



CPAP and NIMV in Clinical Practice: Seoul Experience

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Conflicts of Interest

Disclosures for this presentation

Yonsei University

Faculty member

Monitor Corporation

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Accuray

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Member of the Clinical Leadership Board

Oncosoft

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No conflicts of interest relevant to this presentation

YONSEI CANCER CENTER

Institution Overview

9,620

New patients treated
in 2025

91%

Advanced RT
(IMRT / SBRT / Carbon ion)

10%

of all RT patients
in Korea

180 RO staff members

LINAC



Elekta
(8)

Tomo/
Radixact
(4)

CyberKnife
(1)

Varian
TrueBeam (1)

Carbon ion
(3)

MR/CT Simulator



Philips Ingenia
MR Sim

Canon LB

GE Revolution

Canon
Exceed LB

Canon One Prism

CPAP/NIMV



Philips
CPAP (4)

Philips
EV300 (2)

MEKICS
OmniOx
(4)

Why CPAP?

1,000+ breast cancer patients treated per year

DIBH doubles treatment time → throughput crisis in a high-volume center

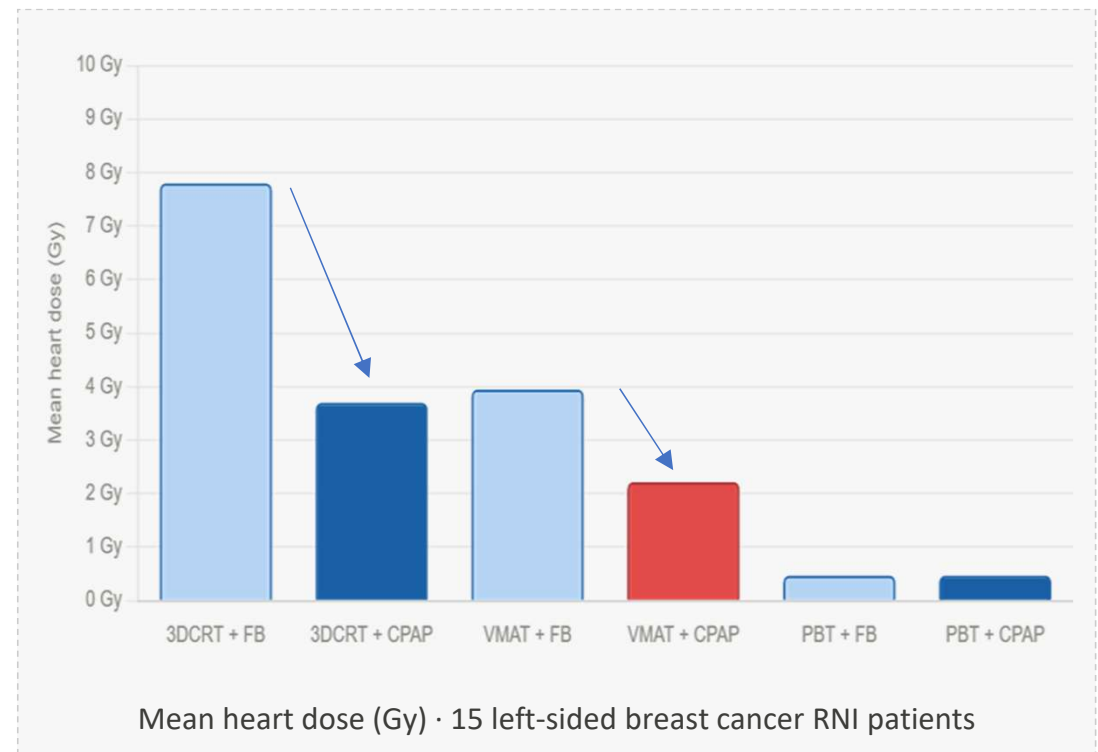
CPAP expected to spare heart and shorten treatment time

2020 — Decision to adopt CPAP at Yonsei Cancer Center

Study 1: CPAP + VMAT Planning Study

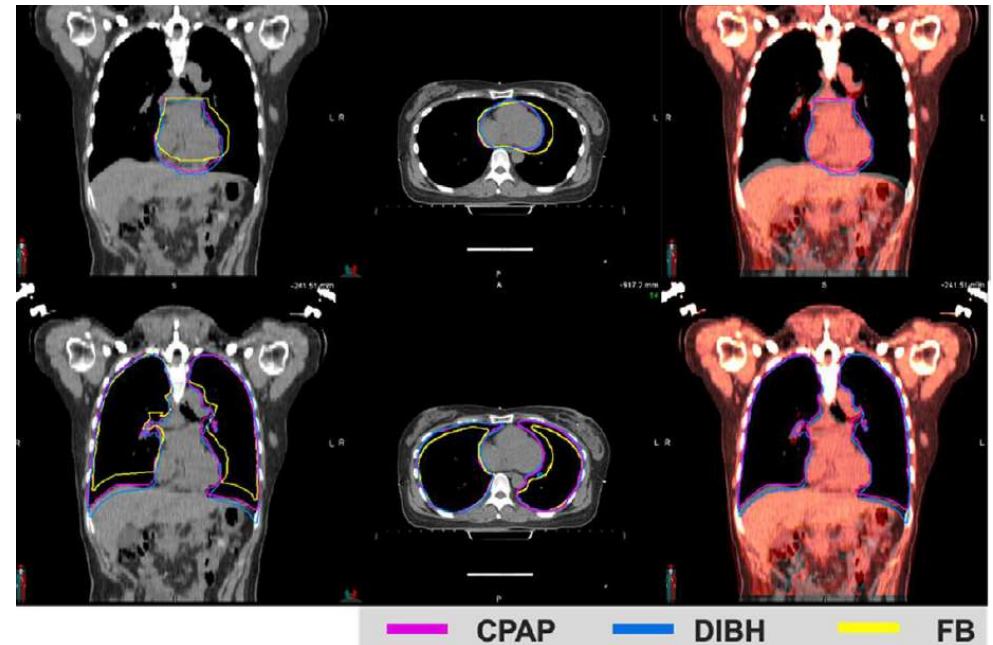
15 left-sided breast cancer patients
8 RNI (IMN included) planning techniques compared
(3DCRT, VMAT, PBT × FB/CPAP × CF/HF)

VMAT + CPAP: MHD **2.2 Gy**
VMAT + FB: MHD 3.95 Gy (-44%)
3DCRT + FB: MHD 7.8 Gy



Study 2: CPAP = DIBH — but 4× faster

	CPAP	DIBH	Free breathing
Mean heart dose (Gy)	1.05	1.05	1.34
Max LAD dose (Gy)	4.44	4.73	7.33
Treatment time	110 sec	385 sec	—
Physician's choice (based on compliance)	90%	—	—



CPAP shortens treatment time by 4× with equivalent cardiac protection

Study 3: Inter- and Intra-fraction Deviations

	Inter-fx	Intra-fx
Right breast (FB)	0.53 cm	0.14 cm
Left breast (DIBH)	0.66 cm	0.23 cm
Left breast (CPAP)	0.69 cm	0.24 cm

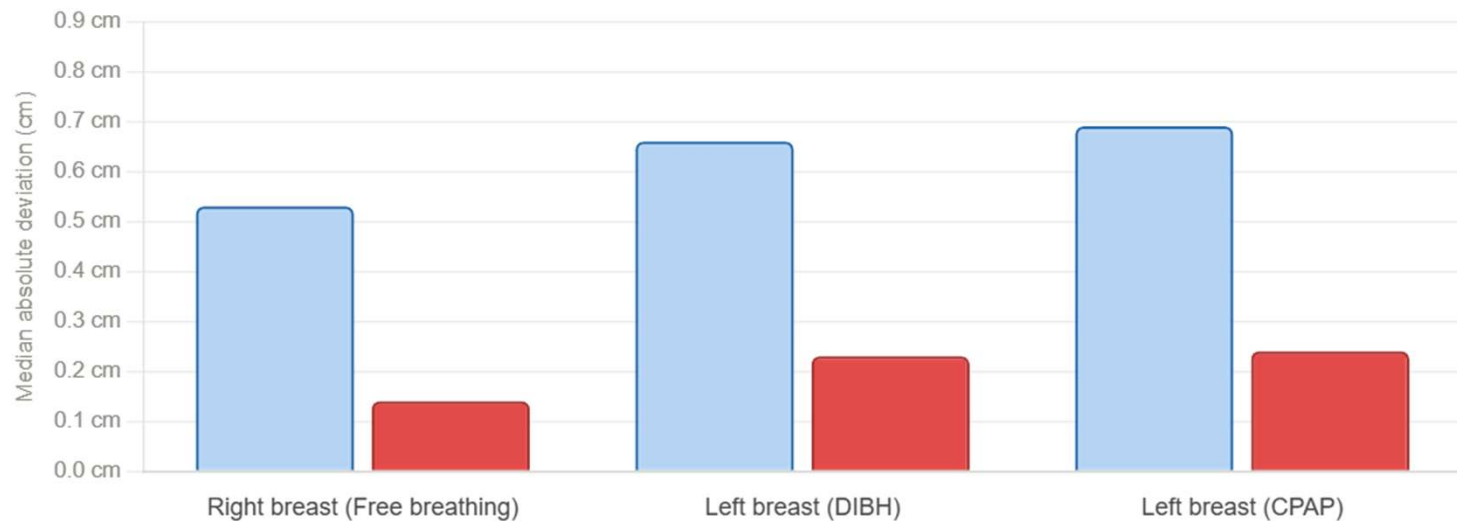
Most patients: intra-fraction deviation < 3 mm ✓

Outliers: Large intra-fraction deviation
7 cases — insufficient target coverage
2 cases — heart V25Gy > 20× increase

57 patients

- 24 DIBH
- 13 CPAP
- 20 FB

2,273 CBCTs



Study 4: Reproducibility & 237-Patient Experience

Inter-fraction heart position error

2 ± 2 mm

Reproducible across 300 daily CBCTs

Intra-fraction breast motion in 4D-CT

≤ 2.5 mm

CC 2.5 mm · AP 1.8 mm · ML 0.5 mm (outlier: 8 mm)

CPAP success rate in simulation (n = 237)

93%

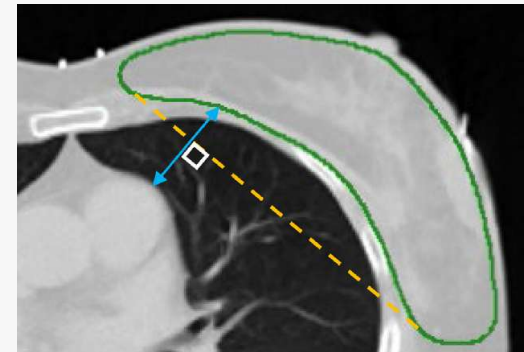
Successfully applied in routine practice

Mean heart dose in 237 patients

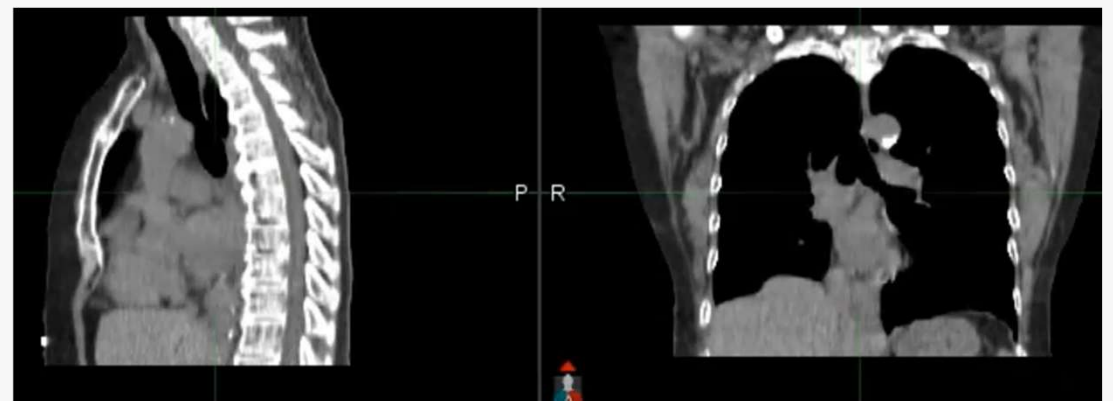
2.0 / 1.1 Gy (IMNI / no IMNI)

Choi et al., Pract Radiat Oncol 2022 ·

Heart-to-target distance (CBCT)



Outlier patient with a large upper chest movement



SGRT validation of CPAP

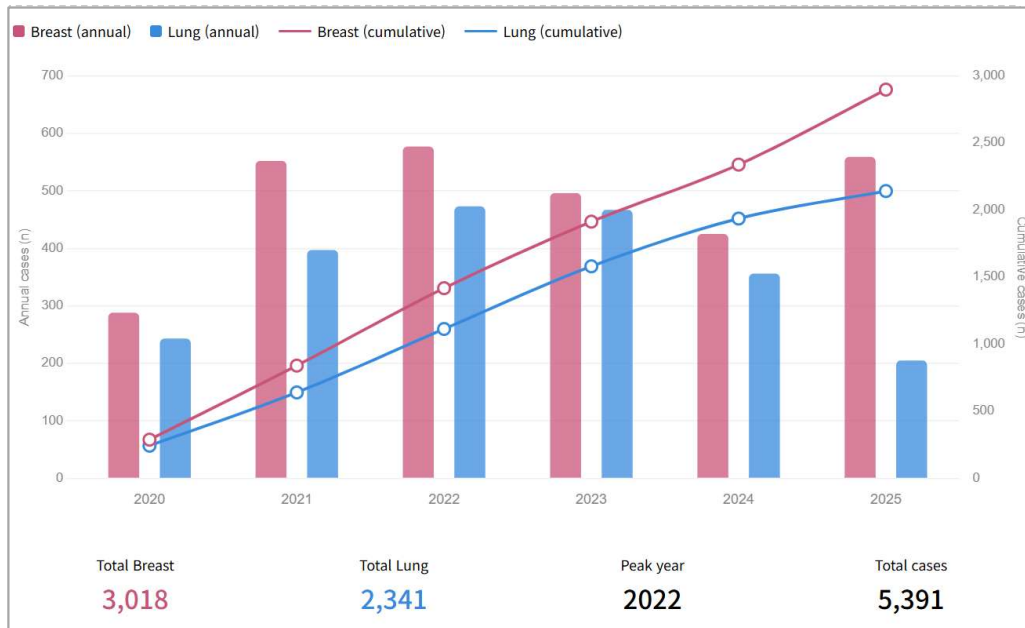
Scope	Preclinical	Clinical (DIBH vs CPAP)	Clinical (Monitoring)
Purpose	<ul style="list-style-type: none"> • Setup accuracy • Respiratory tracking feasibility 	<ul style="list-style-type: none"> • Setup accuracy • Dosimetric comparison • Workflow analysis 	<ul style="list-style-type: none"> • CPAP SGRT positional reproducibility • Treatment efficiency
Methods	Phantom study	Left-sided breast cancer patients (9 DIBH, 11 CPAP)	15 CPAP SGRT, 15 SGRT (+27 free breathing)
Findings/ Conclusions	<ul style="list-style-type: none"> • IGRT vs SGRT : Comparable • Decent respiratory tracking 	<ul style="list-style-type: none"> • Setup: Comparable • Superior dosimetry • Better workflow 	<ul style="list-style-type: none"> • CPAP SGRT : Stable during treatment • Similar treatment efficiency
Publication	<i>Radiation Physics and Chem, 2026</i>	<i>Physical and Engineering Sciences in Medicine, 2026</i>	<i>J Appl Clin Med Phys. 2025 Oct;26(10):e70284</i>

How We Do It — CPAP Protocol

- 1 No prior patient education
- 2 Facial mask applied directly in simulation room
- 3 Pressure gradually increased → target **13-15 cmH₂O**
- 4 If tolerated → immediate CT scanning
(If not tolerated, decreased to 10-13 cmH₂O)
- 5 Average time to CT scan: **Less than 10 min**



CPAP at Yonsei: Real-World Practice



- Pre-treatment **CBCT verification** for all breast patients
- Intra-fraction motion monitoring
Surface-guided RT (SGRT) integration
→ Automatic beam-off if threshold exceeded
- 3-directional 5 mm **robust optimization** (RayStation)
→ Best skin dose robustness vs flash (unpublished)

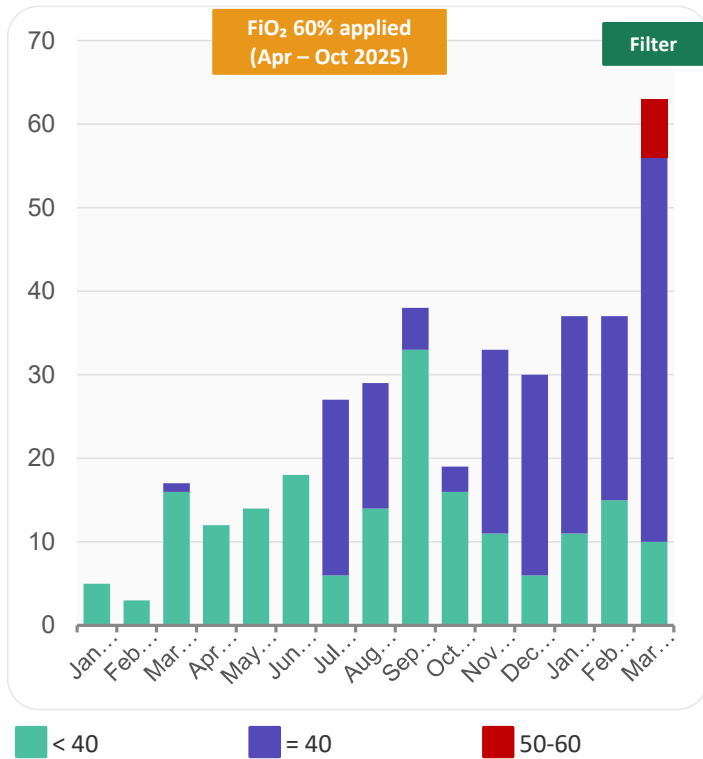
~1,000 breast / thorax patients treated with CPAP annually



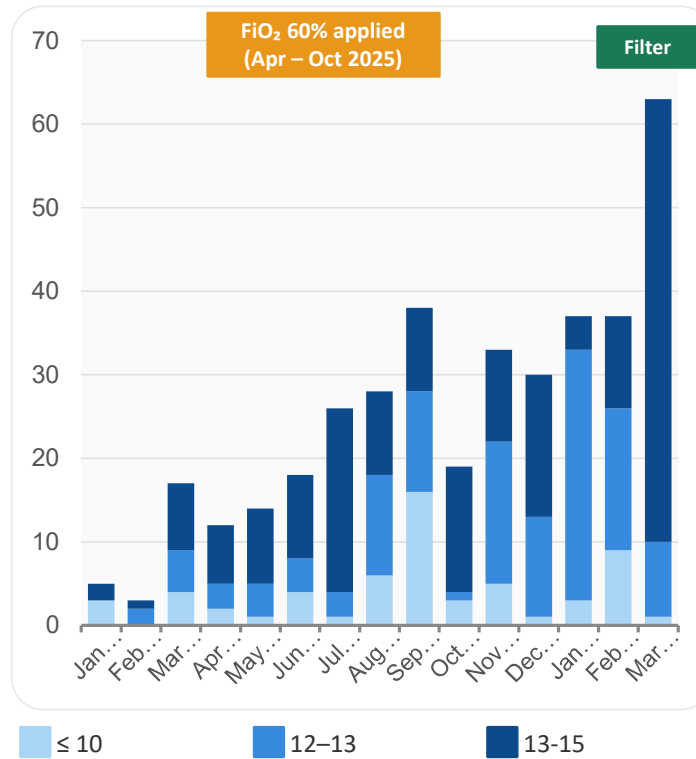
BiPAP Protocol Evolution (Jan 2025 – Mar 2026)

Total n = 382

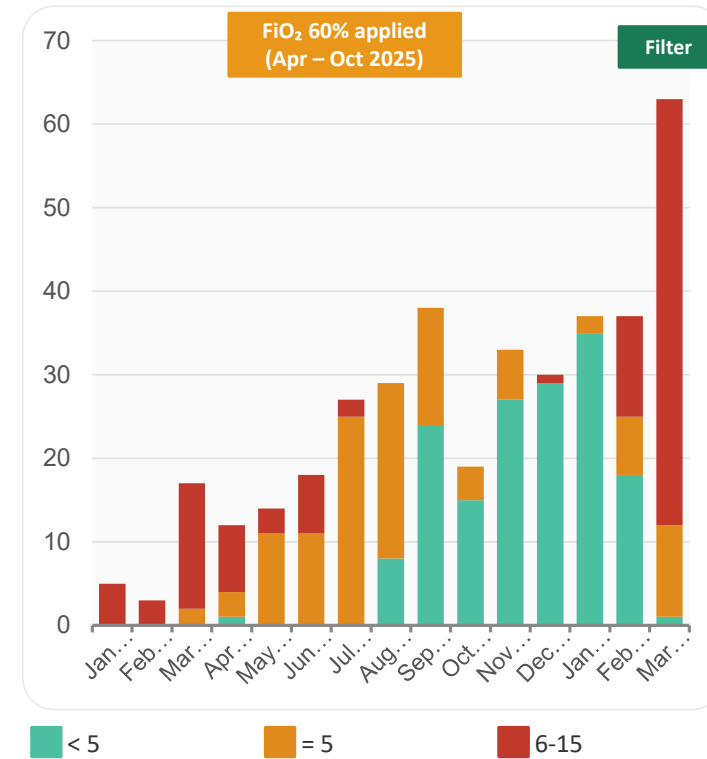
BR (bpm)



PEEP (cmH₂O)



Pinsp (cmH₂O)



Hidden Capability — and a New Constraint

RR issue in Philips EV300

Adult mode: RR max 40 bpm

Pediatric mode: **RR up to 60 bpm** ✓

→ NIMV-60 successfully achieved

4D-CT constraint

Most CT scanners: underestimation or failure at RR 60

GE Revolution (our institution):

Rotation time 0.2s · volumetric 4D · markerless

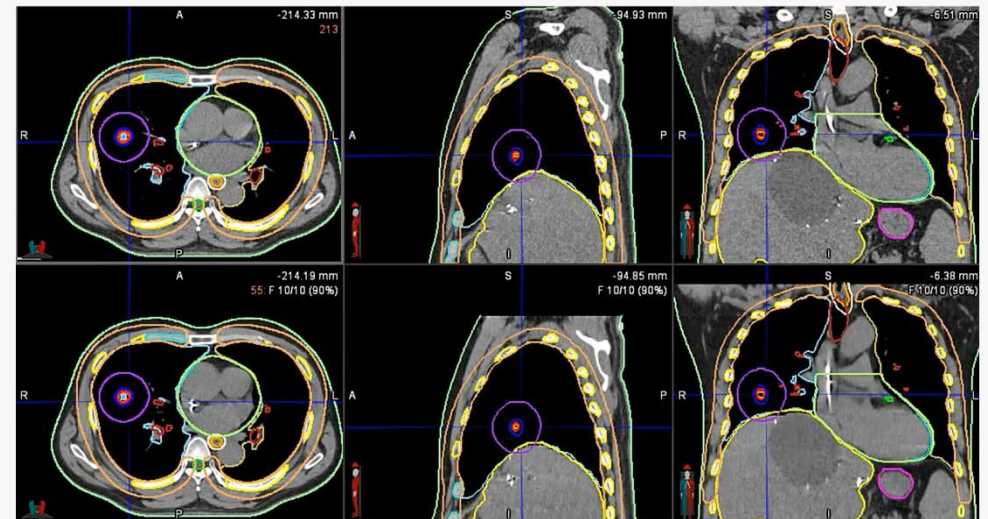
→ RR 60 imaging possible

Current practice:

GE Revolution room → RR 60

Other CT rooms → RR 40

[4D-CT images: RR60]



BiPAP PEEP 15cmH₂O, Pinsp 15cmH₂O

TROUBLESHOOTING 3

We Thought We Didn't Need It — We Were Wrong

Why we skipped the filter:

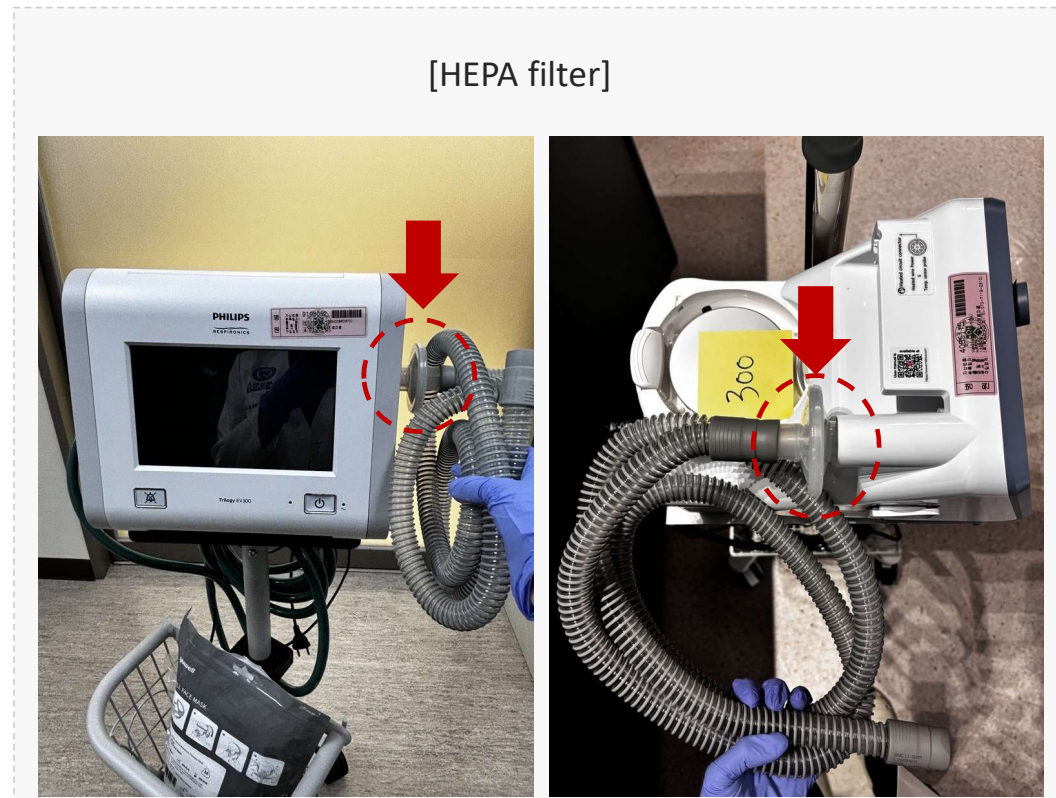
- ✓ Positive pressure device
- ✓ New mask + tubing per patient
- ✓ Short use < 20 min, healthy patients
- ✓ Infection control team approved

What happened:

16 (approximately 5%) failed simulation
("uncomfortable — cannot continue")

After adding HEPA filter:

- Failure rate markedly reduced
- PEEP, PC, RR targets all achievable
- Breathing signal stable

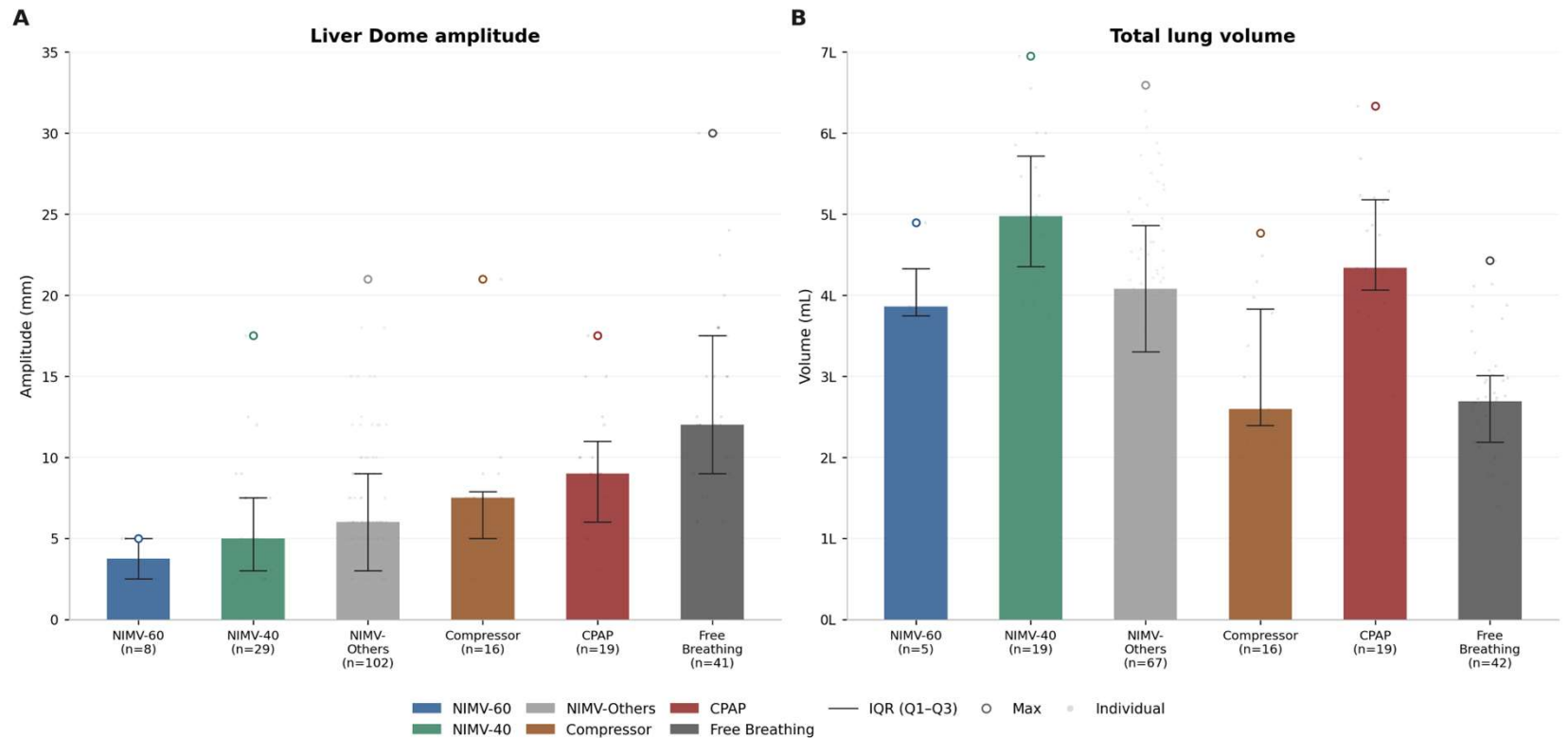
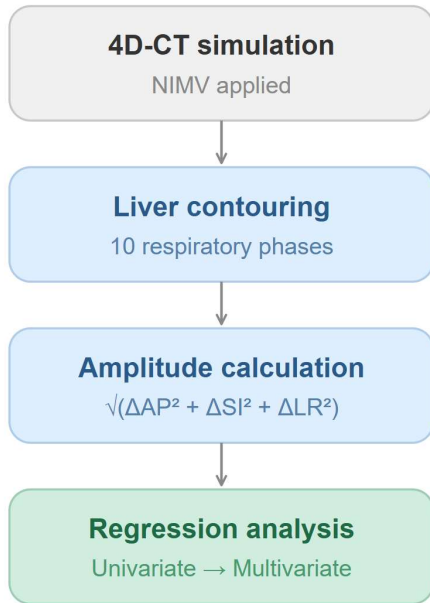


MOTION AMPLITUDE

Motion Amplitude Across Breathing Techniques (n = 211)

GTV and liver dome amplitude measured from all 10 phases of 4D-CT · Unpublished

Methods



NIMV-60 achieves the smallest motion amplitude

Which BiPAP Parameter Most Reduces Intrafraction Motion?

NIMV patients only · Parameter analysis · Unpublished

Dependent variable	R ²	F(4,134)
Liver Dome	0.119	4.51
Amplitude (mm)	Adj R ² = 0.092	p = 0.002

Variable	Coef	95% CI	p-value	Std β
BR (breaths/min)	-0.112	[-0.192, -0.032]	0.007 **	-0.951
PEEP (cmH ₂ O)	-0.368	[-0.647, -0.088]	0.010 *	-0.859
O ₂ supplementation	-0.641	[-2.027, +0.746]	ns	-0.318
Pinsp (cmH ₂ O)	-0.017	[-0.215, +0.181]	ns	-0.057

Key findings

PEEP ↑

Higher PEEP → smaller amplitude (independent)

BR ↑

Higher breathing rate → smaller amplitude (independent)

Both PEEP and BR are independently associated with motion reduction in NIMV patients

Target: PEEP ≥ 15 cmH₂O + 60 BR when tolerated

How We Do It — NIMV Protocol

Step	RR (bpm)	Flow trigger	Ti (sec)	PC (cmH ₂ O)	PEEP (cmH ₂ O)	IPAP (cmH ₂ O)	Rise time
1	Natural RR (25)	OFF	1.0	7	3	10	2 (normal)
2	30	OFF	0.8	7	7	14	1 (fast)
3	35	OFF	0.7	10	10	20	1 (fast)
Monitor closely (RR ≥ 40)	4	OFF	0.5	13	13	26	1 (fast)
	5	OFF	0.4	13	13	26	1 (fast)
Target	6	OFF	0.3	15	15	30	1 (fast)

* Step 1 uses the patient's natural breathing rate. Most patients breathe at RR 15–20; starting at 25 reduces acclimation time. (VTE: 800–1,100 mL)

* From Step 4 (RR 40), breathing cycle accelerates noticeably — monitor for patient discomfort. Instruct shallow chest breathing, not deep abdominal breaths. (Target VTE: 500–700 mL)

* Steps 5–6 are finalized at simulation based on patient body habitus and condition. (VTE 200–300 mL = excellent; 400–500 mL = controllable with respiratory gating)

* ★ RR > 40: 4D-CT acquisition currently only possible with GE Revolution CT

Enhancing Patient Comfort: Abdominal Compression

Clinical observation

Patients feel significantly more stable and comfortable with slight abdominal pressure during BiPAP ventilation

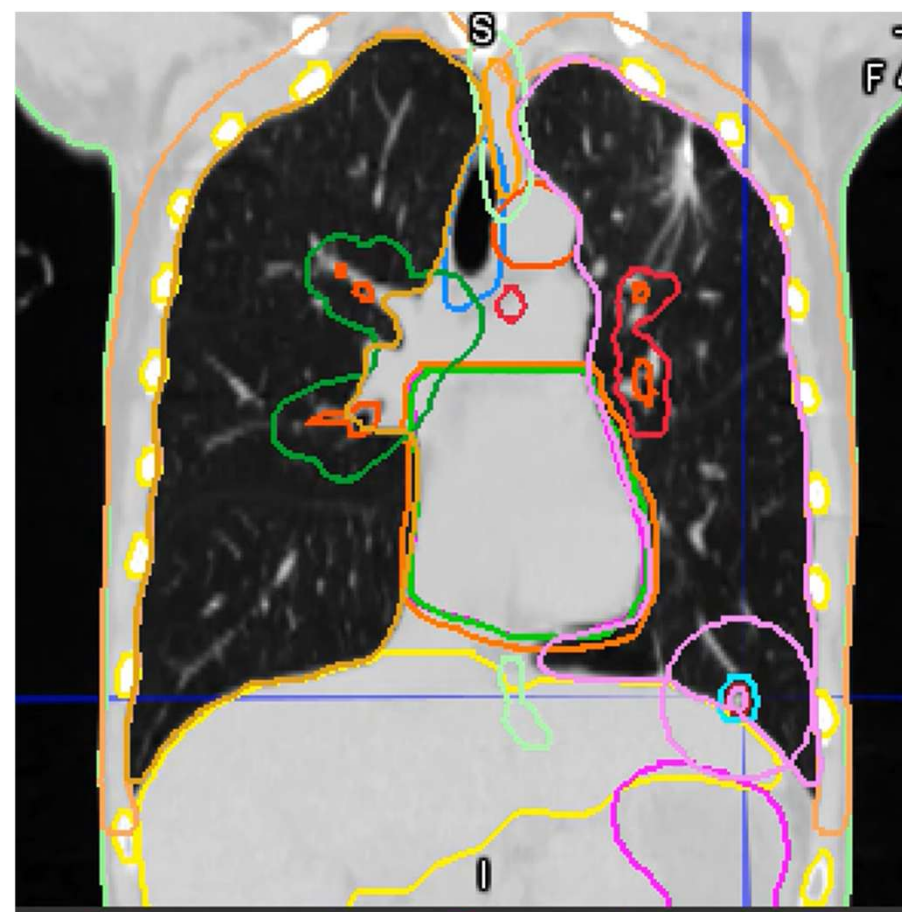
Our approach

- ZiFix™ abdominal compressor applied over the abdomen
- Minimal pressure — **tactile feedback only, not active compression**
- Improves patient tolerance → better motion management ???



4D-CT Examples

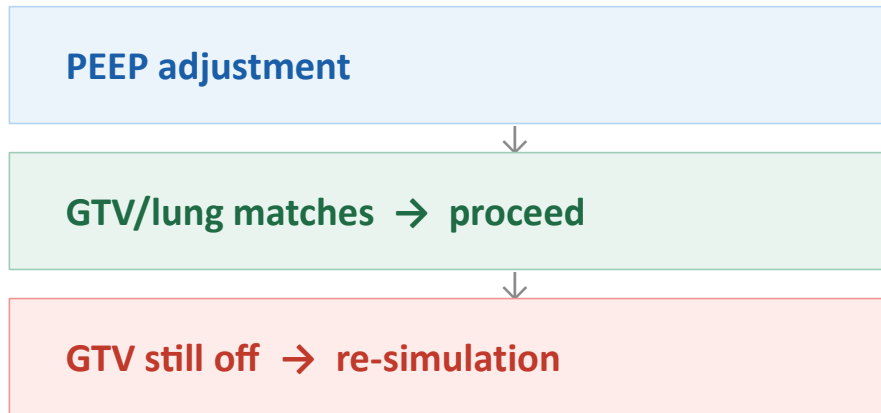
Respiratory Motion Under NIMV



TROUBLESHOOTING 4

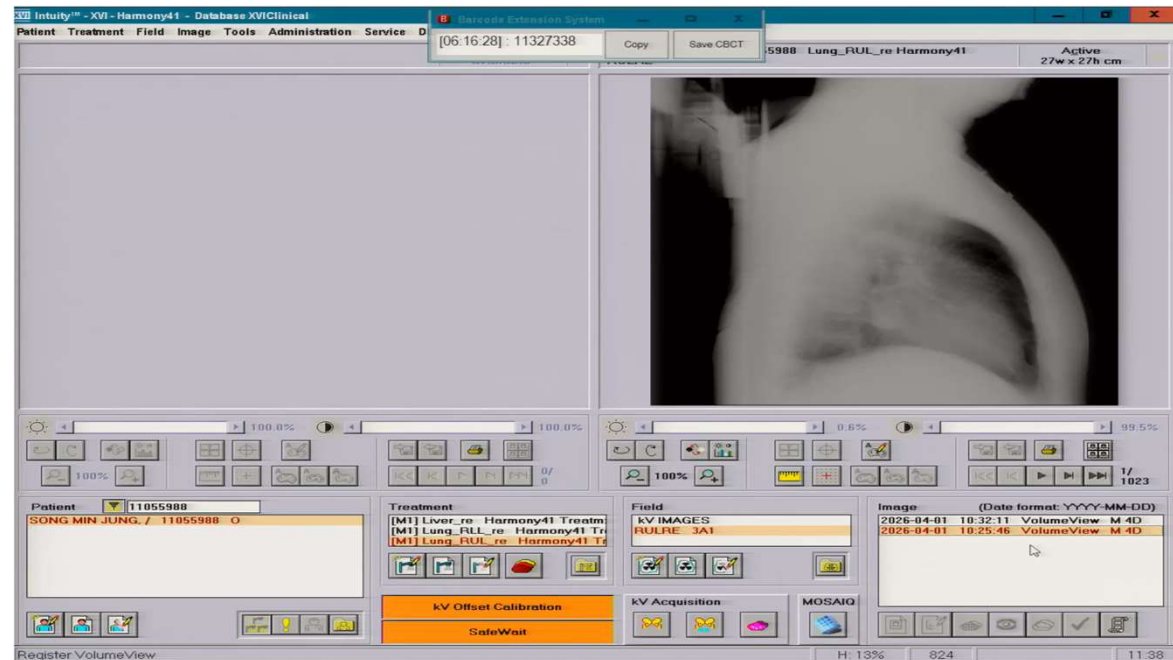
Lung Volume Mismatch on First Treatment Day

Problem: Day 1 CBCT differs from simulation CT



In most cases, PEEP adjustment alone is sufficient

Do not fixate on a fixed PEEP value — individualize to match lung expansion



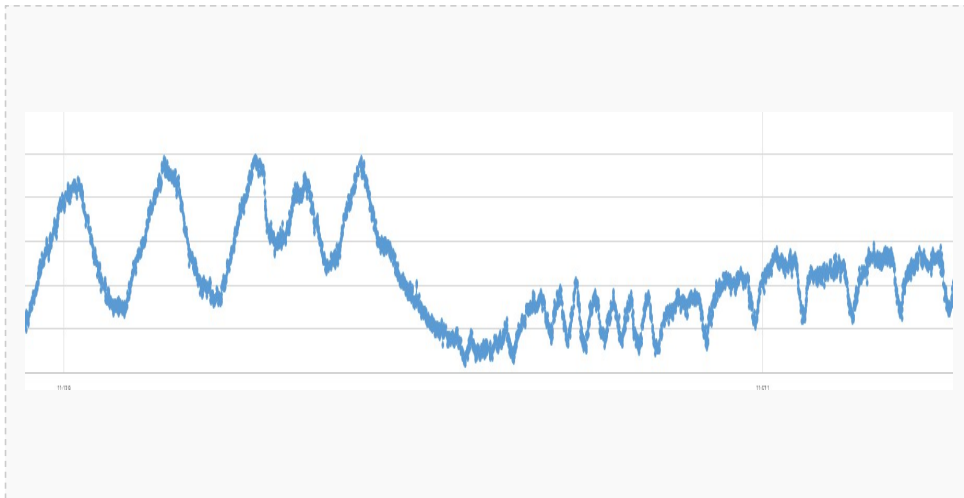
Day 1, 1st CBCT
show ,mismatch

PEEP increased by 2 cmH₂O
→ Repeat CBCT confirmed



Beyond ITV: BiPAP for Gating and Tracking

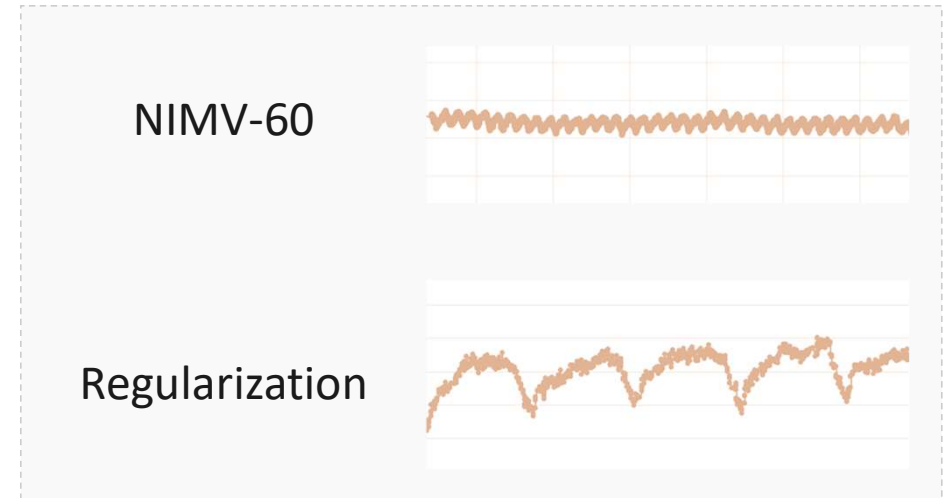
Real patient breathing



Baseline drift
Irregular amplitude



With BiPAP



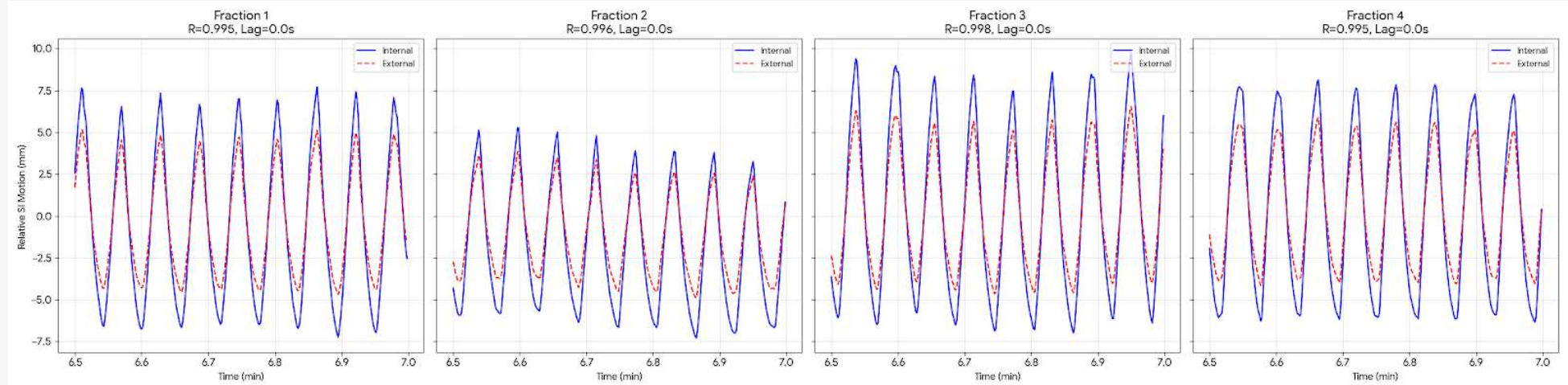
Regular and stable rhythm

Same device — fundamentally different rationale from ITV-based treatment

QUESTION 1 — Does BiPAP affect internal–external motion correlation?

BiPAP + CyberKnife: External vs Internal Marker

Key question: Does the external marker accurately reflect internal target motion under BiPAP?



- Excellent synchrony maintained across all fractions
- $R = 0.995\text{--}0.998$, Lag = 0.0 s in all fractions
- BiPAP does not disrupt internal–external marker correlation

BiPAP Respiratory Regularization Protocol for Gating / Tracking

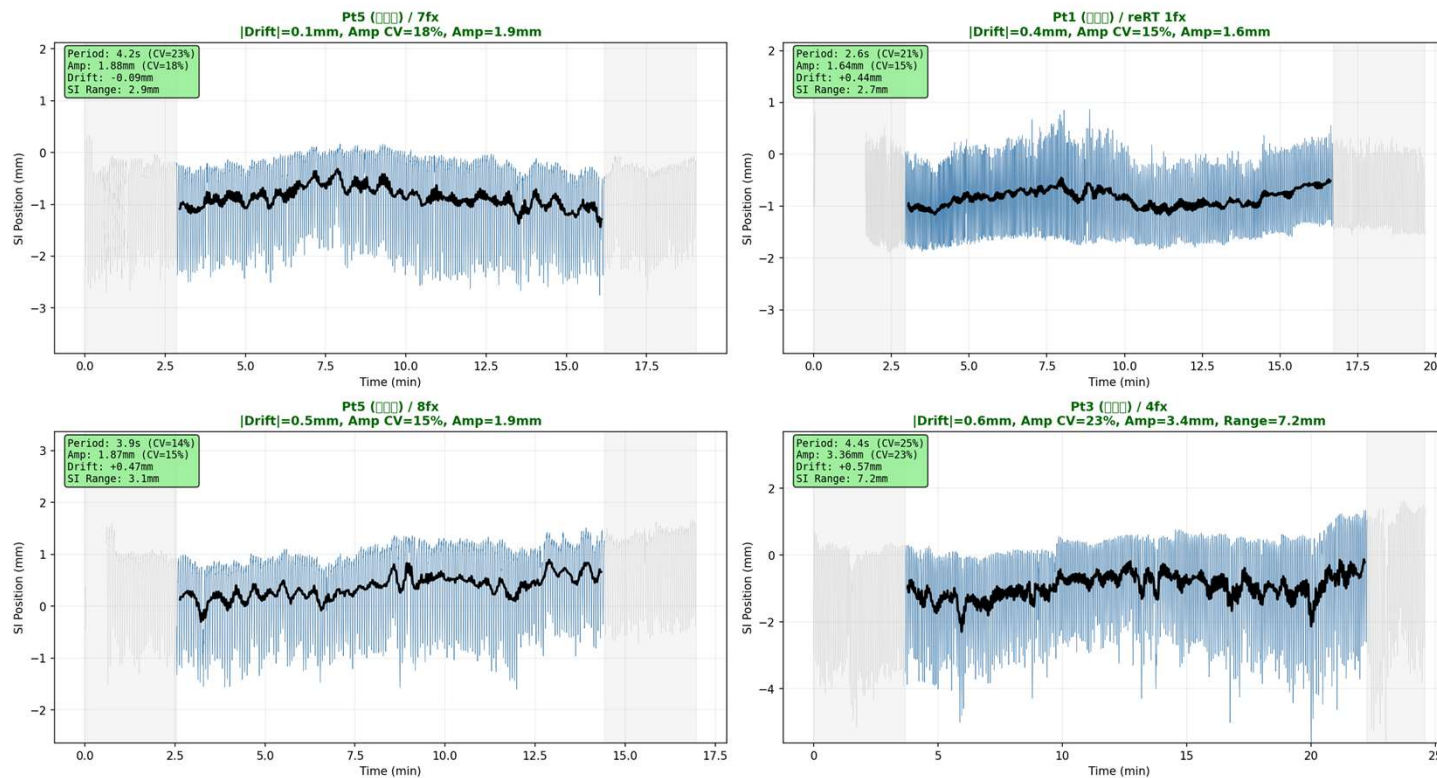
Step	Parameter	Setting / Action (Philips EV300)
1. Check natural RR	Record	Natural RR = ___ bpm
2. Initial setting	Flow trigger	OFF (ignore patient's spontaneous breath)
	PC (Pinsp)	7 cmH ₂ O
	PEEP (EPAP)	3 cmH ₂ O
	Rise time	2
	Backup RR	Set 1–4 bpm below natural RR
	Ti	See reference table below (I:E = 1:2)
3. PEEP titration	Titrate up	PEEP 3 → 7 cmH ₂ O (stepwise increase)
	If discomfort	PEEP 7 → 6 → 5 cmH ₂ O or PC 7 → 5 cmH ₂ O
	Final PEEP	5–7 cmH₂O (individualized based on patient tolerance)

Protocol under development — not yet clinically validated

RR	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ti (s)	2.0	1.8	1.7	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.8	0.8

CyberKnife + BiPAP: Internal Marker Log Analysis

- Representative Cases: Well-controlled Respiratory Motion Under BiPAP

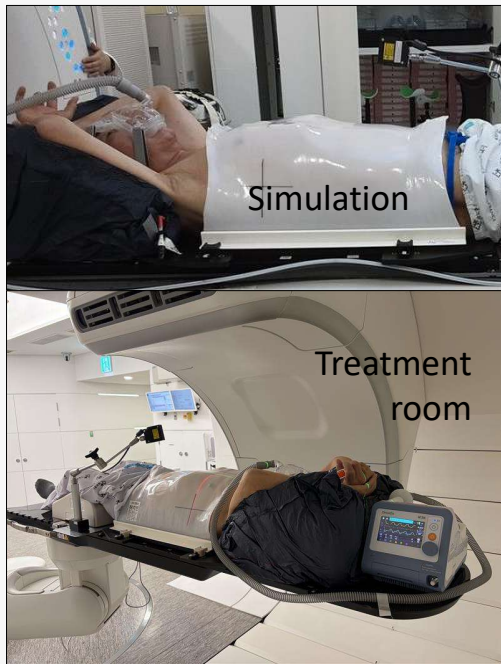


- Gray = before BiPAP adaptation · Blue = during treatment · Black = moving average (baseline)
- Drift < 1 mm · Amplitude CV 15–25% · SI Range 2.7–7.2 mm

Carbon Ion Gating + BiPAP

The same challenge: **baseline drift and irregular breathing**

We hypothesized BiPAP could provide the stability needed for reliable gating — and tested it



Top phase: 50%, Gating phase: 40-80%
EPAP 7, IPAP 14, RR18, Ti 1.6

	CT-SIM	Tx			
		Fx 1	Fx 2	Fx 3	Fx 4
Period (s)	3.34 ± 0.13	3.34 ± 0.21	3.35 ± 0.27	3.35 ± 0.16	3.34 ± 0.21
Amplitude (mm)	7.39 ± 0.96	8.86 ± 1.96	6.73 ± 2.15	7.77 ± 1.18	8.55 ± 1.62
Baseline (%)	-1.30 ± 4.09	-0.05 ± 2.97	-2.53 ± 1.64	1.43 ± 2.44	0.02 ± 1.82
Irregularity (%)	6.55	9.18	15.29	7.85	9.64
Tx time	-	2 min 6 s	2 min 47 s	2 min	2 min 46 s
Gating window modification	-	7	8	6	8

Slide courtesy of Dr. Kyung Hwan Kim

CONCLUSIONS

Take-Home Messages

1

Versatile tools

CPAP and BiPAP apply across breast RT, lung SBRT, oligometas SABR, CyberKnife, and Carbon ion — one platform, many applications

2

Game changers

CPAP/BiPAP improve throughput, cardiac sparing, and motion control simultaneously

3

Enormous untapped potential

We are still in the early days — the full scope of application is yet to be explored

4

Collaborative effort needed

Standardized protocols, shared institutional experience, and multicenter data are essential to move the field forward

GE Revolution CT (20)



- GE Revolution CT
 - Detector Width: 8 cm
 - Slice Thickness: 0.625 mm
 - Z-axis coverage: 8 cm per rotation
 - Gantry rotation: 0.28-0.35 sec
 - Spatial resolution: 0.23-0.28 mm
 - Temporal resolution: ~29 ms

→ 4D CT Acquisition

- Detector Width: 4 cm
- Mode: Volumetric (Static, Step-and-Shoot) mode
- Phase-Sorting Reference: External Surrogate (RGSC) / Markerless Option

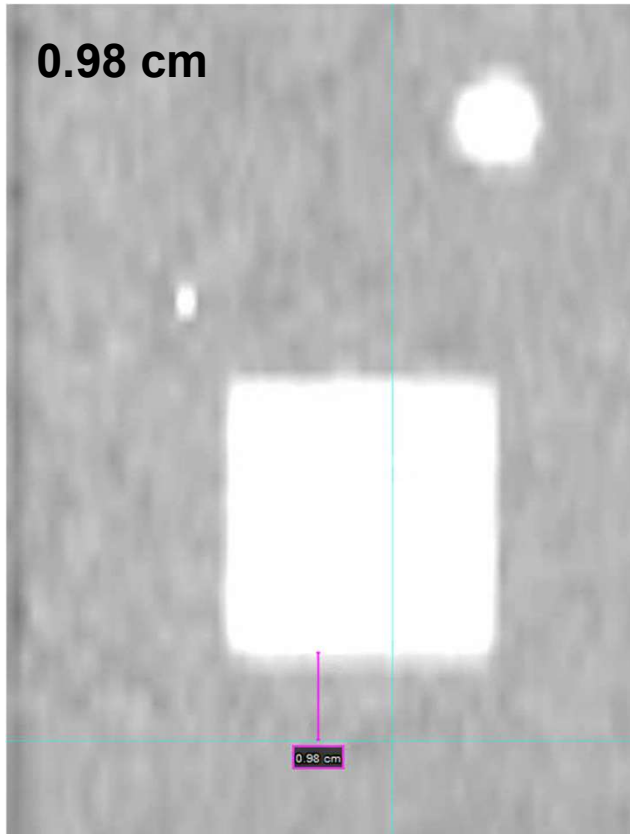
Quasar Moving Phantom

- Moving phantom
 - * Different respiratory cycle (30, 40, 50, 60 RR)
 - * Amplitude: **1 cm** (Superior-Inferior direction)
 - * External marker: RGSC
(Markerless 4D is **unavailable** for phantom)

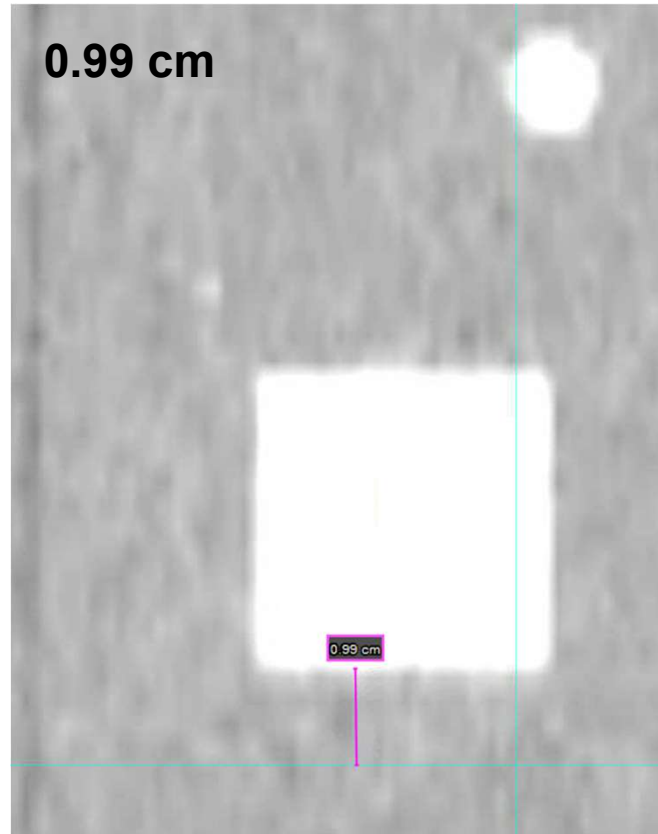


Results (30,40,50 RR) with RGSC

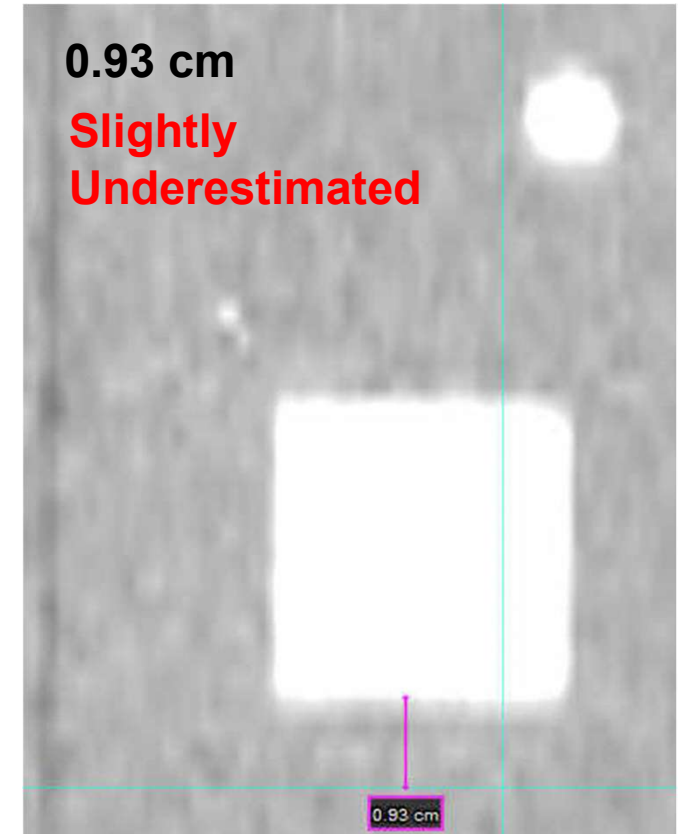
30 RR



40 RR

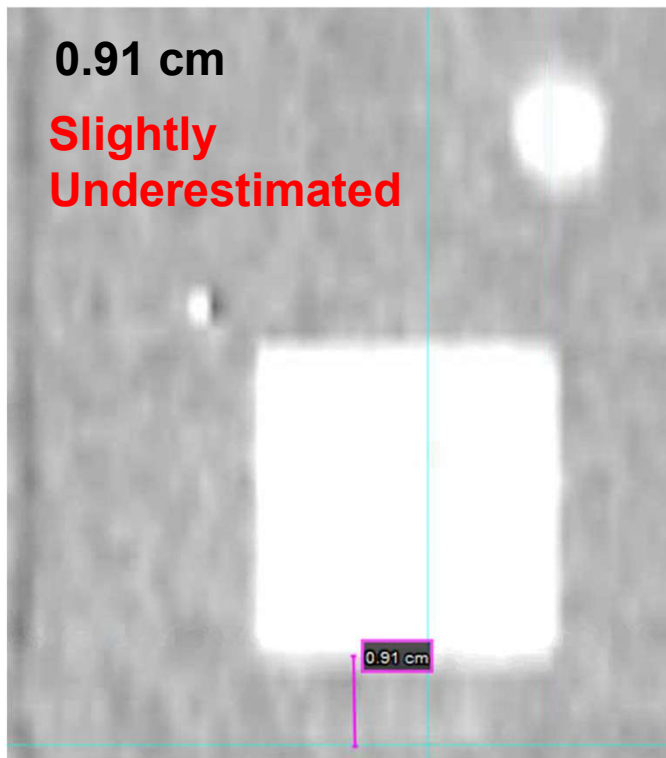


50 RR



Results (60 RR) with RGSC

60 RR



Totally Wrong Sorted Images

