Setup Accuracy of SGRT Systems in DIBH Treatment for Breast Cancer

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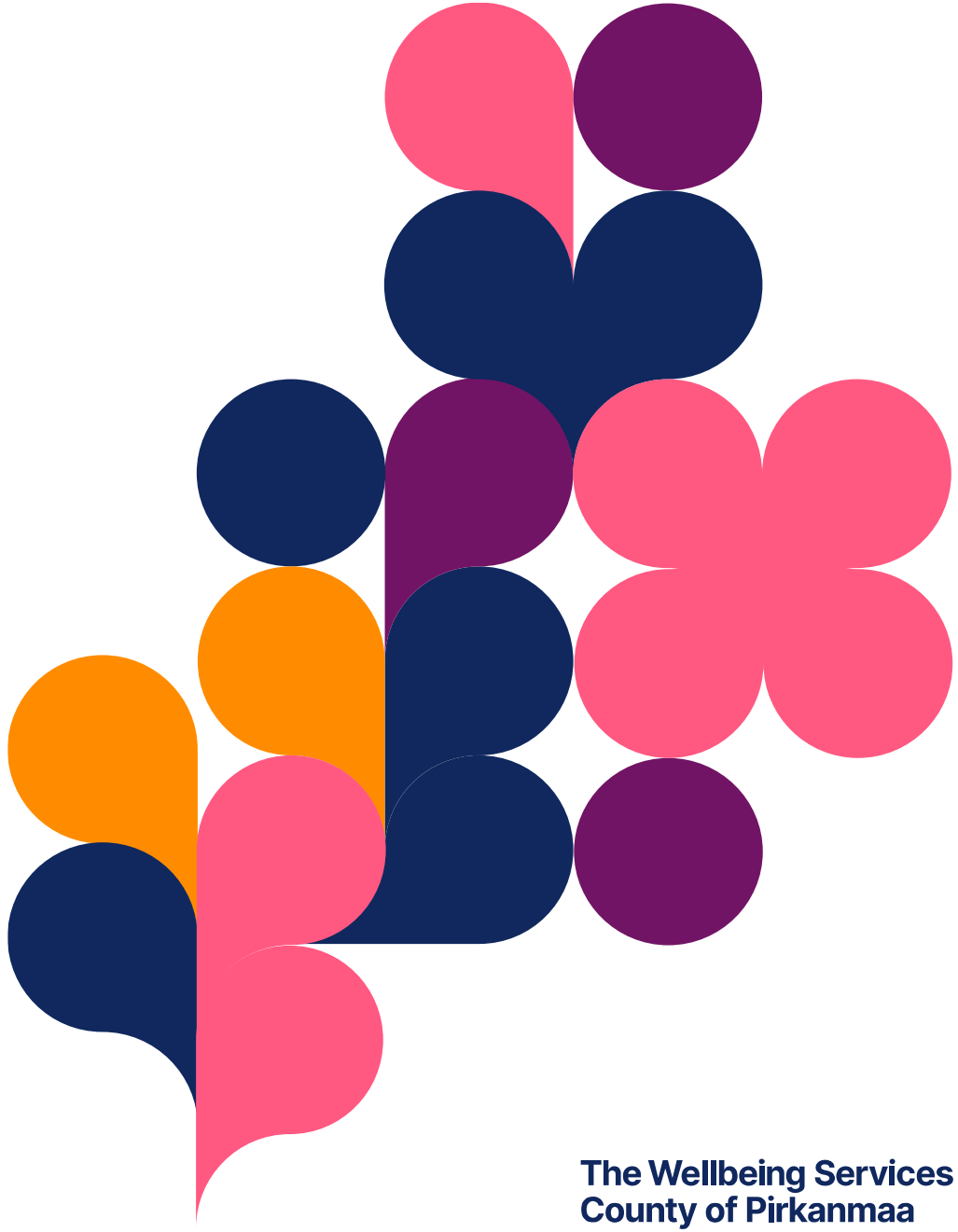

The Wellbeing Services
County of Pirkanmaa

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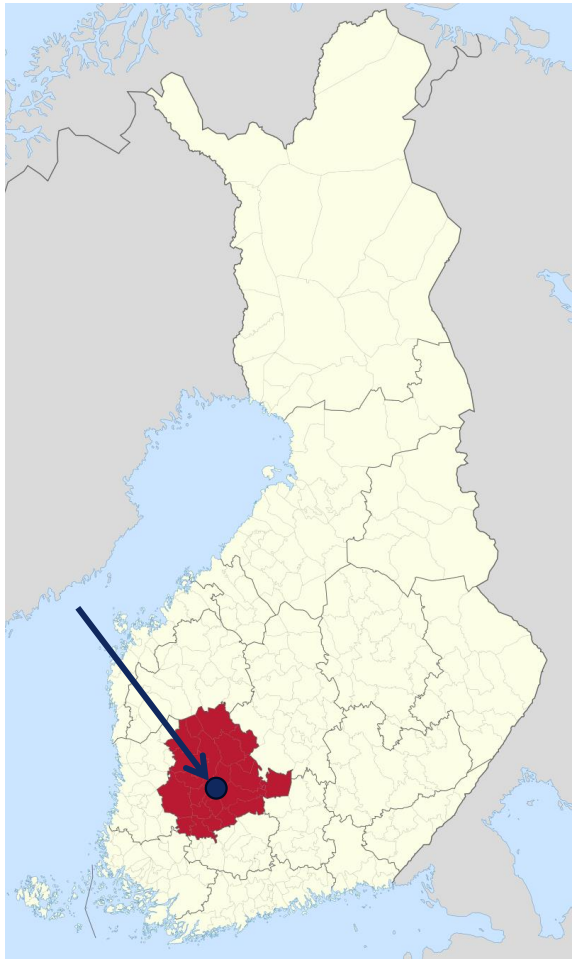
Comparison

3 hospitals
2 vendors

Tampere University Hospital radiotherapy unit

The largest wellbeing county in Finland

- 2nd largest radiotherapy unit in Finland
  - 7 vaults with 6 active TrueBeam linacs
  - 1 Bravos brachytherapy unit
  - 2 CT scanners
  - 1 MRI



Tampere University Hospital radiotherapy unit

- 9+2 oncologists
- 8+2 physicists
- 56 RTTs
- 2500 patients treated yearly

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Tampere University Hospital radiotherapy unit

SGRT users since 2017

- 1st AlignRT 1/2017
- 2nd C-RAD Catalyst 6/2018
- 3rd AlignRT Advance 2022
- 4th AlignRT Advance 2023
  - At the same time Catalyst was replaced with AlignRT
- 5th AlignRT Advance 2024
- 6th Brainlab Exactrac Dynamic 2026

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Why DIBH?

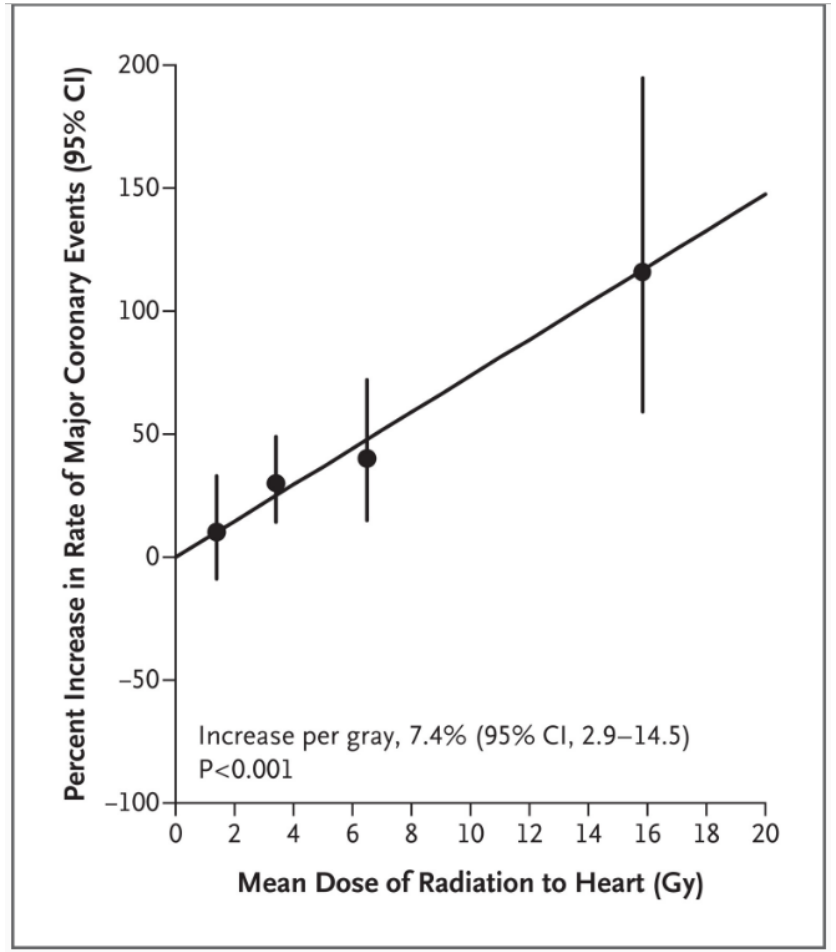
Cardiotoxicity

- There is no safe threshold!
- 3 mm too low BHL → mean heart dose increased 0.5 Gy (24%)

Skyttä *et al.* Acta Oncol. 2016 Aug;55(8):970-5

- BACCARAT study proposes calculation of LAD dose instead of mean heart dose

Jacob *et al.* Radiat Oncol. 2019 Feb 7;14(1):29



Rutter *et al. Int J Radiat Oncol Biol Phys.* 2014 Oct 1;90(2):329-34

Why DIBH?

Lung dose (the evidence is not as clear)

- Slightly lower risk of secondary lung cancer and pneumonitis

  Korreman et al. Int J Radiat Oncol Biol Phys. 2006 Aug 1;65(5):1375-80

  Essers et al. Acta Oncol. 2016;55(4):460-5

- However, no safe threshold here either!

  Marks *et al.* Int J Radiat Oncol Biol Phys. 2010 Mar 1;76(3 Suppl):S70–S76

What actually happens during DIBH?

- Diaphragm contracts and moves downwards

  → increased space in chest cavity

  → decreased pressure in lungs

  → air flows in and expands lungs

- Muscles between the ribs contract

  → ribcage is pulled upward and outward

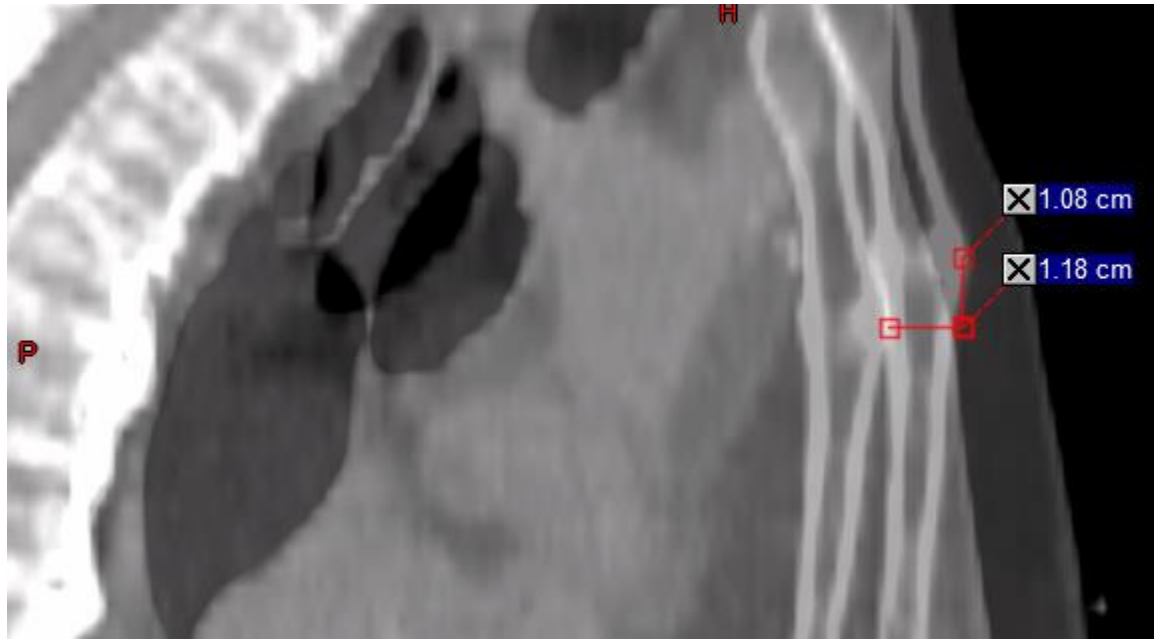
  → thorax diameter increases

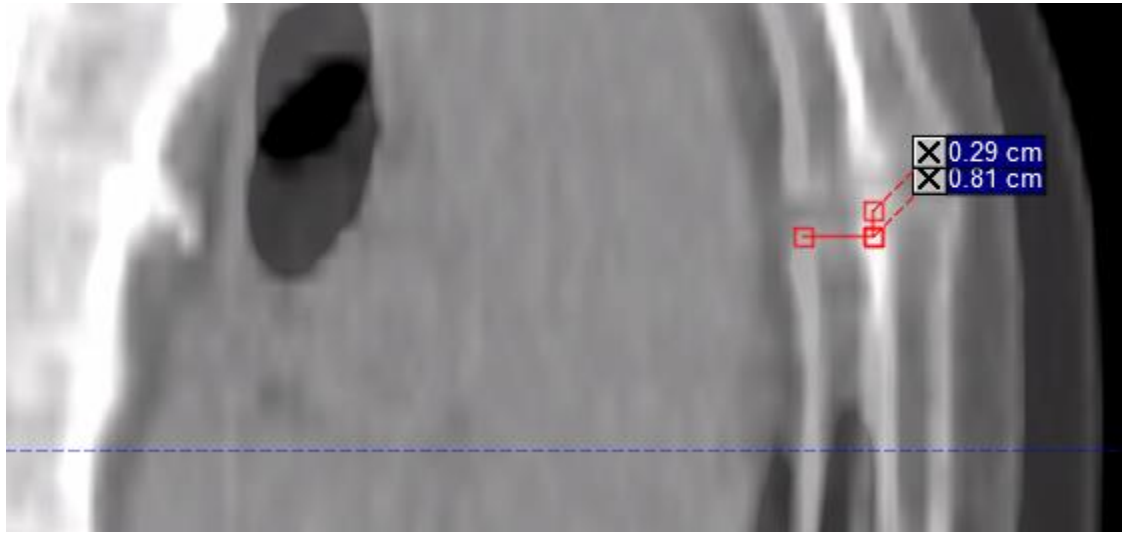
  → decreased pressure in lungs

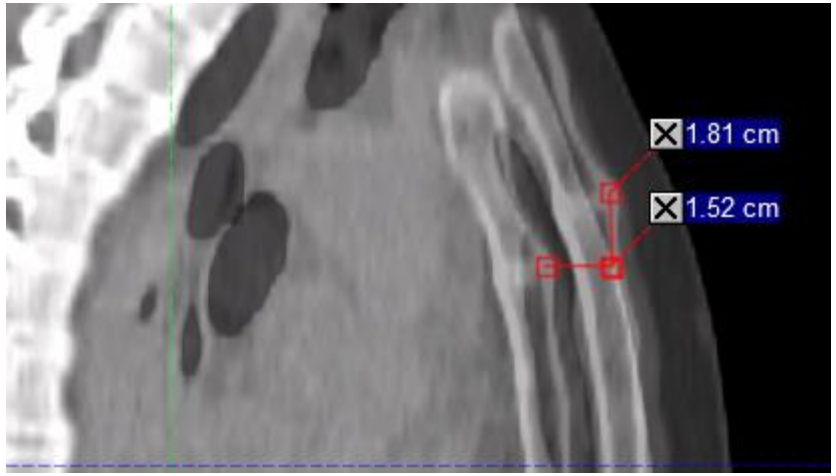
  → air flows in and expands lungs

https://hal.bim.msu.edu/CMEonLine/RibCage/Biomechanics/start.html

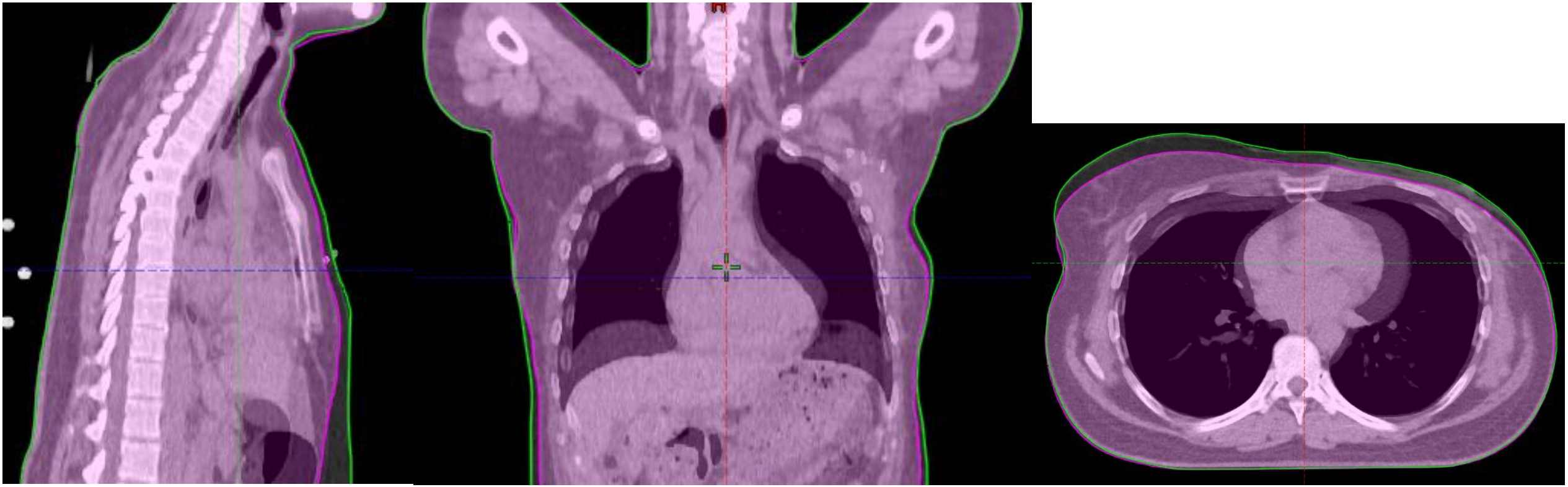
Individual anatomical and physiological variation







Belly breathers



Technological accuracy

- SGRT providers promise sub-millimeter accuracy

Proven submillimetric thermal-surface and x-ray tracking enable planning target volume

Streamlined QA process

- Fast and automated daily QA checks verifying submillimeter accuracy

An entirely non-invasive and contact-free technology, AlignRT uses 3D stereo cameras to track the skin's surface and compare it to the ideal position in the treatment plan with submillimetric accuracy for all patient skin tones, couch, and gantry angles.[8-11]

Selected specifications

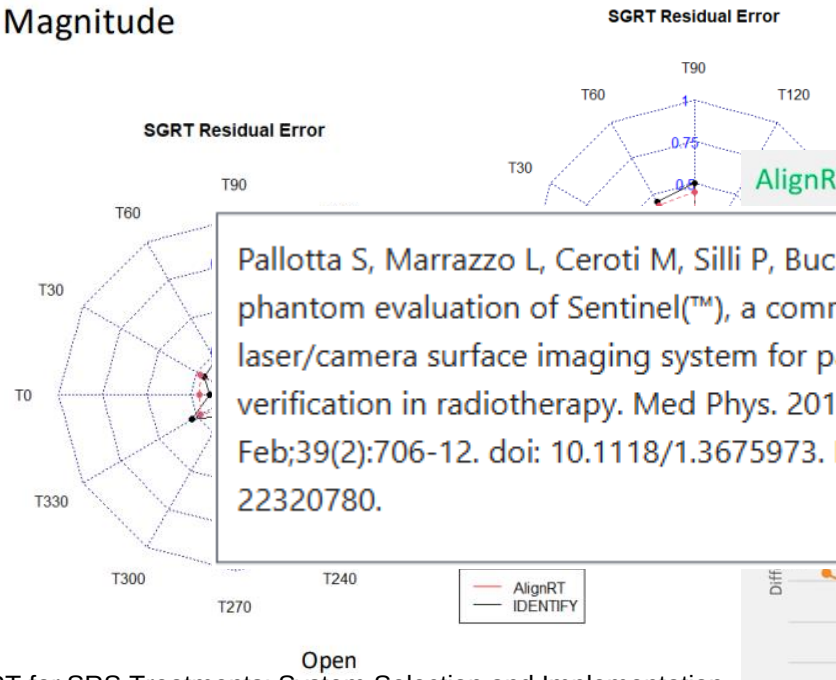
Performance

- ✔ Positioning accuracy: Within 1 mm for rigid body
- ✔ Long term stability: 0.3 mm
- ✔ Registration method: Real-time, non-rigid with deformable models for computing 6 DOF isocentric shifts

Technological accuracy

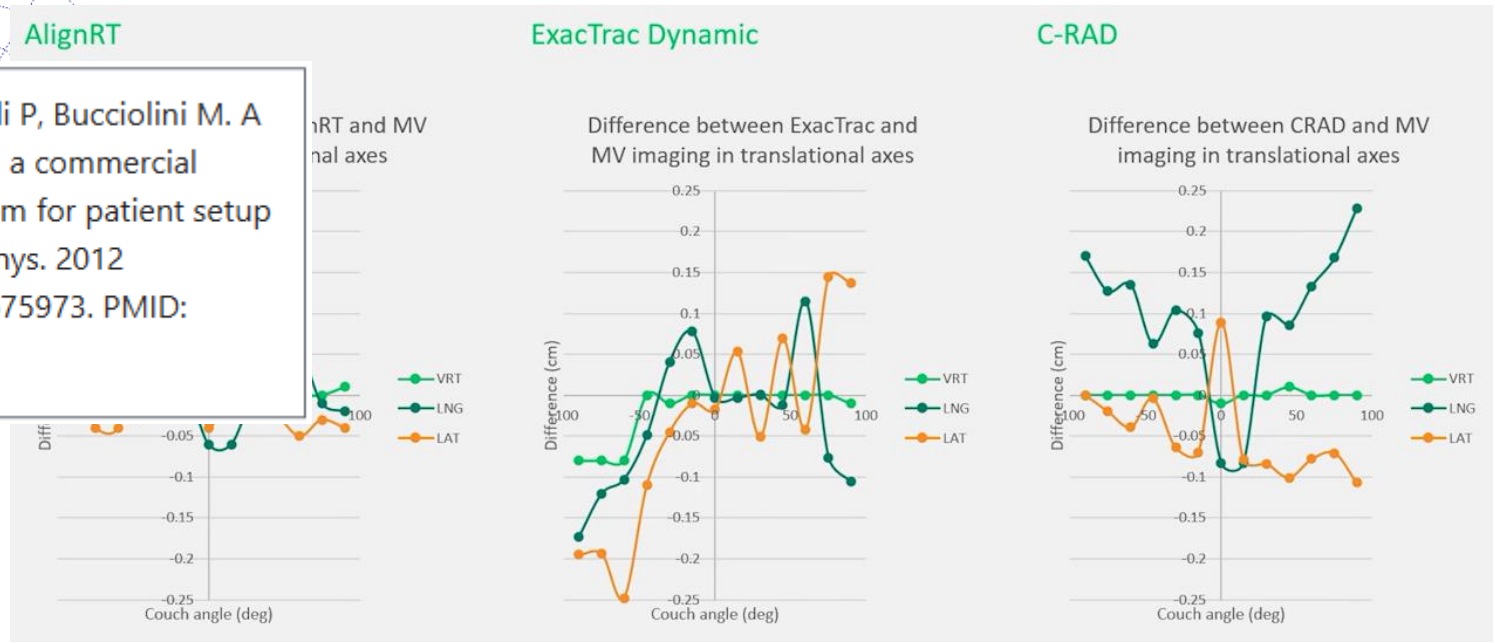
- SGRT systems have sub-millimeter accuracy in phantom studies
  - if there are no couch kicks

Residual Error Magnitude



Pallotta S, Marrazzo L, Ceroti M, Silli P, Bucciolini M. A phantom evaluation of Sentinel(™), a commercial laser/camera surface imaging system for patient setup verification in radiotherapy. Med Phys. 2012 Feb;39(2):706-12. doi: 10.1118/1.3675973. PMID: 22320780.

Vaibhav Mhatre Quality assurance for clinical implementation of an Optical Surface monitoring system." IOSR Journal of Applied Physics (IOSR-JAP) , vol. 9, no. 6, 2017, pp. 15-22.



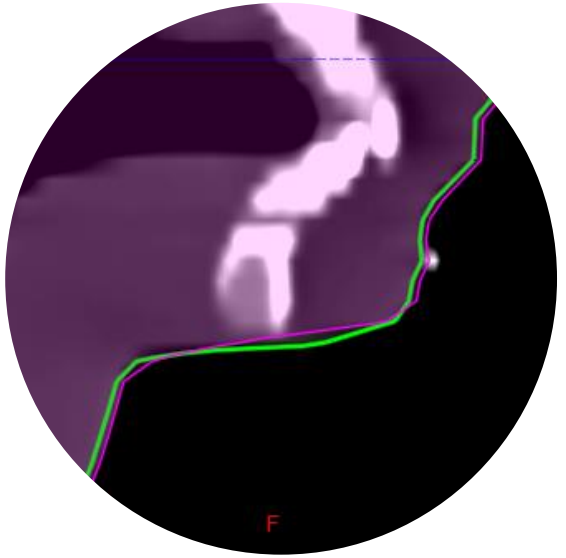
Adi Robinson: SGRT for SRS Treatments: System Selection and Implementation

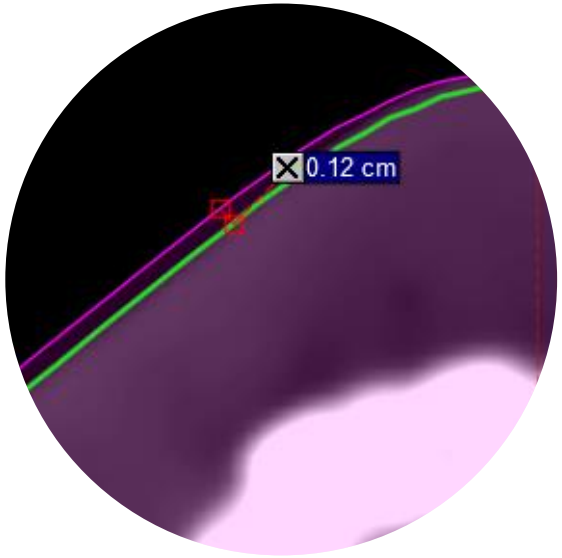
Mark Wanklyn: Comparison of SGRT to MV Isocentre Position for Different SGRT Systems for Use with SRS

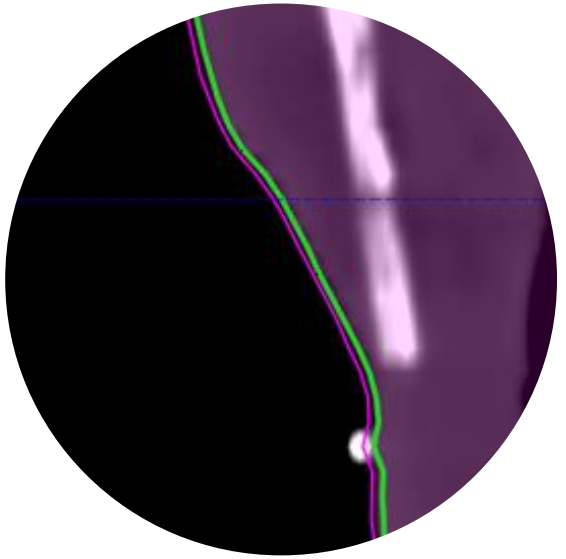
Technological accuracy

Accuracy of the CT body contour

- CT image pixel size ~1 mm
  - Slice thickness?
  - Spatial resolution ≈ 2 × pixel size
- Surface generation:
  350 HU → 250 HU in a phantom
  - Which one is the correct reference surface?
  - Motion induced blur?



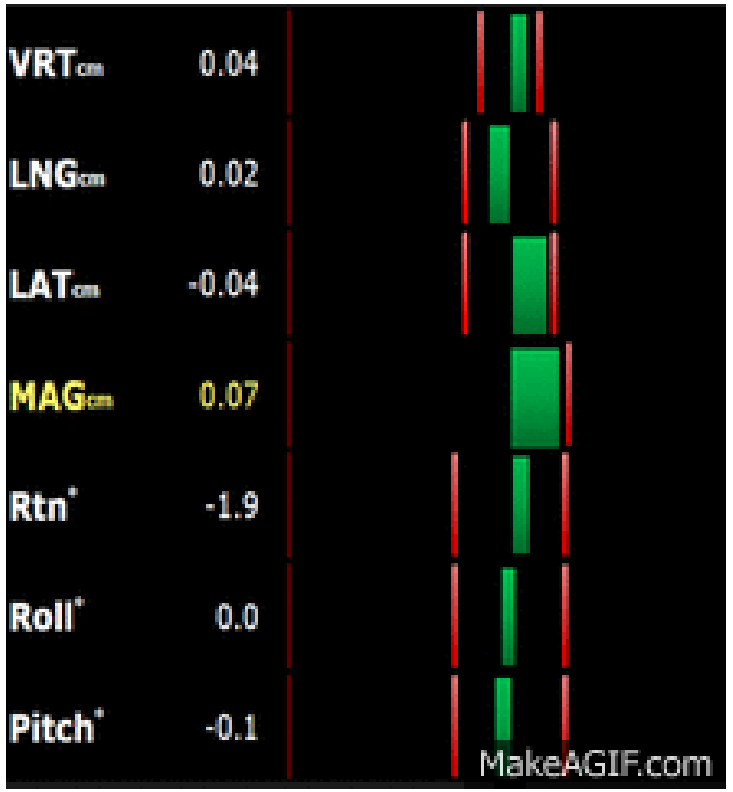




Technological accuracy

New reference surface after kV image & couch shift?

- Good idea!
- Wait, did the patient move during the couch shift?
- Pay attention to them deltas!



Reproducibility of DIBH

- Reproducibility of what?

reproducibility between breath-holds was defined as the consistency between the breathing amplitudes. For this purpose the breathing amplitudes of all breath-holds of a patient were

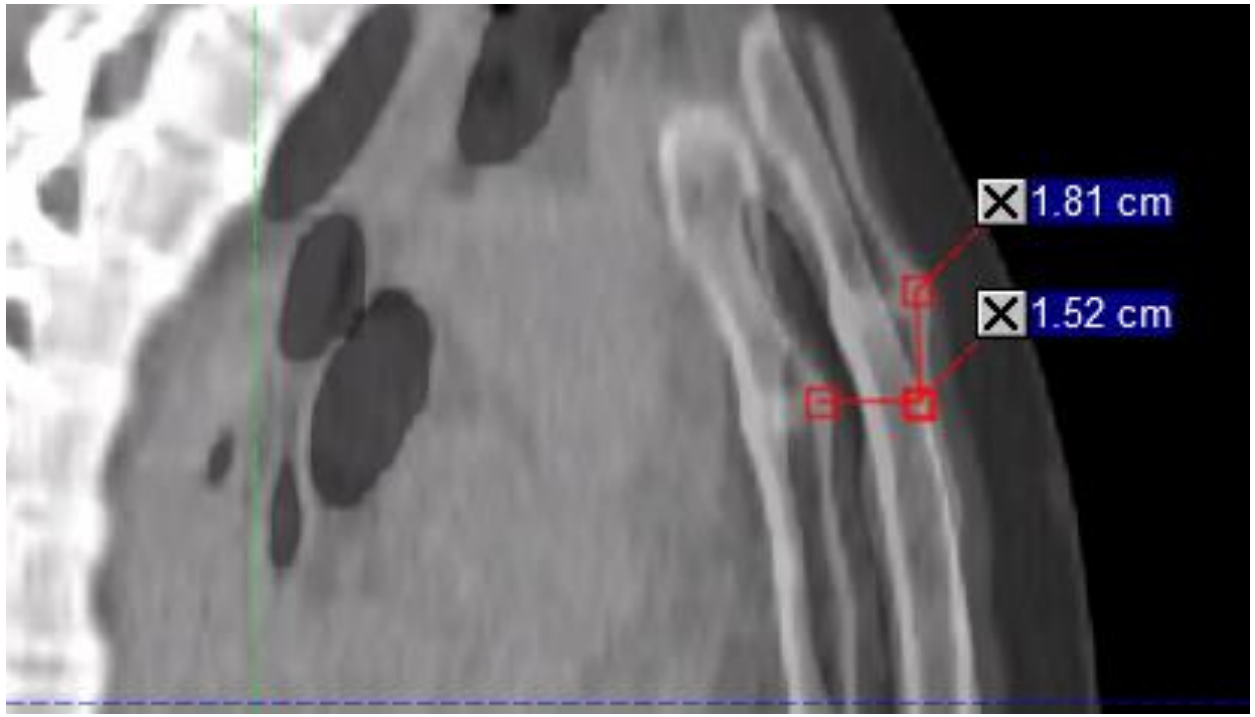
Interfraction BH variations may be relatively large [24], and are not always correlated to variations in the external surrogate breathing signal. Hence, regular target and organs at risk (OAR) position verification with x-ray based images is recommended [25].

ESTRO-ACROP guideline, Aznar *et al.* Radiother Oncol. 2023 Aug:185:109734

Reproducibility of DIBH (according to me)

The aim is to reach similar posture as in the planning CT

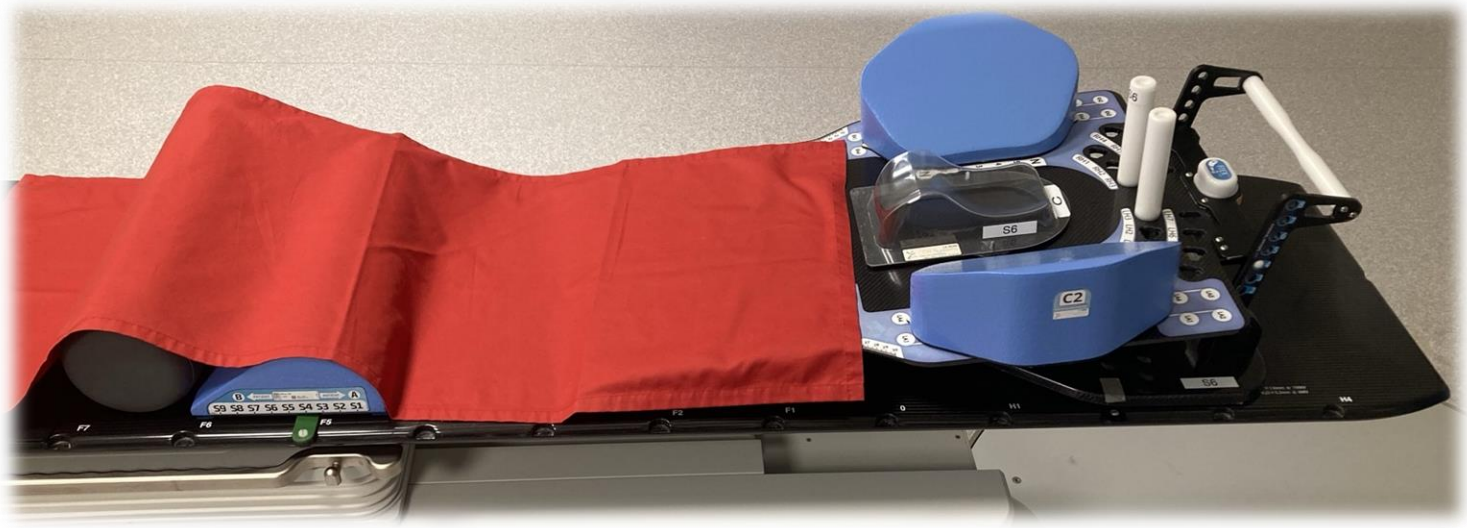
1. The spine is the baseline – match that first
   - VRT offset in spine → wrong BHL
   - LNG offset in spine → difficult to reach the planned surface (and sternum)



Reproducibility of DIBH (according to me)

All fixation devices in TAYS are indexed so *in theory* the patient should always be very close to the planned position

- We calculate the couch values in advance based on the index bars
  - If the FB deltas are not close to zero, the patient is in the wrong place on the breast board
  - Should we move the patient or the couch?



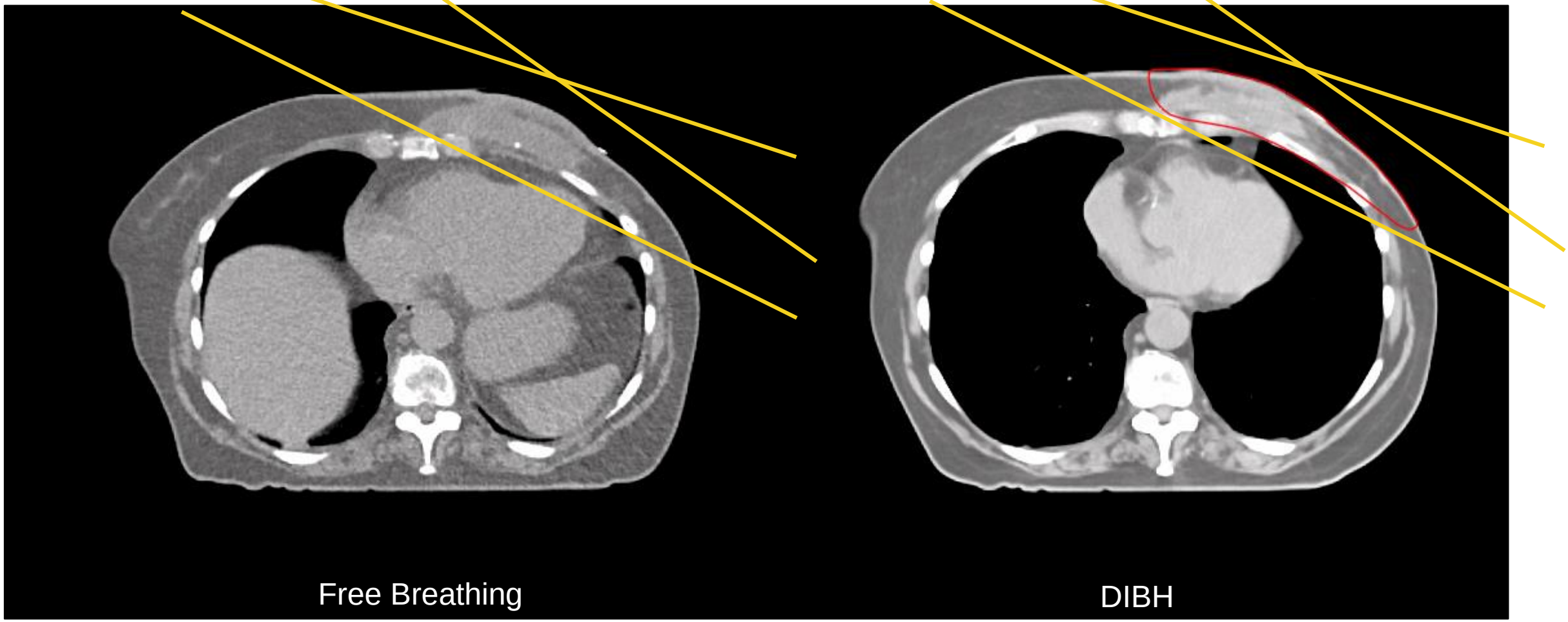
Reproducibility of DIBH (according to me)

During the first 2-3 fractions we begin by taking an extra LAT kV-image just to match the spine and lock the couch VRT

- After this we only move couch VRT based on kV images
- If couch VRT changes, always verify BHL and posture with kV-kV

Possible pitfalls

”Poor DIBH is better than no DIBH”



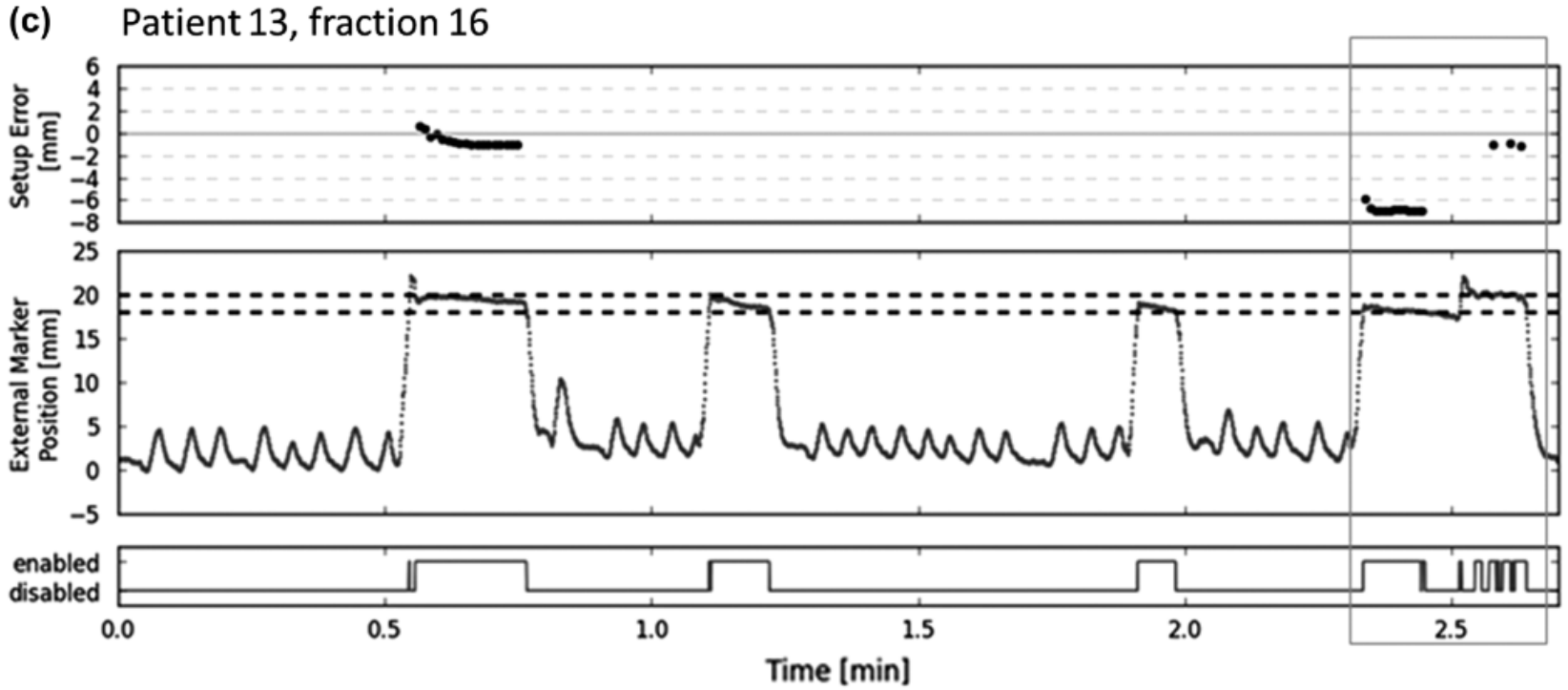
Possible pitfalls

Poor DIBH *seemed* better than no DIBH, error sources:

- Breathing pattern (chest vs abdominal)
  - Lung filling in AP and CC directions
- Patient exhaustion
- Internal organ movement
- Arching of the back
- Relaxation / gravity

Possible pitfalls

- If you only rely on VRT signal (here RPM)



Lutz *et al.* Acta Oncologica, 2016; 55: 193–200

Comparison between three hospitals

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

Comparison between three hospitals

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

Aim of the study

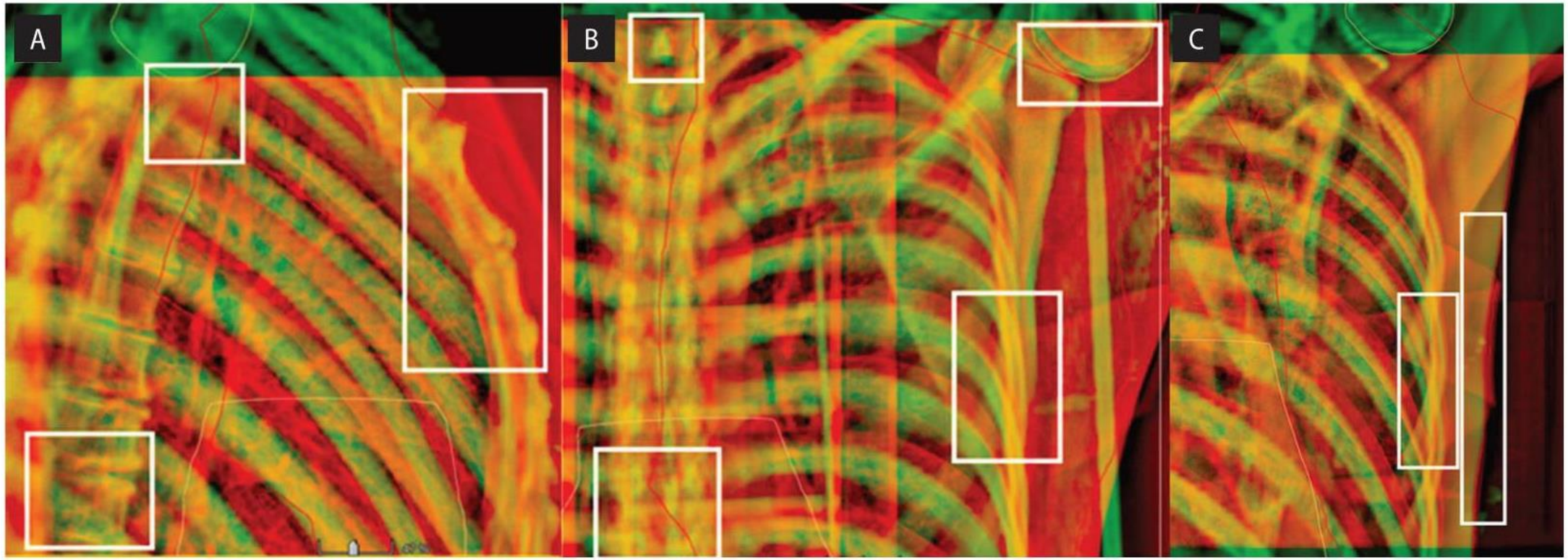
- Evaluate the setup accuracy between 3 hospitals
  - Local SGRT and IGRT workflows
  - 25 mastectomy patients / hospital
  - 25 whole breast + lymph nodes / hospital

There was not much difference between the groups so the groups were combined

Comparison between three hospitals

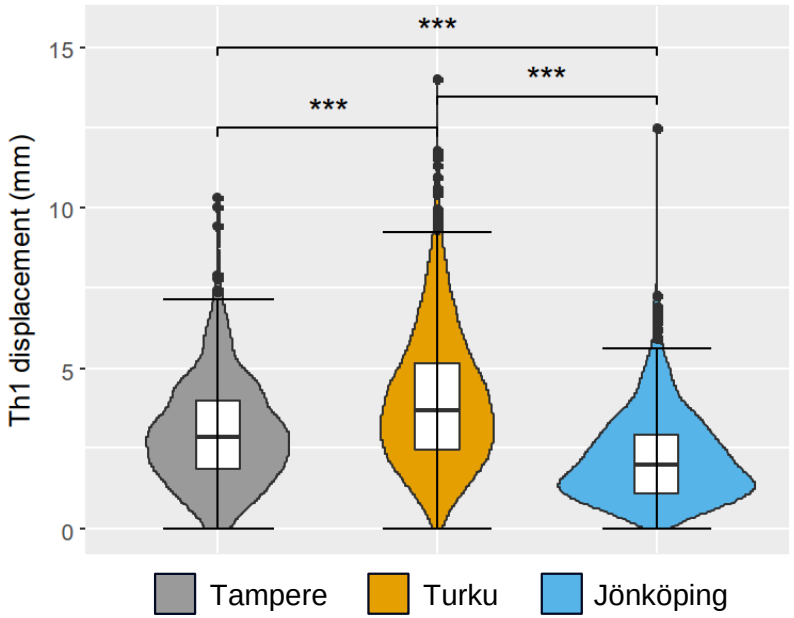
Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

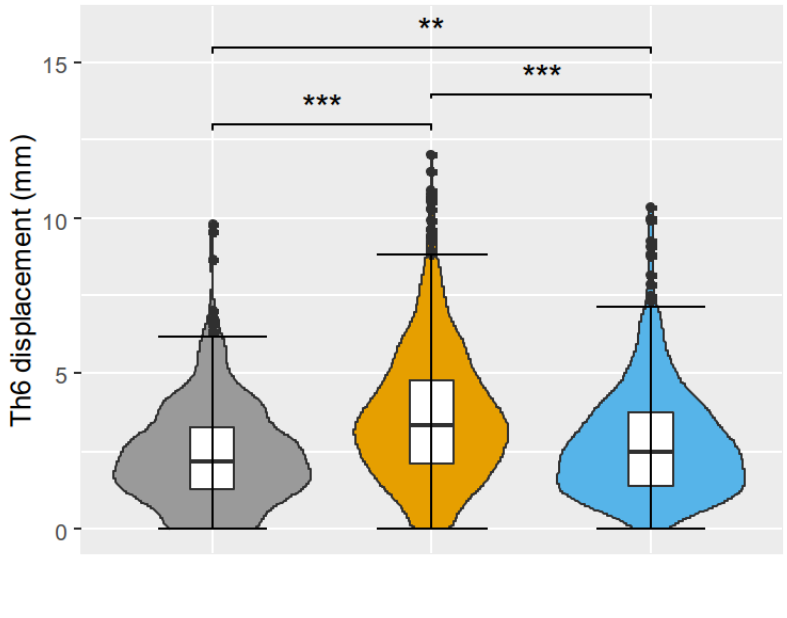
Residual setup errors were measured using orthogonal and tangential kV images

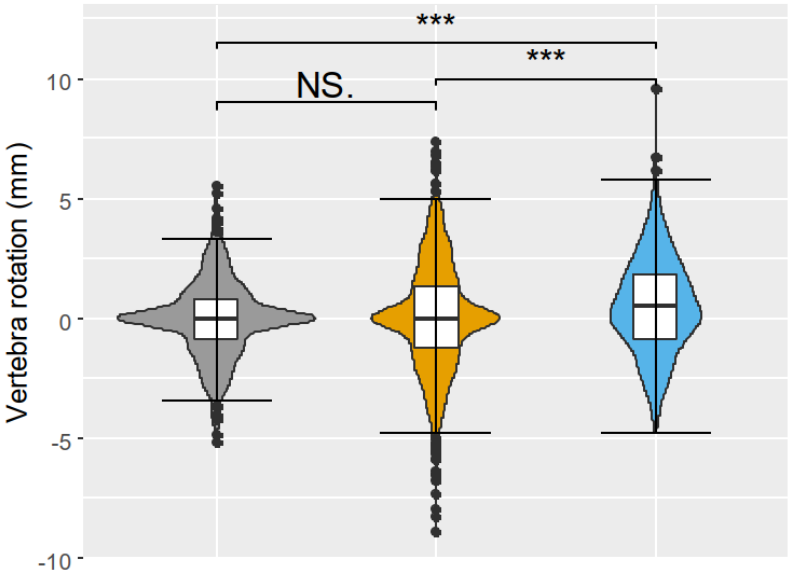


Comparison between three hospitals - spine

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186





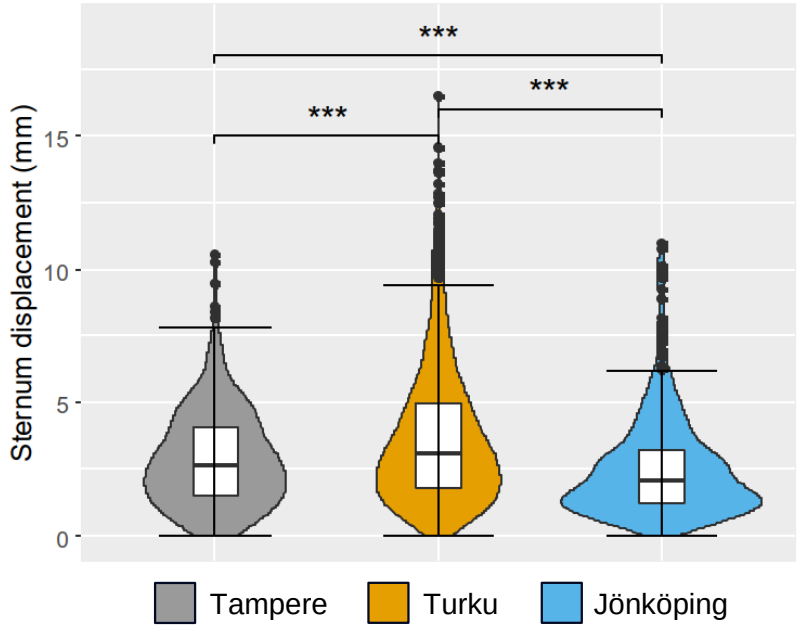


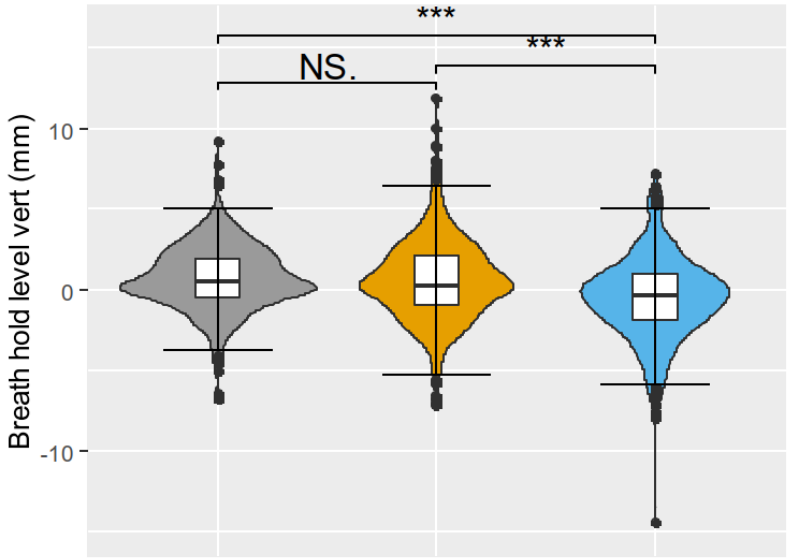
The differences in the workflows can be seen in the distributions of residual errors

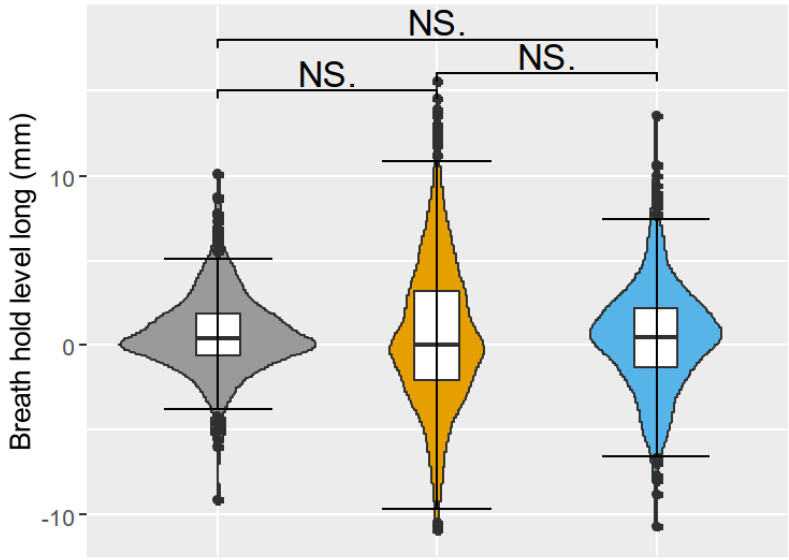
- 6D couch allows correction of pitch
- Spine match

Comparison between three hospitals - BHL

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186





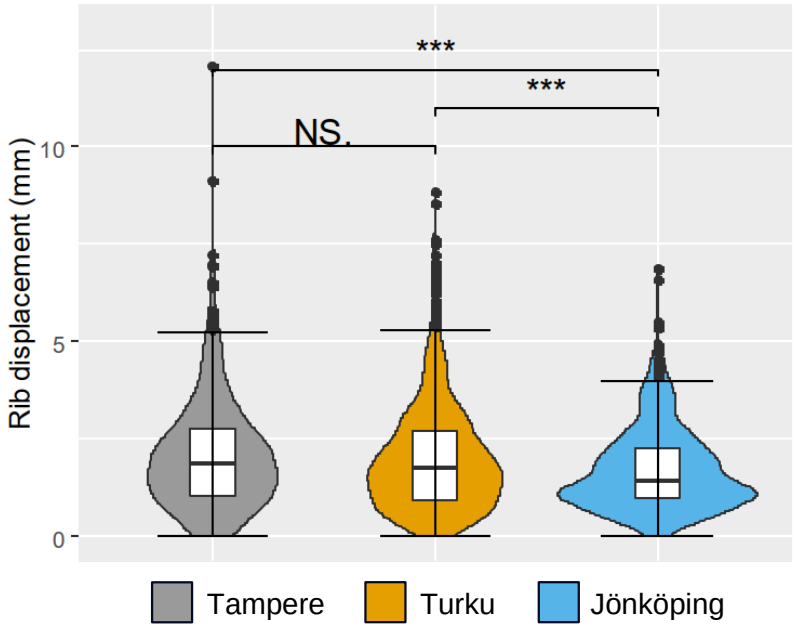


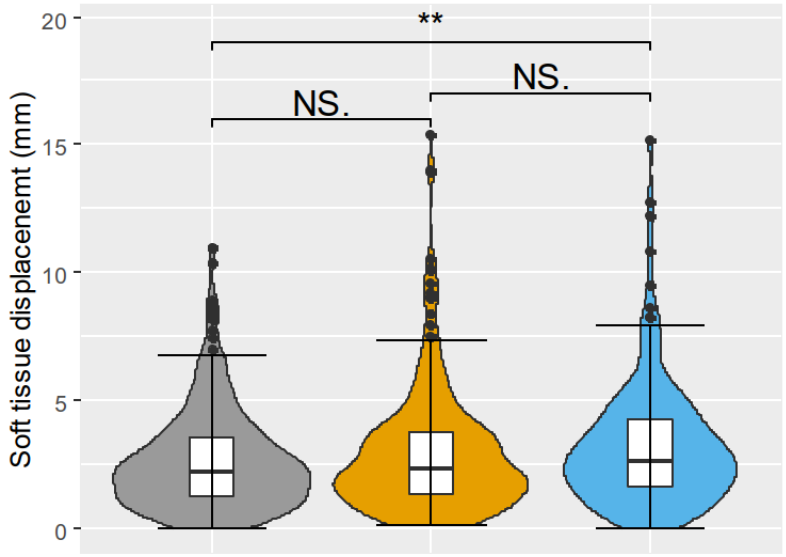
Special attention to BHL can be seen especially as smaller random error

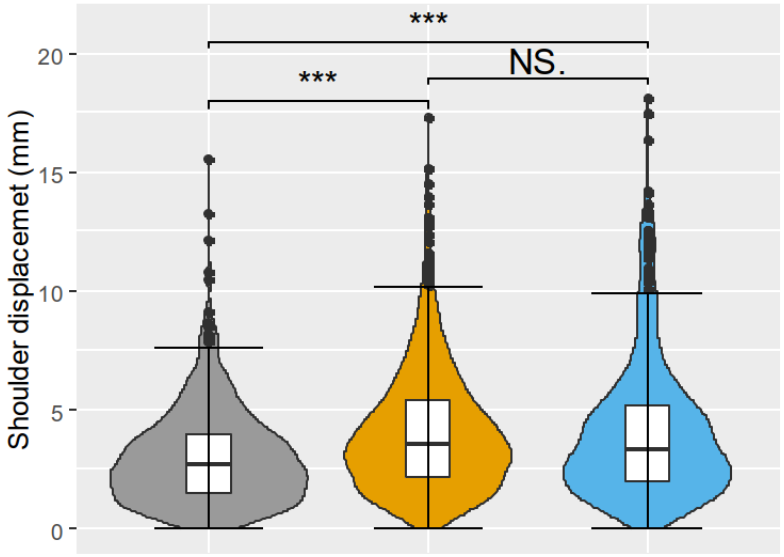
- Even more so in longitudinal direction

Comparison between three hospitals

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186







The differences in the workflows can be seen in the distributions of residual errors

- Arm position has an effect on breast position

Comparison between three hospitals - conclusions

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

All three sites improved their workflows based on the results:

- If systematic BHL errors are observed during first fractions, they are corrected
- New BH reference surface should be verified with kV imaging

Comparison between three hospitals - conclusions

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

All three sites improved their workflows based on the results:

- Tampere now has 6D couch on all breast linacs, 80% DIBH to get more reproducible sternum position
- Turku changed their workflow and tolerances closer to other 2 sites, 10º breastboard tilt
- Jönköping pays more attention to DIBH CC direction and arm position

Comparison between three hospitals - conclusions

Laaksomaa *et al.* Rep Pract Oncol Radiother. 2024 Jun 6;29(2):176-186

1. Setup errors were reflecting the workflows and tolerances

2. Workflow, fixation and tolerances have larger effect than SGRT system

3. Retrospective setup image analysis is beneficial

Thank you for your attention!