LMU KLINIKUM
Gemeinsam. Fürsorglich. Wegweisend.

@stef_corradini

Practice Impact and next steps

Omics & AI for MRLinac

Department of Radiation Oncology, University Hospital, LMU Munich
24.11.22| PD Dr. Stefanie Corradini

Global Disclaimer

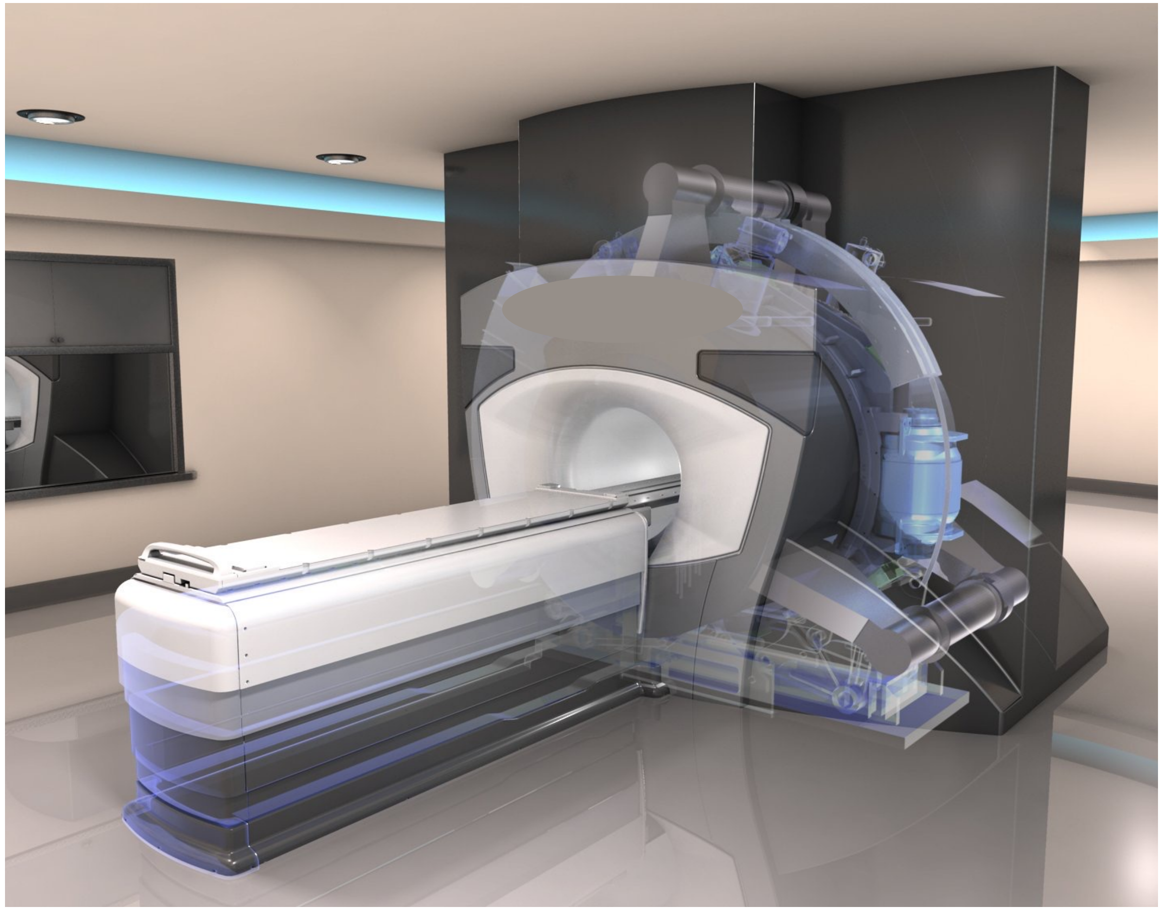
- In keeping with our role as a university hospital, we are active in research and receive funding from various sources

- Research is supported by government agencies: Free State of Bavaria, Cancer Aid, DFG, BMBF (DKTK, DZL) and BMU

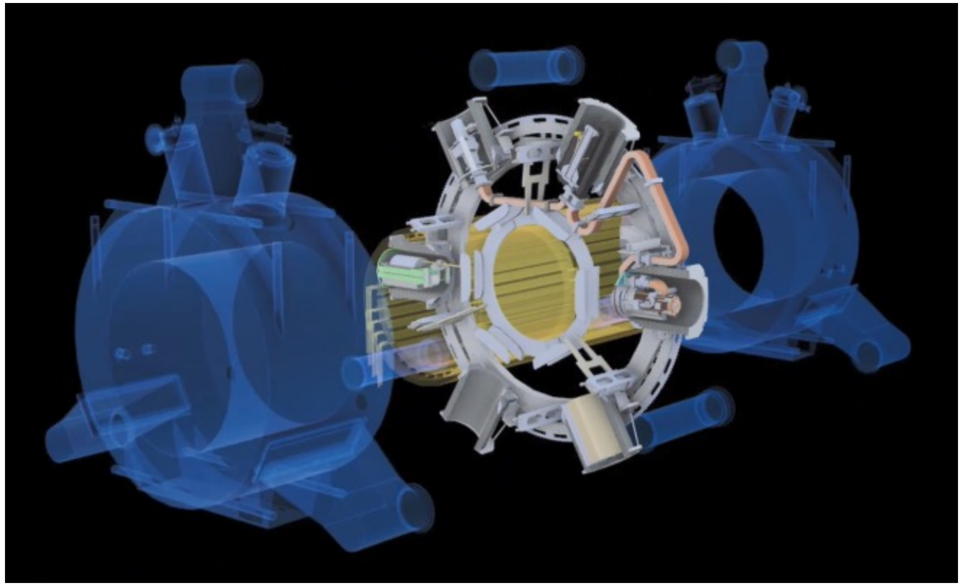
- For individual research projects and/or meeting presentations and participation in advisory boards, the department is supported by:

  AstraZeneca, MERCK, MSD, BMS, ViewRay, ELEKTA, Brainlab and C-RAD and OPASCA

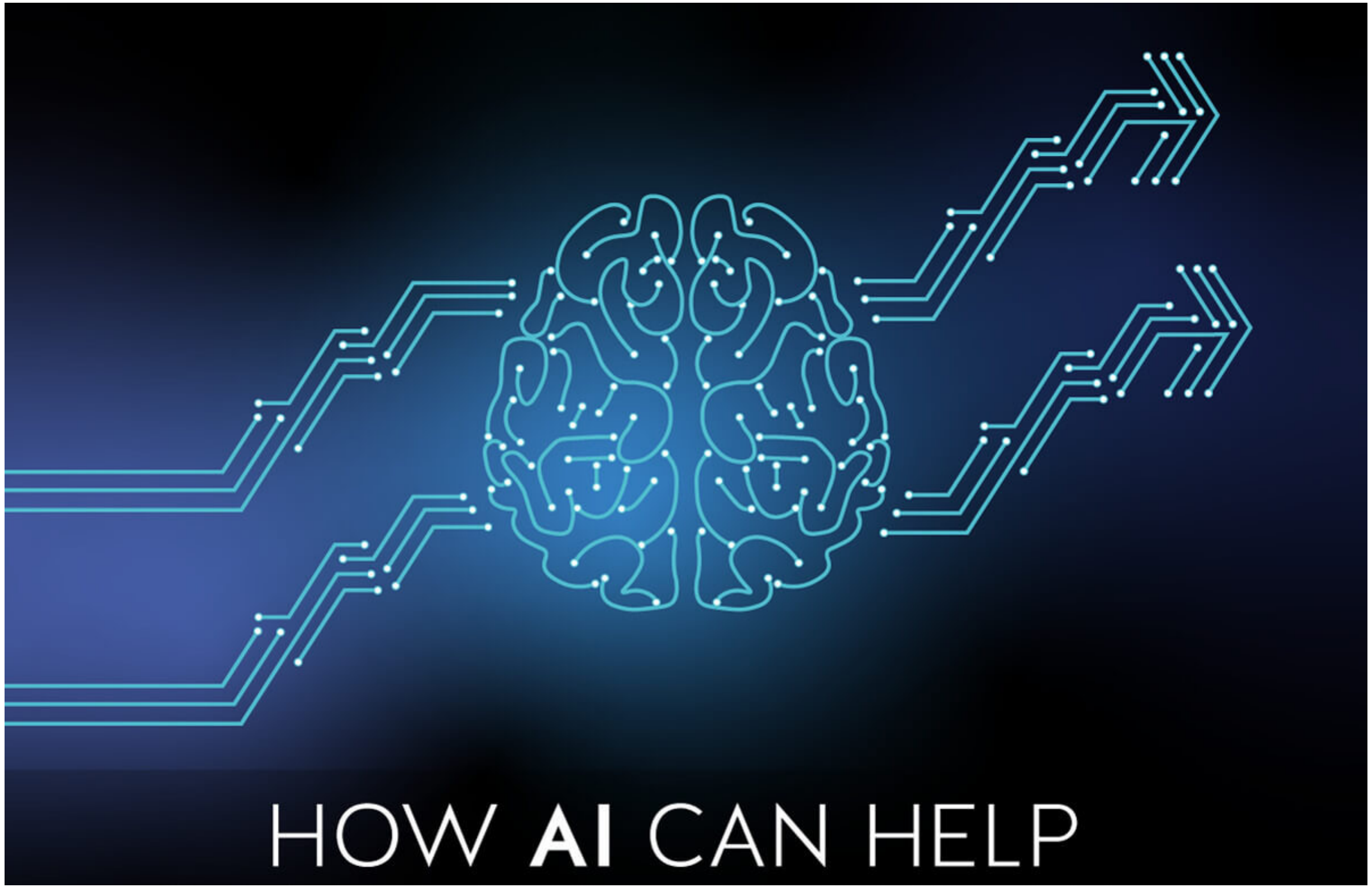
MRgRT
MRIdian



- New Technology: Hybrid MR-Linac Systems
- 5 active Sites in Germany



AI
MRLinac



LMU KLINIKUM

AI in MRgRT
Challenges

Challenges for providers:

- MRI environment → not all patients are suitable
- Adaptive workflows
- Close interdisciplinary teamwork required
- Longer treatment times
- High costs

AI in MRgRT
Challenges

LMU KLINIKUM

Challenges for providers:

- MRI environment → not all patients sutiable
- **Adaptive workflows**
- Close interdisciplinary teamwork required
- **Longer treatment times**
- High costs

AI in MRgRT Workflows

Radiotherapy and Oncology 159 (2021) 146–154

Contents lists available at ScienceDirect

Radiotherapy and Oncology

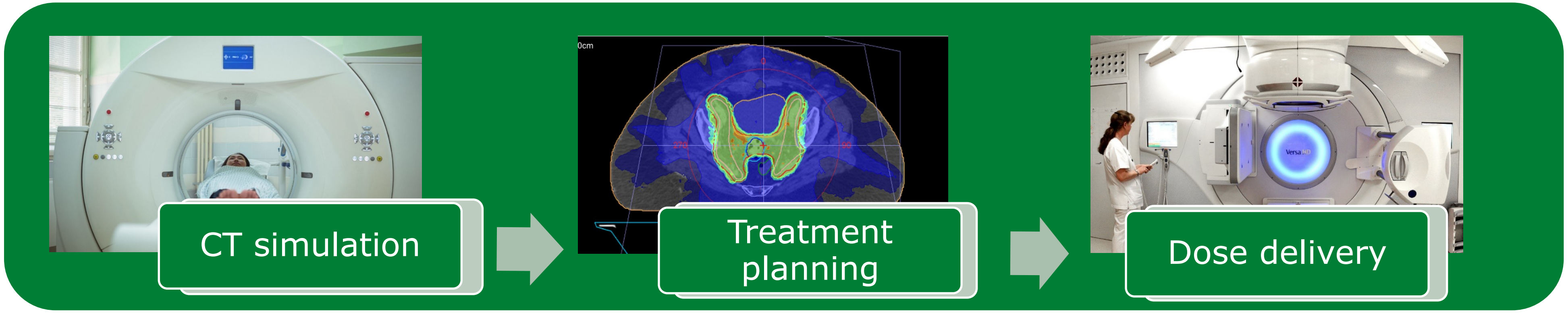
journal homepage: www.thegreenjournal.com

Original Article

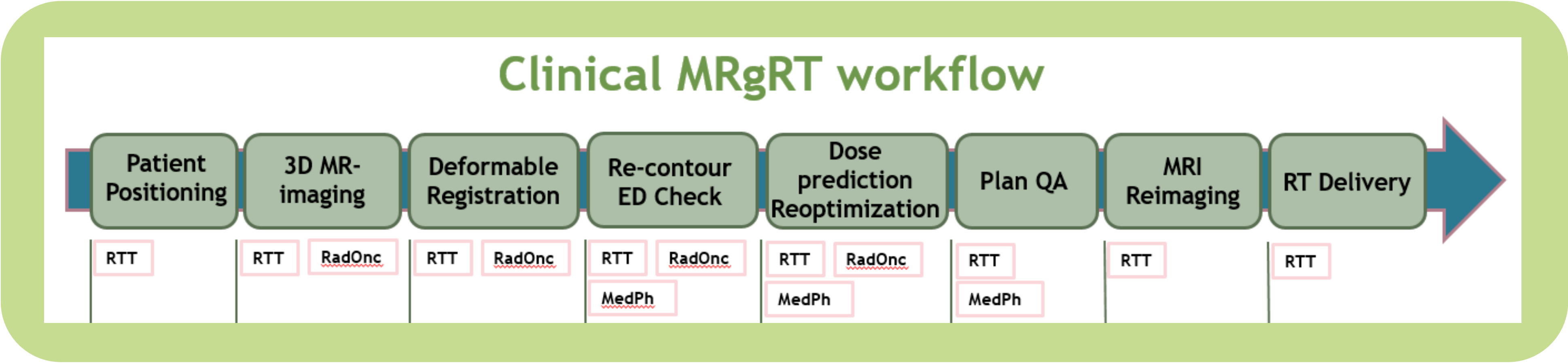
ESTRO-ACROP recommendations on the clinical implementation of hybrid MR-linac systems in radiation oncology

Stefanie Corradini [a,*], Filippo Alongi [b], Nicolaus Andratschke [c], David Azria [d], Omar Bohoudi [e], Luca Boldrini [f], Anna Bruynzeel [e], Juliane Hörner-Rieber [g], Ina Jürgenliemk-Schulz [h], Frank Lagerwaard [e], Helen McNair [i], Bas Raaymakers [h], Tine Schytte [j], Alison Tree [i], Vincenzo Valentini [f], Lotte Wilke [c], Daniel Zips [k], Claus Belka [a]

CT



MRI



Strahlenther Onkol (2020) 196:691–698
https://doi.org/10.1007/s00066-020-01578-z

ORIGINAL ARTICLE

First prospective clinical evaluation of feasibility and patient acceptance of magnetic resonance-guided radiotherapy in Germany

Sebastian Klüter[1,2,3] · Sonja Katayama[1,2,3] · C. Katharina Spindeldreier[1,2,3] · Stefan A. Koerber[1,2,3] · Gerald Major[1,2,3] · Markus Alber[1,2,3] · Sati Akbaba[1,2,3] · Jürgen Debus[1,2,3,4,5] · Juliane Hörner-Rieber[1,2,3,5]

AI in MRgRT
Patient acceptance

Challenges for patients:

- **65% complaint rate of at least 1 item**
  - Cold temperature
  - Noise
  - Duration of treatment
  - Paresthesia
  - Uncomfortable positioning

AI in MRgRT
Patient acceptance

Strahlenther Onkol (2020) 196:691–698
https://doi.org/10.1007/s00066-020-01578-z
ORIGINAL ARTICLE

First prospective clinical evaluation of feasibility and patient acceptance of magnetic resonance-guided radiotherapy in Germany

Sebastian Klüter[1,2,3] · Sonja Katayama[1,2,3] · C. Katharina Spindeldreier[1,2,3] · Stefan A. Koerber[1,2,3] · Gerald Major[1,2,3] · Markus Alber[1,2,3] · Sati Akbaba[1,2,3] · Jürgen Debus[1,2,3,4,5] · Juliane Hörner-Rieber[1,2,3,5]

Challenges for patients:

- **65% complaint rate of at least 1 item**
  - Cold temperature
  - Noise
  - **Duration of treatment**
  - Paresthesia
  - Uncomfortable positioning

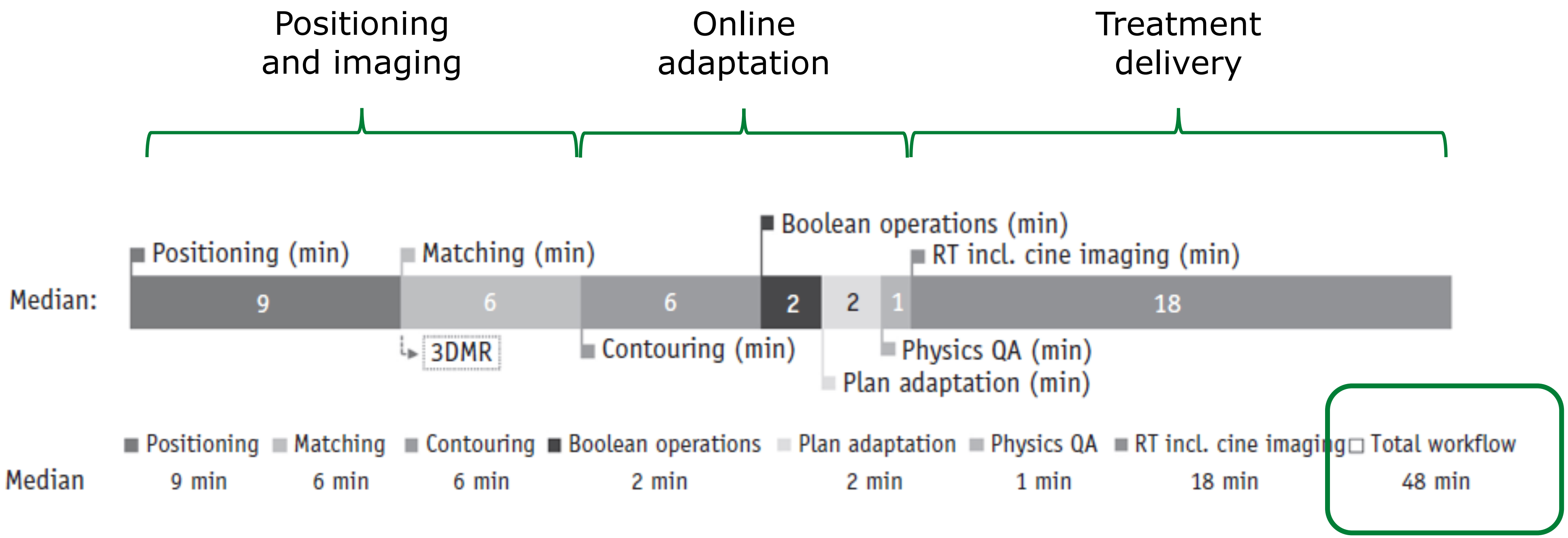
AI in MRgRT
Treatment duration

Role of On-Table Plan Adaptation in MR-Guided Ablative Radiation Therapy for Central Lung Tumors

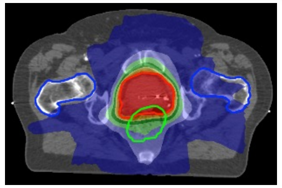
Tobias Finazzi, MD, Miguel A. Palacios, PhD,
Femke O.B. Spoelstra, MD, PhD, Cornelis J.A. Haasbeek, MD, PhD,
Anna M.E. Bruynzeel, MD, PhD, Ben J. Slotman, MD, PhD,
Frank J. Lagerwaard, MD, PhD, and Suresh Senan, MRCP, FRCR, PhD

Department of Radiation Oncology, Amsterdam University Medical Centers, Vrije Universiteit Amsterdam, The Netherlands

Received Dec 10, 2018. Accepted for publication Mar 20, 2019.

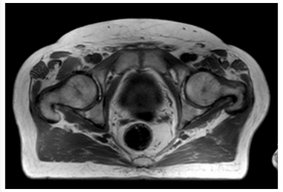


MRgRT workflow
Where can AI help?



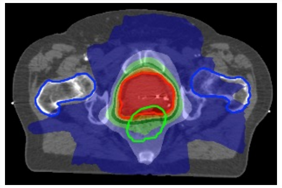
Baseline treatment optimization

→



In-room MRI

→



Treatment optimization

→

Treatment

→

Follow up

Automatic segmentation

Synthetic CT generation

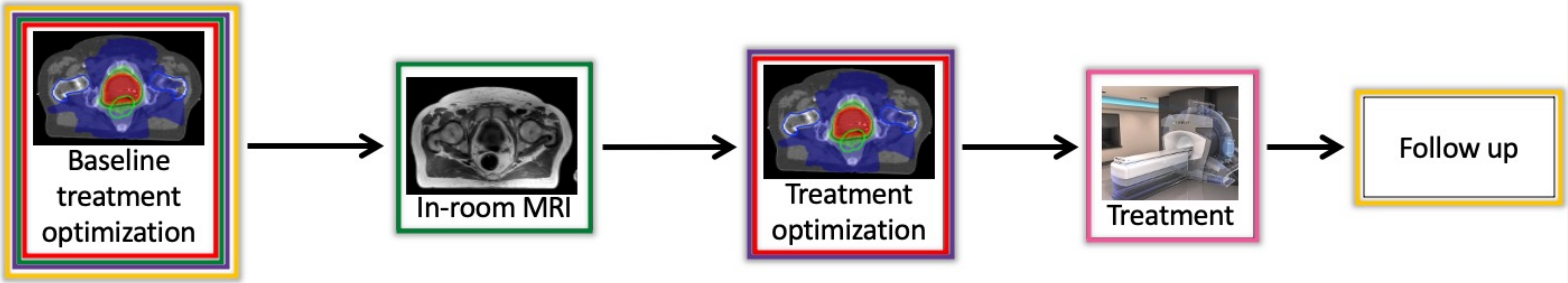
Dose prediction and automatic planning

Motion tracking

Outcome prediction

Courtesy of G. Landry

MRgRT workflow
Where can AI help?



Automatic segmentation
Synthetic CT generation
Dose prediction and automatic planning
Motion tracking
Outcome prediction

Courtesy of G. Landry

Automatic segmentation
Why?

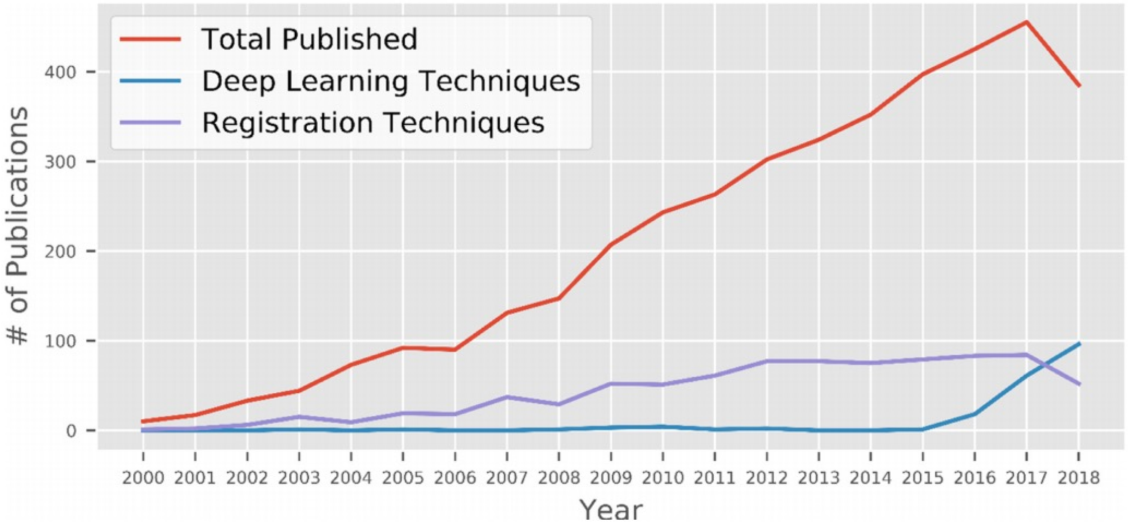
Automatic segmentation
DL is now well established

ELSEVIER

Seminars in RADIATION ONCOLOGY

Advances in Auto-Segmentation

Carlos E. Cardenas, PhD, Jinzhong Yang, PhD, Brian M. Anderson, MS, Laurence E. Court, PhD, and Kristy B. Brock, PhD



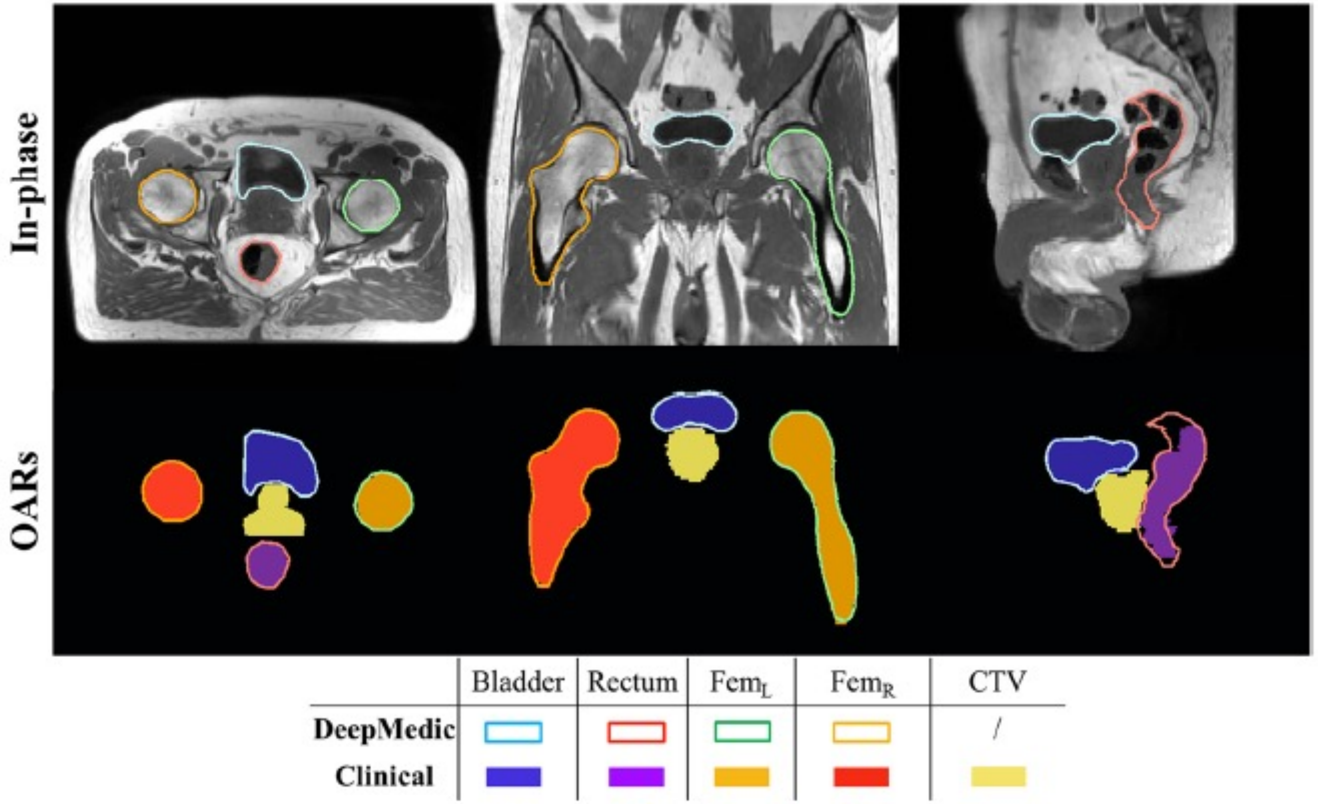
- **Deep learning auto-segmentation algorithms have quickly become the state-of-the-art in medical image segmentation**
- some applications produce better results than the measured inter- and intraobserver contouring variability

Automatic segmentation
DL is now well established

Clinical implementation of MRI-based organs-at-risk auto-segmentation with convolutional networks for prostate radiotherapy

Mark H. F. Savenije[1,2†], Matteo Maspero[1,2*†], Gonda G. Sikkes[1], Jochem R. N. van der Voort van Zyp[1], Alexis N. T. J. Kotte[1], Gijsbert H. Bol[1] and Cornelis A. T. van den Berg[1,2]

OARs and target volume

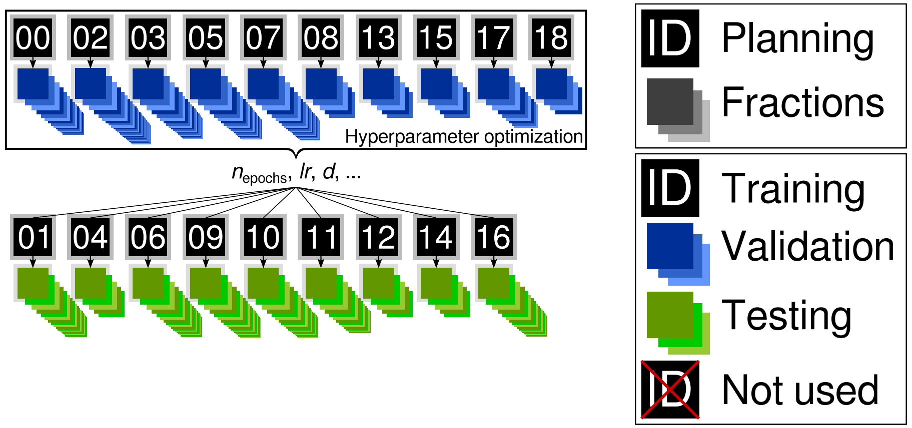


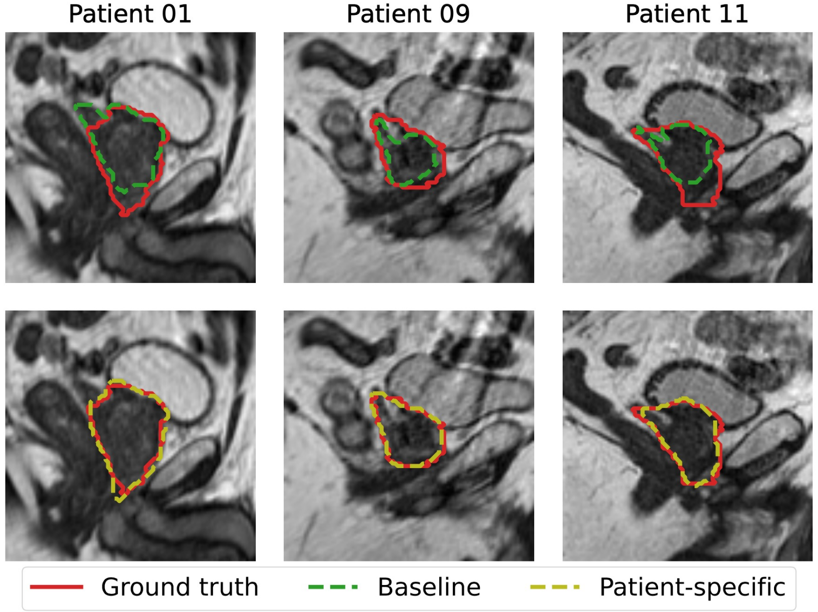
Automatic segmentation is:

- Less intra- and interobserver variability
- Reduce manual segmentation time during Online Adaptation
- **Time efficient**
- **Improve consistency and reproducibility**

Automatic segmentation
Exploit planning knowledge

Patient-specific fine tuning

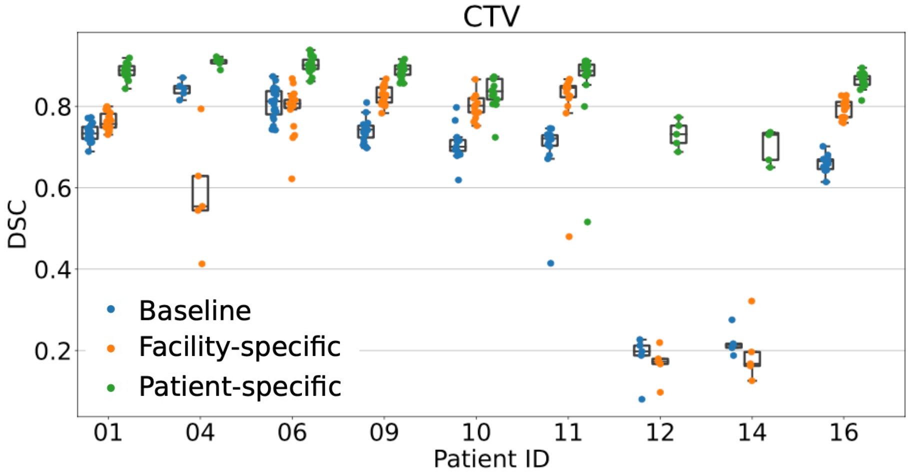




M. Kawula

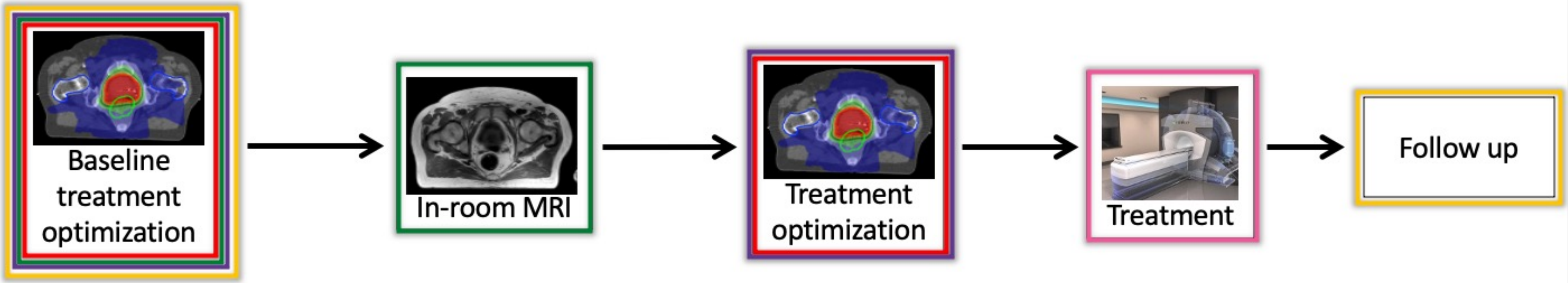
PD Dr. C. Kurz

- Make use of prior information from **patient-specific** planning images for fraction image segmentation



Kawula,...,**Landry**, Kurz. *Under review*

MRgRT workflow
Where can AI help?



Automatic segmentation

Synthetic CT generation

Dose prediction and automatic planning

Motion tracking

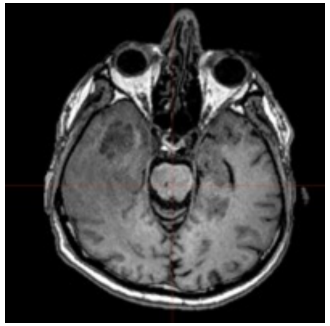
Outcome prediction

Courtesy of G. Landry

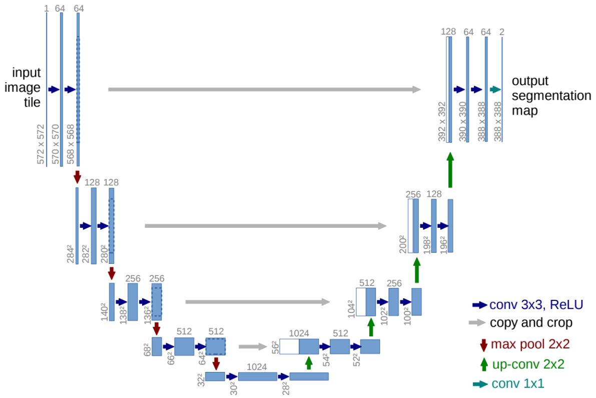
Synthetic CT generation
Electron Denstity map

Neppl, **Landry**, et al. Acta Oncol 2019
Spadea et al. IJROBP 2019

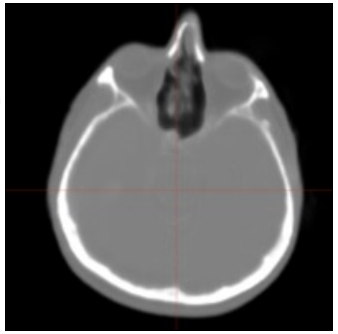
Input → **U-Net** → **Output** ← Loss → **Target**



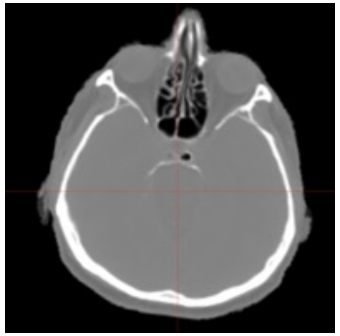
MRI



generic U-net for illustration purposes



sCT



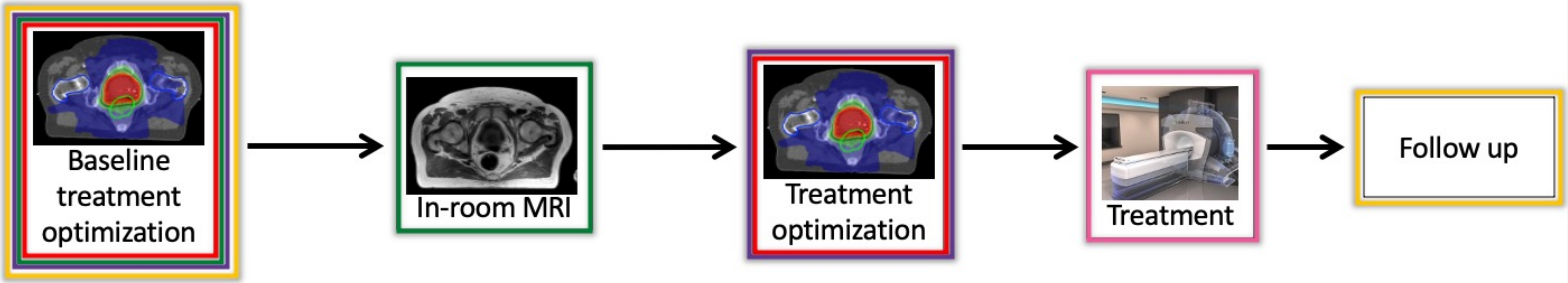
CT

Synthetic CT Generation is:

- ➢ Time saving
- ➢ Less radiation exposure
- ➢ **Allows for a MR-only workflow**
- ➢ Reduces uncertainties of image registration

Courtesy of G. Landry

MRgRT workflow
Where can AI help?



Automatic segmentation

Synthetic CT generation

Dose prediction and automatic planning

Motion tracking

Outcome prediction

Courtesy of G. Landry

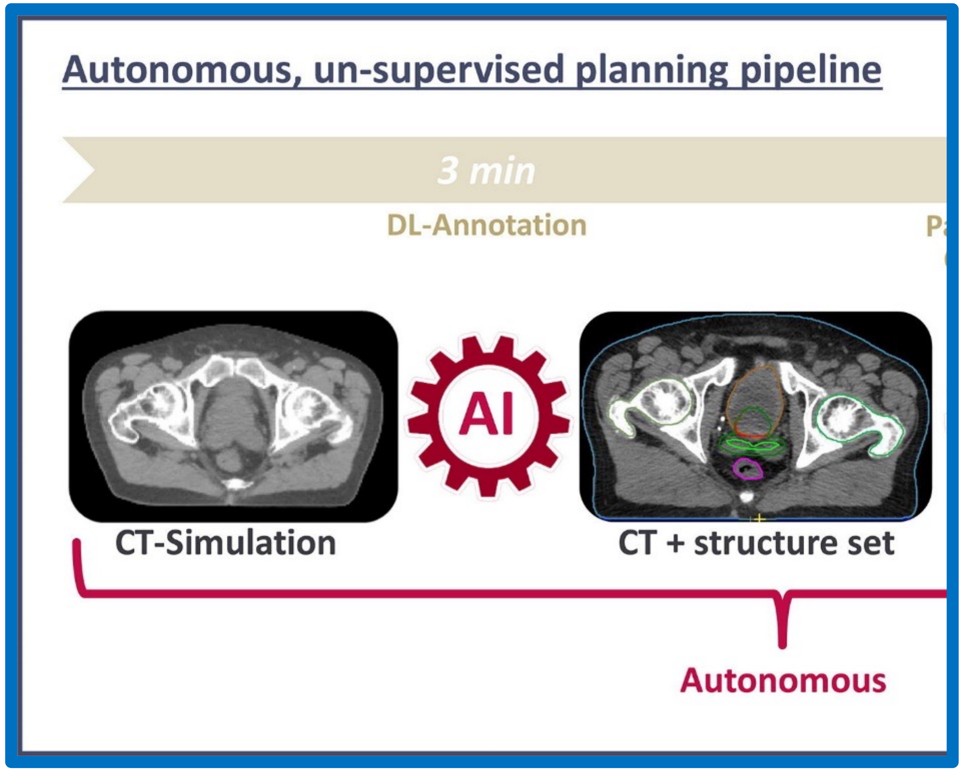
Automatic planning
MRgRT

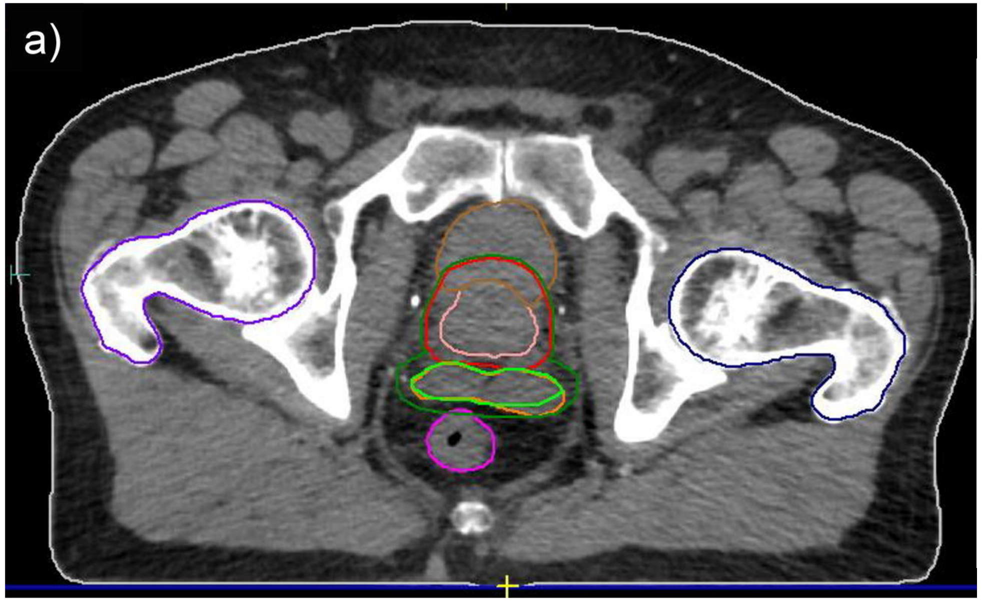
Contents lists available at ScienceDirect
Radiotherapy and Oncology
journal homepage: www.thegreenjournal.com

Original Article

First experience of autonomous, un-supervised treatment planning integrated in adaptive MR-guided radiotherapy and delivered to a patient with prostate cancer

Luise A. Künzel [a,*], Marcel Nachbar [a], Markus Hagmüller [a], Cihan Gani [b], Simon Boeke [b], Daniel Zips [b,c], Daniela Thorwarth [a,c]





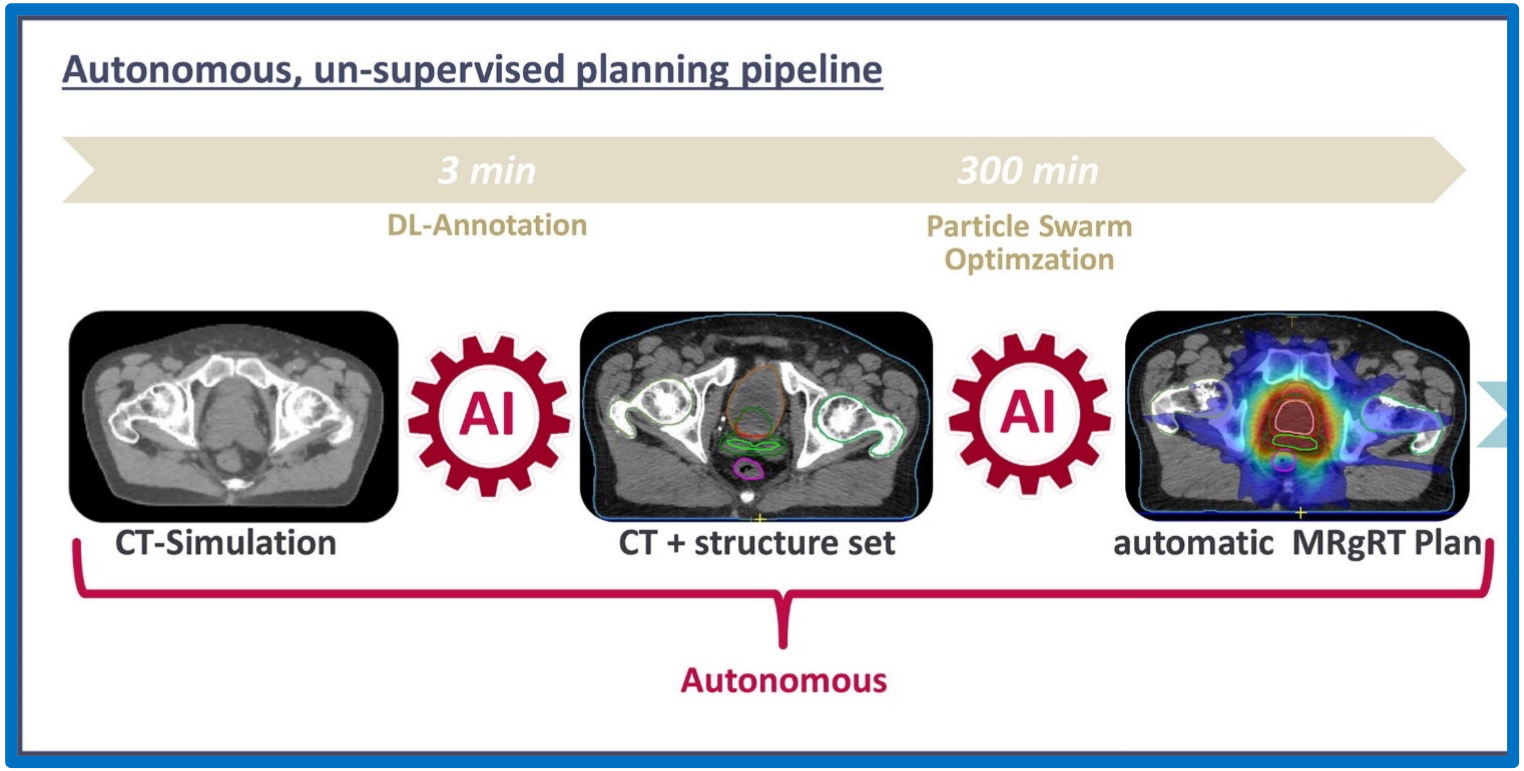
Automatic planning
MRgRT

Contents lists available at ScienceDirect
Radiotherapy and Oncology
journal homepage: www.thegreenjournal.com

Original Article

First experience of autonomous, un-supervised treatment planning integrated in adaptive MR-guided radiotherapy and delivered to a patient with prostate cancer

Luise A. Künzel [a,*], Marcel Nachbar [a], Markus Hagmüller [a], Cihan Gani [b], Simon Boeke [b], Daniel Zips [b,c], Daniela Thorwarth [a,c]

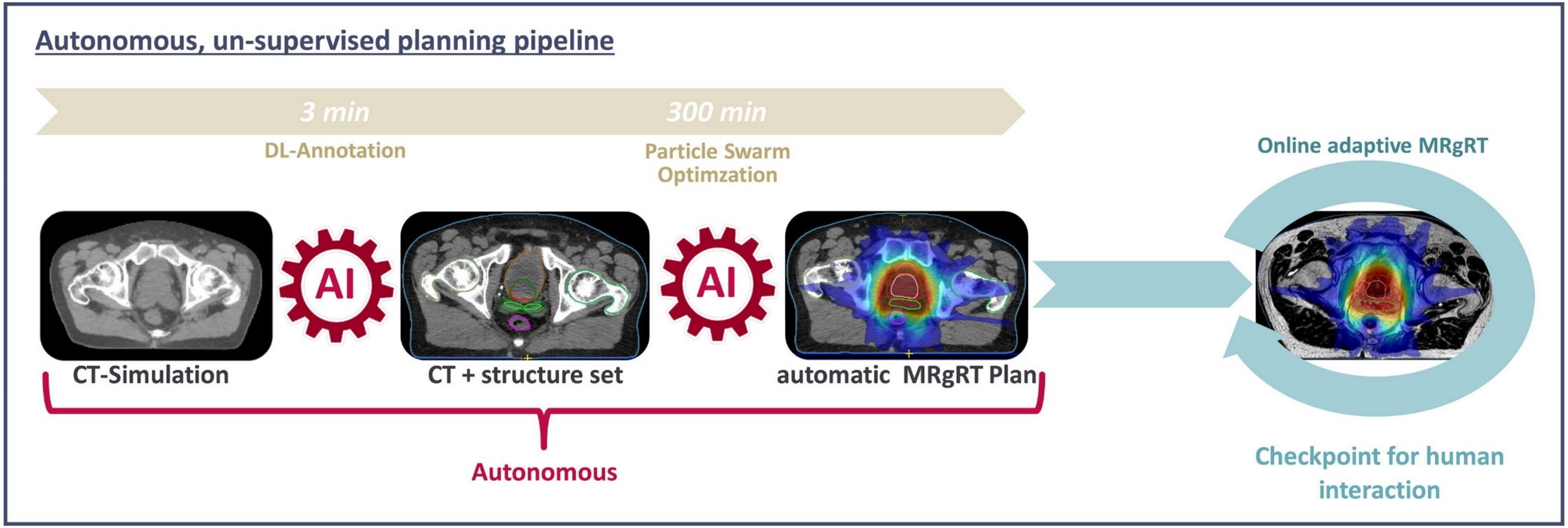


Automatic planning
MRgRT

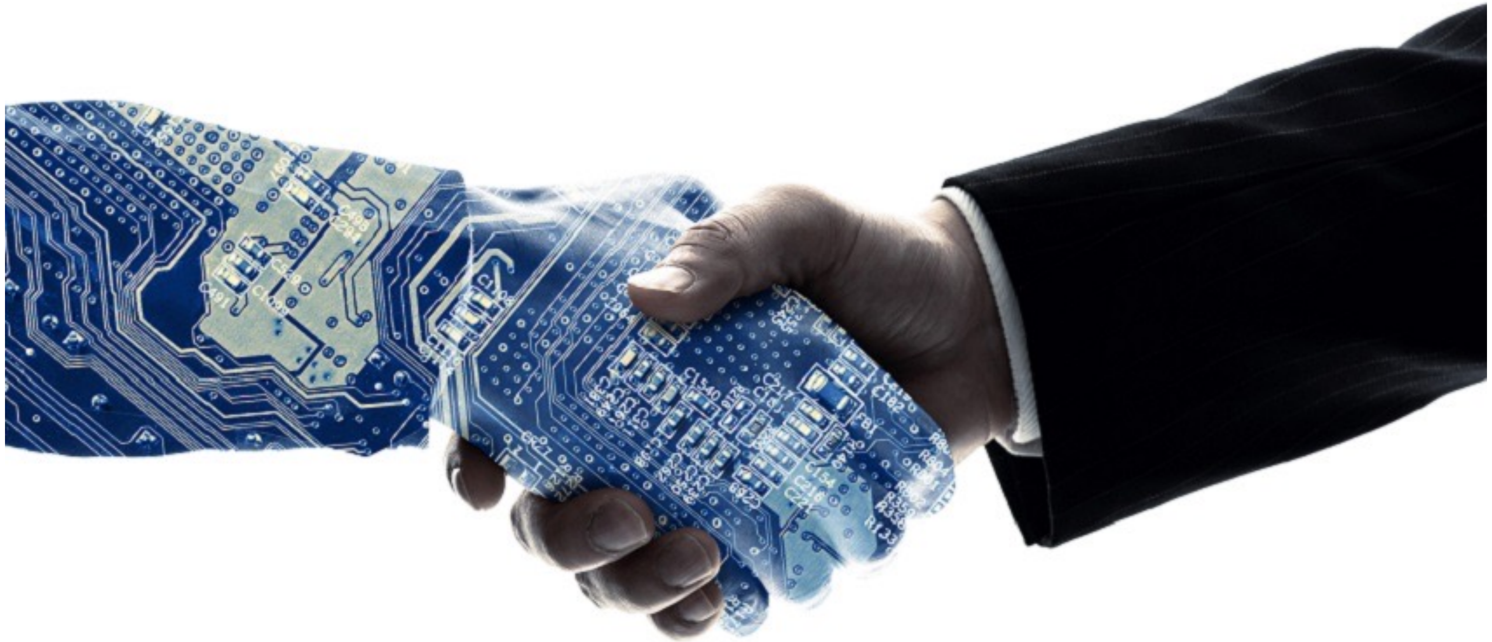
Contents lists available at ScienceDirect
Radiotherapy and Oncology
journal homepage: www.thegreenjournal.com
ELSEVIER
Original Article

First experience of autonomous, un-supervised treatment planning integrated in adaptive MR-guided radiotherapy and delivered to a patient with prostate cancer

Luise A. Künzel[a,*], Marcel Nachbar[a], Markus Hagmüller[a], Cihan Gani[b], Simon Boeke[b], Daniel Zips[b,c], Daniela Thorwarth[a,c]



Can we trust AI?
MRgRT



Quality Assurance for AI-Based Systems: Overview and Challenges (Introduction to Interactive Session)

Michael Felderer & Rudolf Ramler

Stepwise implementation

AI

Phase 4: Fully automated.
Humans only define their goal, the right means as well as execution of those is performed by computers.

Phase 3: Partly automated.
Systems take over simple tasks and actively prevent common errors that would otherwise require human intervention.

Phase 2: Assistance Function.
Systems provide guidance and passively prevent common errors.

Phase 1: Decoupling.
Manual choice of means, indirect link to physical world.

Phase 0: It works.
Manual choice of means, usually physical work.

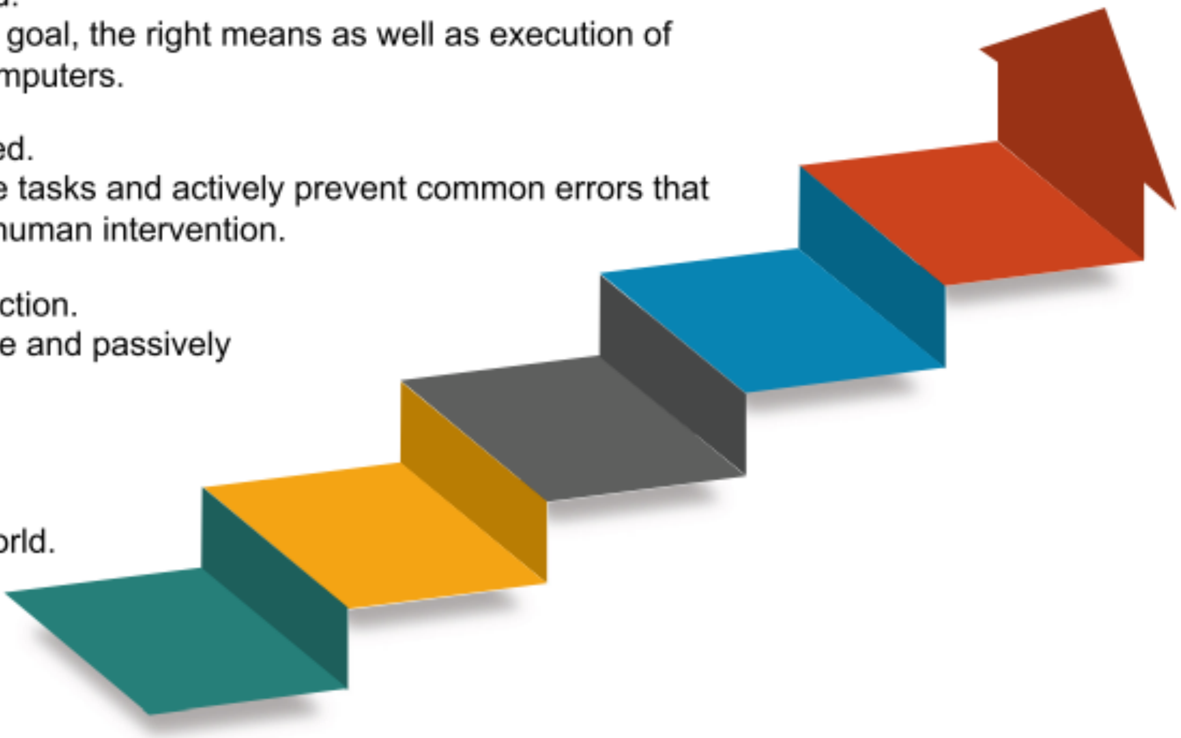


Fig. 1. Automation phases

Stepwise implementation
MRgRT

Article
Architectural Framework for Exploring Adaptive Human-Machine Teaming Options in Simulated Dynamic Environments

Azad M. Madni * and Carla C. Madni

- **Open Questions:**
  - Can AI **replace humans**? Is AI a **threat to human jobs**?
    - Changing in roles: from operator to monitor/supervisor
    - Managaging of automation
  - Will AI **impact our education/training**?
    - Reduction of human skills/competencies →
      human interventions still possible?
  - Can we **trust and rely on AI**?
    - Transparency in AI operations affects human trust
    - Over-reliance vs under-reliance
    - **QA**
  - Is AI a **tool** or a **teammate**?
    - Complex human-machine interaction

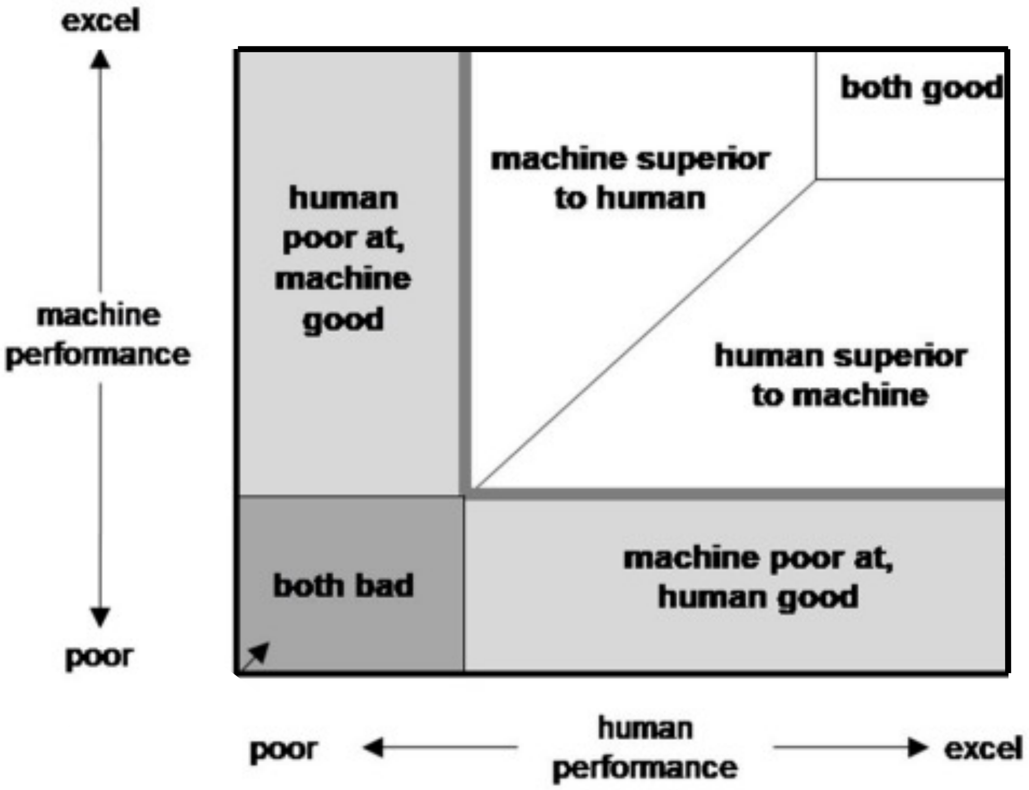
Human-Machine Teams
MRgRT

- Shared task execution

Article

Architectural Framework for Exploring Adaptive Human-Machine Teaming Options in Simulated Dynamic Environments

Azad M. Madni * and Carla C. Madni

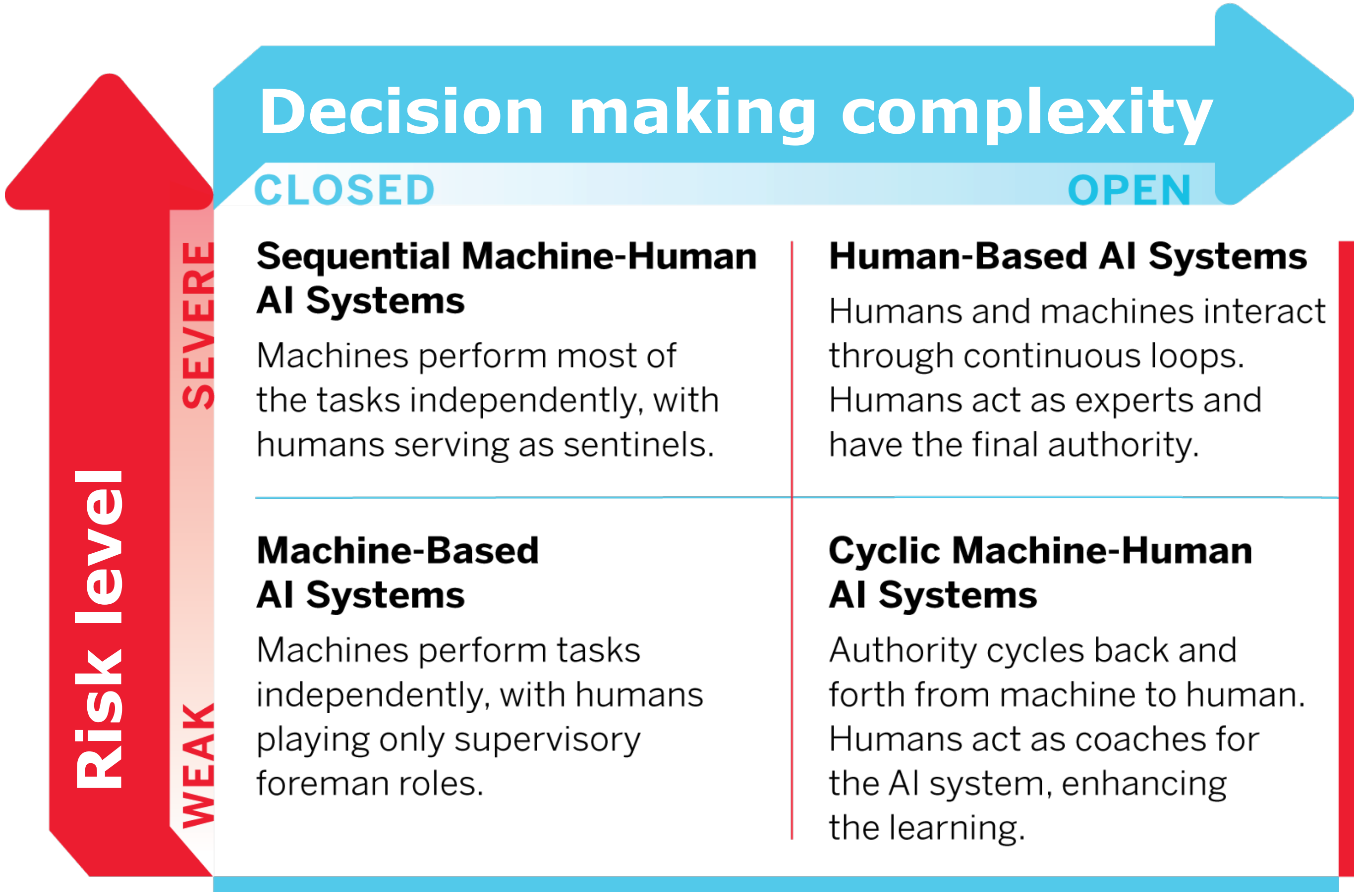


Human-Machine Teaming
Decision making

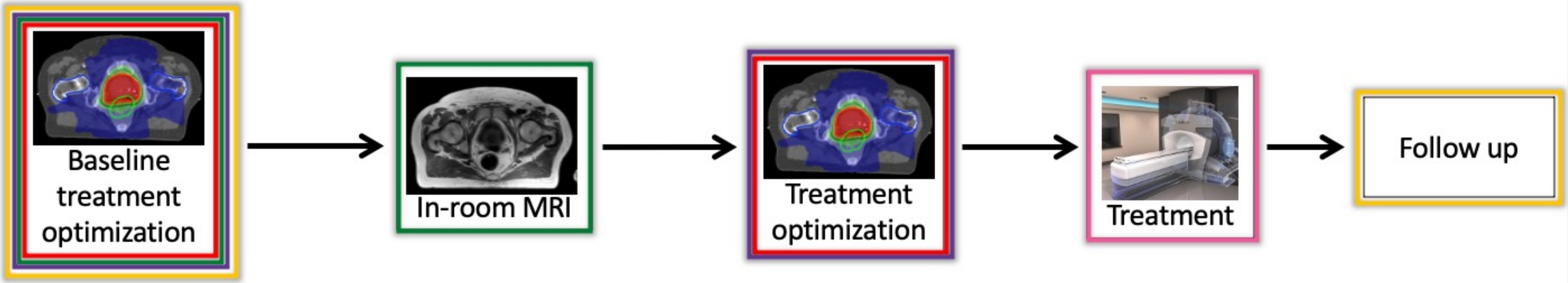
INNoVATION STRATeGIES

What does the human face of AI look like?

By Maria Jesus Saenz, Elena Revilla and Cristina Simon



MRgRT workflow
Where can AI help?



Automatic segmentation

Synthetic CT generation

Dose prediction and automatic planning

Motion tracking

Outcome prediction

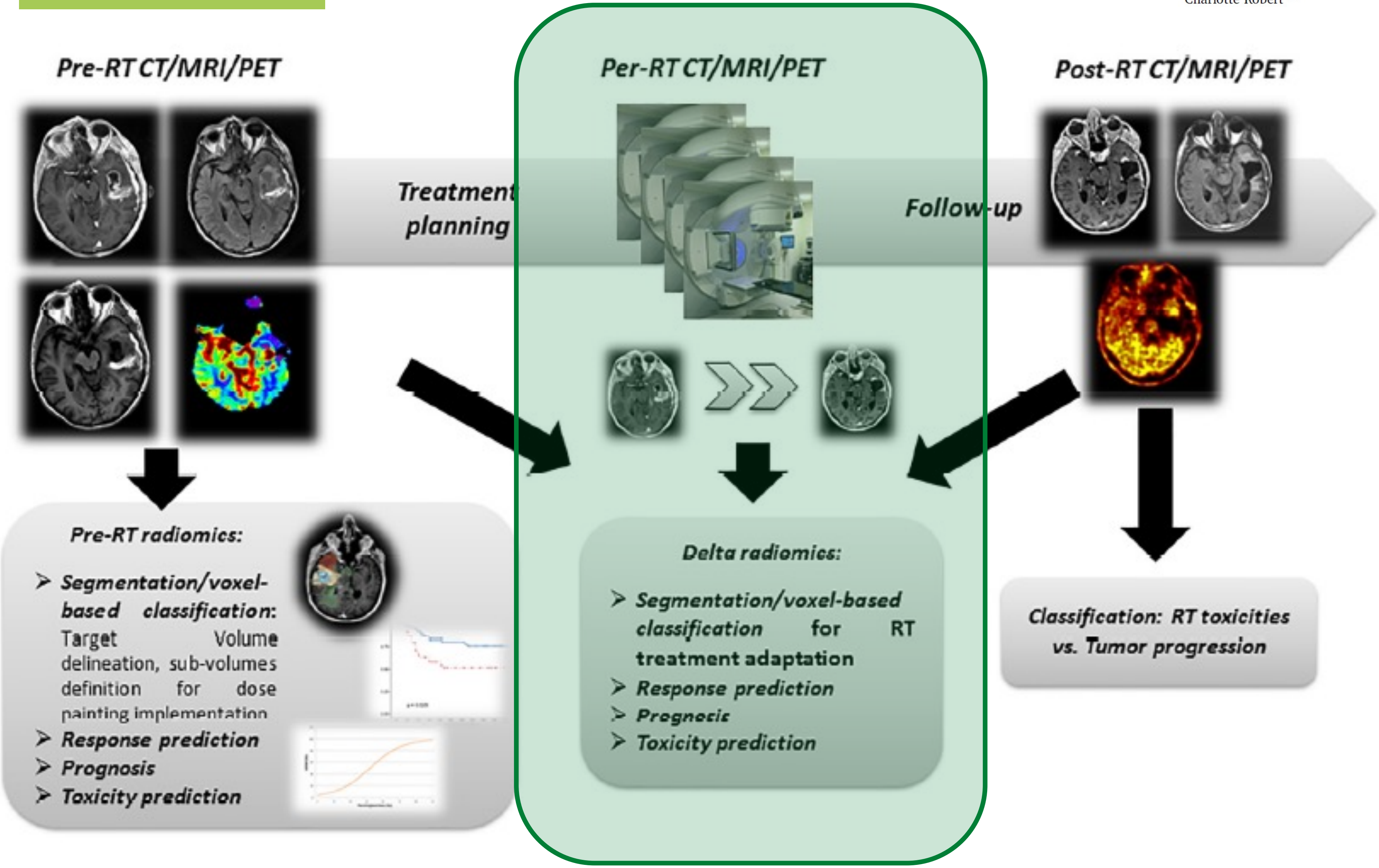
Courtesy of G. Landry

Outcome prediction
Radiomics


Contents lists available at ScienceDirect
Methods
journal homepage: www.elsevier.com/locate/ymeth

Reinventing radiation therapy with machine learning and imaging biomarkers (radiomics): State-of-the-art, challenges and perspectives

Laurent Dercle[a,1], Theophraste Henry[b,c,1], Alexandre Carré[b,d], Nikos Paragios[e], Eric Deutsch[b,d], Charlotte Robert[b,d,*]



Predictive Models:

- Early treatment response prediction
- Toxicity prediction

Outcome prediction

Early treatment response

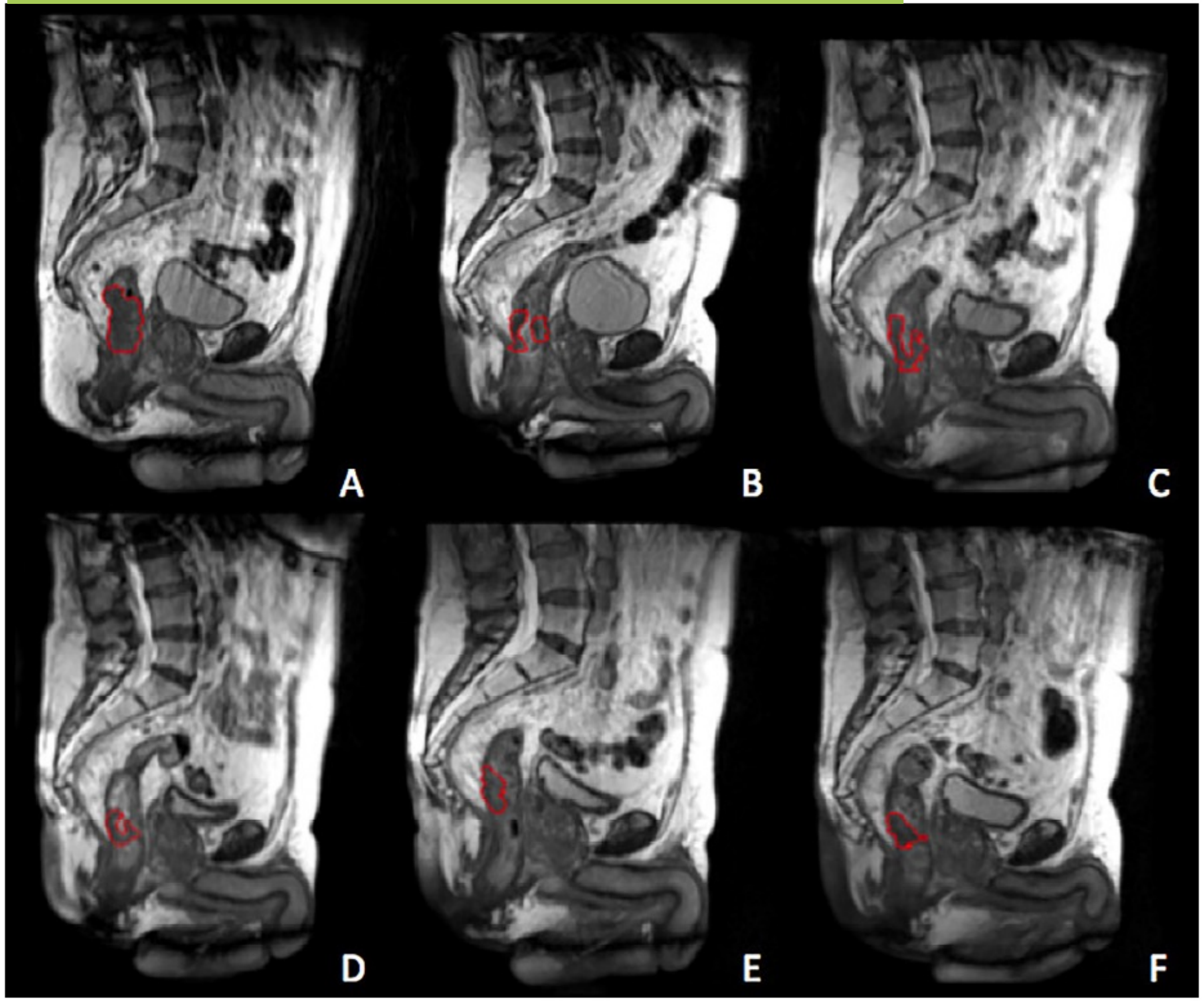


FIGURE 1 | Gross tumour volum (GTV) delineated at the treatment simulation **(A)** and at the different treatment fractions selected for the delta-radiomics analysis, corresponding to BED levels of 13 Gy **(B)**, 26 Gy **(C)**, 40 Gy **(D)**, 54 Gy **(E)** and 67 Gy **(F)**. The GTV is represented by the red contour.

RESEARCH Open Access

Applicability of a pathological complete response magnetic resonance-based radiomics model for locally advanced rectal cancer in intercontinental cohort

Luca Boldrini[1], Jacopo Lenkowicz[1], Lucia Clara Orlandini[2], Gang Yin[2], Davide Cusumano[1], Giuditta Chiloiro[1], Nicola Dinapoli[1], Qian Peng[2*], Calogero Casà[1], Maria Antonietta Gambacorta[1], Vincenzo Valentini[1] and Jinyi Lang[2]

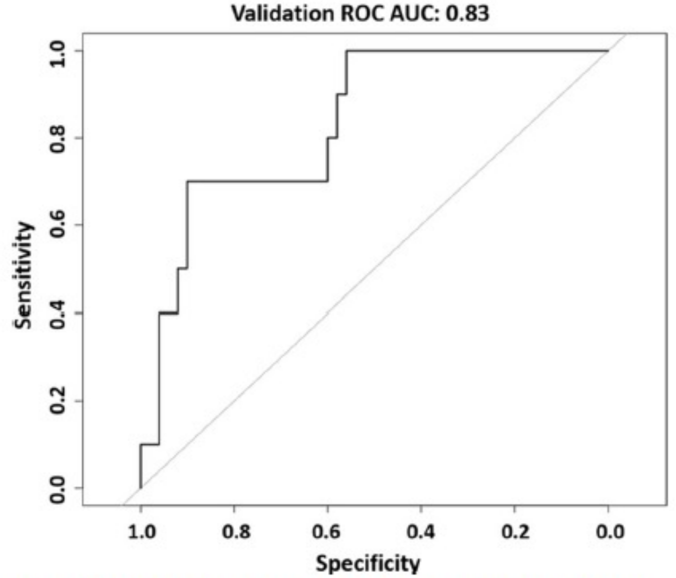
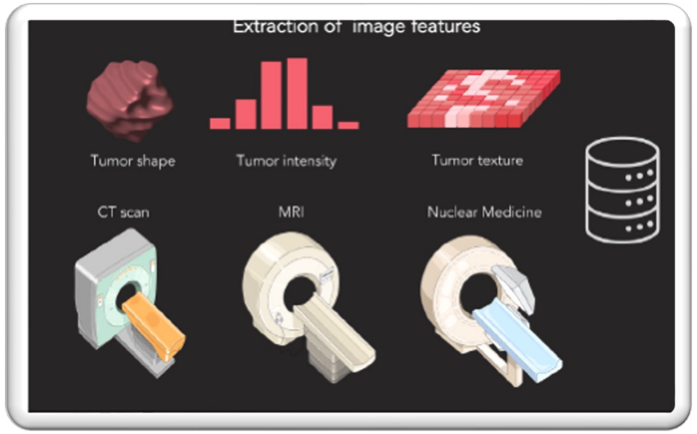


Fig. 1 ROC curve obtained for the entire cohort of intercontinental patients

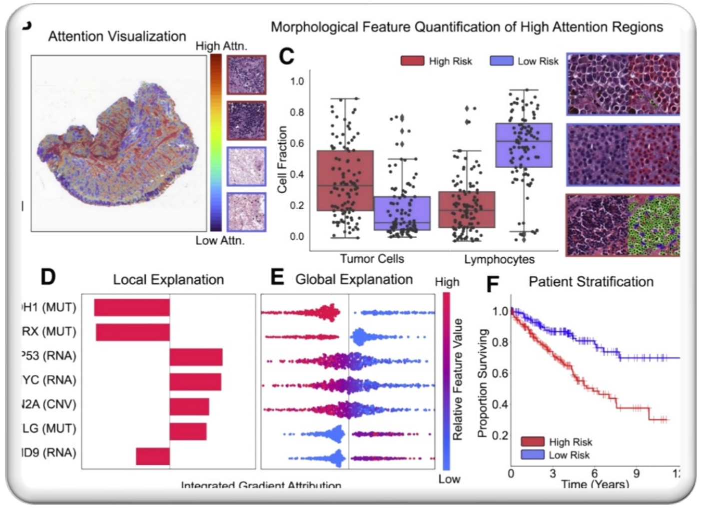
LMU KLINIKUM

Outcome prediction
Individualized radiotherapy

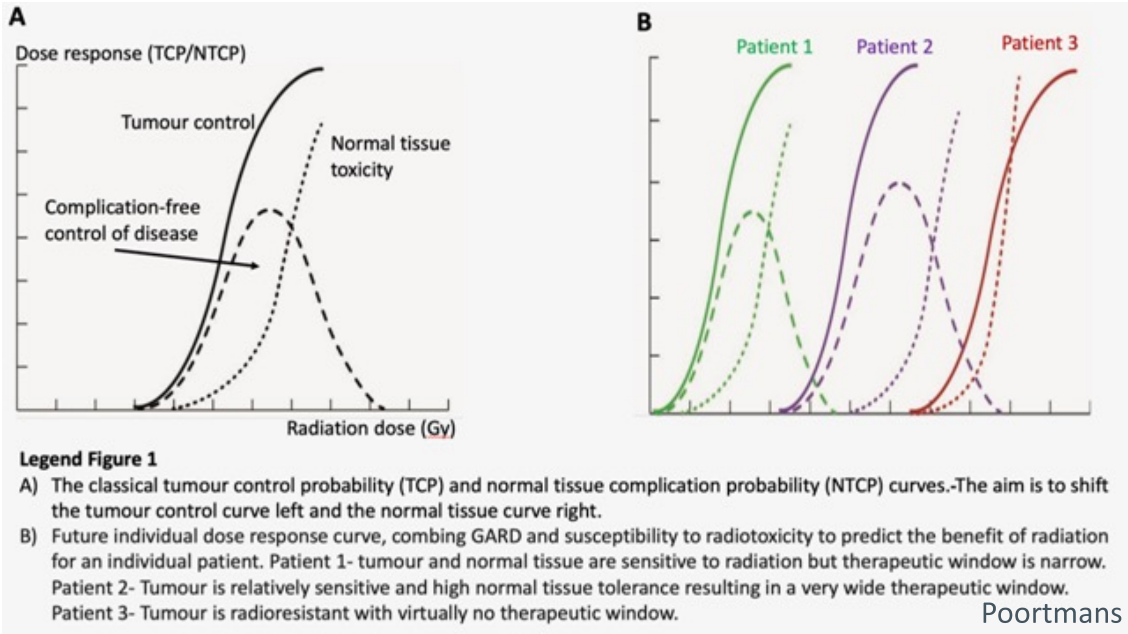


Imaging Biomarkers

+



Clinical/ Biological/ Genomic Biomarkers



Predictive Models:

- Individualized treatments
- Fully exploit **individual therapeutic window**

AI in cancer therapy
Perspective on MRgRT

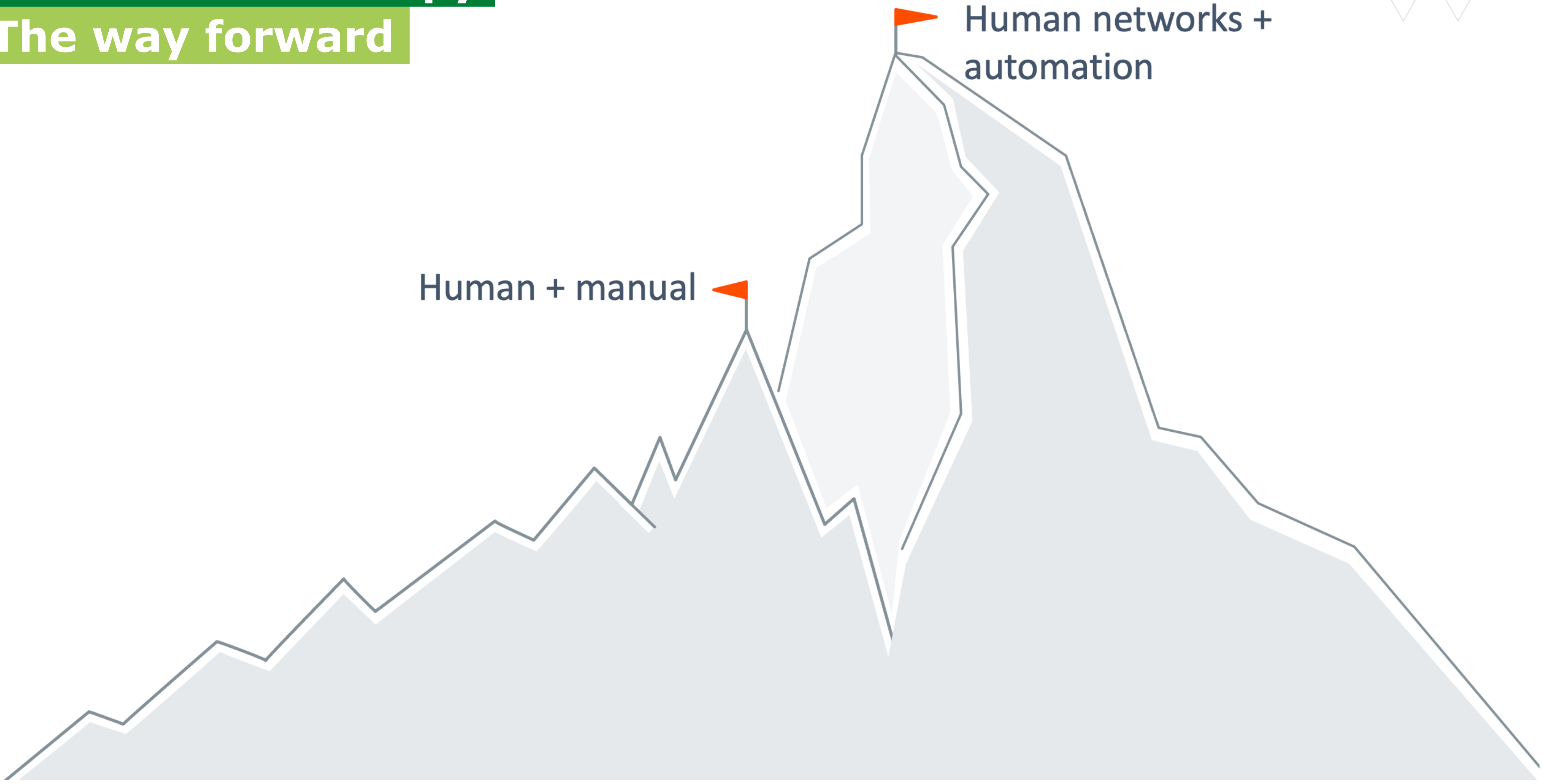
LMU KLINIKUM

- **AI can support MRgRT:**
  - **AI is a tool** & can increase **quality, standardization and acceleration** of the different treatment steps
  - AI algorithms are applicable to **almost all aspects** of the MRgRT workflow
  - Autosegmentation is one of the most visible applications
  - AI can provide predictive and prognostic information on outcome and FU

AI in cancer therapy
The way forward

AI in cancer therapy
The way forward

AI in cancer therapy
The way forward



LMU KLINIKUM

LMU KLINIKUM
Gemeinsam. Fürsorglich. Wegweisend.

Thank you
For your attention!

@stef_corradini

Stefanie Corradini

Stefanie.corradini@med.lmu.de