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Motion management in radiation oncology

Expert: **Dr Jenny Bertholet,** Inselspital, Bern, Switzerland

Discussant: **Prof Pierfrancesco Franco,** University of Eastern Piedmont, Novara, Italy

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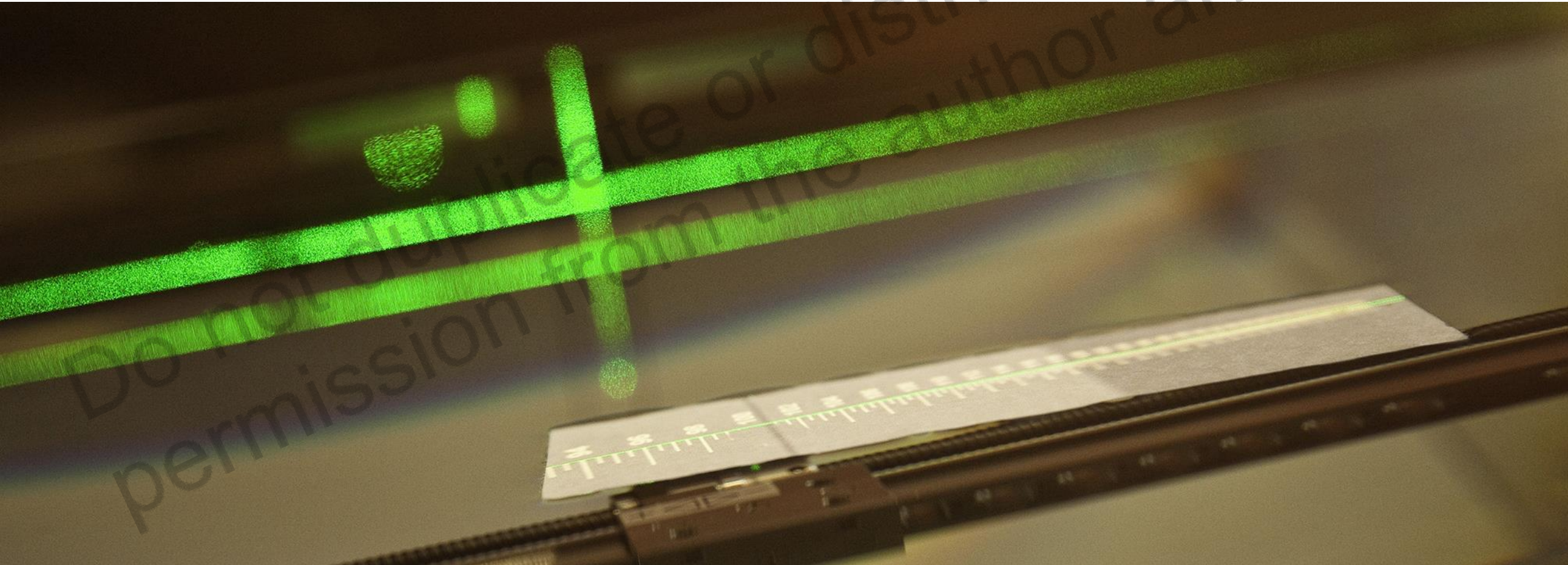
UNIVERSITÄT BERN

Division of Medical Radiation Physics

European School of Oncology

Motion management in radiation oncology

Jenny Bertholet, PhD



Today

- Motion in radiation oncology
- Motion mitigation strategies overview
- Motion monitoring and mitigation
- Current status in clinical practice

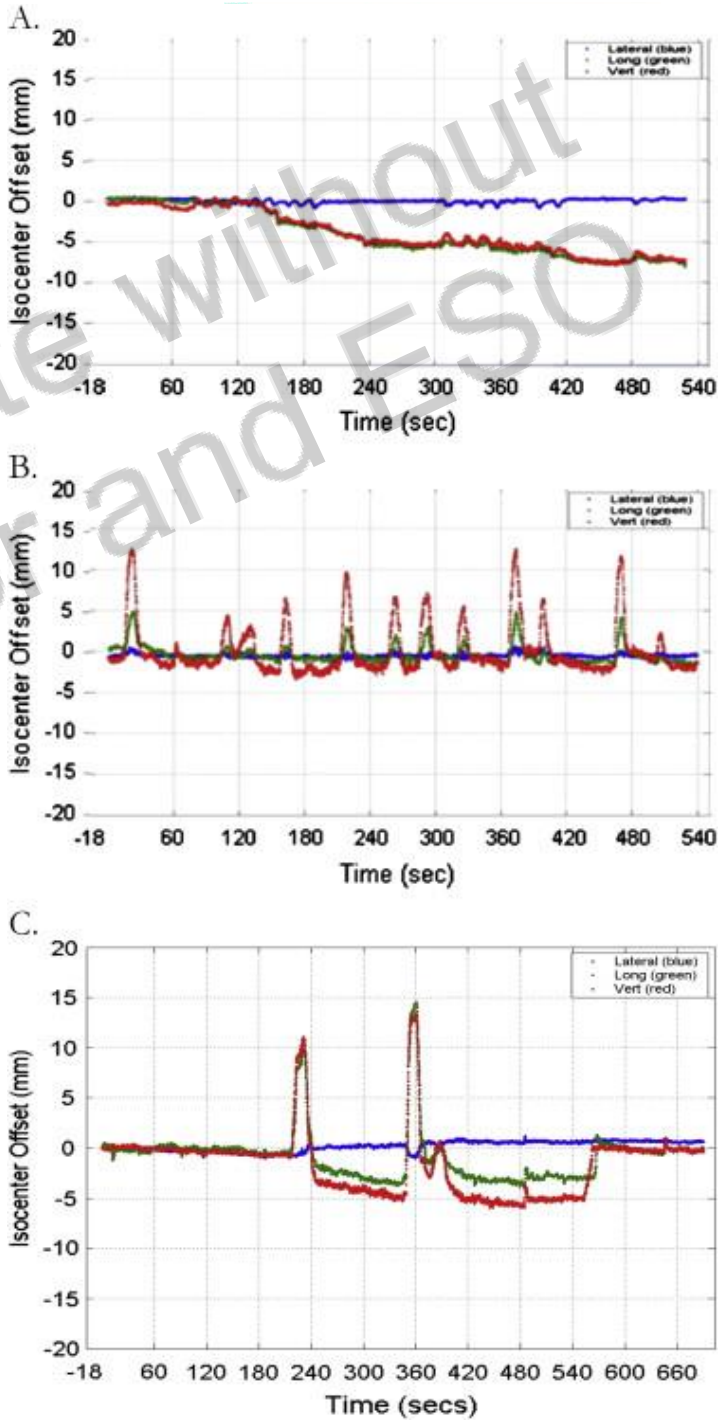
Remember you can ask questions and send comments at any time

Motion in Radiation Oncology

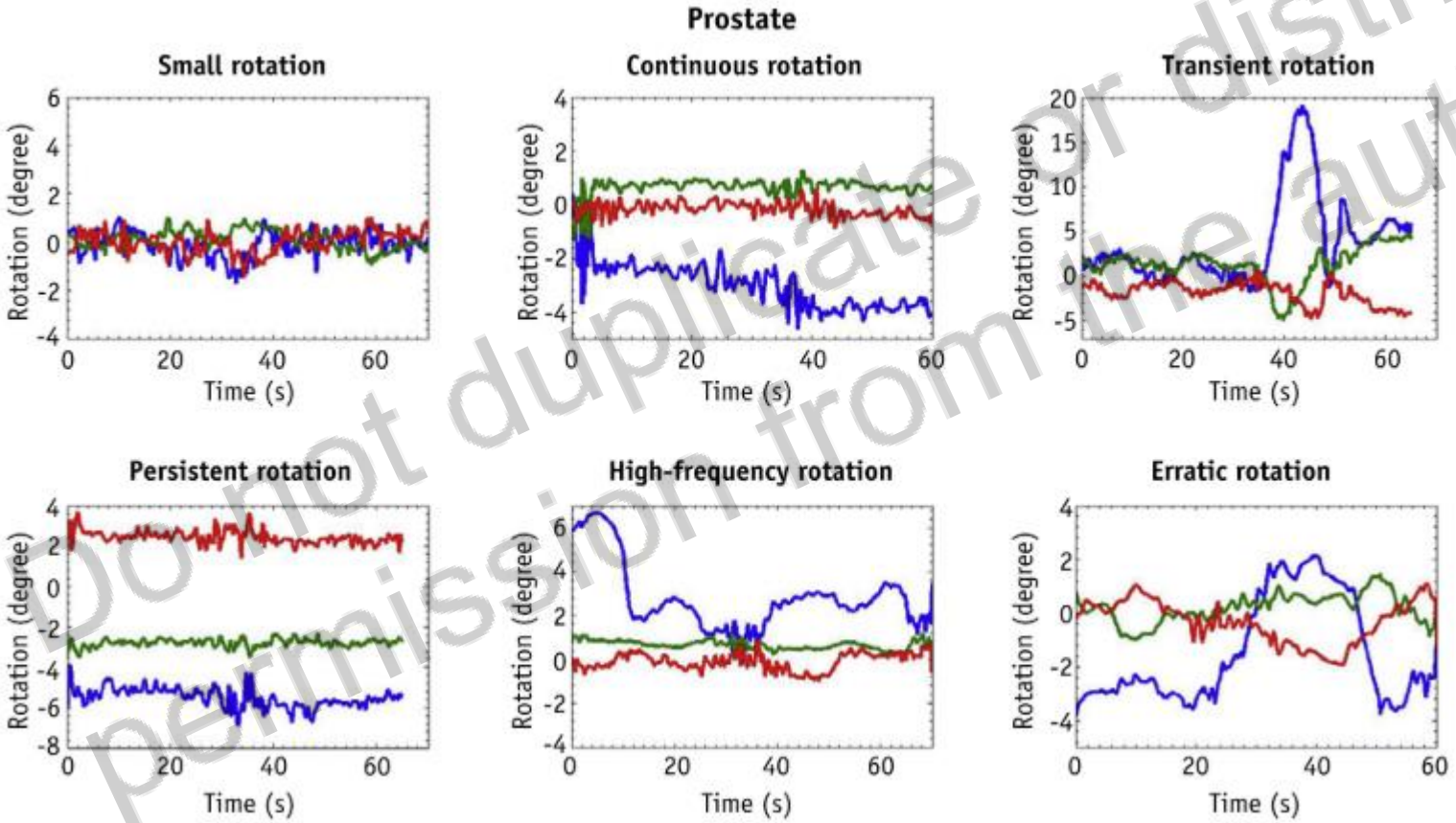
Hunt et al. Clin Onc. 2018

Prostate

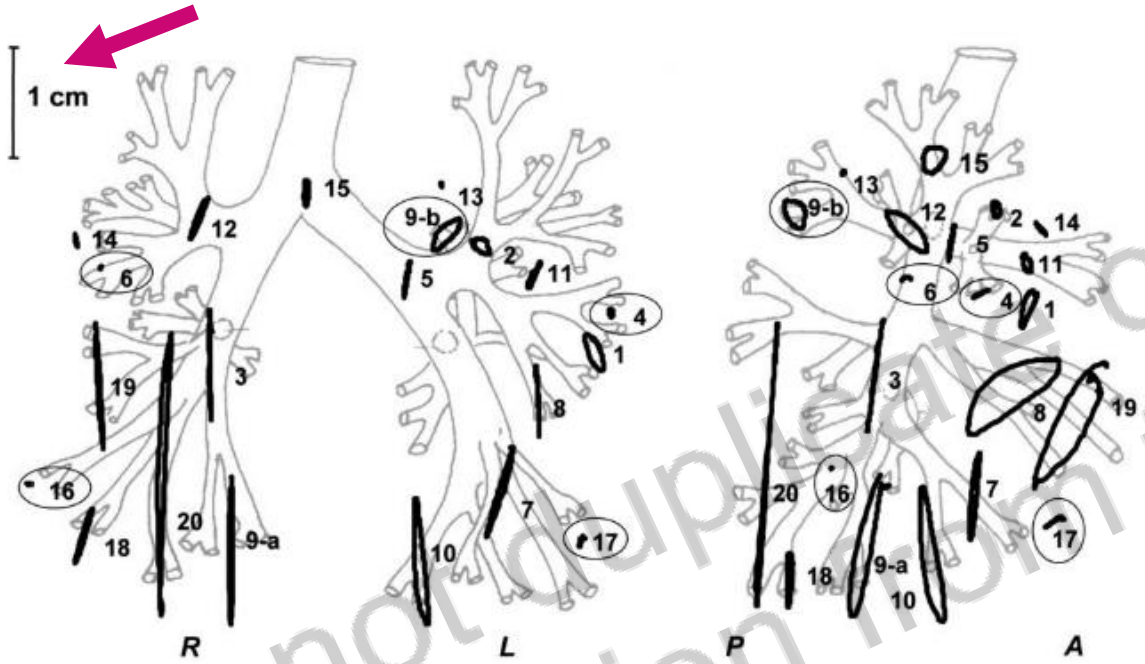
Langen et al. IJROBP. 2008



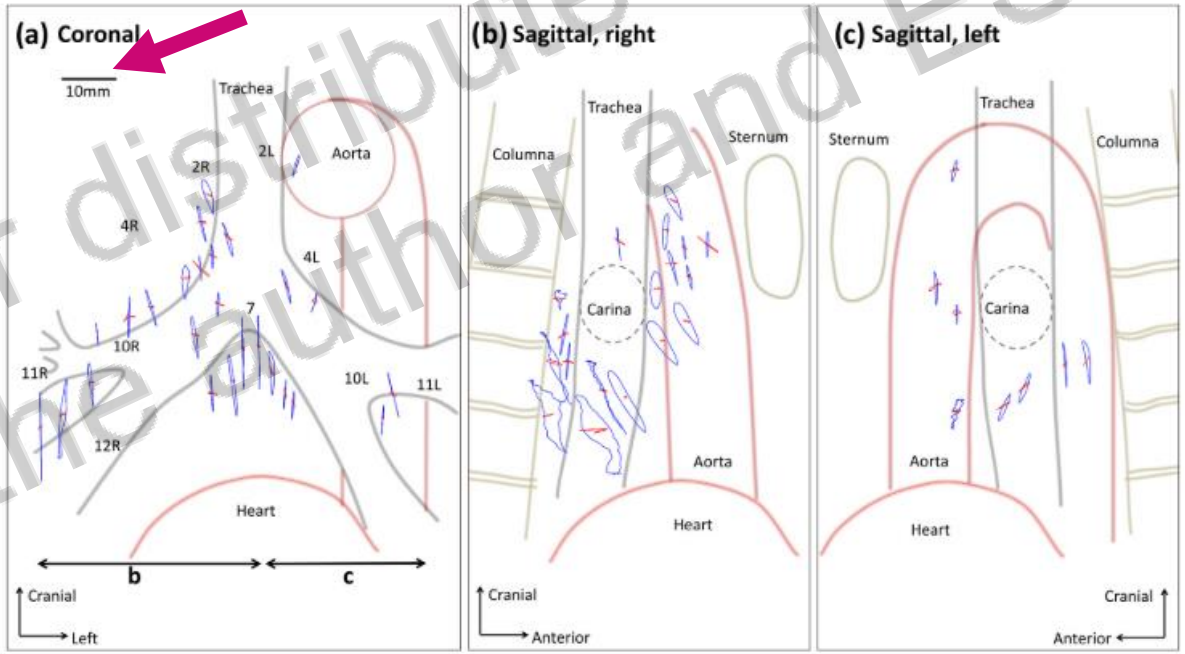
Huang et al. IJROBP. 2014



Lungs and lymph nodes



Seppenwoolde et al. IJROBP. 2002

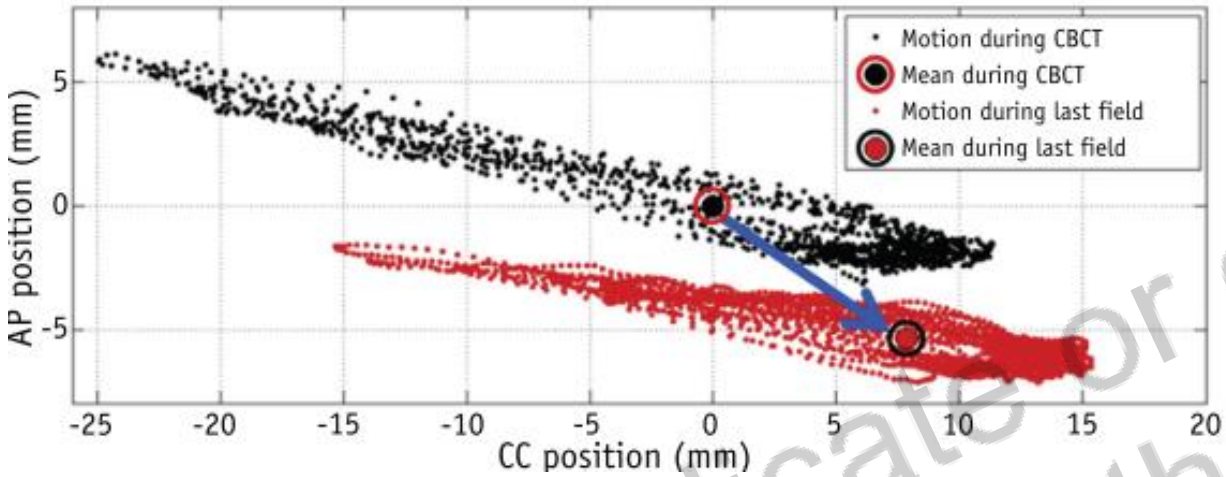


Schmidt et al. Radiother Oncol. 2016

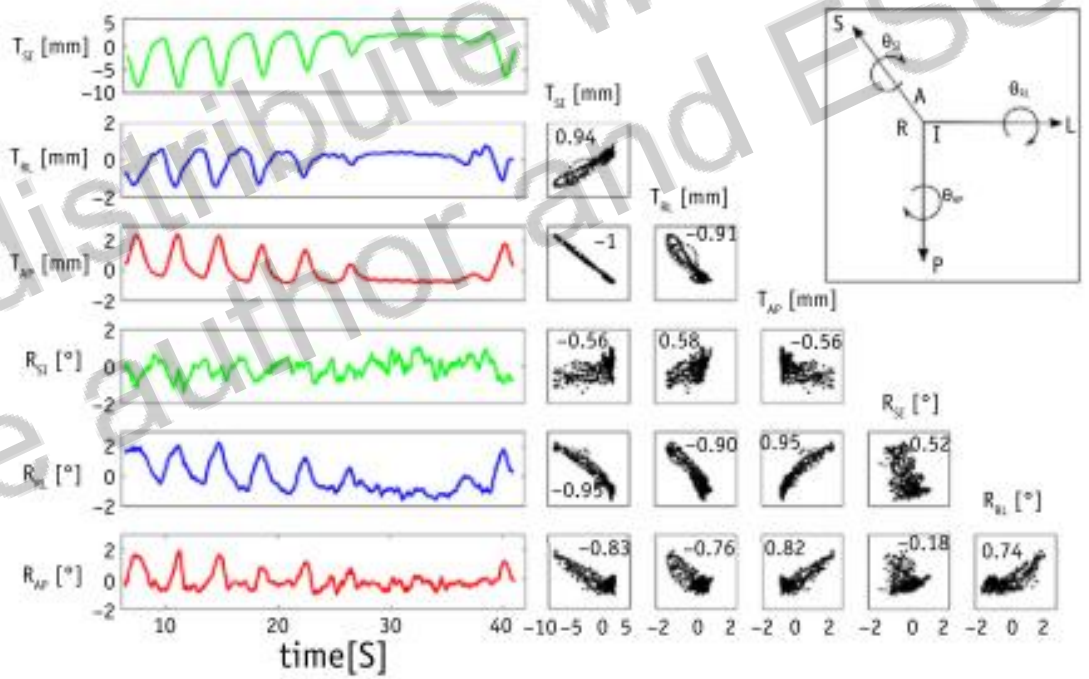
Cardiac component

Respiratory component

Liver



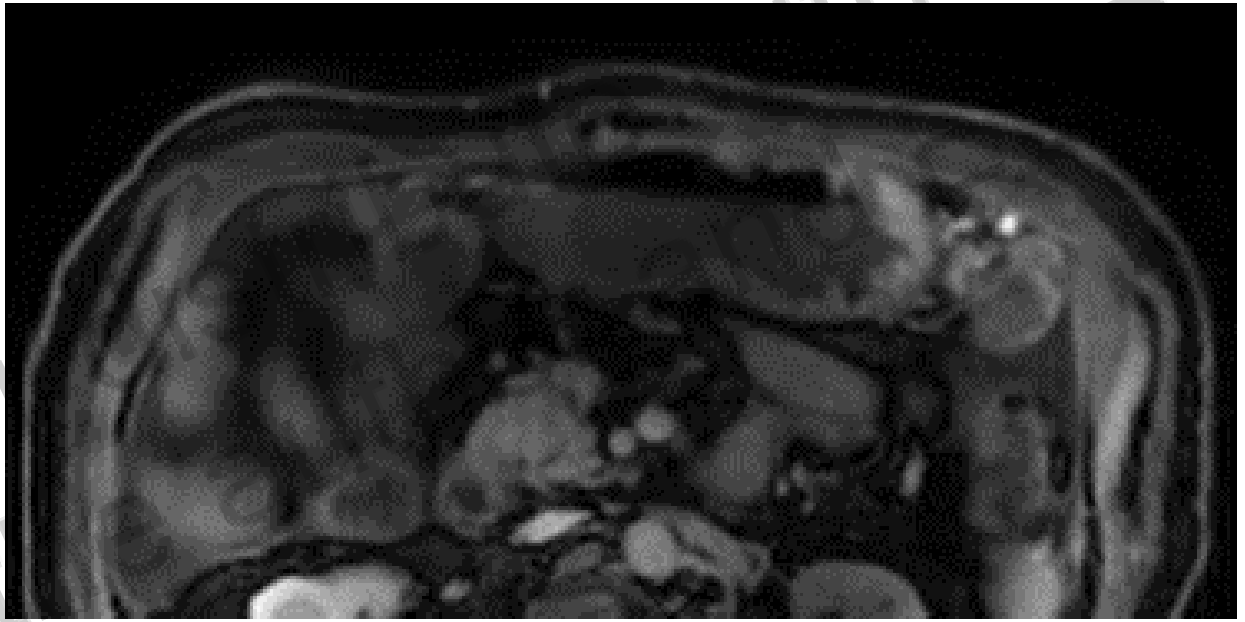
Worm et al. IJROBP. 2018



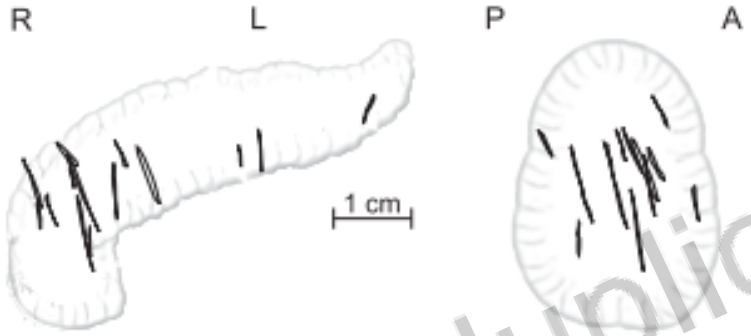
Bertholet et al. IJROBP. 2016

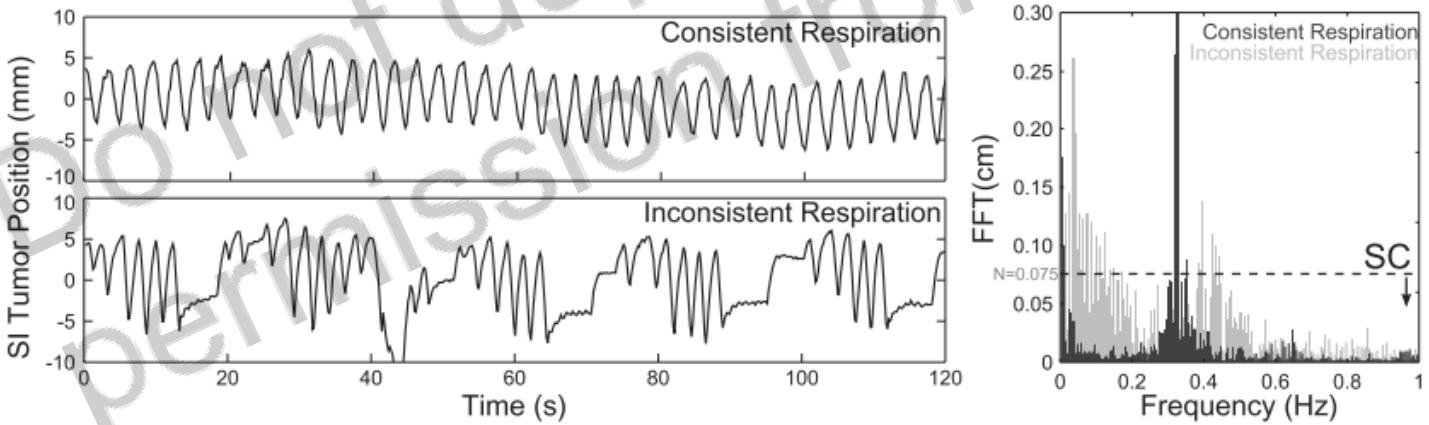
Pancreas and GI

Johansson et al. Med Phys. 2021

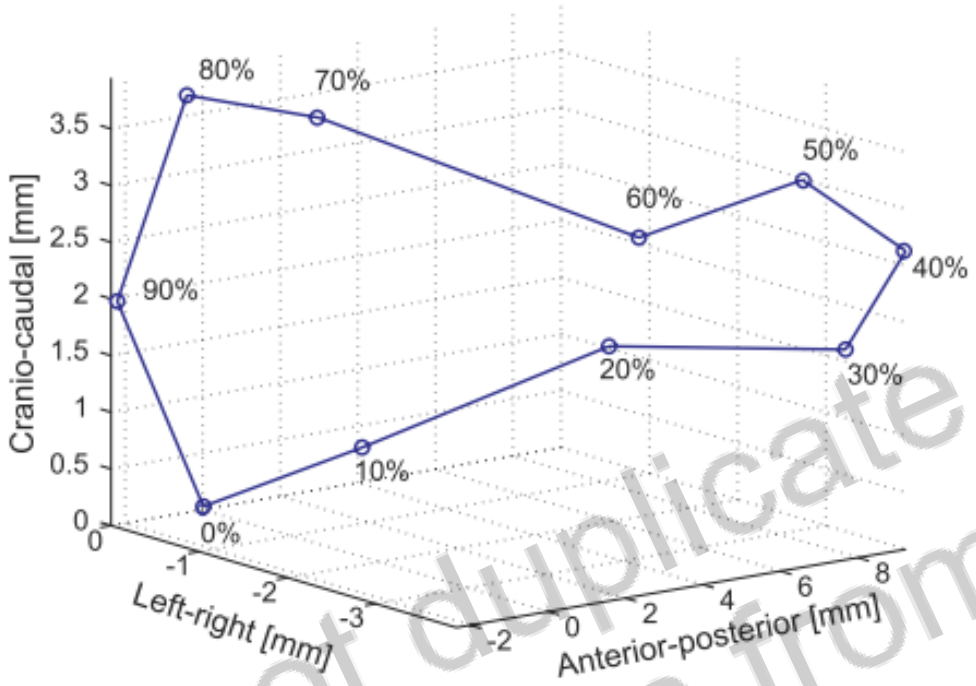


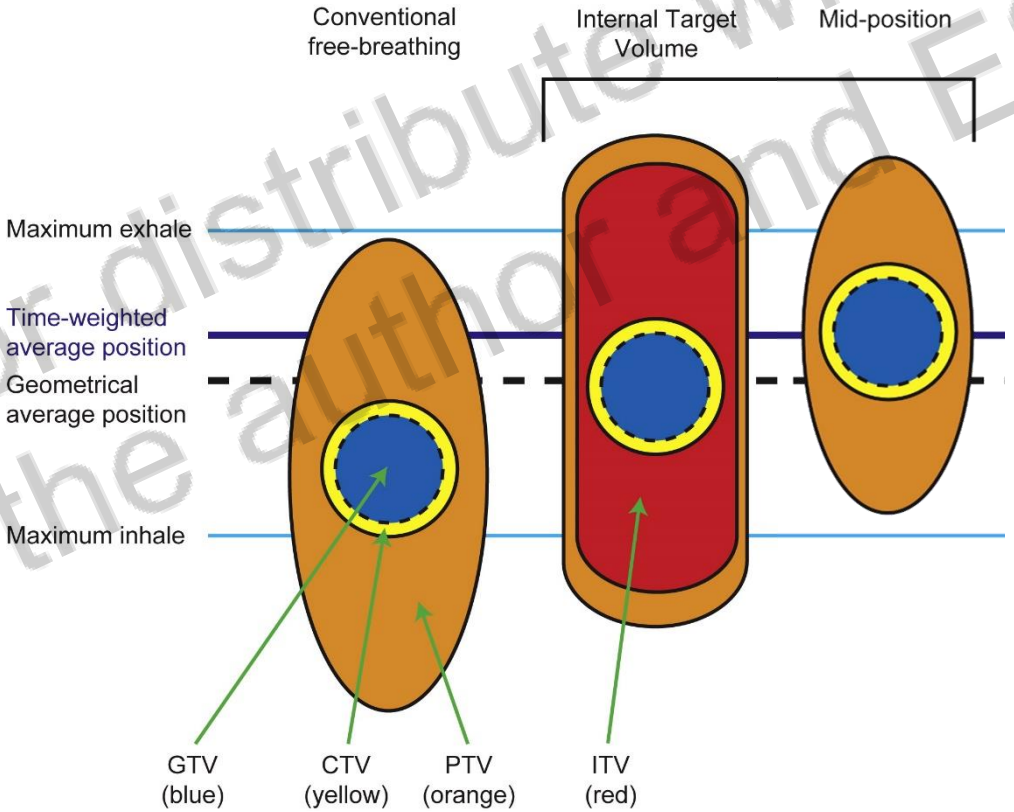
Jones et al. Radiother Oncol. 2015





Passive motion management: margins





$$M_{PTV} = 2.5\Sigma + 1.64\sqrt{\sigma^2 + \sigma_p^2} - 1.64\sigma_p(\mathrm{mm}),$$

systematic random penumbra

Wolthaus et al.IJROBP. 2008

PHYSICS CONTRIBUTION

COMPARISON OF DIFFERENT STRATEGIES TO USE FOUR-DIMENSIONAL COMPUTED TOMOGRAPHY IN TREATMENT PLANNING FOR LUNG CANCER PATIENTS

Jochem W. H. Wolthaus, M.Sc., Jan-Jakob Sonke, Ph.D., Marcel van Herk, Ph.D., José S. A. Belderbos, M.D., Ph.D., Maddalena M. G. Rossi, D.C.R. (R.), R.T.T., Joos V. Lebesque, M.D., Ph.D., and Eugène M. F. Damen, Ph.D.

(respiratory) motion mitigation

Active mitigation

Margins

Compression

Keall et al. (AAPM Task Group 76) Med Phys. 2006

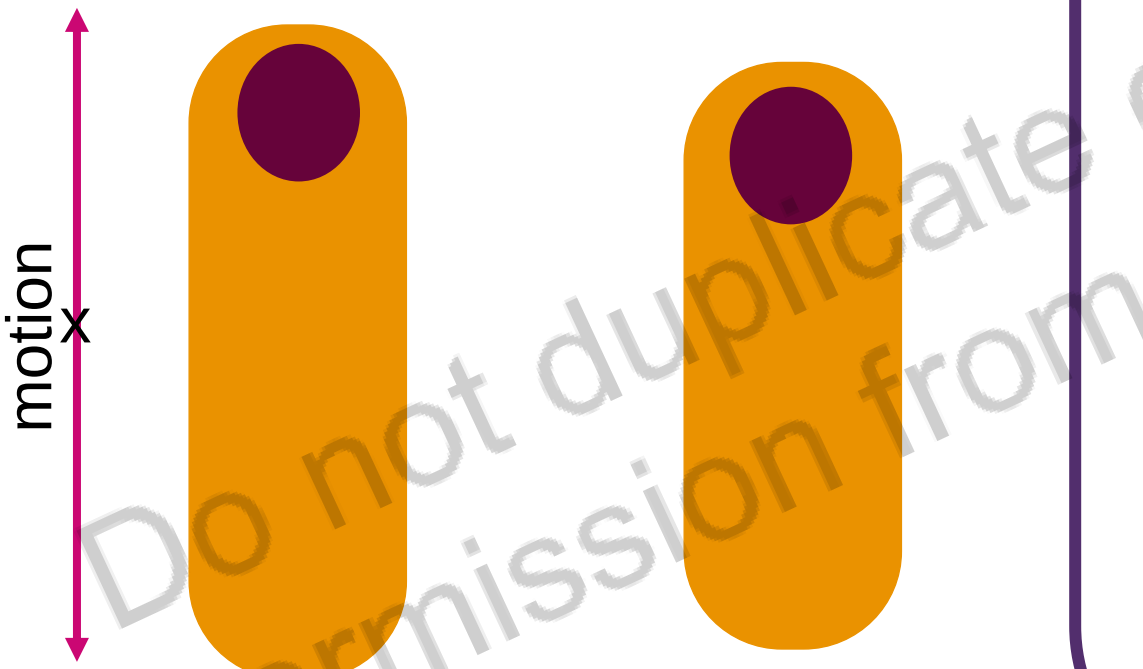
(respiratory) motion mitigation

Active mitigation

Margins

Compression

Breath-hold



Keall et al. (AAPM Task Group 76) Med Phys. 2006

(respiratory) motion mitigation

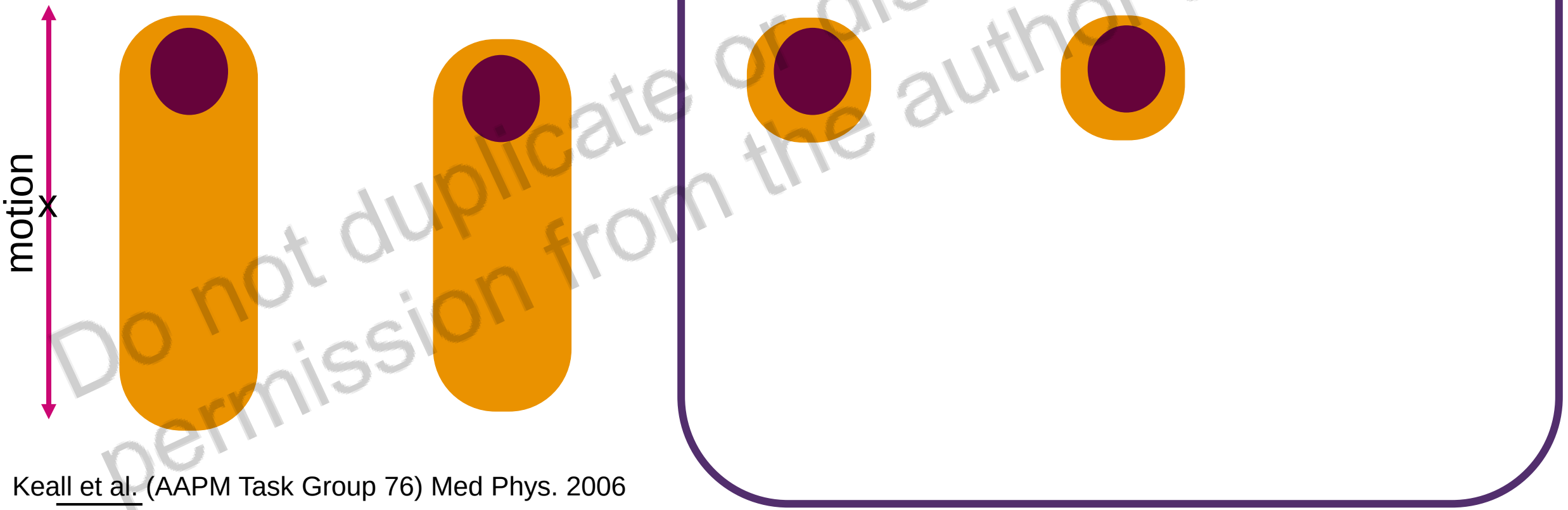
Active mitigation

Margins

Compression

Breath-hold

Gating

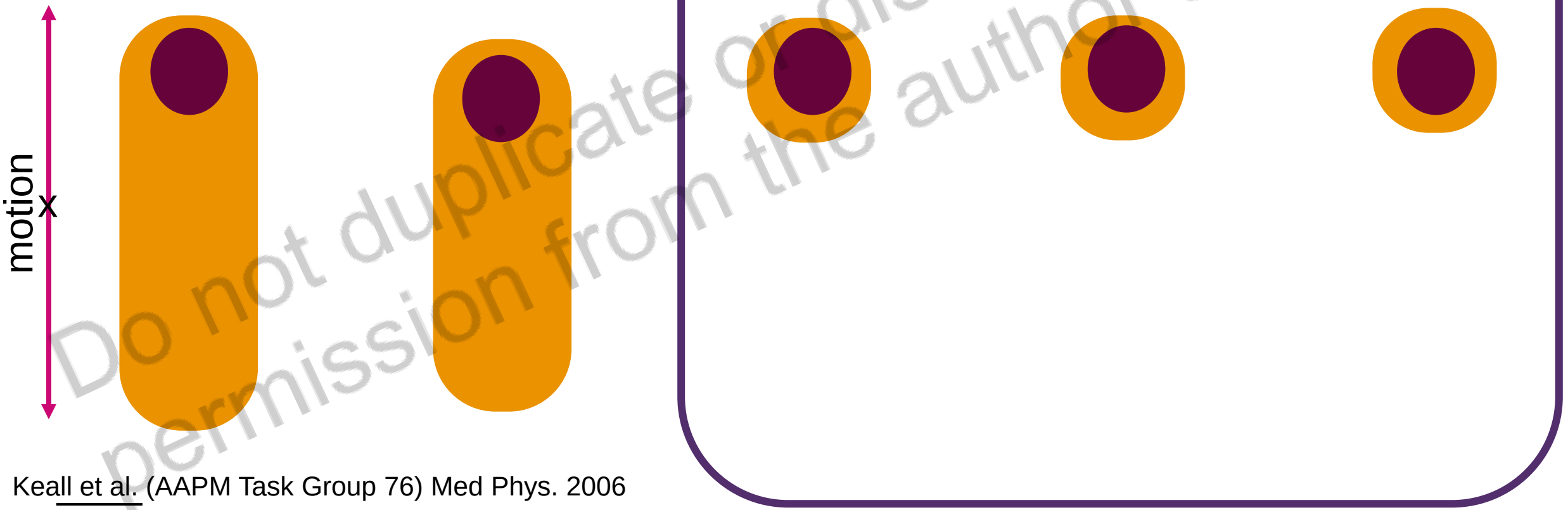


Keall et al. (AAPM Task Group 76) Med Phys. 2006

(respiratory) motion mitigation

Active mitigation

Margins | Compression | Breath-hold | Gating | Tracking



Keall et al. (AAPM Task Group 76) Med Phys. 2006

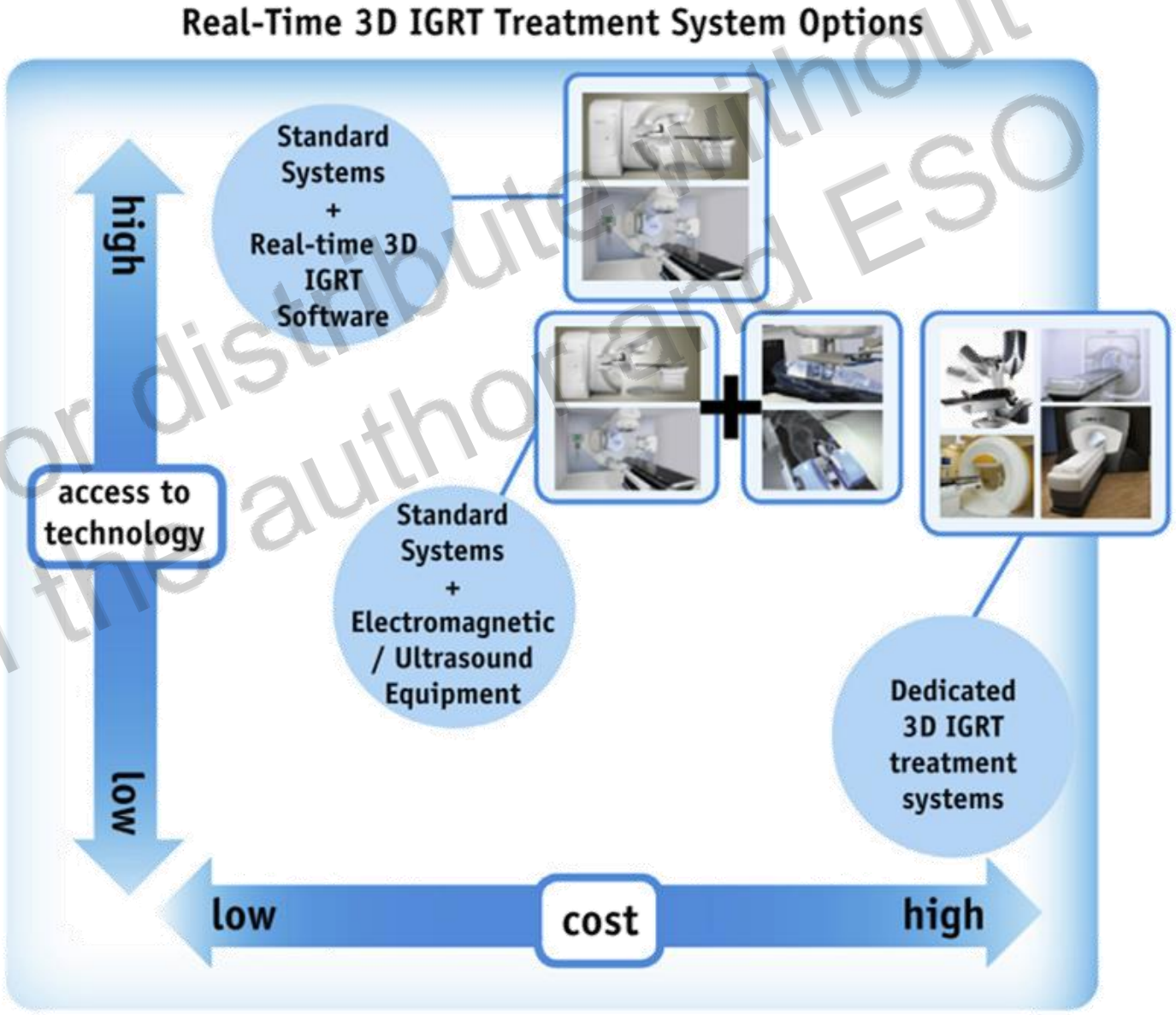
Real-time monitoring

Active mitigation

Motion monitoring

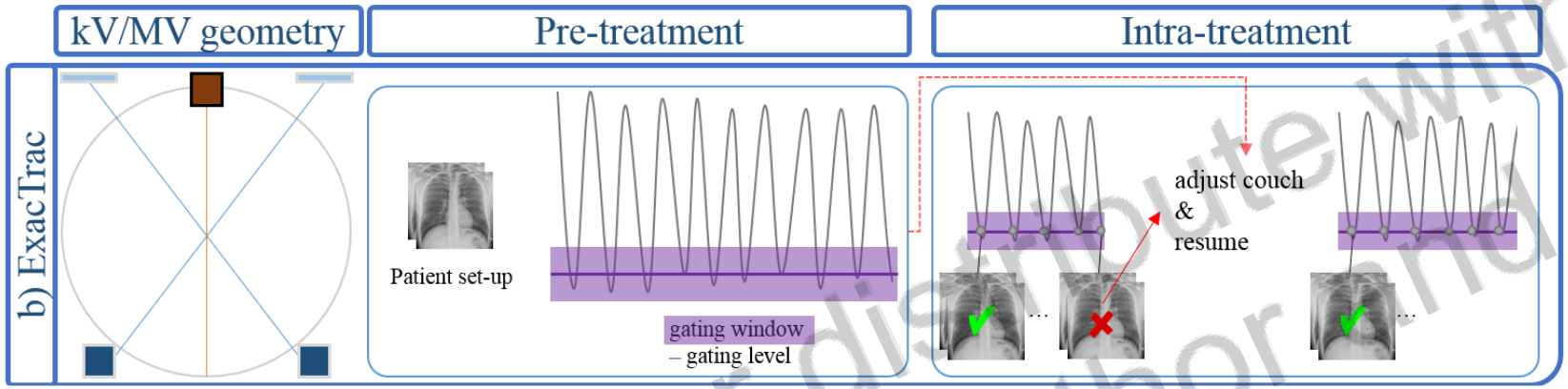
- kV/MV imaging
- MR imaging
- US imaging
- Surface imaging
- Electromagnetic transponders
- Breathing surrogates
- Hybrid methods

Bertholet et al. PMB. 2019 (Topical Review)



Keall et al. IJROBP. 2018

Hybrid kV/optical monitoring



mitigation

Gating / repositioning

Robotic tracking

Gimbal tracking

Legend: kV souce | kV detector | MV souce | MV detector | mobile | fixed | Within tolerance ✔ | Out of tolerance ✖

MLC tracking

Image-based localization with DMLC tracking for Intensity Modulated Arc Therapy (RapidArc plan delivered without variable dose rate or gantry angle)
Stanford University
October 2008

Management of three-dimensional intrafraction motion through real-time DMLC tracking

Amit Sawant,[a)] Raghu Venkat, Vikram Srivastava, and David Carlson
Department of Radiation Oncology, Stanford University, Stanford, California 94305

Sergey Povzner and Herb Cattell
Varian Medical Systems, Palo Alto, California 94304

Paul Keall
Department of Radiation Oncology, Stanford University, Stanford, California 94305

Radiotherapy and Oncology 155 (2021) 131–137

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journal homepage: www.thegreenjournal.com

ELSEVIER

Original Article

MLC tracking for lung SABR is feasible, efficient and delivers high-precision target dose and lower normal tissue dose

Jeremy Booth[a,b,*], Vincent Caillet[a,c], Adam Briggs[a], Nicholas Hardcastle[d,e], Georgios Angelis[a,b], Dasantha Jayamanne[a,f], Meegan Shepherd[a], Alexander Podreka[a], Kathryn Szymura[a], Doan Trang Nguyen[c,g], Per Poulsen[h], Ricky O'Brien[c], Benjamin Harris[i], Carol Haddad[a], Thomas Eade[a,f], Paul Keall[c]

MEDICAL PHYSICS
The International Journal of Medical Physics Research and Practice

Aapm Scientific Report | Free Access

AAPM Task Group 264: The safe clinical implementation of MLC tracking in radiotherapy

Paul J. Keall, Amit Sawant, Ross I. Berbeco, Jeremy T. Booth, Byungchul Cho, Laura I. Cerviño, Eileen Cirino, Sonja Dieterich, Martin F. Fast, Peter B. Greer, Per Munck af Rosenschöld, Parag J. Parikh, Per Rugaard Poulsen, Lakshmi Santanam, George W. Sherouse, Jie Shi, Sotirios Stathakis
... See fewer authors

First published: 01 December 2020 | https://doi.org/10.1002/mp.14625 | Citations: 1

MR-guided MLC tracking

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

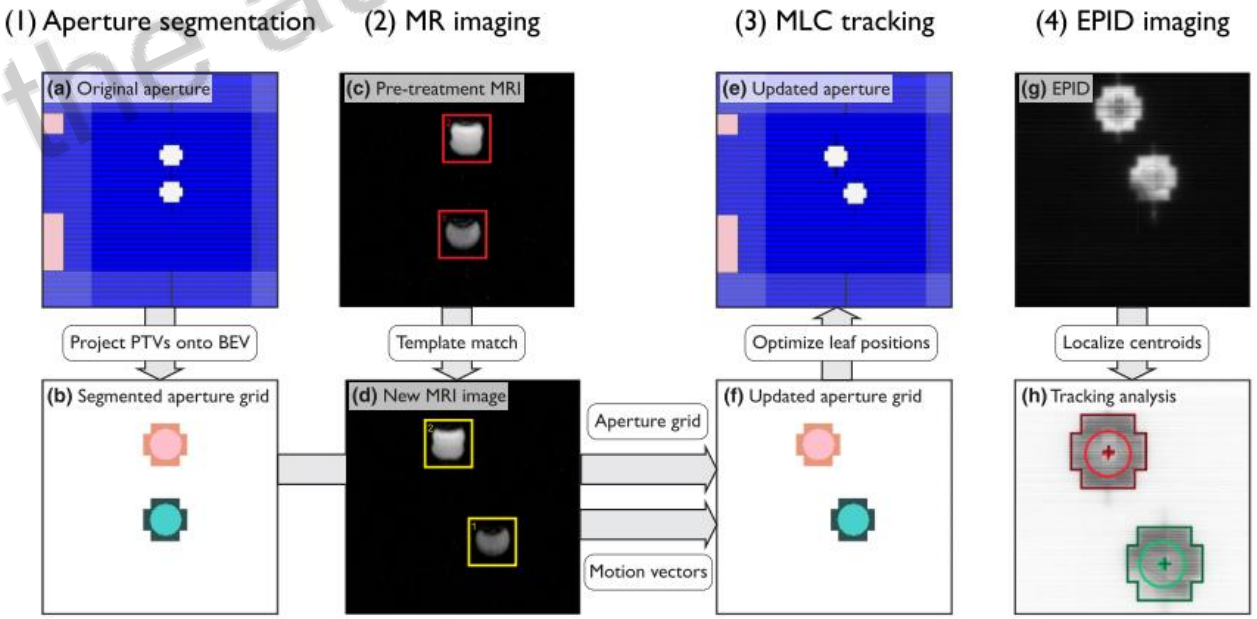
NOTE

Technical note: MLC-tracking performance on the Elekta unity MRI-linac

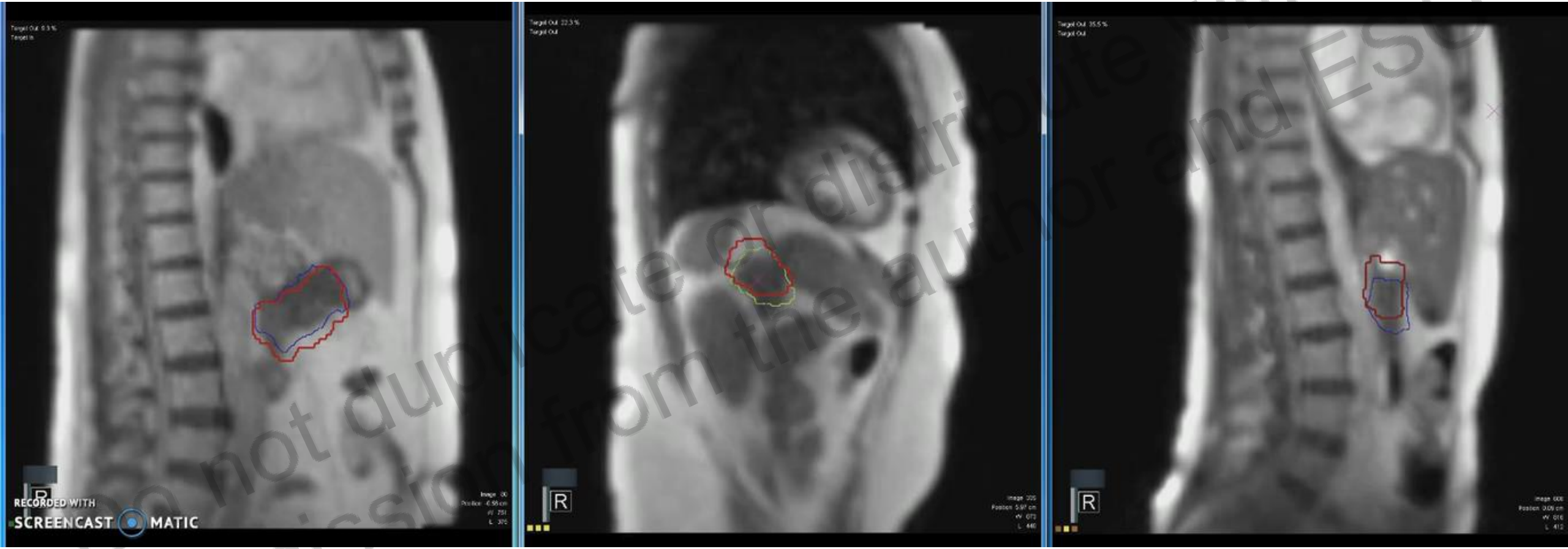
M Glitzner[1,3], P L Woodhead[1,2], P T S Borman[1], J J W Lagendijk[1] and B W Raaymakers[1]

[1] Department of Radiotherapy, University Medical Center Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands
[2] Elekta AB, Stockholm, Sweden
[3] Author to whom any correspondence should be addressed.

Liu et al. Med Phys. 2020



MR linac – Gating (free-breathing/breath-hold)



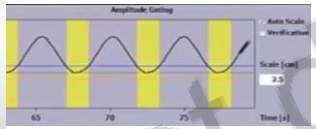
Video Feedback System for MR-guided Radiotherapy Using Breath-hold Gated Treatment Delivery in Pancreatic Cancer Patients

This video shows three examples of what patients actually see during their treatment. They observe in real-time the gating target (in blue or green) within the gating boundary (in red) on a sagittal tracking image derived from the MRIdian console.

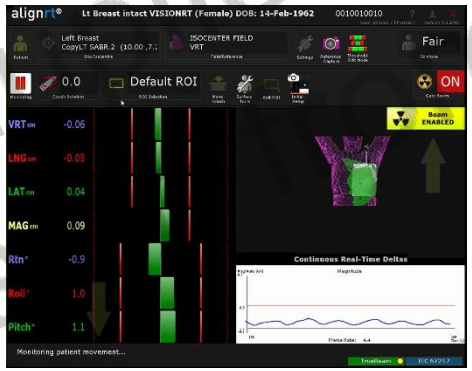
Tetar et al. Cureus 10(2)

Add-on monitoring equipment

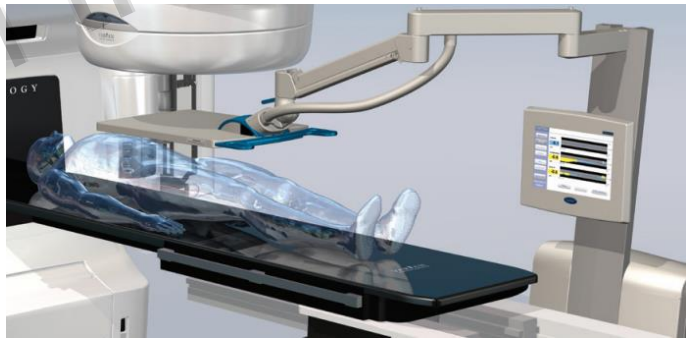
Respiratory surrogates
Widely available
Surrogacy quality?
Gating (esp. BH)


Surface imaging
Positioning
Gating



Electromagnetic transponders
System specific
Gating



Ultrasound
Prostate only
System specific
Gating

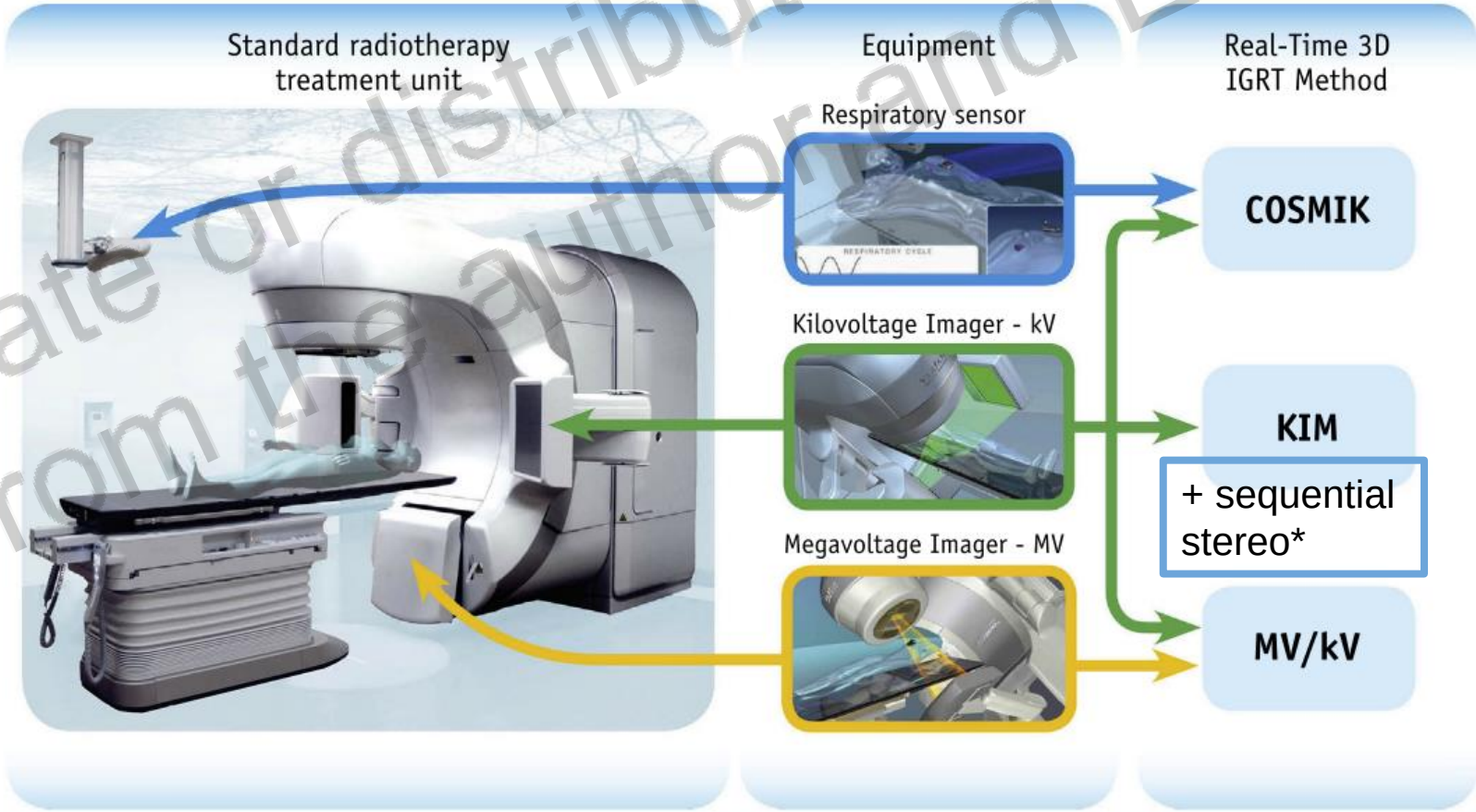
Solutions on conventional linacs

International Journal of Radiation Oncology biology • physics
www.redjournal.org

Improving Positioning Accuracy

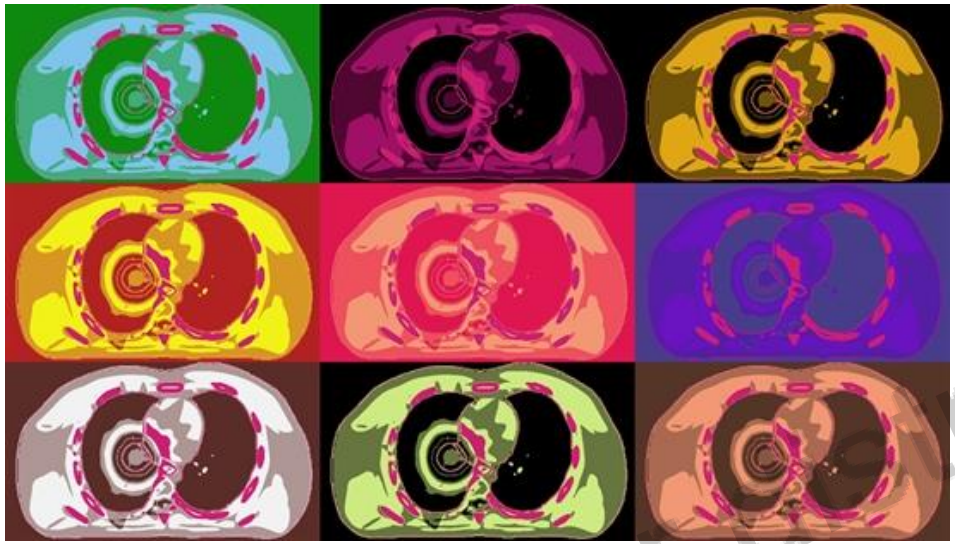
Review of Real-Time 3-Dimensional Image Guided Radiation Therapy on Standard-Equipped Cancer Radiation Therapy Systems: Are We at the Tipping Point for the Era of Real-Time Radiation Therapy?

Paul J. Keall, PhD,* Doan Trang Nguyen, PhD,* Ricky O'Brien, PhD,* Pengpeng Zhang, PhD,† Laura Happersett, PhD,† Jenny Bertholet, PhD,‡,§ and Per R. Poulsen, PhD§



PHYSICS

Pattern Of Practice for Adaptive and Real Time Radiation Therapy (POP-ART RT)



ESTRO

Anastasi et al. Radiother Oncol. 2020

- Institutional practice for real-time respiratory motion management (RRMM)
- Wishes for increase use/change of technique or new implementation
- Barriers to increased use or implementation

- 200 centres from 41 countries responded

Main results – Patterns of Practice

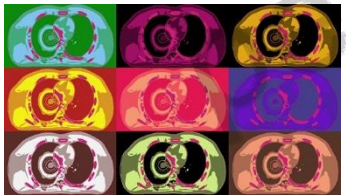
Breast

- Evidence of clinical benefit in inspiration breath-hold
- 56% of respondents used RRMM
- Monitoring with respiratory surrogates / surface imaging

Lung / Liver / Pancreas

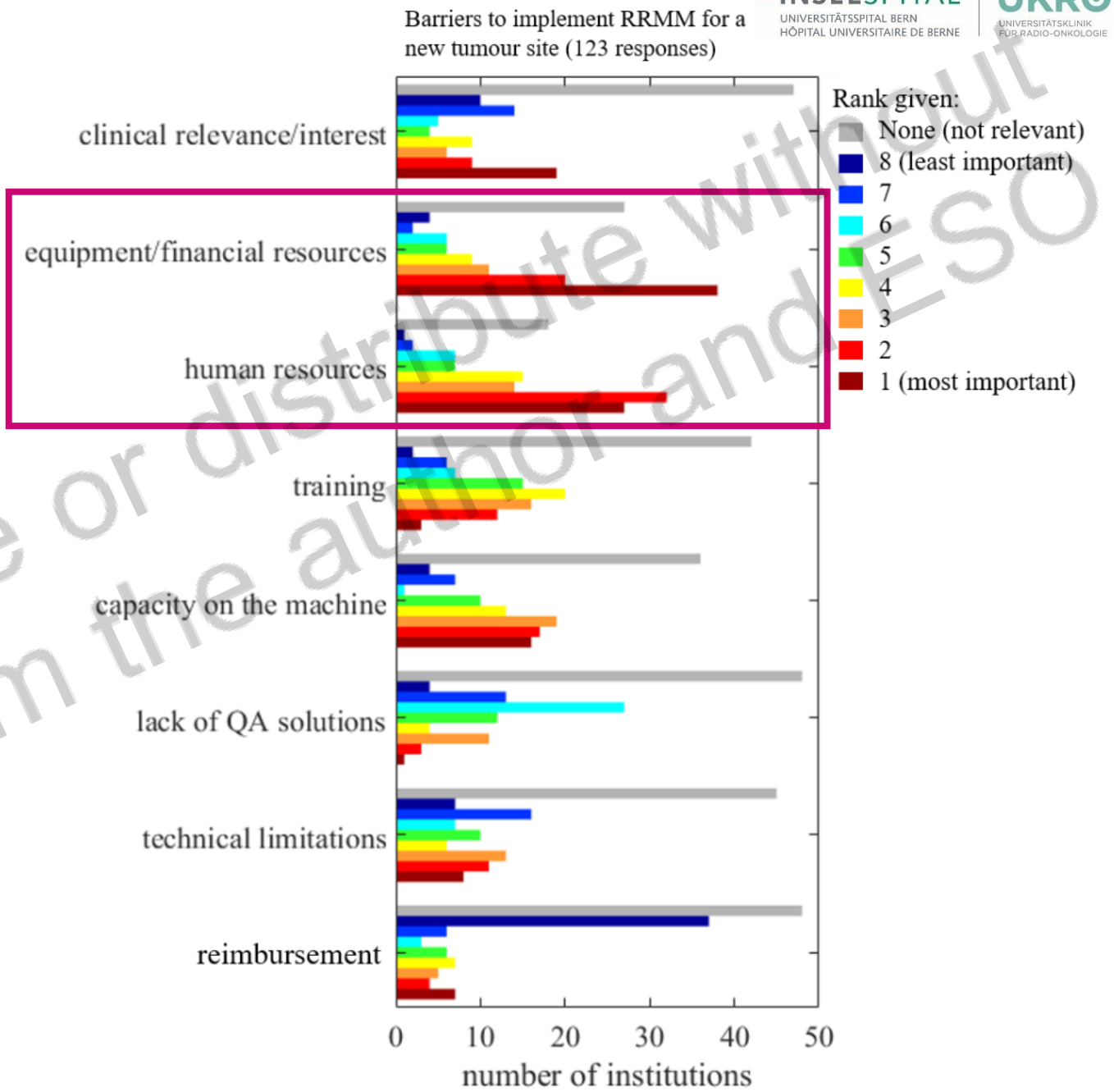
- Need for higher accuracy in SBRT
- 32% / 22% / 15% of respondents used gating
- Monitoring with breathing surrogate

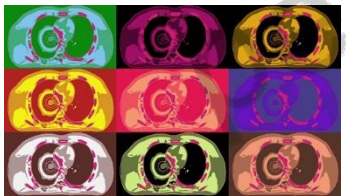
  (4 institutions with MR)
- 10% / 8% / 5% used tracking (Cyberknife except one)



Wishes for implementation

- 40% of respondents had plans to implement RRMM for a new treatment site in the next 2 years

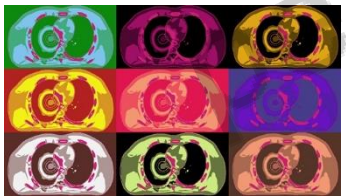




Summary: RRMM in clinical practice

- Mostly gating with respiratory surrogate
- Large interest in implementing RRMM (breast, lung)
- Limited by material/human resources

It is a fast evolving field with promising development…



Take home messages

- Many organs move during RT delivery
  - Order of magnitude: centimeters!
- Margins are widely used
  - But limited by irregular motion
- Active methods require specialized equipment at the moment
  - But can better compensate for irregular motion (smaller margins!)
- Wide interest for implementation of active mitigation in clinical practice
  - Limited by human and material resources

Acknowledgements

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Antje Knopf
Björn Eiben
Jamie McClelland
Uwe Oelfke
the POP-ART RT team
The AMS and UKRO team

Thank you for your attention!
Happy to take questions