

Motion management, Deep Inspiration Breath Hold

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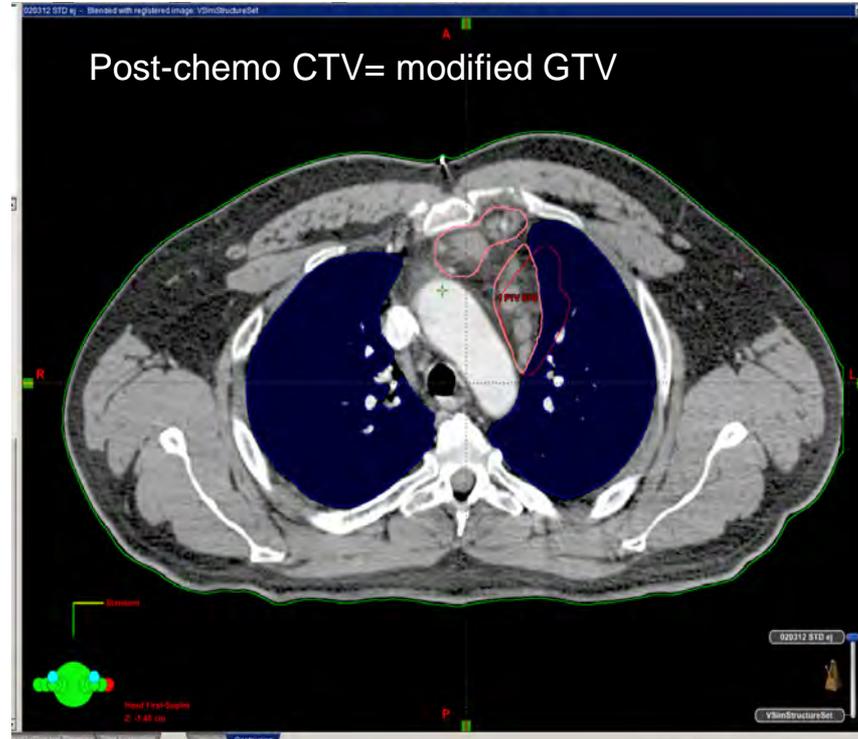
Copenhagen

Denmark

Background

- Radiotherapy-induced late effects are severe
 - but difficult to assess and quantify as they are the result of (often) outdated treatment regimens
- The risk of late effects is influenced by both radiation dose and irradiated volume
 - => introduction of more conformal delivery techniques and breathing adaptation

Involved Node Radiotherapy



Deep inspiration breath-hold (DIBH)

- Also called gating....

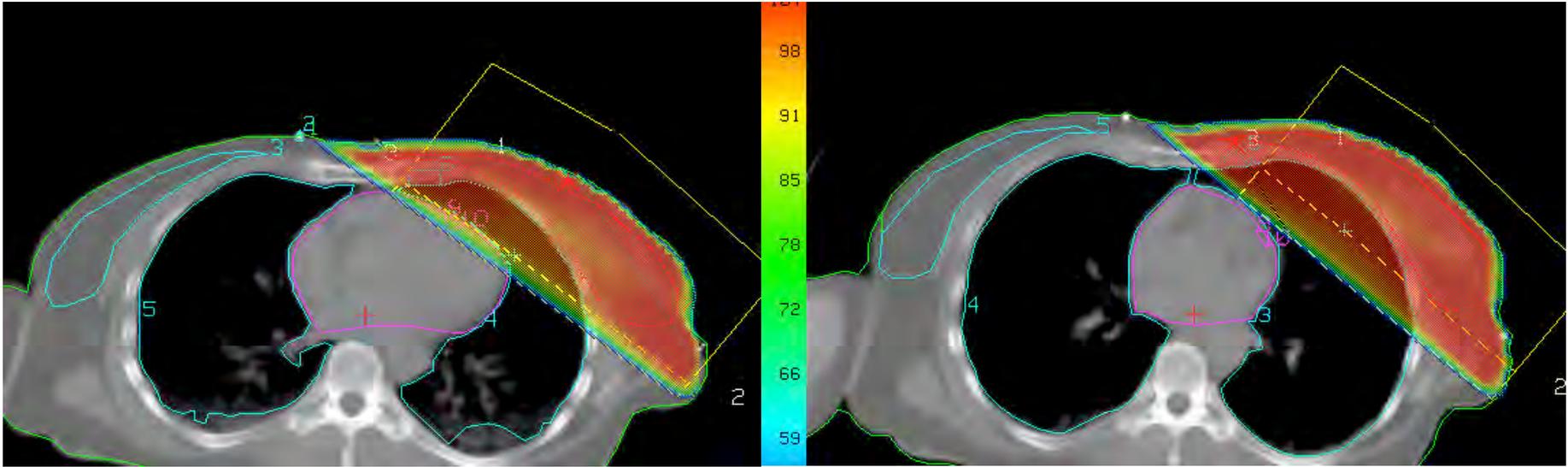
Treatment delivery while the patient holds his/her breath in deep inspiration

Lung volume is increased
Heart is rotated downwards

Standard for breast cancer.
Protocols ongoing in lung cancer, gastric lymphoma

DIBH at Rigshospitalet

- Deep inspiration treatment since 2003 in left-sided breast cancer patients
- > 1000 patients



Rigshospitalet (The Finsen Center)

- 2 dedicated CT scanners
- 1 dedicated MR scanner
- Joint facilities with Nuclear Medicine department
 - 7 PET/CT, one dedicated to RT planning
 - 2 PET/MR
 - Radiographers rotating between departments

- 11 linacs

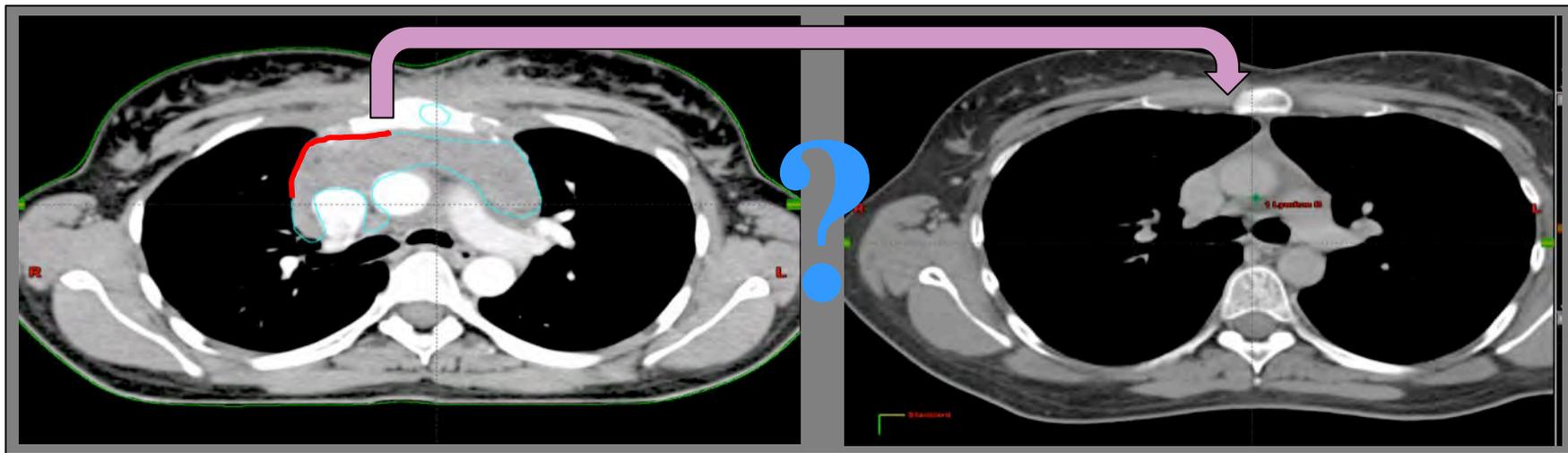
Phase II protocol: Methods

- 22 patients
- Pre chemo scan:
 - 400 MBq FDG on Siemens Biograph 40 PET/CT
- Wb PET/CT free breathing
- Define breath hold volume
- CT: 1 FOV in breath hold
- PET: 3 breath holds of 20 seconds each
- Visual coaching to ensure reproducibility

Fusing prechemo and planning images

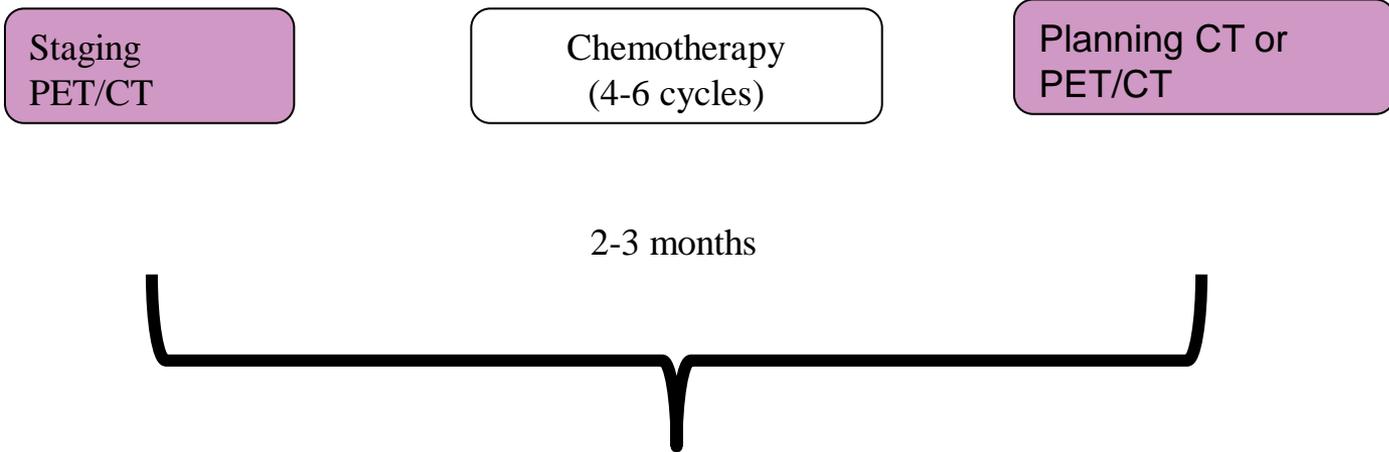
Pre-chemo PET/CT
free breathing

Planning CT
at deep inspiration



DIBH through the whole imaging chain

All images in DIBH



How to handle registration uncertainties ?

- Ensure a treatment-like position already at staging
 - Flat table top
 - Arms up
 - Chest board
- Provide DIBH PET/CT at staging
- All these take time, logistic effort, and a good collaboration with the PET department!

Respiration monitoring

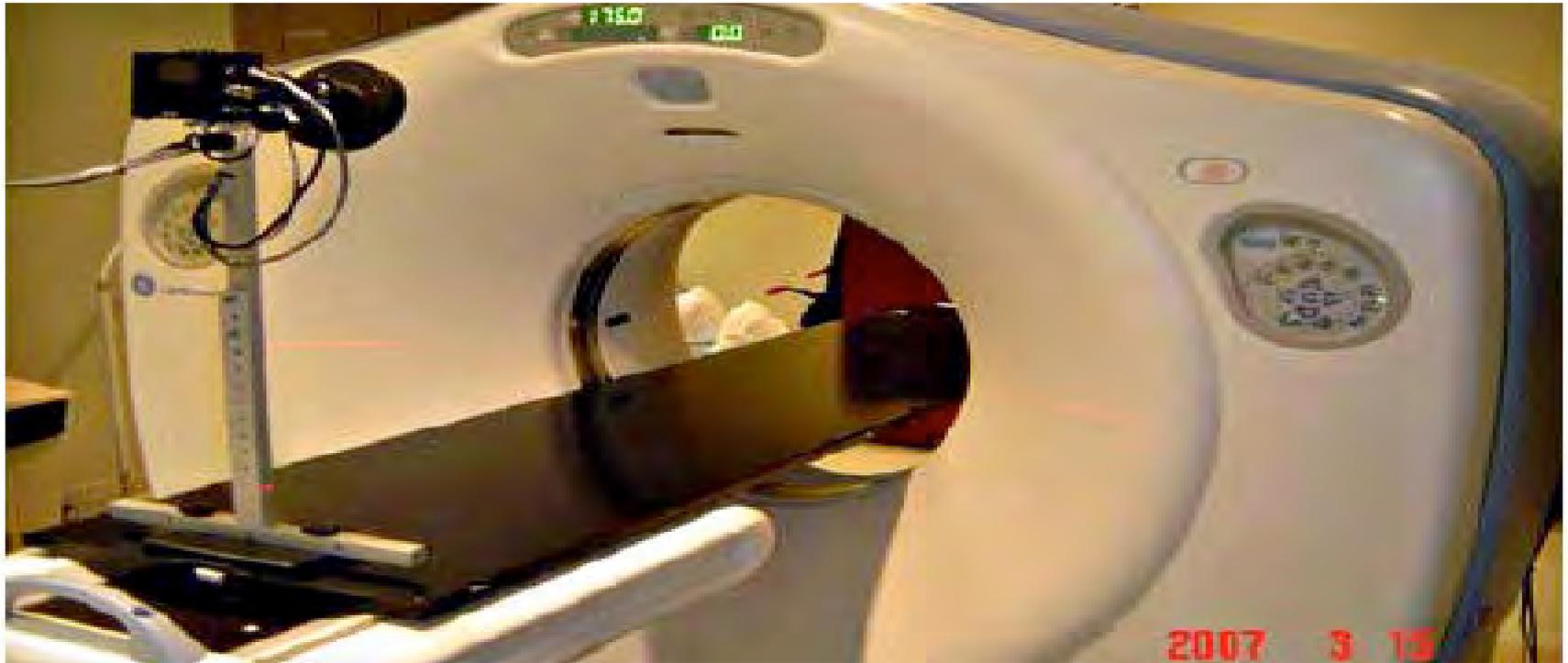


Varian RPM system:

- Deep inspiration breath hold
- Gating
- 4D CT

On all linacs and scanners

CT + PET/CT



Equipment



Courtesy of Sidsel Damkjær, Copenhagen

At Rigshospitalet: RPM system from Varian + third part screens/goggles

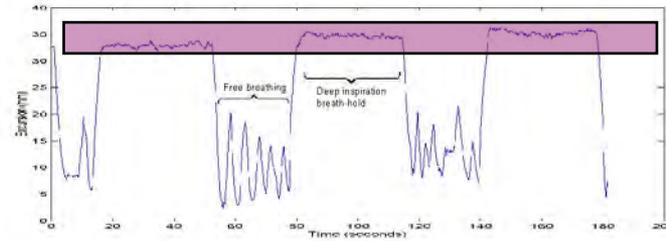
Alternatives: ABC system from Elekta, VisionRT, C-RAD sentinel...

Goggles

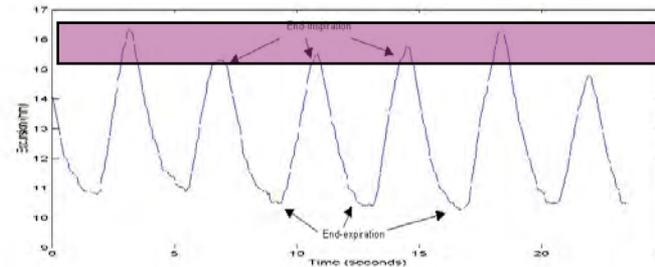


Patient Coaching

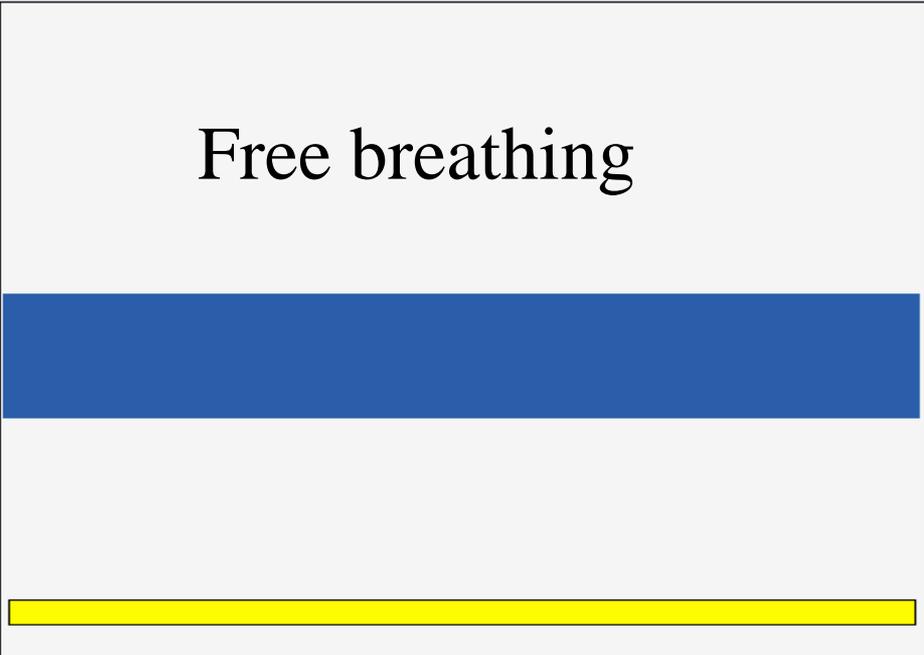
- Deep inspiration breath hold
 - Duration 20s



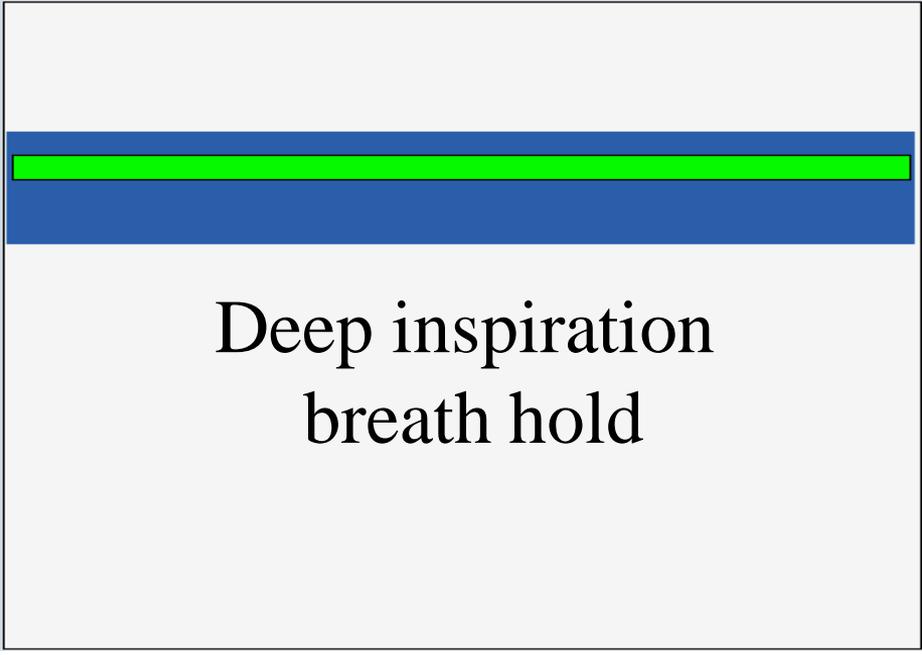
- Free breathing
 - Duration 2s



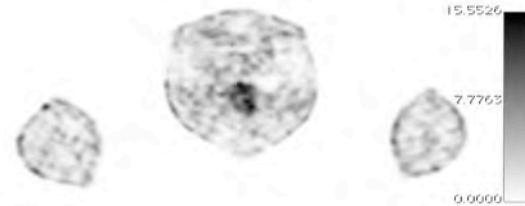
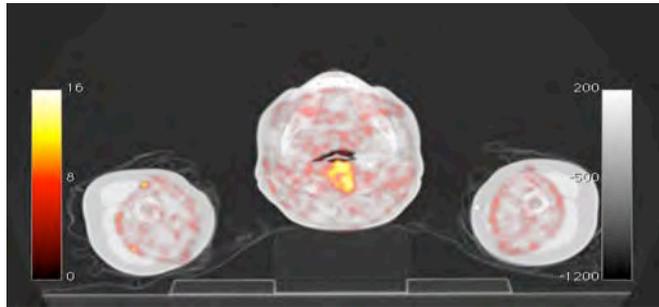
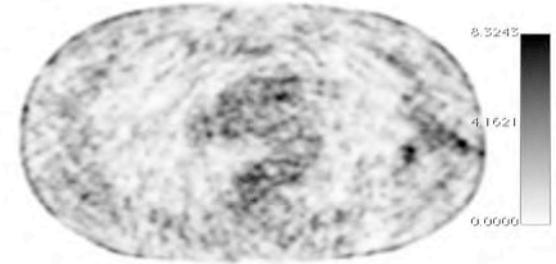
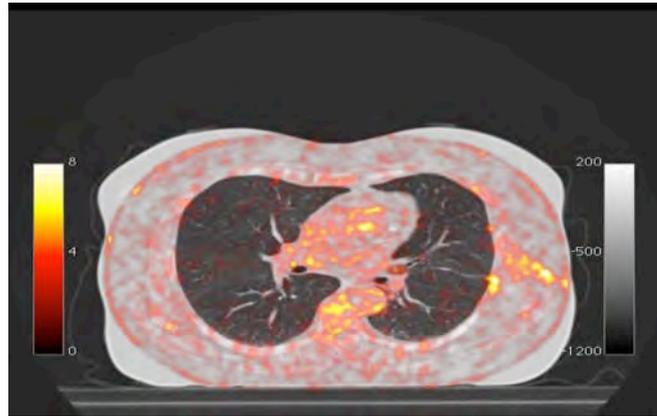
Free breathing

A diagram illustrating free breathing. It consists of a light gray rectangular box. Inside, there is a thick blue horizontal bar in the middle. At the bottom of the box, there is a thin yellow horizontal bar.

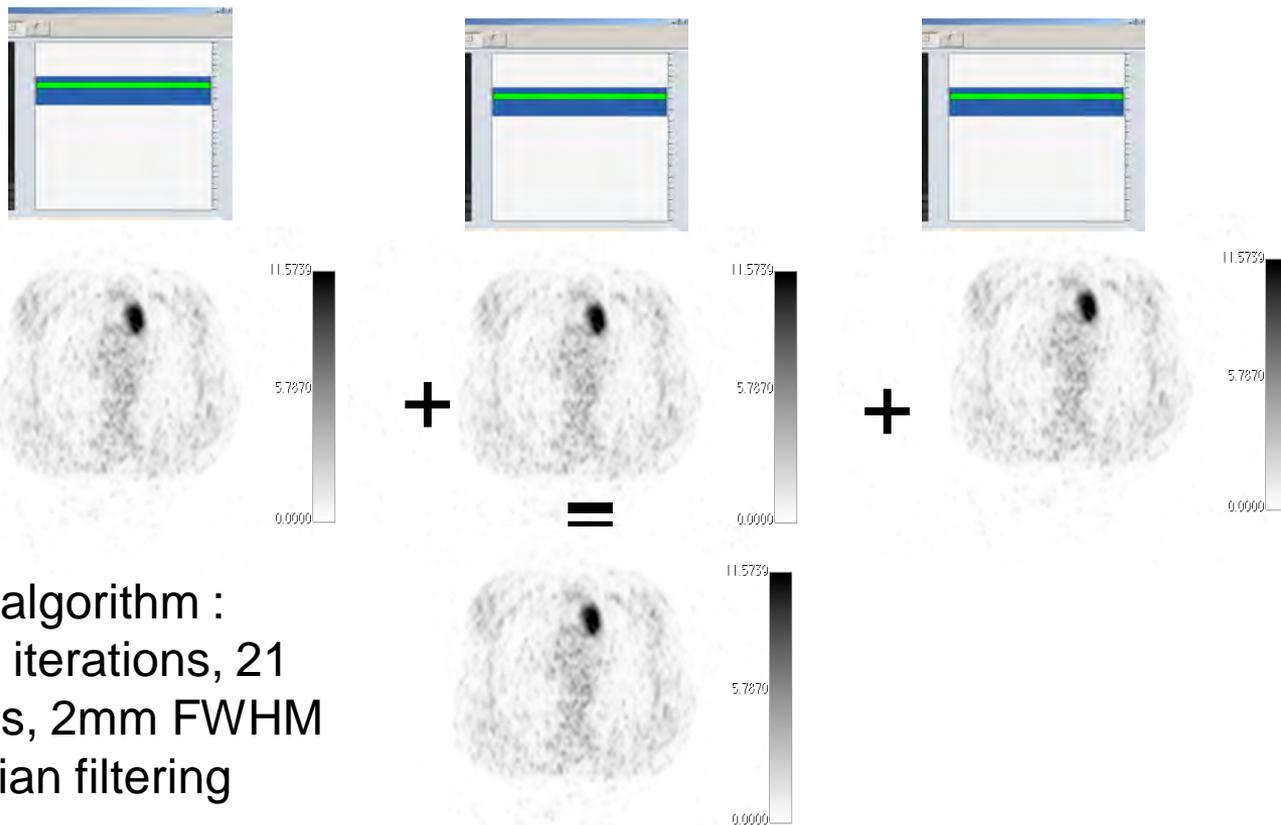
Deep inspiration
breath hold

A diagram illustrating a deep inspiration breath hold. It consists of a light gray rectangular box. At the top, there are two thick horizontal bars: a blue one on top and a green one below it. The text "Deep inspiration breath hold" is centered in the lower half of the box.

Some problems at start-up !!

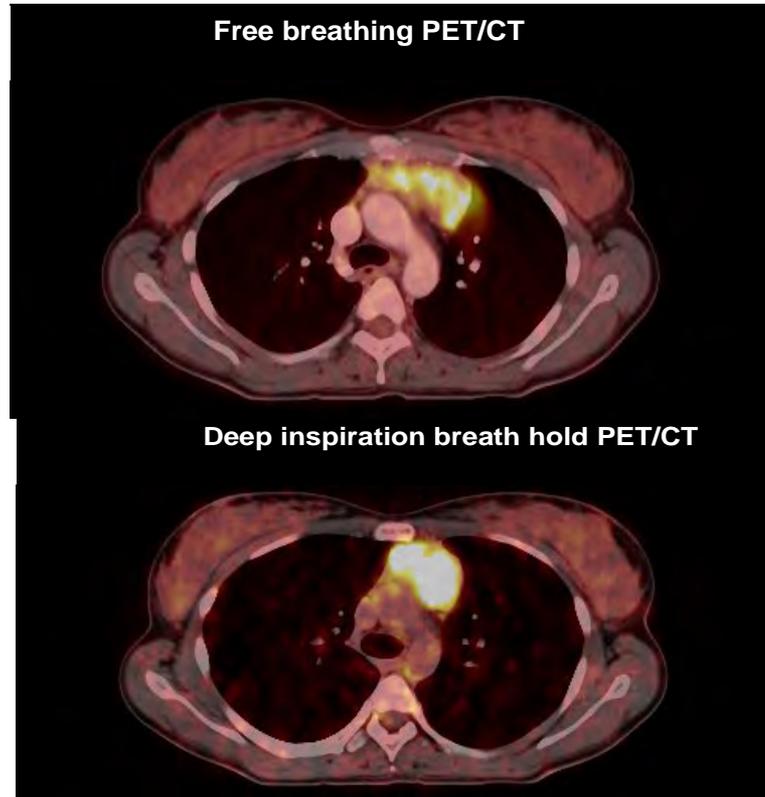


Methods: Image reconstruction



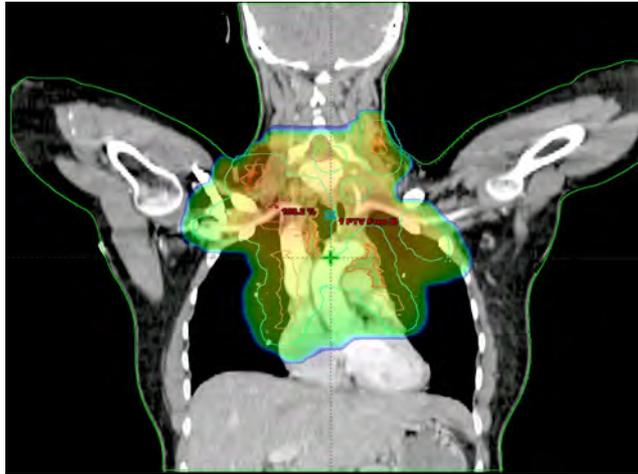
TrueX algorithm :
PSF, 3 iterations, 21
subsets, 2mm FWHM
Gaussian filtering

Deep inspiration breath-hold (DIBH)

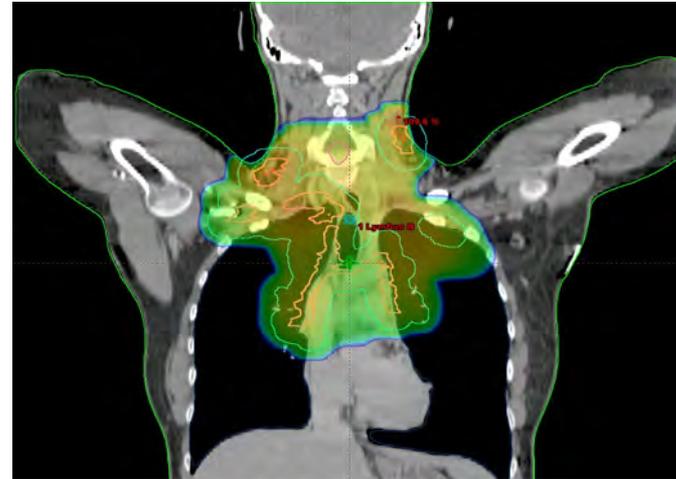


Breath hold decreases the exposure of healthy tissues

Free breathing



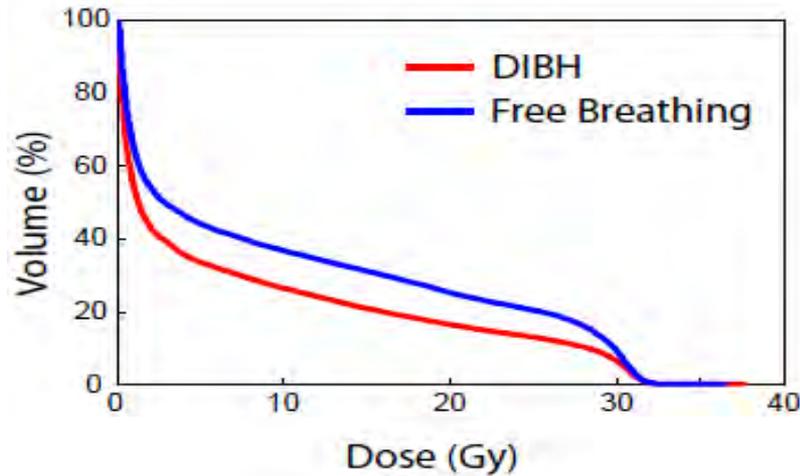
Deep inspiration breath-hold



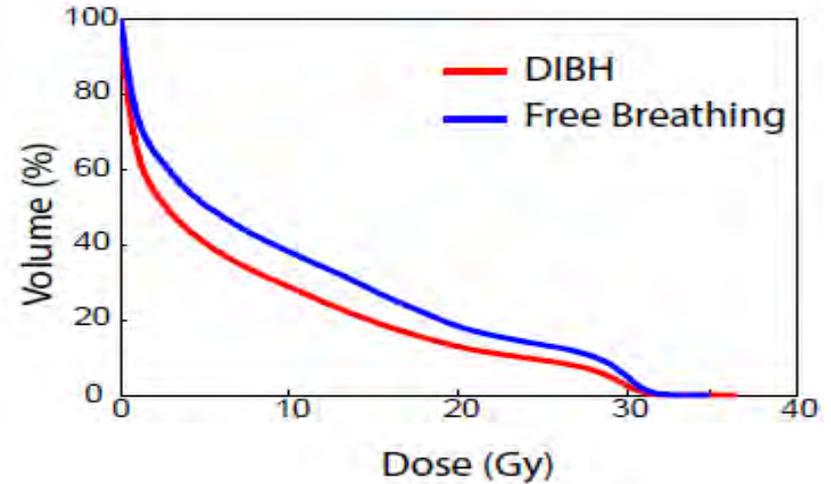
Notice lung volume and heart position

Benefit: over the whole group

Lung



Heart



Compared to free breathing, DIBH reduced

- Mean estimated lung dose by 2.0 Gy (median: 8.5 Gy vs. 7.2 Gy) ($p < 0.01$)
- Mean heart dose by 1.4 Gy (6.0 Gy vs. 3.9 Gy) ($p < 0.01$).
- Lung and heart V20Gy were reduced with a median of 5.3% and 6.3%.
- Mean dose to the female breasts were equal with FB and DIBH.

Our experience with DIBH in lymphoma

- Standard for all mediastinal cases
- Having the staging PET/CT in DIBH increased our physicians' confidence
- The dosimetric benefit was clear enough to make DIBH our standard treatment for HL

Work flow

- Staging, pre-chemotherapy whole body PET/CT
- CT
- PET
- Define the area for DIBH
- CT DIBH
- 6 breath holds of 20 seconds each

CT values

- 200 mAs
- 120 Kv
- Slice thickness (mm) 2
- Pitch 0.8
- Rotation time (s) 0.5

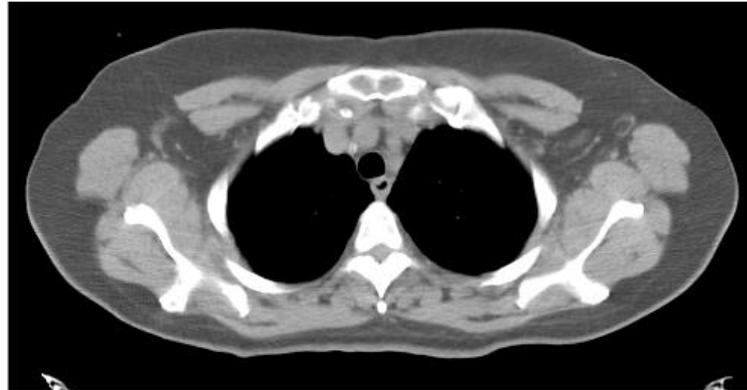
Diagnostic CT



Low dose CT



with and without IV

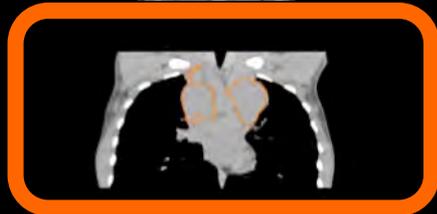


Registration for contouring

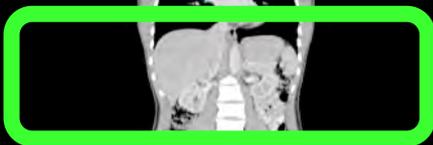
Pre-chemo PET/CT



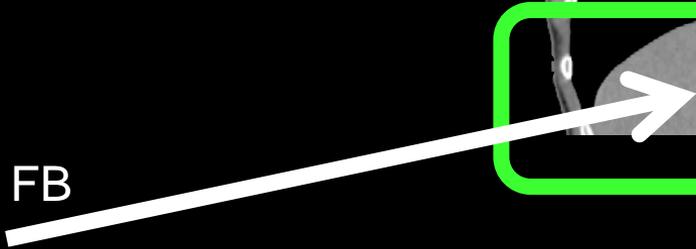
FB



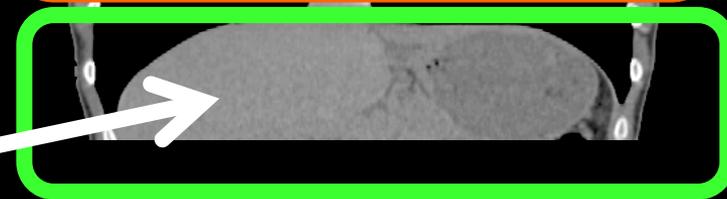
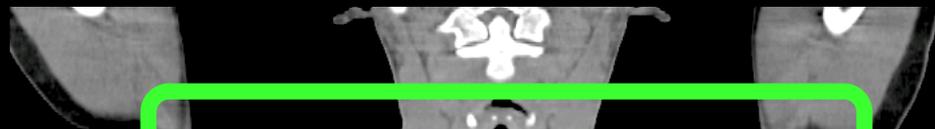
DIBH



FB



Planning CT in DIBH



What do you need?

- Booking PET exam: 15 min extra
- Trained staff for coaching as well as scanning
- Collaboration RT & PET
- Enough patients to obtain experience

PET/CT Scan



Flat table top



Breast Board



Lie comfortable



Arms Up



Arms Up



Pillow Under the Knees



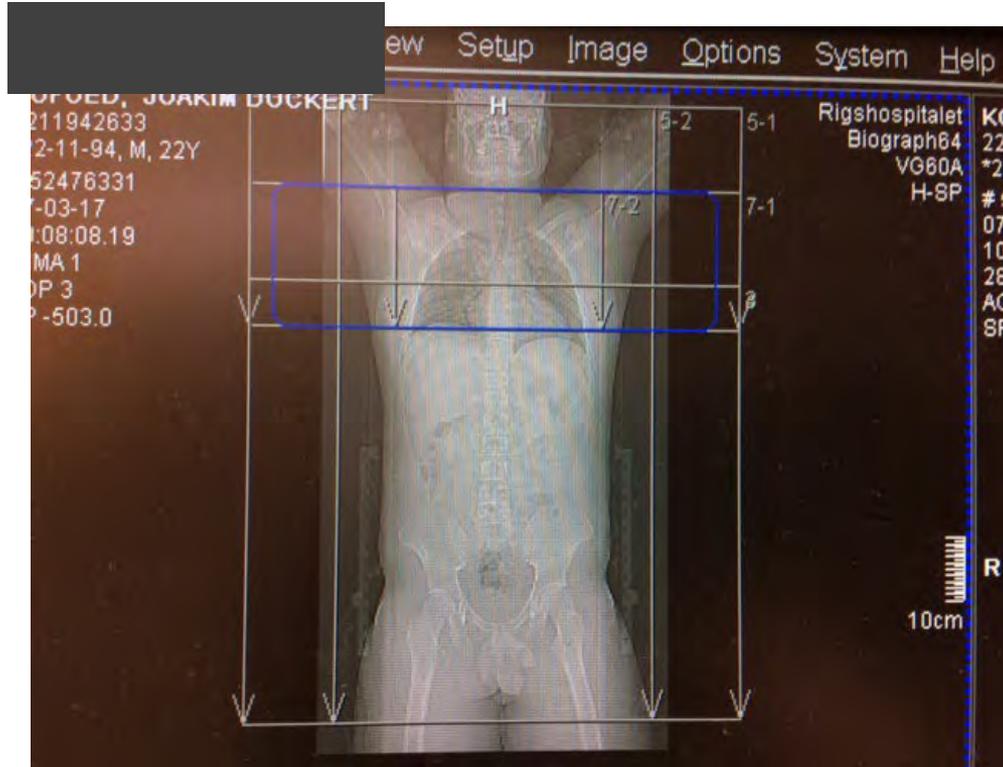
Whole Body PET/CT in Free Breathing



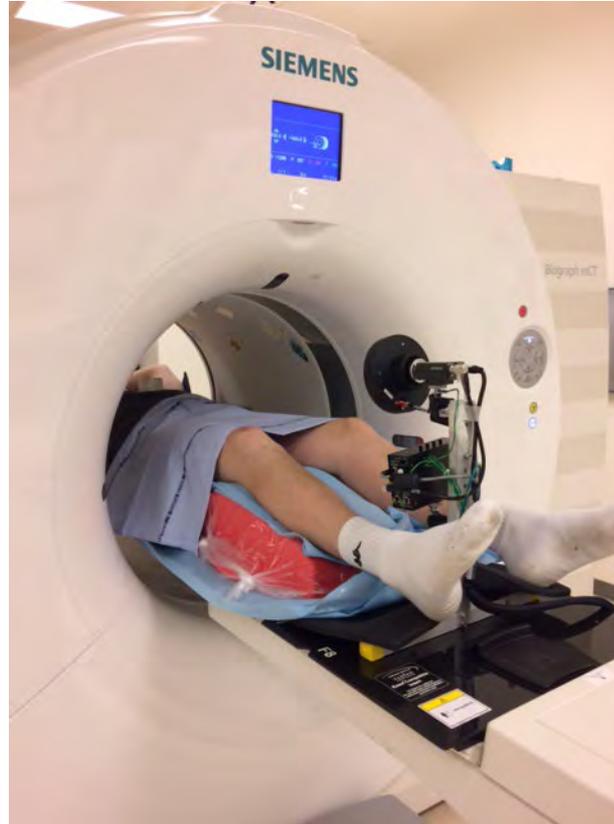
Whole Body PET/CT in Free Breathing



Choose Filter View 22 cm



6 DIBH 20 Secs Each



Long Axial Field of View - LAFOV Siemens Quadra Vision PET/CT



Alberts et al, EJNMMI 2021 Dec;48(13):4456-4462

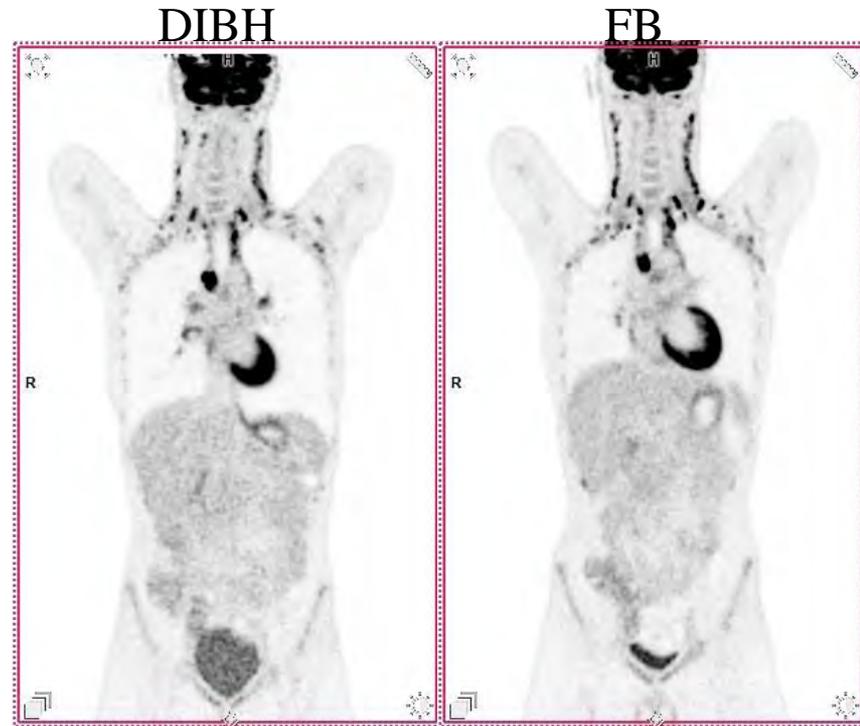
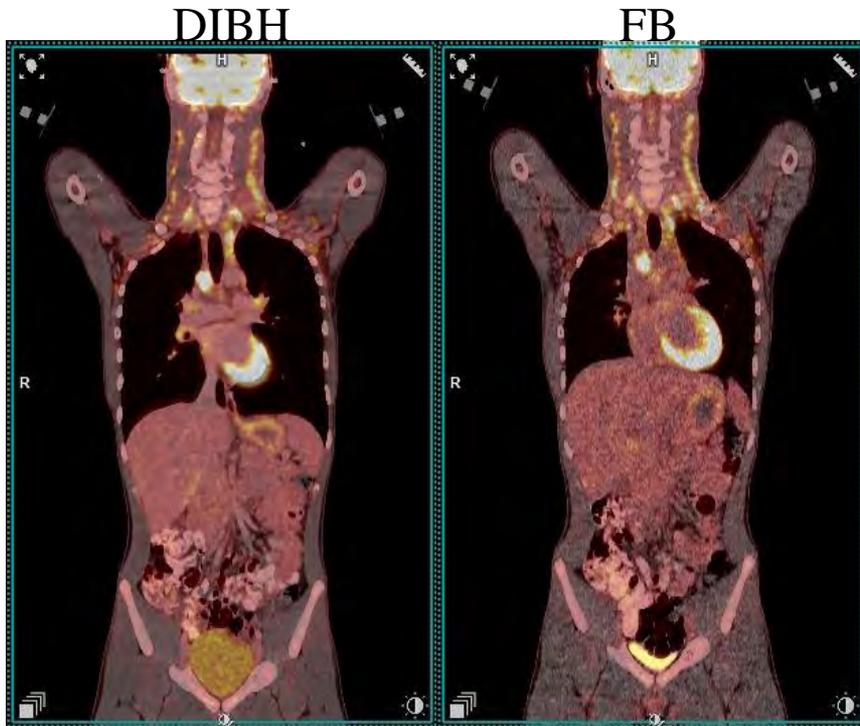
Prenosil et al, J Nucl Med. 2022 Mar;63(3):476-484

DIBH PET/CT - Varian RGSC





Quadra DIBH



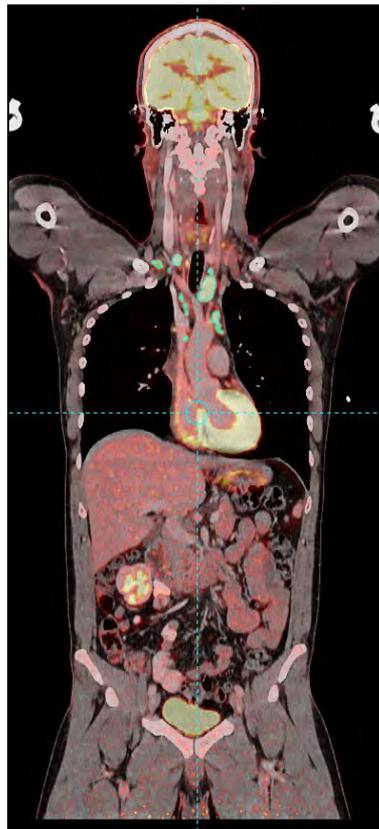
4 x 18 sec

72 sec

Results

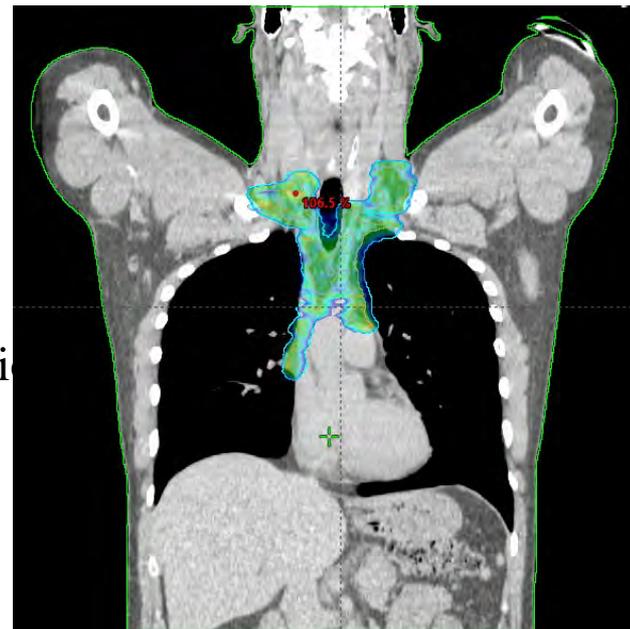


Free Breathing
Staging
Results



DIBH

→
Planning CT Fusi



LAFOV PET/CT-scan in DIBH.
Mediastinal GTV delineated based on PET

Conclusion

- DIBH implementation in lymphoma very successful
- Protocol in patients with spleen and gastric involvement ongoing

Acknowledgements

Department of radiation therapy,
especially:

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