Artificial Intelligence:

impact on Health Systems

Yolande Lievens, MD, PhD

Ghent University Hospital & Ghent University

What is a health system?
How to generate impact for the health system?

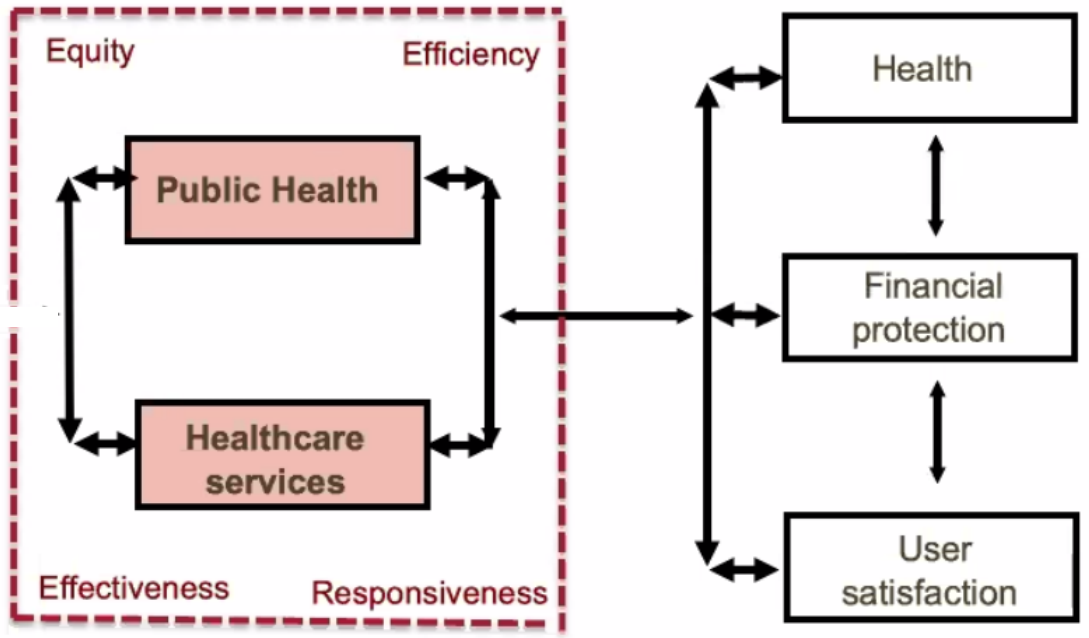
What is the impact of artificial intelligence on the health system?
On the radiation oncology system?

How can we embed artificial intelligence in the health system?

what is a health system?

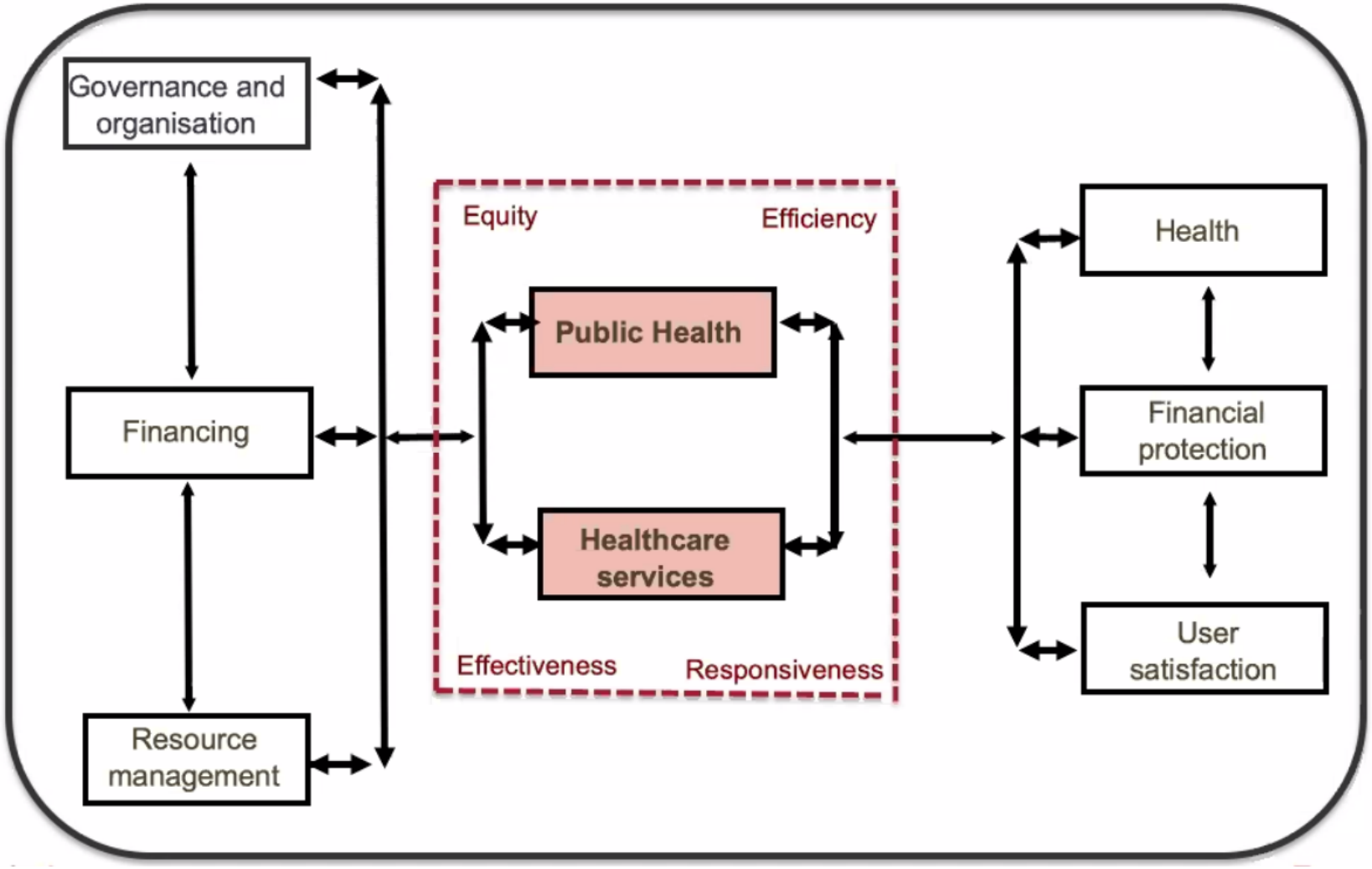
A health (care) system is an organisation
of people, institutions, and resources
that delivers health care services
to meet the health needs of target populations.

what is a health system?

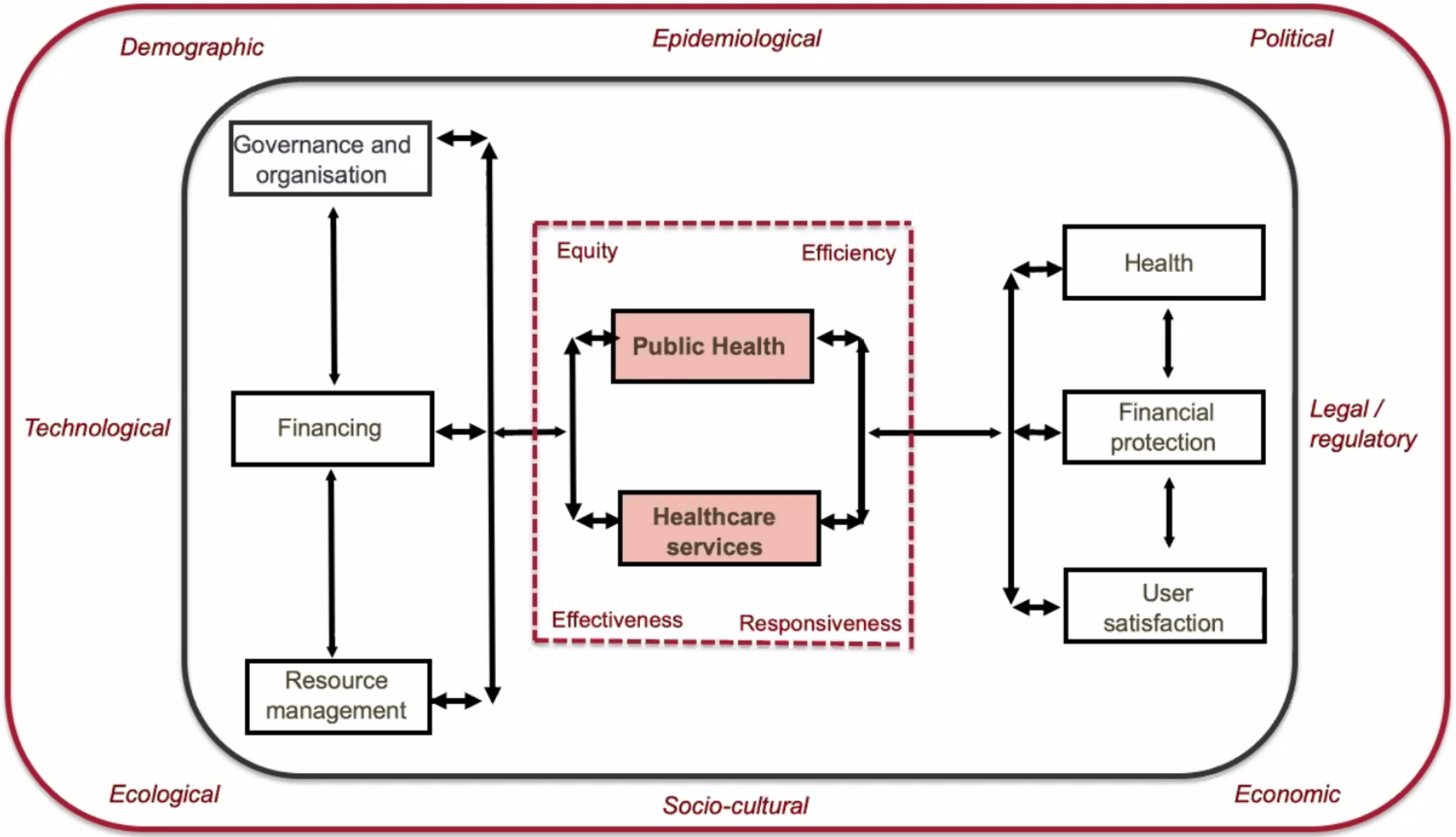


Rifat Atun. Building a High Value Health System

what is a health system?

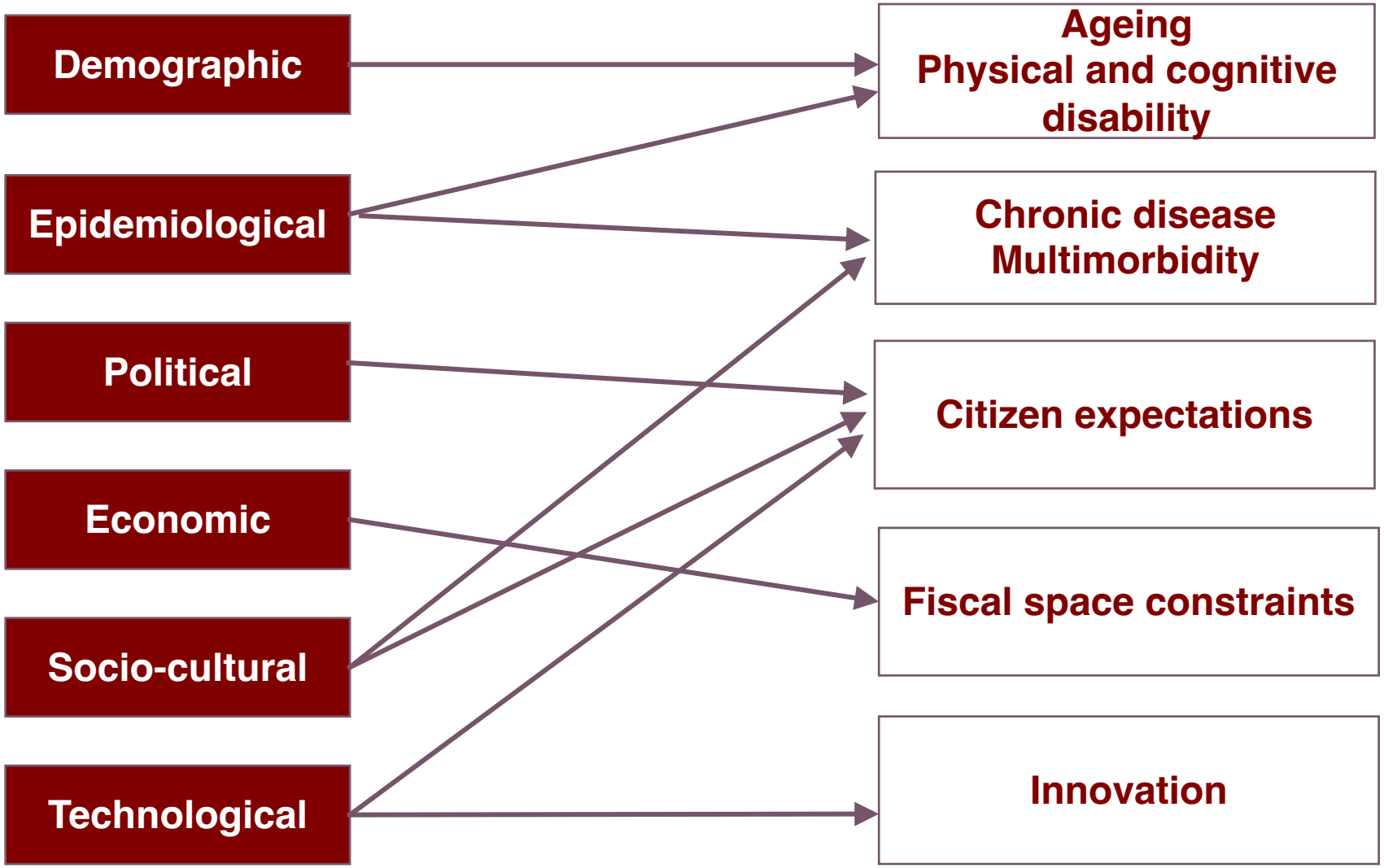


Rifat Atun. Building a High Value Health System



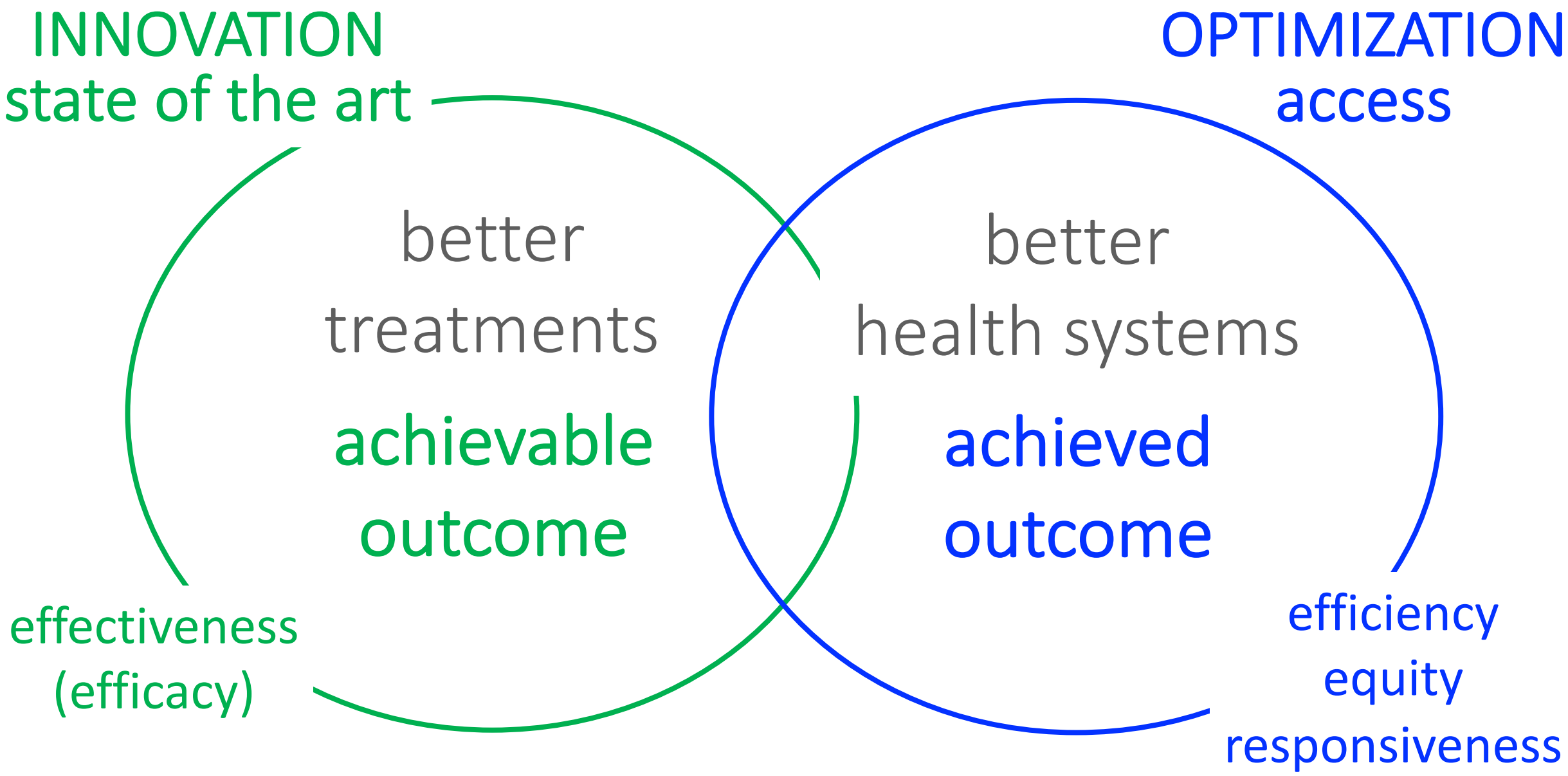
Rifat Atun. Building a High Value Health System

challenge: rapidly converging contextual transitions



Courtesy Rifat Atun

impact


INNOVATION
state of the art
OPTIMIZATION
access
better
treatments
achievable
outcome
better
health systems
achieved
outcome
effectiveness
(efficacy)
efficiency
equity
responsiveness

efficiency

Cost-Effectiveness

$$\frac{\text{Cost}_{\text{new}} - \text{Cost}_{\text{old}}}{\text{Outcome}_{\text{new}} - \text{Outcome}_{\text{old}}}$$

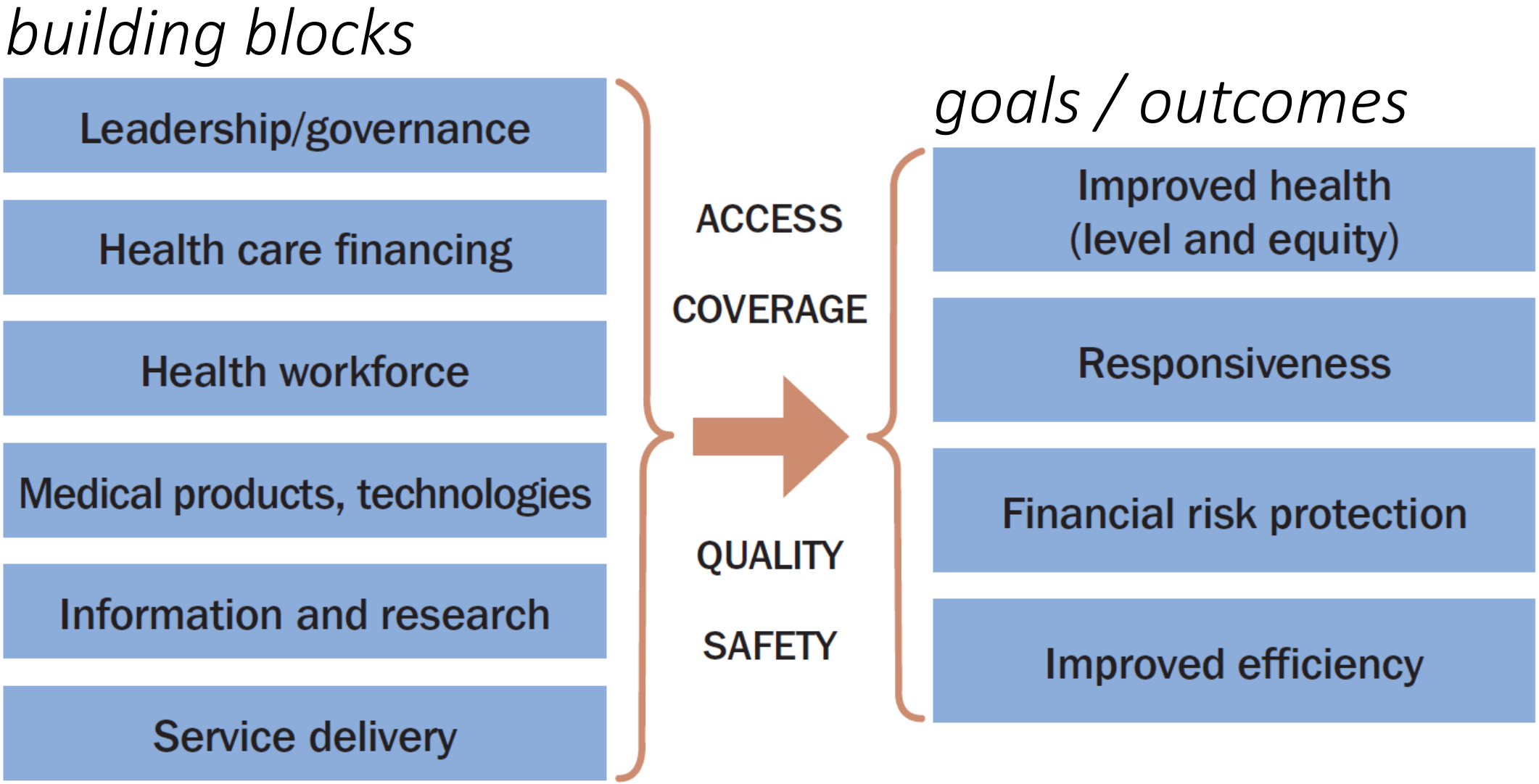
resource use / time proxy for cost!

Value

$$\frac{\text{Health Outcomes that matter to } \textit{patients}}{\text{Costs of delivering these outcomes}}$$

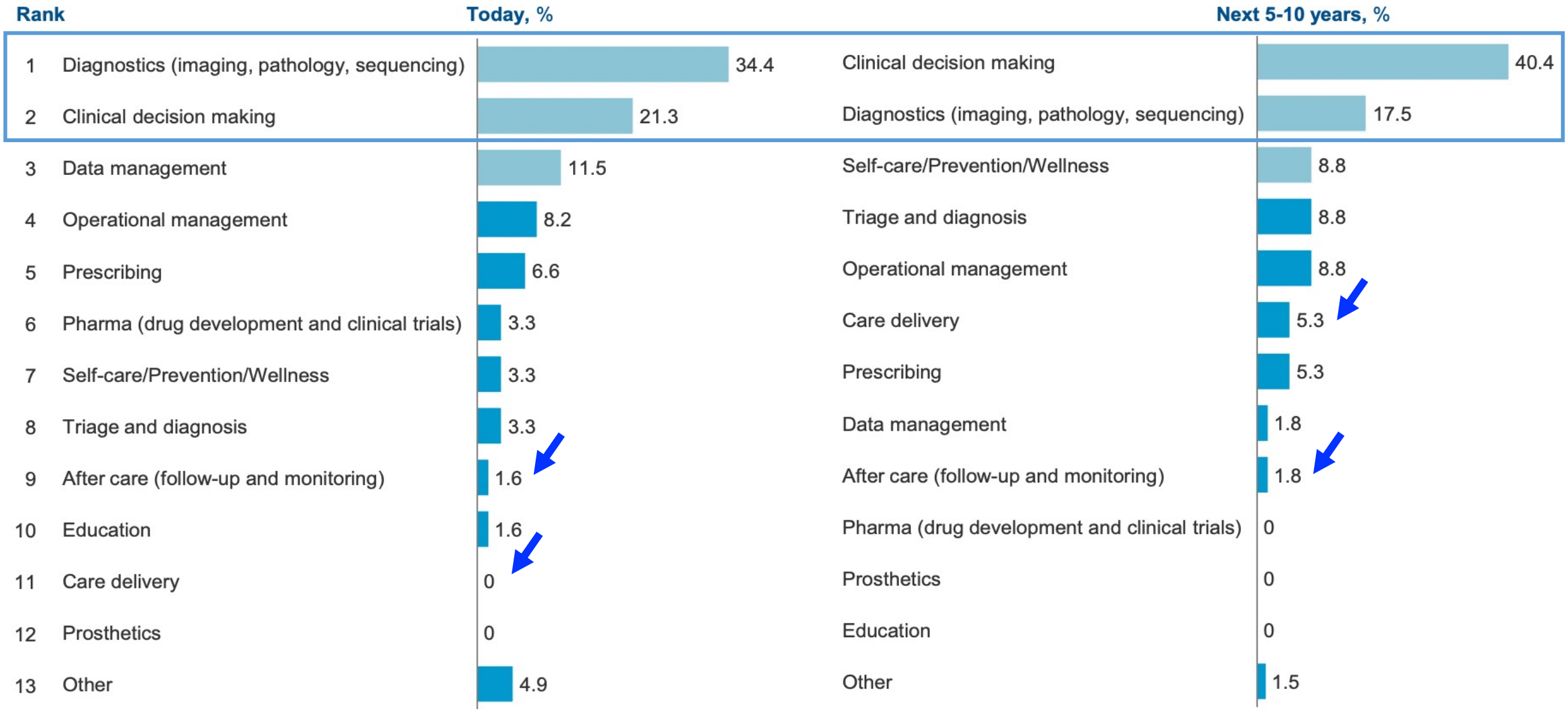
Porter M. N Engl J Med 2010

what is a health system?



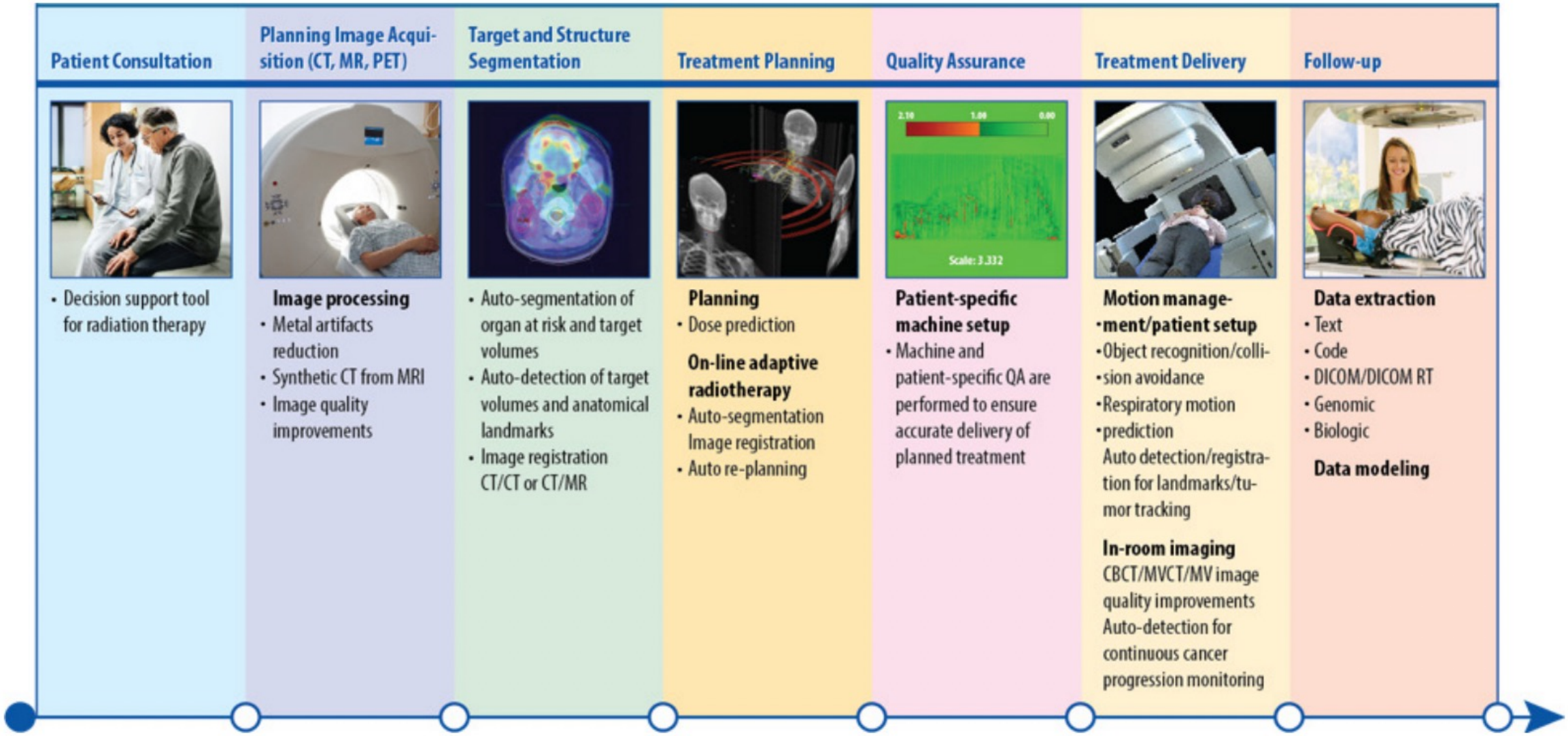
WHO Health Systems Framework

applications of AI in health care



Health and McKinsey - Transforming Health Care with AI, 2020

applications of AI in radiation oncology



El Naqa et al, BJR 2020

frontiers in Oncology

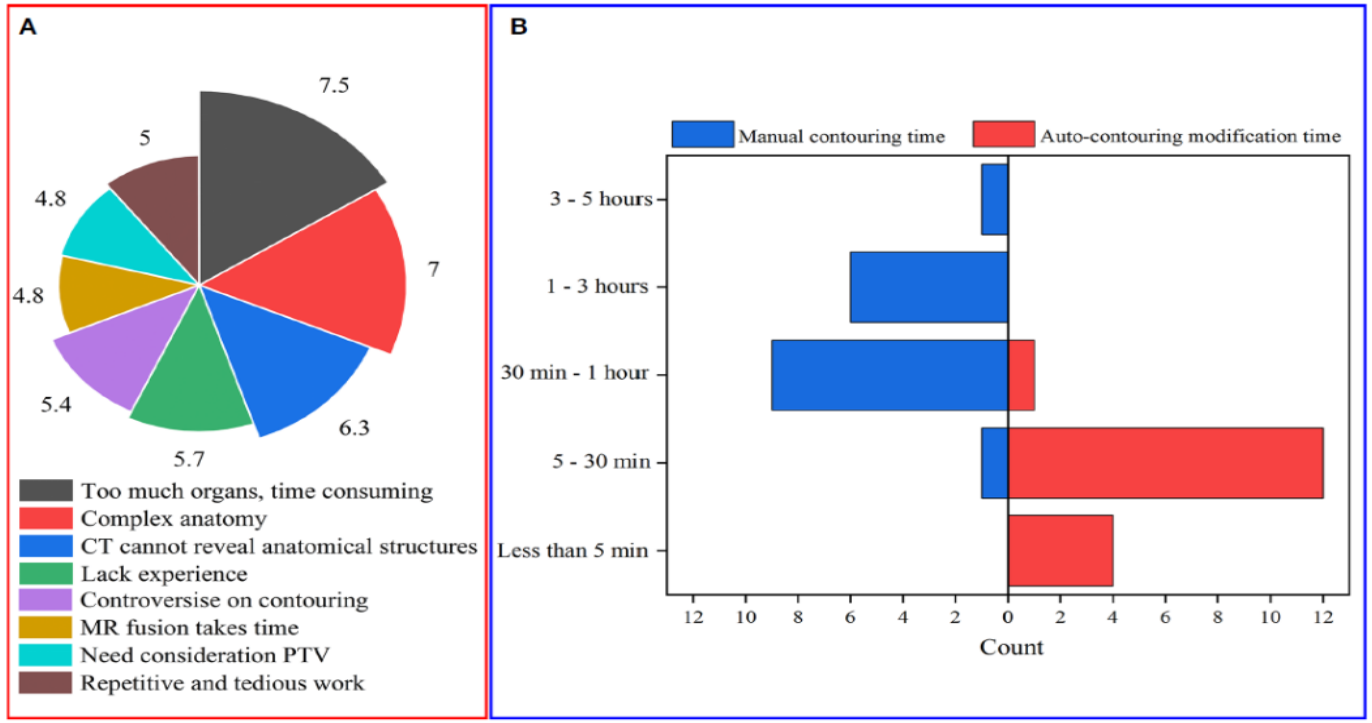
ORIGINAL RESEARCH
published: 05 May 2021
doi: 10.3389/fonc.2021.638197

A Preliminary Experience of Implementing Deep-Learning Based Auto-Segmentation in Head and Neck Cancer: A Study on Real-World Clinical Cases

Yang Zhong[1,2,3†], *Yanju Yang*[1,2,3†], *Yingtao Fang*[1,2,3], *Jiazhou Wang*[1,2,3*] *and Weigang Hu*[1,2,3*]

OPEN ACCESS

substantial decrease in delineation time

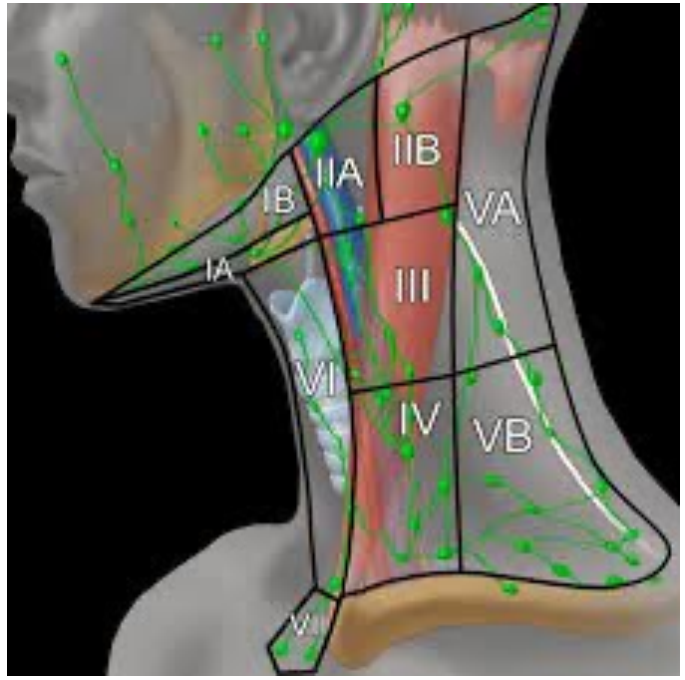


Zhong et al, Front Oncol 2021

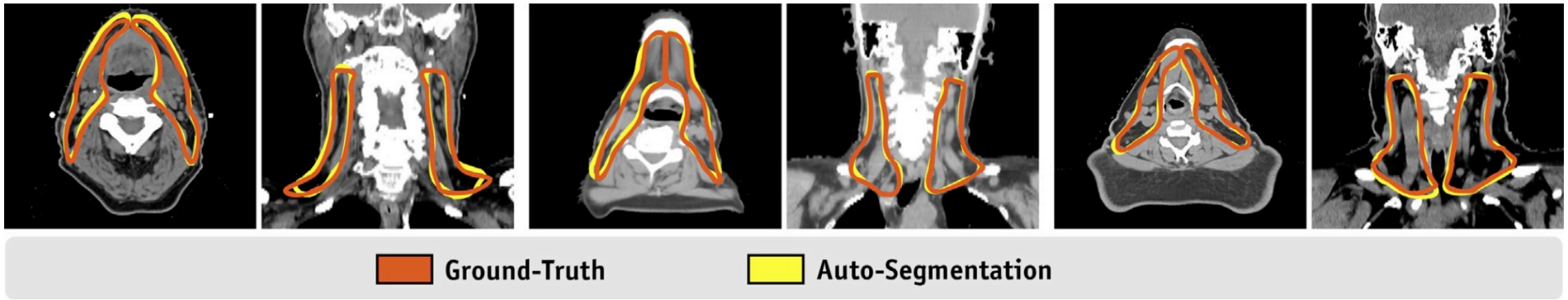
Physics Contribution

Generating High-Quality Lymph Node Clinical Target Volumes for Head and Neck Cancer Radiation Therapy Using a Fully Automated Deep Learning-Based Approach

Carlos E. Cardenas, PhD,* Beth M. Beadle, MD, PhD,†
Adam S. Garden, MD,‡ Heath D. Skinner, MD, PhD,§
Jinzhong Yang, PhD,* Dong Joo Rhee, MS,* Rachel E. McCarroll, PhD,‖
Tucker J. Netherton, DMP,* Skylar S. Gay, BS,* Lifei Zhang, PhD,*
and Laurence E. Court, PhD*



IJROBP 2020



Cardenas et al, IJROBP 2022

	Nonpostoperative (n = 25)			Postoperative (n = 7)		
	Scores			Scores		
	1	2	3	1	2	3
Reviewer 1						
Ia-V right	25	0	0	4	3	0
Ia-V left	25	0	0	7	0	0
Ib-V right	25	0	0	4	3	0
Ib-V left	25	0	0	7	0	0
II-IV right	25	0	0	4	3	0
II-IV left	25	0	0	7	0	0
RP right	25	0	0	7	0	0
RP left	25	0	0	7	0	0
Reviewer 2						
Ia-V right	14	11	0	4	3	0
Ia-V left	14	11	0	4	3	0
Ib-V right	14	11	0	4	3	0
Ib-V left	14	11	0	4	3	0
II-IV right	14	11	0	4	3	0
II-IV left	14	11	0	4	3	0
RP right	21	4	0	5	2	0
RP left	21	4	0	5	2	0
Reviewer 3						
Ia-V right	0	25	0	0	5	2
Ia-V left	0	24	1	0	7	0
Ib-V right	0	25	0	0	5	2
Ib-V left	1	23	1	0	7	0
II-IV right	2	23	0	0	6	1
II-IV left	4	21	0	1	6	0
RP right	9	16	0	1	6	0
RP left	11	14	0	2	5	0

Individual cases were reviewed on a slice-by-slice basis by 3 radiation oncologists each having more than 10 years of HNC experience.

Auto-segmentation scores: 1 = clinically acceptable without requiring edits; 2 = requiring minor edits (ie, stylistic recommendations, <2 minutes); 3 = requiring major edits.

Abbreviation: HNC = head and neck cancer.

remaining yet variable need for human interaction

Cardenas et al, IJROBP 2022

cancers

MDPI

Article

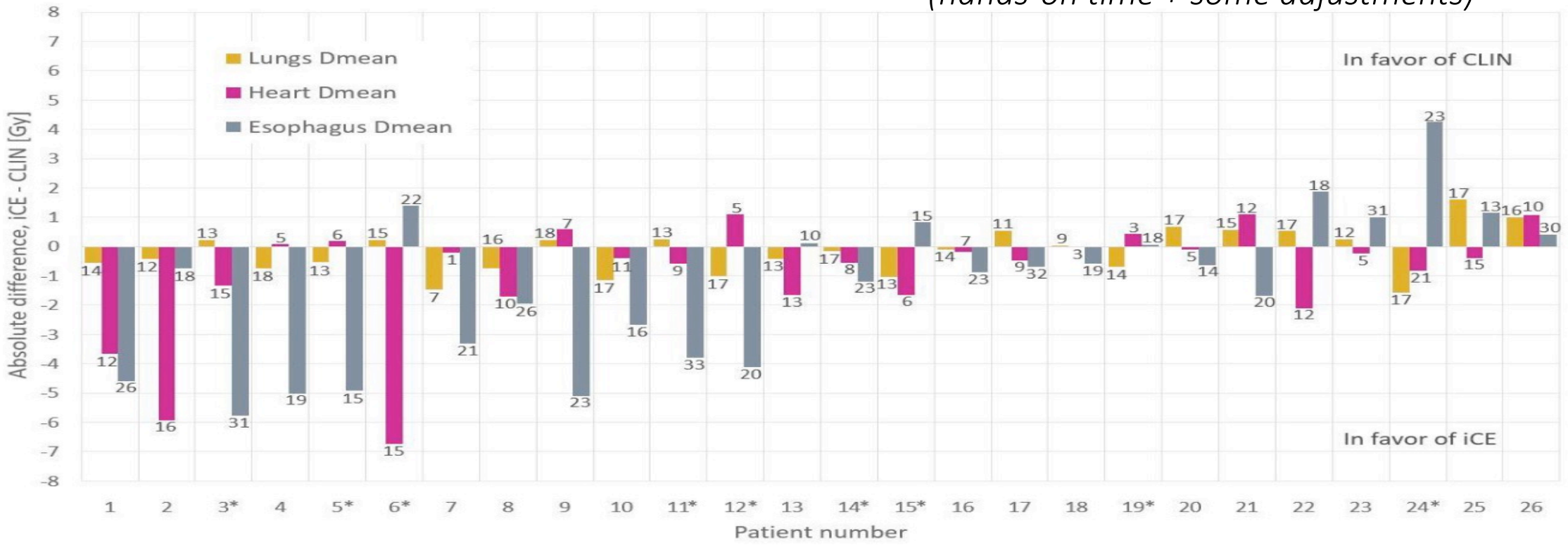
Enhancing Radiotherapy for Locally Advanced Non-Small Cell Lung Cancer Patients with iCE, a Novel System for Automated Multi-Criterial Treatment Planning Including Beam Angle Optimization

Kristine Fjellanger [1,2,*], Liv Bolstad Hysing [1,2], Ben J. M. Heijmen [3], Helge Egil Seime Pettersen [1], Inger Marie Sandvik [1], Turid Husevåg Sulen [1], Sebastiaan Breedveld [3] and Linda Rossi [3]

Manual plans: 2 – 4h (<1h to full day)

Automated plans: less than 10min

(hands-on time + some adjustments)



Fjellanger et al, Cancers 2020

To date: increased **efficiency in the radiation treatment planning process** most evident

Ideally, a system that
- accurately identifies both **normal and target volumes**,
- estimates the **optimal modality** and **beam arrangement**,
- achieves deliverable plans that **maximize TCP and minimize risk of toxicity**,
- **integrates clinically relevant data** from multiple sources (e.g. EHR, imaging data) to further tailor the treatment approach.

As such:
speed-up the process, **reduce** the time burden of human intervention, allow for a **shorter** interval from simulation to initiation of treatment,
and **facilitate paradigm shifts** such as online adaptive planning.

at least similar outcomes

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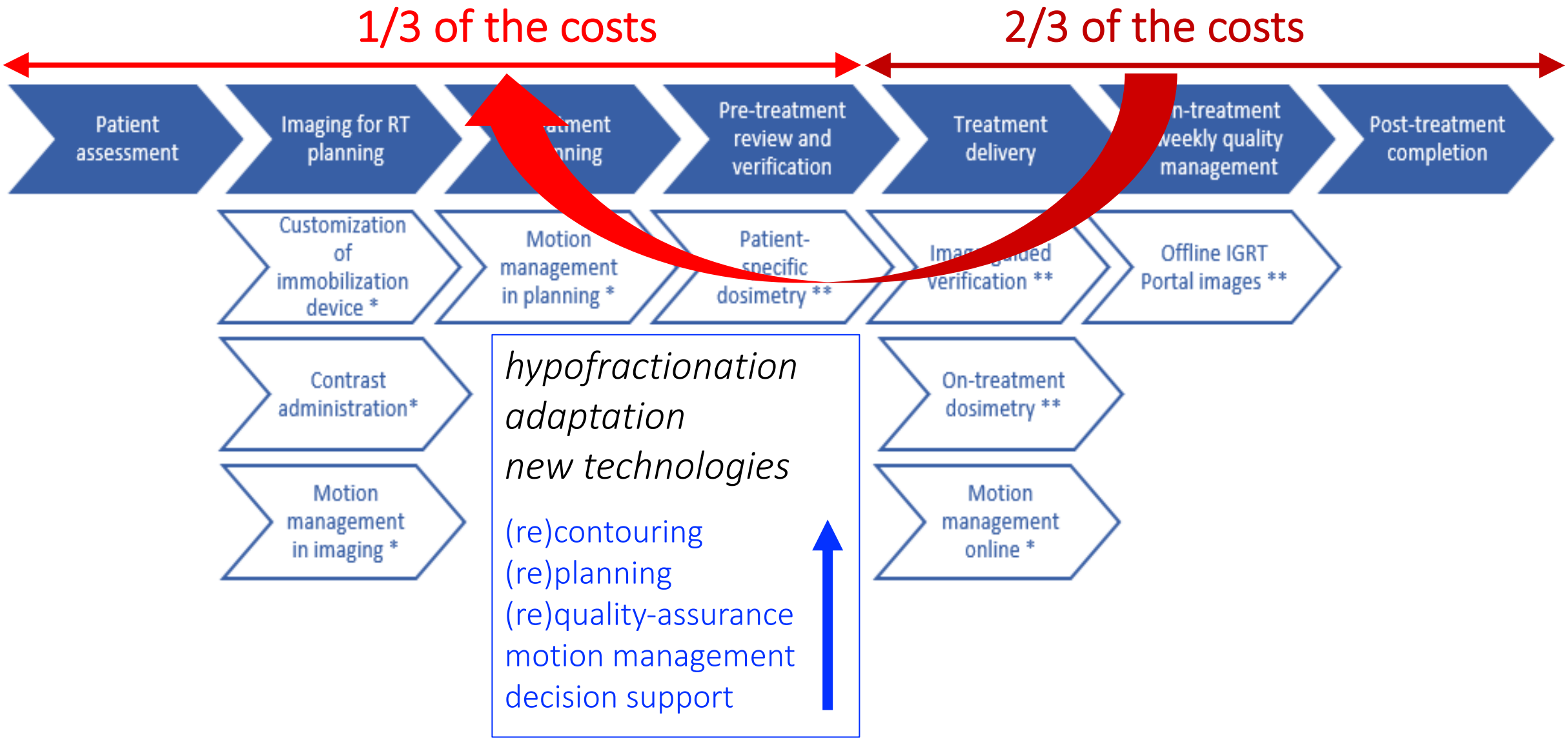
lower resource time, lower cost?

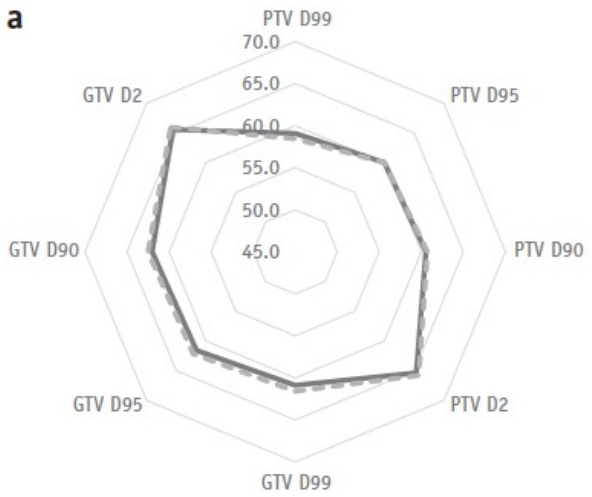
Thompson et al, Radiother Oncol 2018

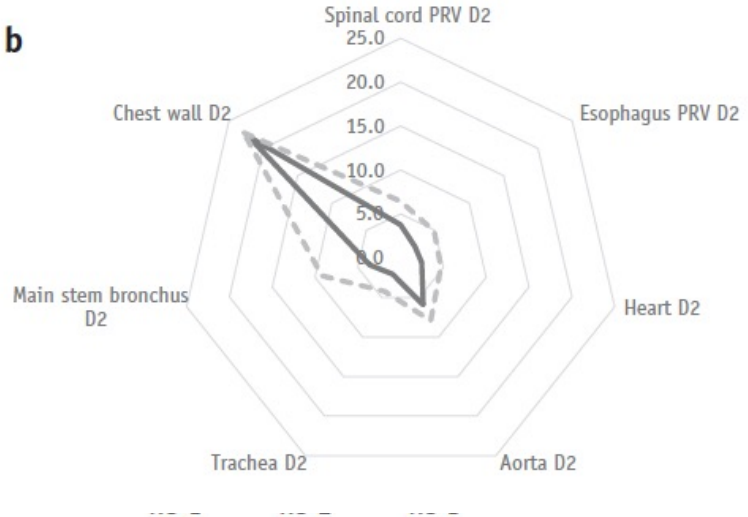
applications of AI in RO, cost impact?

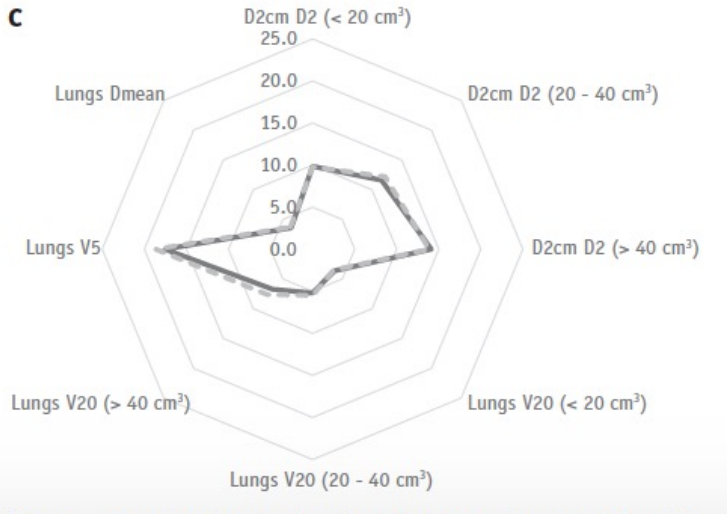


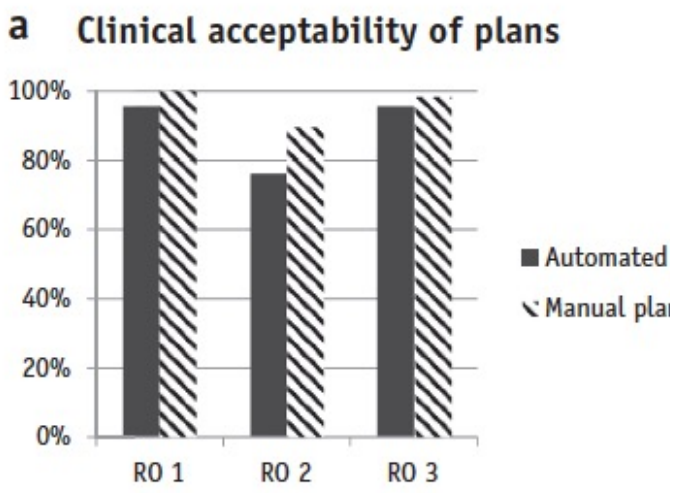
Courtesy Defourny Noémie, 2019

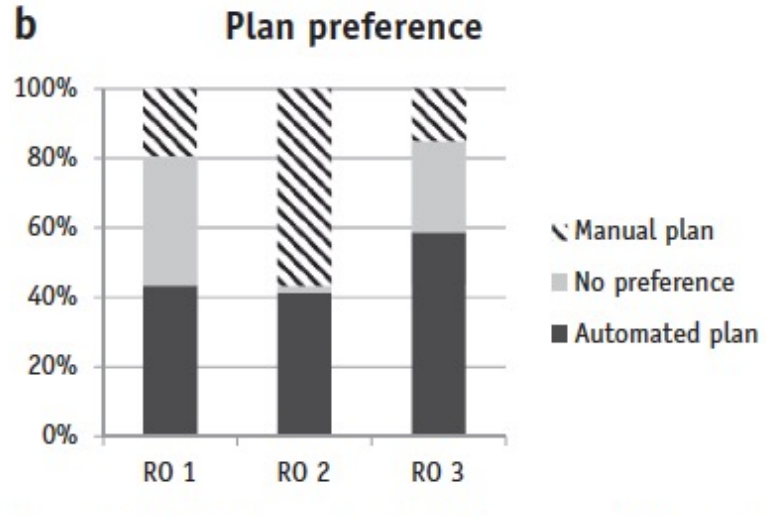
impact on costs?











75% clinically acceptable without manual fine-tuning, yet still requires human input and validation

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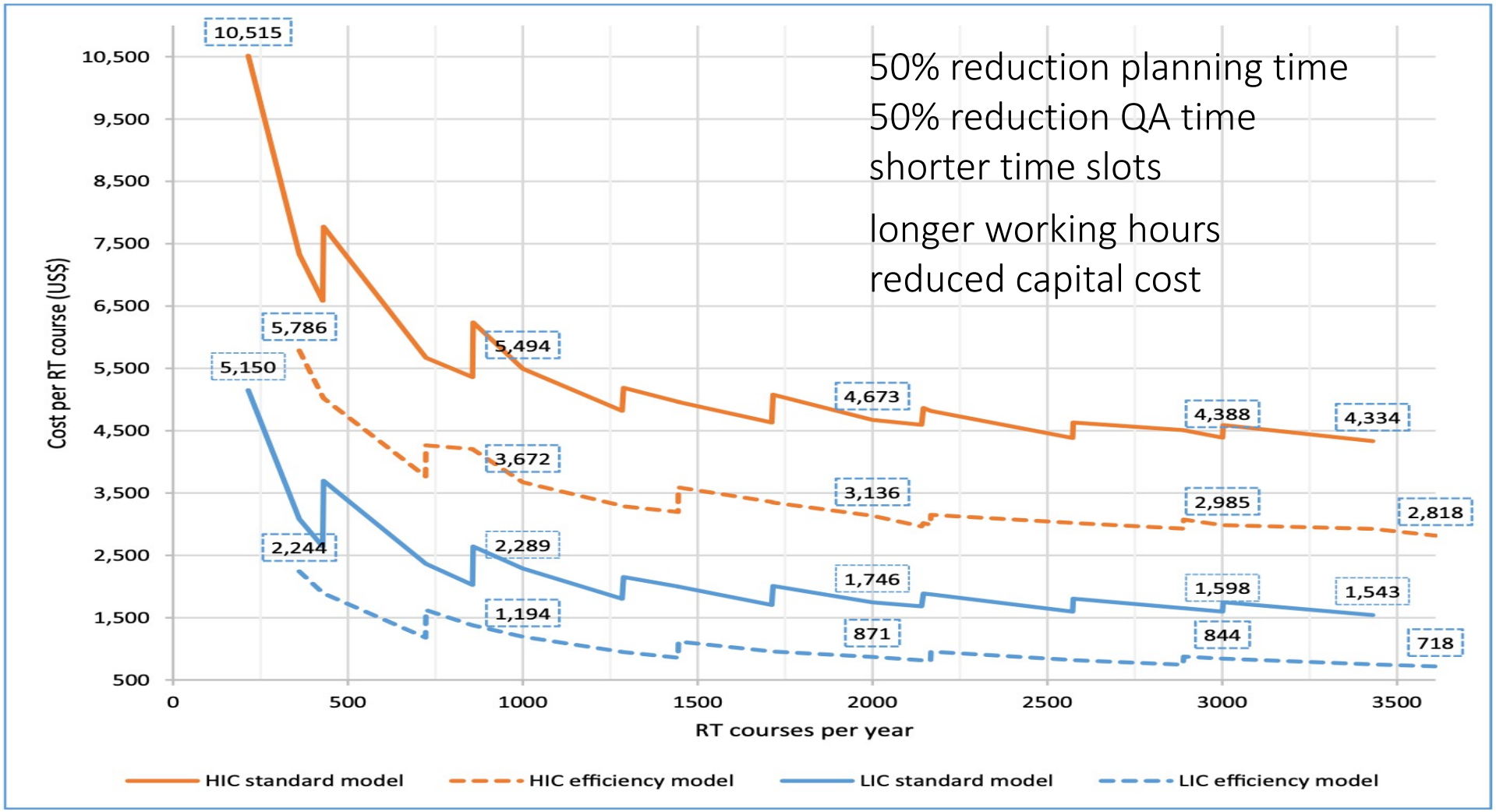
average optimization time -77.3%
minor impact on total cost -3,6%

Vanderstraeten B et al, IJROBP 2018

impact on costs?



Atun et al, Lancet Oncol 2015, Van Dyk et al, Radiother Oncol 2017

opportunities for the radiation oncology workforce

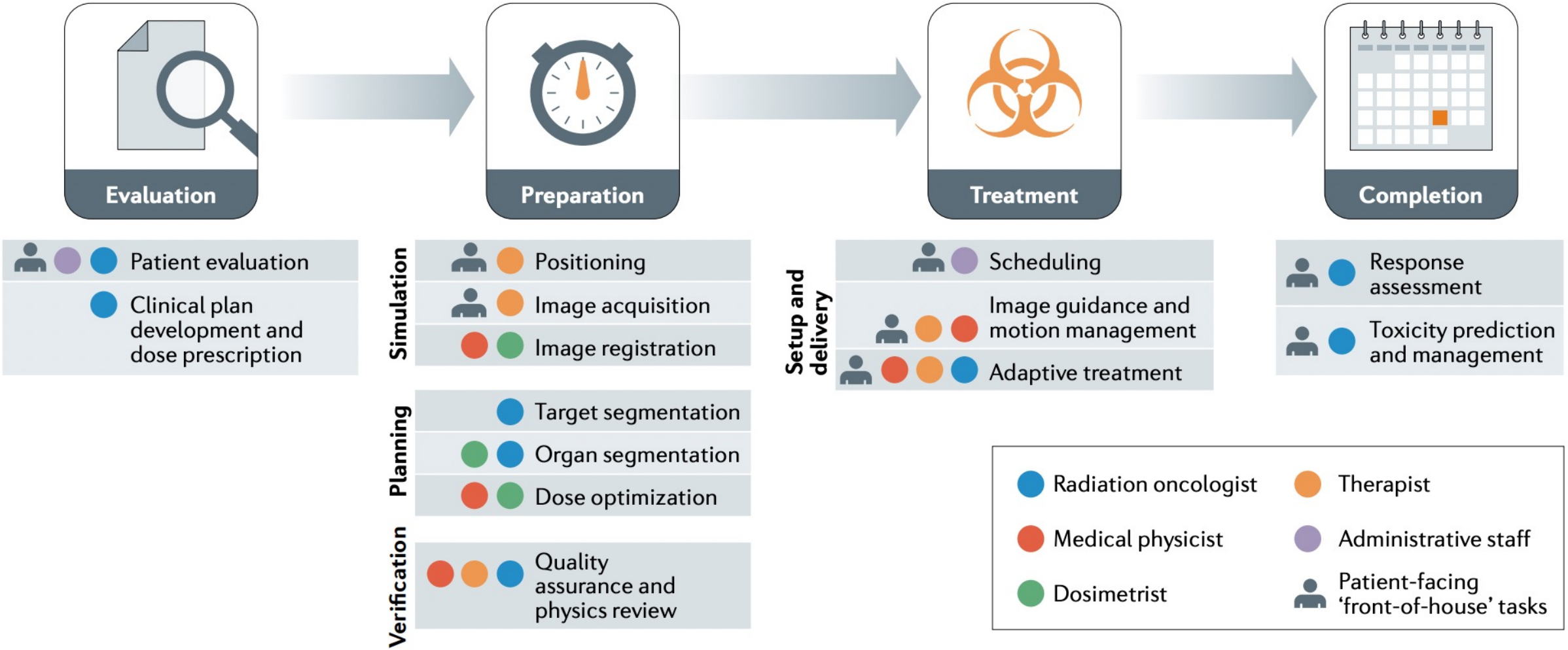
	High-income countries	Upper-middle-income countries	Lower-middle-income countries	Low-income counties
Fractions	76 424 000	77 014 000	40 974 000	13 268 000
>200,000 radiation oncology professionals worldwide!				
Radiation oncologists to be trained	15 500	16 800	9900	3300
Medical physicists to be trained	17 200	12 500	7200	2400
Radiation technologists to be trained	51 900	45 300	24 900	8100

Atun et al, Lancet Oncol 2015

the health workforce, reduced time needs

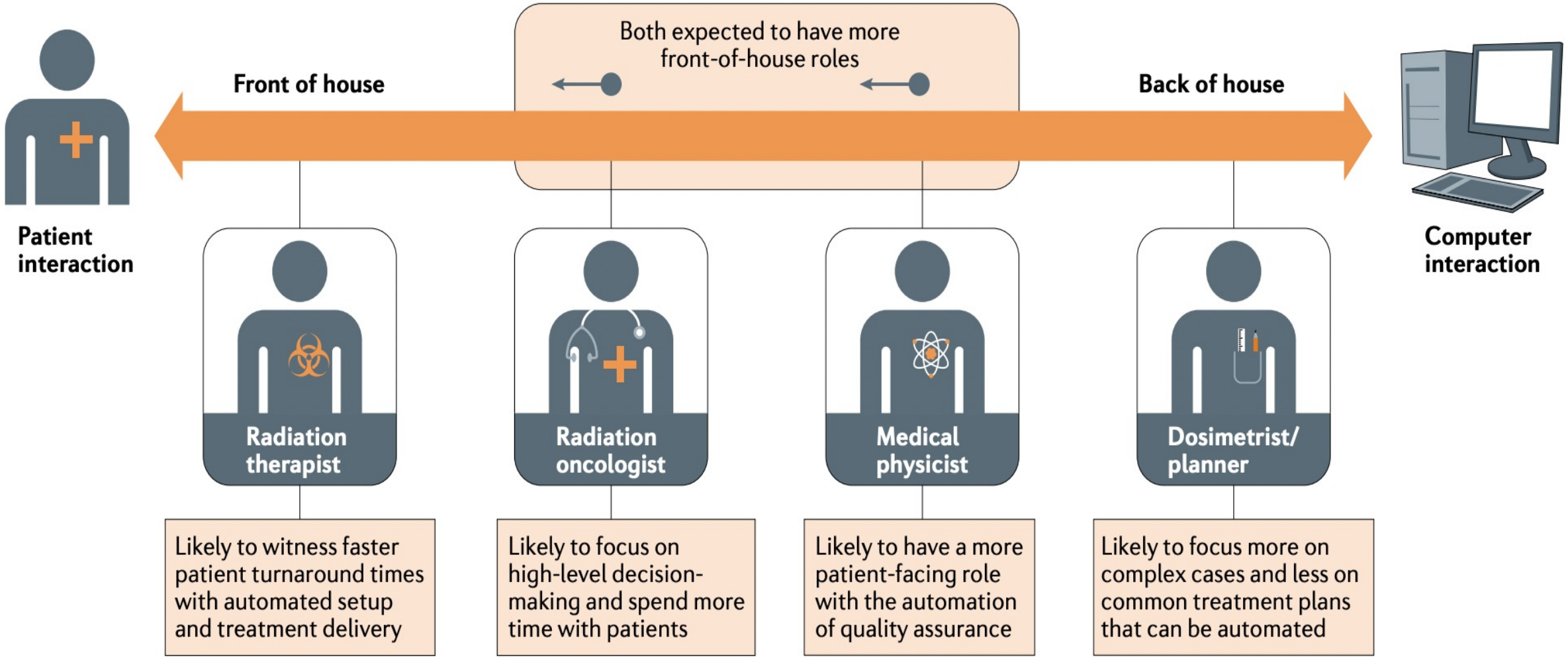
Health and McKinsey - Transforming Health Care with AI, 2020

the radiation oncology workforce, task shifting



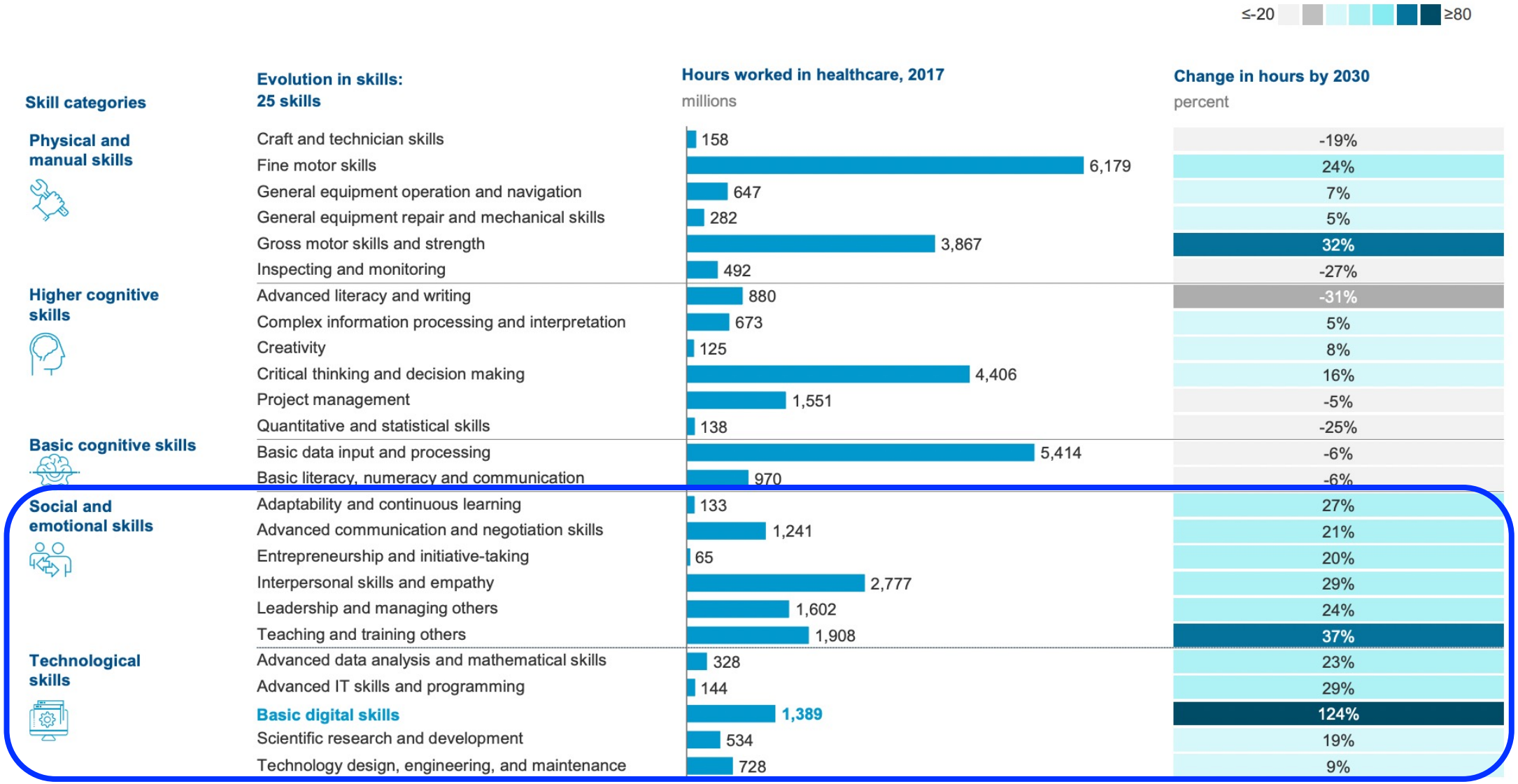
Huynh et al, Nat Rev Clin Oncol 2020

the radiation oncology workforce, task shifting



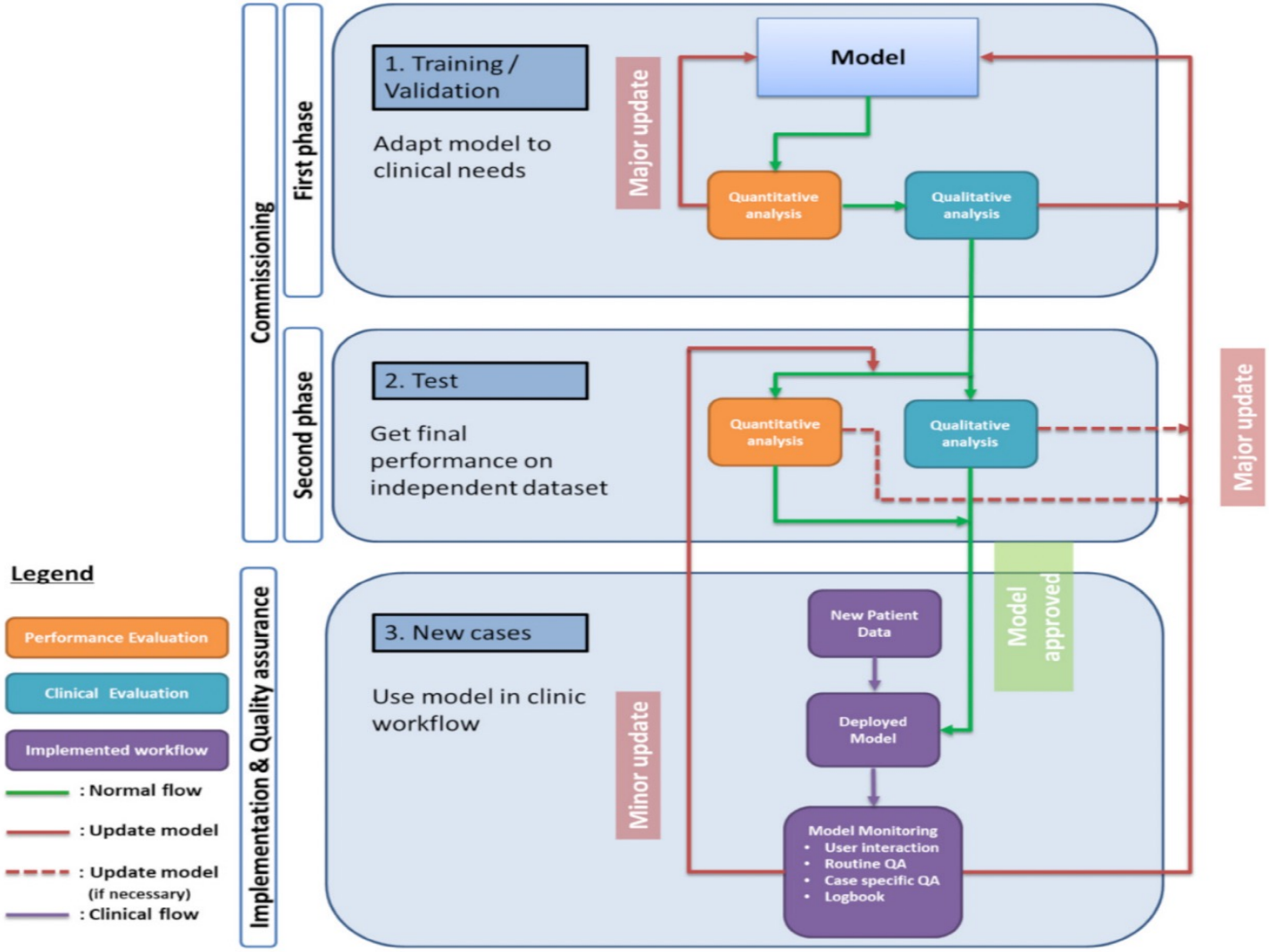
Huynh et al, Nat Rev Clin Oncol 2020

the health workforce, task shifting



Health and McKinsey - Transforming Health Care with AI, 2020

sustainability of AI systems



integration of AI in clinical workflow

→ development of the algorithms

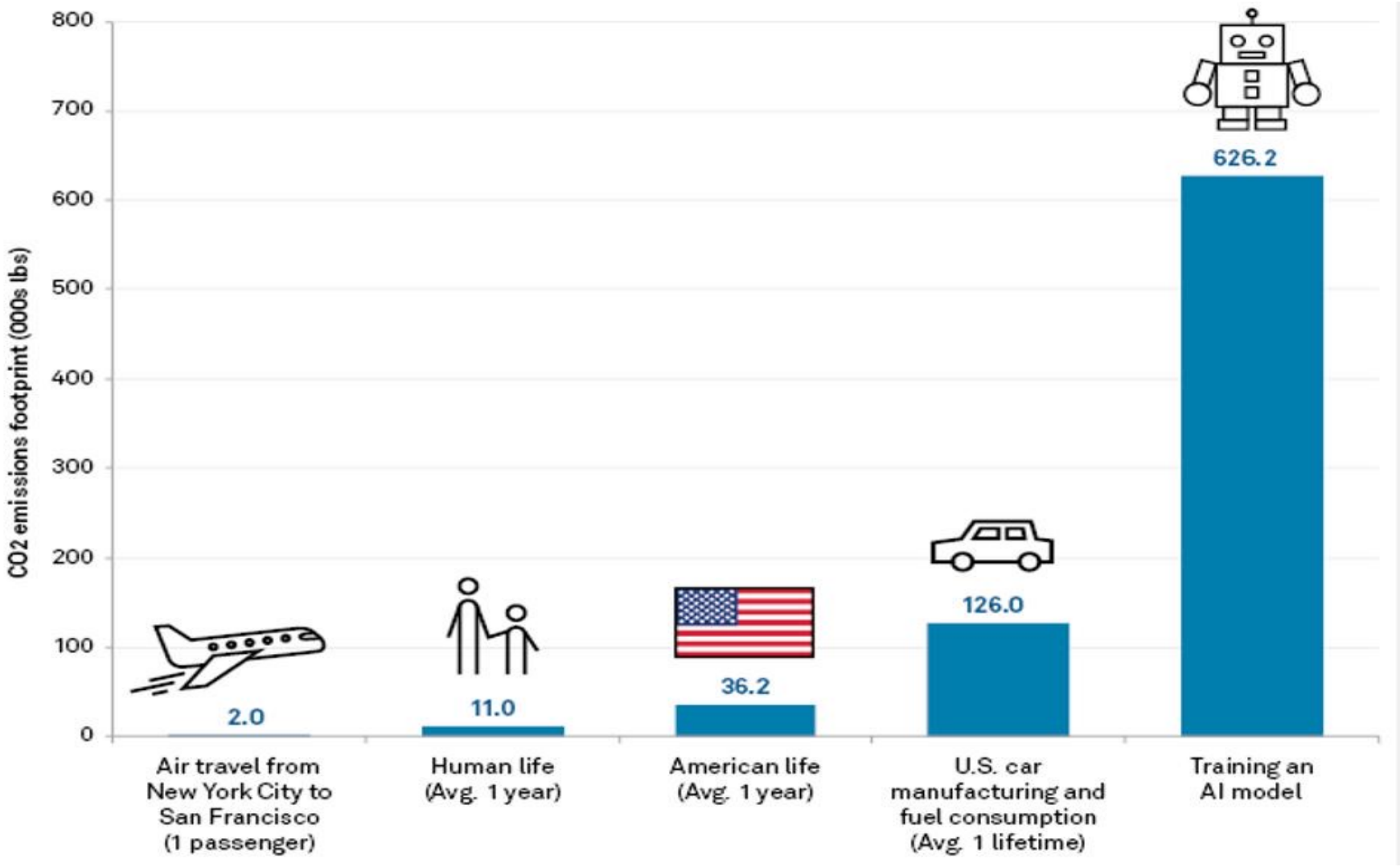
→ additional QA and maintenance demands

accuracy of 4 months half-life

continuous adaptation and learning

Vandewinckele et al, Radiother Oncol 2020

sustainability of AI systems



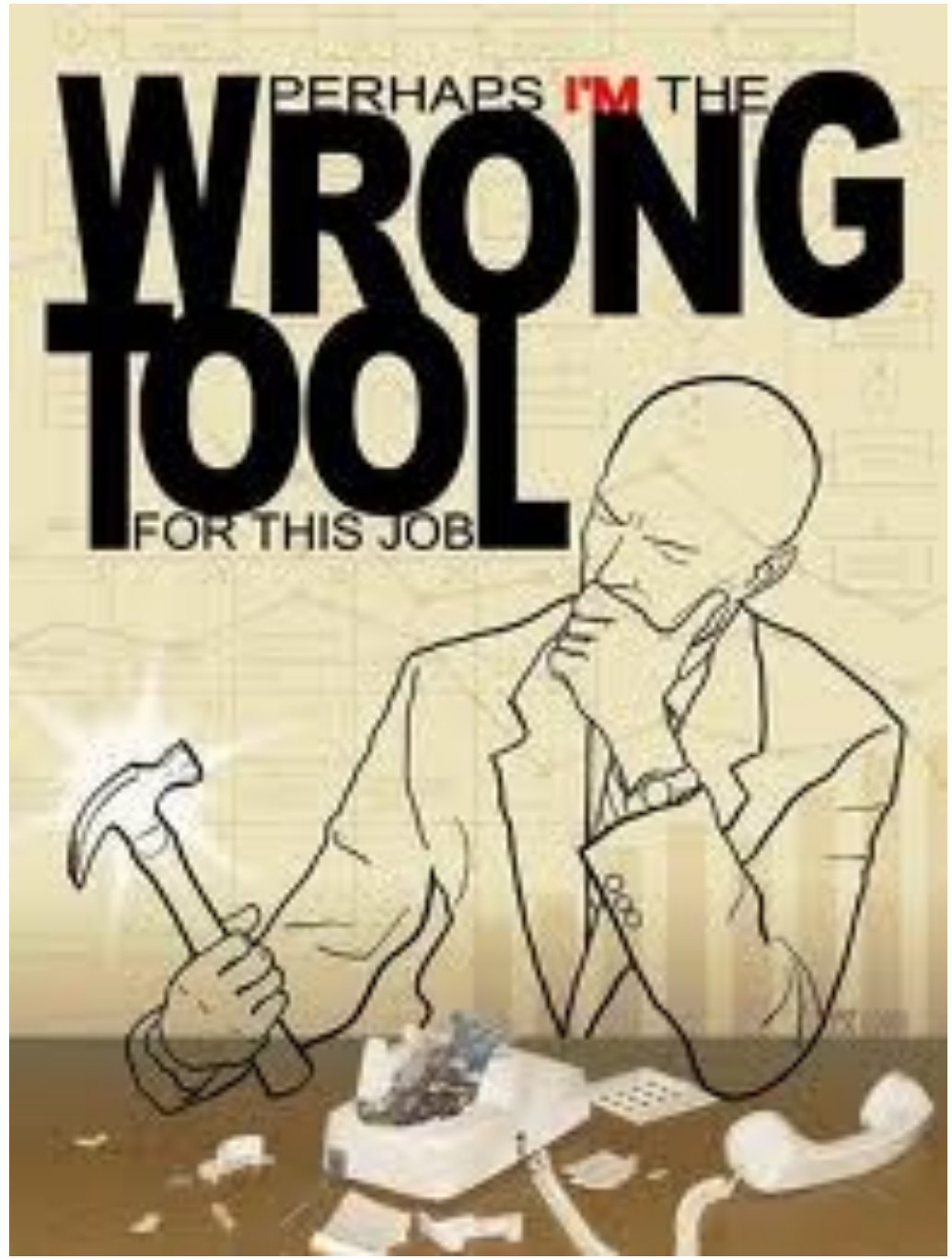
Strubell et al, College of Information and Computer Sciences University of Massachusetts Amherst

challenges

- Human barriers to AI adoption in healthcare;
- Developing a better understanding of interaction between human and algorithm;
- Algorithmic interpretability and explainability.
- Logistical difficulties in implementing AI systems
- Achieving robust regulation and rigorous quality control;
- Susceptibility to adversarial attack or manipulation;

- Dataset shift;
- Accidentally fitting confounders versus true signal;
- Challenges in generalisation to new populations and settings;
- Algorithmic, discriminatory bias.

Kelly et al. BMC Medicine 2019


PERHAPS I'M THE
WRONG
TOOL
FOR THIS JOB

what needs to be done

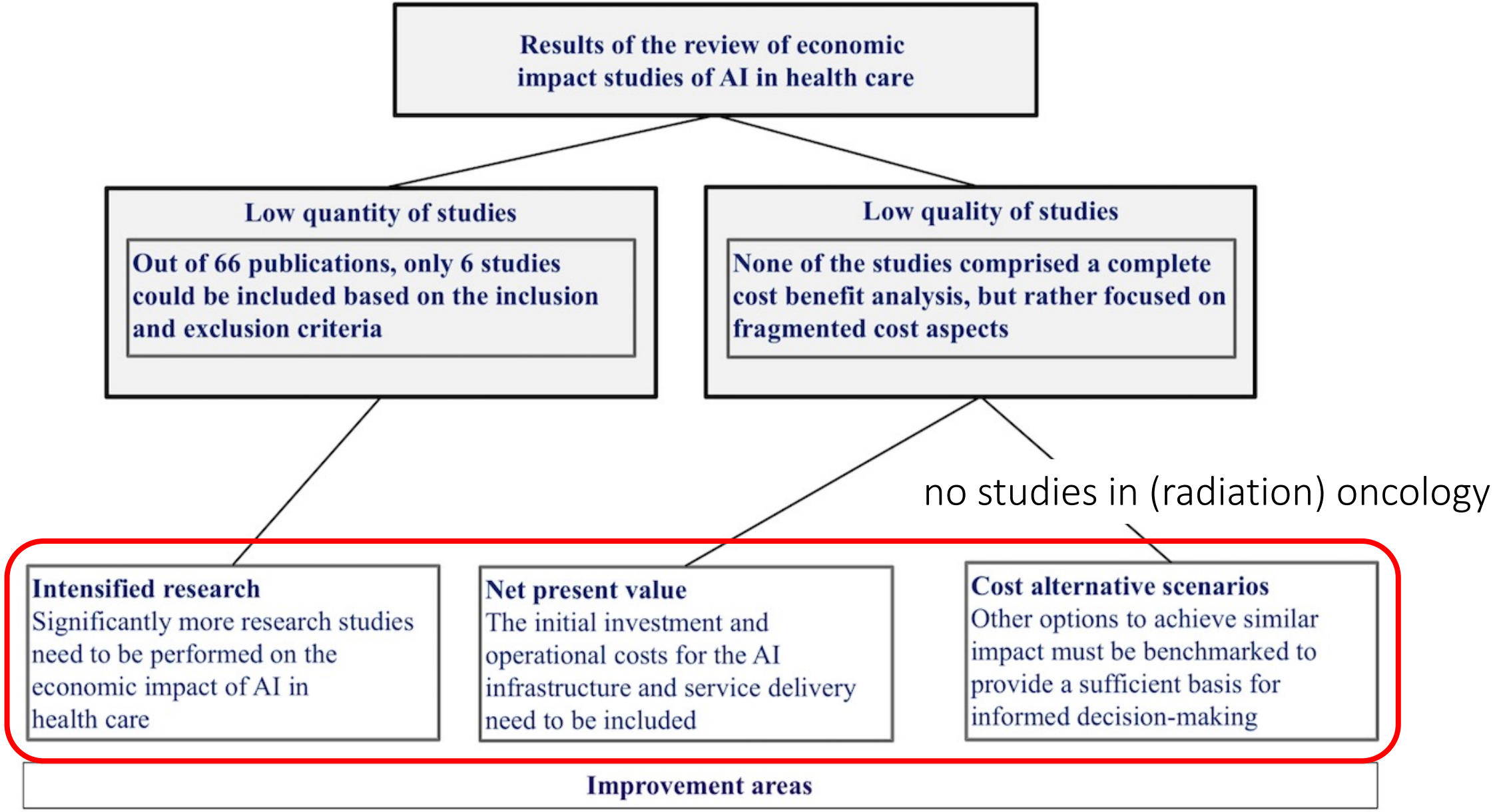
- Promote population-representative data with accessibility, standardization, and quality is imperative.
- Prioritize ethical, equitable, and inclusive health care AI while addressing explicit and implicit bias.
- Near-term focus is needed on augmented intelligence vs AI autonomous agents.
- Develop and deploy appropriate training and educational programs to support health care AI.
- Leverage frameworks and best practices for learning health care systems, human factors, and implementation science to address the challenges in operationalizing health care AI.
- Balance innovation with safety via regulation and legislation to promote trust.

Matheny et al, JAMA 2020;
based on the National Academy of Science report (The Hope, the Hype, the Promise, the Peril.)

where do we stand in terms of impact?

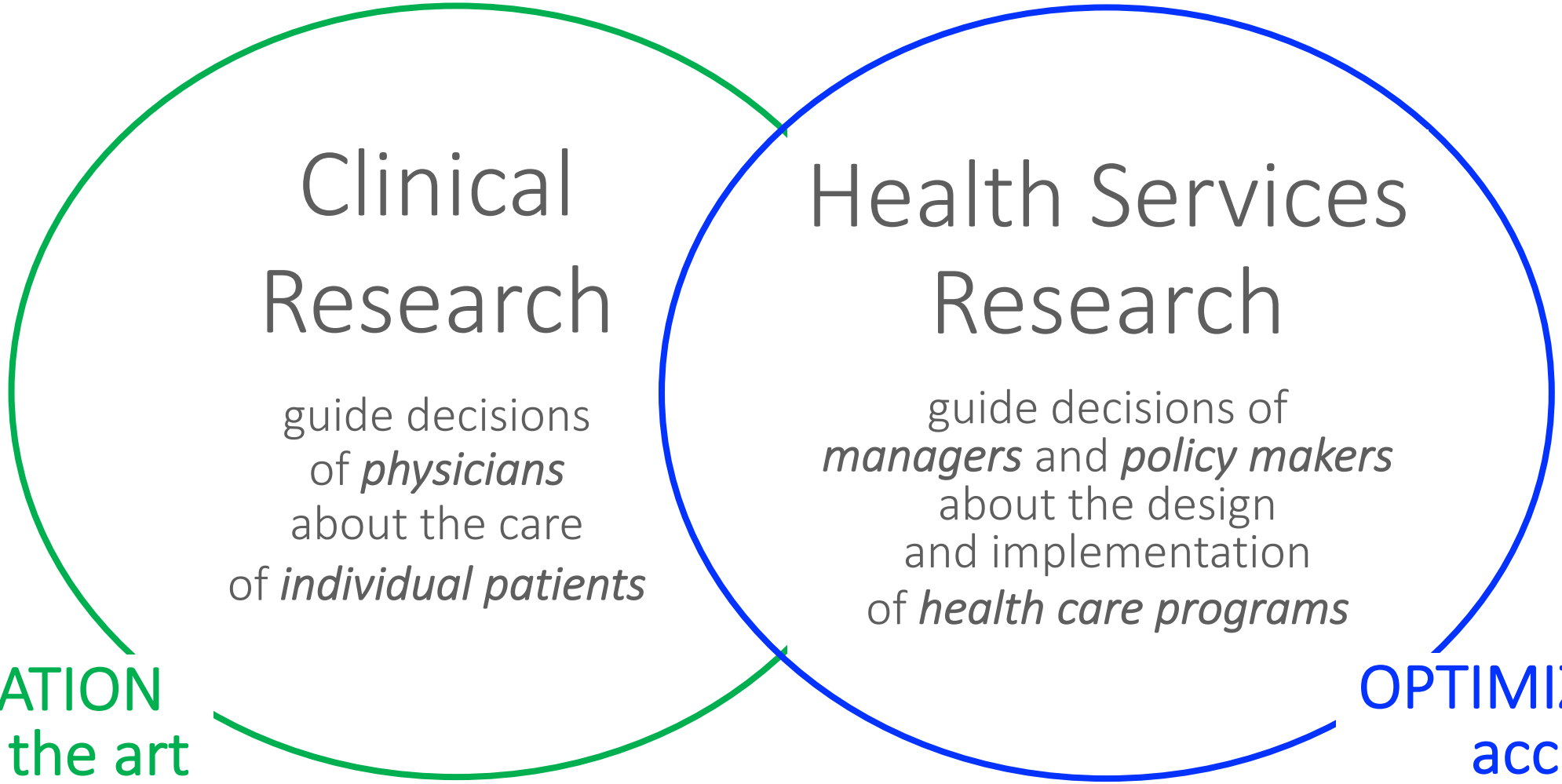
- limited number of models trained on prospective data
- almost no (randomised) clinical trials, using clinical outcomes as trial endpoints to demonstrate longer-term benefit
- limited understanding about the breadth and effectiveness of AI in radiotherapy, with difficulty comparing different algorithms
- metrics used do not necessarily reflect clinical applicability

- limited number of cost analyses
- barely any cost-effectiveness data



Wolff et al, J Med Internet Res 2020

what needs to be done



INNOVATION
state of the art

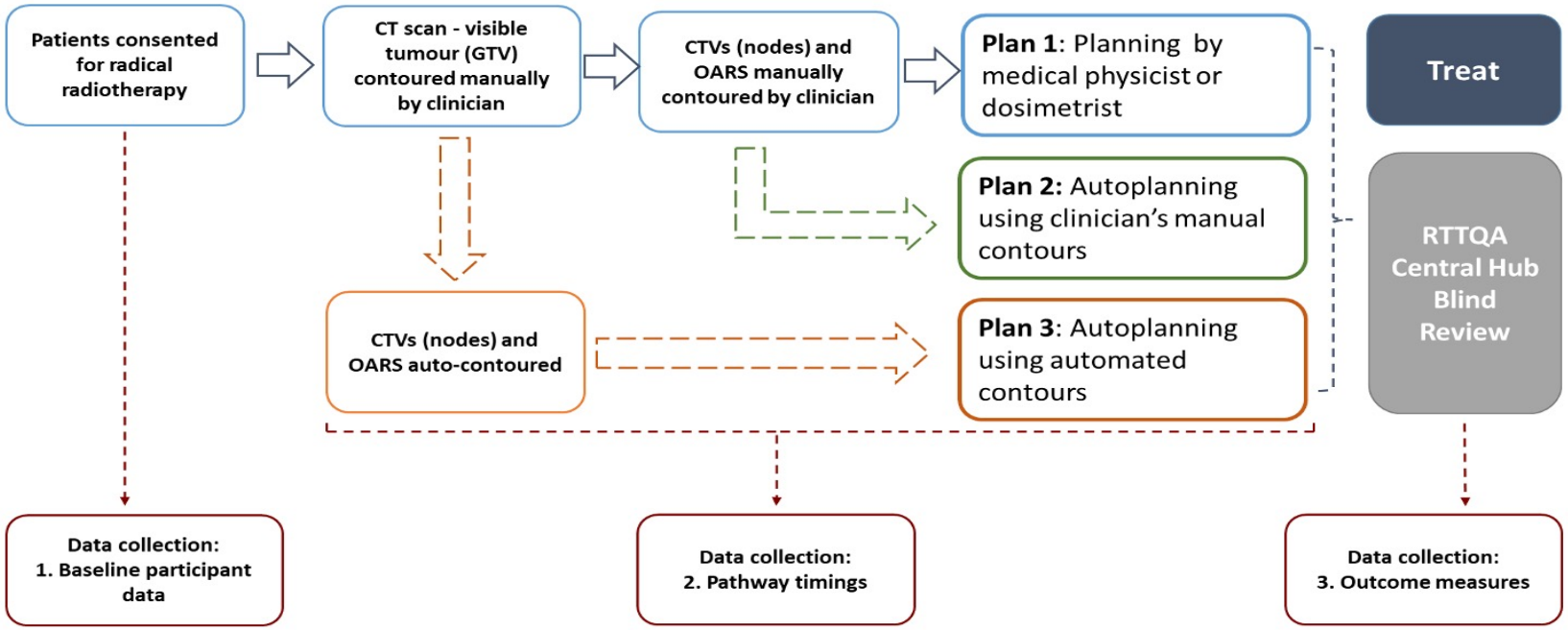
OPTIMIZATION
access

achievable outcome

achieved outcome

what needs to be done

dedicated trials



Key
Blue boxes: standard manual pathway;
Red boxes: fully automated pathway;
Green box: manual contours and automated plan
CTV – Clinical target volumes – areas of microscopic disease
GTV – Gross tumour volume – Visible tumour
OARS – Organs at risk of radiation damage

ARCHERY
ex. of prospective clinical trial
outcome & cost of AI in LMIC

Courtesy Ajay Aggarwal

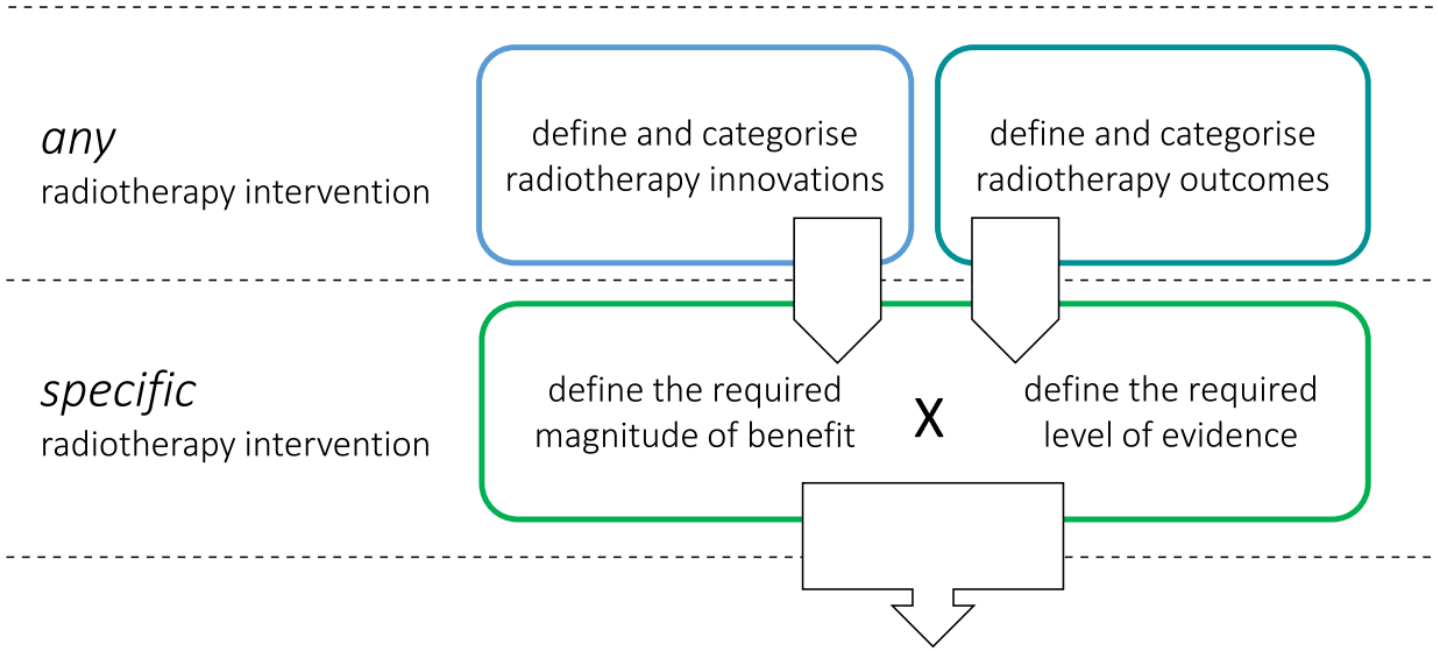
what needs to be done

ESTRO HERO

better understanding the value

Health Outcomes
that matter to *patients*

Costs
of delivering these outcomes

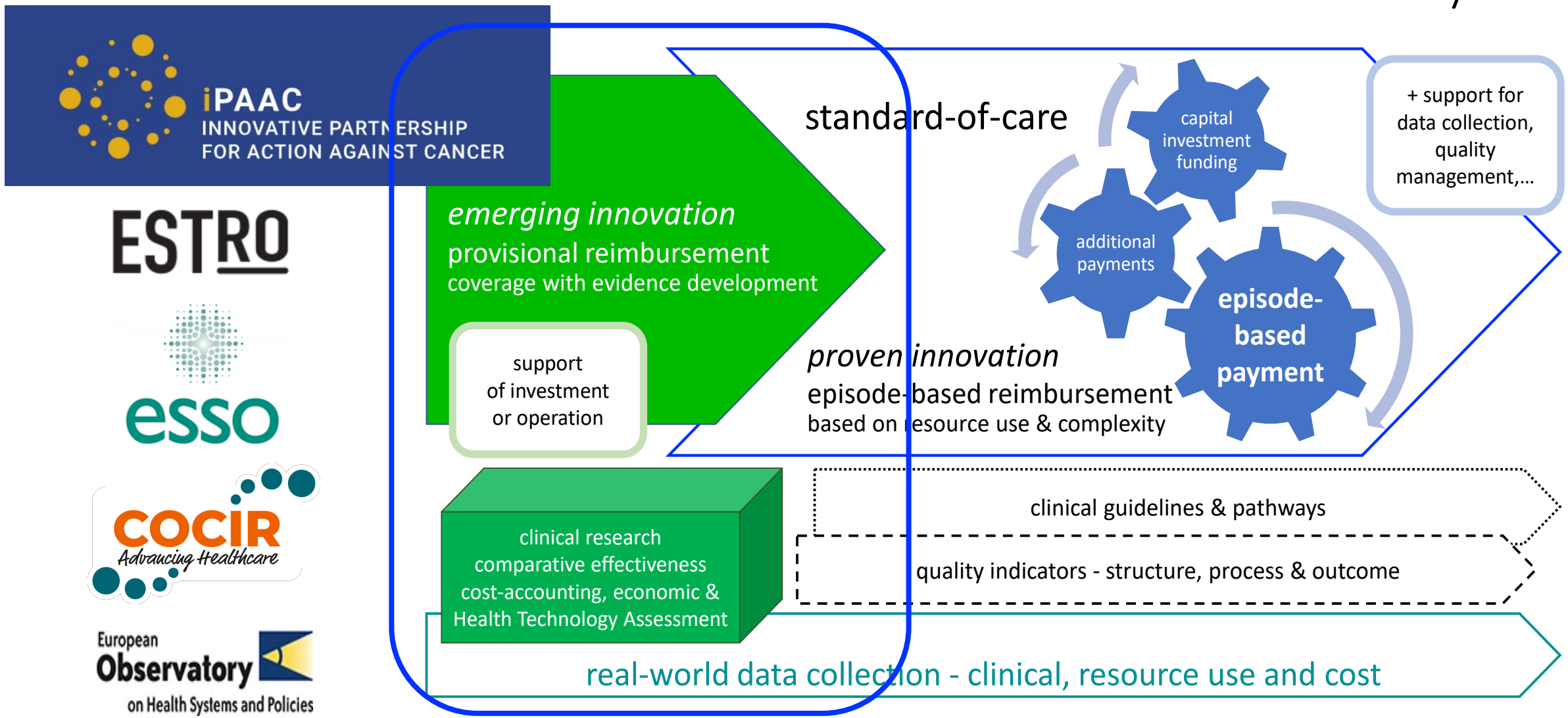


Value-Based Framework for Radiation Oncology

Porter M. NEJM 2010
Lievens et al, Radiother Oncol 2021

what needs to be done

inclusion in reimbursement system?



Borras et al, R&O and EJSO 2021

Lancet Oncology Groundshot Commission

" **Technological advances** do have a part to play
in future European cancer research and control efforts,
but they must be part of an ecosystem that delivers
advances that are patient centred, effective, affordable and equitable,
across the spectrum of site-specific cancers,
cancer control disciplines and research domains. "

launch 16th November 2022

THE LANCET The best science for better lives

Lawler et al, Lancet Oncol 2019


thank you for your attention!