Use of 60% O2 in Clinical Practice
The Kaiser Permanente Experience

Matt Skinner
Chief Medical Physicist

Dr. Dasarahally Mohan, MD
Radiation Oncologist

Kaiser Permanente - South San Francisco
South San Francisco, USA

Kaiser Permanente (KP) Northern California

KAISER PERMANENTE®

- 6 Radiation Oncology centers:
    - Santa Clara
    - Oakland
    - South San Francisco
    - Dublin
    - Rancho Cordova
    - Roseville

https://www.britannica.com/place/California-state

- Regional total of 19 TrueBeams, 3 Bravos HDRs
- Treat about 10,000 patients per year

Kaiser Permanente (KP) South San Francisco

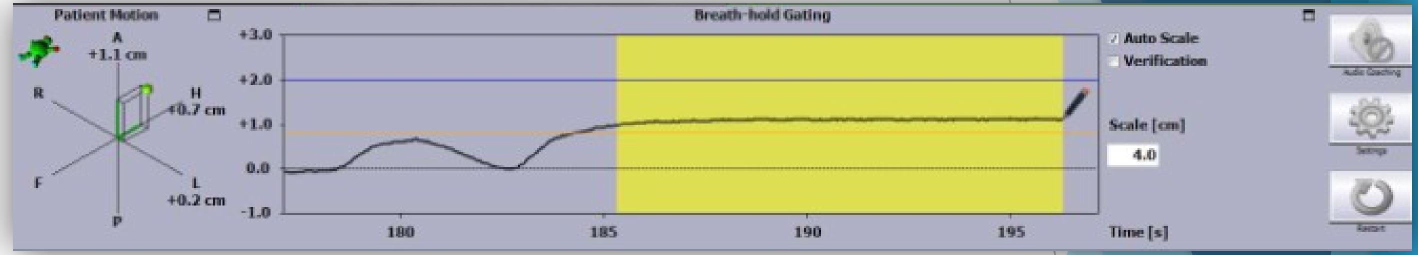
- 4 TrueBeam – 2 HDMLC, 2 Millennium
- 8 Radiation Oncologist, 5 Physicists, 4 Dosimetrists
- ~1850 patients/annually
  - 2025 - 387 breast

- Main stereotactic radiosurgery program
- 900 SRS & SBRT patients annually (~45% of practice)
  - ~ 2025 – 200 lung, liver and abdominal SBRT

Motion Management At Kaiser Permanente

Respiratory motion management used for over a decade for SBRT and breast EBRT

- 4DCT and breath hold CT with Varian RPM and RGSC with video feedback (**VCD**)
- Varian TrueBeam respiratory gating (MV, kV, CBCT and fluoroscopy)



VisionRT AlignRT™

Brainlab ExacTrac Dynamic ™

Motion Management At Kaiser Permanente

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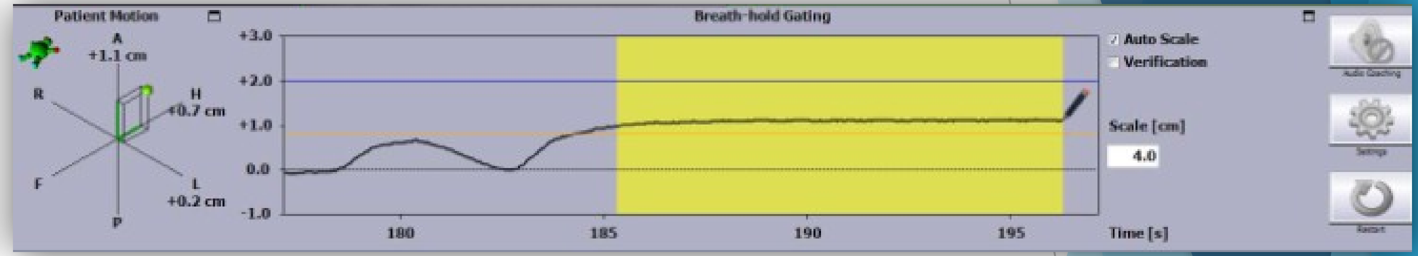


SBRT Motion Management

- 50% treated in free breathing
- ~40% of cases treated under breath hold
- ~10% of cases treated with respiratory gating

Rationale for Breathing Control

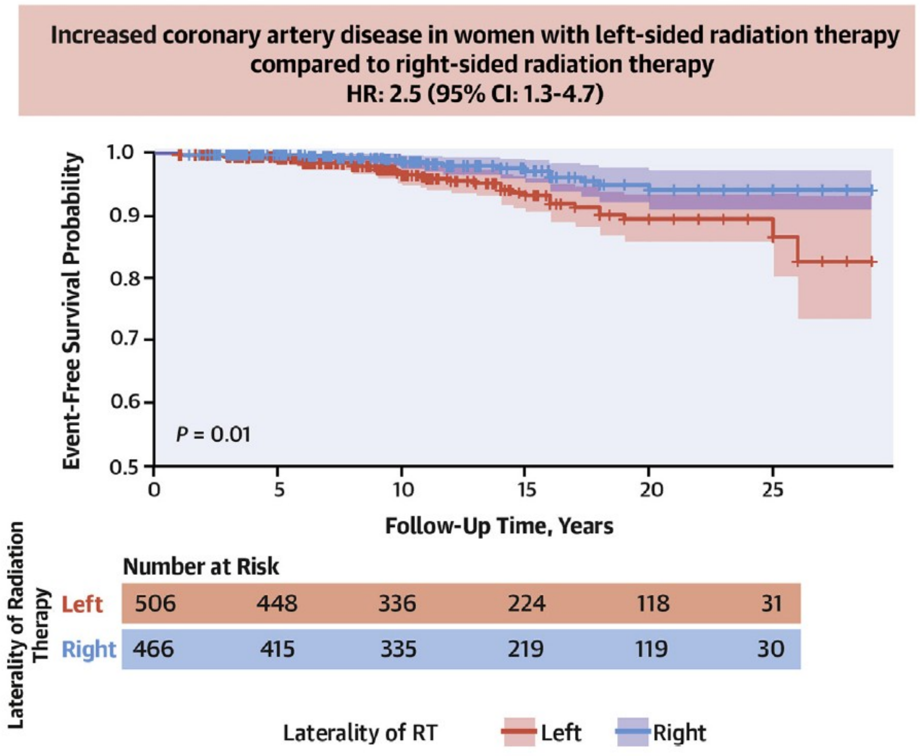
Breast

SBRT

Rationale for Breath Hold in Breast

- RT-related cardiac disease is a significant concern in nearly all patients receiving thoracic RT.
- In breast & Hodgkin lymphoma survivors, for each 1 Gy increase of mean D_{Heart},
  → 7.4% excess relative risk of developing coronary artery disease (CAD).
  - Radiation Related Heart Disease
  - Pericarditis
  - Pericardial fibrosis
  - Diffuse myocardial fibrosis
  - Coronary artery disease
  - Valvular disease
  - Conduction defects

} Relevant to Breast Cancer Radiation



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The NEW ENGLAND JOURNAL of MEDICINE

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Risk of Ischemic Heart Disease in Women after Radiotherapy for Breast Cancer

Sarah C. Darby, Ph.D., Marianne Ewertz, D.M.Sc., Paul McGale, Ph.D., Anna M. Bennet, Ph.D., Ulla Blom-Goldman, M.D., Dorthe Brønnum, R.N., Candace Correa, M.D., David Cutter, F.R.C.R., Giovanna Gagliardi, Ph.D., Bruna Gigante, Ph.D., Maj-Britt Jensen, M.Sc., Andrew Nisbet, Ph.D., Richard Peto, F.R.S., Kazem Rahimi, D.M., Carolyn Taylor, D.Phil., and Per Hall, Ph.D.

METHODS

We conducted a population-based case–control study of major coronary events (i.e., myocardial infarction, coronary revascularization, or death from ischemic heart disease) in 2168 women who underwent radiotherapy for breast cancer between 1958 and 2001 in Sweden and Denmark; the study included 963 women with major coronary events and 1205 controls. Individual patient information was obtained from hospital records. For each woman, the mean radiation doses to the whole heart and to the left anterior descending coronary artery were estimated from her radiotherapy chart.

RADIATION DOSIMETRY

Individual radiotherapy charts, including a diagram or photograph of the treatment fields and a dose plan (where available) were copied. Virtual simu-

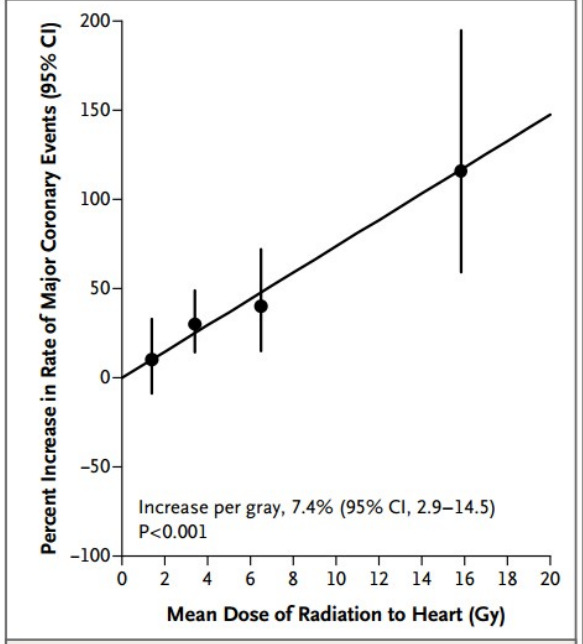


Figure 1. Rate of Major Coronary Events According to Mean Radiation Dose to the Heart, as Compared with the Estimated Rate with No Radiation Exposure to the Heart.

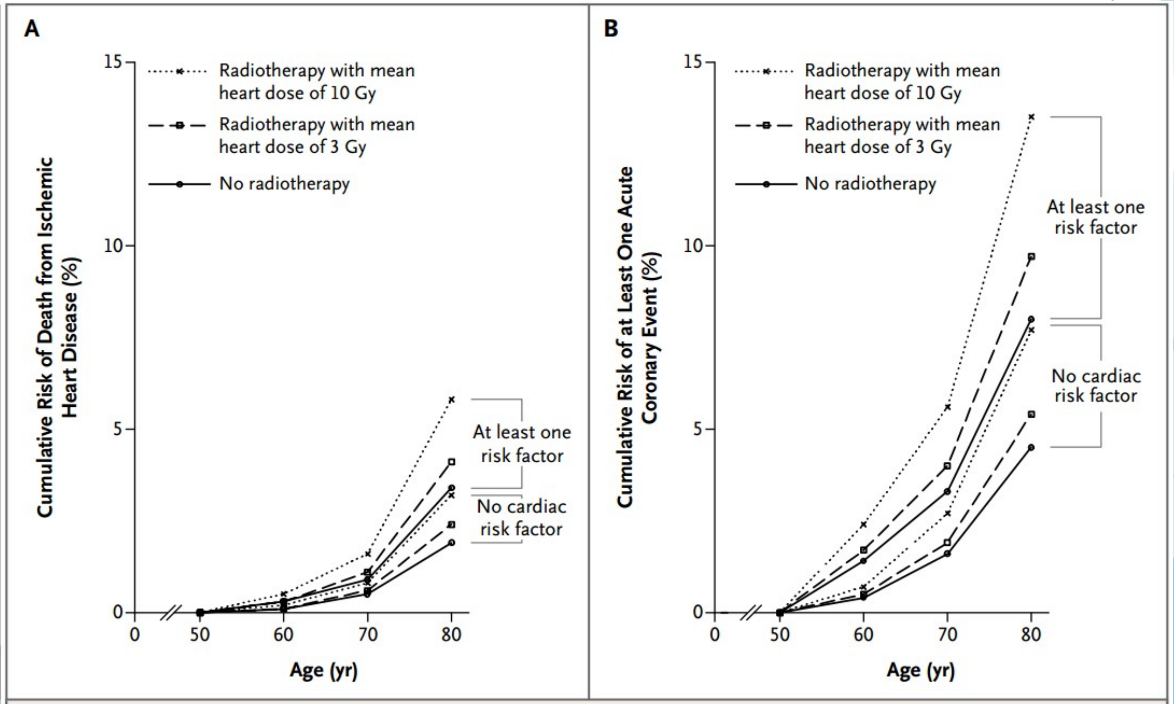
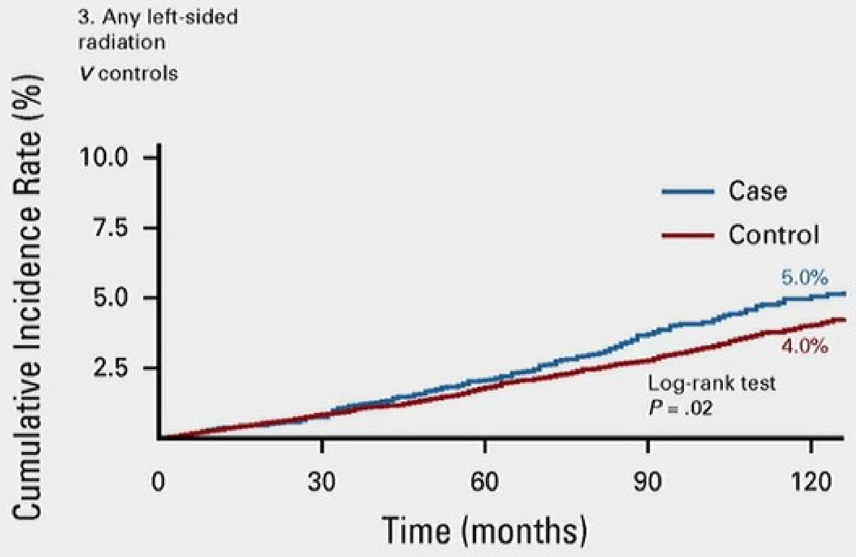


Figure 2. Cumulative Risks of Death from Ischemic Heart Disease and of at Least One Acute Coronary Event.

- No dose threshold for risk of subsequent cardiac event
- Risk apparent within 5 yr

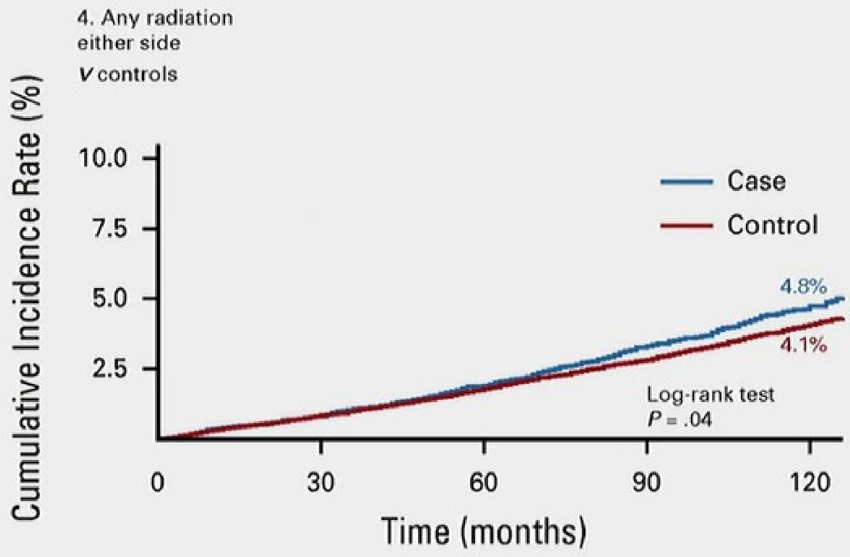
Higher Cumulative Incidence of Heart Failure/Cardiomyopathy in Breast Cancer Cases Receiving Radiation Therapy vs. Non-Cancer Controls

Any left-sided radiation vs. controls



No. at risk:					
Case	4,846	4,324	3,745	2,491	1,220
Control	24,223	20,846	18,352	12,521	6,234

Any radiation vs. controls



No. at risk:					
Case	9,566	8,570	7,467	4,982	2,497
Control	47,833	41,067	36,169	24,577	12,380

Greenlee et al. Journal of Clinical Oncology 2022

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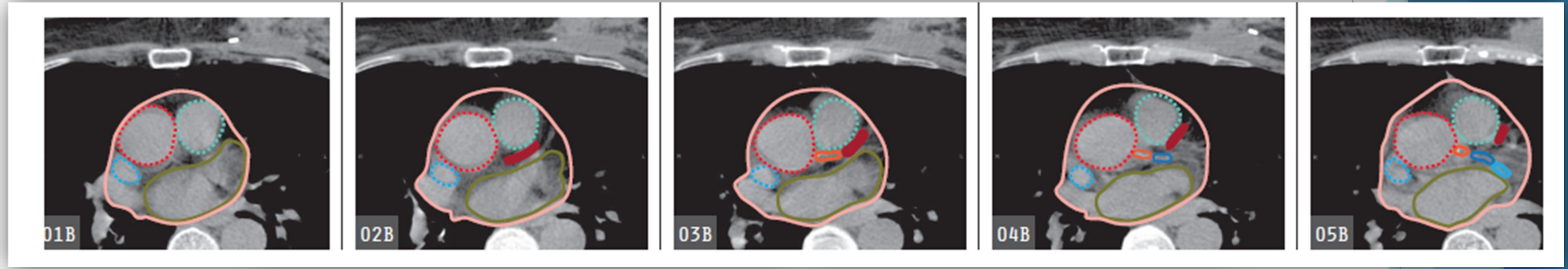
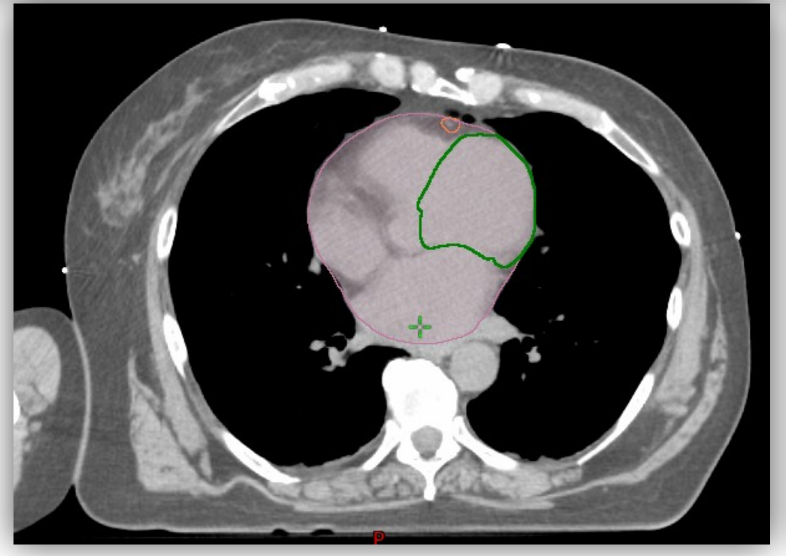
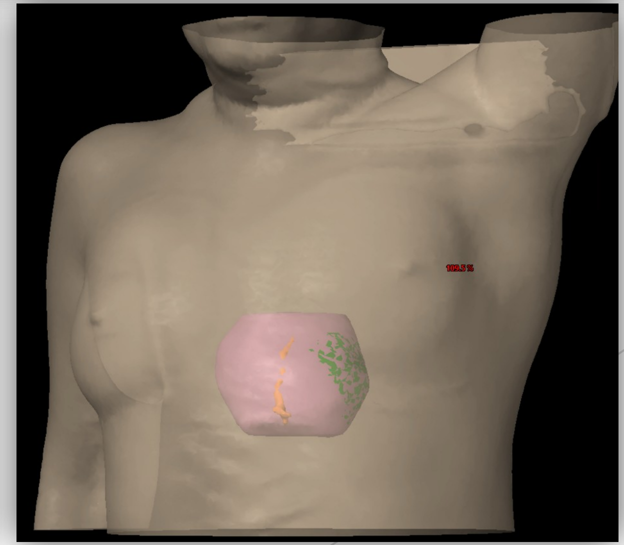
CN BRD Division of Research Collen Room C

Deep Inspiration Breath Hold - Breast

- Identify heart & substructures during contouring phase of planning
  - Heart
  - Left anterior descending coronary artery (*LAD*)
  - Left ventricle

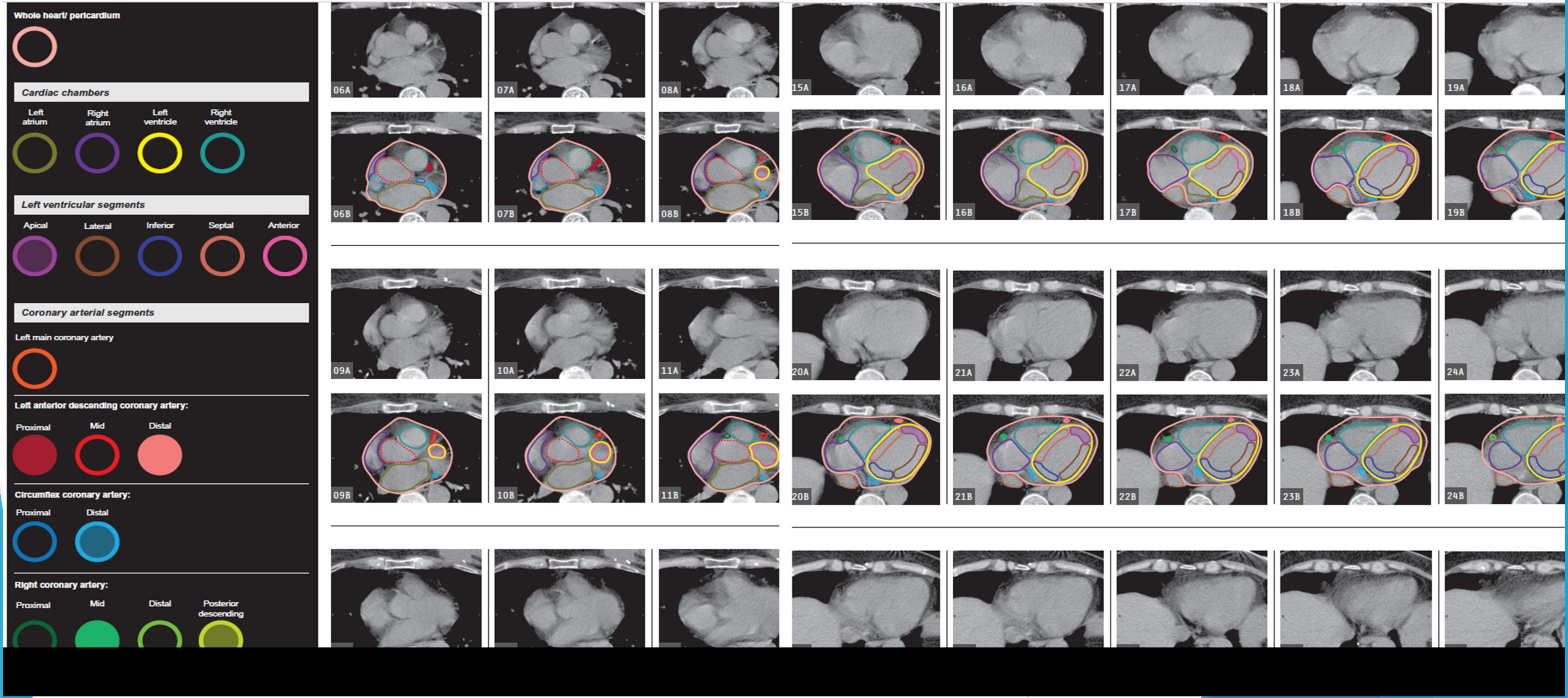






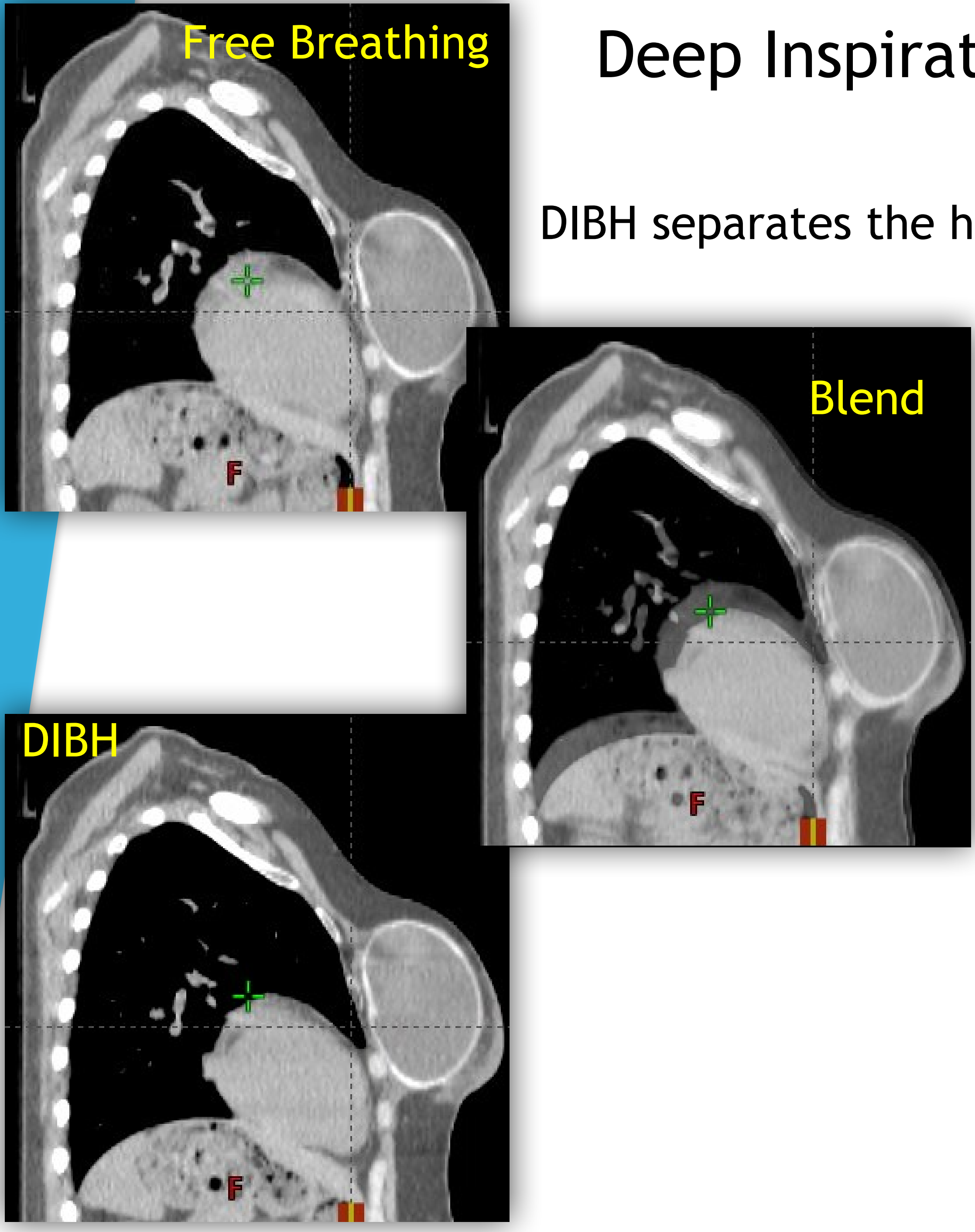
Deep Inspiration Breath Hold - Breast

Contouring guidelines and atlases exist to aid in structure identification



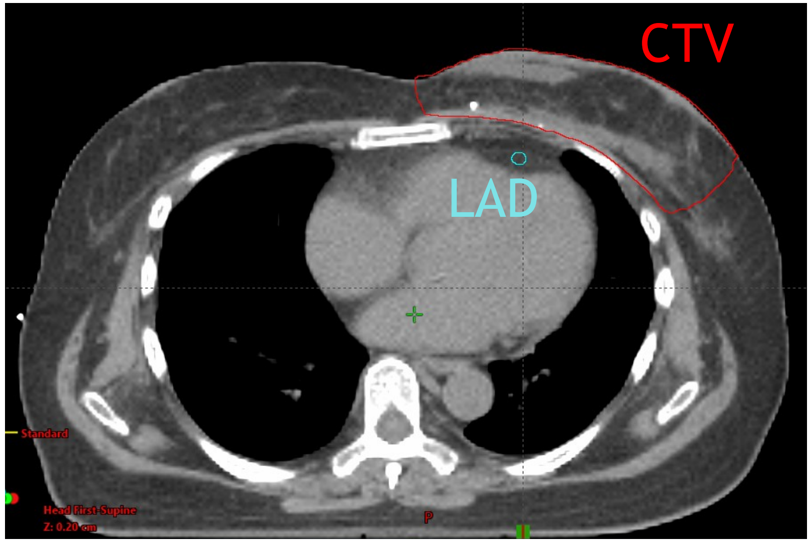
Deep Inspiration Breath Hold - Breast

DIBH separates the heart & substructures from treatment field

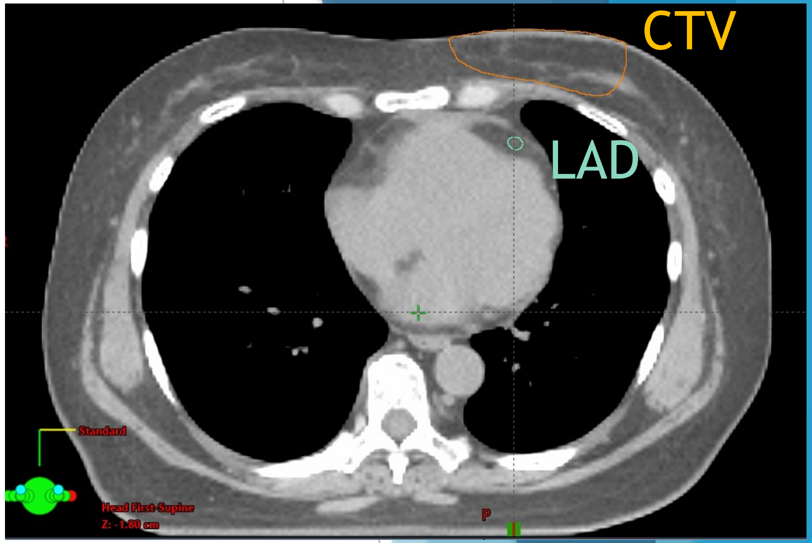


Deep Inspiration Breath Hold - Breast

Free Breathing



DIBH



DIBH effectively increases distance from the target volume to LAD, left ventricle and the heart

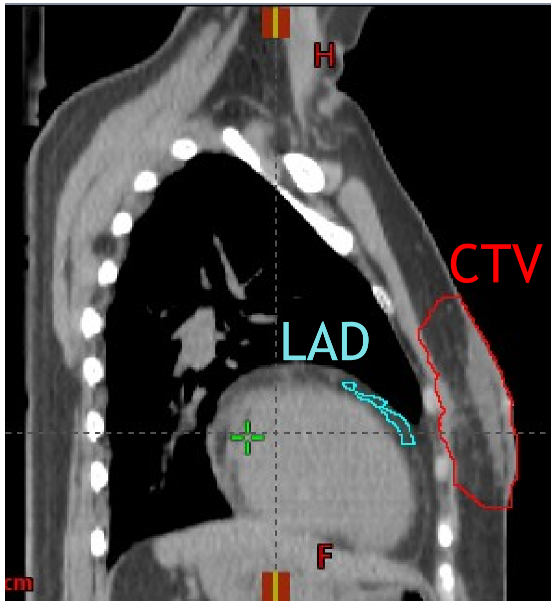
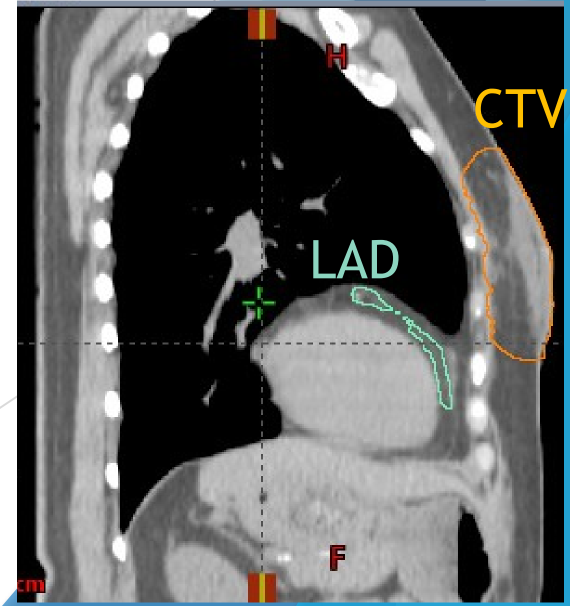


Table 3 Dose constraints for heart and substructures in breast radiotherapy

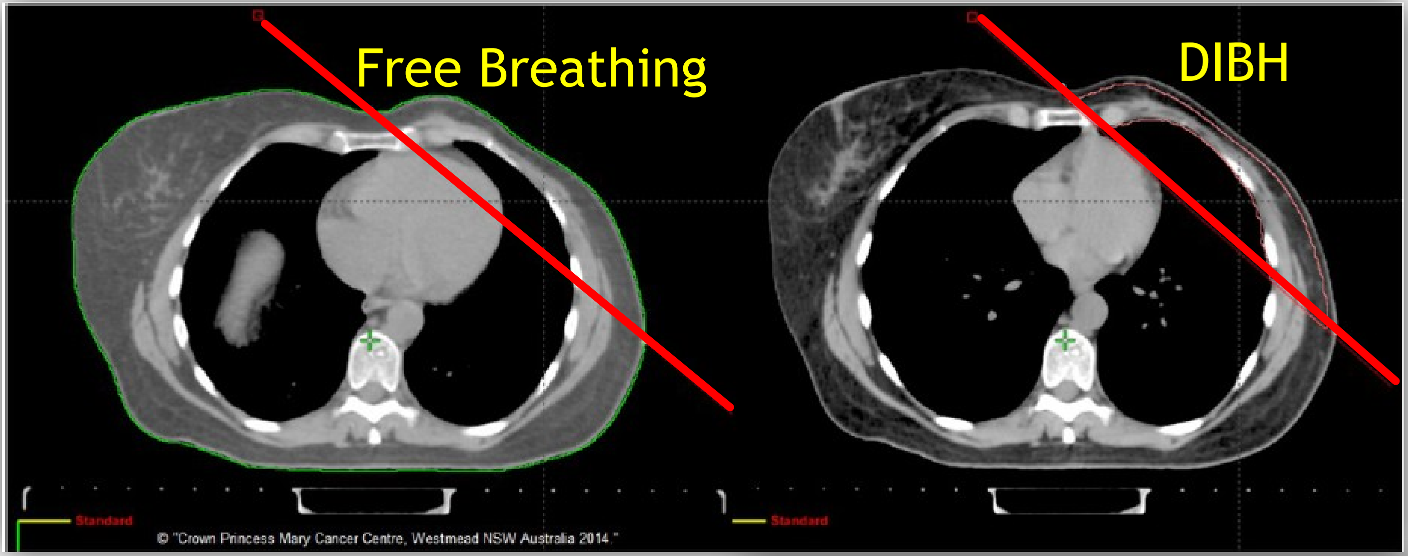
Volume	Constraint	Value
Whole heart	Mean heart dose	<2.5 Gy
Left ventricle	D_{mean} LV	<3 Gy
	$V5_{LV}$	<17%
	$V23_{LV}$	<5%
LAD	$D_{mean}LAD$	<10 Gy
	$V30_{LAD}$	<2%
	$V40_{LAD}$	<1%

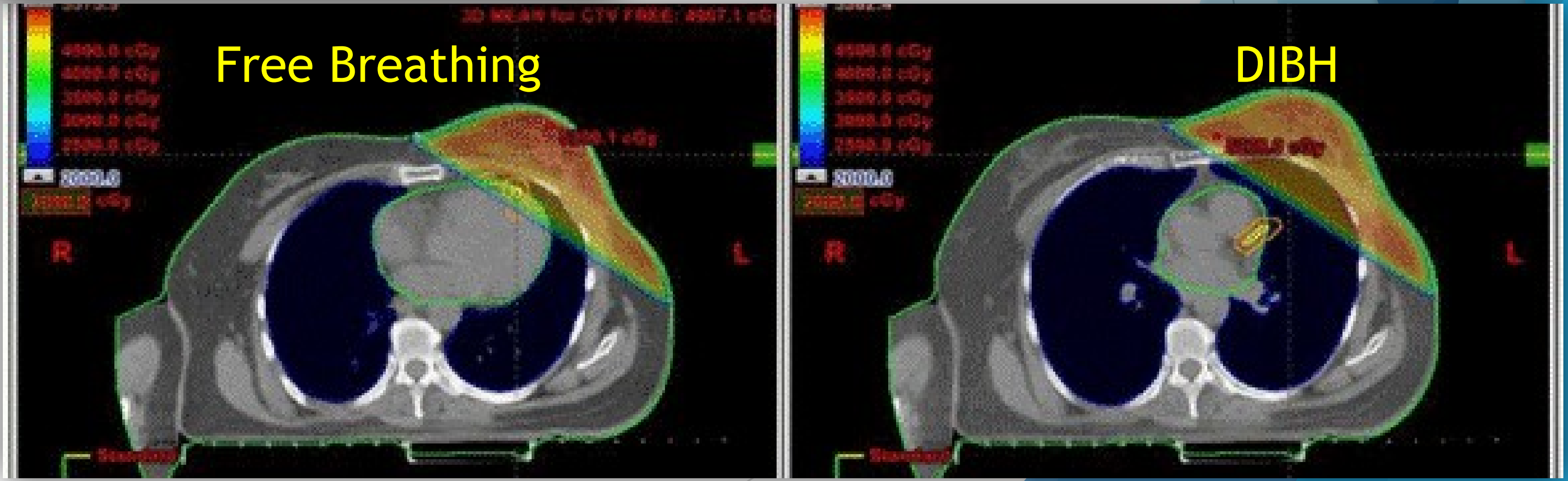
LV left ventricle; *LAD* left anterior descending artery; D_{mean} mean dose of the volume; Vx_{LV} percent of left ventricle volume receiving ≥ x Gy



Rationale for Deep Inspiration Breath Hold (DIBH)

DIBH plans reduce dose to the heart, ventricular wall and coronary arteries





Stereotactic Body Radiation Therapy (SBRT)
Lung, liver, abdomen

- Delivering high doses of radiation in a few fractions
  - 1 - ~8 (*1 – 5 in USA*)

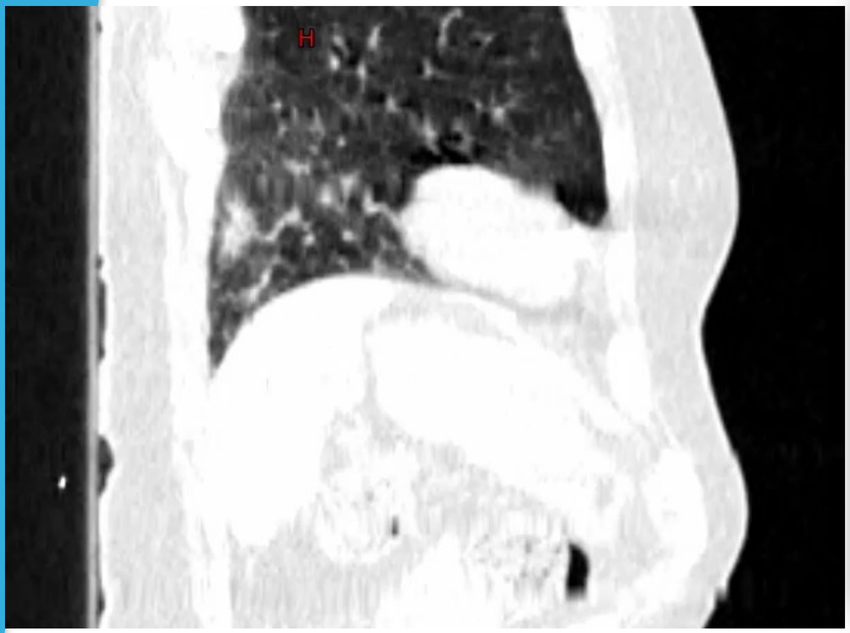
- Lung, liver and abdominal targets and OARs can show up to > 2 cm of motion under free breathing conditions

- Under free breathing, large tumor motion greatly expands treated volume

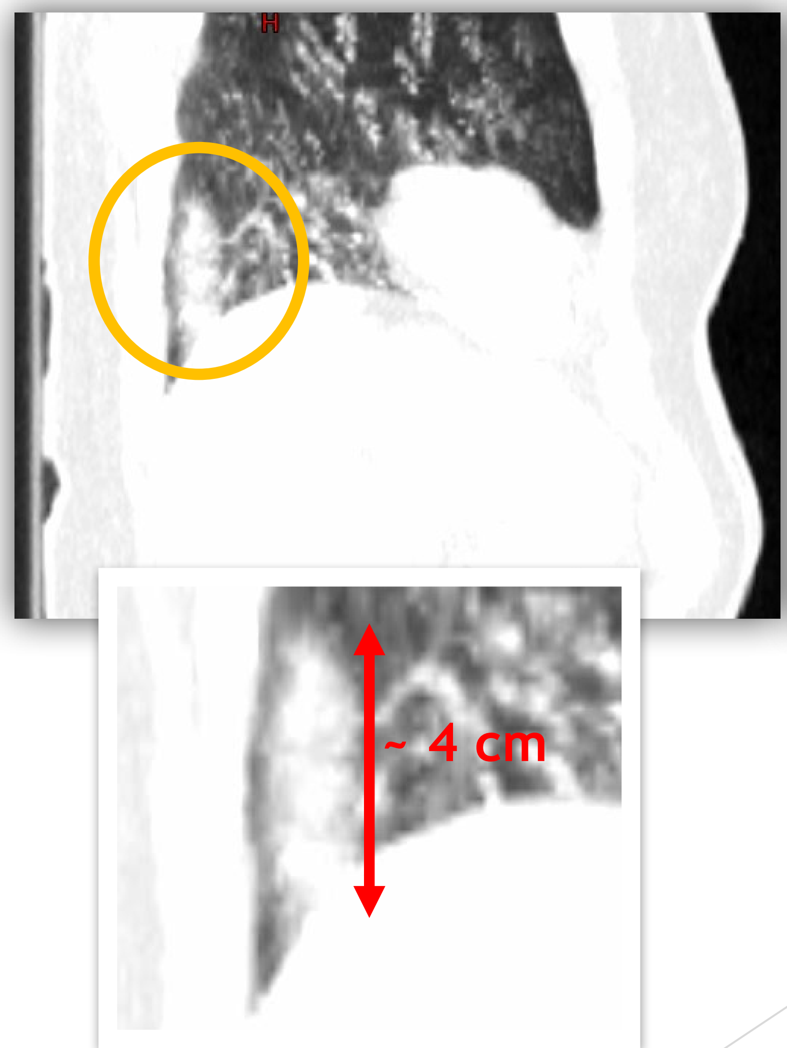
Use breath hold (inspiration or expiration) to freeze motion & reduced treated volume

Inspiration Breath Hold – Lung SBRT

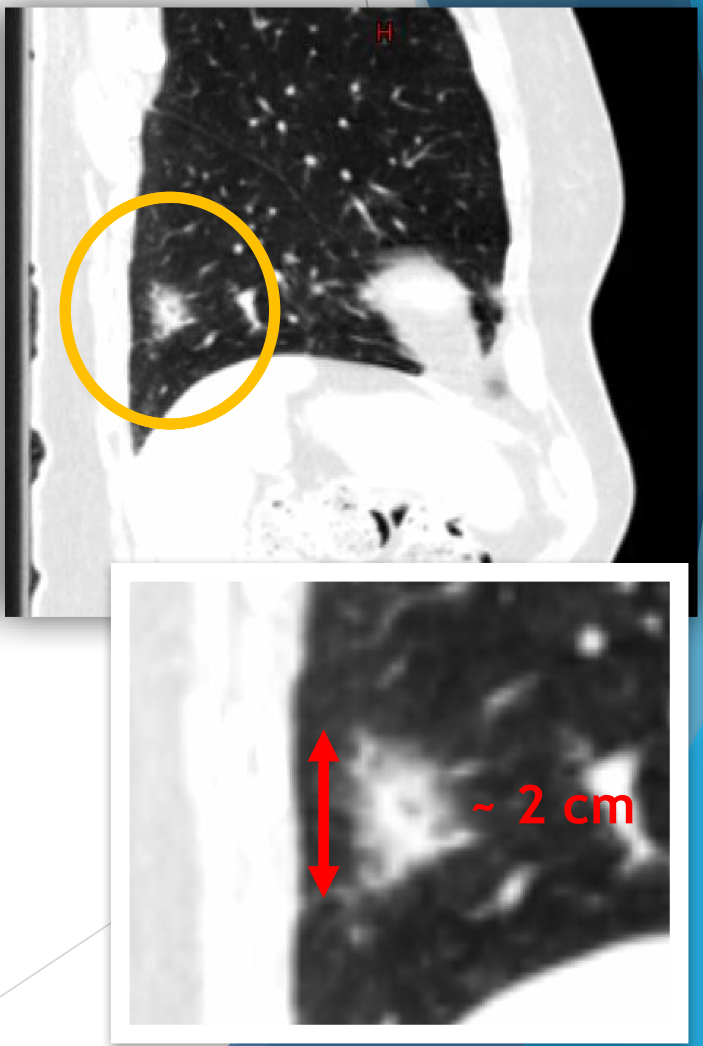
Free Breathing
4DCT



Maximum Intensity Projection
(MIP)



Inspiration
Breath Hold



Breast and Lung Practice

Breast

- UK FF and APBI Rx ~ 26/5
- IMRT, VMAT & RapidArc Dynamic (RAD) delivery (submitted *ASTRO 2026)*
  - IMRT – 5 field, non coplanar
  - VMAT – 2 to 3 arc, coplanar
  - RAD – 1 coplanar arc plus 4 to 6 IMRT ports concurrently
    - → 1000 – 1500 MU

SBRT Lung, Liver, Adrenal

- Prescription ranges from 50 Gy/5 – 54 Gy/3 (rarely 34 Gy/1)
- VMAT – 2 coplanar arcs or RAD (submitted *ASTRO 2026*)
- 2000 – 3000 MU **per field …** >> 1 – 2 minutes to deliver
- *Similar applies to liver and abdominal SBRT*

Both require stable & reproducible breath hold times for image guidance & delivery

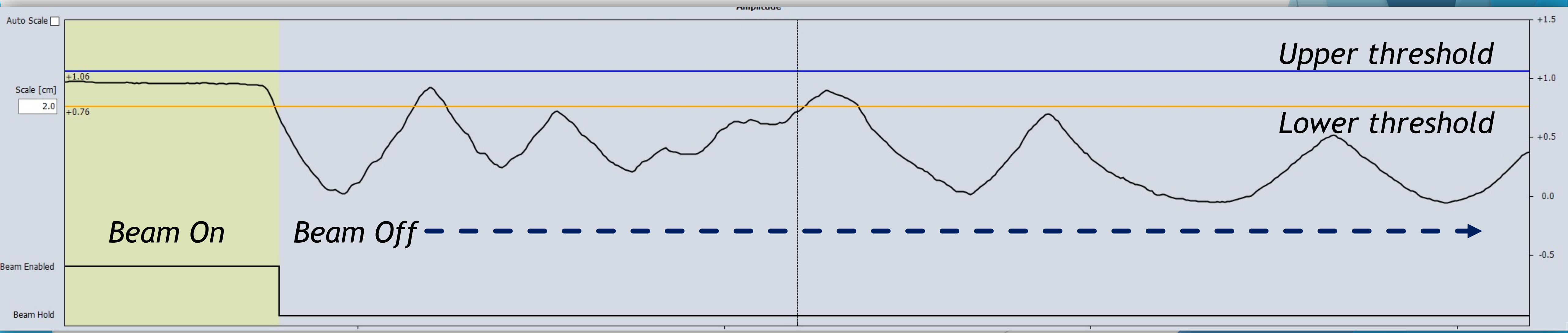
Clinical Example – Inspiration Breath Hold - ***AIR***

Air breathing patients

- Multiple breath holds for IGRT (CBCT)
- Multiple breath holds per treatment field & long breaks between to recover

Often observe irregular breathing patterns at end of breath hold

- *Frequency **increases** as treatment session progresses*



60% O_2 Implementation Timeline

- Spring 2020
  - Initiated during COVID-19
  - Original goal was 10 L /min of 60% O_2
    - COVID Restrictions on aerosol → limited to 7.5 L/min

  - Limited pilot of 10 patients with Dr. Mohan
    - Left-sided breast cancer
    - Identify optimal equipment – nasal canula vs closed mask
    - Develop coaching technique and patient education
    - Compare BH time with air vs 60% O2
    - Solicit patient feedback on experience

- Late 2020 – Implemented for lung and liver SBRT

- 2023 – Dr. Parkes presentation to all 6 Radiation Oncology facilities

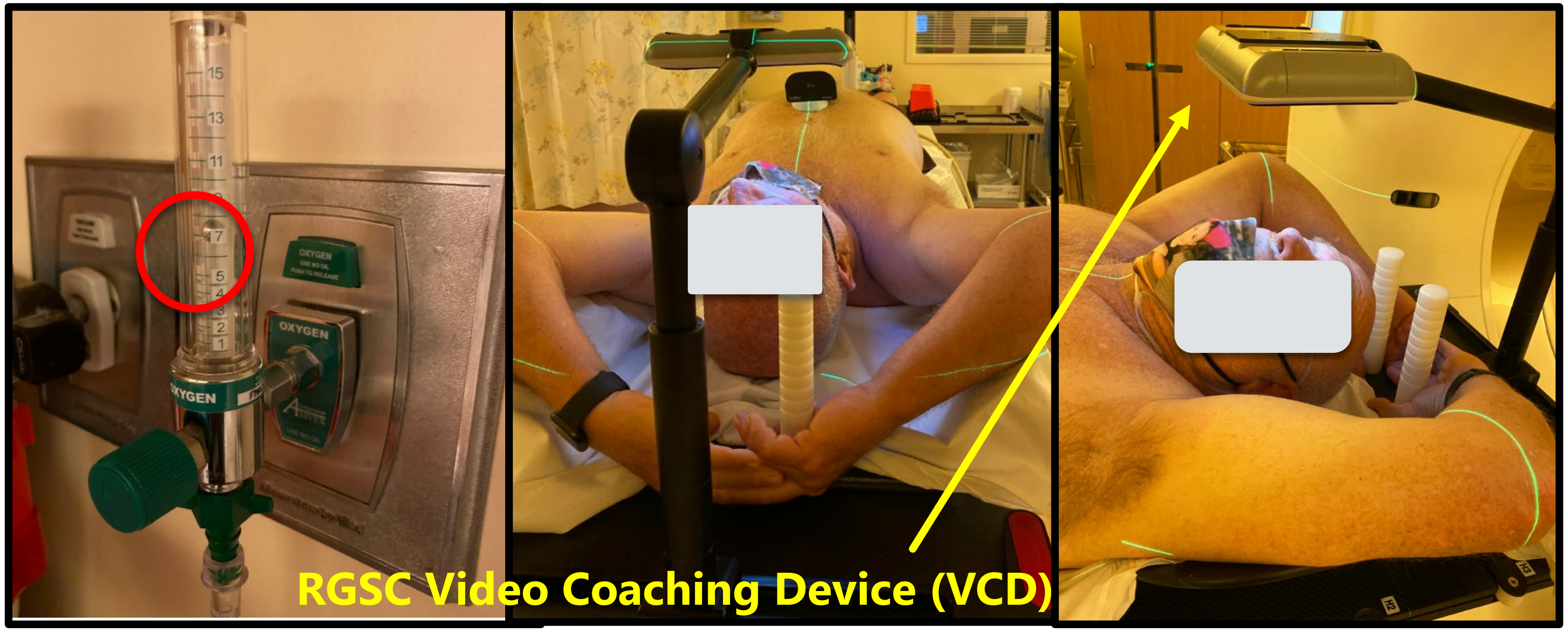
Supplemental 60% O2 at Kaiser Permanente

- **600+** breast patients since 2020
    - Predominantly left sided
    - Increasing right sided cases where MDs want to 'freeze' movement

- Particularly beneficial for high MU treatments
    - UK Fast Forward
    - APBI with University of Calgary method or RapidArc Dynamic

- **200+** SBRT lung, liver and abdominal cases

- Mechanical ventilation has **not** been used in our patients



- VCD helps coach patient during CT-simulation.
- Varian TrueBeam has VCD or AlignRT Real-Time Coach screen
  - Venturi and mask plugged into wall mounted medical oxygen supply)
  - O2 flow to the mask < 8 L/min

Supplemental O_2 Implementation

- Developed patient instructions and coaching procedure for staff
  - At time of MD consult, patients receive documentation and training video

Here are the links to videos that I would like you to watch regarding your radiation treatment and overview of Breast Cancer Radiation Treatment.

Radiation Treatment Overview

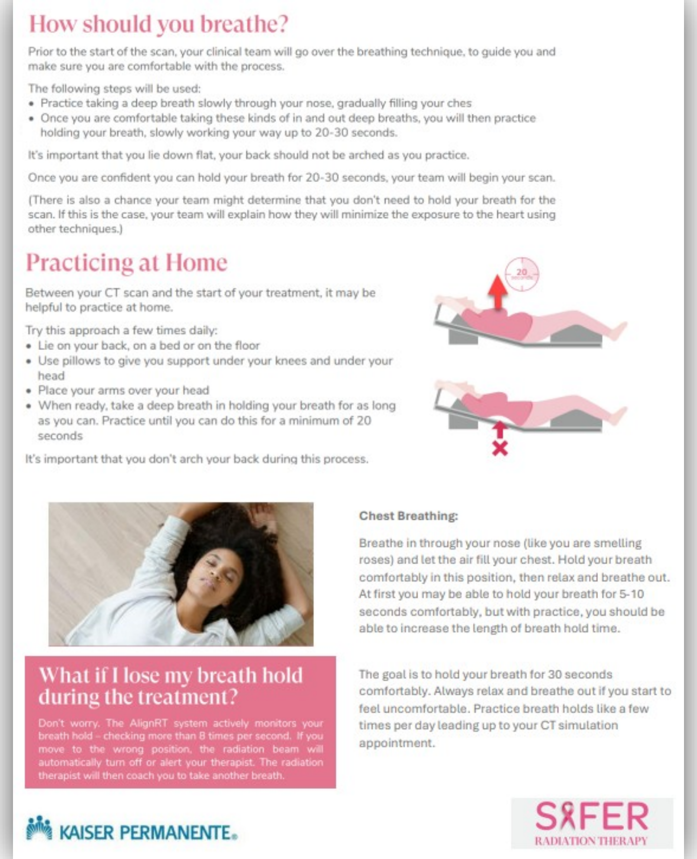
Protecting your Heart During Radiation Treatment

- I have attached a copy of the Radiation Treatment Consent Form for your review.

Additional Resources:
Understanding Breast Cancer Radiation Treatment - KP My Doctor Online

Ductal Carcinoma In-Situ of Breast-NCCN Patient Guidelines

Breath Hold Practice Video



How should you breathe?

Prior to the start of the scan, your clinical team will go over the breathing technique, to guide you and make sure you are comfortable with the process.

The following steps will be used:
- Practice taking a deep breath slowly through your nose, gradually filling your ches
- Once you are comfortable taking these kinds of in and out deep breaths, you will then practice holding your breath, slowly working your way up to 20-30 seconds.

It's important that you lie down flat, your back should not be arched as you practice.

Once you are confident you can hold your breath for 20-30 seconds, your team will begin your scan.

(There is also a chance your team might determine that you don't need to hold your breath for the scan. If this is the case, your team will explain how they will minimize the exposure to the heart using other techniques.)

Practicing at Home

Between your CT scan and the start of your treatment, it may be helpful to practice at home.

Try this approach a few times daily:
- Lie on your back, on a bed or on the floor
- Use pillows to give you support under your knees and under your head
- Place your arms over your head
- When ready, take a deep breath in holding your breath for as long as you can. Practice until you can do this for a minimum of 20 seconds

It's important that you don't arch your back during this process.

Chest Breathing:

Breathe in through your nose (like you are smelling roses) and let the air fill your chest. Hold your breath comfortably in this position, then relax and breathe out. At first you may be able to hold your breath for 5-10 seconds comfortably, but with practice, you should be able to increase the length of breath hold time.

The goal is to hold your breath for 30 seconds comfortably. Always relax and breathe out if you start to feel uncomfortable. Practice breath holds like a few times per day leading up to your CT simulation appointment.

What if I lose my breath hold during the treatment?

Don't worry. The AlignRT system actively monitors your breath hold - checking more than 8 times per second. If you move to the wrong position, the radiation beam will automatically turn off or alert your therapist. The radiation therapist will then coach you to take another breath.

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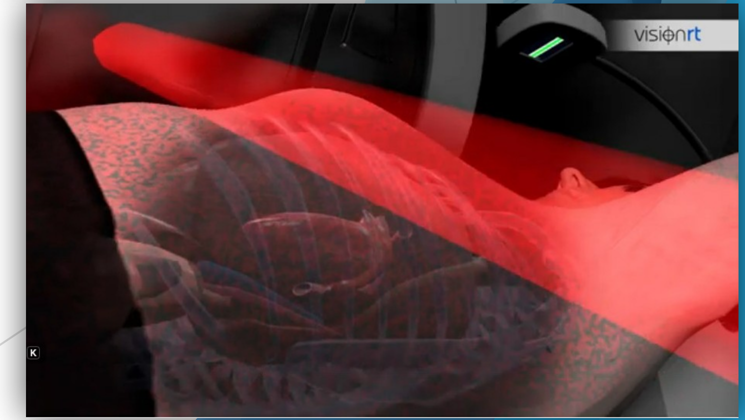
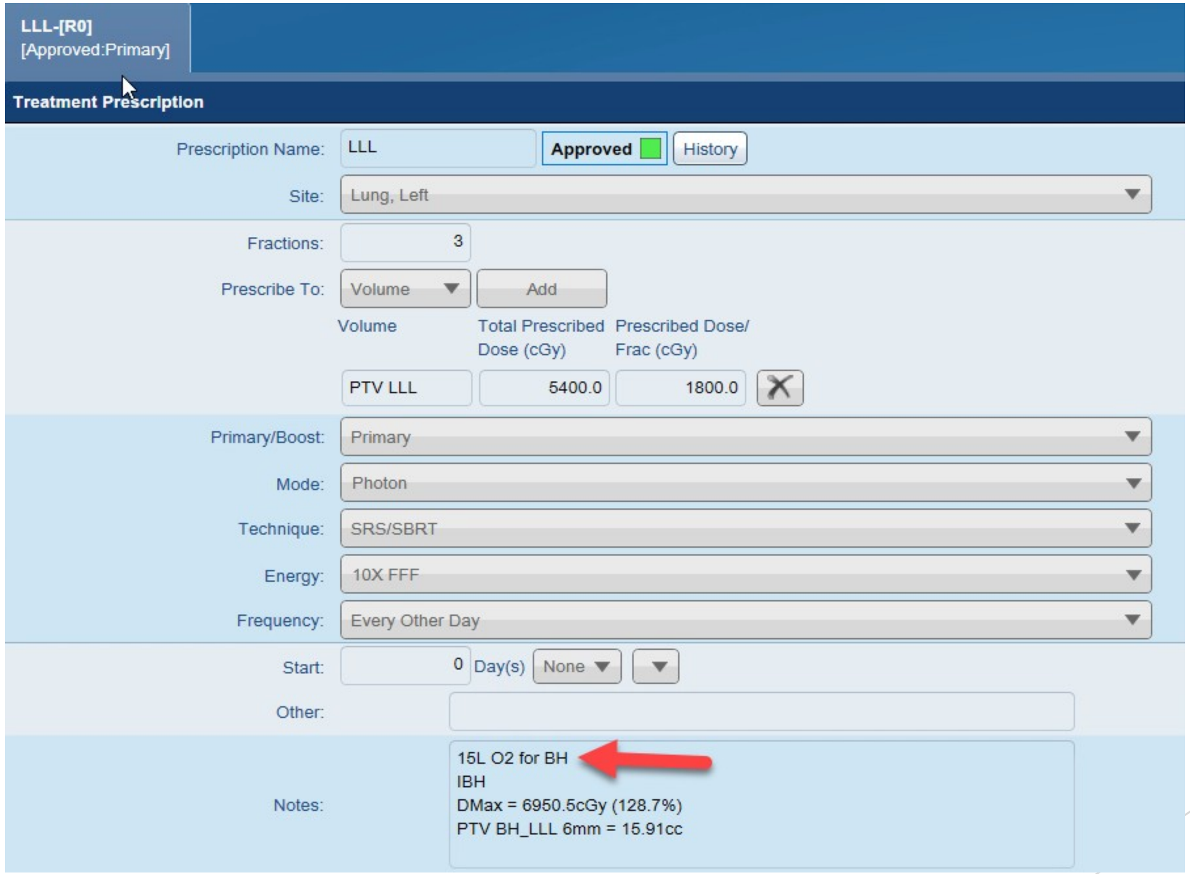
SAFER RADIATION THERAPY



Supplemental O_2 Implementation

- MD includes order for O2 into *NOTES* section of ARIA Prescription workspace
  - Giving O2 requires an order from the Radiation Oncologist



Benefits of Supplemental O_2 vs Air

- Performed a small analysis of 40 patients one year after implementation
  - Waited until operational issues were worked out

- Measured breath hold times with air and 60% O2 in 40 consecutive patients

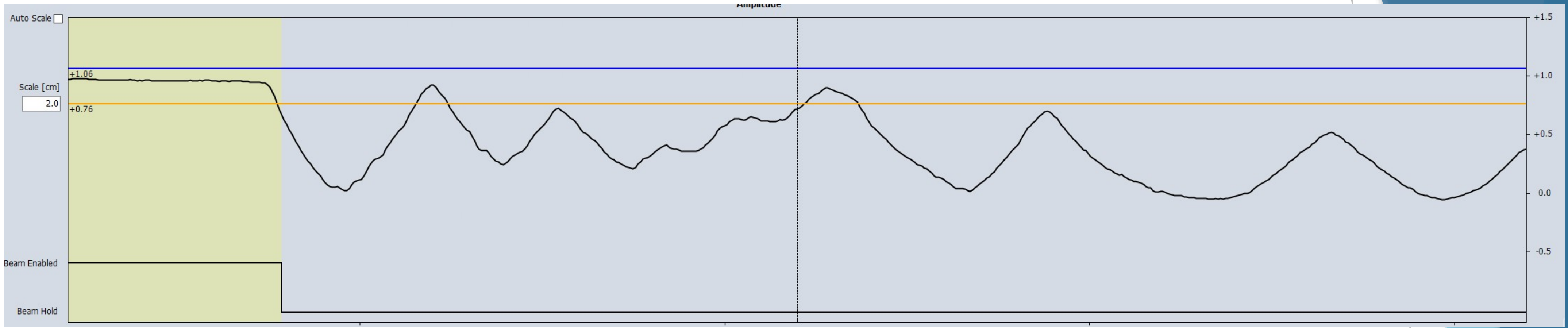
- With air, mean breath hold time ~25 seconds
  - Maximum of 55 seconds

- With 60% O2, mean breath hold time increased to ~45 seconds
  - Maximum of 140 seconds

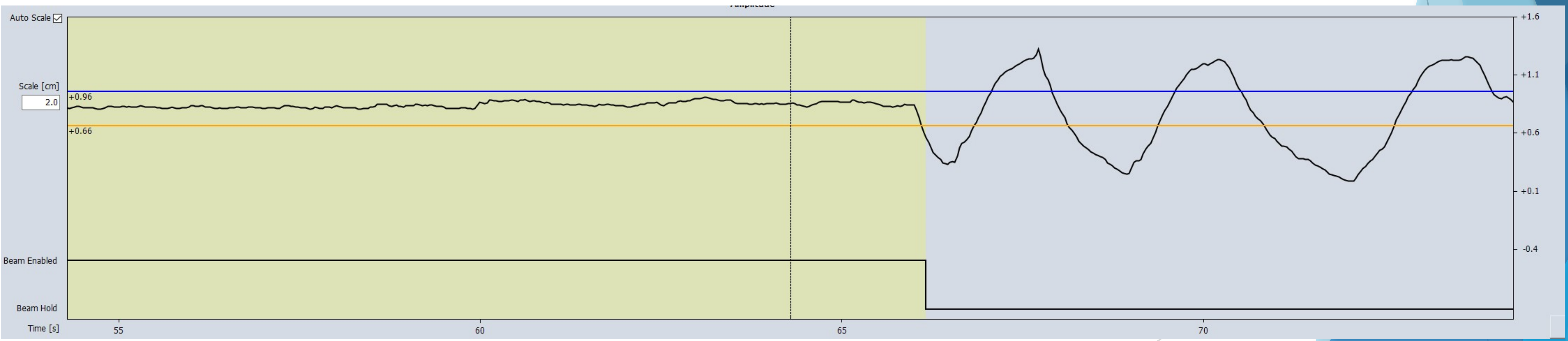
- No 60% O2 patient had a shorter breath hold than they had with air

Benefits of Supplemental O_2 vs Air

- Irregular breathing following 30 s breath hold with **air**



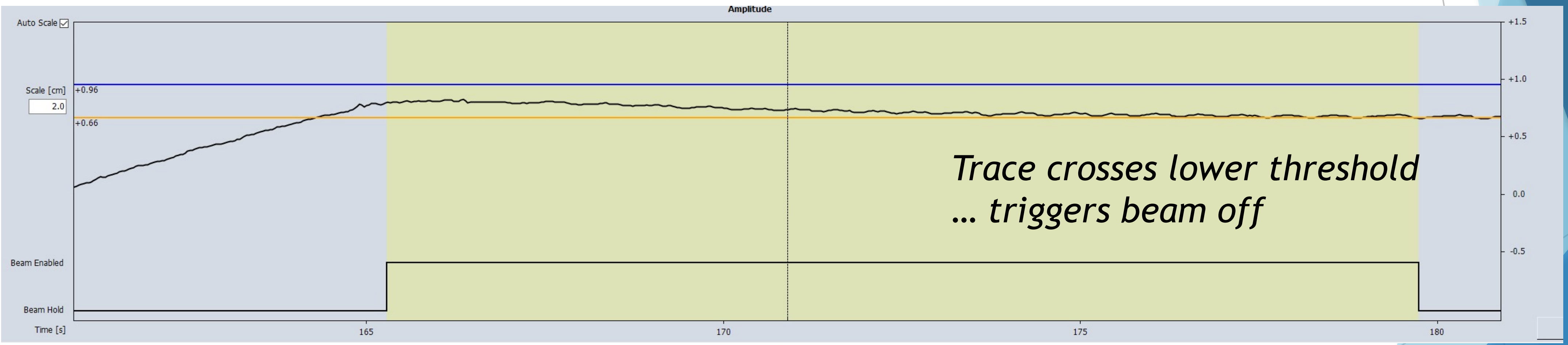
- Periodic & regular breathing after 60 s breath hold with 60% O2



- 60% O2 was more comfortable with repeated breath holds than air

Chest Deflation

- Differences in partial pressures of O2 and CO2 during BH lead to relaxation
- Lung volume can decrease by 0.2 to 0.5 L/min
- With long duration BH, breathing trace can decrease and trigger beam-off



Patients are **not** ‘leaking’ or letting air out

Let patient breathe normally, recover and then continue

Challenges in Implementation

- It’s something new – therefore we need to manage change

“What we did before was fine”

Need continuous education…

Overcoming Resistance

- Encountered significant resistance to implementation from physicians
  - *Our patients do fine breathing regular air – many just don't need it*
  - *Giving O_2 adds too much extra time to setup*
  - *Limited time allotted for education during CT-simulation*
  - *Cost of providing O_2*
  - *Two of four vaults had O_2 hook up. Other two required O2 in cylinder*
  - *Where to put MD order for O_2*
  - *Variation in MD desire & philosophy to incorporate O2 into practice*

Practice Considerations - Education

Radiation Oncologists

Physiology of breath-holding – Not well understood and this dissuade MDs from pursuing O2

Demonstrate benefits of air vs O2
- Consider demo on MD and/or staff
- Experiencing a far longer & more comfortable BH can be very convincing

Dispel misconceptions about difficulty of implementation
- *“yes, it requires 5 minutes extra at CT-simulation… but we gain back far more time during treatment”*
- *“we don’t want patients having uncomfortable breath holds because this leads to unwanted movement and overall inaccuracy”*

Perception of time is very important in a busy clinic

At Kaiser, we have 45-minute CT-sim slots (rate limiting step)

→ Cannot add more steps that will significantly take away this limited time

→ ***Not every patient needs a breath hold***

Practice Considerations - Education

Radiographers / Radiation Therapists

Physiology of breath-holding – May be poorly understood

Importance of patience

- Better to let a patient who is struggling to maintain a BH take a breath and recover then to push through to finish the field

Practical considerations

- Chest deflation – the patient is not ‘leaking’

- Optimization of imaging –
  - MV / kV rather than kV / kV or kV / MV
  - CBCT modes that favor shortest arc
  - SGRT workflows that favor shortest

<u>Don’t wait to give 60% O2 until the patient has issues on treatment !!</u>

Patient Feedback

- Shown to be beneficial for majority of patients
  - Less tired at the end of treatment session
  - Decreases time between breath holds
  - Improves stability during breath hold
  - Decreases tendency of patients to move as they recover

- Some patients report dryness that requires them to cough

- A subset are difficult to coach into a breath hold with air or O2
  - Language barriers, comprehension of instructions, physical limitations

Conclusions

- We’ve now treated ~ 800 patients over 6 years with 60% O_2
- Observed a large increase in mean breath hold times with O_2 compared to air
- Patients are more resilient to long imaging and treatments when provided O_2
- Good patient selection is still required
  - *When the only tool you have is a hammer, everything starts to look like a nail*

- *Overall, adding O_2 has helped ease many patients’ treatment course and improved accuracy of treatment delivery as a result*

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Thank you