Current Limitations and Future of AI in Radiation Oncology

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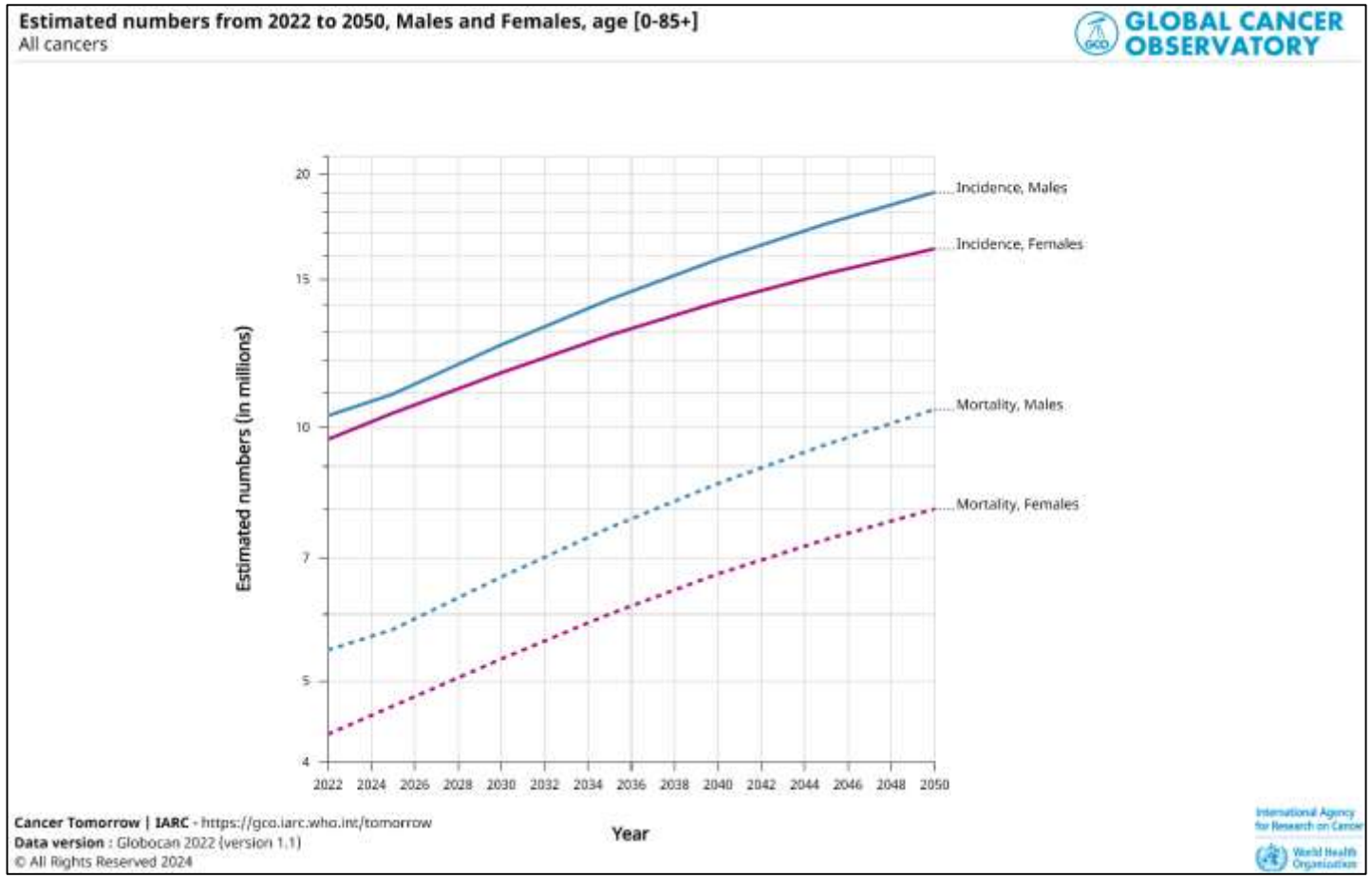
Estimated Burden of Cancer

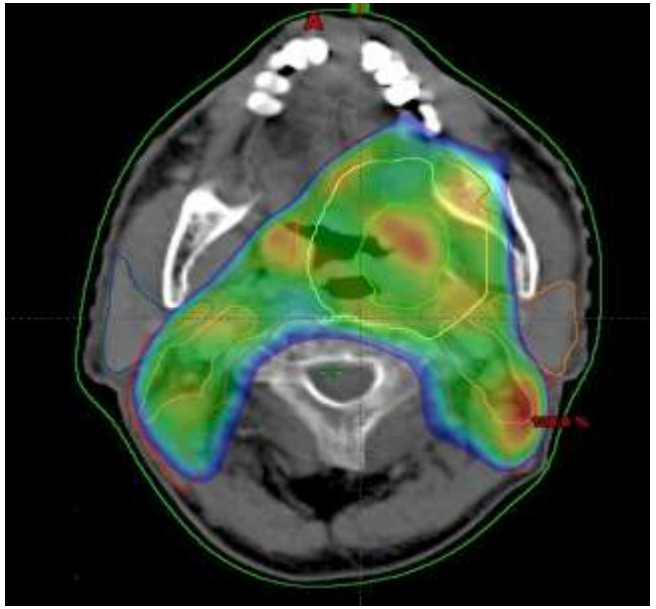


Limitation of Resources

- 70% of the cases from low and middle income countries
- Radiotherapy core modality of treatment
- Most common cancers: Head neck cancers, cervix, breast and prostate
- Access to RT: ranges 10-50%
- Long waiting times- disease progression- poor survival
- Shortage of Radiotherapy workforce
- Labour intensive workflow

- Scaling up RT departments- Use of AI one of the solution
- WHO and IAEA – goal to have RT access to 85%

Time Constraints 2D vs IMRT



- Complexities of treatment- use of multimodality imaging, contouring, planning, plan evaluation and execution
- Exhaustive process- over burdened
- Burnout- 31%*

*Franco P. Radiother Oncol 2020

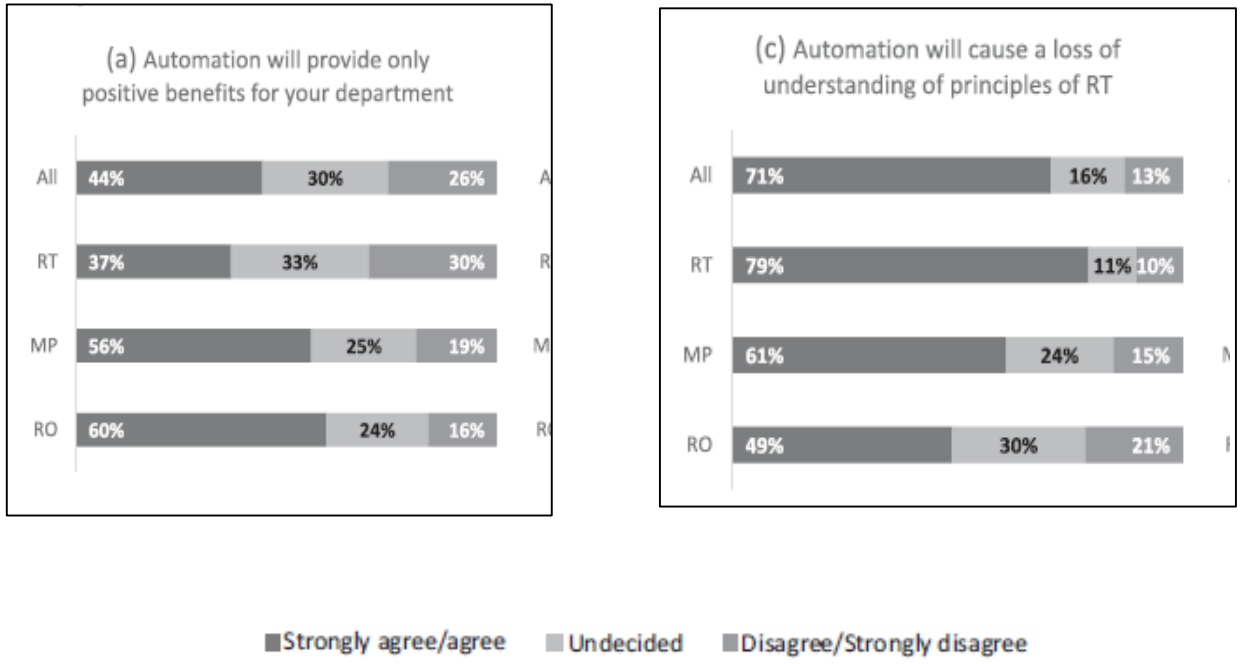
Will AI and automation be helpful?

- 325 Radiation Oncology Professionals: Radiation Oncologist, Medical Physicist, Radiation Technologist

	Will Increase	Will Decrease	No Change
Work output and productivity	88	1	11
Quality of planning	57	13	30
Consistency of planning	90	1	9
Staff focus on patient care	49	9	42
Systematic errors	20	40	36
Random/human errors	9	74	17

Batumalai V. Tech Inn & Pat Supp in Rad Onco 2020

Will AI and automation be helpful?



Attitude and perceived impact of automation, and tasks and/or roles to be pursued.

%	All
Attitude toward planning process automation	
Will reduce job satisfaction	27
Will increase job satisfaction	36
Will not impact job satisfaction	37
Perceived impact of automation on jobs	
Will change the primary tasks of certain jobs	66
Will allow me to do the remaining components of my job more effectively	51
Will eliminate jobs	20
Will not have an impact on jobs	6
Not at all concerned with automation	9
Tasks and/or roles to be pursued	
Learning new skills	66
Research and development activities	74
Being involved in implementation processes	58
Increased patient care focus	56
Training	50
Role expansion/Advanced practice	65

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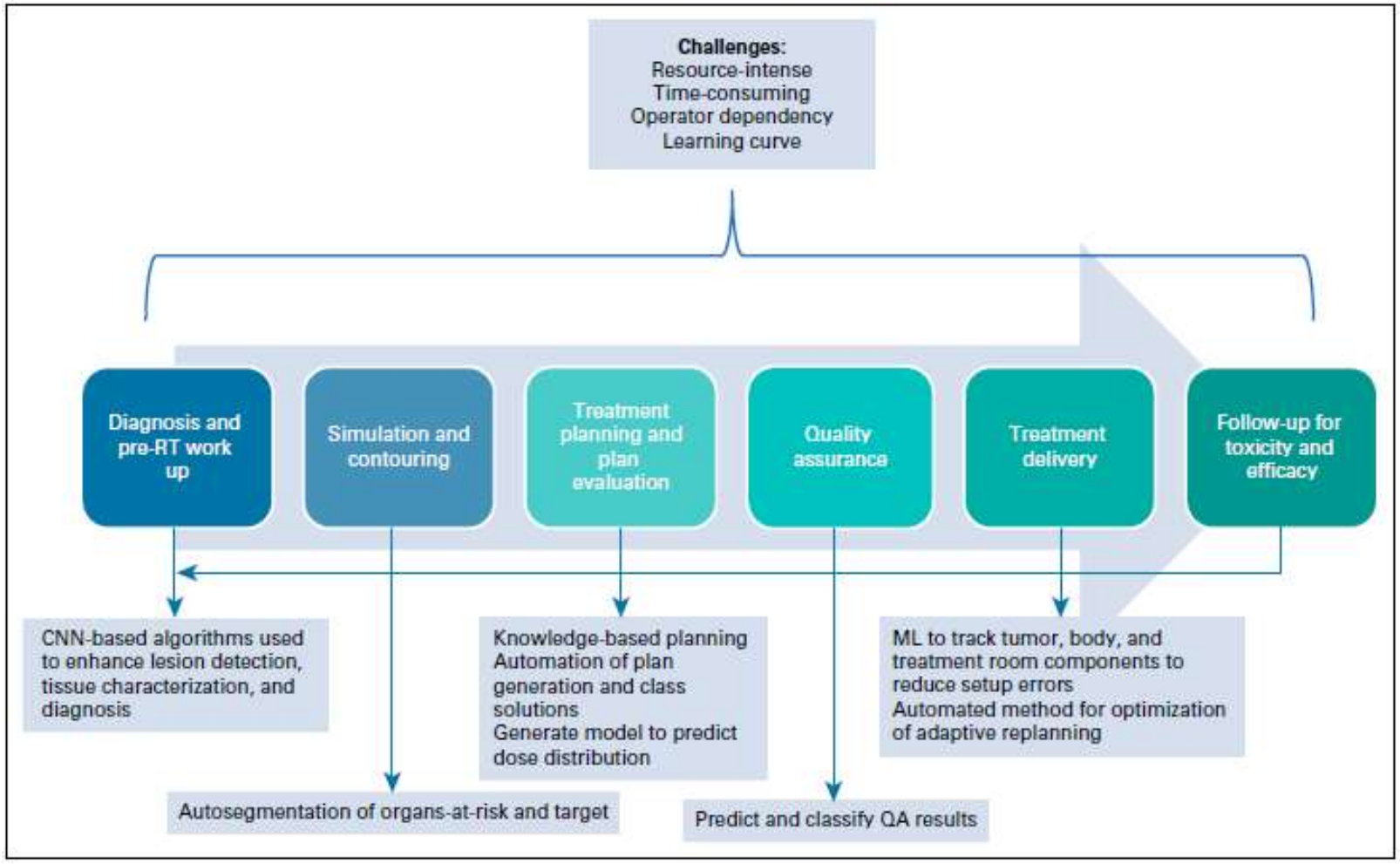
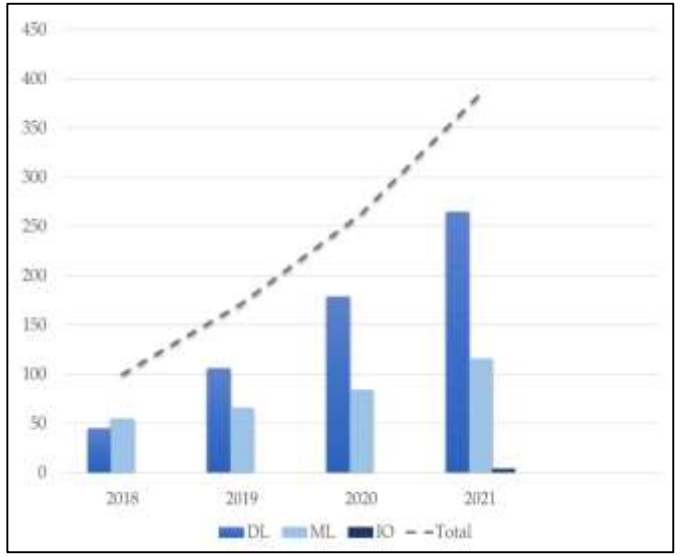
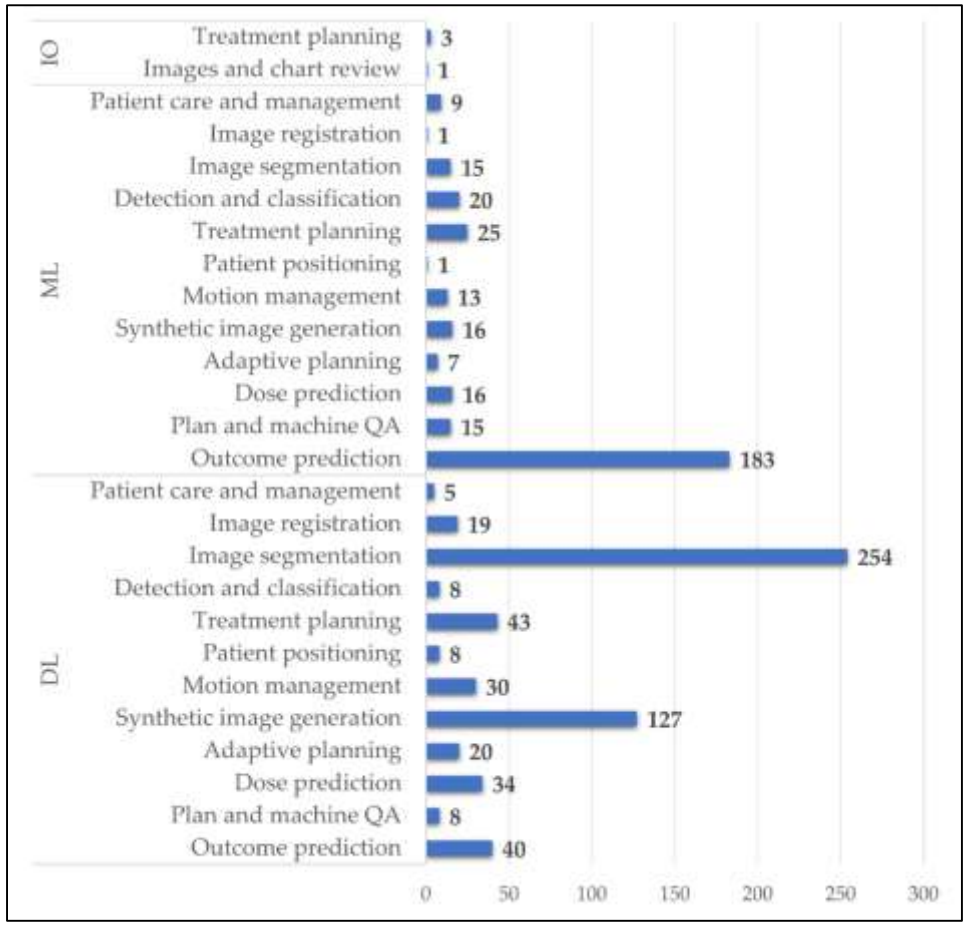
AI in Radiation Oncology

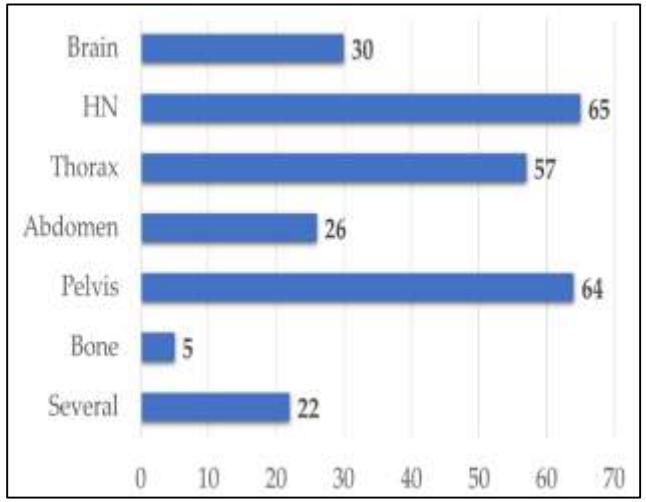


Krishnamurthy R et al. JCO Global Oncology 2022

Research In AI







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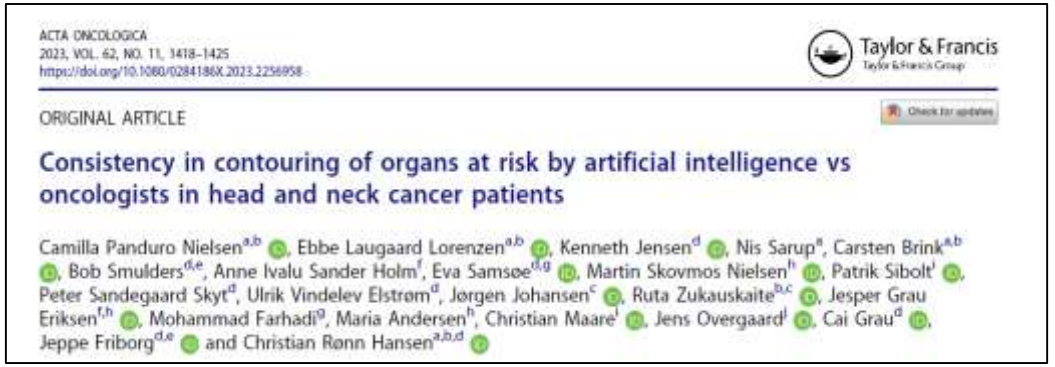
AI for Contouring

AI for contouring of organs at risk- especially in head neck cancer :Closer to reality

- Study by DAHANCA group
- 63 patients of head neck cancers DAHANCA 35 trial- protons vs photons
- Consistency of OAR contouring of Oncologists on photon vs proton plan was compared to that of AI based contouring
- Dice similarity co-efficient was 0.85 for AI and 0.68 for oncologist
- More consistent contours using AI



ACTA ONCOLOGICA
2023, VOL. 62, NO. 11, 1418–1425
https://doi.org/10.1080/0284186X.2023.2256958

Taylor & Francis

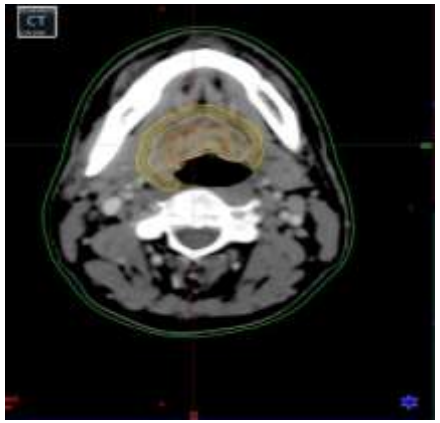
ORIGINAL ARTICLE

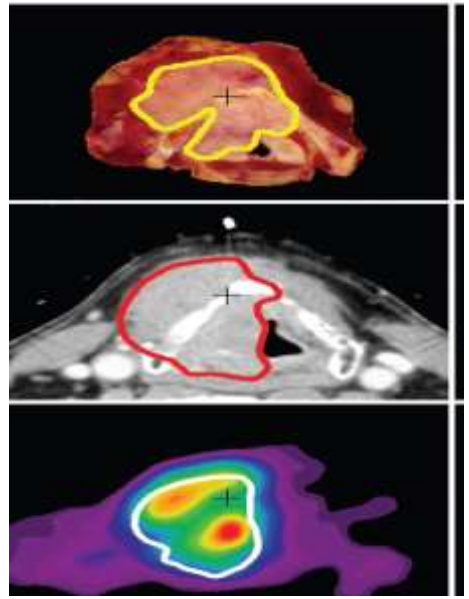
Consistency in contouring of organs at risk by artificial intelligence vs oncologists in head and neck cancer patients

Camilla Panduro Nielsen[a,b], Ebbe Laugaard Lorenzen[a,b], Kenneth Jensen[d], Nis Sarup[a], Carsten Brink[a,b], Bob Smulders[d,e], Anne Ivalu Sander Holm[f], Eva Samsøe[d,g], Martin Skovmos Nielsen[h], Patrik Sibolt[i], Peter Sandegaard Skyt[d], Ulrik Vindelev Elstrøm[d], Jørgen Johansen[c], Ruta Zukauskaite[b,c], Jesper Grau Eriksen[f,h], Mohammad Farhadi[g], Maria Andersen[h], Christian Maare[i], Jens Overgaard[j], Cai Grau[d], Jeppe Friborg[d,e] and Christian Rønn Hansen[a,b,d]

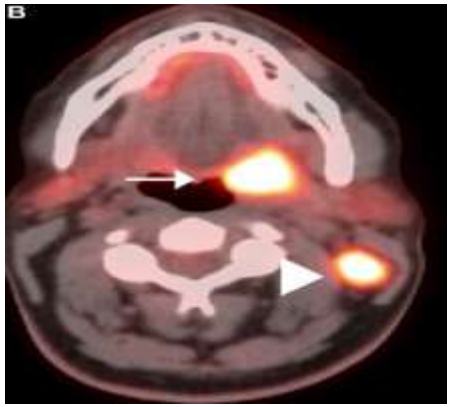
Limitations and Future: AI for Contouring

- Next step in head neck: Delineation of neck nodes
- CTV delineation- more challenging for AI





- Use of multimodality imaging

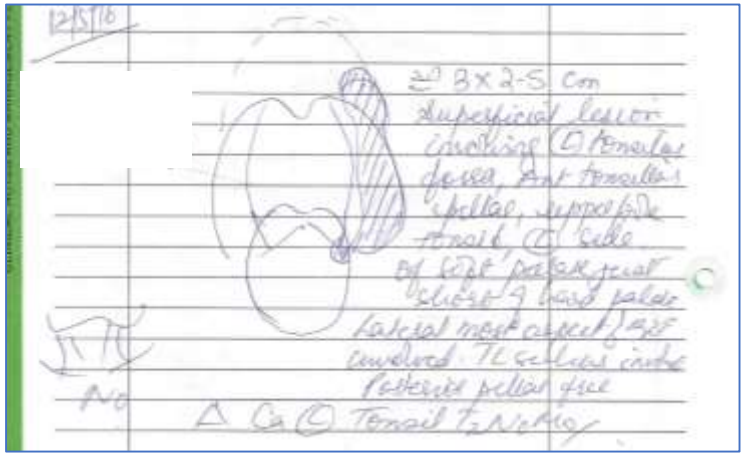


Mismatch Volume 13%

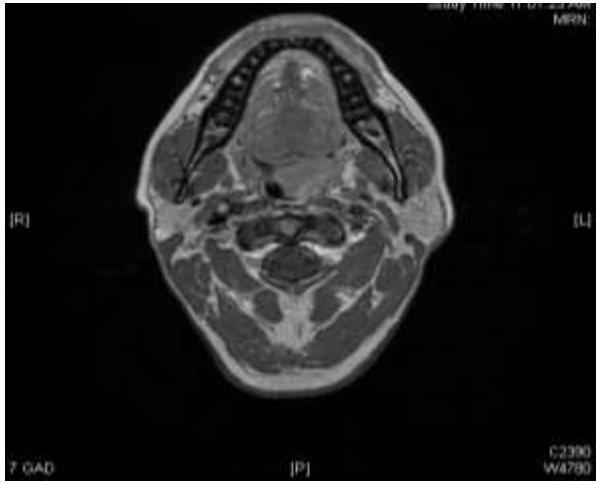
Dalsne JF, Gregoire V et al. Radiology 2004

Limitations of AI: Target Volume Delineation

Clinical Examination/Clinical Photograph



Clinical Diagram

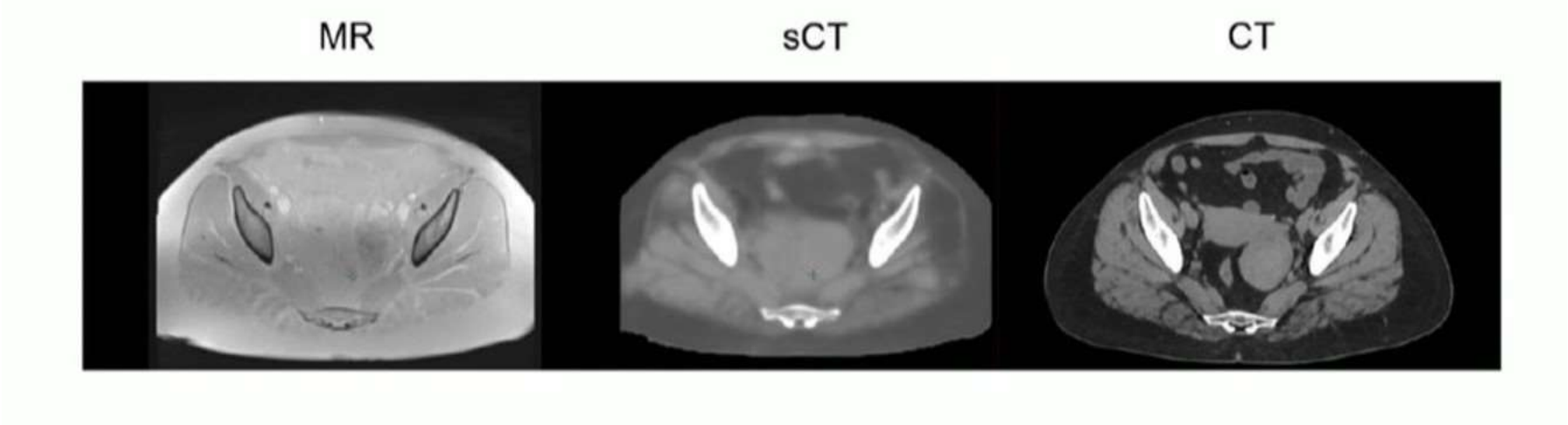


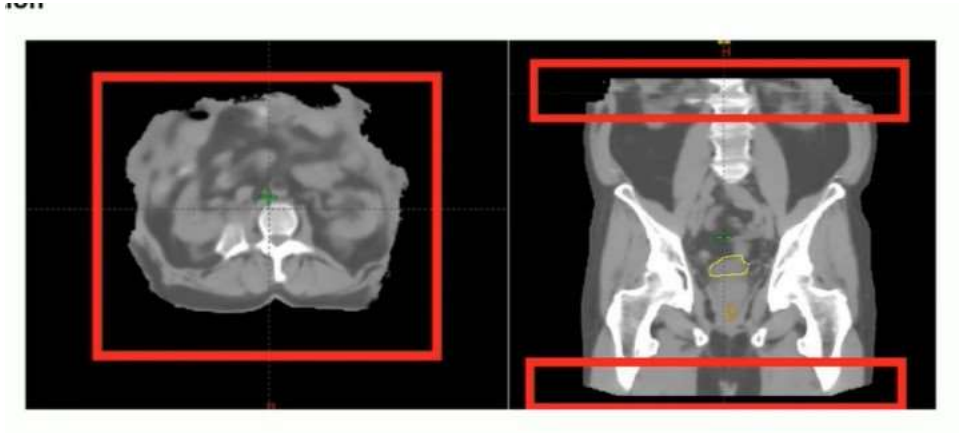
Imaging

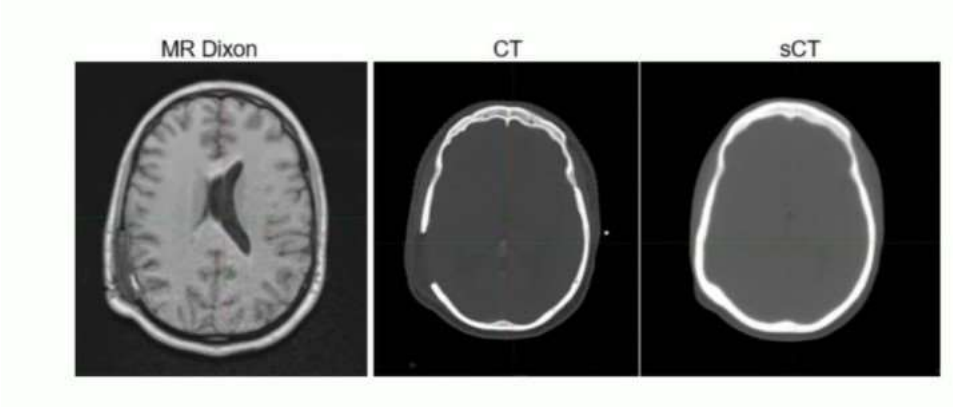
Mucosal Disease

AI for synthetic CT generation

- MR only workflow and generation of synthetic CT







Sophie Perryck. ESTRO 2024

AI for Planning

nature medicine

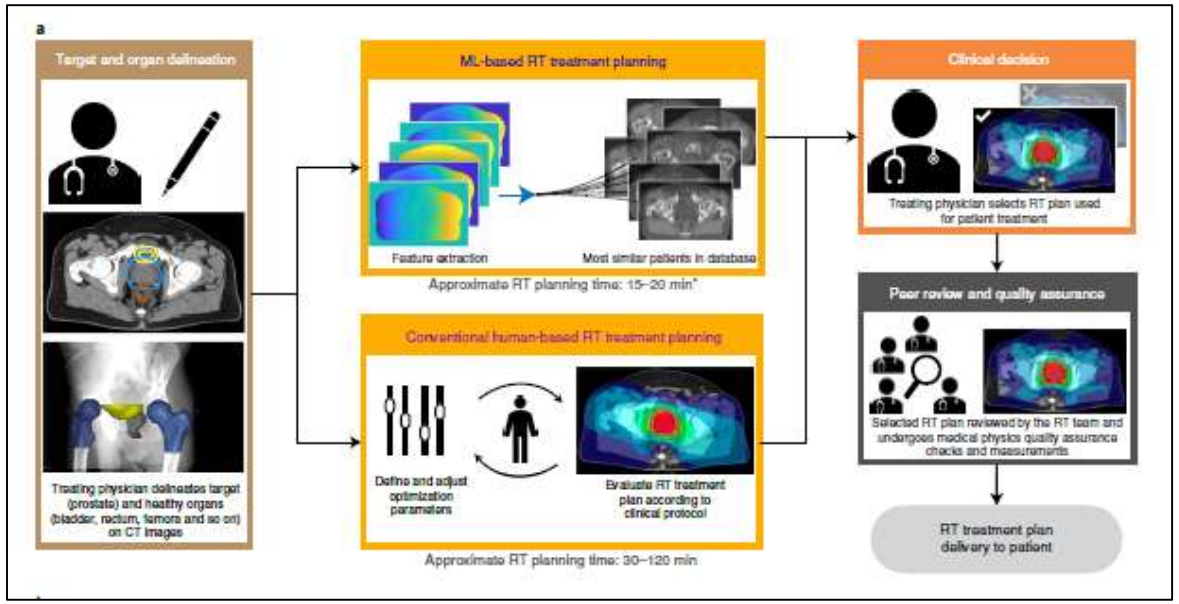
LETTERS

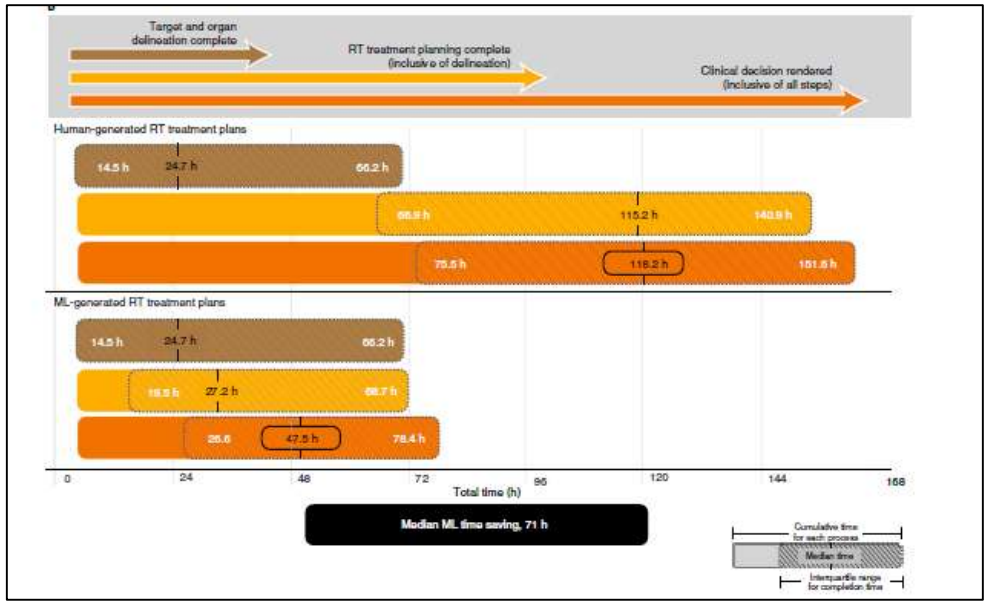
https://doi.org/10.1038/s41591-021-01359-w

Check for updates

Clinical integration of machine learning for curative-intent radiation treatment of patients with prostate cancer

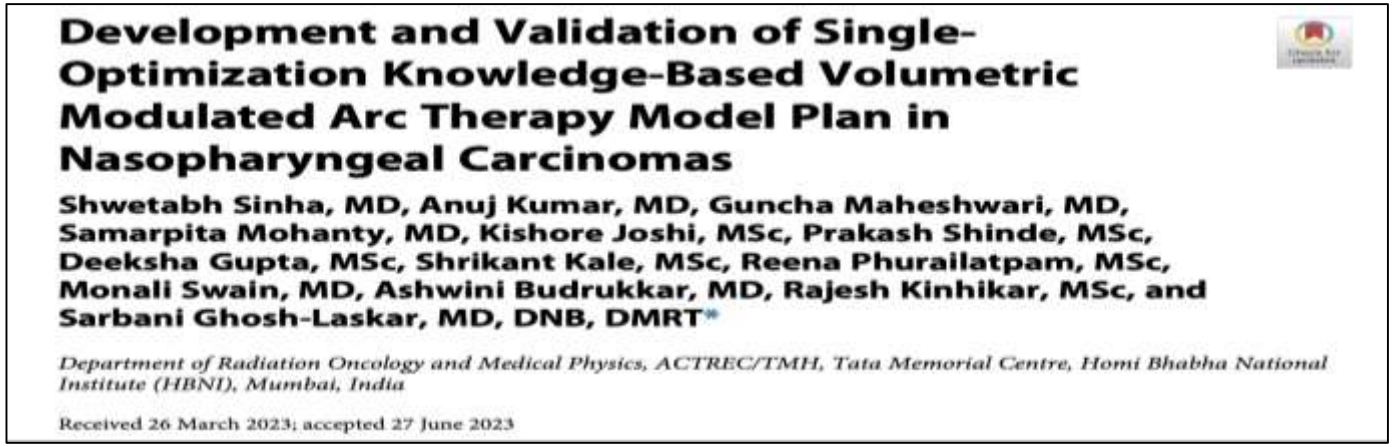
Chris McIntosh[1,2,3,4,5,6,8], Leigh Conroy[1,2,7,8], Michael C. Tjong[1,7], Tim Craig[1,2,7], Andrew Bayley[1,7], Charles Catton[1,7], Mary Gospodarowicz[1,7], Joelle Helou[1,7], Naghmeh Isfahanian[1,7], Vickie Kong[1,7], Tony Lam[1,7], Srinivas Raman[1,7], Padraig Warde[1,7], Peter Chung[1,7], Alejandro Berlin[1,2,7,8] ✉ and Thomas G. Purdie[1,2,6,7,8] ✉





Nature Medicine 2021

Limitations: AI in Planning



Development and Validation of Single-Optimization Knowledge-Based Volumetric Modulated Arc Therapy Model Plan in Nasopharyngeal Carcinomas

Shwetabh Sinha, MD, Anuj Kumar, MD, Guncha Maheshwari, MD, Samarpita Mohanty, MD, Kishore Joshi, MSc, Prakash Shinde, MSc, Deeksha Gupta, MSc, Shrikant Kale, MSc, Reena Phurailatpam, MSc, Monali Swain, MD, Ashwini Budrukkar, MD, Rajesh Kinhikar, MSc, and Sarbani Ghosh-Laskar, MD, DNB, DMRT*

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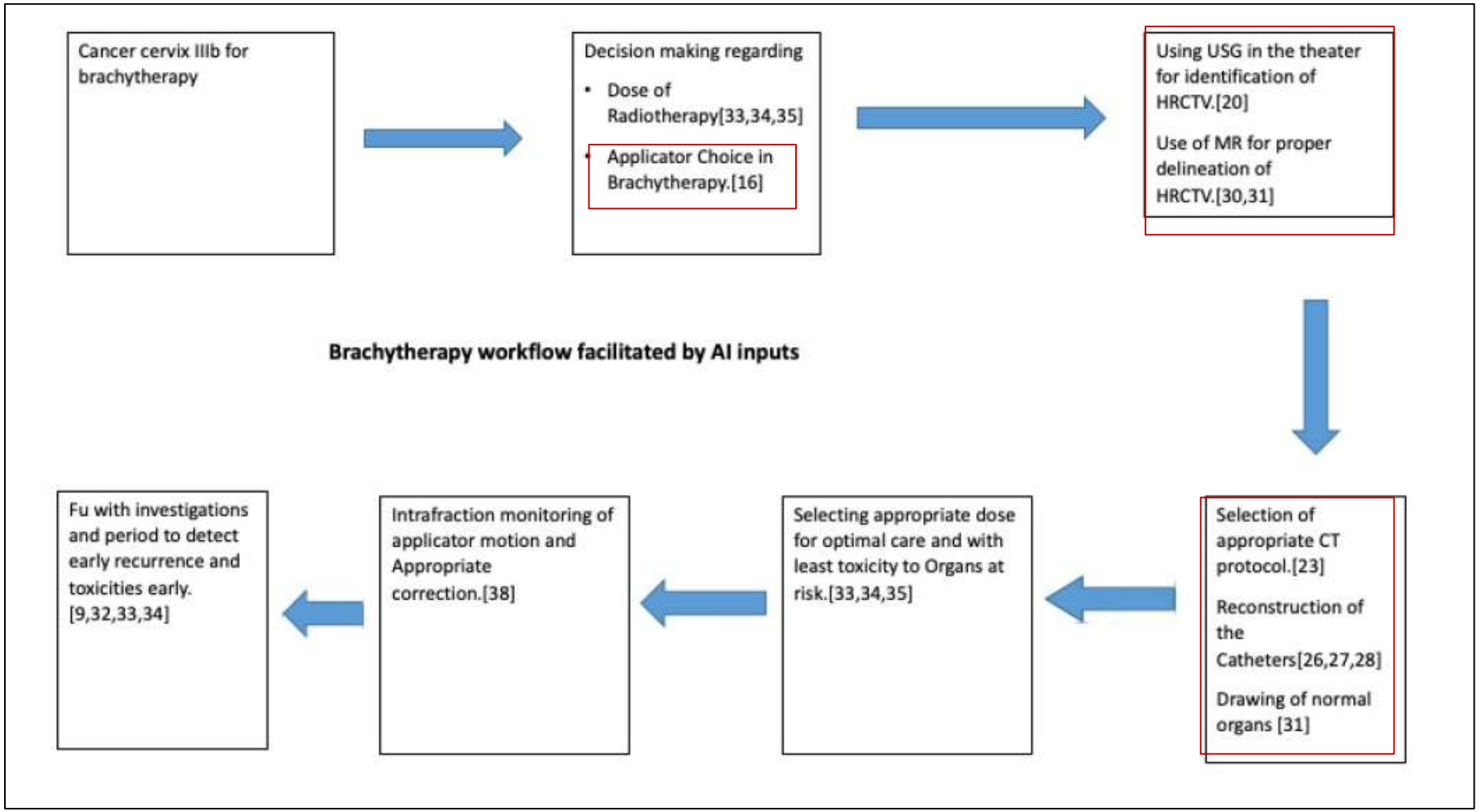
- Small training and Validation sets

AI in plan QA, Commissioning and Machine Performance Check

- Treatment delivery- large amount of data, images
- Challenging and time consuming for human to identify errors in such large data base
- AI based solution- chart review automation- being developed
- Improve the efficiency of implementation of treatment and reduce errors

Santoro M. Appl Sci 2022

AI in Brachytherapy



Banerjee S. Br J Radiol 2021

Limitations

- Radiation Oncologists
    - Judgement may be more accurate
    - Interaction with patient daily
    - Understand the spoken and unspoken patient needs
- AI tools: Computer aids to the staff
- Radiation Oncologist
    - Will remain responsible
    - In charge of the entire treatment

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Concerns

- Quality of data: Garbage in garbage out
- Developments based on small sample size
- Applicability of algorithms across varies ethnicities
- Algorithms developed and tested on Western population may not fit for Asian population
- Need for equity in data representation

Challenges

- Clinical utility of use of AI yet to be determined- all the developments are at technological incubation- upto clinicians to establish its clinical value
- Risk analysis of AI and automation: Manual review will be required for many years
- Black Box Nature of AI: Lack of transparency and difficulty in understanding the outputs
- How AI thinks is still different than how humans think
- Training data: Large datasets are required to train the data properly which may not be feasible
- Patient privacy, anonymity, ethics

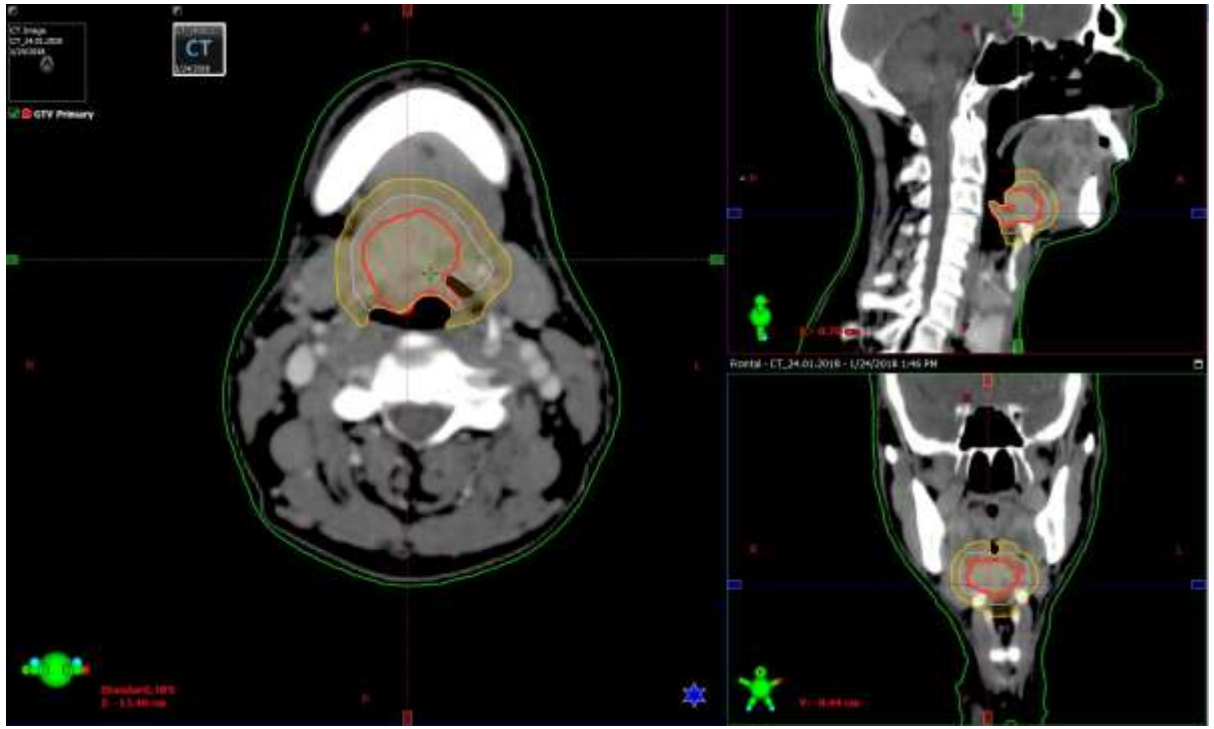
Krishnamurthy R et al. JCO Global Oncology 2022

Will AI replace my job?

- AI may need change in the nature of some jobs
- It will be more about quality assurance checks and inputs to AI
- AI will make you free to some extent to do other jobs peacefully
    - Talking and counselling patient
    - Examining patients
    - Clinical management
    - Reduce wait times to meet doctors

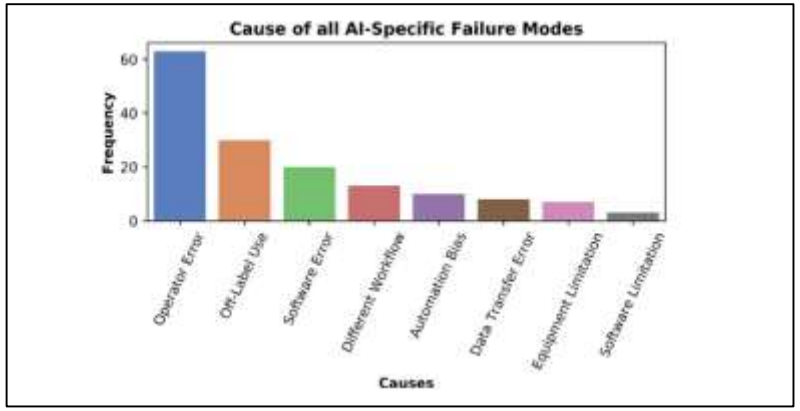
How to teach the younger generation?

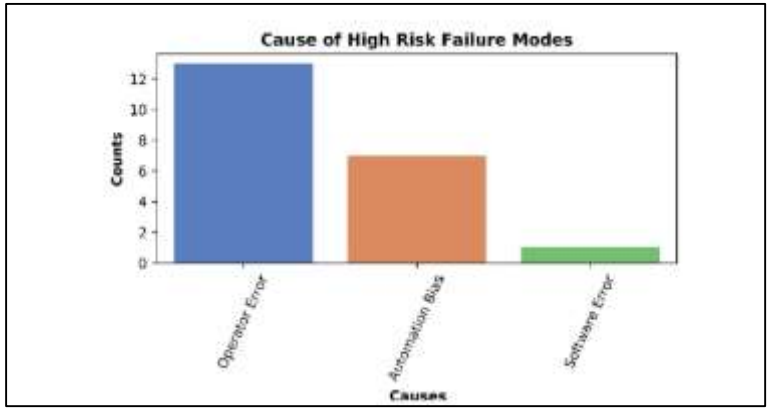
- Evolution from 2D to 3D to IMRT
- Contouring/ Planning/Plan evaluation/ Plan execution: integral components
- Many steps carried out by AI
- How younger generation will learn the basics of contouring
- Also younger generation needs to be trained for use of AI in clinics



Limitations: Errors of AI

- Quantified the risk associated with Radiotherapy Planning Assistant (RPA)
- Mutli- disciplinary team identified and scored each failure mode
- Of the 290 failure modes they identified 126 modes related to AI





Need for training in AI
Simplify the user interface with AI for human understanding

Nealon KA. Pract Radiat Oncol 2022

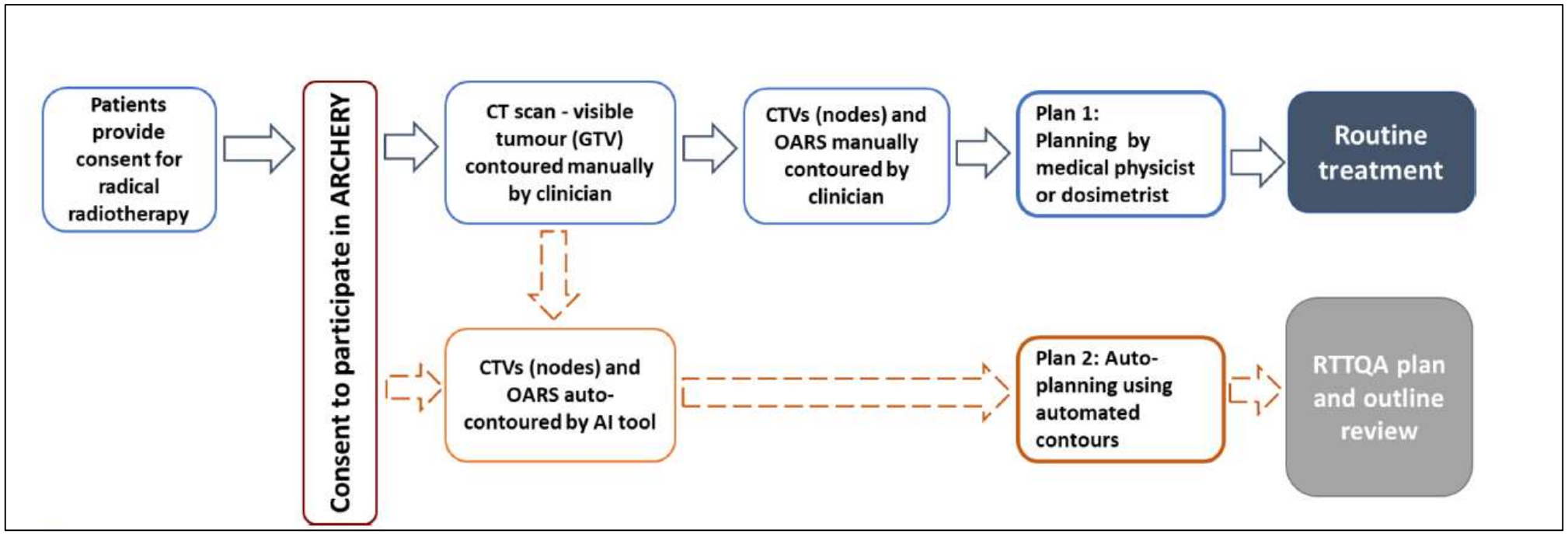
ARCHERY: a prospective observational study of artificial intelligence-based radiotherapy treatment planning for cervical, head and neck and prostate cancer – study protocol

Ajay Aggarwal,[1,2] Laurence Edward Court,[3] Peter Hoskin,[4,5] Isabella Jacques,[1] Mariana Kroiss,[5] Sarbani Laskar,[6] Yolande Lievens,[7] Indranil Mallick,[8] Rozita Abdul Malik,[9] Elizabeth Miles,[5] Issa Mohamad,[10] Claire Murphy ,[1] Matthew Nankivell,[1] Jeannette Parkes,[11] Mahesh Parmar ,[1] Carol Roach,[1] Hannah Simonds,[12] Julie Torode,[13] Barbara Vanderstraeten,[7] Ruth Langley[1]

- Highest Burden of Cancer in Low and Middle Income Countries (LMICs)
- Limited workforce in LMICs
- AI can contribute for achieving sustainable development goals which can be accessible and affordable.
- AI based Radiotherapy Planning Assistant (RPA): Auto-contouring of CTVs and OAR and planning

BMJ Open 2023

ARCHERY



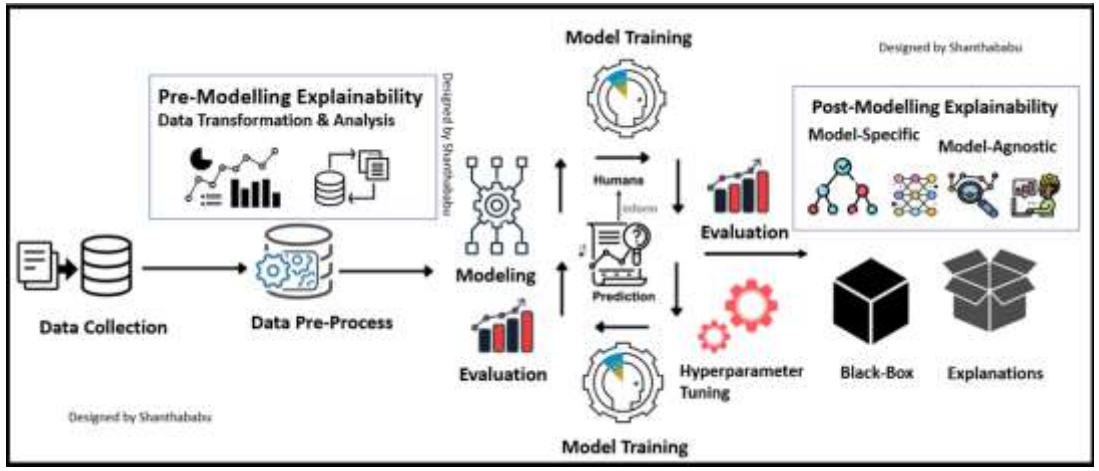
- 4 LMICS
  - India (TMH Mumbai, Tata Kolkata),
  - Jordan
  - Malaysia
  - South Africa

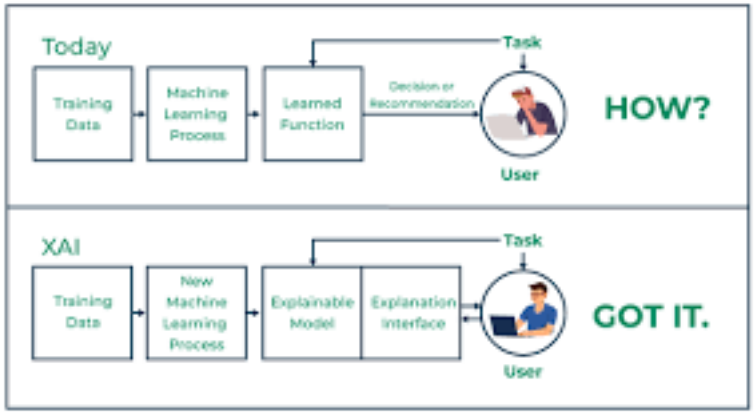
- 3 common sites
  - Head and Neck
  - Cervix
  - Prostate
- Sample size: 330 per tumour site

BMJ Open 2023

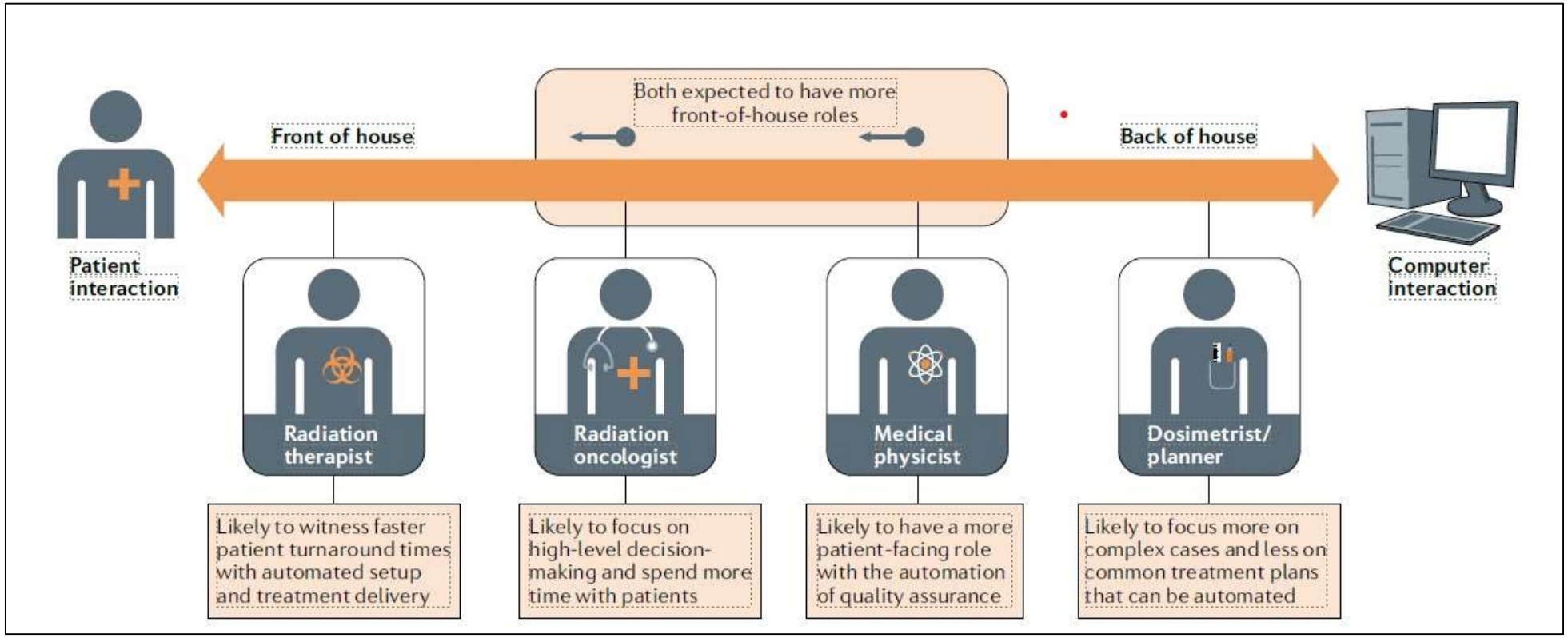
Advancements in AI to Overcome Limitations

- Improved data collection methods and facilitative pooling
- Advances in explainable AI
- Better integration strategies (Mixture of Experts)
- Addressing ethical and regulatory issues comprehensively





Future Job Profiles



Hyunh E. Nature Reviews Clinical Oncology 2020

Future of AI

A PORTABLE ROBOT TO PERFORM PROSTATE BRACHYTHERAPY WITH ACTIVE NEEDLE STEERING AND ROBOT-ASSISTED ULTRASOUND TRACKING

Mahsa Rabiei
University of Hawaii at Manoa
Honolulu, HI

Bardia Konh
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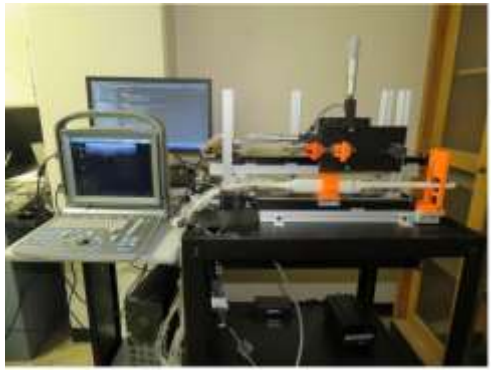
Honolulu, HI



Proceedings of 2022 Design of Medical Devices Conference

How Does Future Look Like?

In 10-15 years: AI assistants

Most of the Radiotherapy process will be AI driven

This includes from CT imaging to treatment and plan adaptation

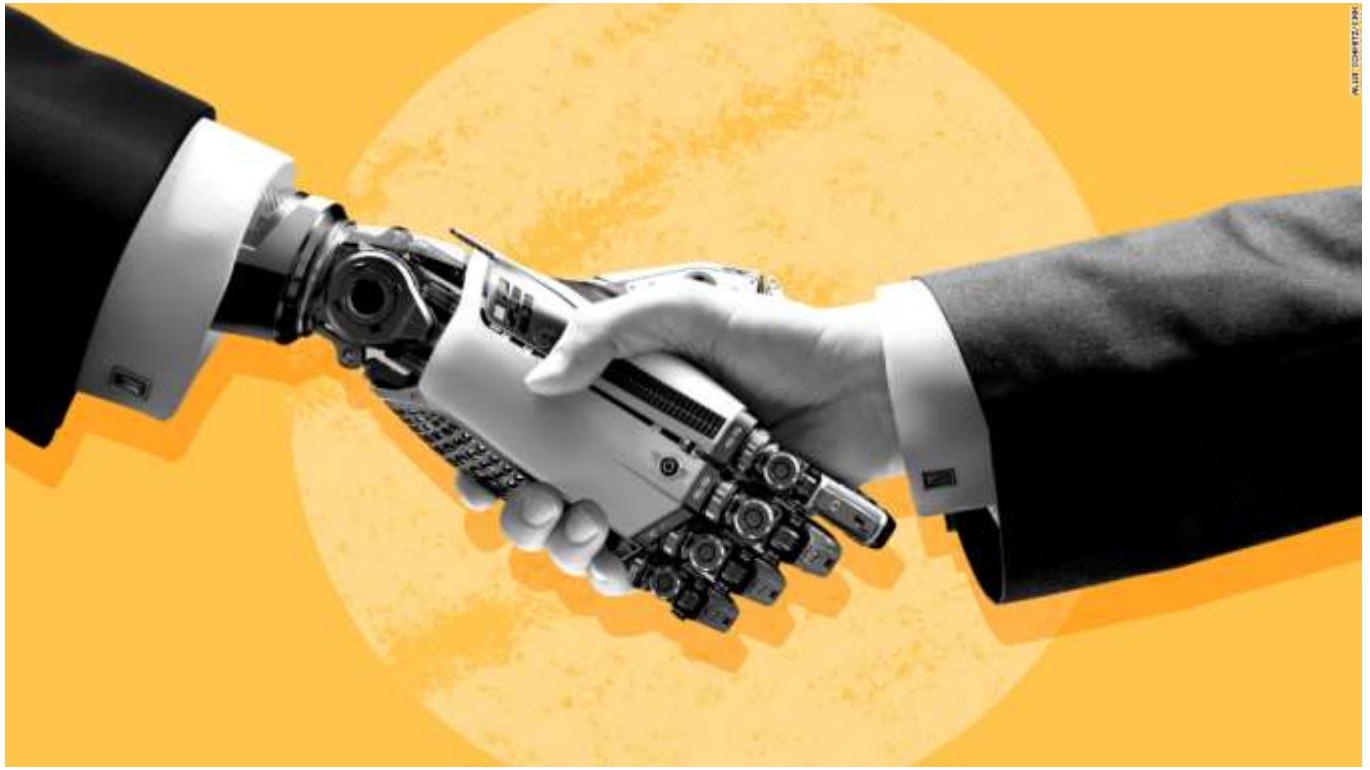
Human Supervision will still be required

Roles have to be modified

Staff needs to be educated for AI- human interaction

Nature Medicine 2021

Collaboration between Humans and Machines



Conclusion

- Artificial intelligence in radiation therapy is still in the early phase, but rapidly progressing
- There is a potential to improve care, make it faster, more efficient and homogeneous
- Auto-segmentation, treatment planning and quality assurance are already being used
- Artificial intelligence has made adaptive plans and treatments feasible
- Physicians have a responsibility to see if the artificial intelligence results correlate with clinical practice

Acknowledgments

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Dr Abhishek Chatterjee
Dr Sheetal Kashid

ashwini.budrukkar@gmail.com