The Ghost in the Shell: Understanding How AI can Improve Adaptive Radiation Therapy Workflows

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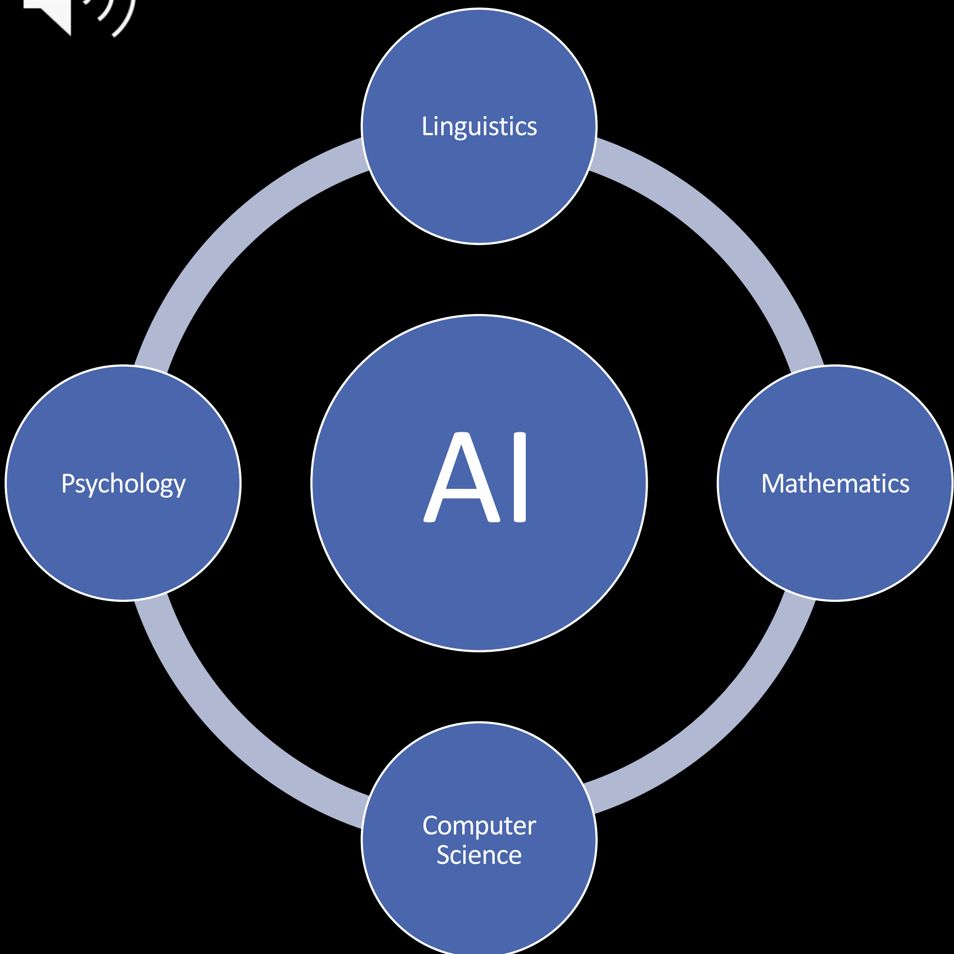


Artificial Intelligence

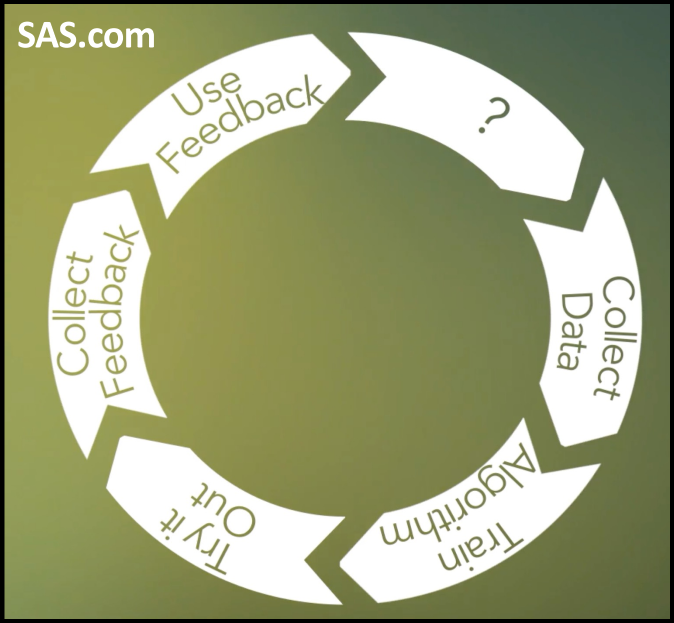
Alan Turing: ~ 1947
John McCarthy: 1956

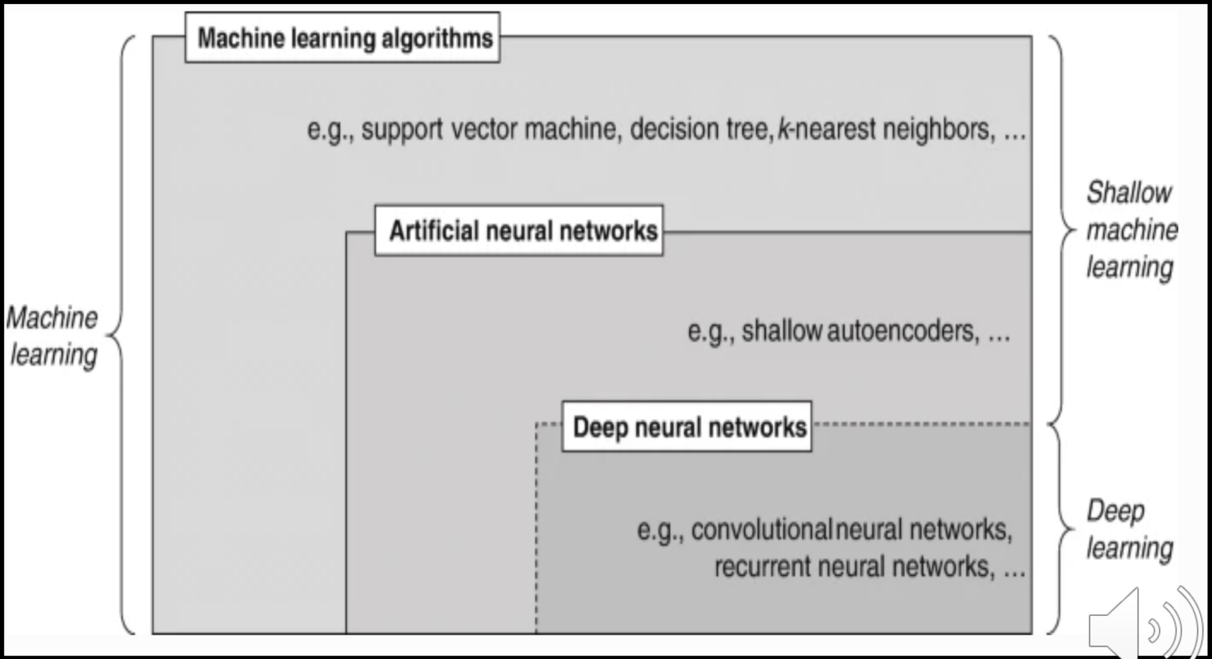
- *“AI is concerned with building machines that can act & react appropriately, adapting their response to the demands of the situation. Such machines should display behavior comparable with that considered to require intelligence in humans.”* Finlay & Dix, 1996

Subsets of AI

- **Early**: Hard-coded, knowledge-based approach

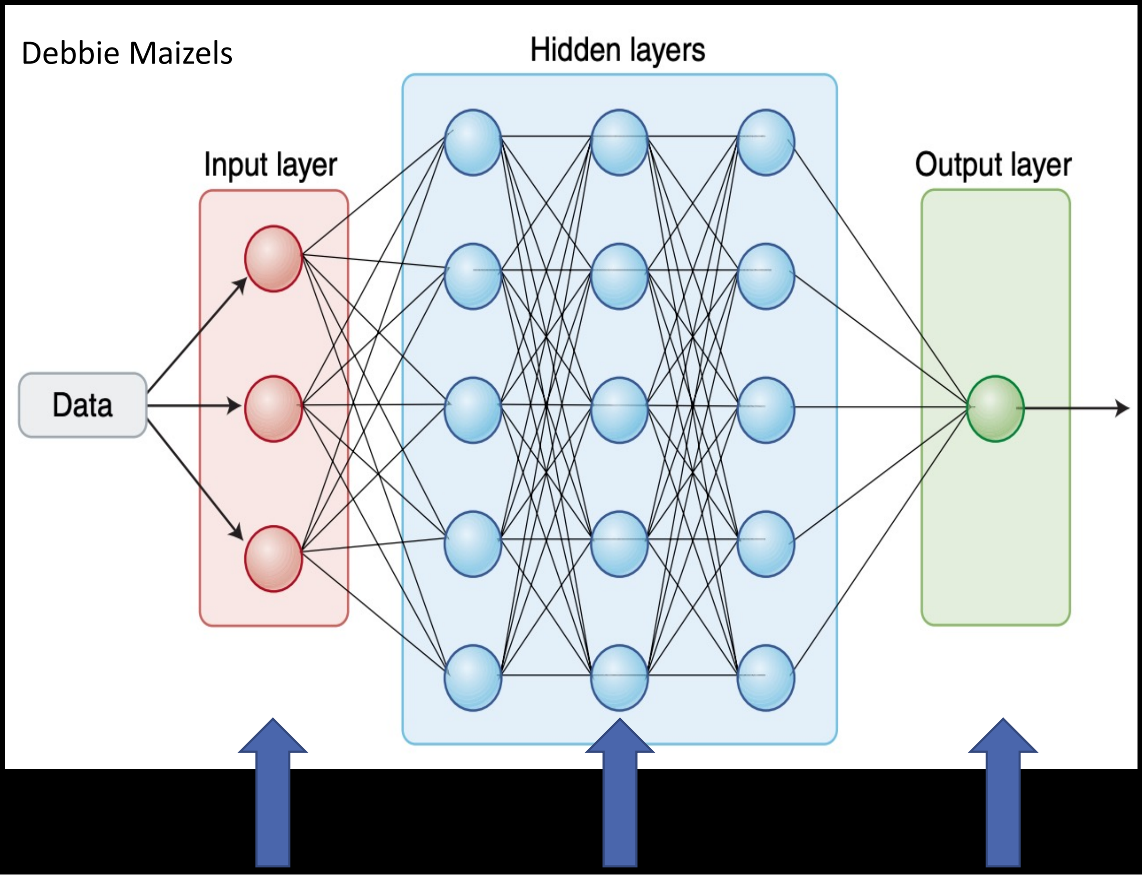
ML Life Cycle





Janiesch, Zschech, & Heinrich, 2021

Deep Neural Networks



Input Layer:
Required
Accepts incoming data
# of Neurons = # of training data features + 1

Hidden Layer:
Not visible to external systems
>1 hidden layer: Deep learning
Transform and model data
"Secret Sauce"
More layers, more computation time

Output Layer:
Required
Accepts data from prior layer
Produces output/result

AI in Our Everyday Use

facebook

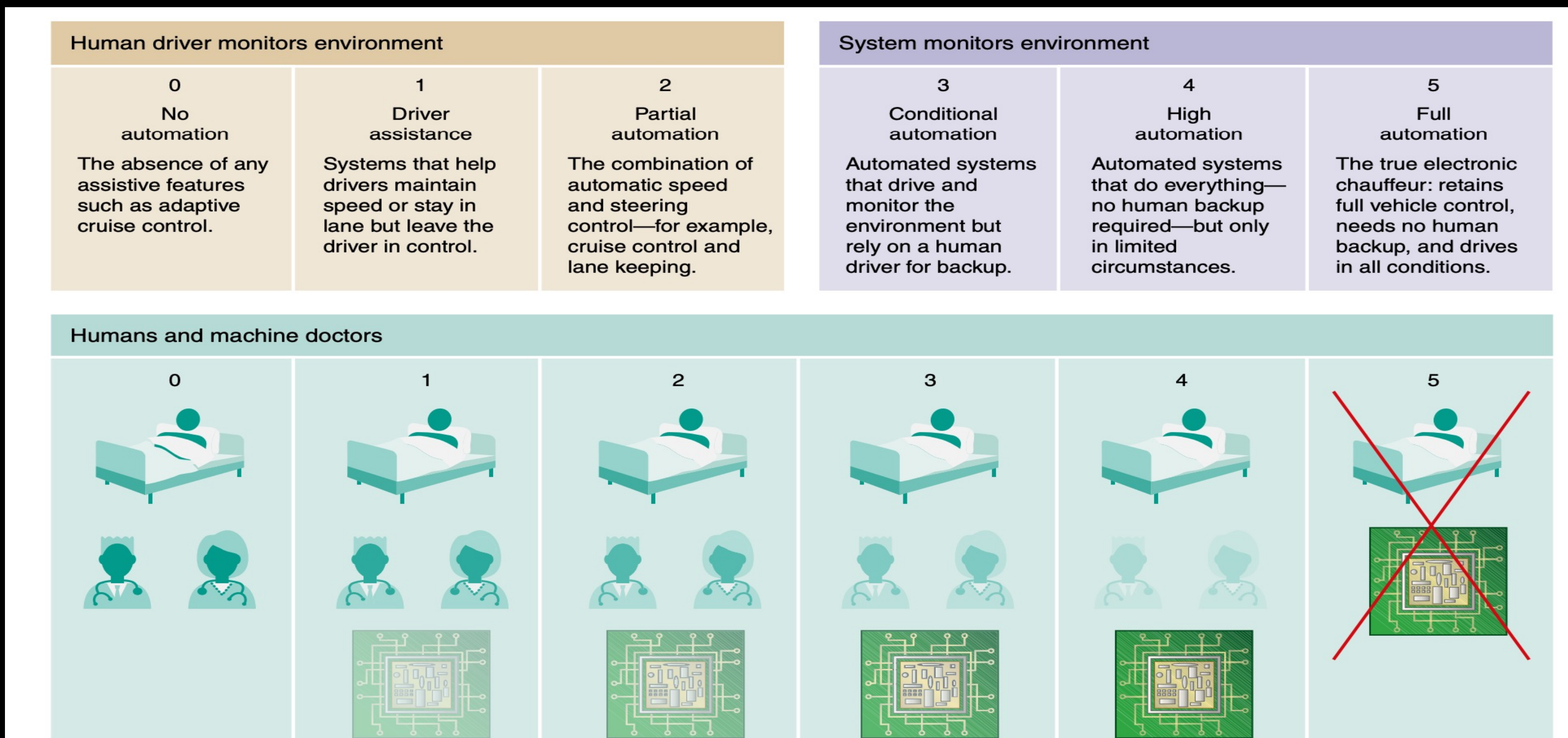
NETFLIX

Google

Word Excel PowerPoint Outlook

OneNote Publisher Access

Comparison to Medicine



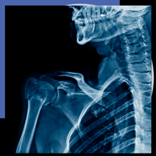
Unlikely

Debbie Maizels

Recent Usage of AI in Medicine

- Chest X-Rays
- CT for head trauma, stroke
- Mammography for density

Radiology

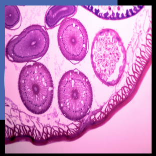


- Electrocardiogram
- Echocardiogram: ejection fraction
- Atrial Fibrillation

Cardiovascular

- Breast cancer & Mets
- Lung Cancer
- Brain Tumors

Pathology



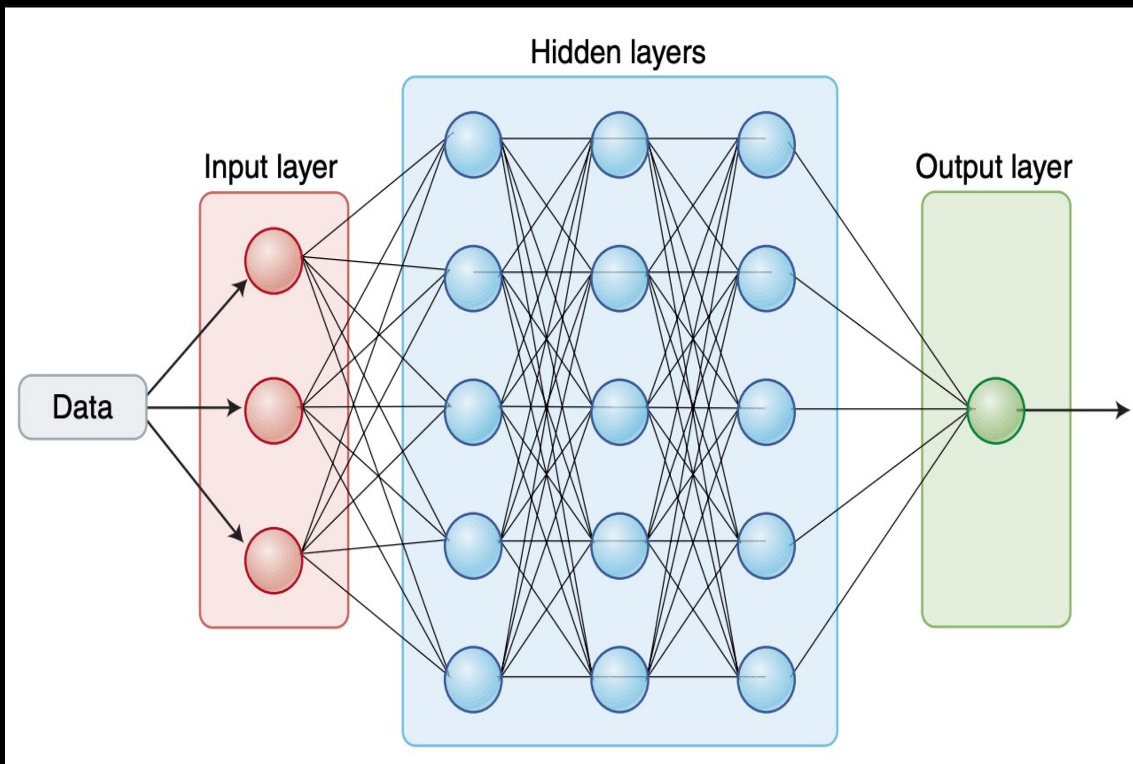
- Diabetic Retinopathy
- Macular Degeneration
- Retinal Disease

Opthalmology

<u>What about AI in radiation therapy?</u>

"The impact of AI on adaptive therapy has the potential to be very significant…" (K. Brock, 2019)

Why Medicine/MD’s may be Reluctant about AI



“Blackbox”

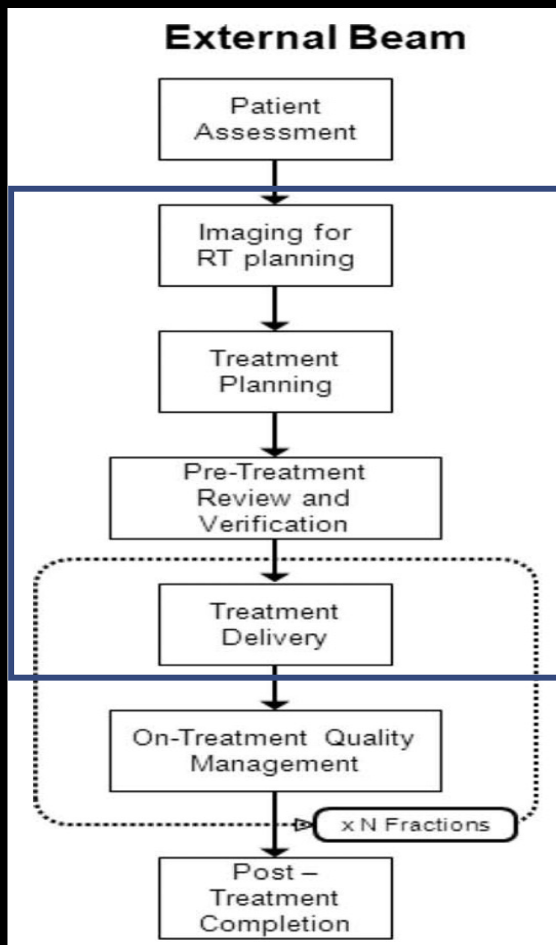
Litigation

Security Risk

Data Bias

Traditional Planning Workflow

1 time



Ford et al., 2012

Emergency/Urgent Cases: Hours
Standard: 3-5 days
Complex: 5+ days

Changes During Therapy

Slow Changes

- Weight loss
- Tumor Changes

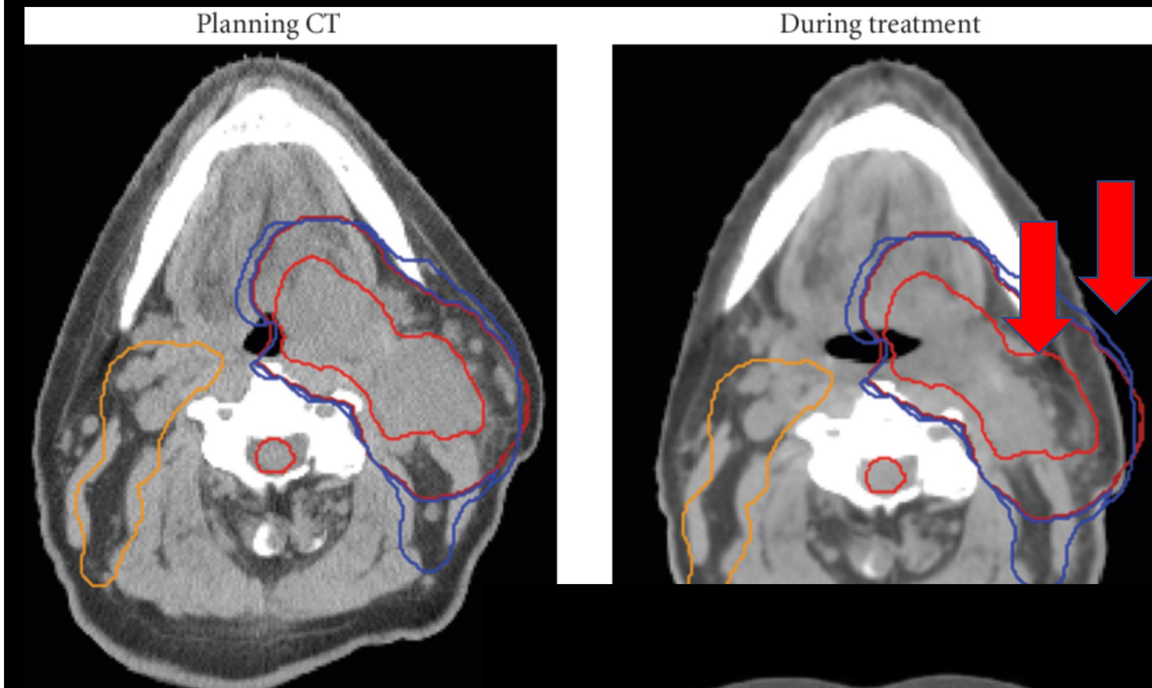
Peristaltic Movement

- Esophagus
- Colon

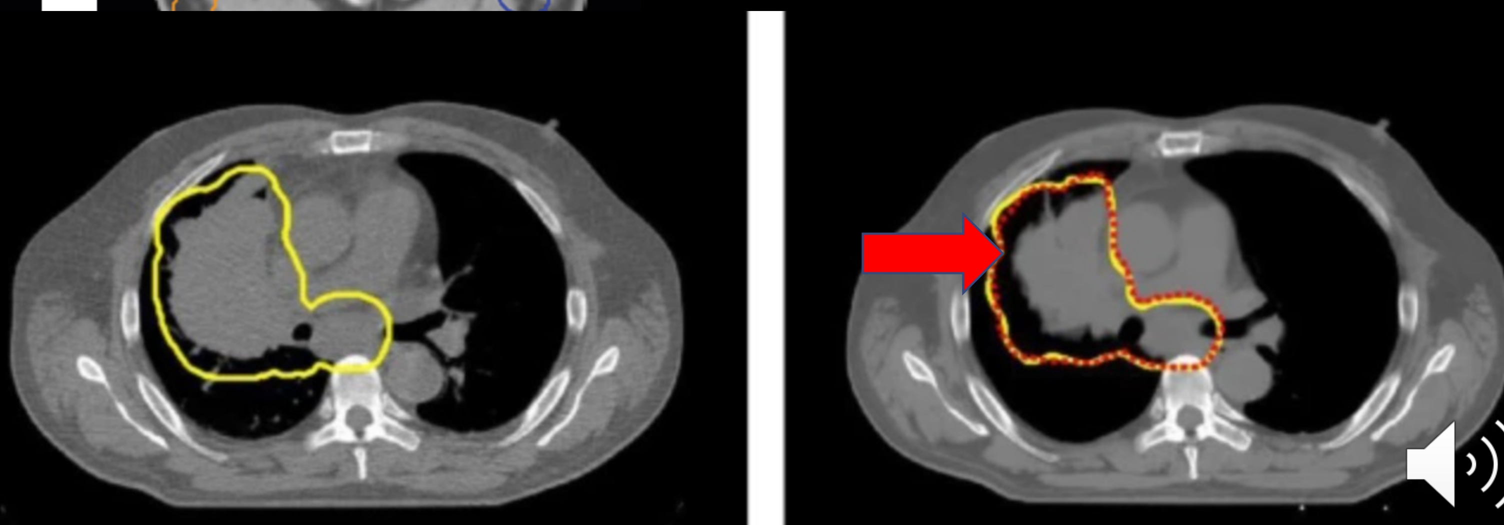
Tumor/OAR Changes

- Motion trajectory
- Change in relative position

Tumor Shrinkage

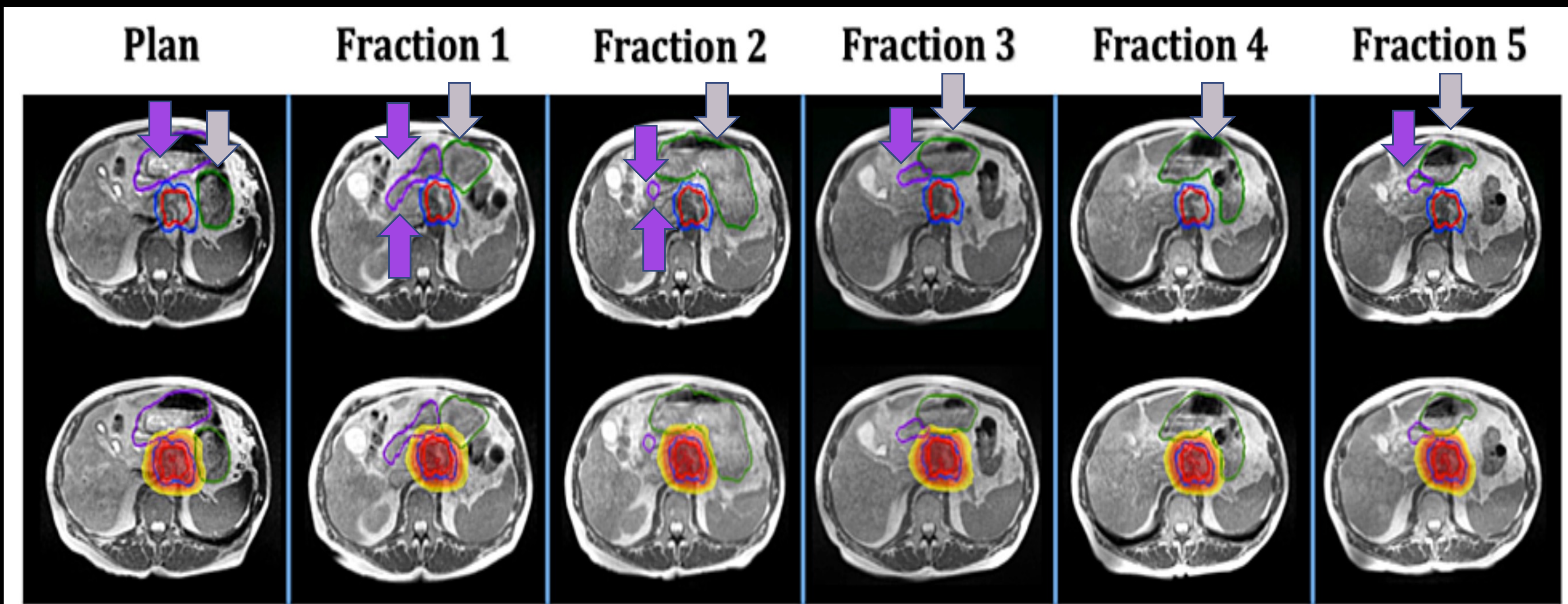


Schwartz & Dong, 2011

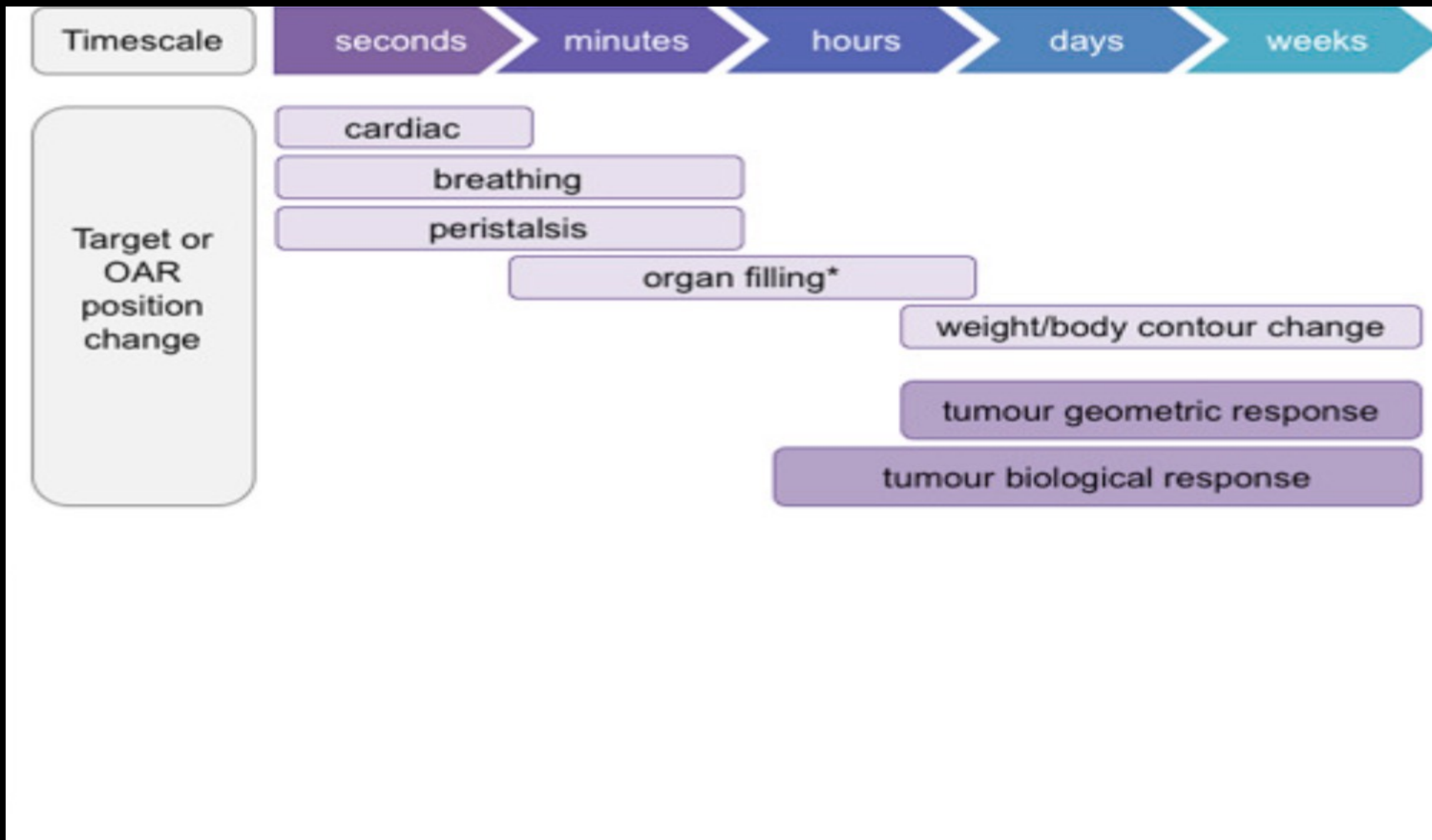


Chen et al., 2020

Inter-fractional Anatomical Change



Luterstein et al., 2018



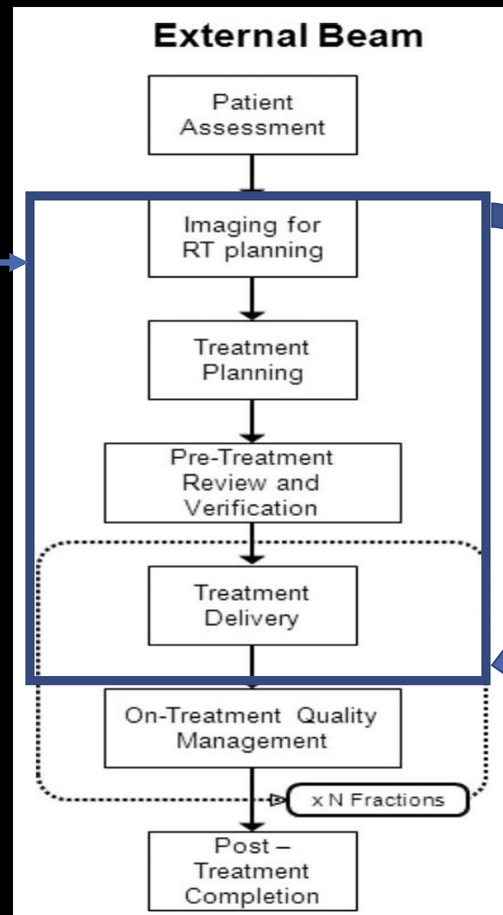
Hunt et al., 2018

3 Adaptive Timepoints

Off-Line

On-Line

Real-Time

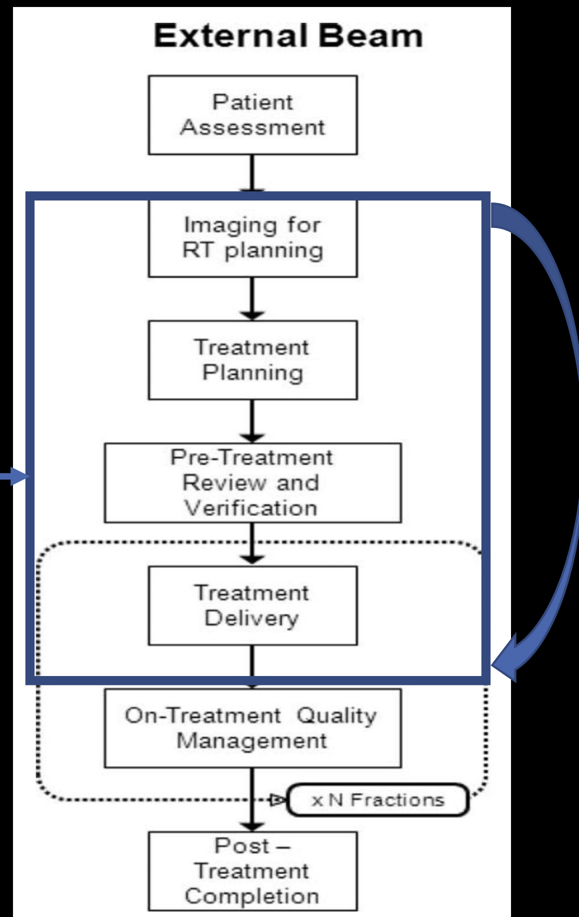


Ford et al., 2012

- Days for Process
- Tx may continue
- Limited number of times
- Best for slow changes (weight loss)

3 Adaptive Timepoints

- Off-Line
- On-Line
- Real-Time

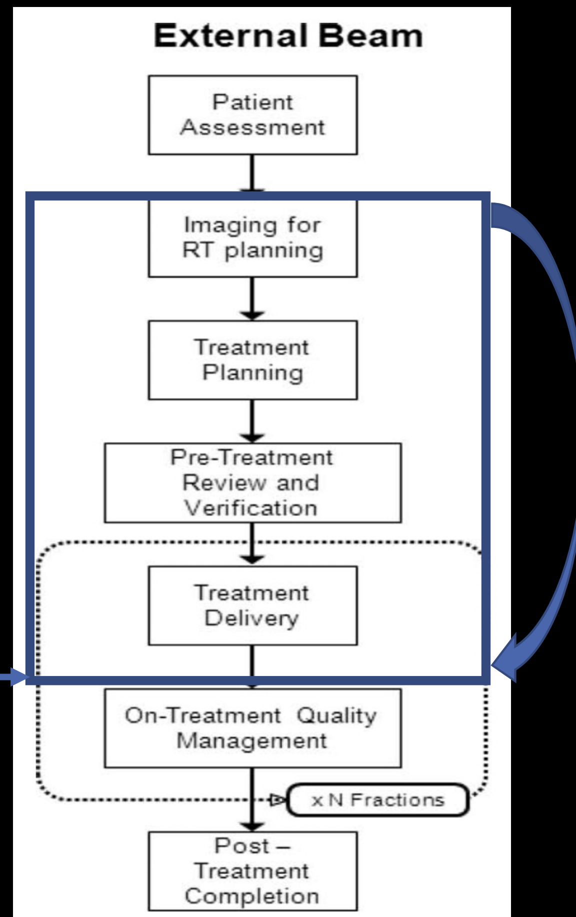


Ford et al., 2012

- ~ 20-30 min
- Tx after the process
- Can occur daily
- Best for more frequent changes (internal anatomy changes)

3 Adaptive Timepoints

- Off-Line
- On-Line
- Real-Time

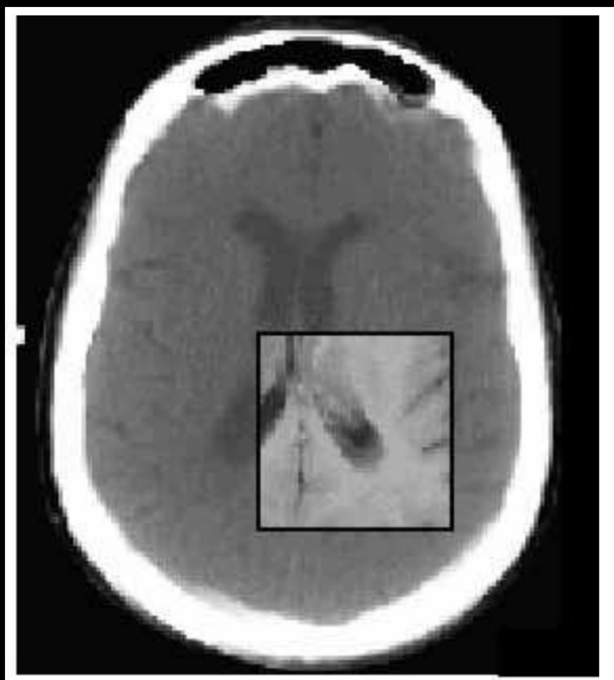


Ford et al., 2012

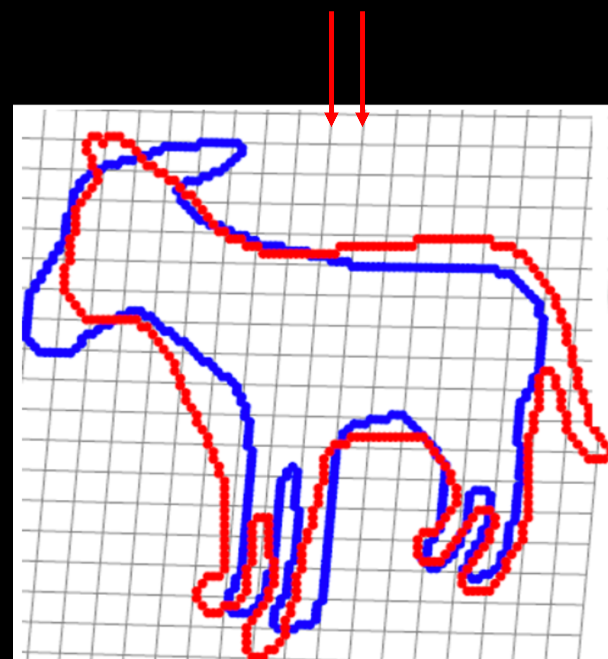
- Seconds-moments
- Tx during adaptation
- Can occur daily
- Best for rapid changes (tumor trajectory, cardiac motion)

How can we compress all of this into minutes?

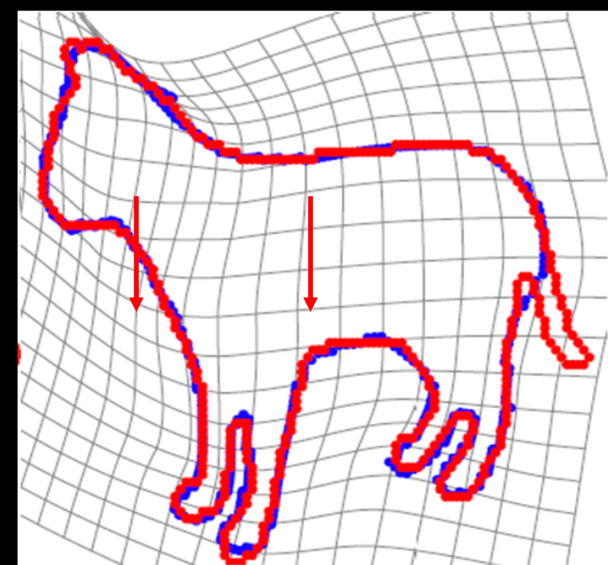
Image Registration & Fusion



Kessler & Li



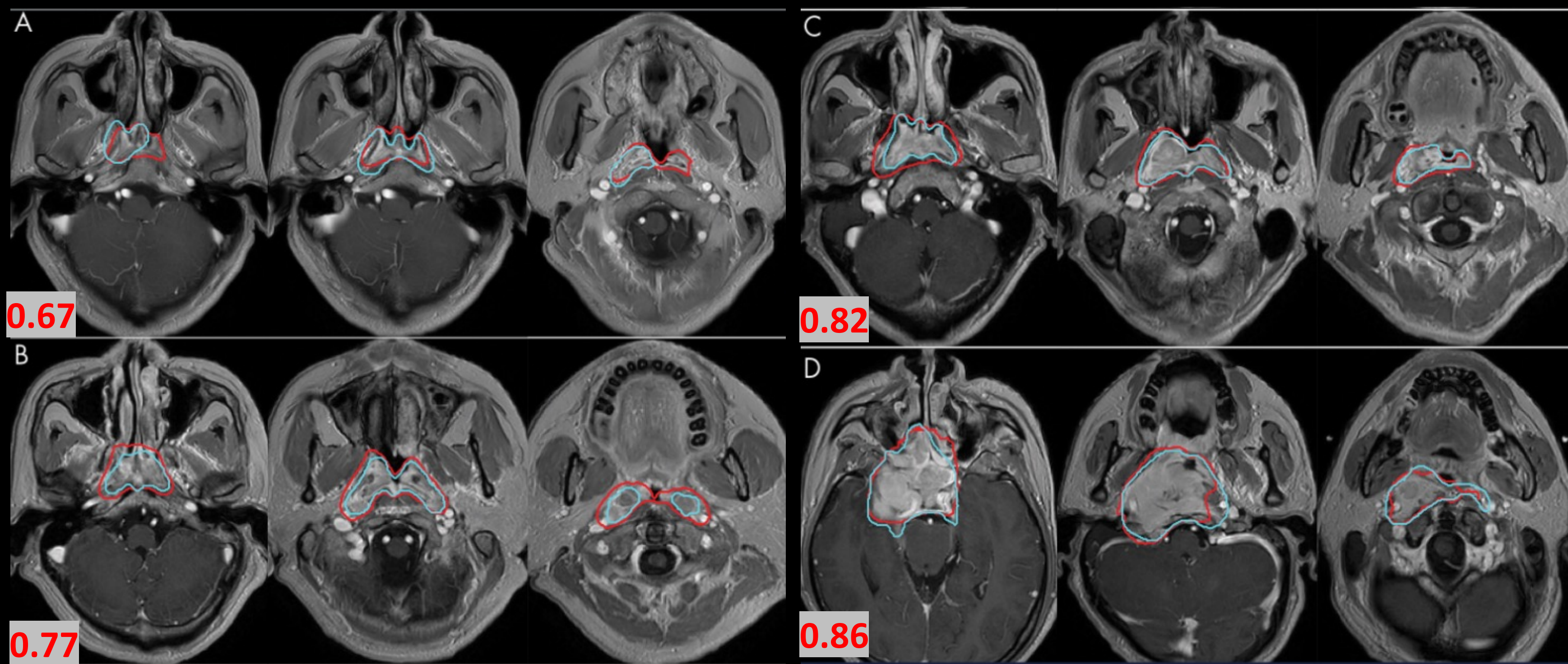
Rigid Fusion



Deformable Fusion

Rouhani & Sappa, 2012

Automated Contouring

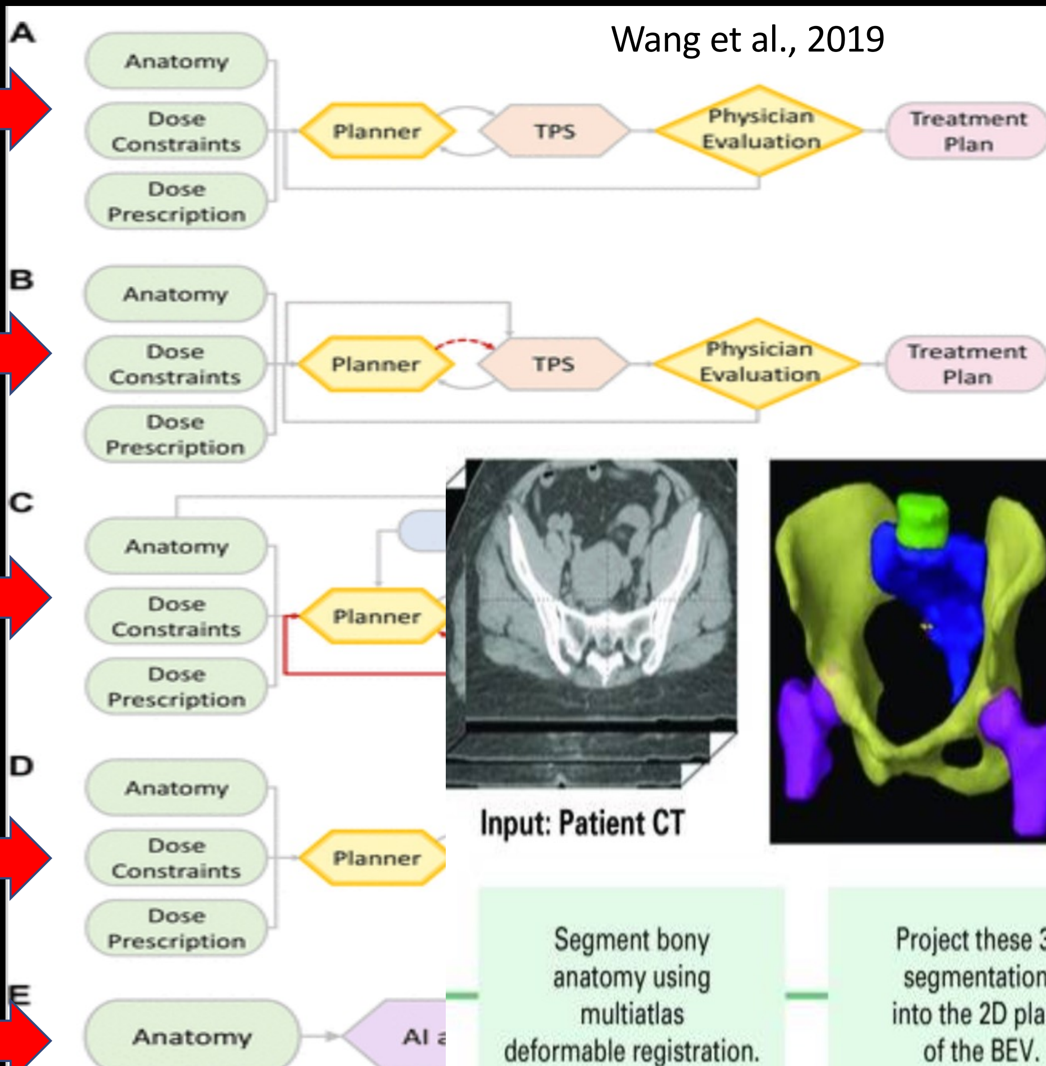


Dice Similarity Coefficients

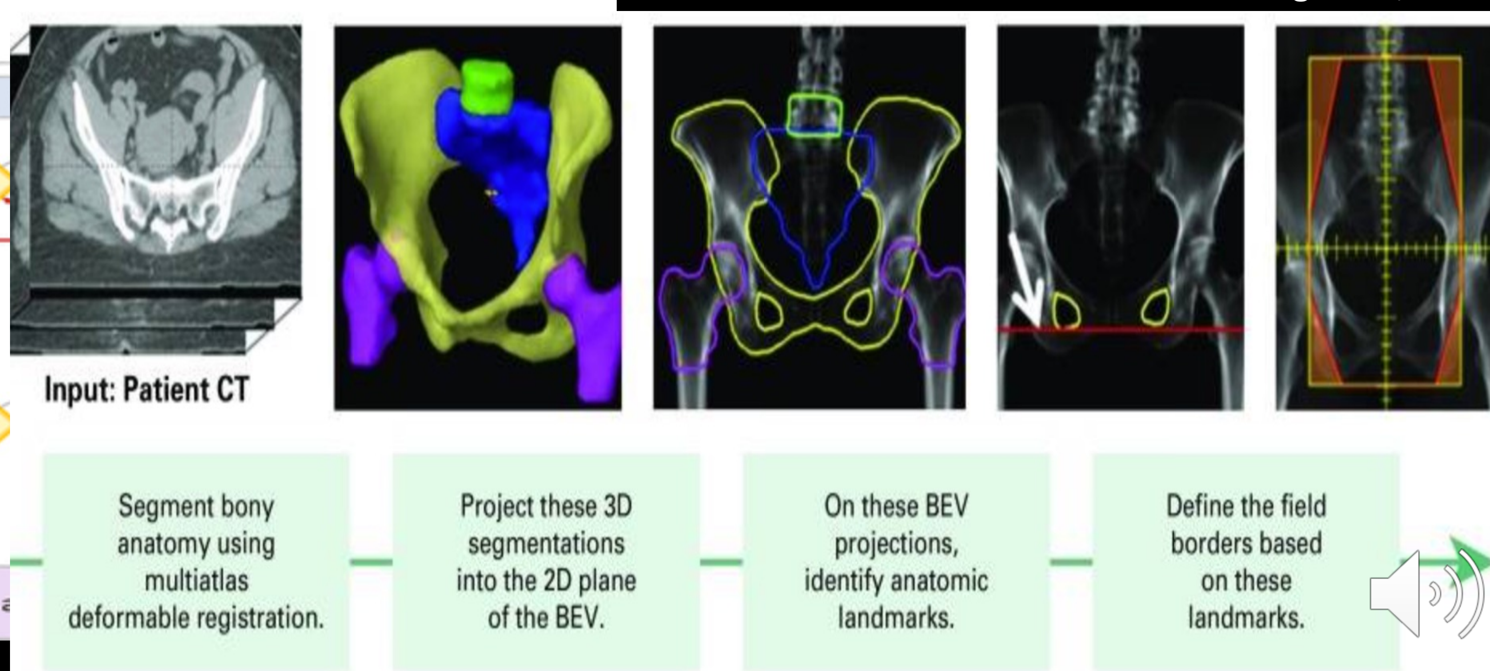
Lin et al., 2019

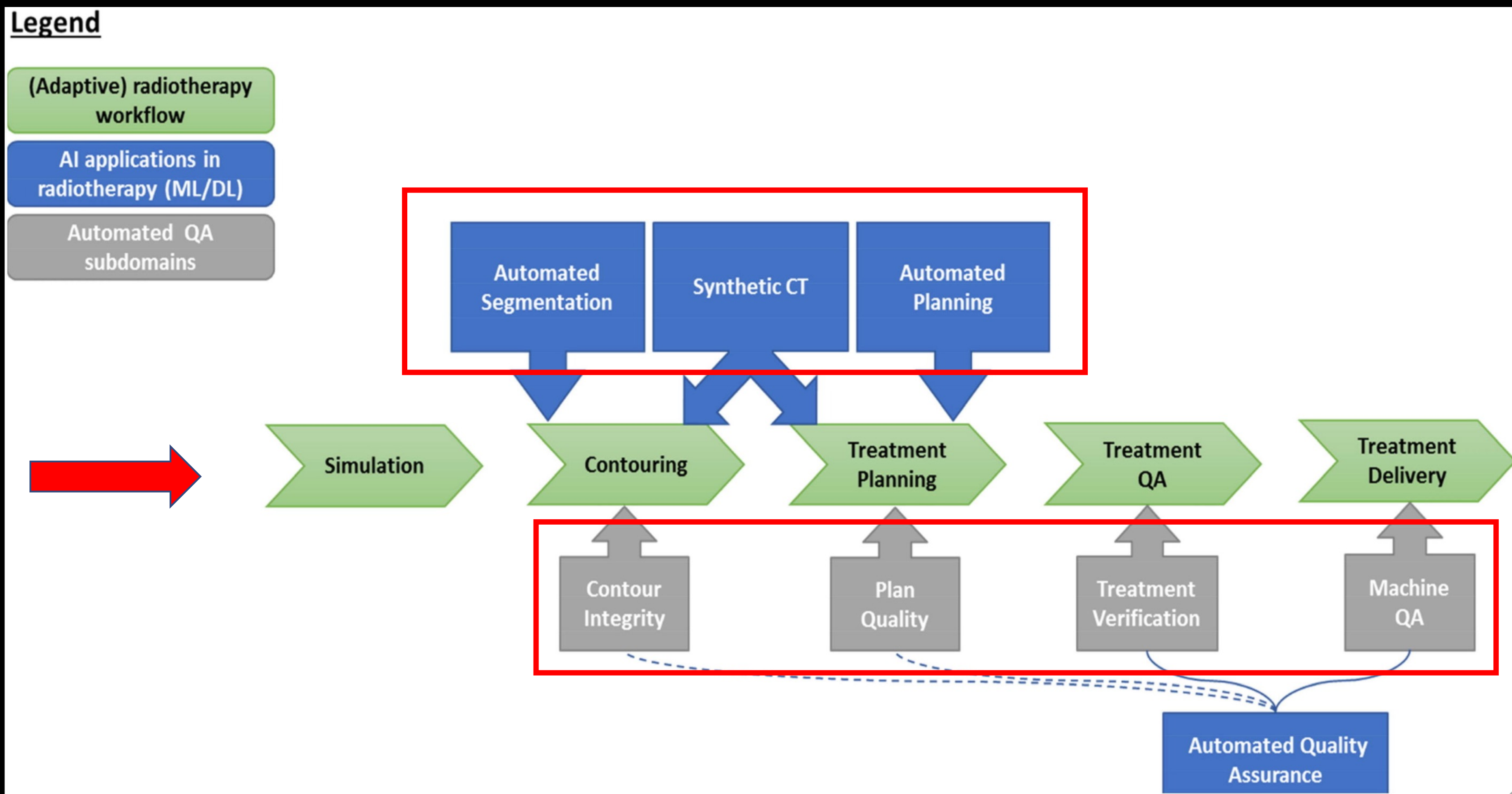
Automated Planning

Wang et al., 2019

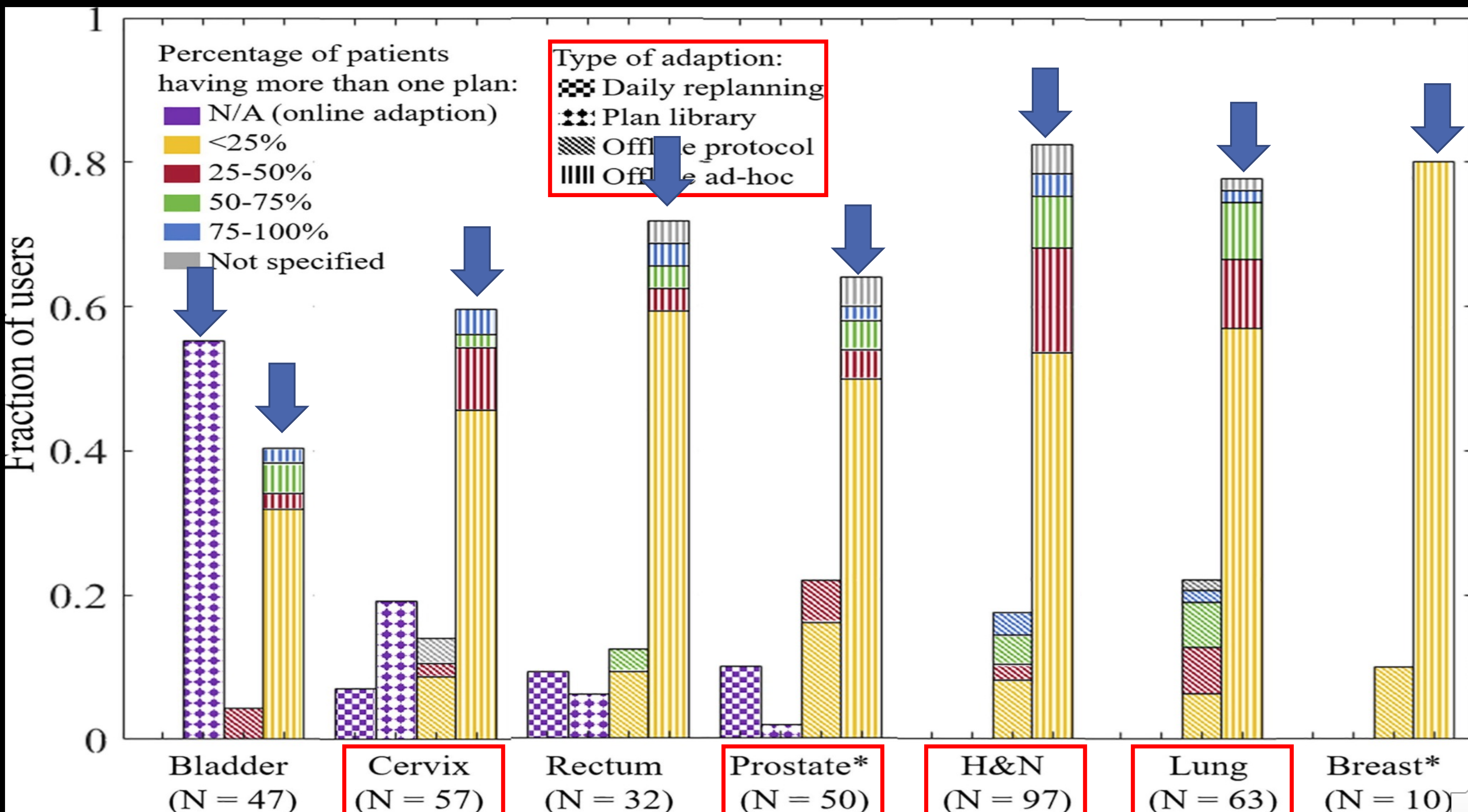


Kisling et al., 2019





Vandewinckele et al., 2020



Bertholet et al., 2020

Benefits

- Improved therapeutic ratio
  - Planning to a volume that changes
  - Sparing OAR's due to anatomical changes

Challenges

- Longer treatment times
- Increased workload
- Limited image quality
- RTT training
- Uncertainty of dose accumulation

Thank You

- Questions for all speakers will be at the end of the session