



Deep Inspiratory Breath Hold Assisted by Continuous Positive Airway Pressure Ventilation for Lung Stereotactic Body Radiotherapy

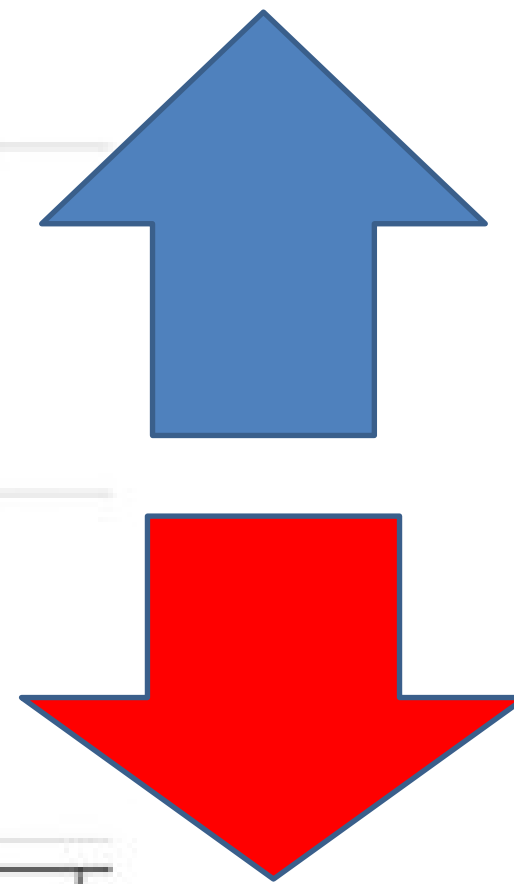
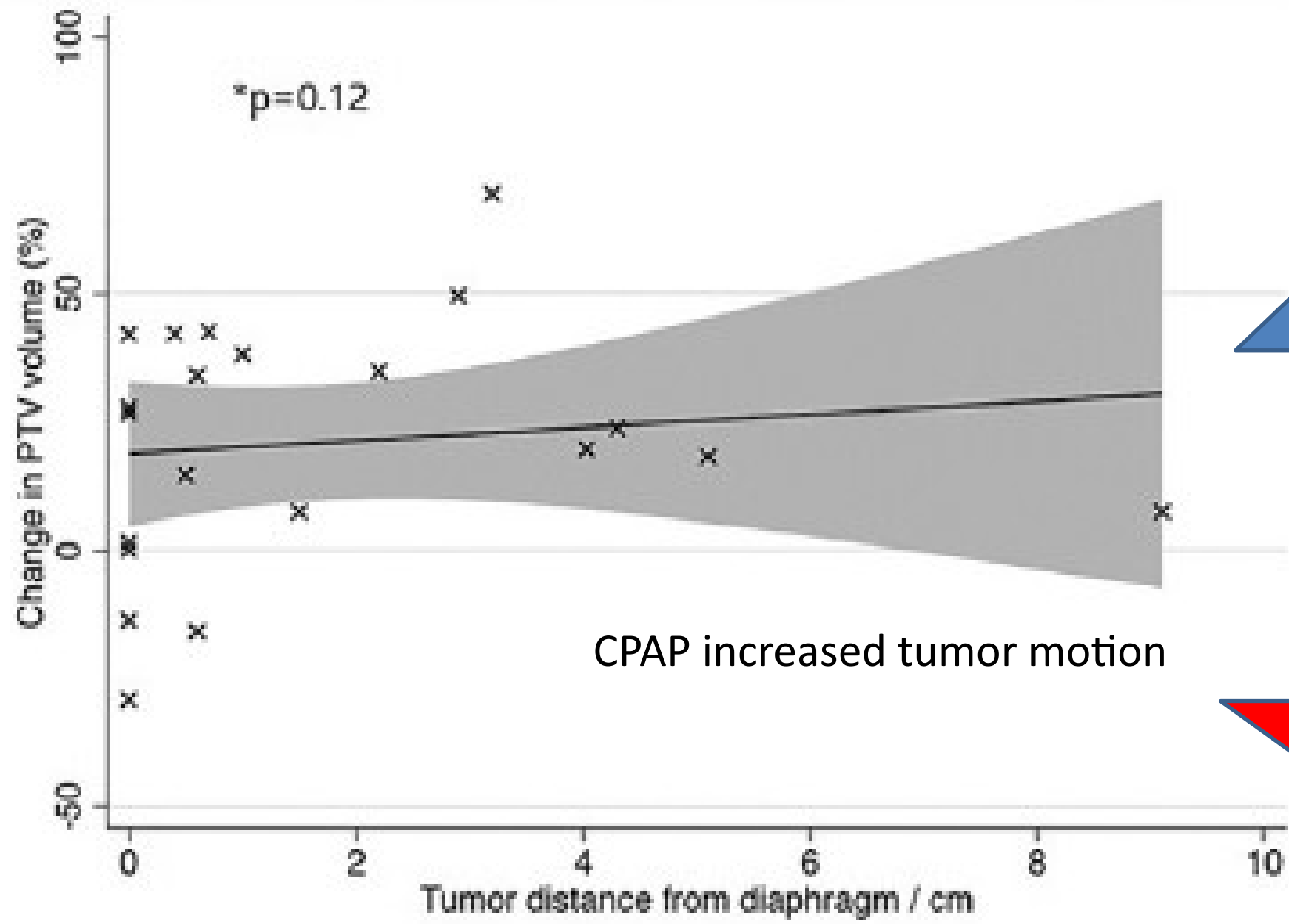
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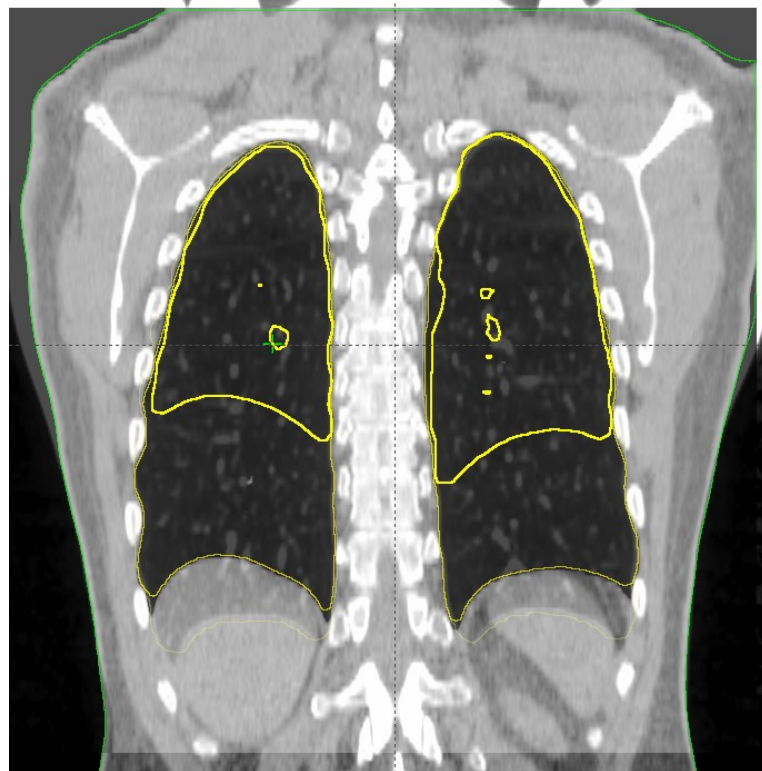


Free Breathing (FB) + 4D-CT	Deep Inspiratory Breath Hold (DIBH)	Continuous Positive Airway Pressure (CPAP)
- High risk of geographic miss	- Excellent dose reduction	- Passive intervention
- Requires large ITV expansion	- Good target immobilization - FLAW: Difficult for patients with pulmonary comorbidities to sustain; duration is unpredictable.	- Effectively recruits alveoli and increases lung volume - FLAW: does not always reliably reduce tumor motion especially close to the diaphragm
- Increased toxicity risk to OARs		

If tumor motion not mitigated to less than 1 cm -by DIBH or CPAP alone -hypothesized combination of CPAP WITH DIBH to be effective



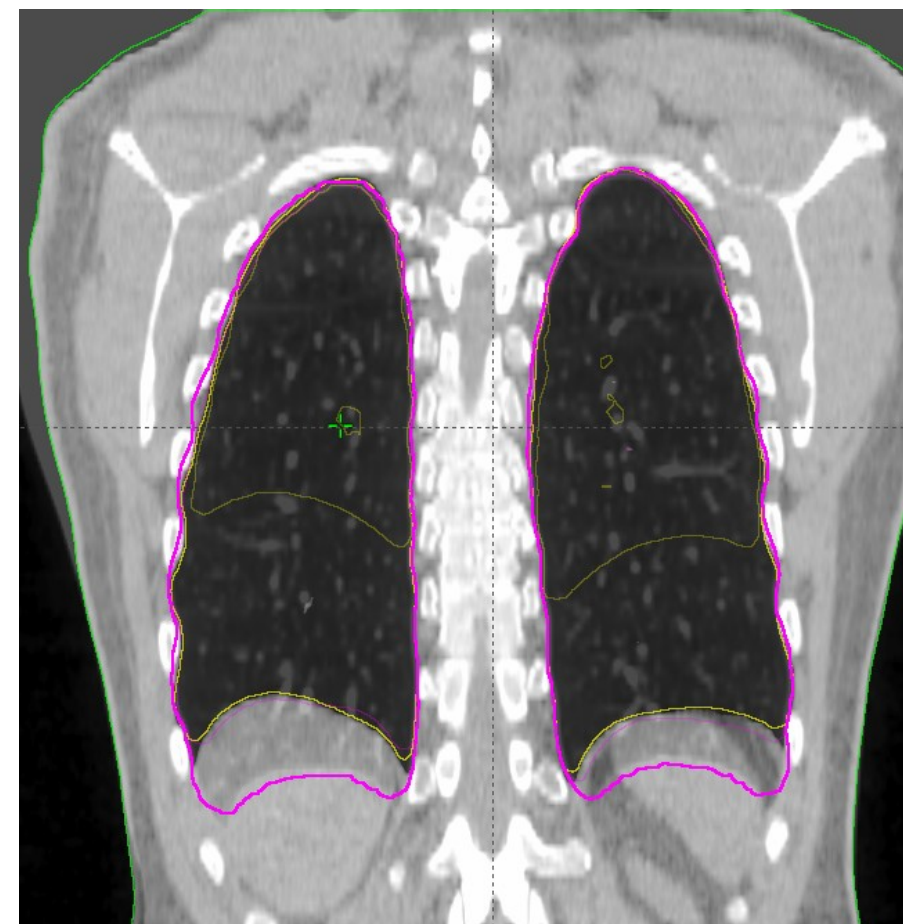
Breathing	Total Lung Volume
Free Breathing	2592 cc
DIBH	5280 cc
CPAP+DIBH	6320 cc



2592 cc



5280 cc



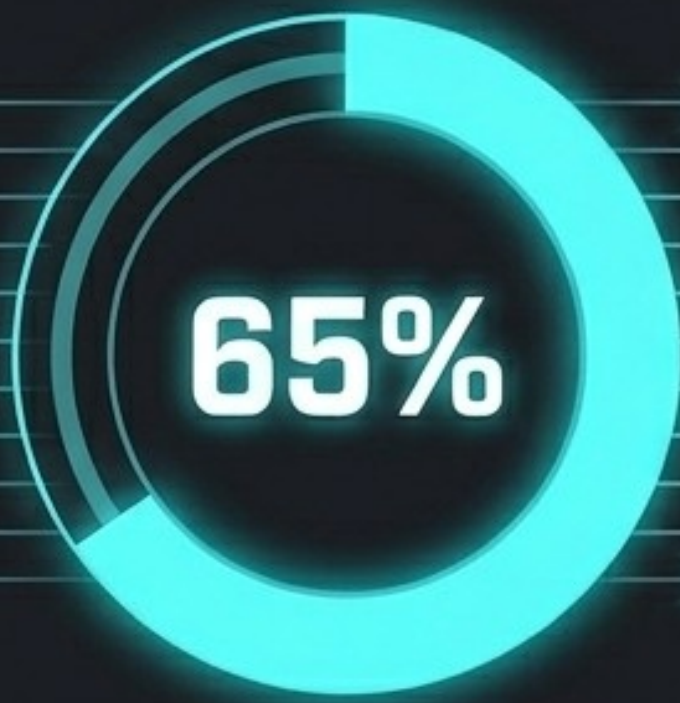
6320 !!!

Total patients 45
Total lesions 71

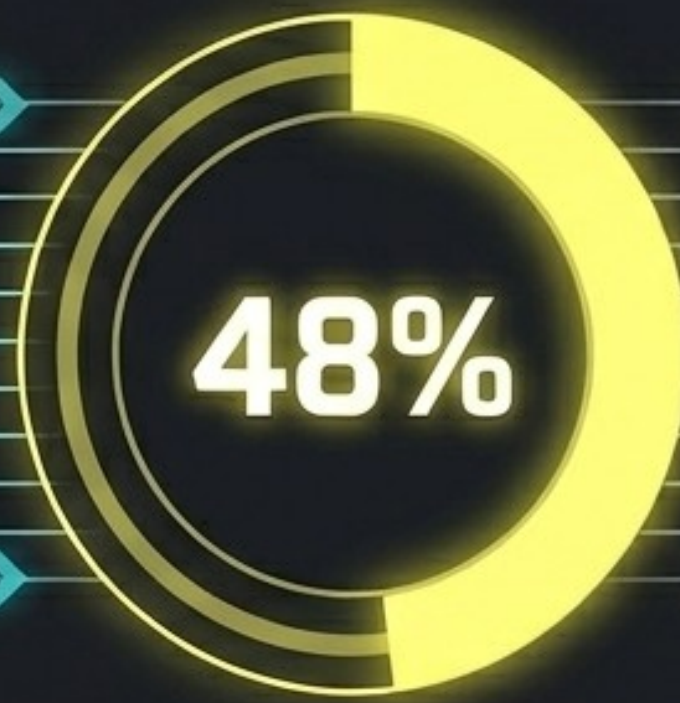
Patients' variables		N (%)
Age	(mean, range)	67.7 (43-87)
1. Gender	Female	19 (43%)
	Male	26 (57%)
Tumor origin	Primary lung cancer	5 (7%)
	Lung metastasis	66 (93%)
Histology	Breast	8 (11.3%)
	Colon	32 (45%)
	Cervix/endometrium	3 (4.2%)
	Lung	14 (19.7%)
	Melanoma	3 (4.2%)
	Pancreases	5 (7%)
	Sarcoma	4 (5.6%)
	Salivary gland	1 (1.4%)
	Kidney	1 (1.4%)
Prior lung radiation	Yes	35 (65%)
	No	19 (35%)
Main reason for using CPAP-DIBH	Lower lobe location	34 (48%)
	Multiple lesions	26 (36.6%)
	Centrally located	7 (10%)
	N/A	4 (5.6%)
GTV cm ³	(mean (SD))	4.5 (7.9)
PTV cm ³	(mean (SD))	20 (27)
Lung volume cm ³	(mean (SD); median (IQR))	5295 (1106); 5226 (4517-6000)
Dose (Gy)	mean (SD)	52.2 (3.5)

High-Risk Cohort Profile (2017-2021)

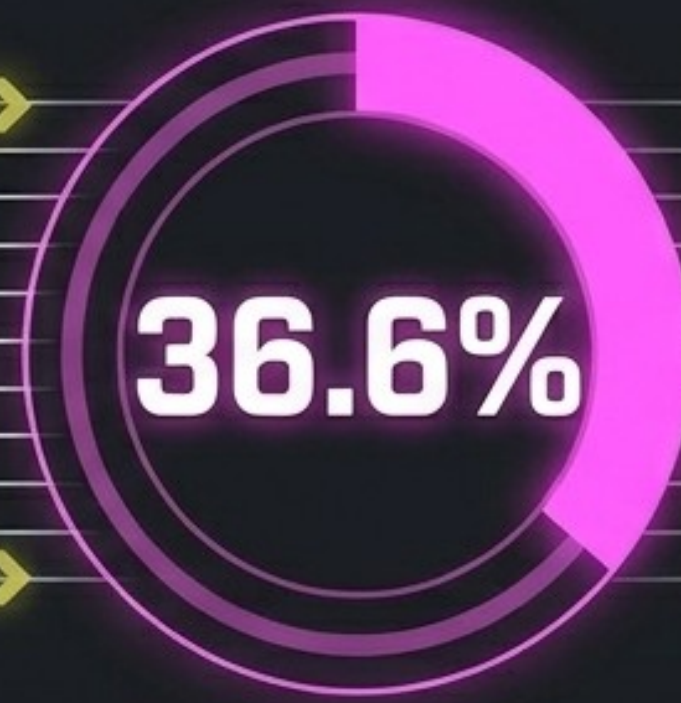
45 Patients | 71 Lesions Treated



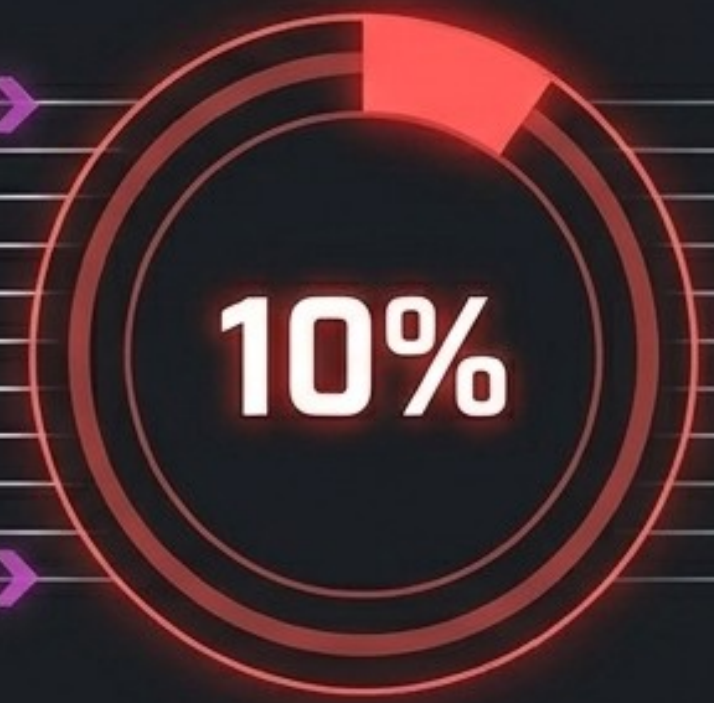
Prior Lung
Radiation
[35/71]



Lower Lobe
Location
[34/71]



Multiple Synchronous
Lesions
[26/71]



Central Location
Adjacent to OAR
[7/71]

93% Metastatic

Mean GTV: 4.5 cm³

Mean Dose: 52.2 Gy

Treatment Delivery Setup

2

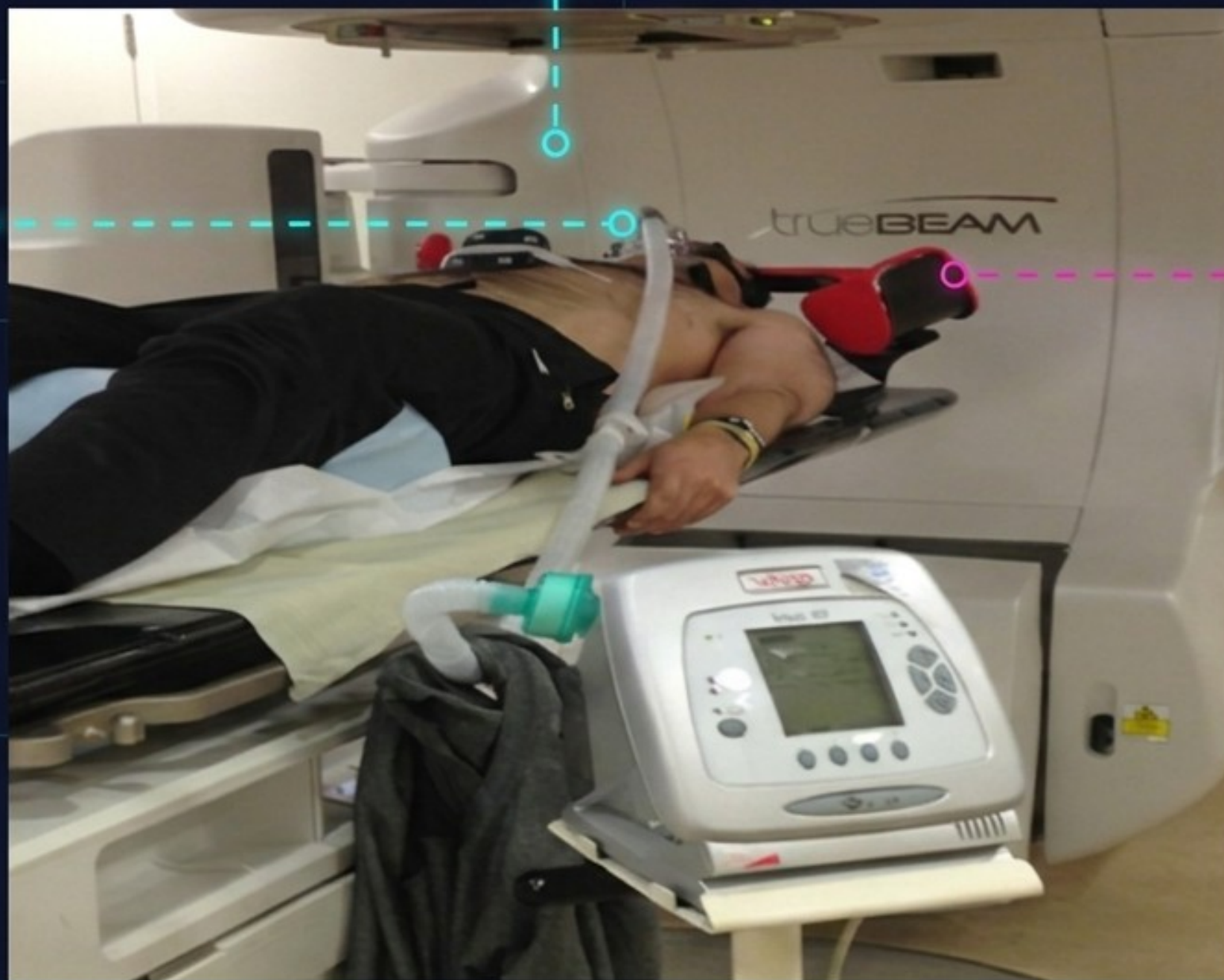
Varian TrueBeam Linear Accelerator

Utilizing FFF (Flattening Filter Free) mode for high dose rate delivery (1,000–1,400 MU/min).

1

Full-Face CPAP Mask

Delivering gradual positive pressure up to 15 cm H₂O.

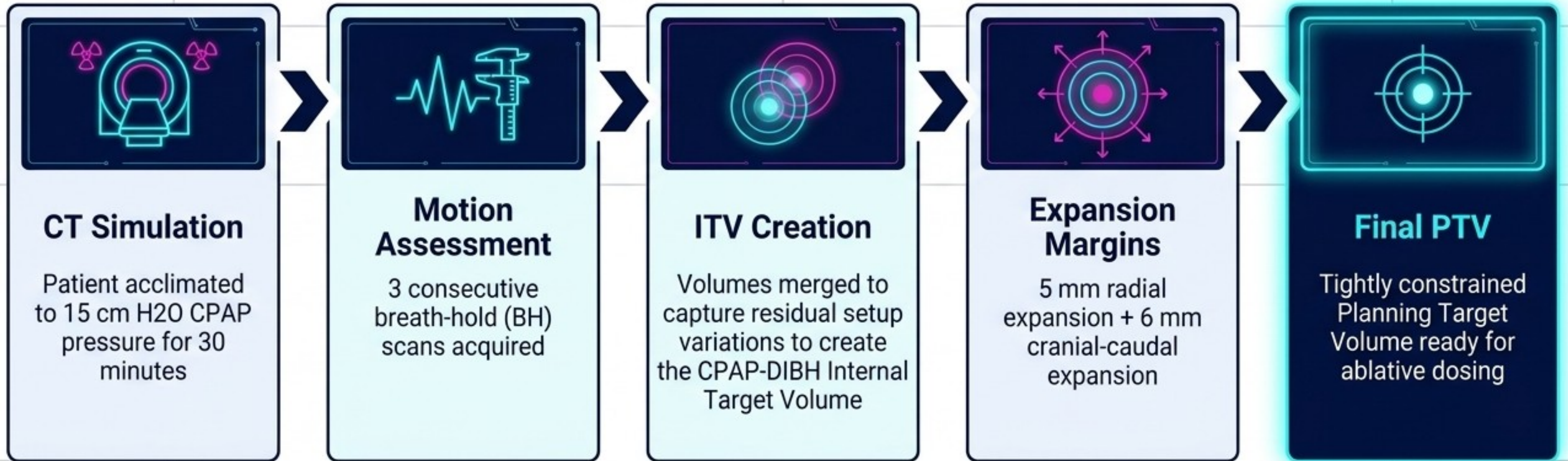


3

RPM Infrared Tracking System

Incorporating surface motion detectors to monitor respiration and breath-hold stability, paired with audio feedback.

Planning and Simulation Strategy



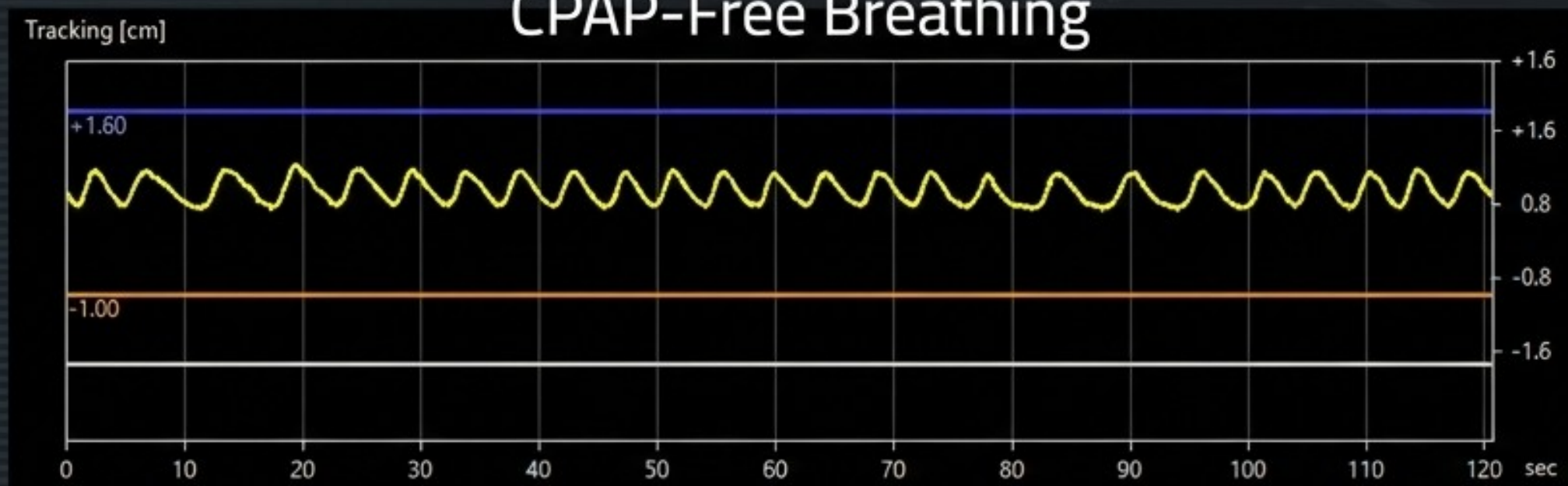
Volumetric Protocol Execution

Tolerability of CPAP-DIBH

- **1/45 syncope prior to the first treatment (not attributed to the CPAP use, (syncopal episodes occurred both prior and unrelated to CPAP use)**
- **2/45 discomfort from the CPAP air pressure during initial evaluation and refused further use of CPAP.**
- **All patients who started treatment with CPAP-assisted DIBH SBRT continued use of CPAP throughout the course of treatment.**

Tolerability & Intrafraction Stability

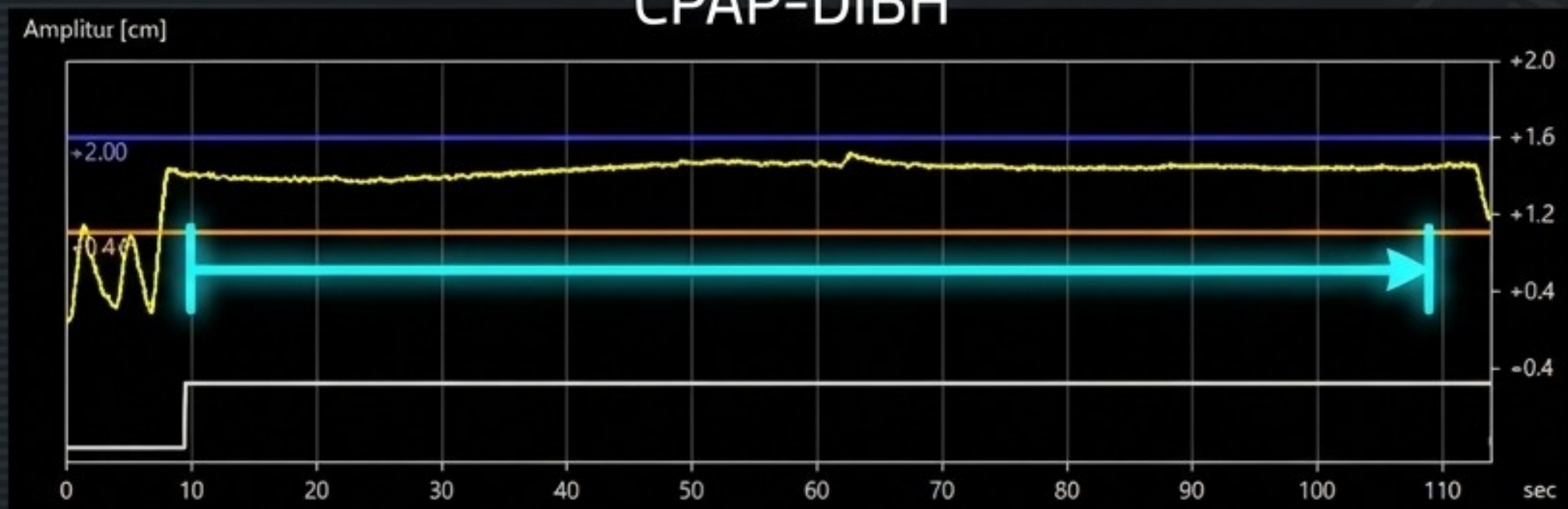
CPAP-Free Breathing



Median Breath Hold
Duration: 41.2 Seconds
(IQR 31-46.8s)

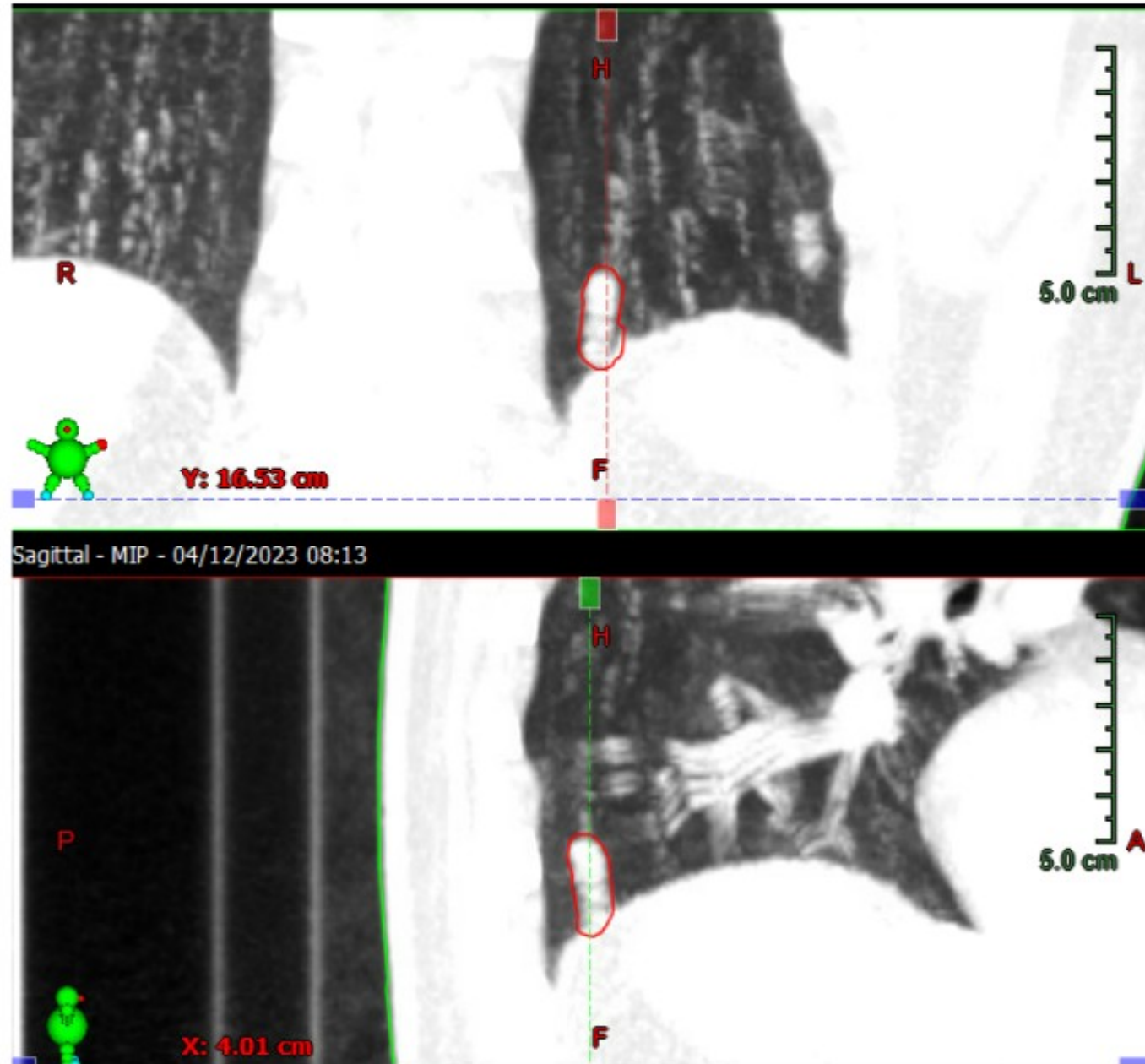
Zero treatment
interruptions due to
CPAP-DIBH failure.

CPAP-DIBH

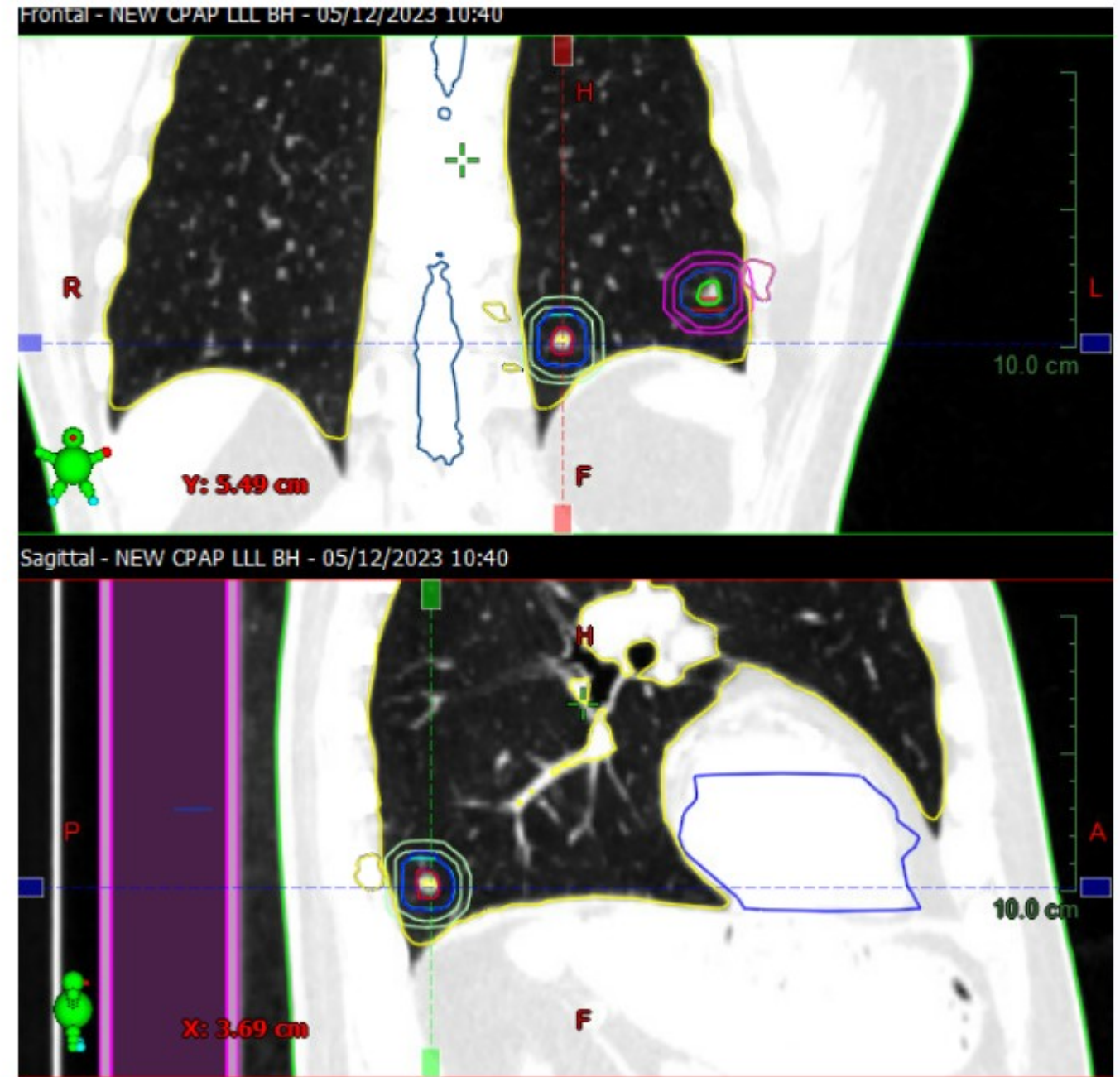


The combination of 15 cm H₂O pressure and **audio coaching** yields a highly **reproducible, flat** waveform, drastically reducing the PTV compared to free breathing.

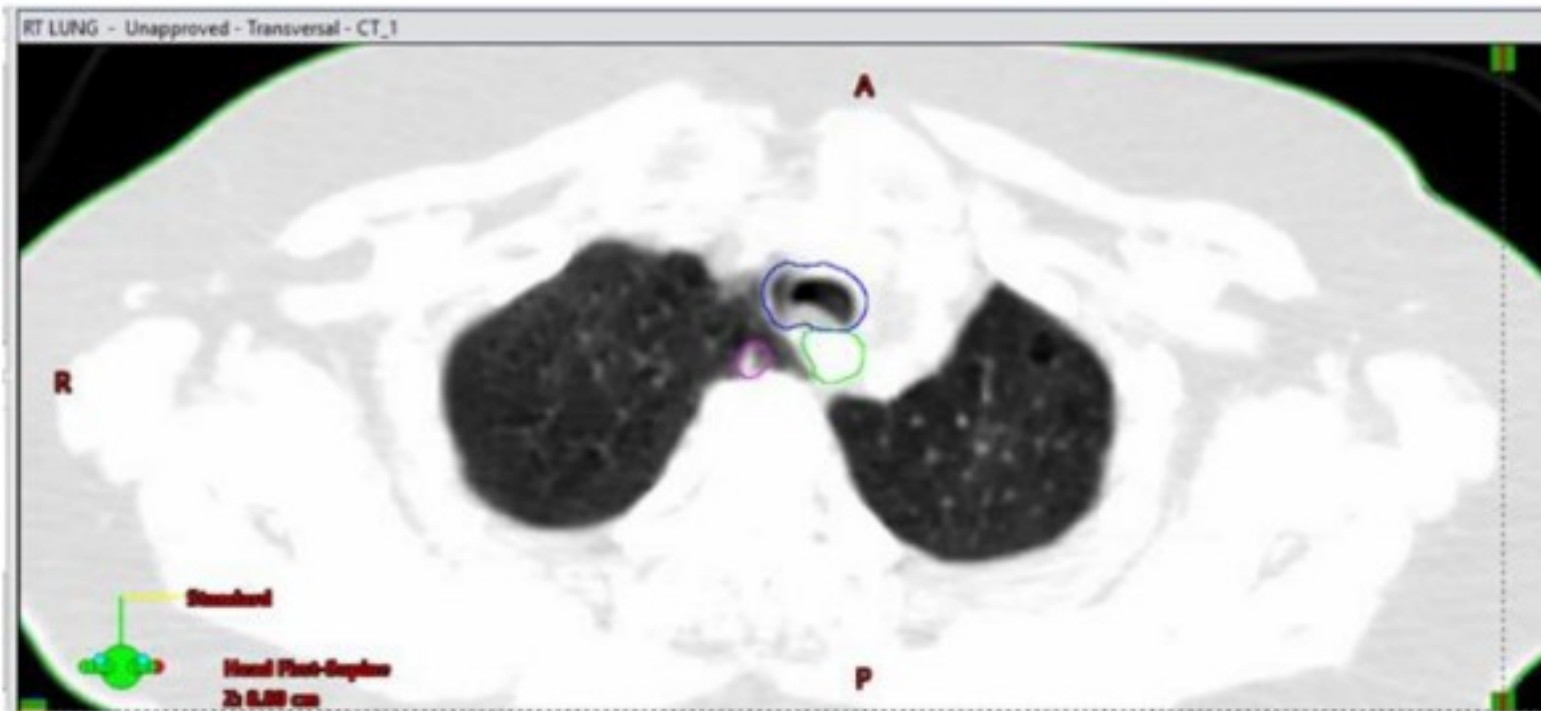
CPAP 15 cm H20 Lung volume 4182



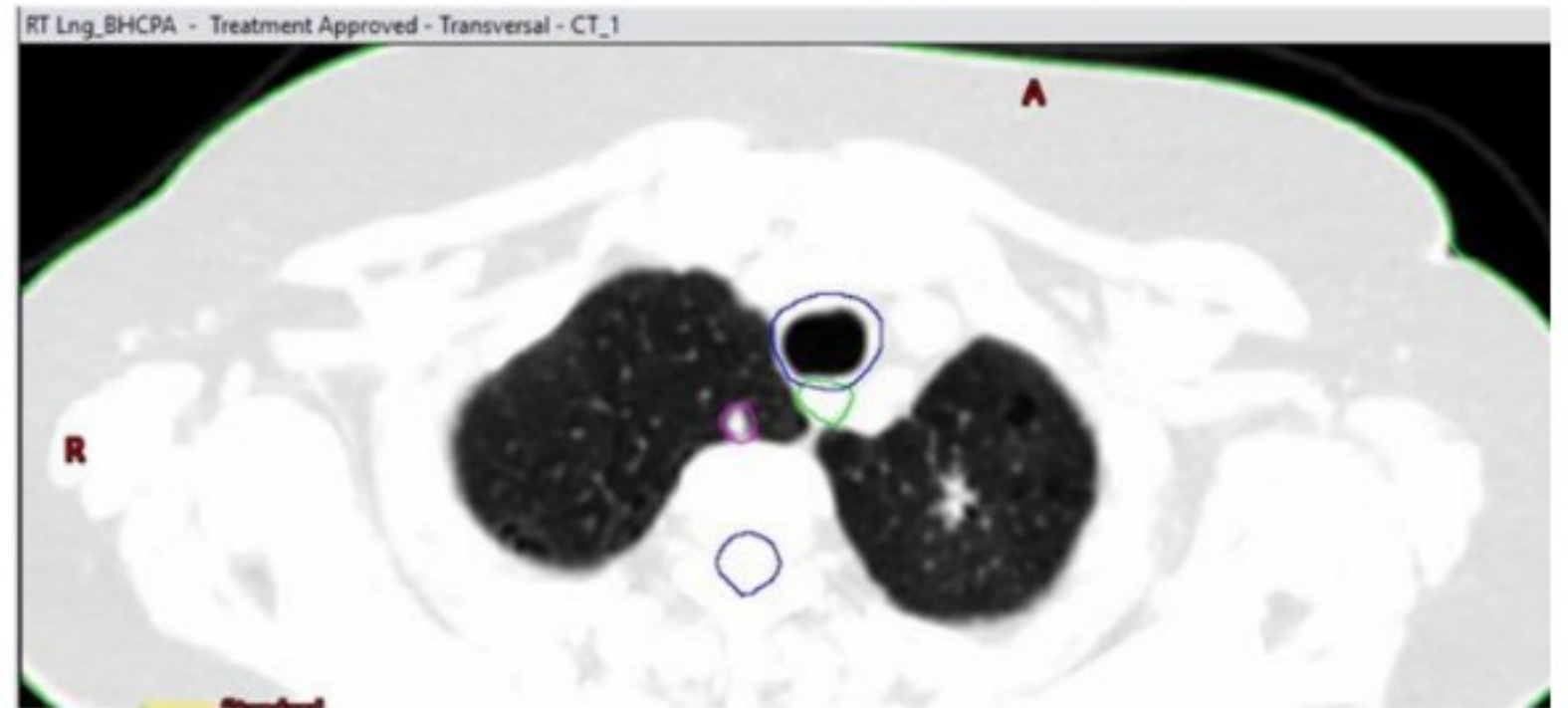
CPAP 15 cm H20+ BH Lung volume 5717



4A – Free breathing



4B CPAP-DIBH

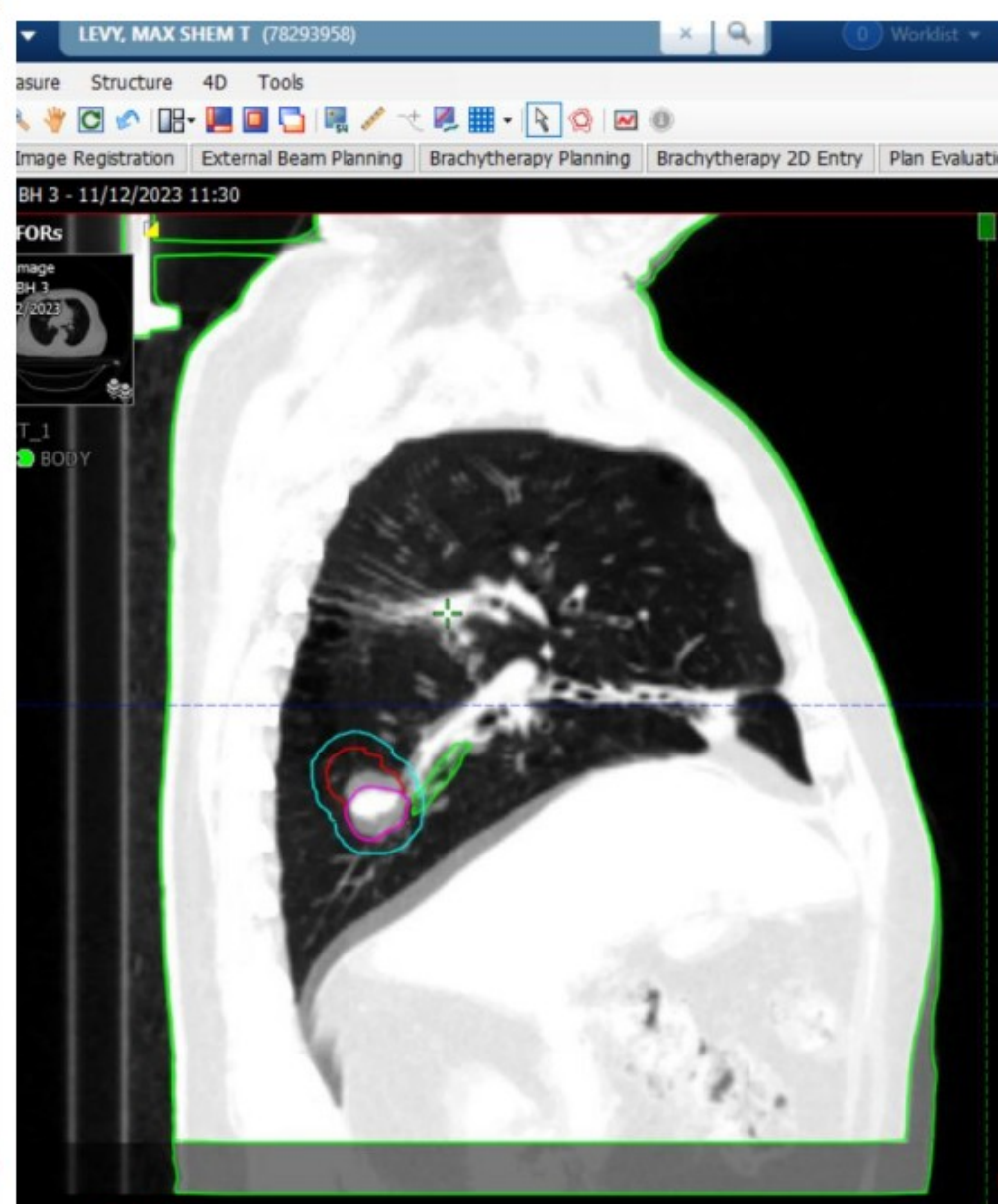
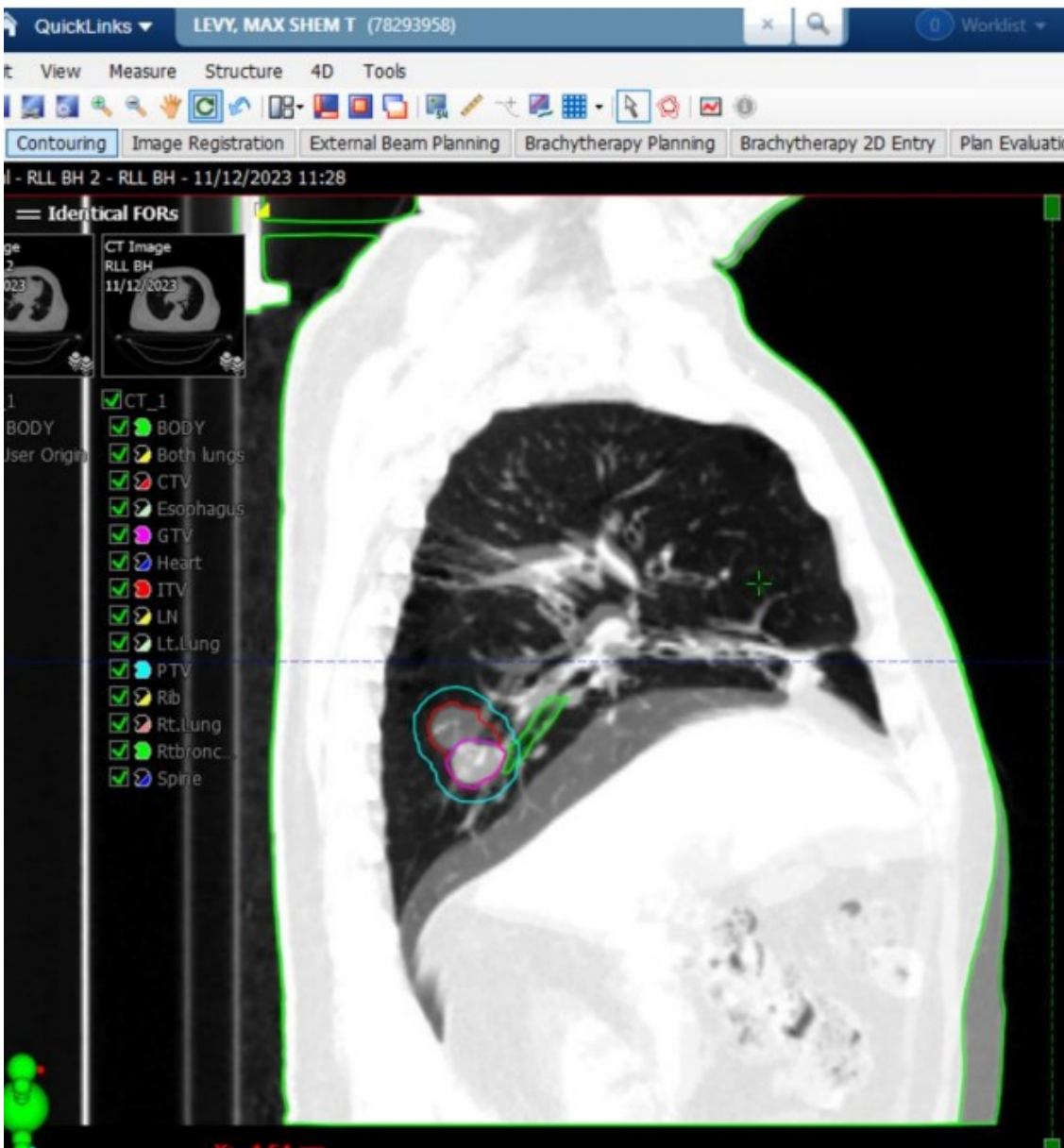


The tumor was located adjacent to the trachea and esophagus.

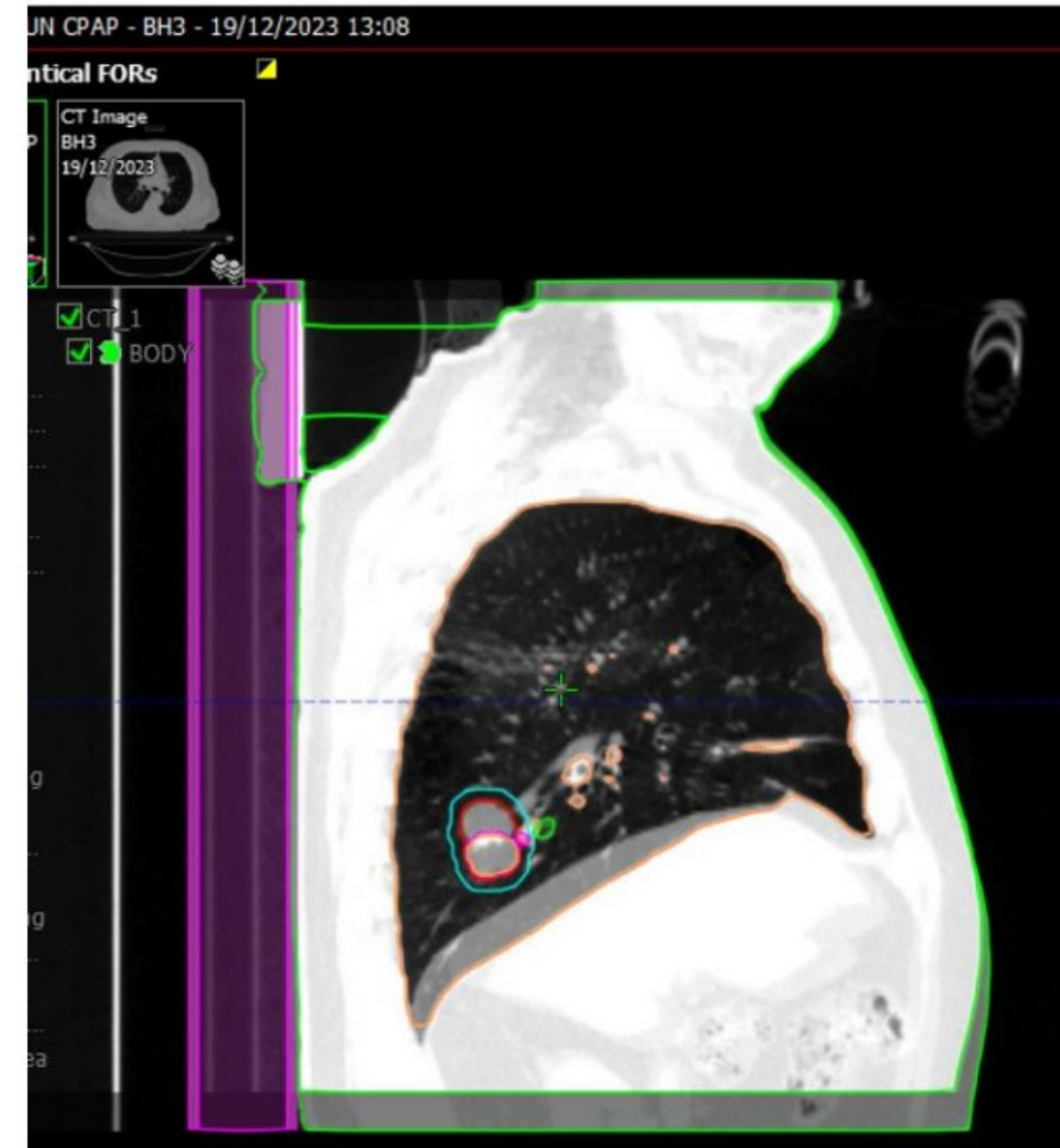
with CPAP-DIBH, extra air was introduced between the tumor and the OAR as well as anatomical shifts in OAR location, thus allowing ablative doses to be delivered and without significant toxicity.

The minimal distance between the GTV and the mediastinal OAR was 0.84 cm (SD 0.65) in free breathing. The distance increased by 0.38 cm to 1.23 cm (SD 0.84) with the used of CPAP-DIBH (p=0.002)

DIBH planning CT is registered to BH 2 BH 3



CPAP+BH



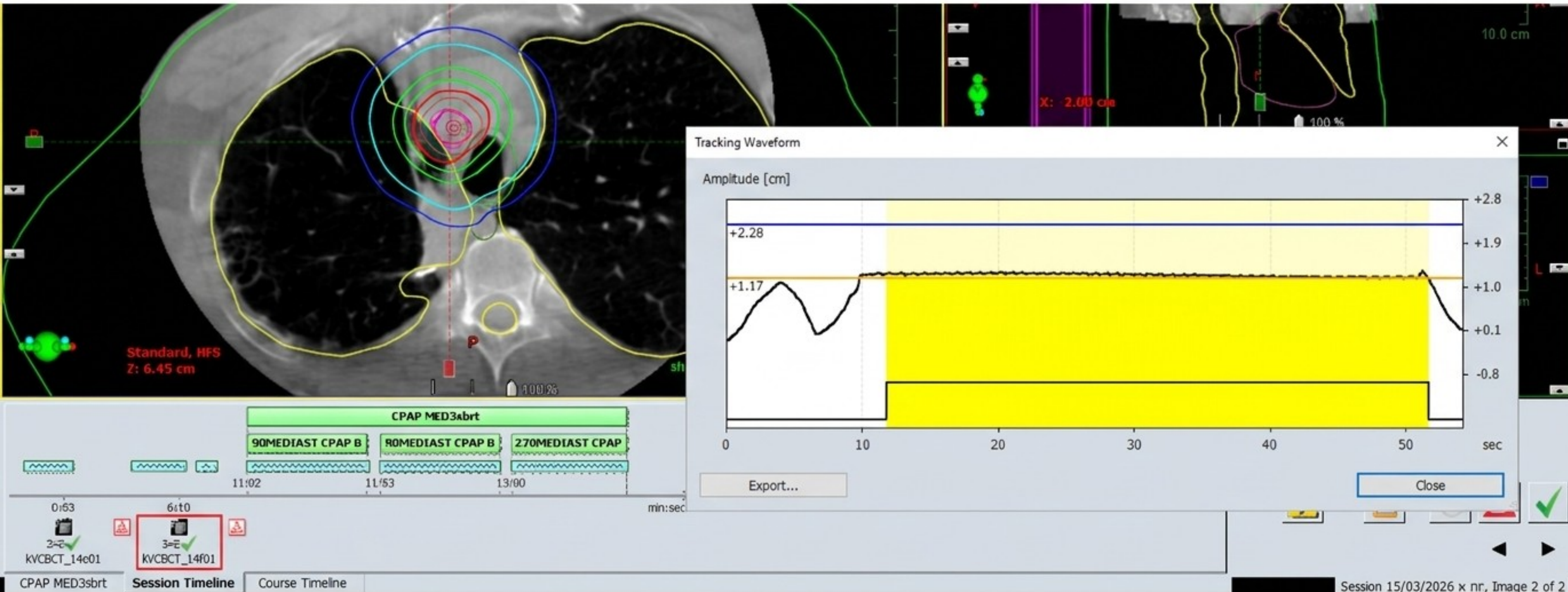
DIBH one breath is not the same as the other. With CPAP intra fraction motion is mitigated

Clinical Application: SBRT in Ultracentral Locations

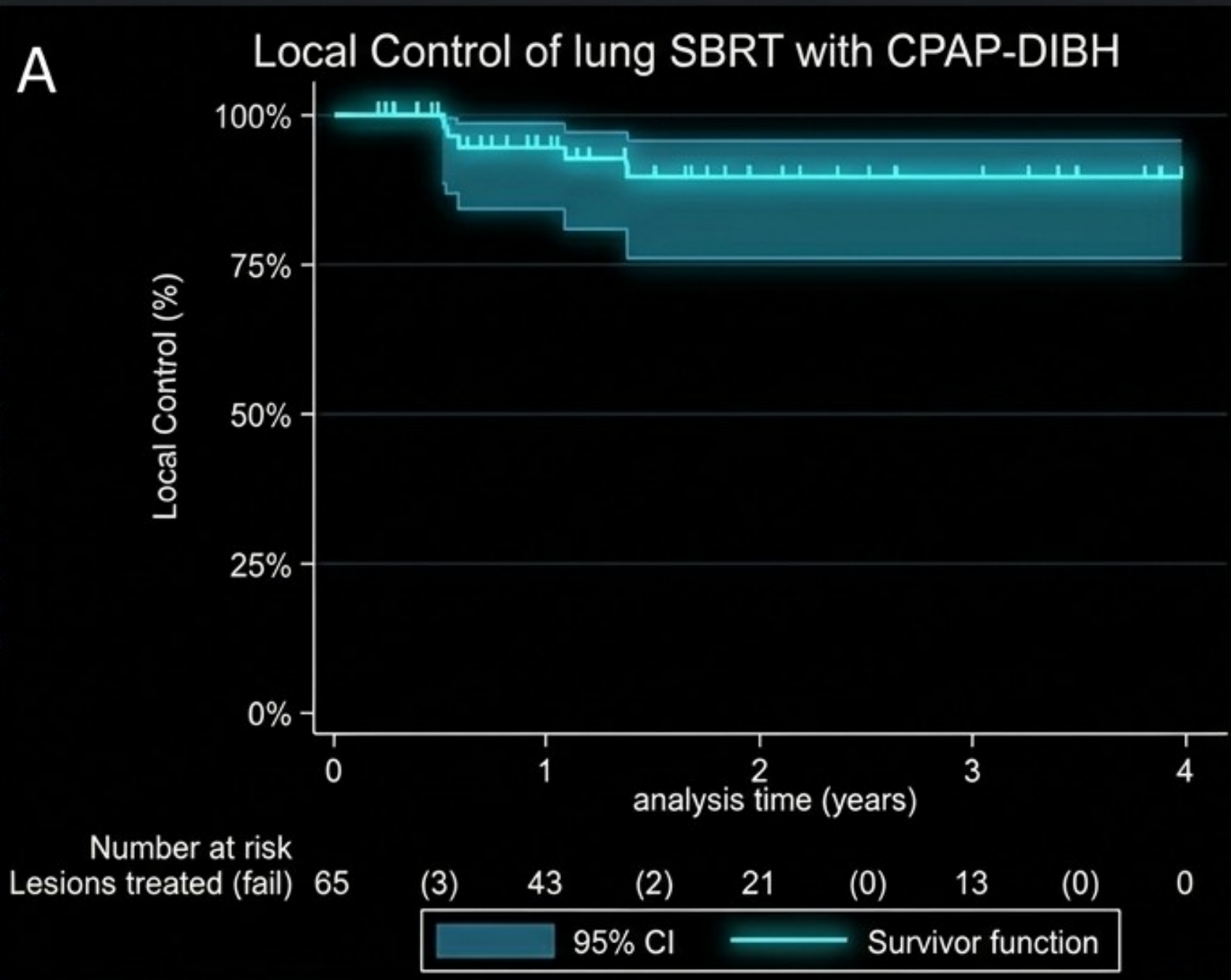
Case Profile: Mediastinal recurrence of lung cancer following a prior lobectomy.

The Constraint: Dose to the trachea must be strictly limited to avoid fatal necrosis.

The CPAP-DIBH Solution: By utilizing the technique, the PTV margin was aggressively minimized, keeping the tracheal dose within acceptable safety parameters while maintaining a stable mediastinum.



Oncologic Outcomes & Toxicity Profile



**89.5% Local Control
at 2 Years** (95% CI 76–95.5)

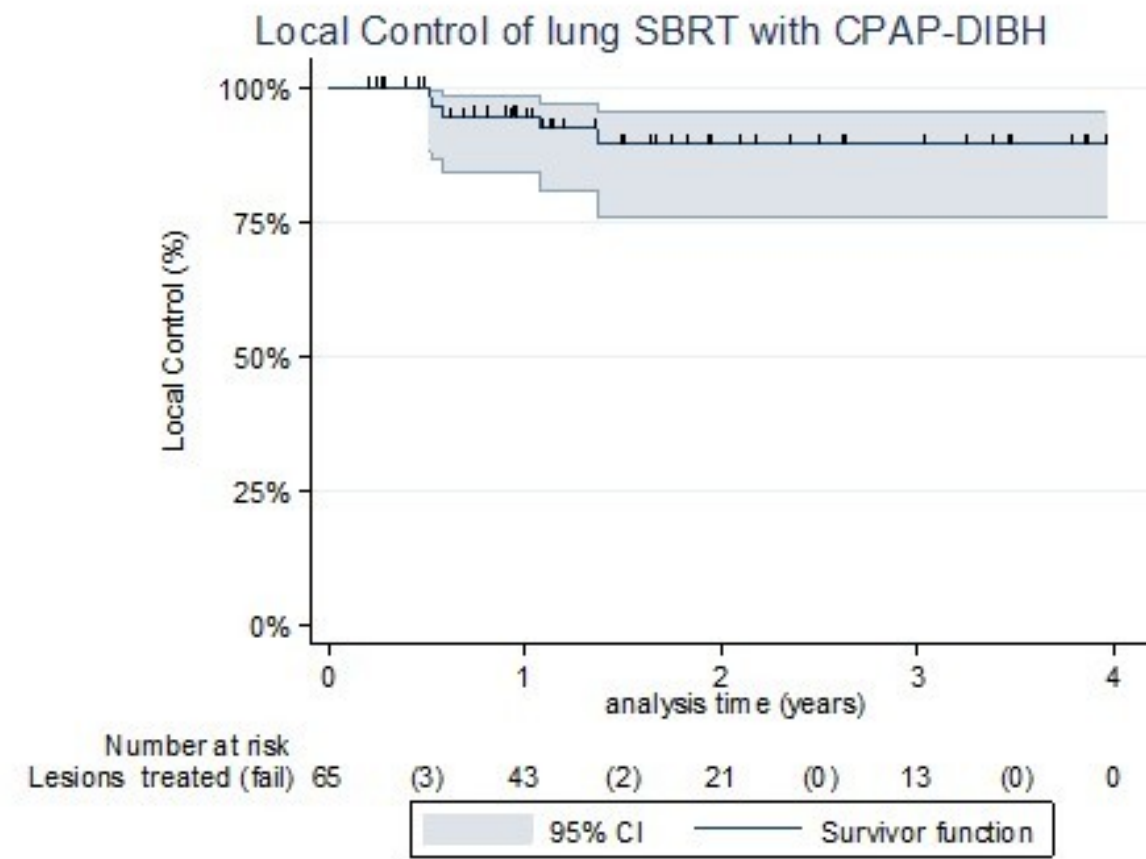
Toxicity Findings:

- Grade 2 Respiratory Toxicity: Only 6% (4/65 courses)
- Grade 3 Toxicity: 1.5% (1 case pre-existing AFib)

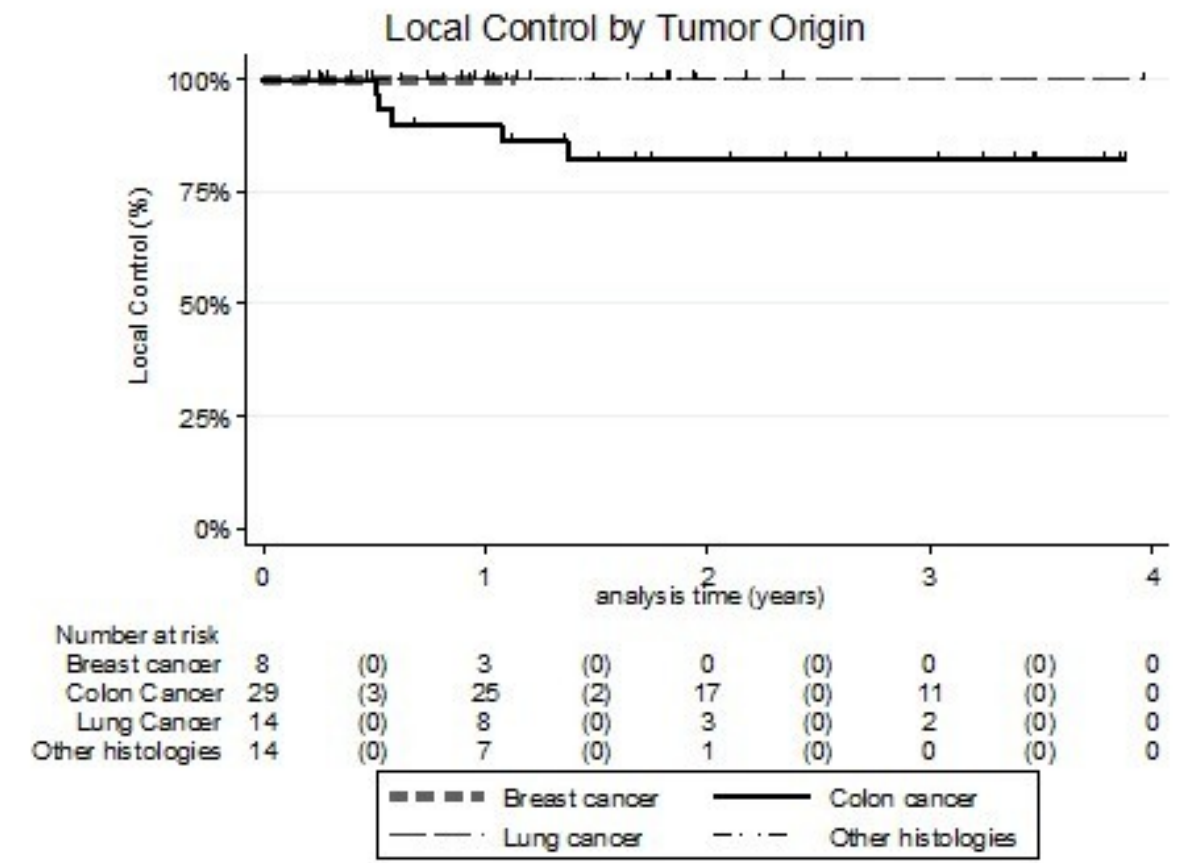
0% Grade ≥ 2 Esophageal or Tracheal Toxicities

Insight: Despite 65% of cases having prior radiation, lung toxicity remained exceptionally low, likely due to reduced normal lung exposure via hyperinflation.

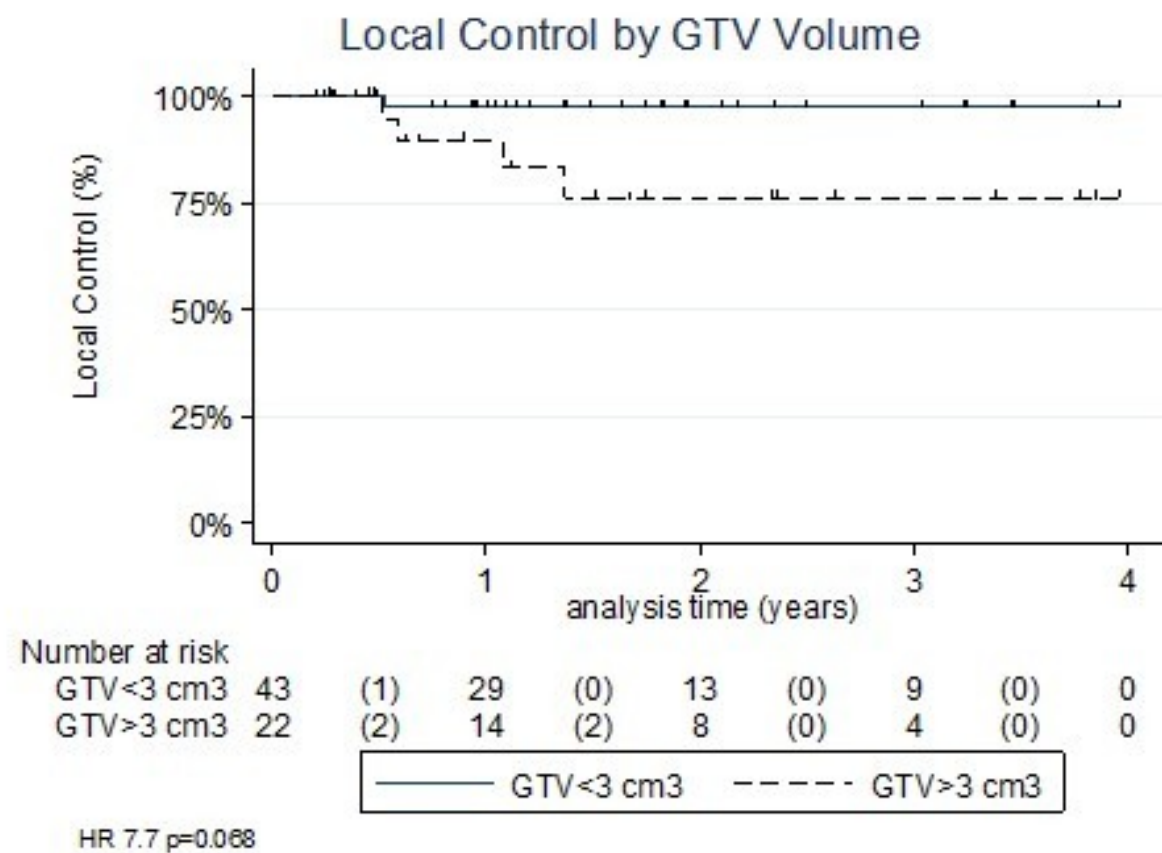
1A



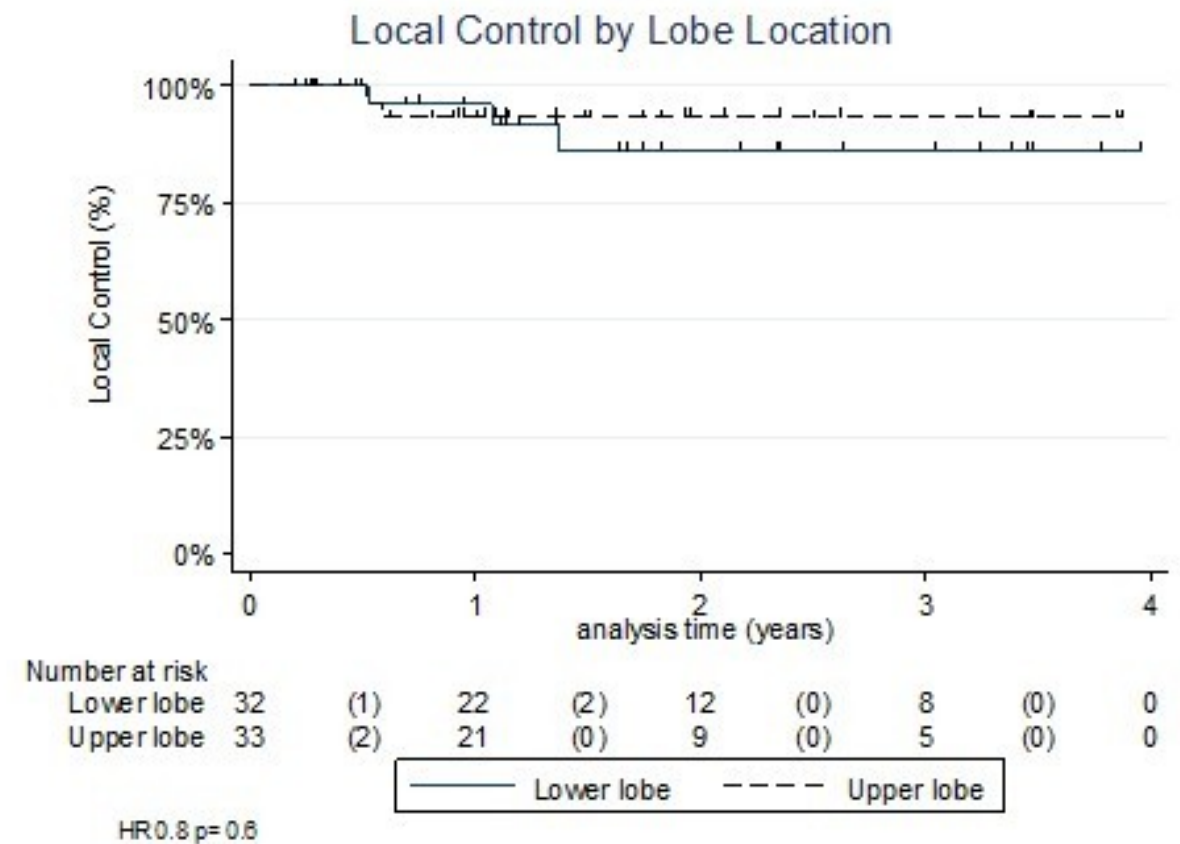
1B



1C



1D



Conclusion & The Clinical Horizon



Proven Efficacy

89.5% 2-year local control, even in patients with multiple lesions and prior radiation.



Exceptional Safety

41-second median breath holds enable ablative doses with zero severe mediastinal toxicity.



The Horizon

The protocol has now scaled to 128 patients and >600 fractions of CPAP-DIBH.

This accessible, low-cost intervention is ready for broader clinical adoption in high-risk SBRT.

The Future of Motion Management at Sheba

Next Steps (2025)

Comprehensive analysis of the expanded patient cohort.

Current Milestone

Over **128 patients** treated with **>600 fractions** using CPAP-DIBH to date.

Future Innovation

Prospective dosimetric comparisons and exploration of **supplemental oxygen** to extend safe breath-hold duration.

Redesigning the boundaries of precision radiotherapy.