HITRI plus
Heavy Ion Therapy Research Integration

Upright patient positioning – renewed interest in a promising paradigm for particle therapy

LENNART VOLZ

BIOPHYSICS, GSI, GERMANY

CO-CHAIR TO THE UPRIGHT RADIOTHERAPY RESEARCH COMMITTEE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

Rationale for upright particle therapy

- Challenge particle therapy gantries are large and thus very costly (esp. for heavy ions)

HIT

- 600t, 25m length

QST (NIRS)

- 300t, ~10m length

„System Cost. The simple, yet not widely accepted answer is to eliminate the gantry“
- Jay Flanz, Phys. Med. Biol. 66 (2021)

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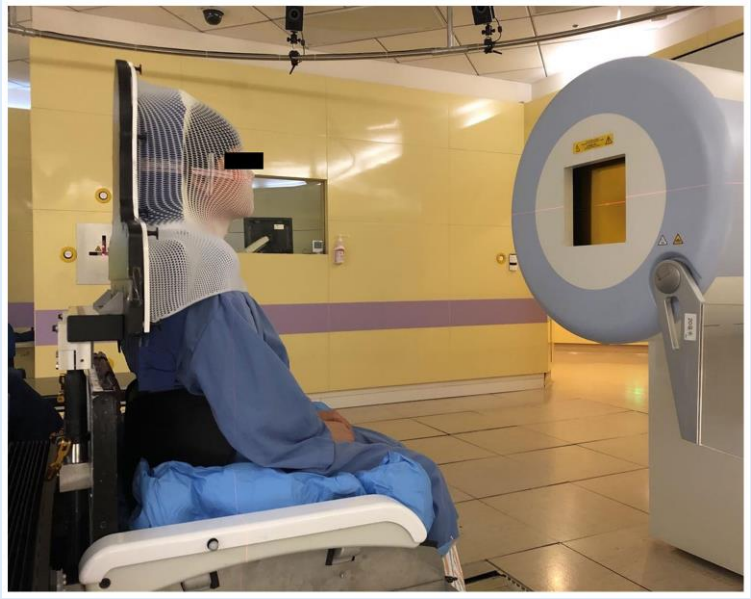
Gantry-less: move the patient, not the beam

Upright



Sun et al. (2021) Front. Oncol.

Horizontal rotation

Beyer et al. (2024) Rad. Oncol.

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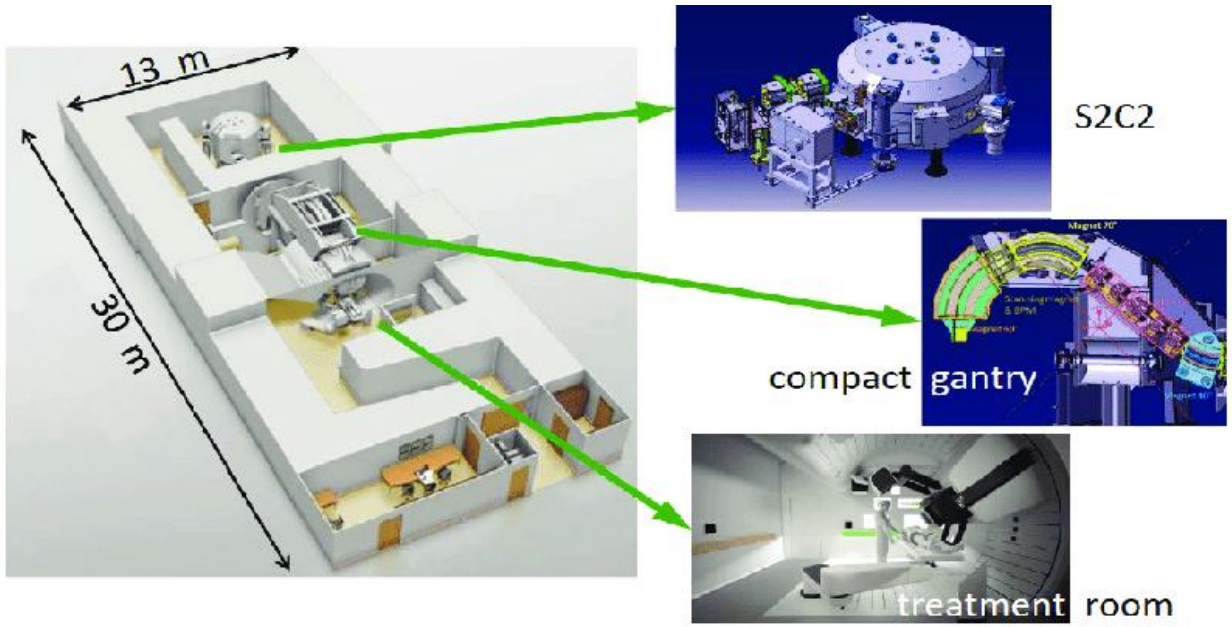
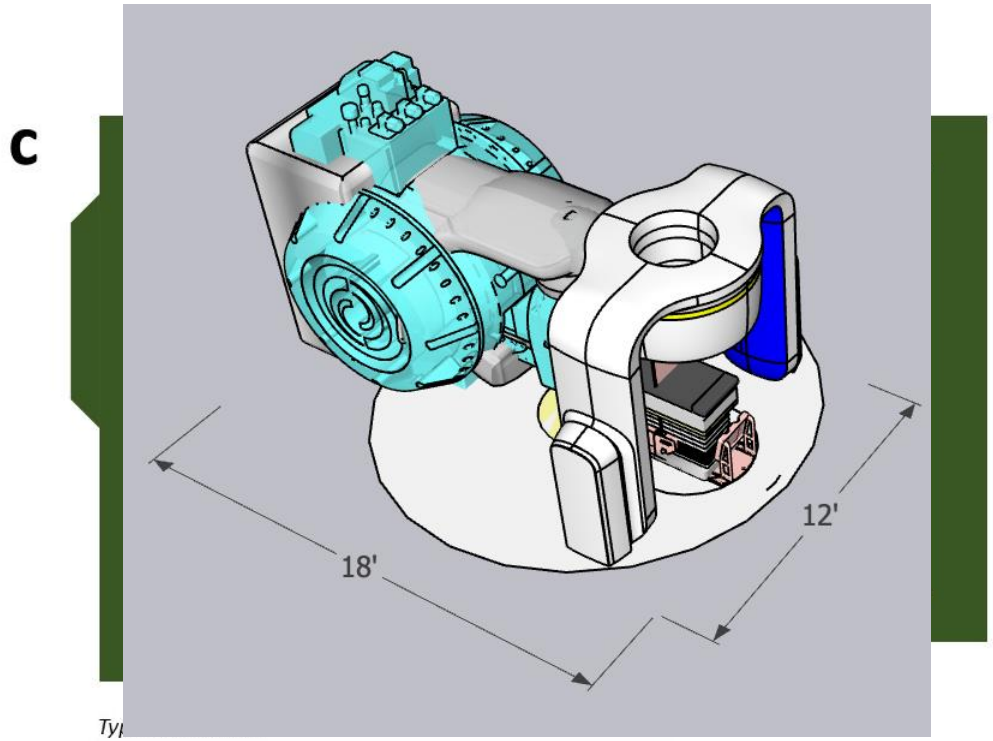
Footprint and room design



U. Amaldi (2015) Modern Physics Letters A 30(17):1540018



Mevion FIT system overlayed on LINAC
Courtesy to N. Schreuder (Leo Cancer Care Ltd.)

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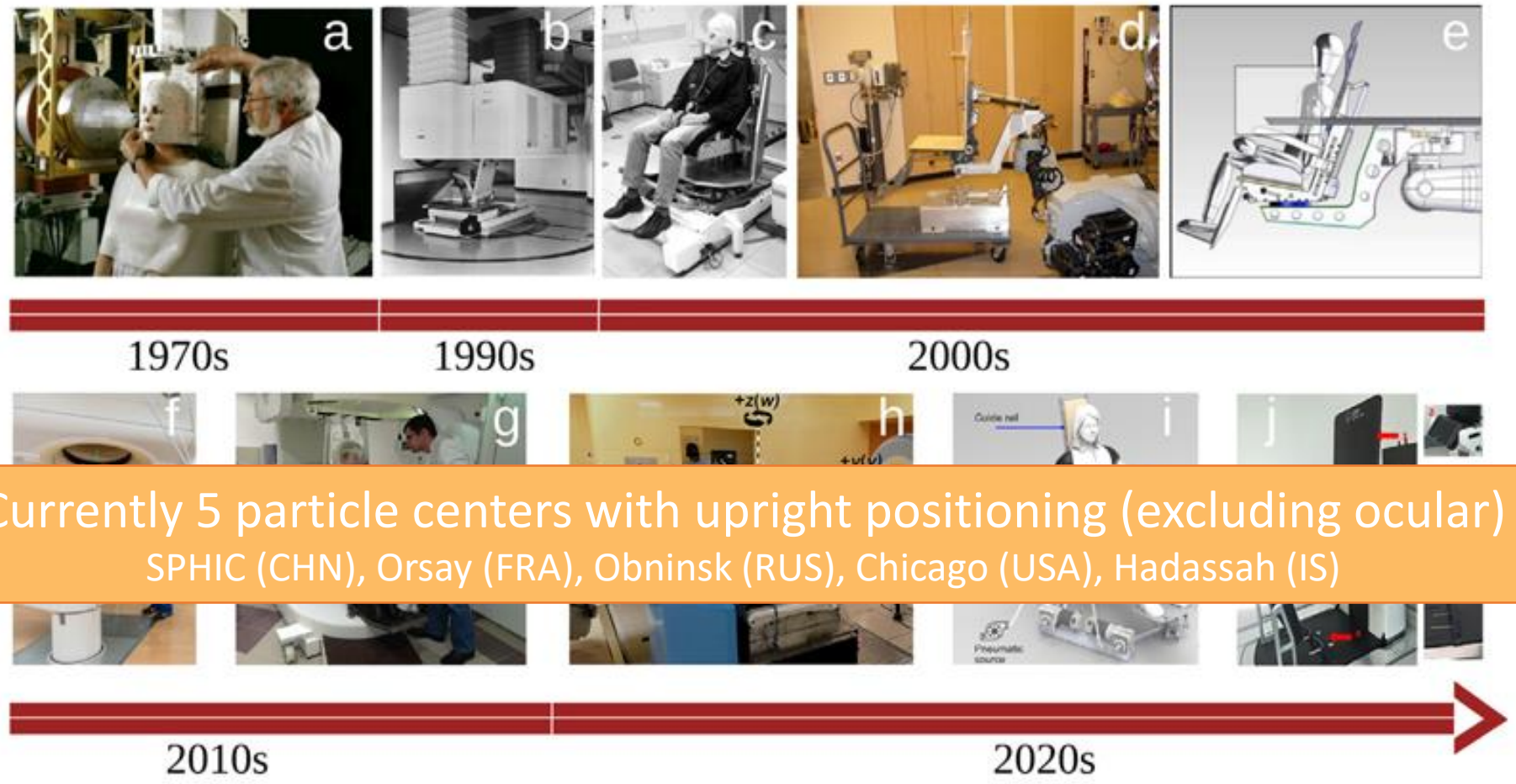
Historical reflection of particle therapy chairs



Currently 5 particle centers with upright positioning (excluding ocular)

SPHIC (CHN), Orsay (FRA), Obninsk (RUS), Chicago (USA), Hadassah (IS)

Graeff, Volz, Durante (2023) PPNP

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Current main vendors

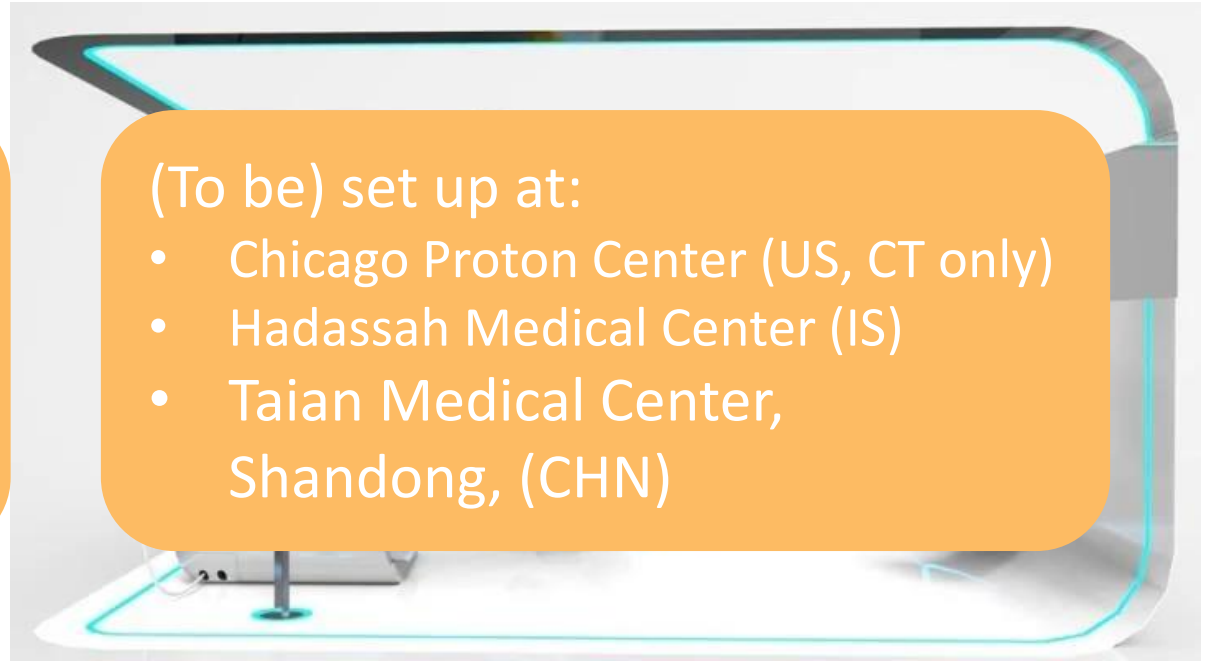
(To be) set up at:

- McLaren Proton Center, Flint, Michigan (US)
- UW, Madison Wisconsin
- Stanford (US)
- CNAO (IT)
- Centre Leon Berard (FR)

Marie ™ - Leo Cancer Care upright patient positioning system and CT scanner

(To be) set up at:

- Chicago Proton Center (US, CT only)
- Hadassah Medical Center (IS)
- Taian Medical Center, Shandong, (CHN)



P-Cure Ltd., compact 360° gantry-less adaptive proton therapy system

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Imaging

Jinsaki et al. (2020) Invest. Radiol.
Canon Medical

P-Cure

Leo Cancer Care

ASG Superconductors

Not yet clear which modalities are essential

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Upright proton therapy for head&neck cancer

- Promising results reported in literature for head and neck cancer
- Historically, always the first site that is treated, because of simplicity and anatomical stability between positions

COMBINATION OF PHOTON AND PROTON RADIATION THERAPY FOR CHORDOMAS AND CHONDROSARCOMAS OF THE SKULL BASE: THE C… IENCE

Photon combined with upright protons in 2000

GEOR… MAR, M.D.,*
DOMINIQUE … HASBOUN, M.D.,§
PATRICIA MOISSON, M.D.,¶ REGIS PERRAND, PH.D.,¶ ANNE BEAUDRÉ, PH.D.,†
GILBERT BOISSERIE, PH.D.,§ GENEVIÈVE GABORIAUD, PH.D.,‡ ALEXANDRE MAZAL, PH.D.,‡
KATIA KÉRODY, PH.D.,¶ MICHEL SCHLIENGER, M.D.,¶ AND JEAN-JACQUES MAZERON, M.D., PH.D.*§

…entre de Protonthérapie d'Orsay, Orsay, France; †Institut Gustave Roussy, Villejuif, France; ‡Institut Curie, Paris, France; §Groupe Pitié Salpêtrière, Paris, France; ‖Centre René Huguenin, Saint Cloud, France; ¶Hôpital Tenon, Paris, France

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Research | Open access | Published: 20 December 2021

Proton therapy with a fixed beamline for skull-base chordomas and chondrosarcomas: outcomes and toxicity

Konstantin Gordon, Igor Gulidov, Sergey Koryakin, Daniil Smyk, Tatyana Makeenkova, Danil Gogolin, Olga Lepilina, Olga Golovanova, Alexey Semenov, Sergey Dujenko, Kira Medvedeva & Yuri Mardynsky

Radiation Oncology **16**, Article number: 238 (2021) | Cite this article

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ORIGINAL RESEARCH article

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Sec. Radiation Oncology
Volume 14 - 2024 | https://doi.org/10.3389/fonc.2024.1348291

This article is part of the Research Topic
Radiotherapy for Head and Neck Cancers
View all 8 articles >

Upright proton therapy for esthesioneuroblastoma: a single-institution experience

Konstantin Gordon[1,2*] Igor Gulidov[1] Daniil Smyk[1,2] Alexey Semenov[1] Kirill Golubev[1]
Alyona Lemaeva[1] Sergey Koryakin[1] Enar Jumaniyazova[2] Polina Vishnyakova[2] Irina Eremina[2]
Timur Fatkhudinov[2] Andrey Kaprin[1,2]

[1] Proton Therapy Department, A. Tsyb Medical Radiological Research Center - Branch of the National Medical Radiological Research Center, Obninsk, Russia
[2] Research Institute of Molecular and Cellular Medicine, Medical Institution, P. Lumumba People's Friendship University of Russia, Moscow, Russia

Patient comfort

- "…all patients (with lung cancer) experienced the sitting position as more comfortable than the supine position" [1]
- "…regarding comfort in the arms during treatment, patients (with HNC cancer) preferred the seated position over the supine position" [2]
- "(pelvic) …the scores suggested positively in favour of the upright positioning system or at least similar…patients appreciated the easiness of getting in and out of the chair, they could breathe more easily, and most patients felt more stable in the upright position." [3]
- 7 of 9 participants (breast) reported preferring the upright position [4]

[2]

[1] Duisters, Cindy, et al. Radiotherapy and oncology 79.3 (2006): 285-287.
[2] McCarroll, Rachel E., et al. JACMP 18.1 (2017): 223-229.
[3] Boisbouvier, S., et al. Technical Innovations & Patient Support in Radiation Oncology 24 (2022): 124-130.
[4] Boisbouvier, S., et al. Frontiers in Oncology 13 (2023): 1250678.

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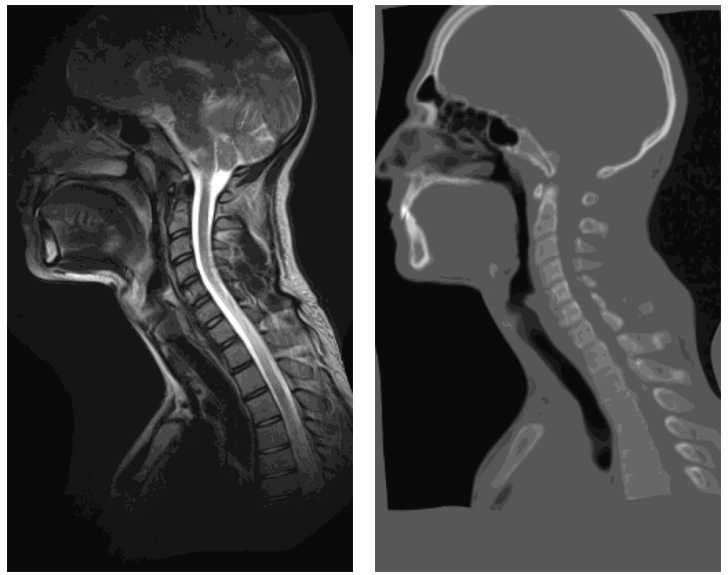
Anatomical differences supine to upright

- Change in gravity affects (nearly) all treatment sites
  - Sole exception: intracranial and even there, small differences appear e.g. at the optical nerves
- Requires suitable robust planning and adaptive/motion mitigation strategies



Courtesy Ye Zhang
CPT-DIR
(xialipku.github.io

Li et al. (2024) ArXiv

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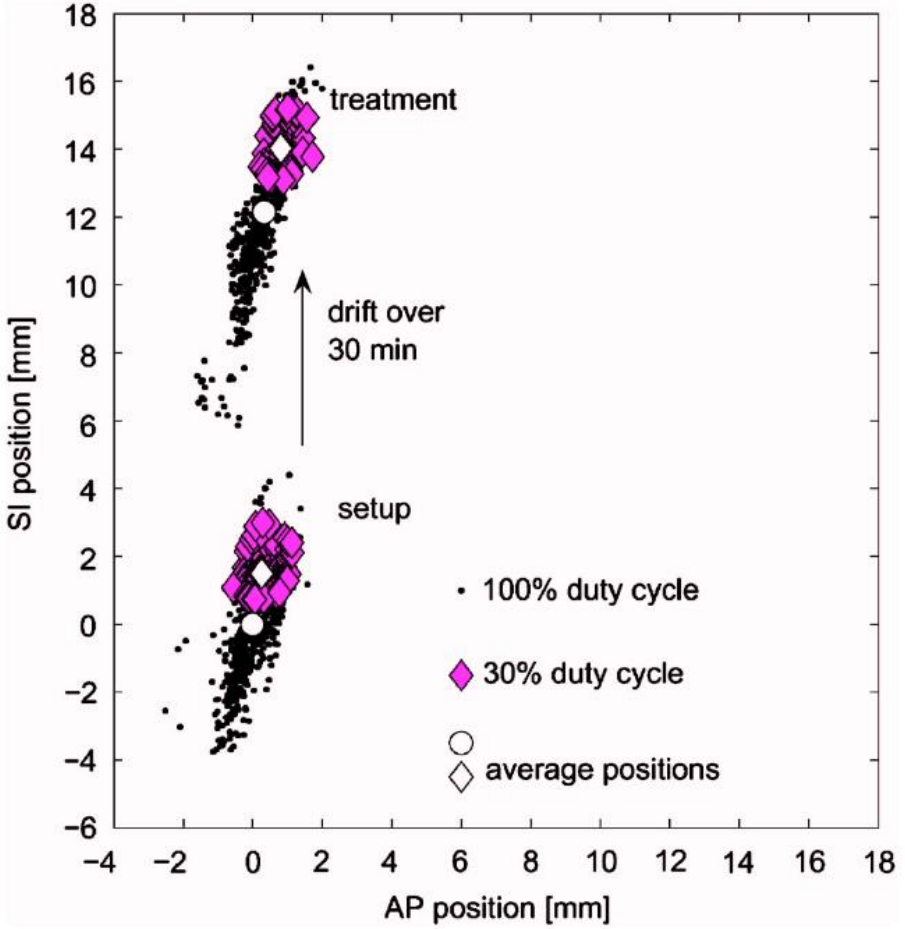
Challenge: anatomical differences between postures

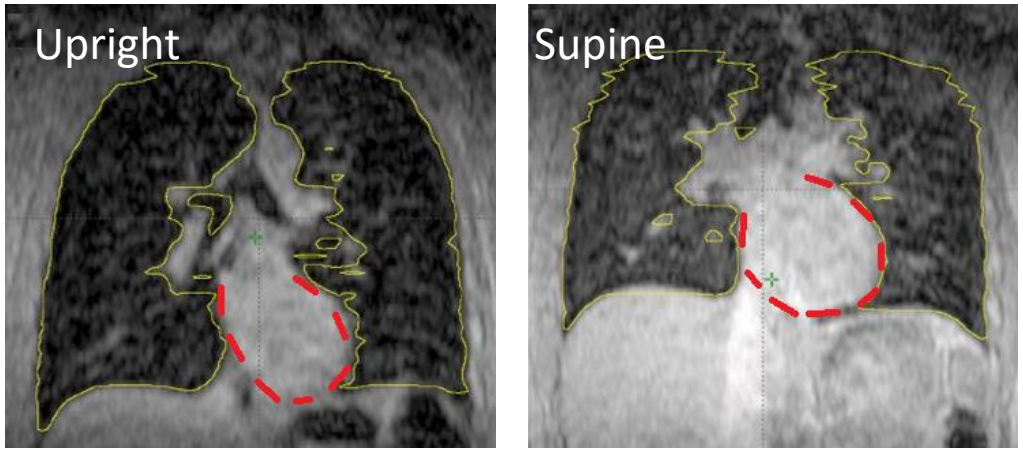
- Von Siebenthal (2007) open-bore MRI study:
  - Liver drift over 30 of minutes after lying down
  - Average position drift of 12mm observed
- Inferior shifts in kidney by up to several centimeters

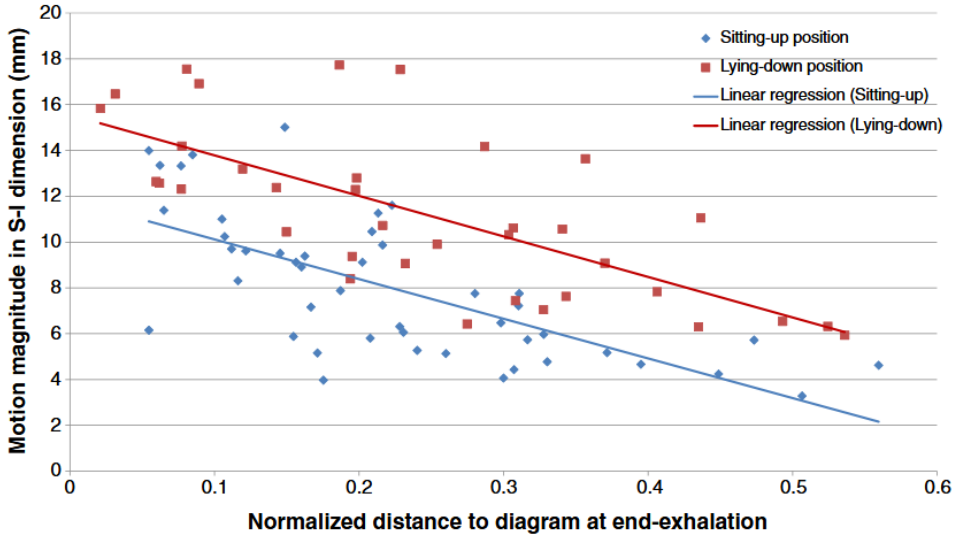
(Reiff et al. 1999, Hayes et al. 2013)

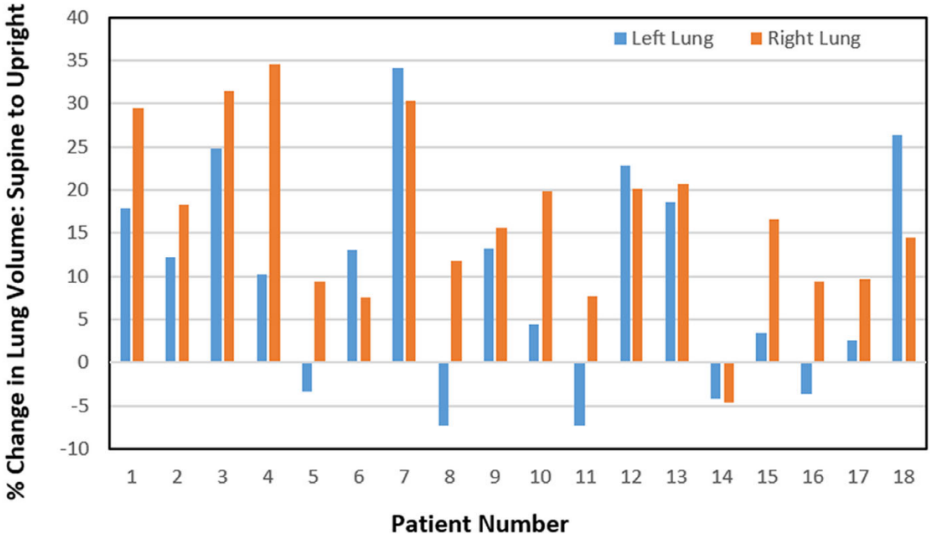


von Siebenthal et al. (2007) Med. Phys

Anatomical differences: Lung







Yang et al. (2014) Pract. Radiat. Oncol.:

- Increase in lung volume and reduced breathing motion

Marano et al. (2024) J. Appl. Clin. Med. Phys.:

- Observed no significant difference in diaphragm motion

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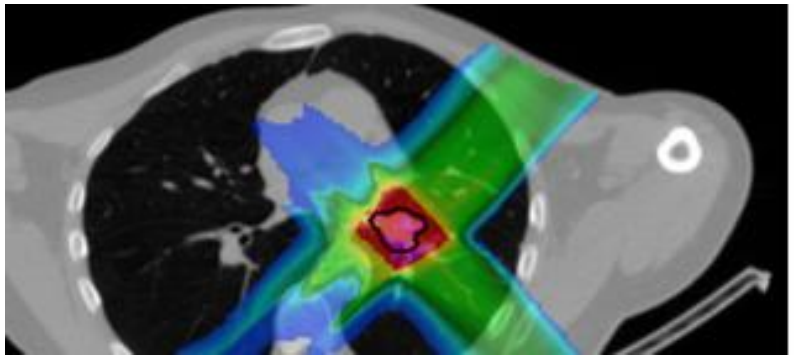
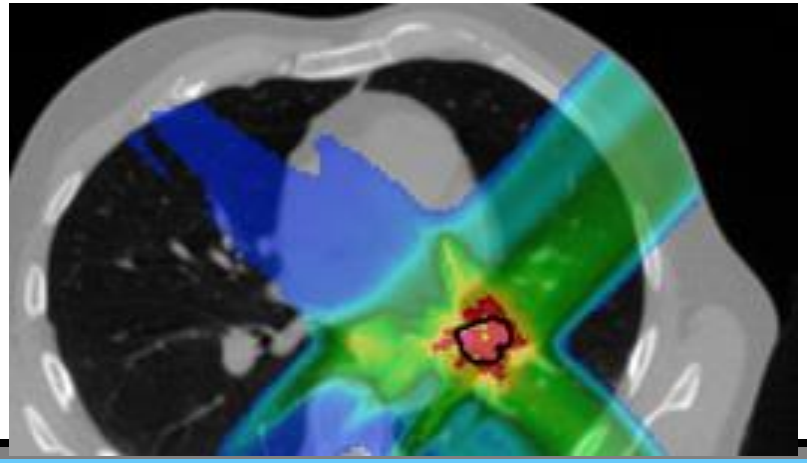
Upright versus Supine Carbon Ion Therapy

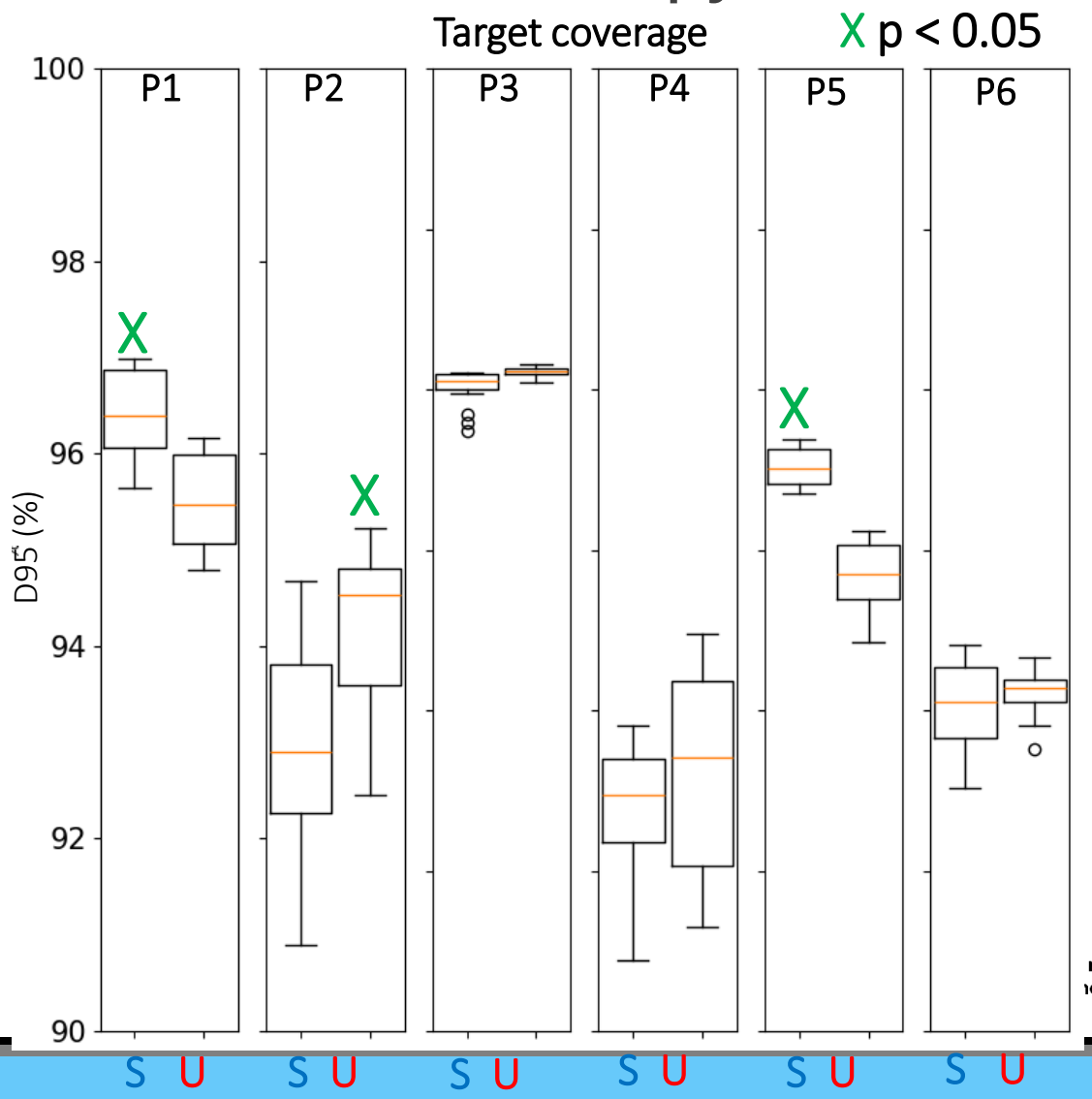
INTERPLAY EFFECT

Upright (Δmotion=3 mm)



Supine (Δmotion=6 mm)





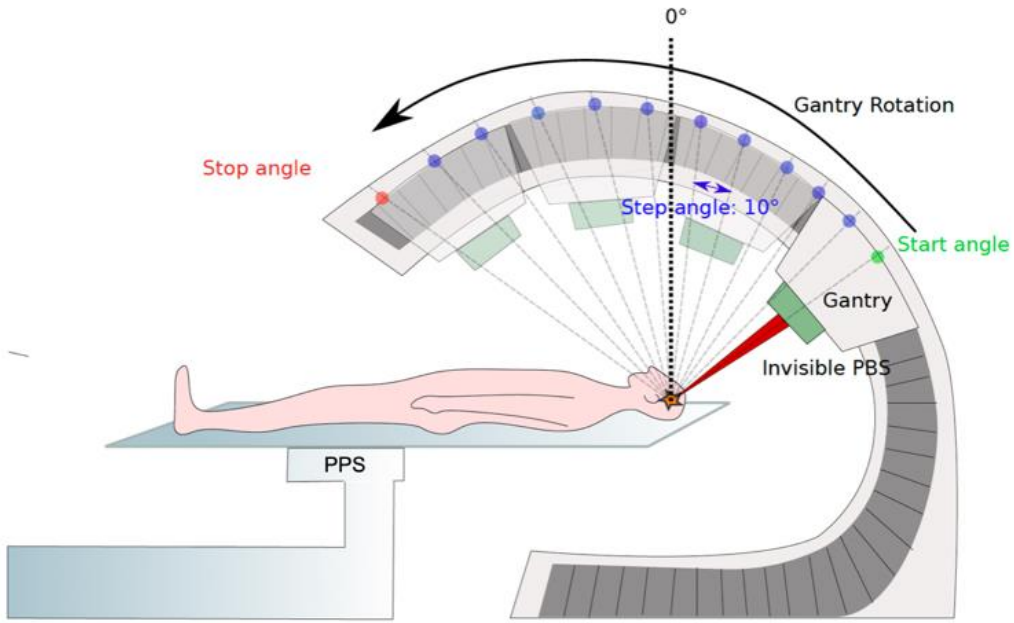
- Statistically significant difference for 3 patient
- Supine D_{95} > Upright D_{95} for 2 patients
- Maximum difference ~ 3%

received funding from the European Union's Horizon 2020
novation programme under grant agreement No 101008548

M.C. Martire et al., to be submitted

In cooperation with NWCPC

Particle arc therapy: exploiting the upright posture



S. Wuyckens (2024), PhD thesis

Sun et al. (2021) Front. Oncol.

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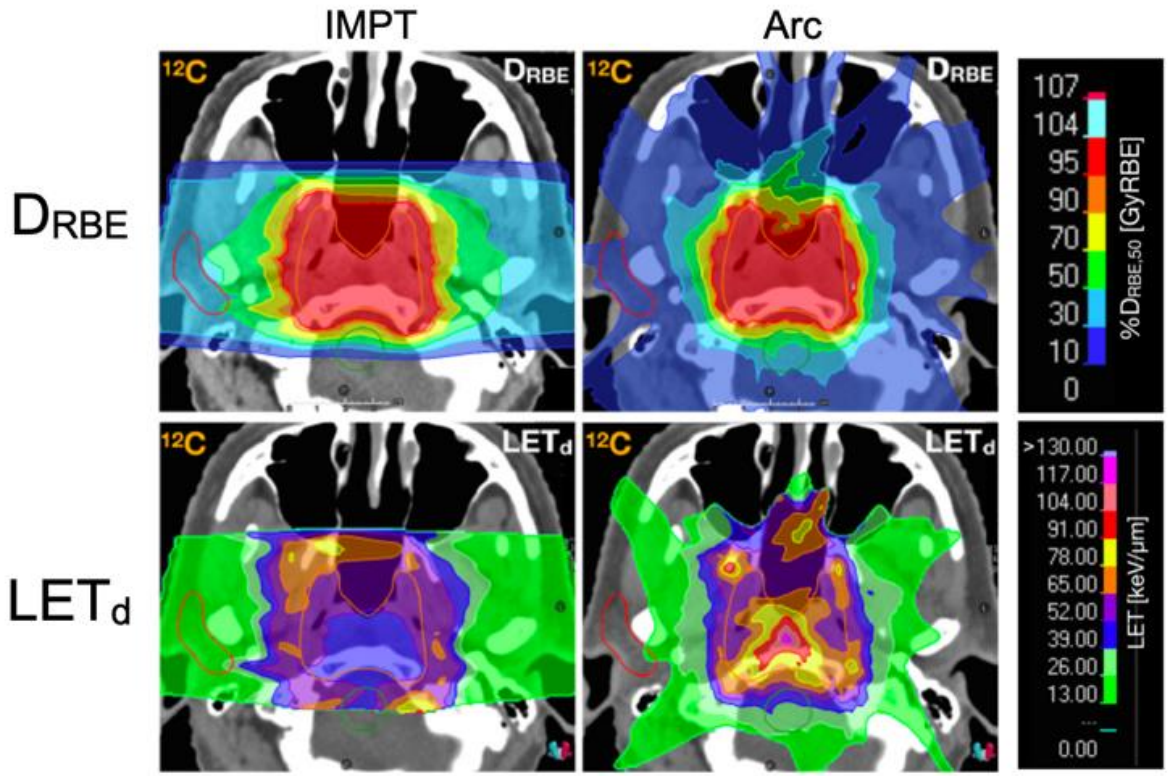
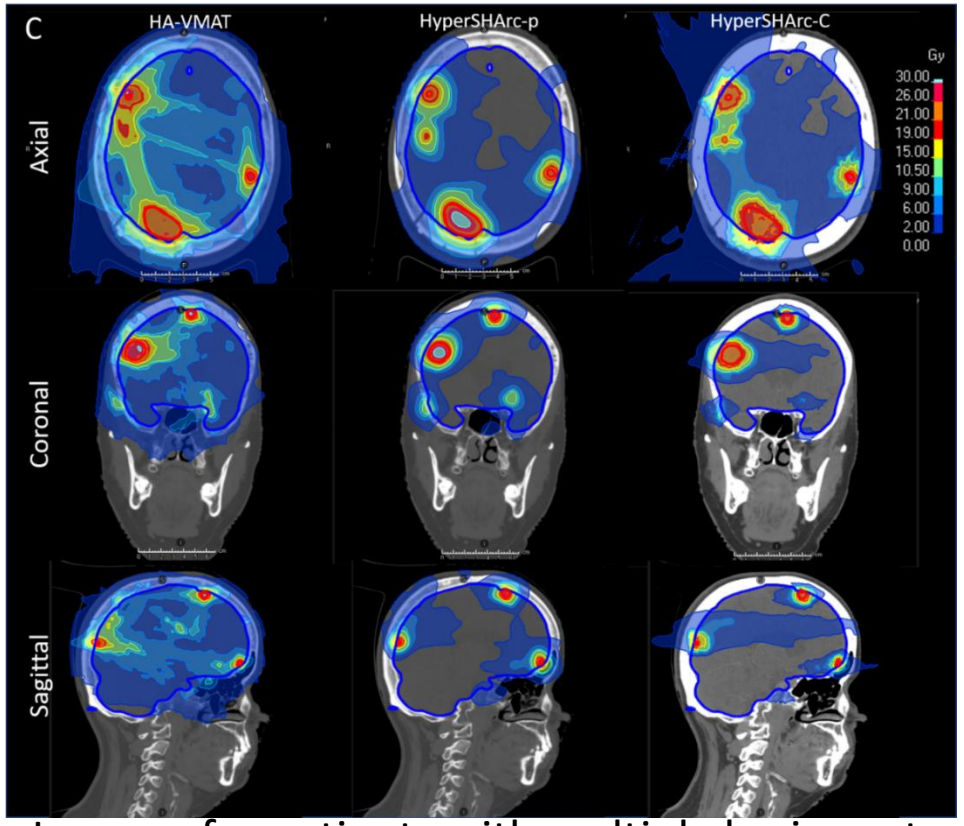
Particle arc therapy: LETd advantage and new treatment options



S. Mein et al. (2022) IJROBP



Ion arcs for patients with multiple brain metastases
L. Volz et al. (2025) Adv. Rad. Onc.

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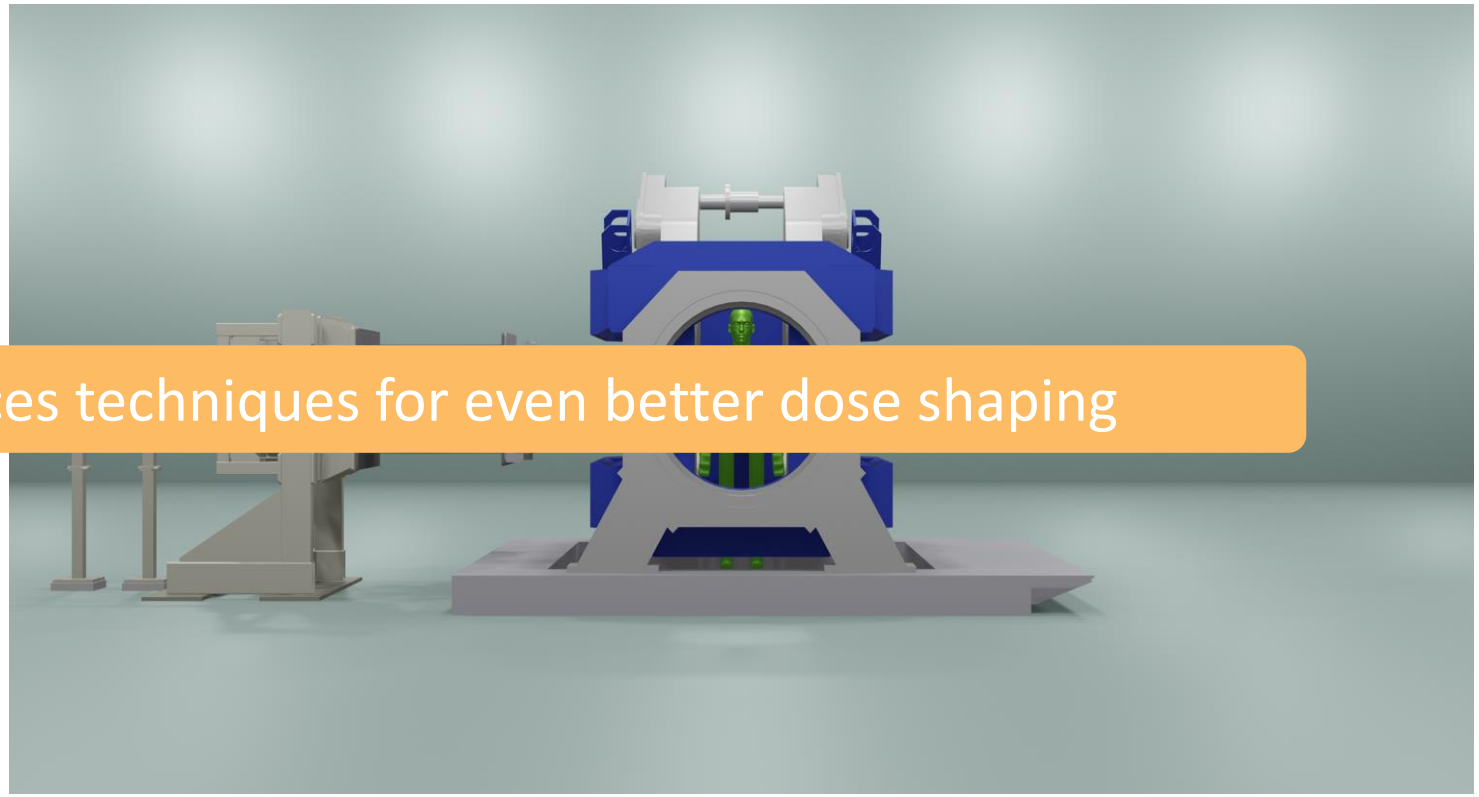
Advanced techniques

Combined photon-particle therapy: F. Amstutz et al.

Amstutz et al. (2024) Rad. Onc. Volume 190, 109973, January 202

In-beam MR-guidance: A. Hoffmann, OncoRay



Potential to enable advances techniques for even better dose shaping

Image courtesy: A. Hoffmann, OncoRay, Dresden, Germany

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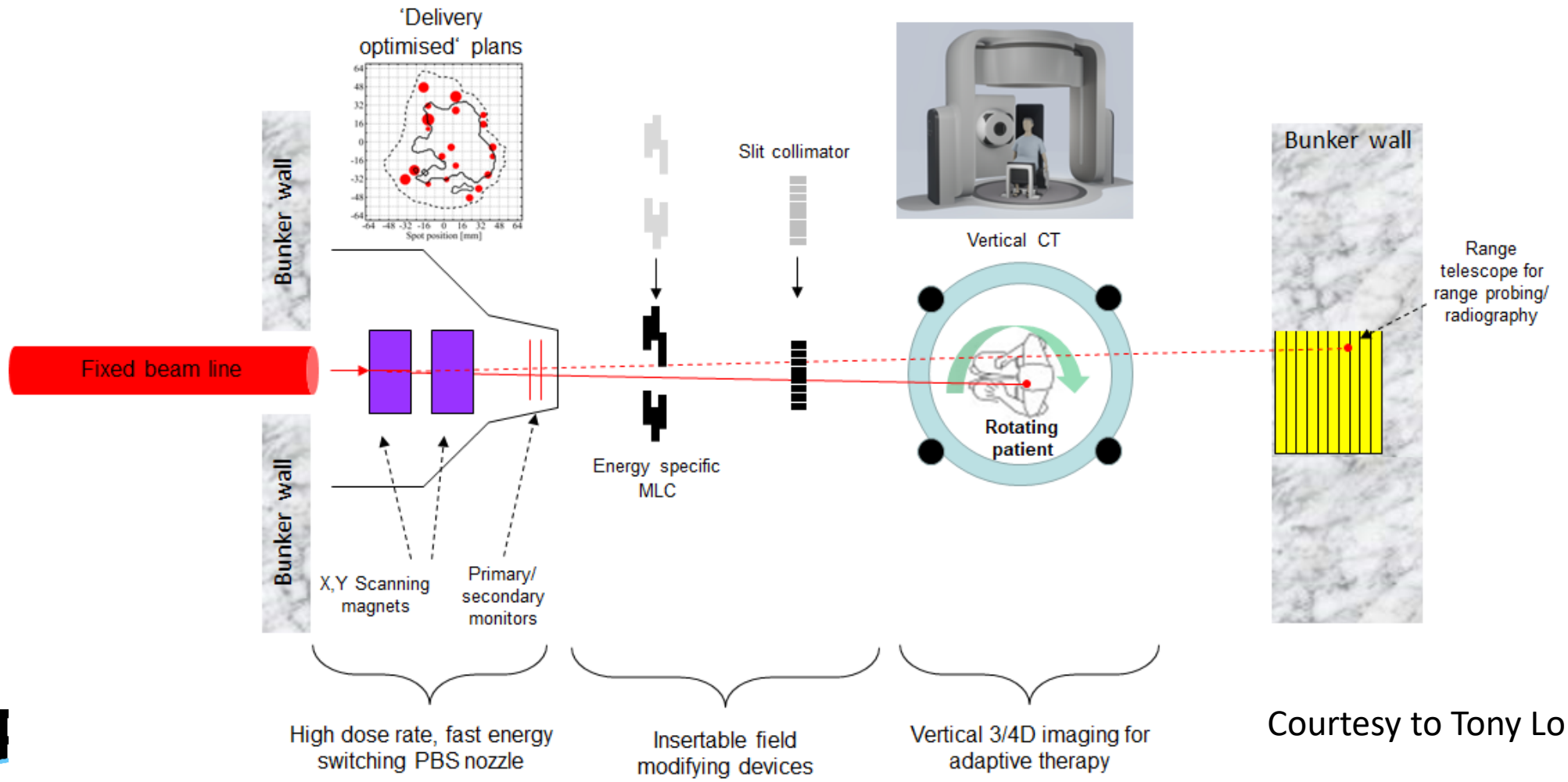
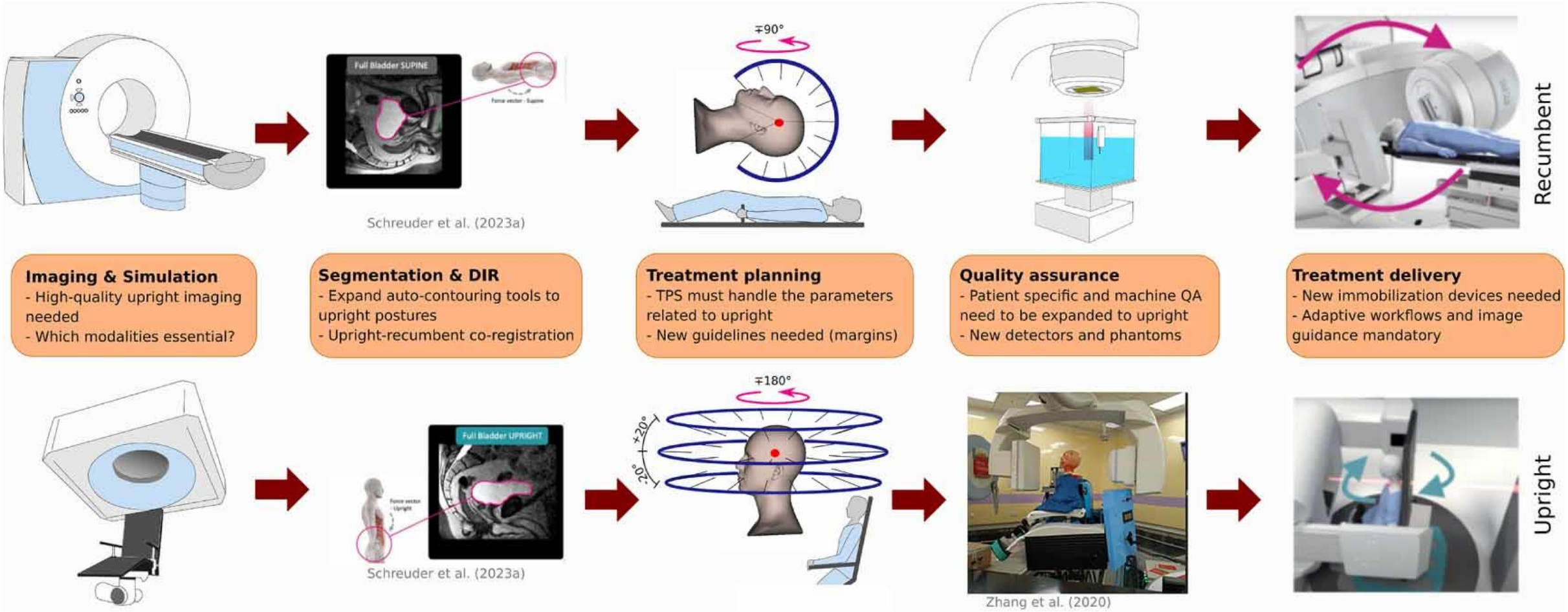
The “Swiss Army knife” of Particle Therapy – Tony Lomax



Courtesy to Tony Lomax (PSI)

n Union’s Horizon 2020
reement No 101008548

Gantry-less: a paradigm shift



Volz et al. (2024) PMB

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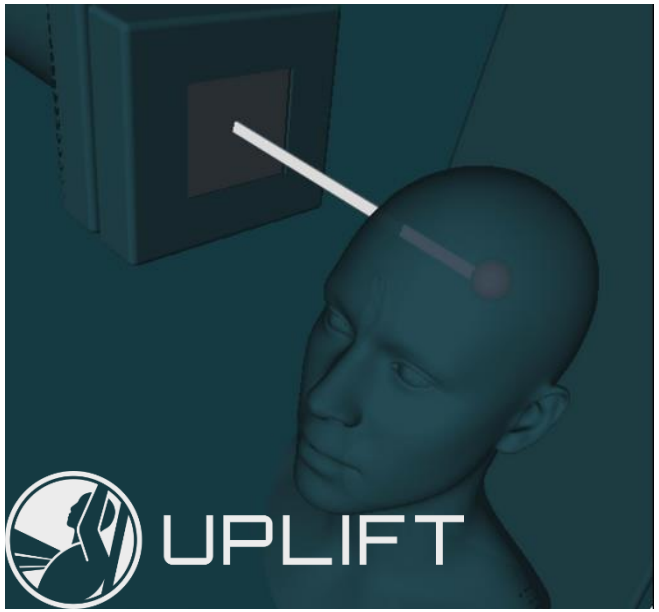
UPLIFT Doctoral network



Sheffield Hallam University – Knowledge Applied
Loughborough University
LEO Cancer Care
GSI
dkfz.
THERAPANACEA
Centre Léon Bérard
CNAO
RaySearch Laboratories
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19 PhD Projects at 15 Supervising Partners
~5M Euro funding
Headed by Christian Graeff at GSI

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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

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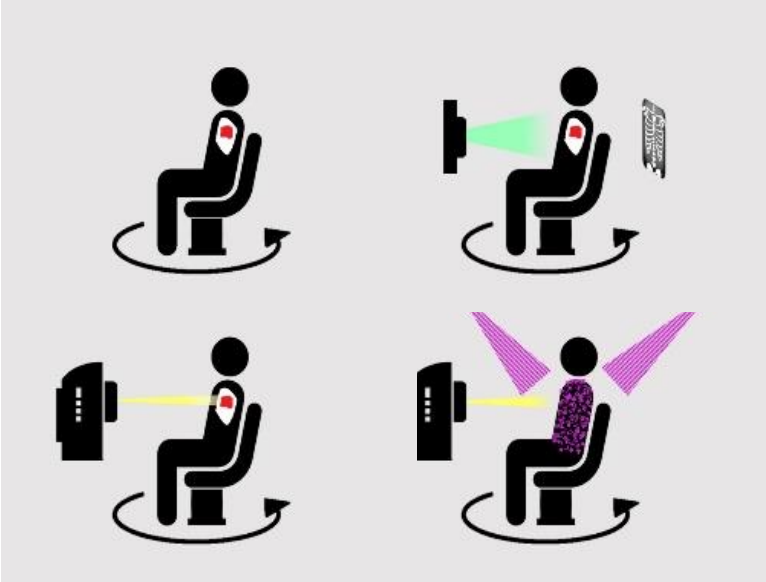
Literature on upright patient positioning

- Review of upright **photon** therapy [1]
- Review of upright **particle** therapy [2]
- Commentary on the challenges of upright therapy and some suggested solutions [3]
- In-depth review on past and present upright endeavours [4]



[1] Rahim, Sulman, et al. "Upright radiation therapy—A historical reflection and opportunities for future applications." Frontiers in Oncology 10 (2020): 213.
[2] Volz, Lennart, et al. "Considerations for upright particle therapy patient positioning and associated image guidance." Frontiers in Oncology 12 (2022): 930850.
[3] Hegarty, Sarah, et al. "Please Place Your Seat in the Full Upright Position: A Technical Framework for Landing Upright Radiation Therapy in the 21st Century." Frontiers in Oncology 12 (2022): 821887.
[4] Volz, Lennart et al. “Opportunities and challenges of upright patient positioning in radiotherapy” PMB 2024

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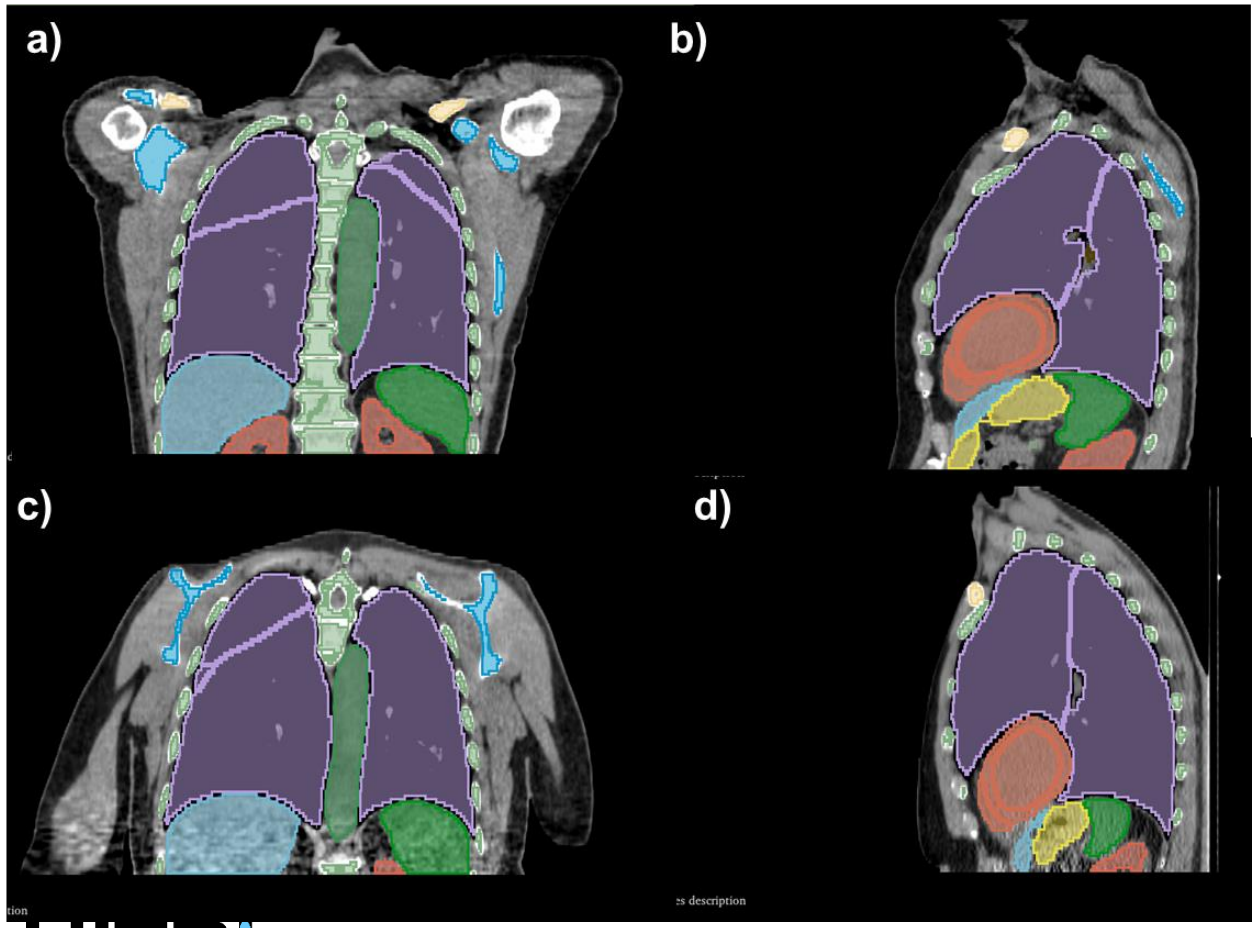
Auto-contouring tools

Supine

Upright



- Auto-contouring tools need to be expanded to upright position
- Promising results with supine trained AI segmentation tools (TotalSegmentator, Wassertal et al.)
  - Further potential with retraining on limited datasets
- Deformable image registration challenged by anatomy differences

M.C. Martire, L. Volz et al., to be submitted

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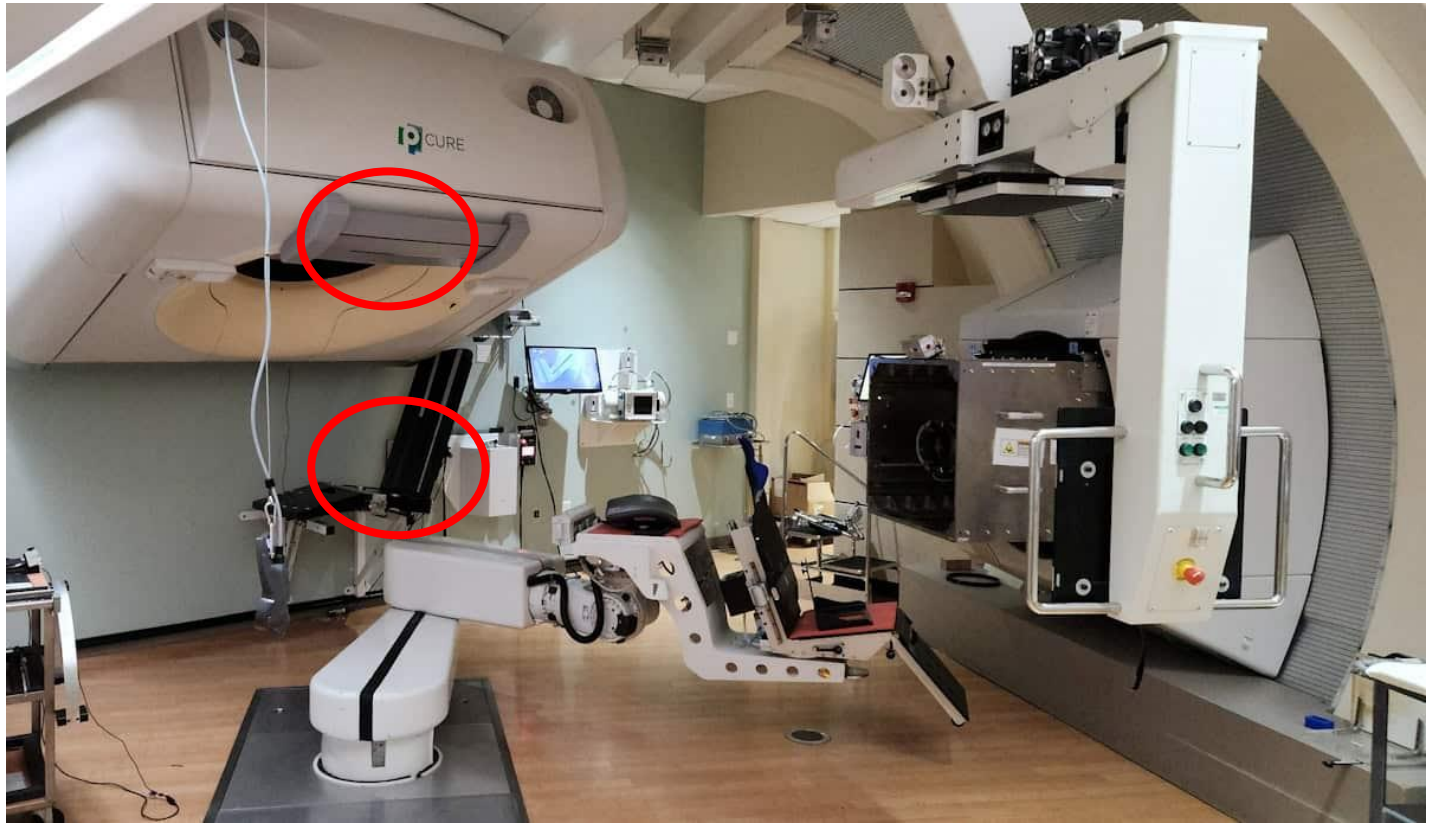
Technical challenge: one-fits-all solution?



https://physicsworld.com/a/hope-or-hype-can-upright-treatment-increase-access-to-advanced-radiotherapy/

At Chicago Proton Center:

- Treatment of head&neck (since 2012) and thoracic patients (since 2016)
- Two chairs, due to limited workspace and collision issues (robot arm with CT, nozzle)

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