (https://doi.org/10.1200/JCO.18.00622)
Chest Wall		D0.1cc<39Gy V35Gy<30cc	Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?)
Esophagus PRV	D0.1cc<44Gy	V40Gy<5cc	Amsterdam VUMC Experience (?)
Great Vessels	D0.1cc<63Gy V57Gy<10cc		Rose et al 2017 (https://doi.org/10.1016/j.ejmp.2017.04.010) RTOG 0813 (https://doi.org/10.1200/JCO.18.00622)
Heart	D0.1cc<60Gy	V40Gy<15cc	RTOG(?) Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?)
Skin	D0.1cc<44Gy V38Gy<10cc		RTOG 0813 (https://doi.org/10.1200/JCO.18.00622) Consensus Bordet
Spinal Canal PRV	D0.1cc<32Gy	D0.1cc<28Gy	Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?) Amsterdam VUMC Experience (?)
Stomach	D0.1cc<44Gy V40Gy<5cc	D0.1cc<40Gy	Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Raman, Yau et al (?)
Lungs-GTV	V20Gy<10%		Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?)
Trachea PRV	D0.33cc<55Gy		Chen et al 2019 (?) RTOG 0813 (https://doi.org/10.1200/JCO.18.00622)

OAR:

- proximal bronchi,
- heart,
- esophagus,
- chest wall;

CLINIC ASPECTS

Lung

LungSBRT 48Gy/4fr

OAR	Mandatory	Optimal	Reference
Brachial Plexus	D0.1cc<27Gy	D3cc<23.6Gy	NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
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Esophagus PRV	D0.1cc<30Gy V18.8Gy<5cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Great Vessels	V43Gy<10cc D0.1cc<48Gy		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Heart	D0.1cc<34Gy V28Gy<15cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Skin	D0.1cc<36Gy V30Gy<10cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051) Consensus Bordet
Spinal Canal PRV	D0.1cc<25Gy	D0.1cc<21Gy V13.6Gy < 1.2 cc	Grimm et al 2016 (?) NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
Stomach	D0.1cc<27.2Gy V17.6Gy<10cc		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)
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Trachea PRV	D0.1cc<34.8Gy		NRG Oncology RTOG 0915 (https://doi.org/10.1016/j.ijrobp.2018.11.051)

LungSBRT 60Gy/8fr

OAR	Mandatory	Optimal	Reference
Brachial Plexus	D0.1cc<38Gy	D0.1cc<27Gy	Rose et al 2017 (https://doi.org/10.1016/j.ejmp.2017.04.010) Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007)
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Esophagus PRV	D0.1cc<44Gy	V40Gy<5cc	Amsterdam VUMC Experience (?)
Great Vessels	D0.1cc<63Gy V57Gy<10cc		Rose et al 2017 (https://doi.org/10.1016/j.ejmp.2017.04.010) RTOG 0813 (https://doi.org/10.1200/JCO.18.00622)
Heart	D0.1cc<60Gy	V40Gy<15cc	RTOG(?) Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?)
Skin	D0.1cc<44Gy V38Gy<10cc		RTOG 0813 (https://doi.org/10.1200/JCO.18.00622) Consensus Bordet
Spinal Canal PRV	D0.1cc<32Gy	D0.1cc<28Gy	Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?) Amsterdam VUMC Experience (?)
Stomach	D0.1cc<44Gy V40Gy<5cc	D0.1cc<40Gy	Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Raman, Yau et al (?)
Lungs-GTV	V20Gy<10%		Hanna et al 2018 (https://doi.org/10.1016/j.clon.2017.09.007) Clinical Oncology 2017 (?)
Trachea PRV	D0.33cc<55Gy		Chen et al 2019 (?) RTOG 0813 (https://doi.org/10.1200/JCO.18.00622)

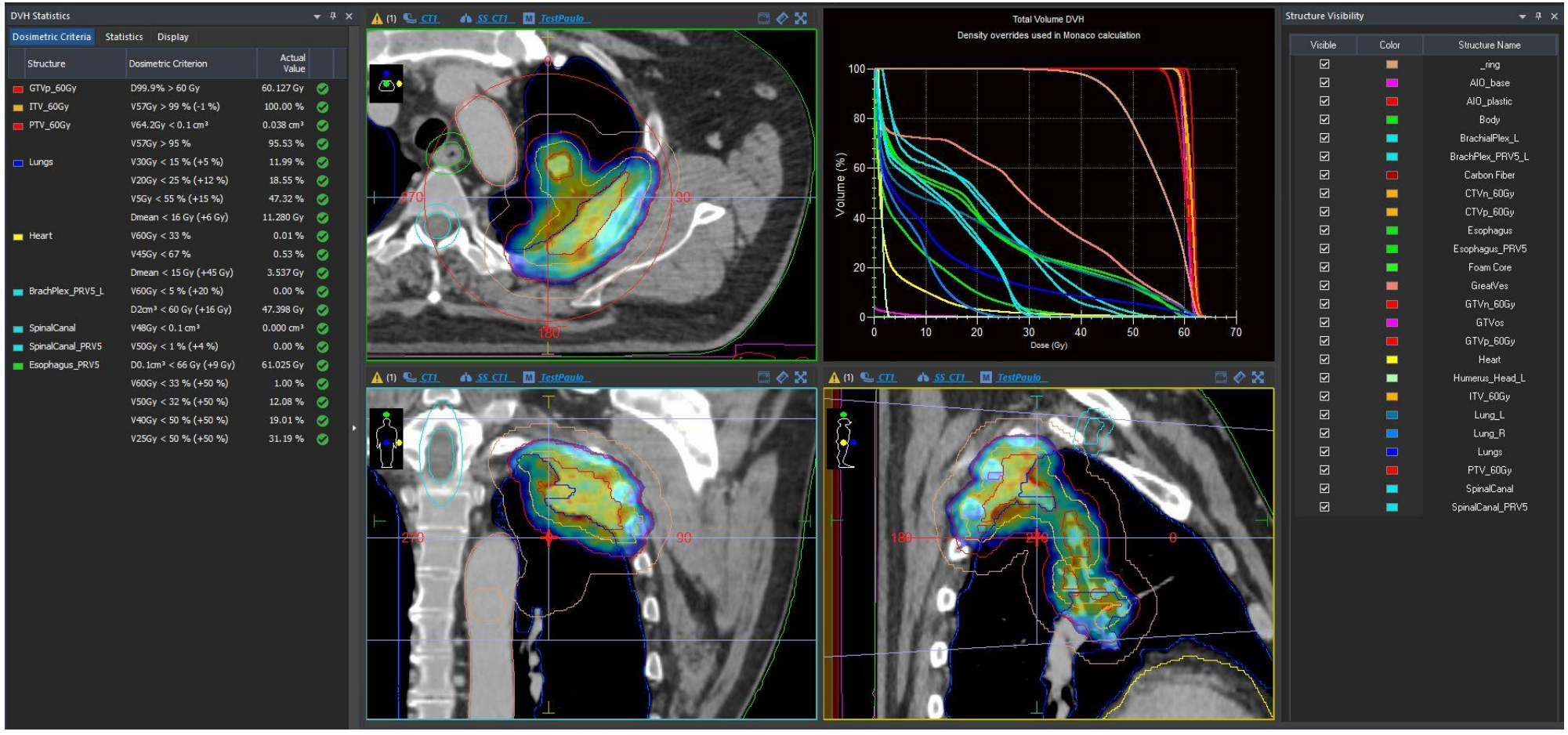
OAR:

- proximal bronchi,
- heart,
- esophagus,
- chest wall;

CLINIC ASPECTS

Lung

- 60 Gy / 30 fx… Why not SBRT?



OAR:

- proximal bronchi,
- heart,
- esophagus,
- chest wall;

Isodose ≥60 Gy

CLINIC ASPECTS

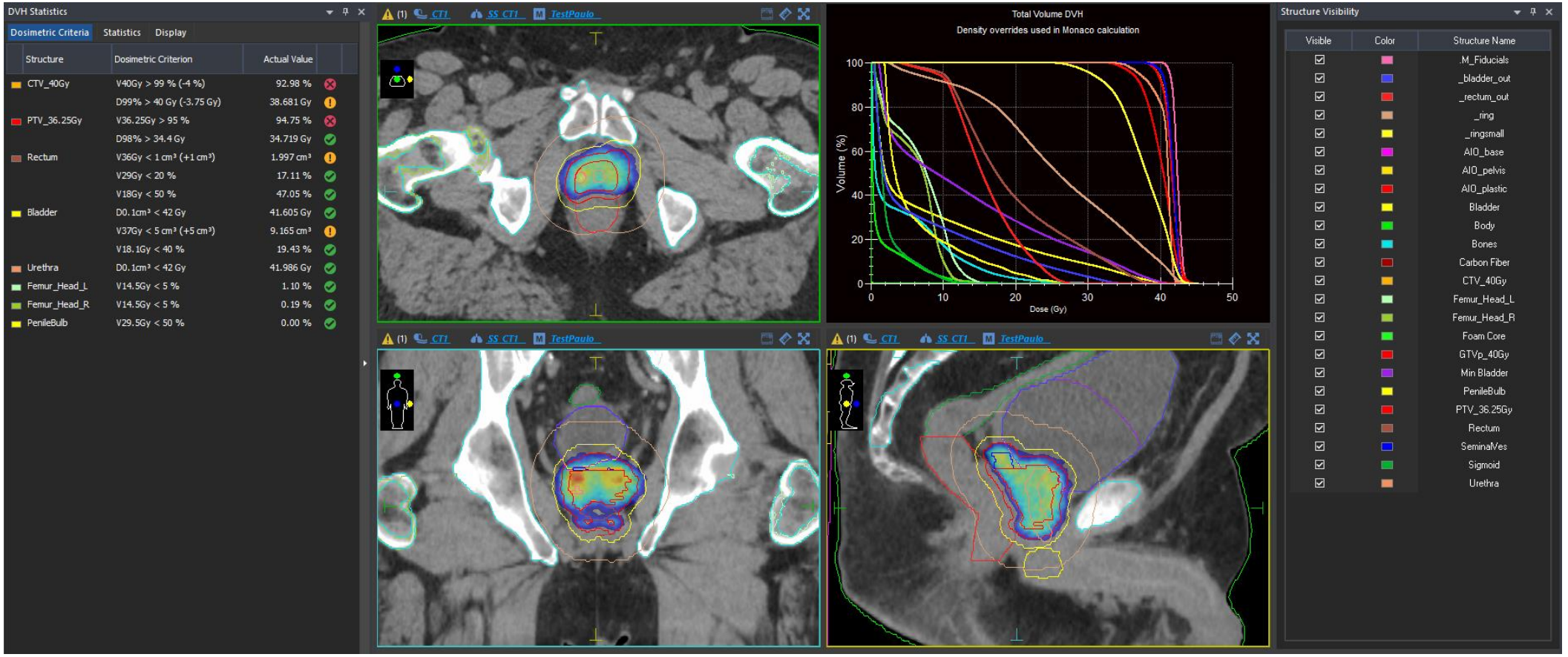
Prostate

- **Low α/β** → hypofractionation advantage
- **Institutional scheme**: 36.25–40 Gy / 5 fx
- Reproducible patient preparation (bladder / rectum)
- Fiducials or MRI-guided options
- Reduced margins (≈ 2–3 mm) depending on setup strategy
- **OARs**: bladder, rectum, bowel, urethra;

CLINIC ASPECTS

Prostate

- 40 Gy / 5 fx (CT-LINAC: 5 mm PTV)



OAR:

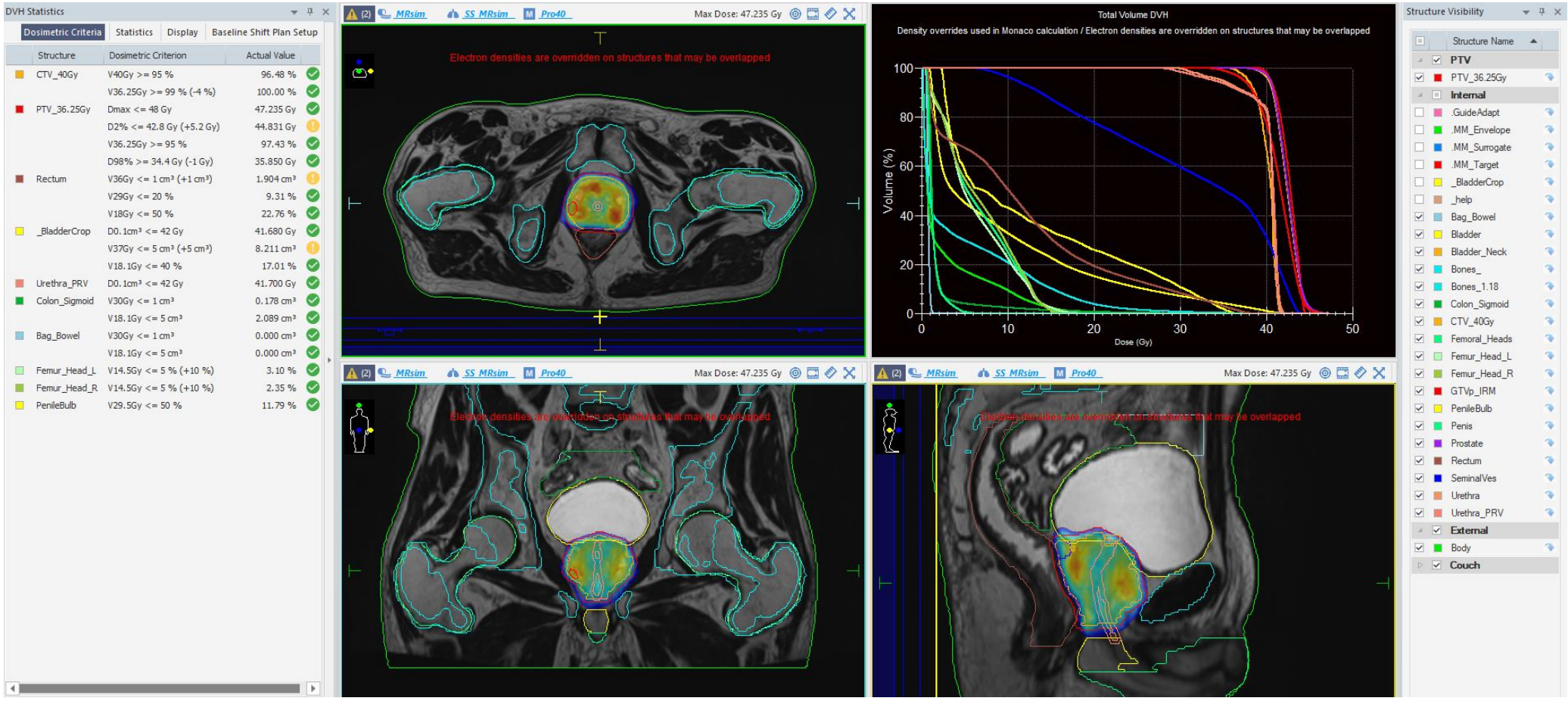
- bladder,
- rectum,
- bowel,
- urethra;

Isodose ≥ 36,25 Gy

CLINIC ASPECTS

Prostate

- 40 Gy / 5 fx (MRI-LINAC: 3 mm PTV)



OAR:

- bladder,
- rectum,
- bowel,
- urethra;

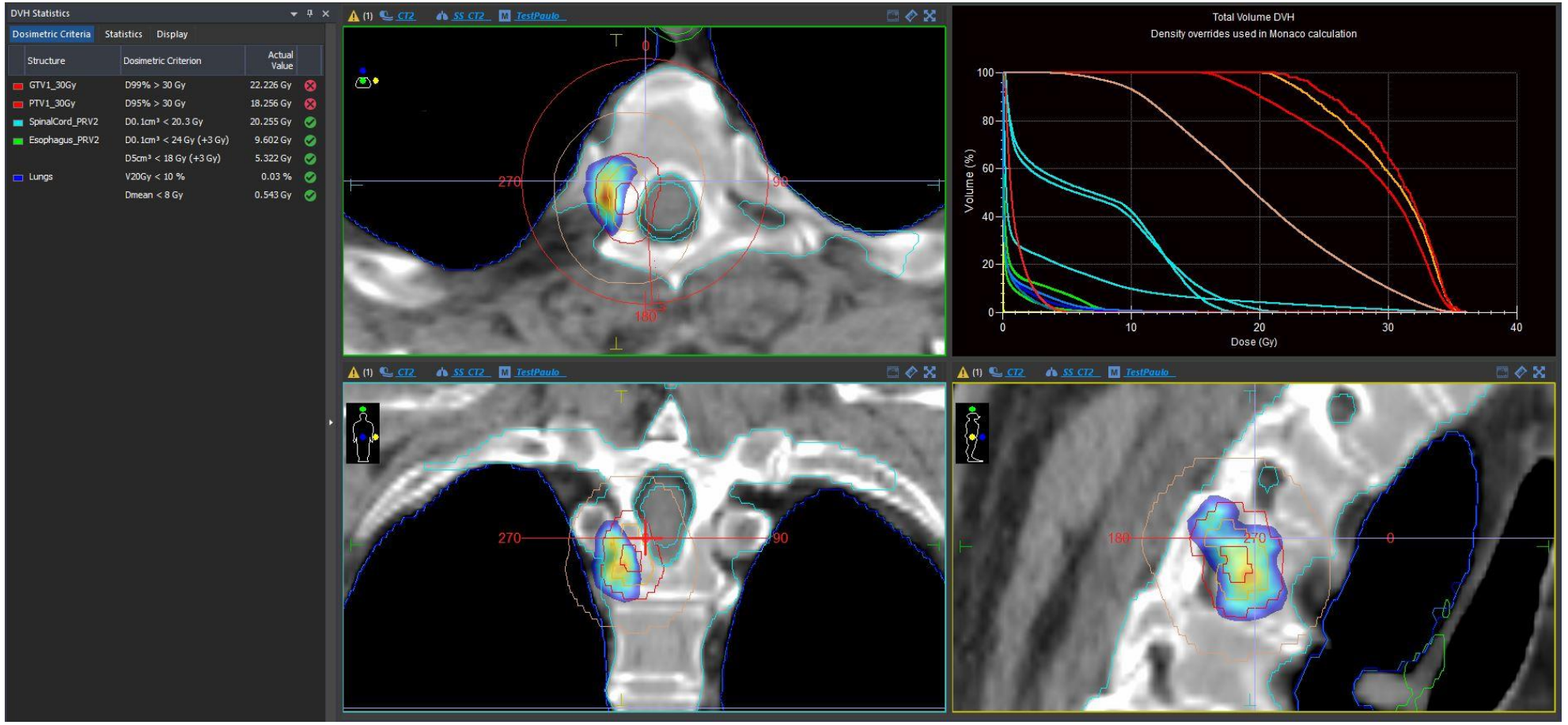
Isodose ≥ 36,25 Gy

Spine & other bone metastasis

- **Indications**: vertebral / osseous metastases requiring local control;
- **Institutional scheme**: 30 Gy / 3 fx;
- Assess vertebral stability;
- Exclude symptomatic spinal cord compression;
- **OARs**: spinal cord, nerve sac;

Spine & other bone metastasis

- 30 Gy / 3 fx;



OAR:

- spinal cord,
- nerve sac;

Re-irradiation

- Evaluate geometric overlap vs new OAR exposure;
- Use cumulative BED to estimate tolerance (and interval between courses);

Palliation

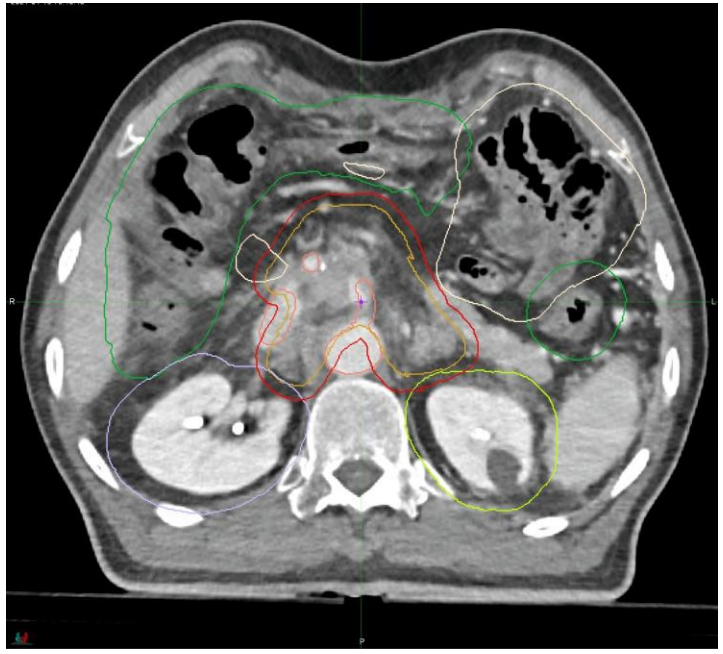
- Used for symptom relief (pain, hemoptysis, airway obstruction) when curative therapy is not feasible.
- **Typical fractionations**:
  - 12–16 Gy × 1 for bone met pain relief; *(Chow et al., JAMA Oncol 2019)*
  - 25–50 Gy in 5–10 fx for thoracic palliation; *(Lindsay et al., Radiother Oncol 2021)*
  - 30–40 Gy in 5 fx for osseous metastases (RCC etc.); *(Bauer-Nilsen et al., IJROBP 2022)*
- SBRT offers rapid symptom relief and local control (BED_{10} ≈ 60–100 Gy) with few fractions.
- Planning must still respect OAR tolerance & motion control standards.
- Simpler arc strategies often preferred for palliative patients (faster delivery, comfort).

Liver & Pancreas

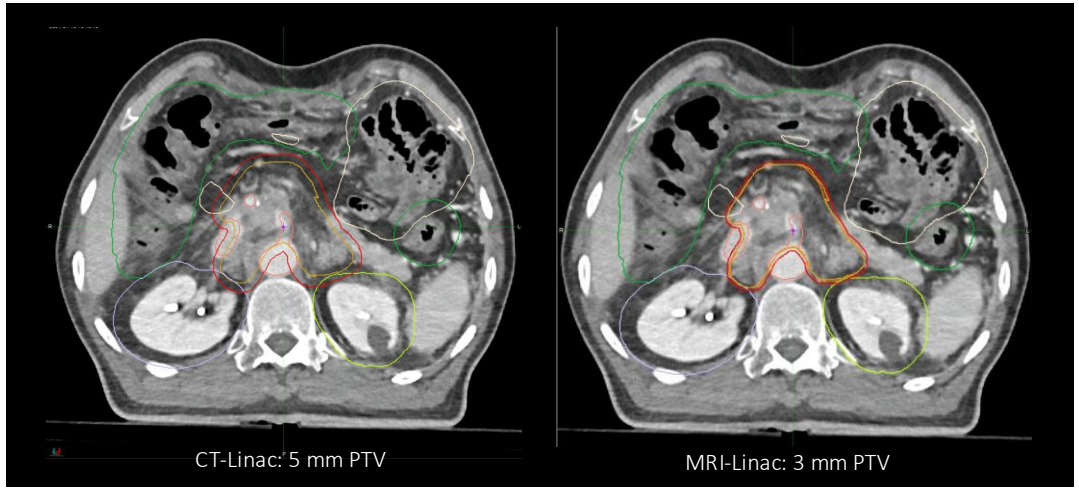
- **Liver**: 40–45 Gy / 5 fx
- **Pancreas**: 50 Gy / 5 fx (STEREOPAC protocol)
- **Motion management**: gating / DIBH / tracking
- Pay attention to healthy liver volume and digestive structures

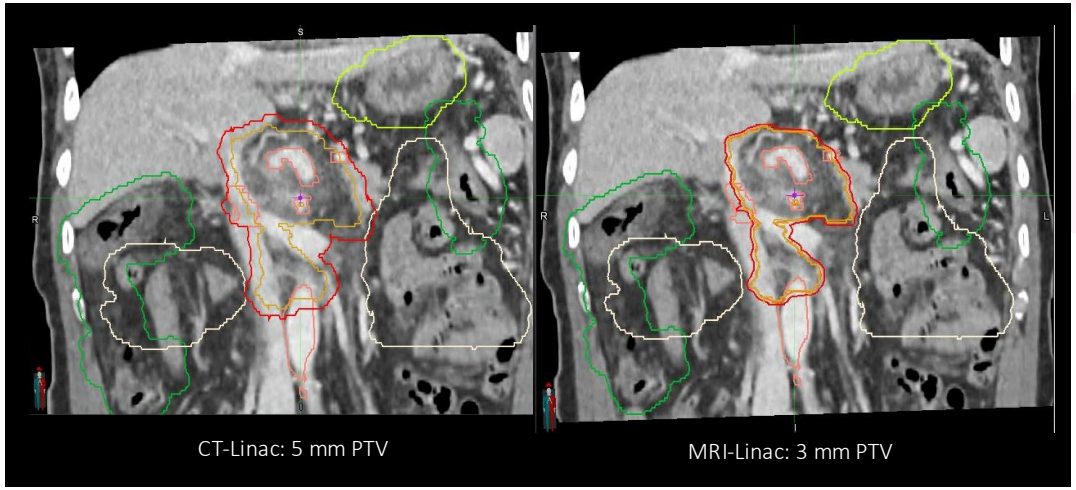
Liver & Pancreas

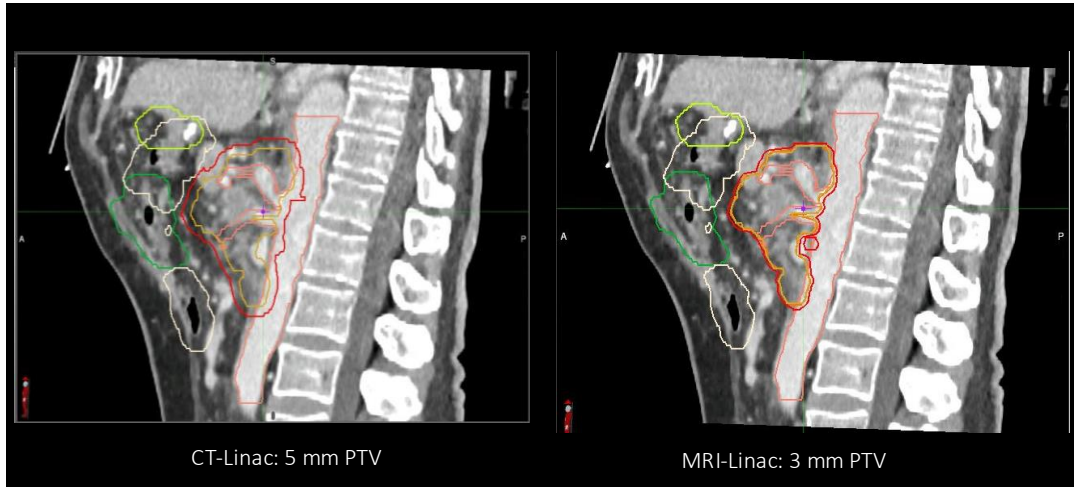
- **Liver**: 40–45 Gy / 5 fx
- **Pancreas**: 50 Gy / 5 fx (STEREOPAC protocol)
- **Motion management**: gating / DIBH / tracking



Liver & Pancreas

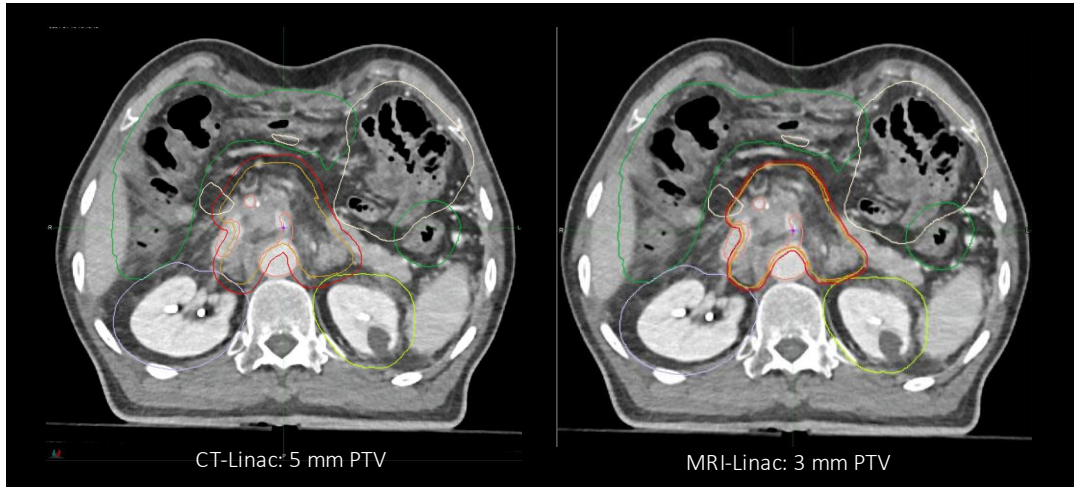


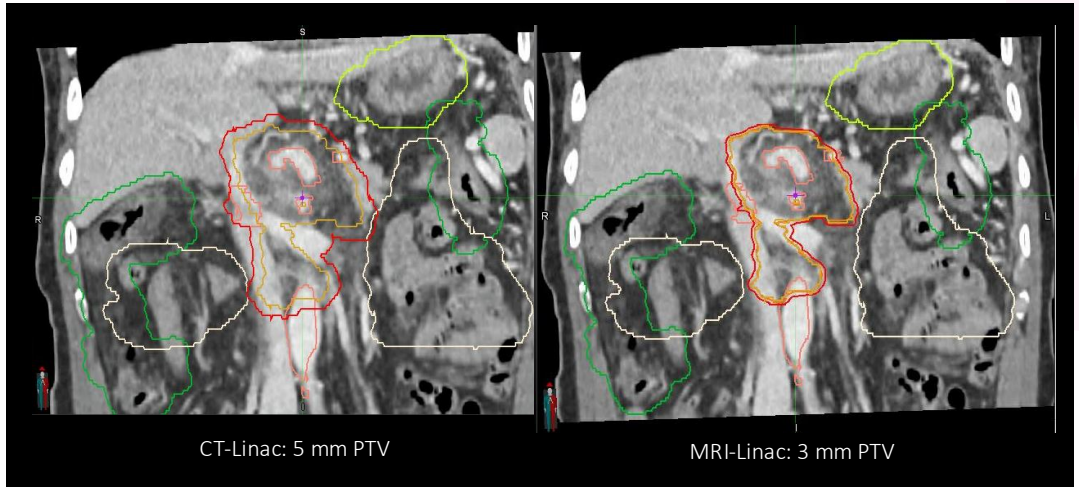


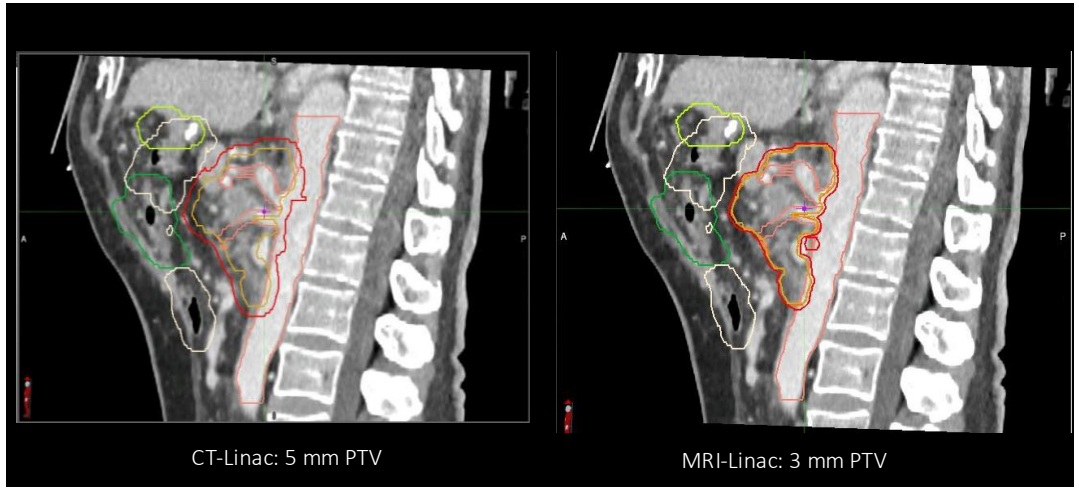


CLINIC ASPECTS

Liver & Pancreas







Total Measurements			
1389			
<|3| mm	>|3| mm		
1320	69	>|4| mm	
		35	>|5| mm
			24
%			
95,09	4,97	2,56	1,73

Intrafraction motion analyses in pancreatic cancer SBRT

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TAKE AWAY NOTE

1. **SBRT combines precision and efficiency**: high doses per fraction, excellent local control when OARs are respected

2. **Specific radiobiology**: BED remains a useful benchmark, but caution with high doses and low α/β tissues

3. **Rigorous physics**: complex planning, small margins, advanced algorithms, importance of MRI guidance and motion management

4. **Clinical diversity**: lung, prostate, spine, liver, pancreas — each with adapted schemes and constraints

5. **Safety and quality first**: key role of RTTs, strict verification, and possible adaptive strategies

TAKE AWAY NOTE

SBRT is a powerful and demanding technique, requiring full mastery of radiobiology, physics, and clinical aspects to deliver a safe and effective treatment.

REFERENCES

SBRT Physics & Planning

- Pokhrel D et al. *J Appl Clin Med Phys* 2019 – FFF VMAT for lung SBRT improves dose coverage, ↓ beam-on time.
- Basler L et al. *Radiat Oncol* 2018 – Dose to circulating lymphocytes; relevance for IO combos.
- Zhang K et al. *Front Oncol* 2023 – Arc number vs MU in liver SBRT auto-planning.
- JMIRS 2022 – FF vs FFF VMAT dosimetry comparison.
- Zhou C et al. *Med Phys* 2017 (PMC 5420128) – Algorithm switch & dosimetric protocols.

ICRU Report 91. *Strahlenther Onkol* 2019 – Prescribing, recording & reporting stereotactic treatments.

Clinical / Palliative SBRT

- Chow E et al. *JAMA Oncol* 2019 – Single vs multi-fraction SBRT for bone pain.
- Lindsay PE et al. *Radiother Oncol* 2021 – Thoracic palliative SBRT symptom relief.
- Bauer-Nilsen K et al. *IJROBP* 2022 – Osseous metastases SBRT outcomes.

Consensus & Guidelines

- Kroeze SGC et al. *Lancet Oncol* 2023 – EORTC-ESTRO OligoCare consensus on SBRT + IO/TT.
- Guckenberger M et al. *Radiother Oncol* 2024 – ESTRO guideline for spine SBRT.
- Guninski RS et al. *Radiother Oncol* 2024 – Meta-analysis for ESTRO spine SBRT guideline.

Pancreas SBRT & Trials

- *SMART Pancreas Trial. IJROBP* 2024 – 50 Gy / 5 fx (BED_{10} ≈ 100 Gy), MR-guided adaptive.
- *Clin Transl Radiat Oncol* 2024 – Systematic review of 31 prospective SBRT studies (PDAC).
- Bouchart C et al. *BMC Cancer* 2023 – STEREOPAC trial protocol (iHD-SBRT ± chemo).
- *IJROBP* 2023 – Phase 1 dose-escalation 3 fx SBRT for LAPC.
- Reddy SS et al. *J Gastrointest Oncol* 2024 – SBRT for recurrent pancreas (≈ 33 Gy / 5 fx).

THANK YOU!

QUESTIONS?