

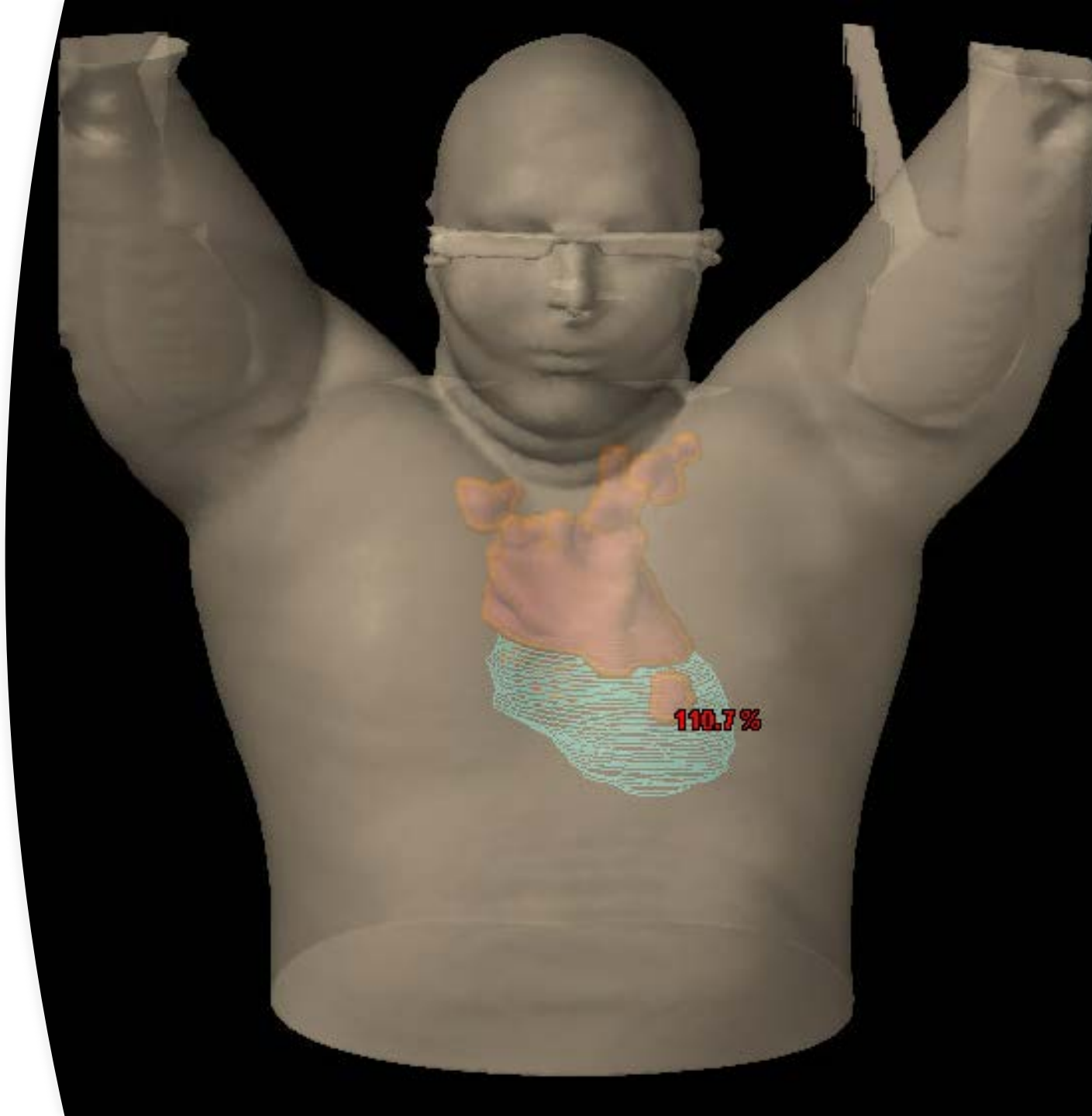
Moving Targets The Maastro Solution

Kim van der Klugt, RTT Maastro

Bastiaan Ta, radiation oncologist Maastro

Overview

- Mediastinal lymphoma
- Available RT techniques in Maastricht
- Implementation
 - Benefits, pitfalls and lessons learned
- Cases and dosimetric data
- Future plans



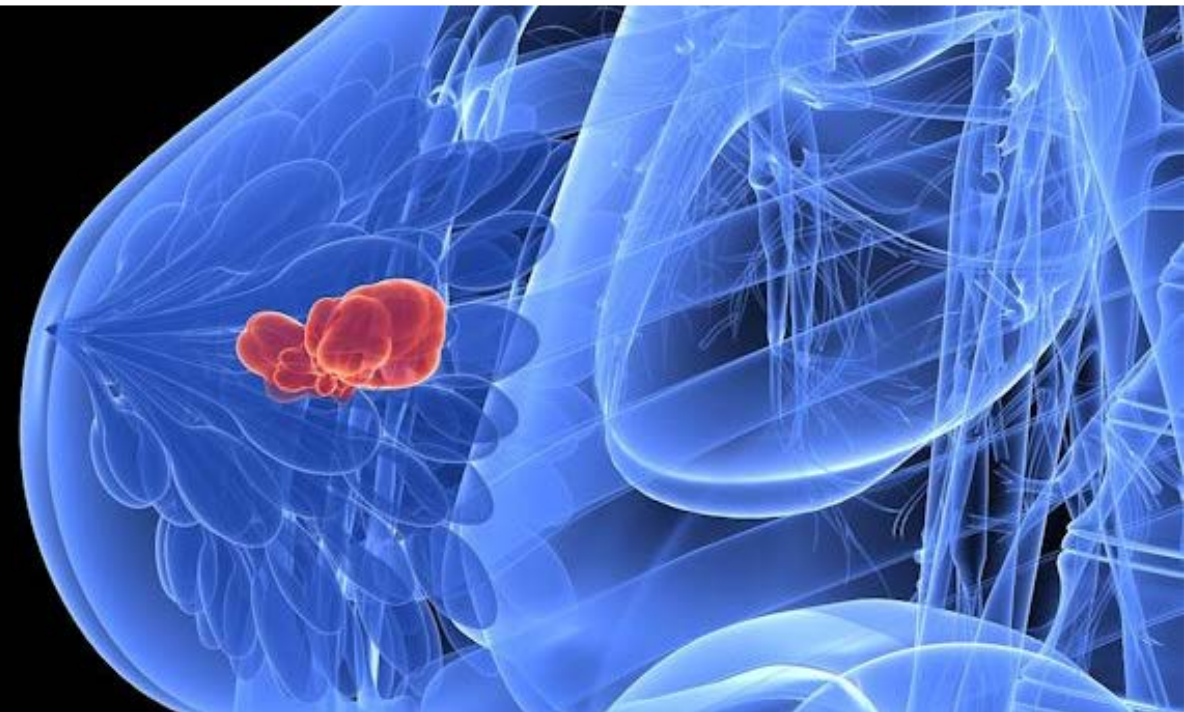
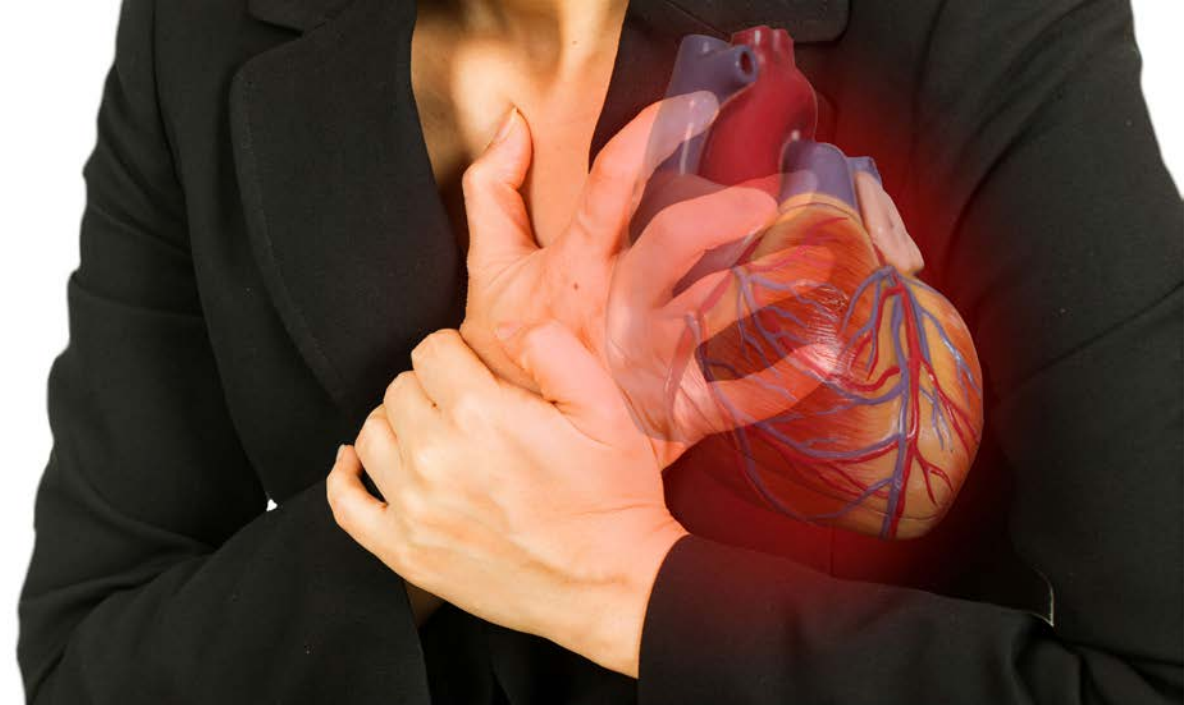
Mediastinal Lymphoma

Hodgkin Lymphoma, Primary Mediastinal B-Cell Lymphoma and Diffuse Large B-Cell Lymphoma

- HL / PMBCL: mean age 30 yrs
- Stage I/II: high PFS and OS rates (95-99%)
- RT dose range: 20 - 40 Gy

Late effects should be minimized

- Cardiac toxicity
 - Secondary tumours
- | | |
|-----------------------|------|
| Model based selection | 2019 |
| | 2022 |



Radiotherapy techniques

Photon Free-breathing

Proton Free-breathing

Photon Breath-hold

Proton Breath-hold

Maastrro – Until 2019

Photon Free-breathing

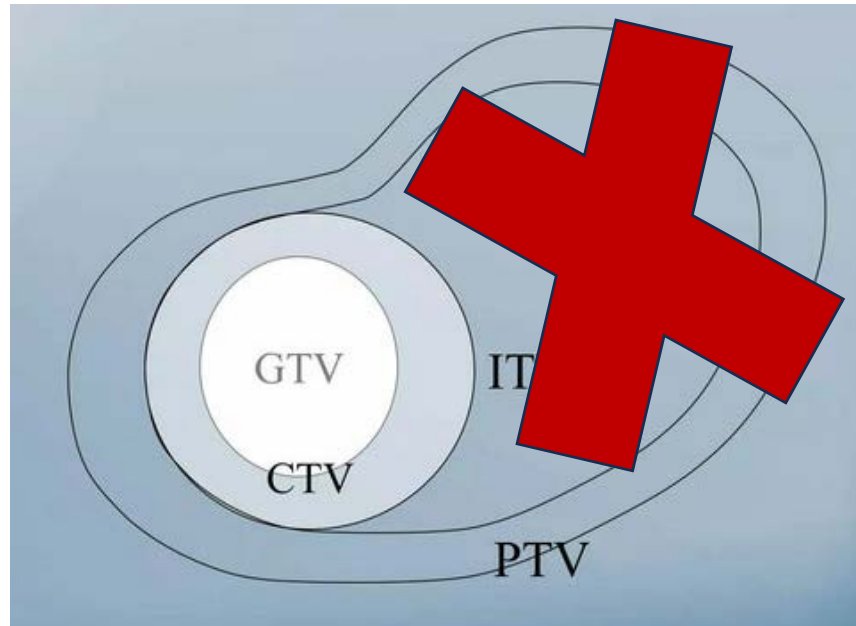
Proton Free-breathing

Photon Breath-hold

Proton Breath-hold

Volumetric arc therapy (VMAT)
Respiratory correlated CT (4D-CT)
PTV margin 8 mm

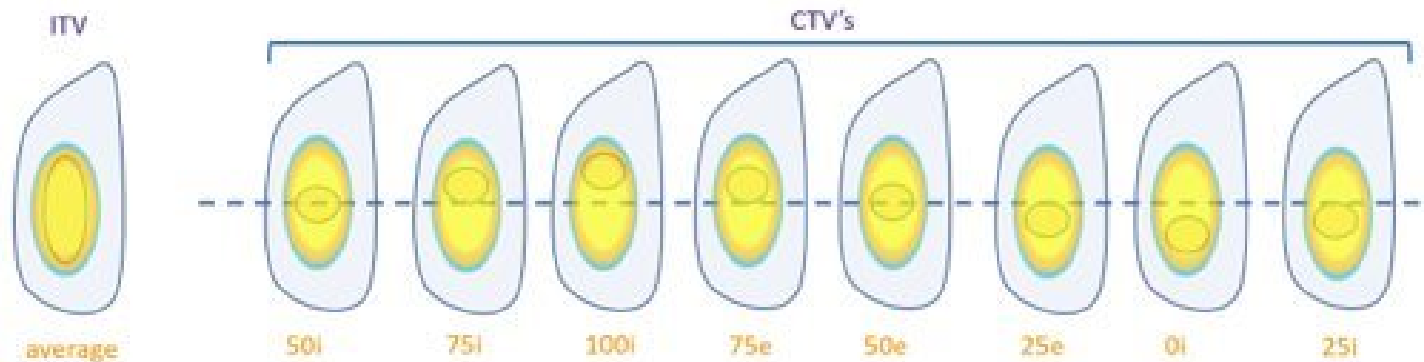
Moving Targets - ITV



Gross Tumor Volume (GTV) defined by Conventional CT (Free Breathing)



Internal Target Volume (ITV) defined by 4 dimensional CT (10 Phases Combined)



Maastrro - June 2019

Photon Free-breathing

Proton Free-breathing

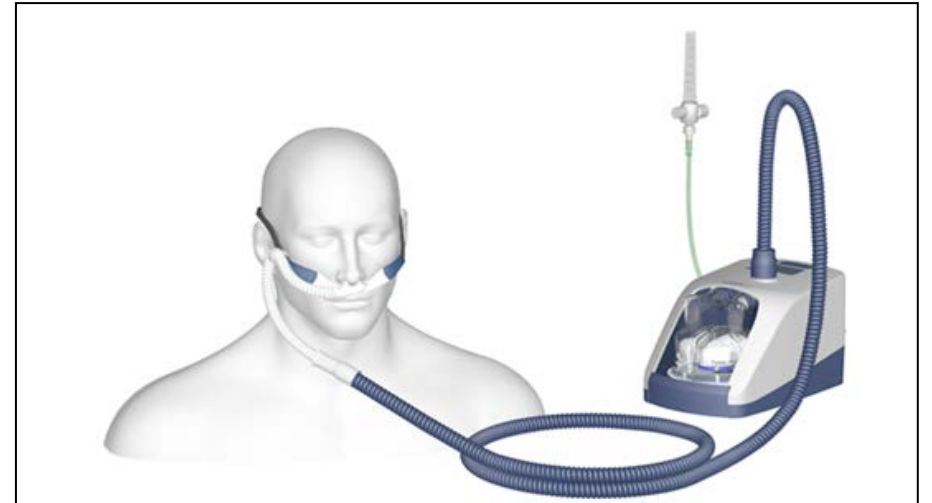
Photon Breath-hold

Proton Breath-hold

Volumetric arc therapy (VMAT)
Nasal High Flow Therapy

ENTheR study

Visually guided breath-hold with nasal high flow therapy



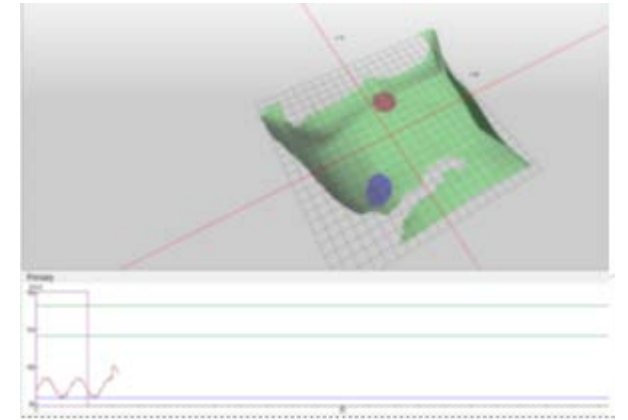
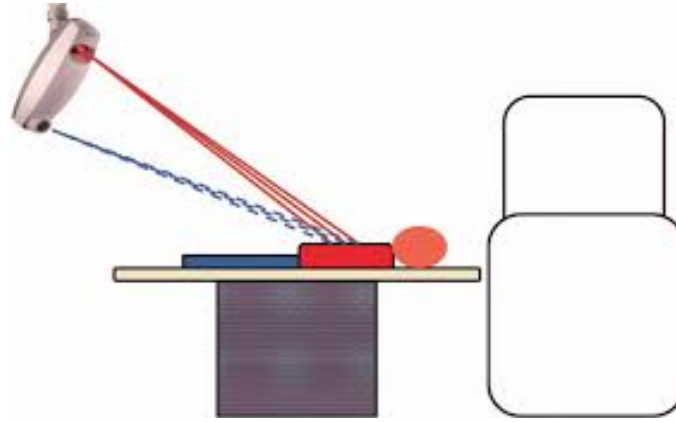
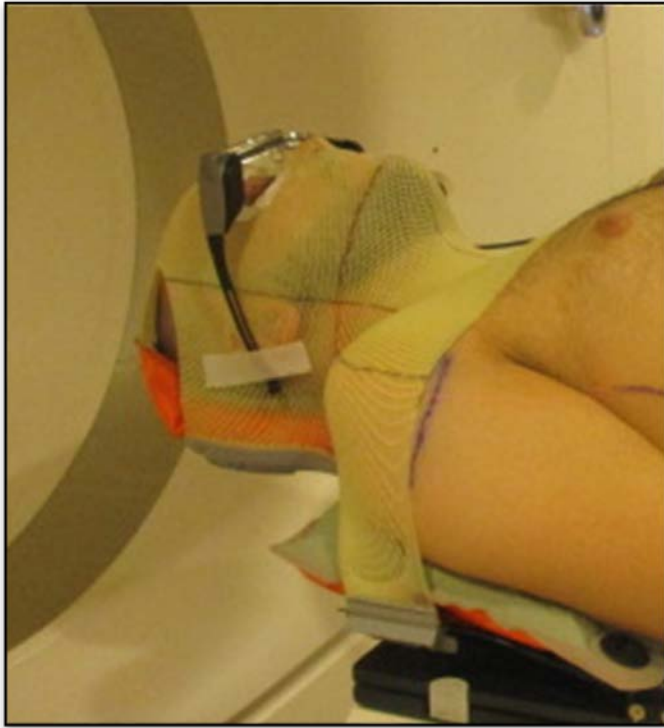
Non-small cell lung cancer patients

Reduce breathing motion

NHFT with humidified air (flow 40 L/min and 80% O₂)

First time used in RT setting

CT: Immobilization and C-RAD surface scanning system



Immobilization in treatment position

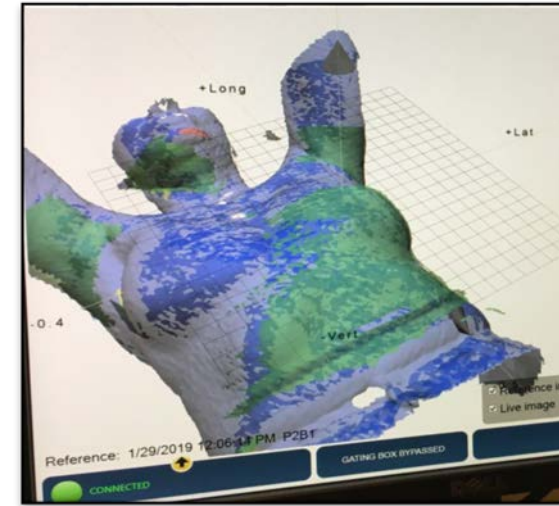
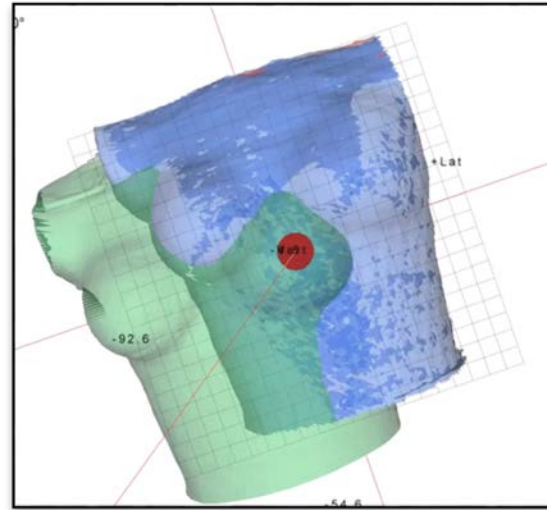
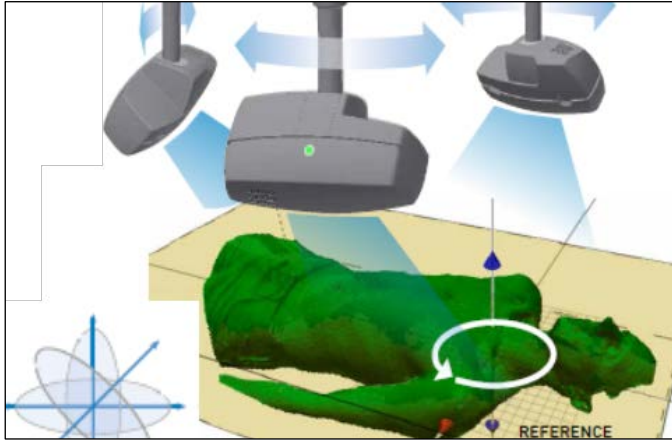
Sentinel on CT

Reference: 4/5/2019 12:16:01 PM



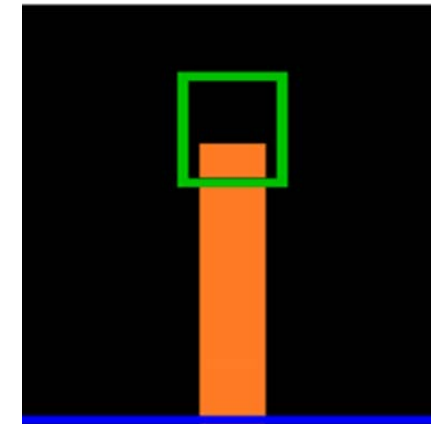
Catalyst on Linac during treatment

C-RAD surface scanning system



C-RAD on Linac

BH with visual coaching



Photon
Breath-hold

Mediastinal lymphoma

Compared to photon in FB ($n=11$)

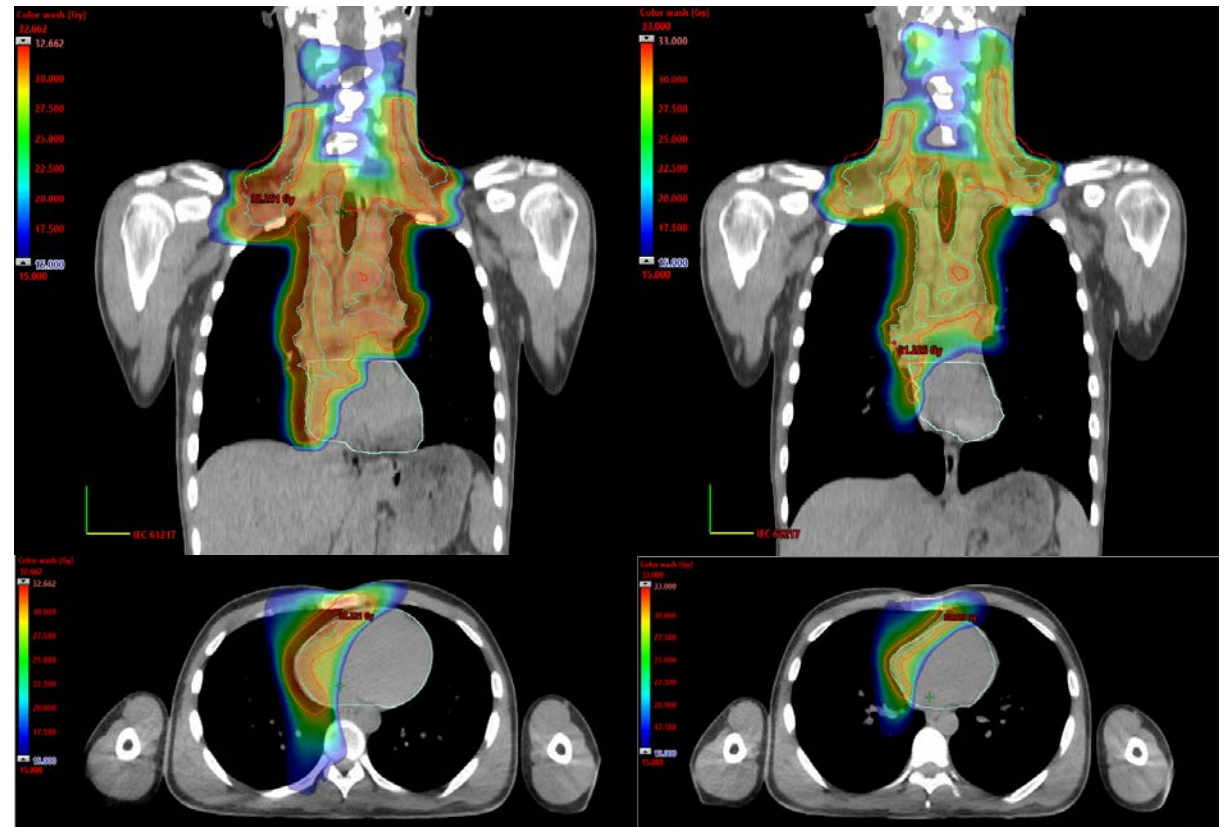
Average mean heart dose ↓ 2.0 Gy

Average mean lung dose ↓ 2.6 Gy

Average mean breast dose ↓ 0.6 Gy

Evaluation of pre-/post-RT Cone Beam CTs

Mediastinal PTV margin: 5 mm sufficient



Maastrro - October 2019

Photon Free-breathing

Proton Free-Breathing

Photon Breath-hold

Proton Breath-hold

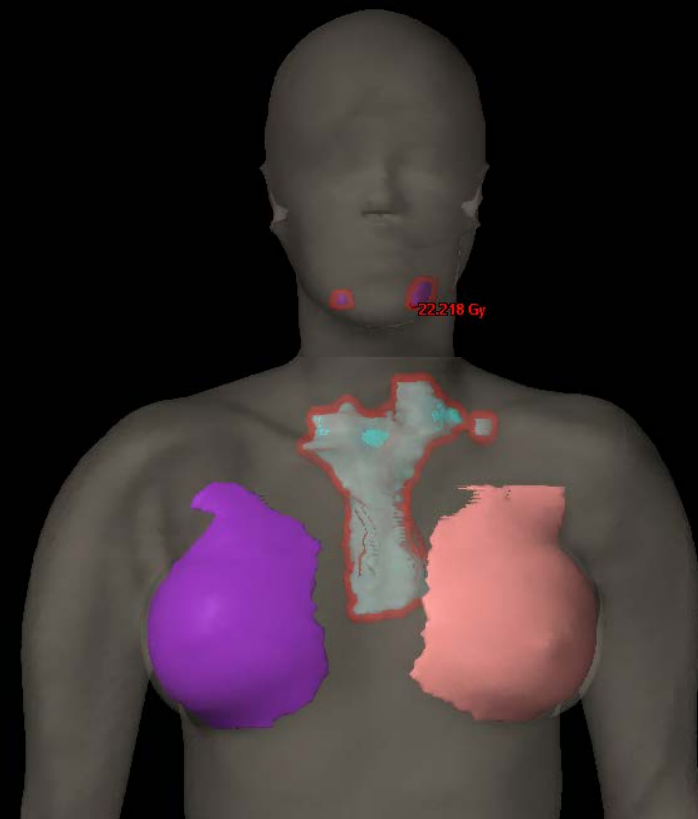
Intensity Modulated Proton Therapy (IMPT)
Model-based selection: mean heart dose

Proton
Free-breathing

Case 1

21-year-old female, classic type HL, stage IIA

- GSHG risk factor (3 areals) / EORTC favourable
- 2x ABVD + Interim-PET (complete response) + 1x AVD
- Involved site RT 10x 2 Gy
- No cardiac risk factors



CTV

PTV BH

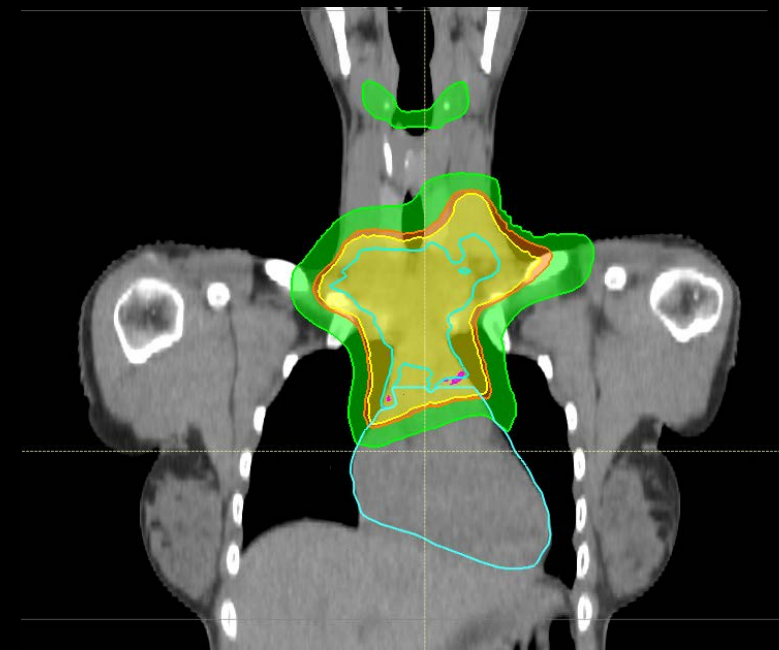
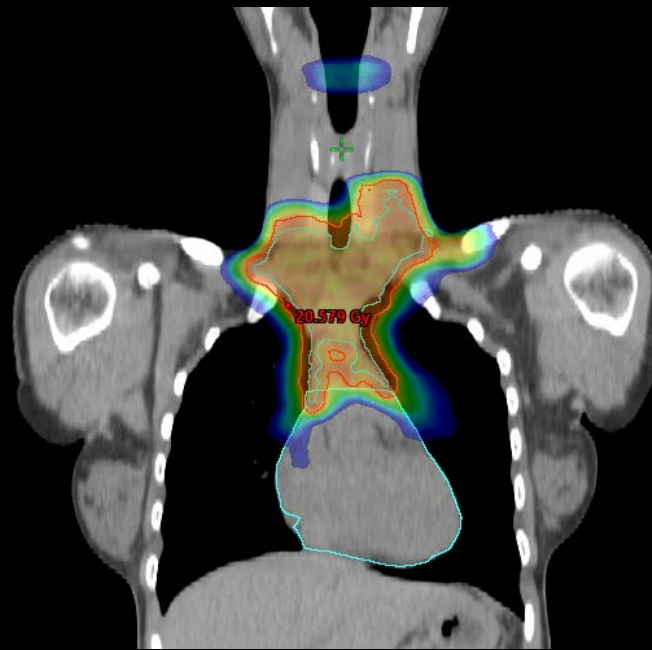
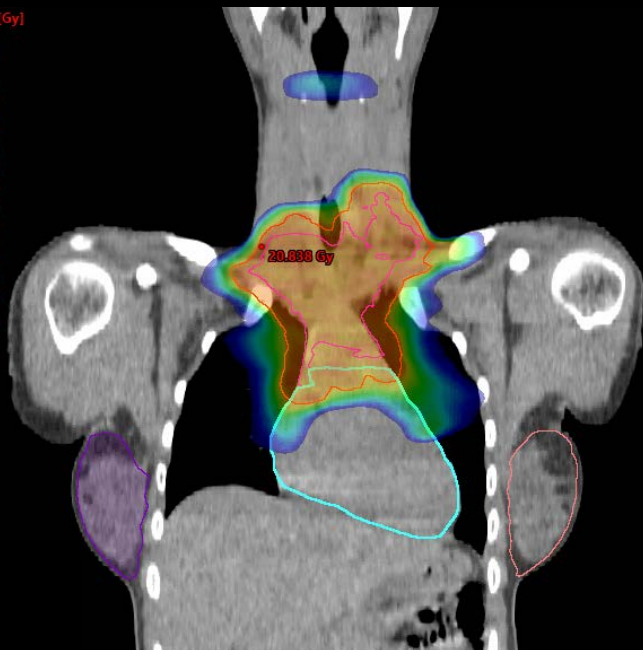
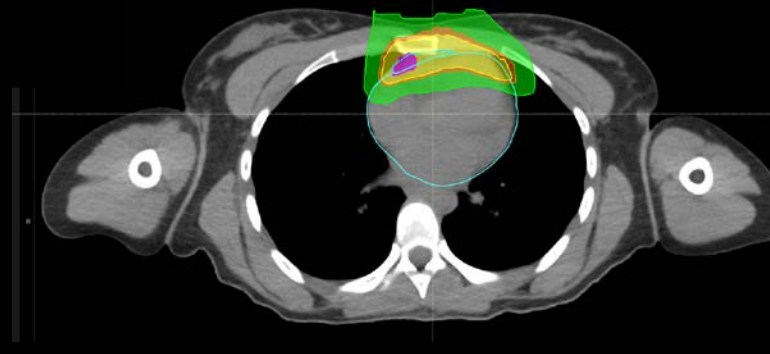
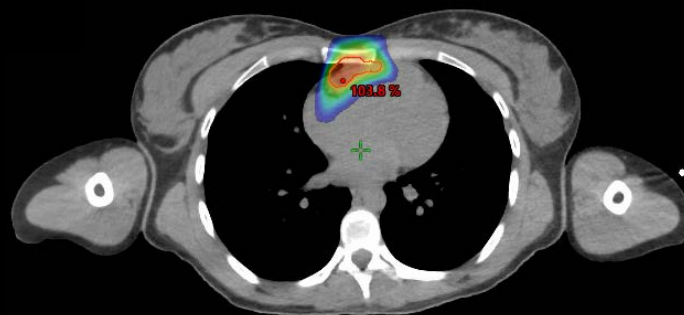
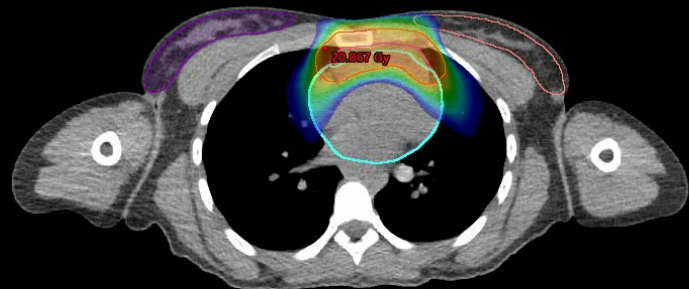
Photon-FB

vs

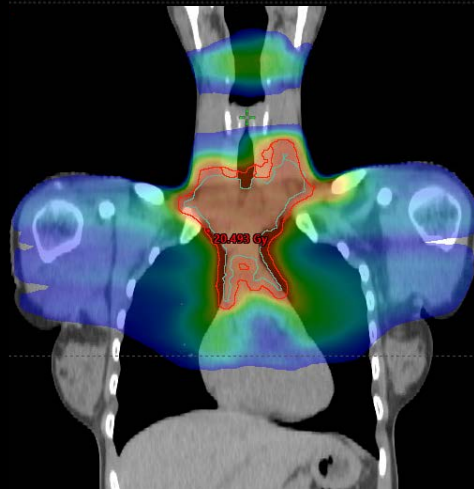
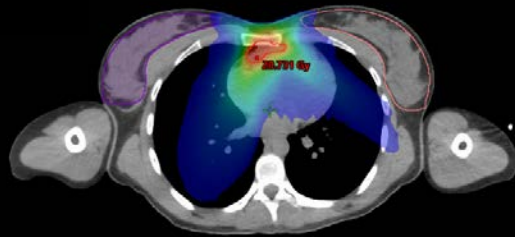
Photon-BH

vs

Proton-FB

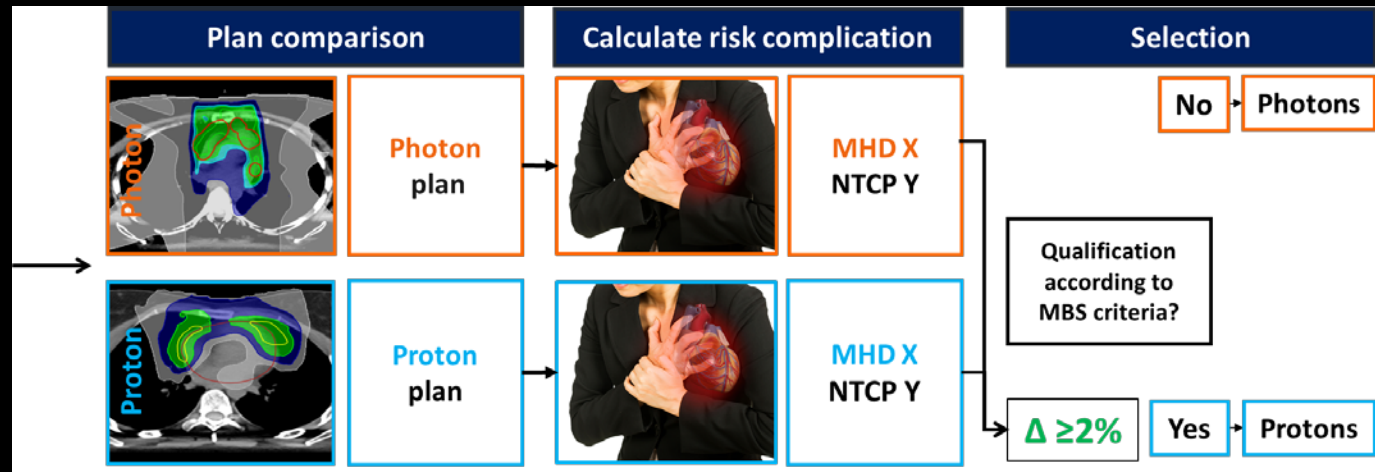


Case 1



4 Gy isodose

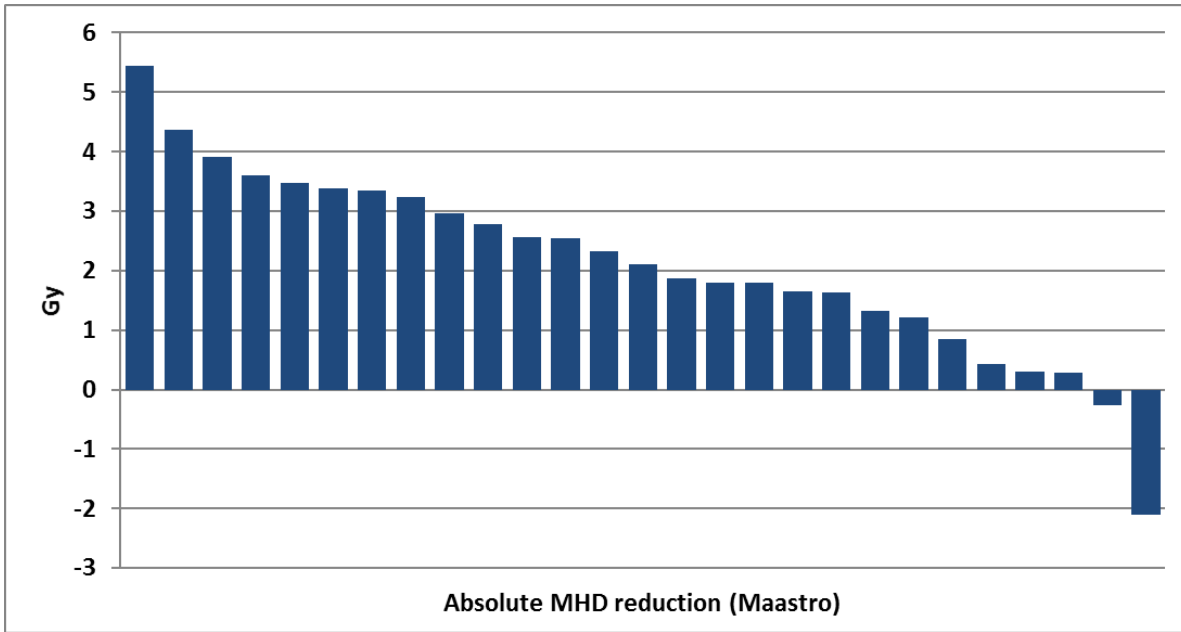
Organs at risk	Photon-FB	Photon-BH	Proton-FB
Mean heart dose	6.1 Gy	4.5 Gy	3.8 Gy
Mean lung dose	6.2 Gy	3.9 Gy	2.8 Gy
Mean breast doses (L/R)	1 / 0.8 Gy	0.9 / 0.8 Gy	0.6 / 0.3 Gy



Proton
Free-breathing

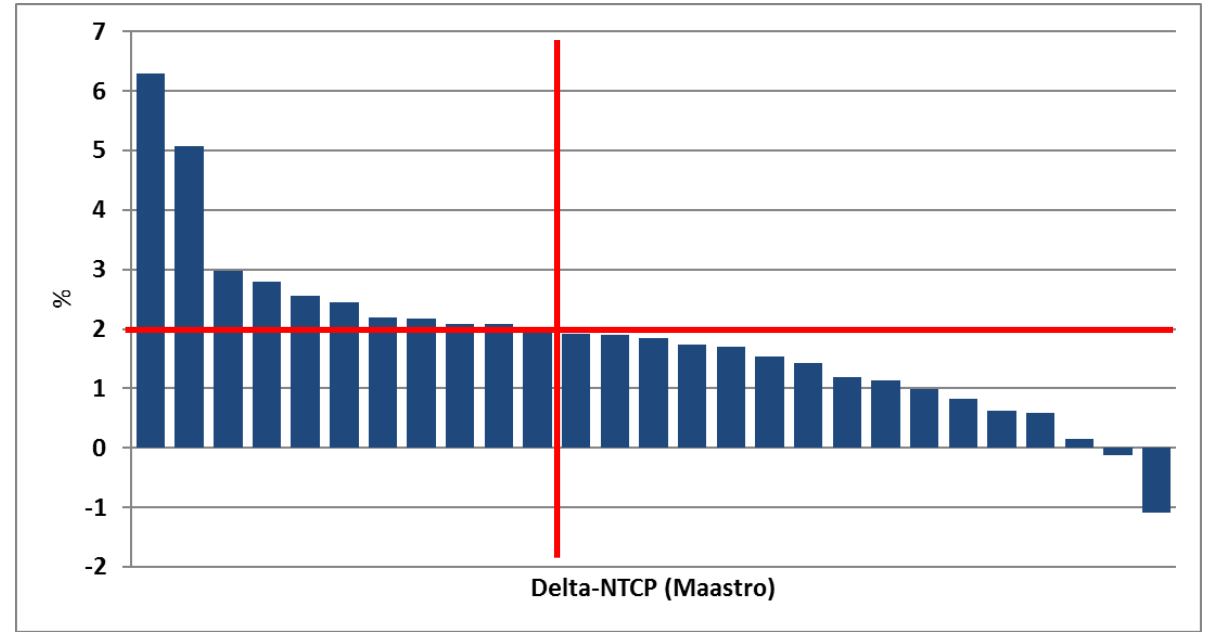
Mean Heart Dose

Absolute dose reduction vs Delta-NTCP (%) for ACE



MHD reduction

Mean 2.1 Gy



Delta-NTCP

Mean 1.8%

n = 11 / 27 patients qualified for IMPT

Proton
Free-breathing

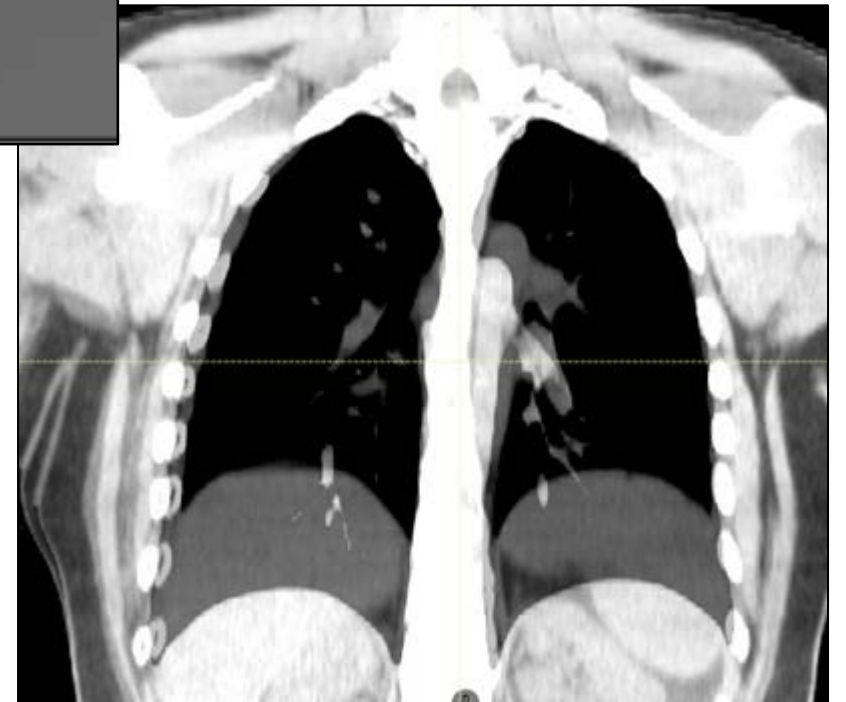
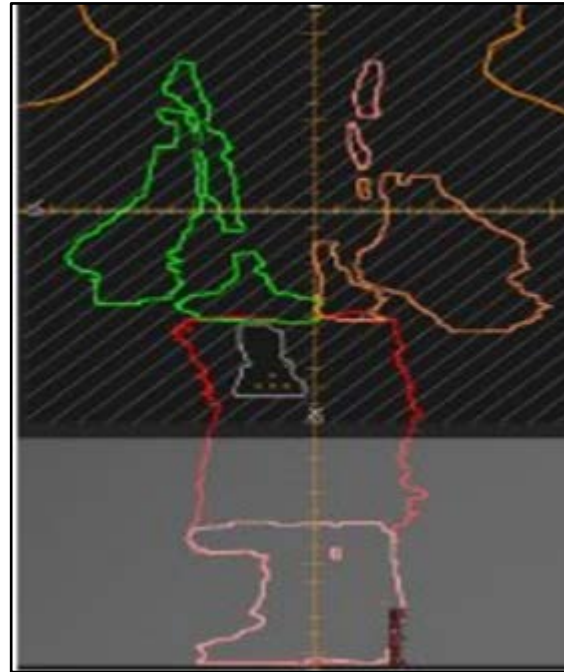
Treatment planning

Beam set-up: individualized

CTV was split into subunit-CTV's on all phases of the 4D-CT

Robustness margin and evaluation

Weekly reCT for recalculation and evaluation



Maastrro 2021 - 2023

Photon Free-breathing

Proton Free-Breathing

Photon Breath-hold

Proton Breath-hold

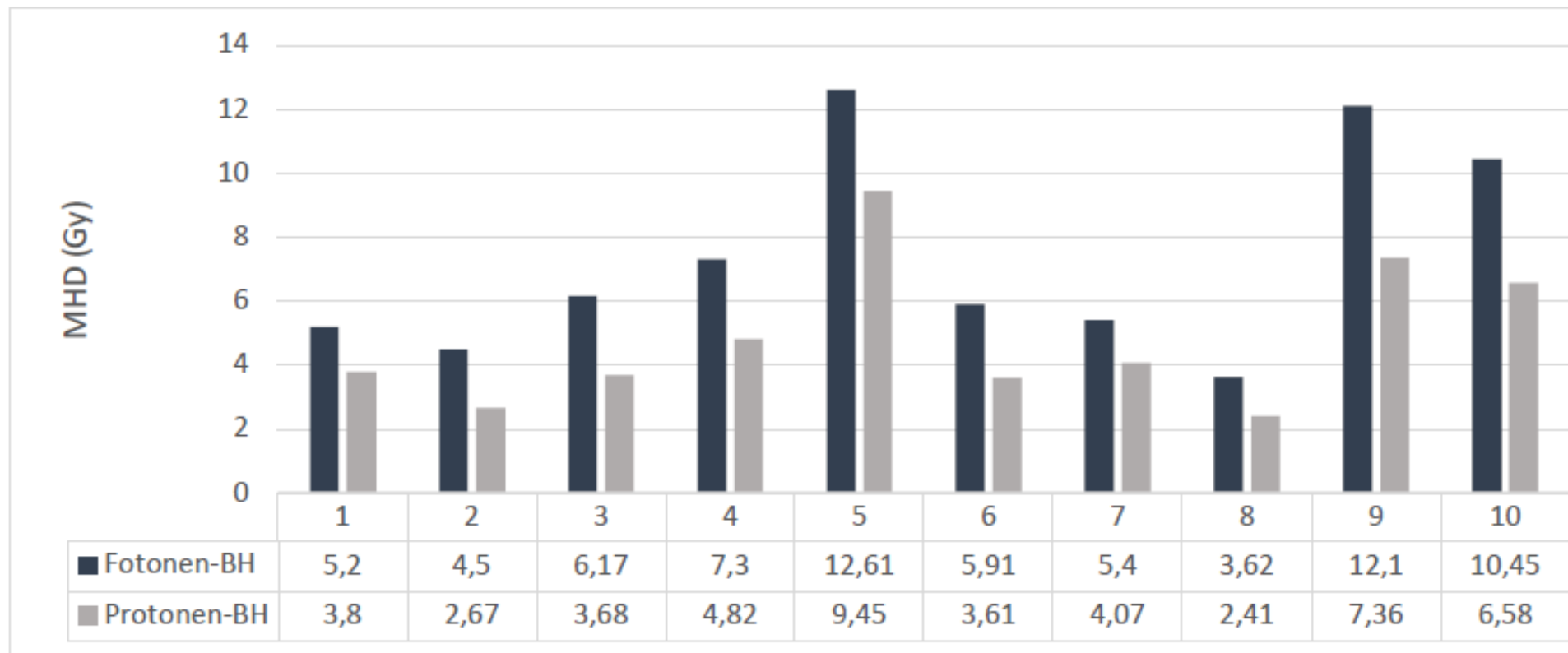
Intensity Modulated Proton Therapy (IMPT)

Skandion, Uppsala
n=16 (2019 - 2023)



In silico plan comparison

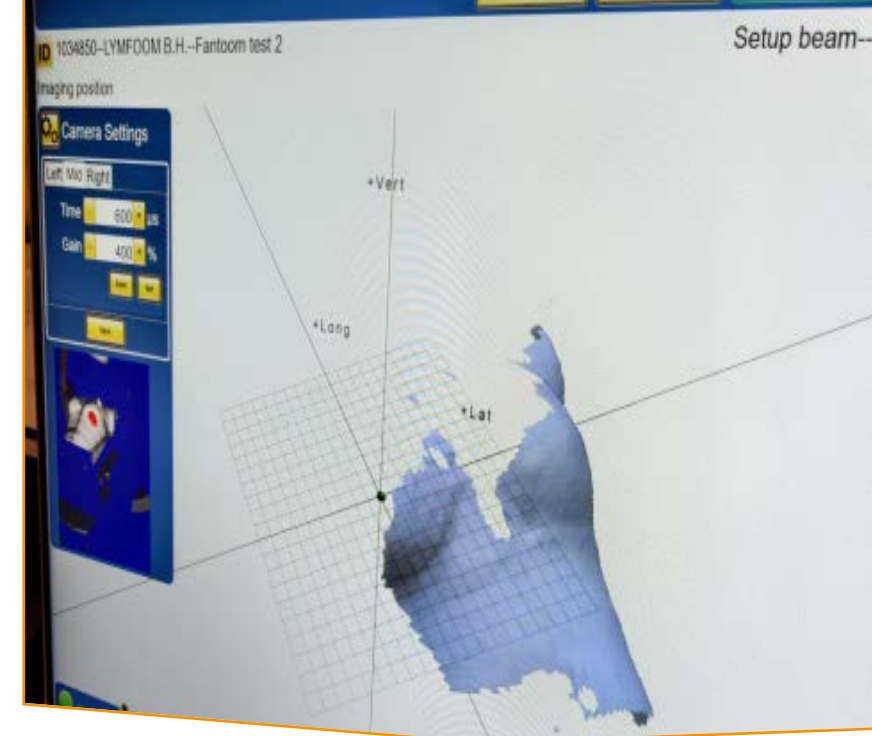
10 patients who did not qualify



Seven out of ten would've qualified for proton therapy with proton-BH

Proton
Breath-hold

Implementation challenges

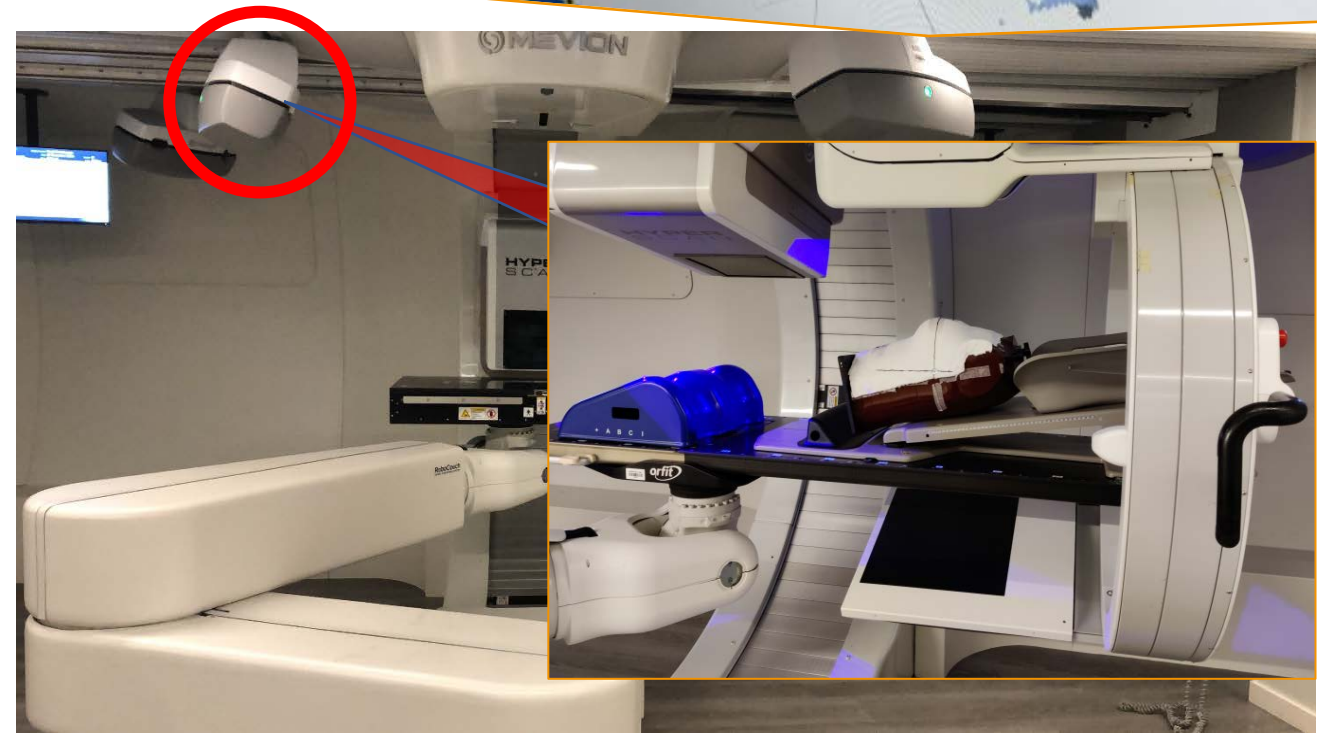


Extra C-RAD Catalyst

"Interrupt" issue of the CBCT

Inadequate C-RAD signal with normal immobilization devices

New immobilization devices



Proton
Breath-hold

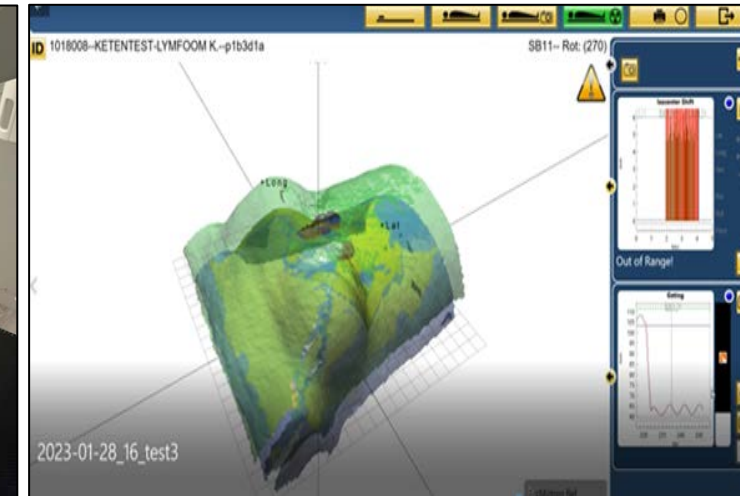
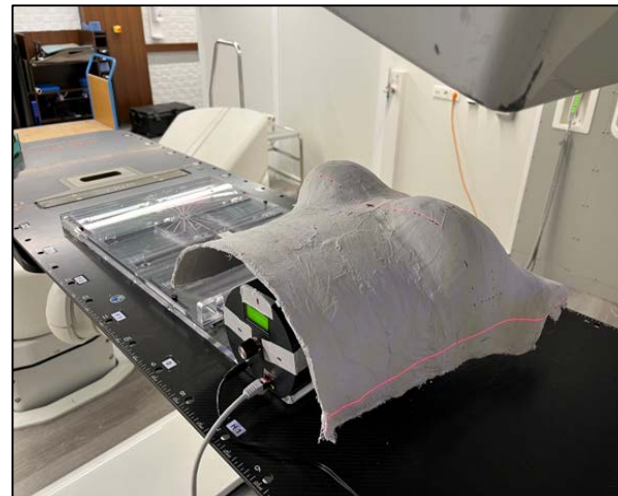
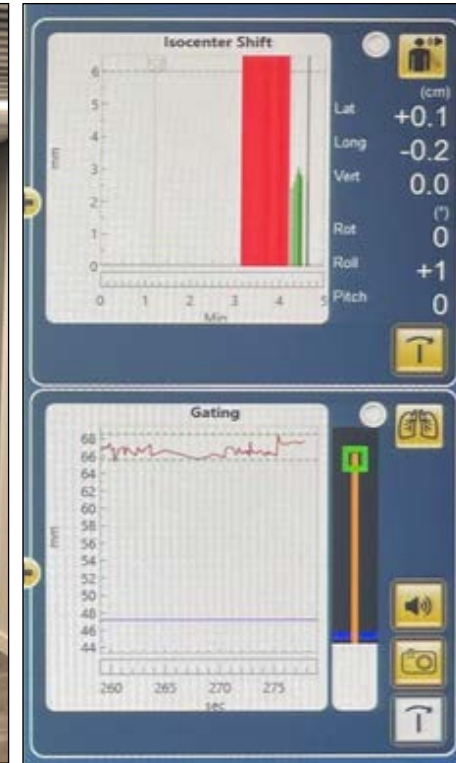
End-to-end testing

Isocenter shifts and C-RAD gating signal

Creating protocols

Educate the RTTs & learning curve

Evaluate proctocols



Proton
Breath-hold

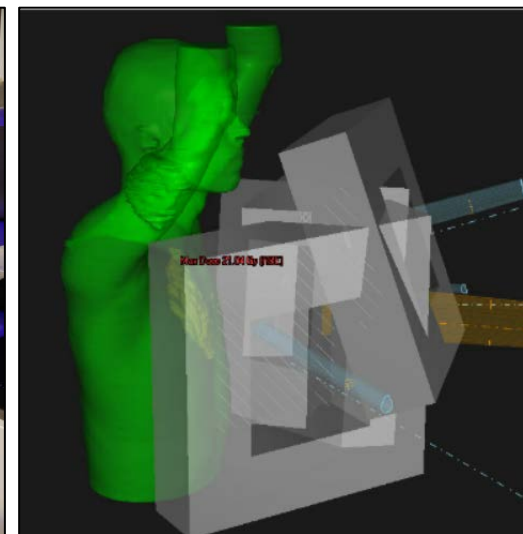
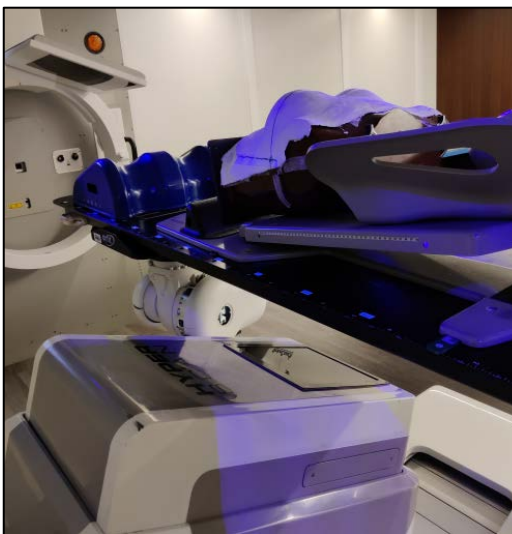
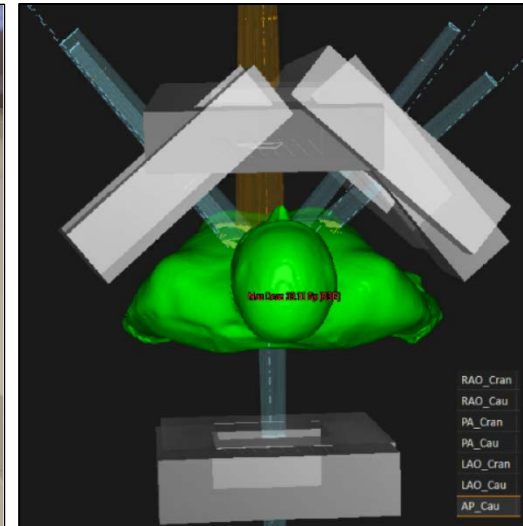
Decreased preparation time Proton-FB vs Proton-BH

Decreased delineation time

No more 4D and baseline shift optimization

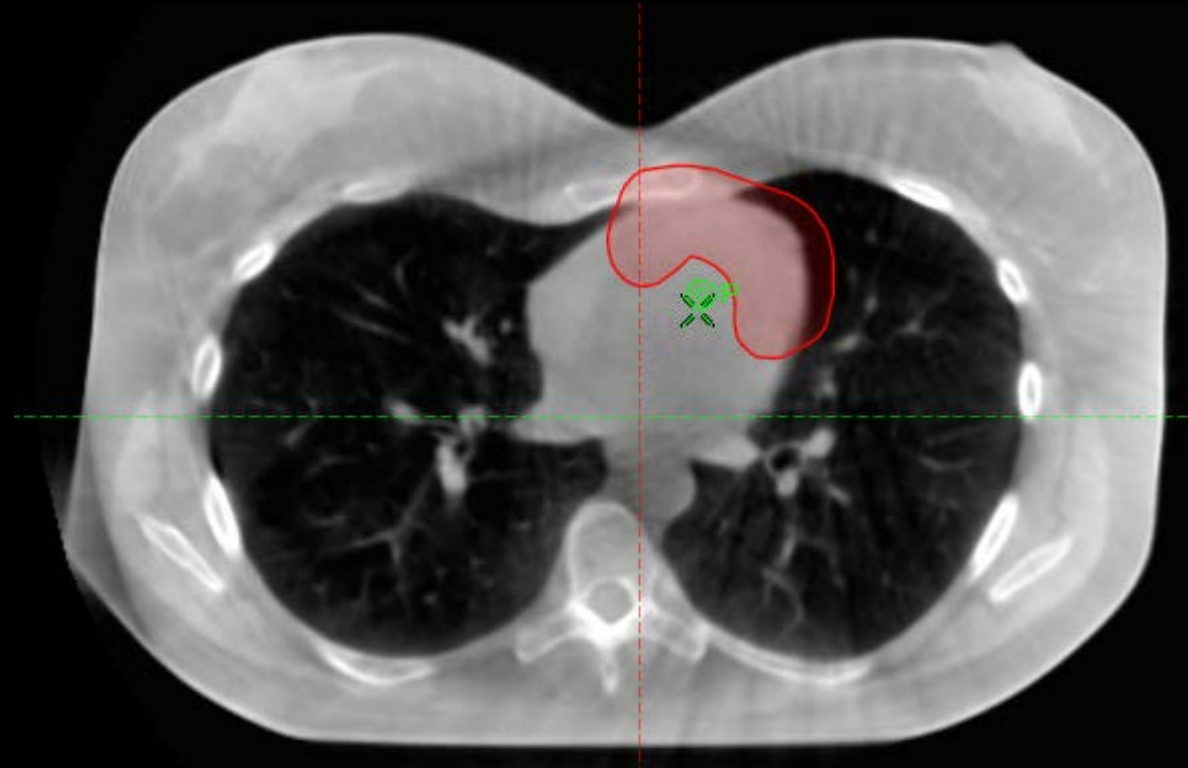
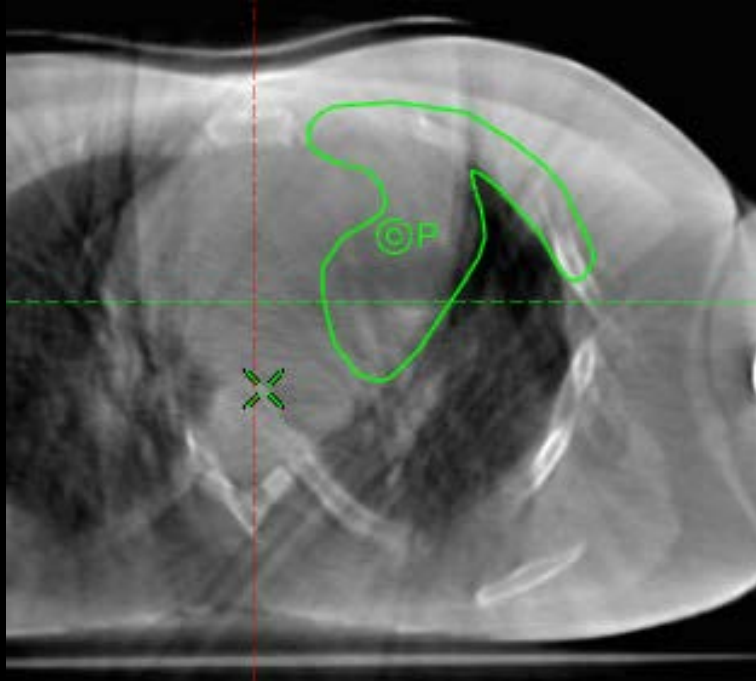
Number of beam and isocenters

Evaluation margin of the subunit-CTVs after 10 patients



Proton
Breath-hold

Cone beam improvement: FB vs BH



Better quality of the Cone beam

No adaptations needed and faster dosimetric analyses on the weekly repeat-CT

Maastrro – December 2023

Photon Free-breathing

Proton Free-Breathing

Photon Breath-hold

Proton Breath-hold

Intensity Modulated Proton Therapy (IMPT)

Skandion, Uppsala
Maastrro, Maastricht

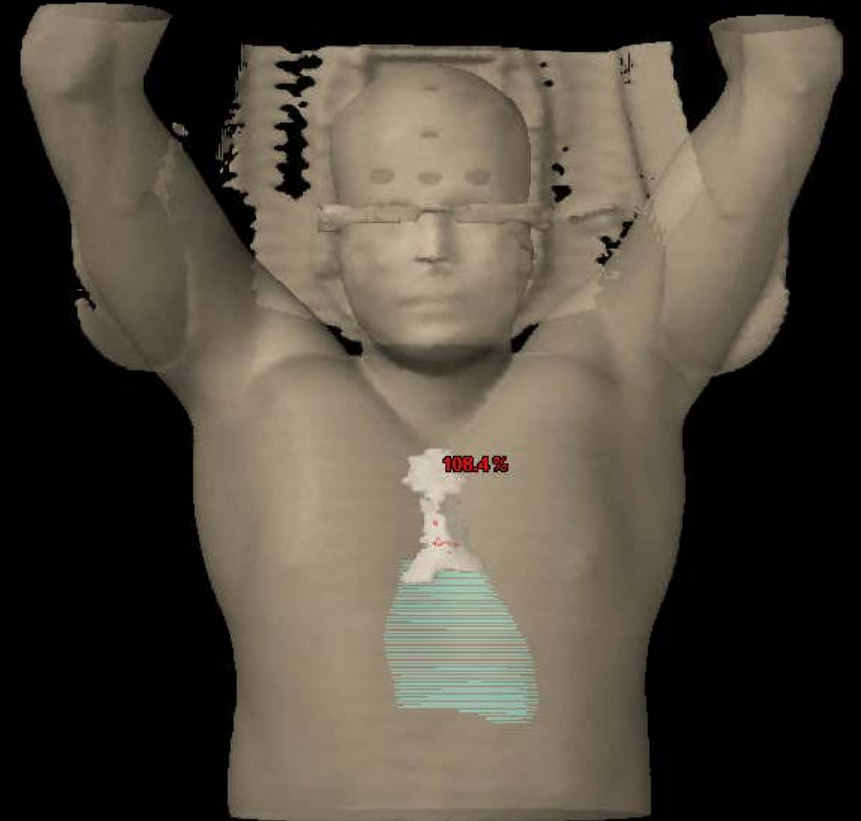


Proton
Breath-hold

Case 2

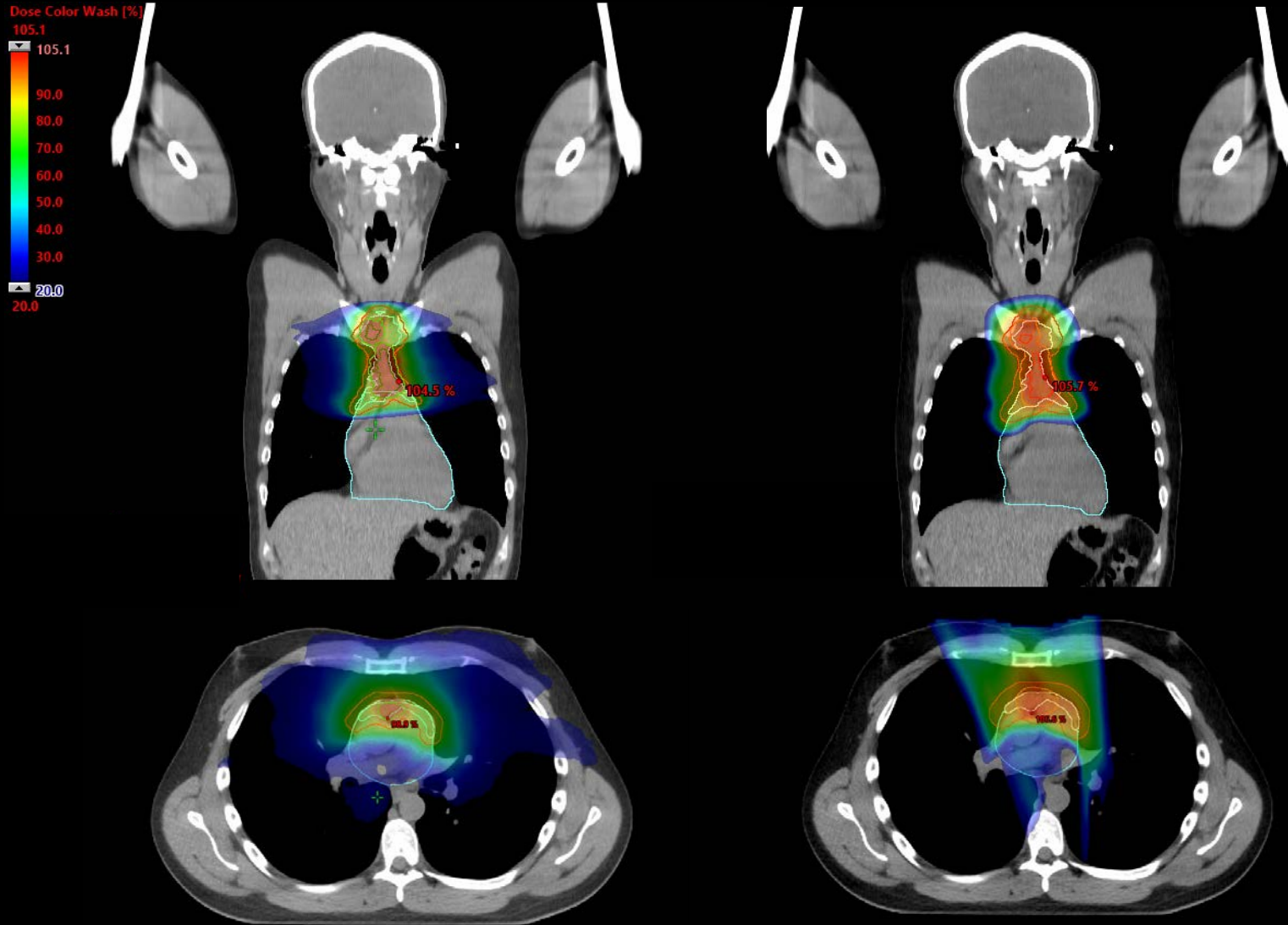
26 yr old male, PMBCL, stage IA, bulky

- 1x R-CHOP + switch to 5x DA-EPOCH-R
→ PMR on end-of-treatment PET
- Involved site RT 20x 1.56 Gy; and
Boost on residual disease 20x 2 Gy
- Smoker



CTV

Photon-BH vs Proton-BH



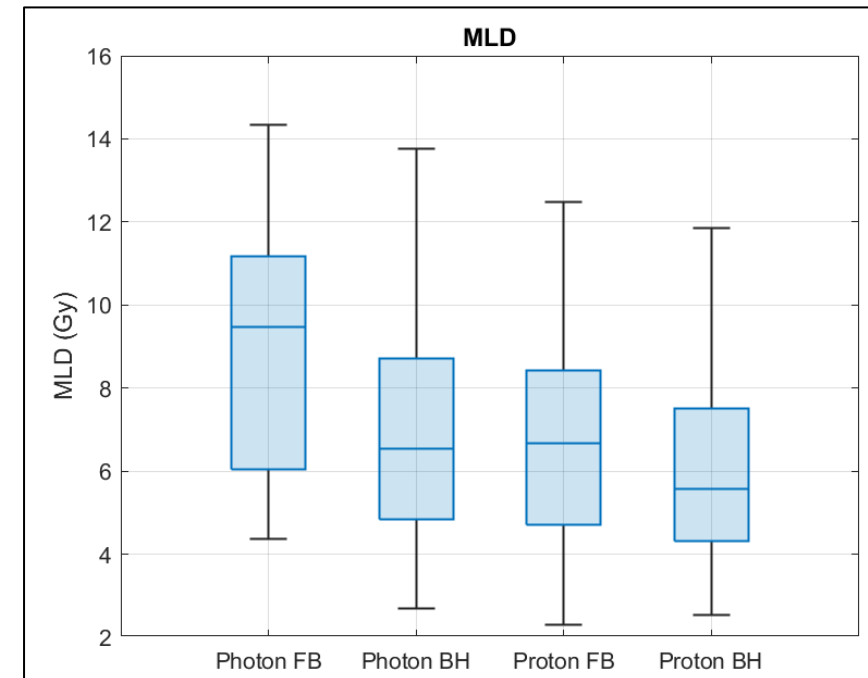
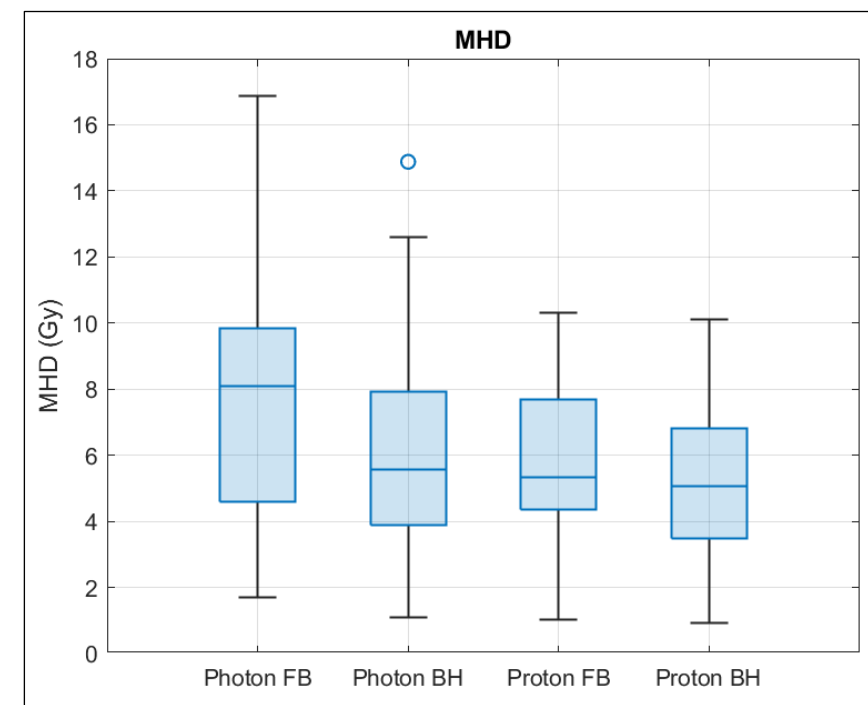
Proton
Breath-hold

Organs at risk	Photon-BH	Proton-BH
Mean heart dose	3.3 Gy	1.9 Gy
Mean lung dose	5.3 Gy	3.6 Gy

Future plans

Four-way plan comparison

- In silico ($n=55$): dosimetric evaluation
- Maastricht preselection tool
 - Predict which technique leads to the lowest MHD/MLD/MBD in each patient
 - Predict which patient has a very likely chance of qualifying for proton therapy
 - First in silico interim results ($n=28$)



Thank you for your attention



Special thanks to the entire project group

Medical physicists Richard Canters, Gloria Vilches Freixas, Esther Kneepkens

RTTs Fleur Vereijken, Maud Cobben, Maud van den Bosch, Indra Lubken,
Anne van Engelen, Cissy Stultiens, Marije Velders

Radiation Oncologists Maaike Berbée

Questions?

Test group NFHT

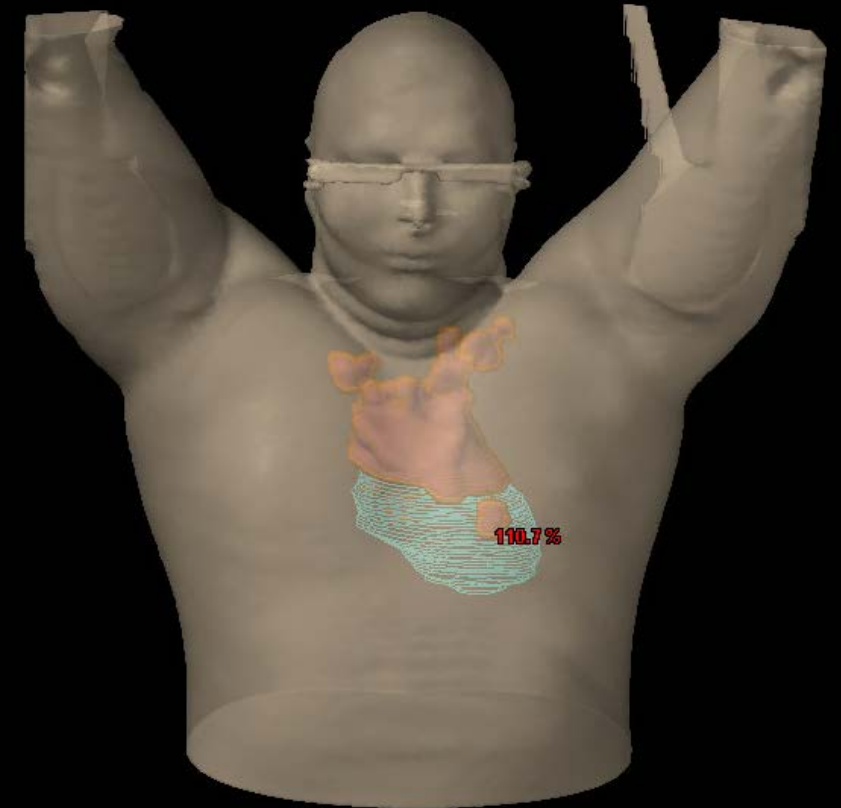
Type of support	Person #1	#2	#3	#4
No flow, no O2	30 sec	55	25	60
Flow + 21% O2	55	70	35	130
Flow + 80% O2	90	110	60	255 sec

Proton
Free-breathing

Case 3

28 yr old male, classic type HL, stage IIB, non-bulky

- GSHG risk factors (4 areals) / EORTC unfavourable
- 2x ABVD + Interim-PET (partial response) →
2x escBEACOPP → CMR on end-of-treatment PET
- Involved site RT 15x 2 Gy
- Smoker



CTV

CTV_5

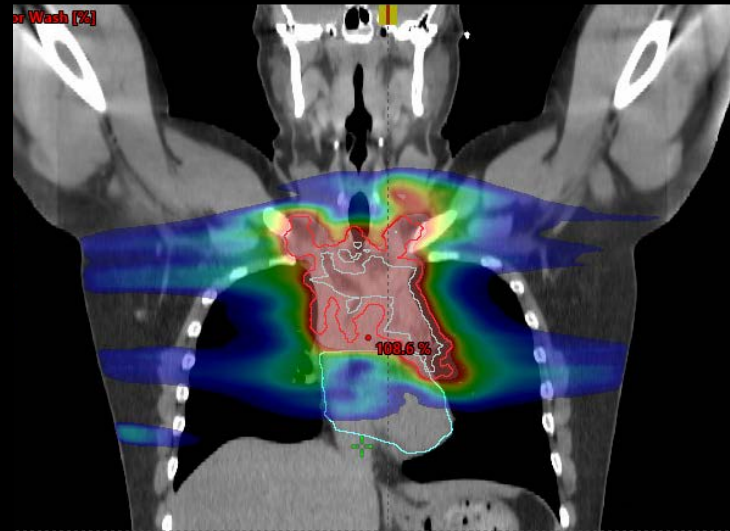
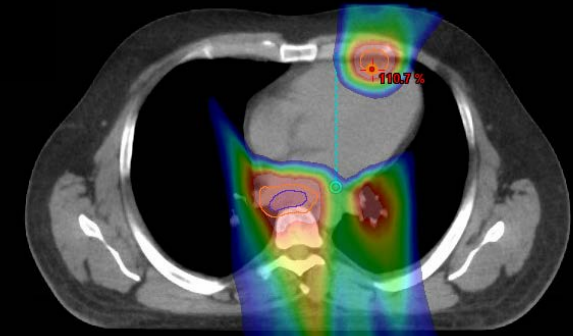
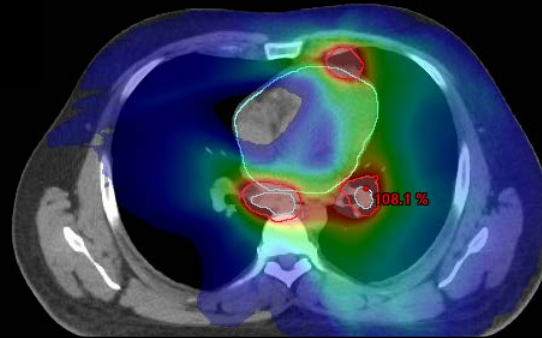
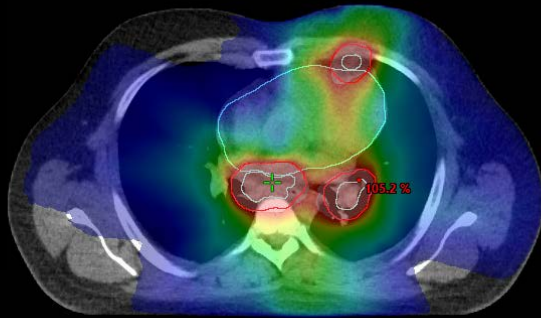
Photon-FB

vs

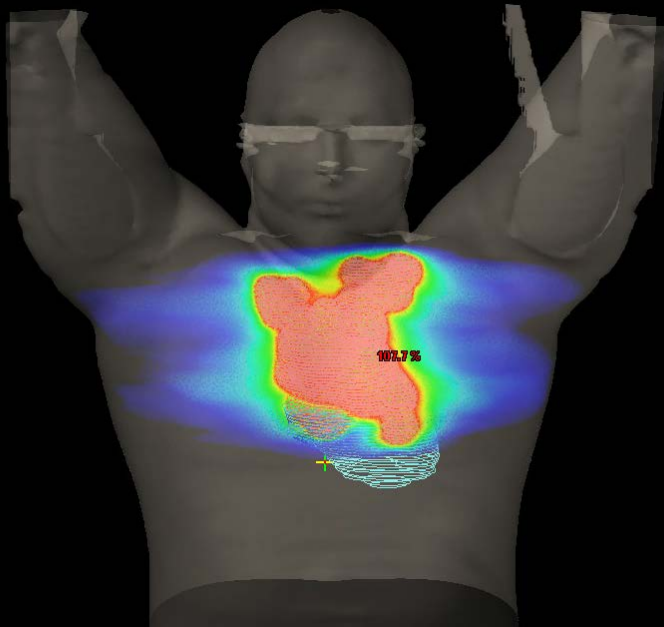
Photon-BH

vs

Proton-FB



Case 3



Organs at risk	Photon-FB	Photon-BH	Proton-FB
Mean heart dose	14.5 Gy	19.4 Gy	9.5 Gy
Mean lung dose	11.7 Gy	9.6 Gy	6.5 Gy

Proton Breath-hold

First impressions After five patients

Positive plan comparison based on

- 3x breasts
- 1x heart and lungs
- 1x heart

Stable breath holds

- Longer treatment times: more intra-fraction shifts

Learning curve patients / RTTs: 45 → 30 min

No adaptations needed and faster dosimetric analyses on the weekly repeat-CT

