Real-time MRI Guided Prostate Radiotherapy

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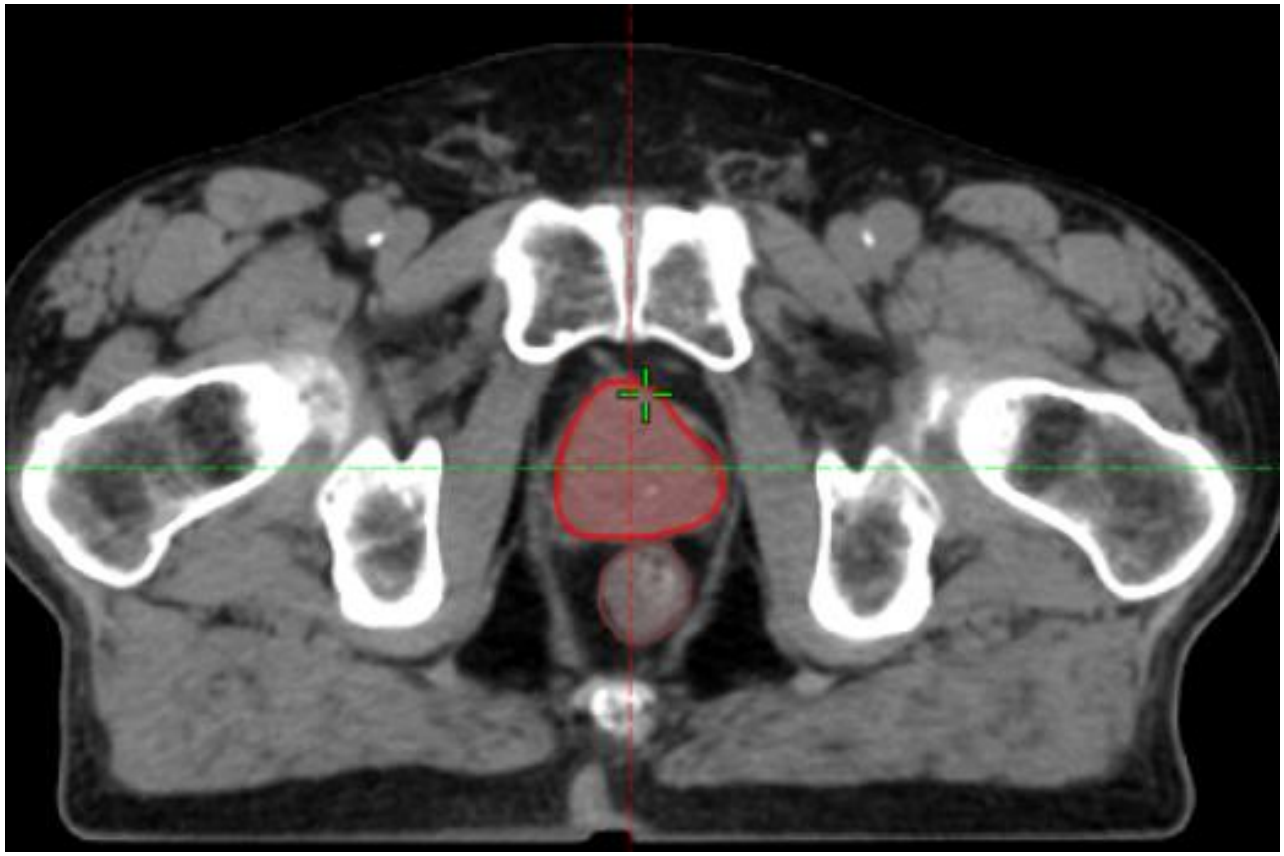
Objectives

- Describe the importance of imaging to radiotherapy planning and delivery

External Beam Radiotherapy

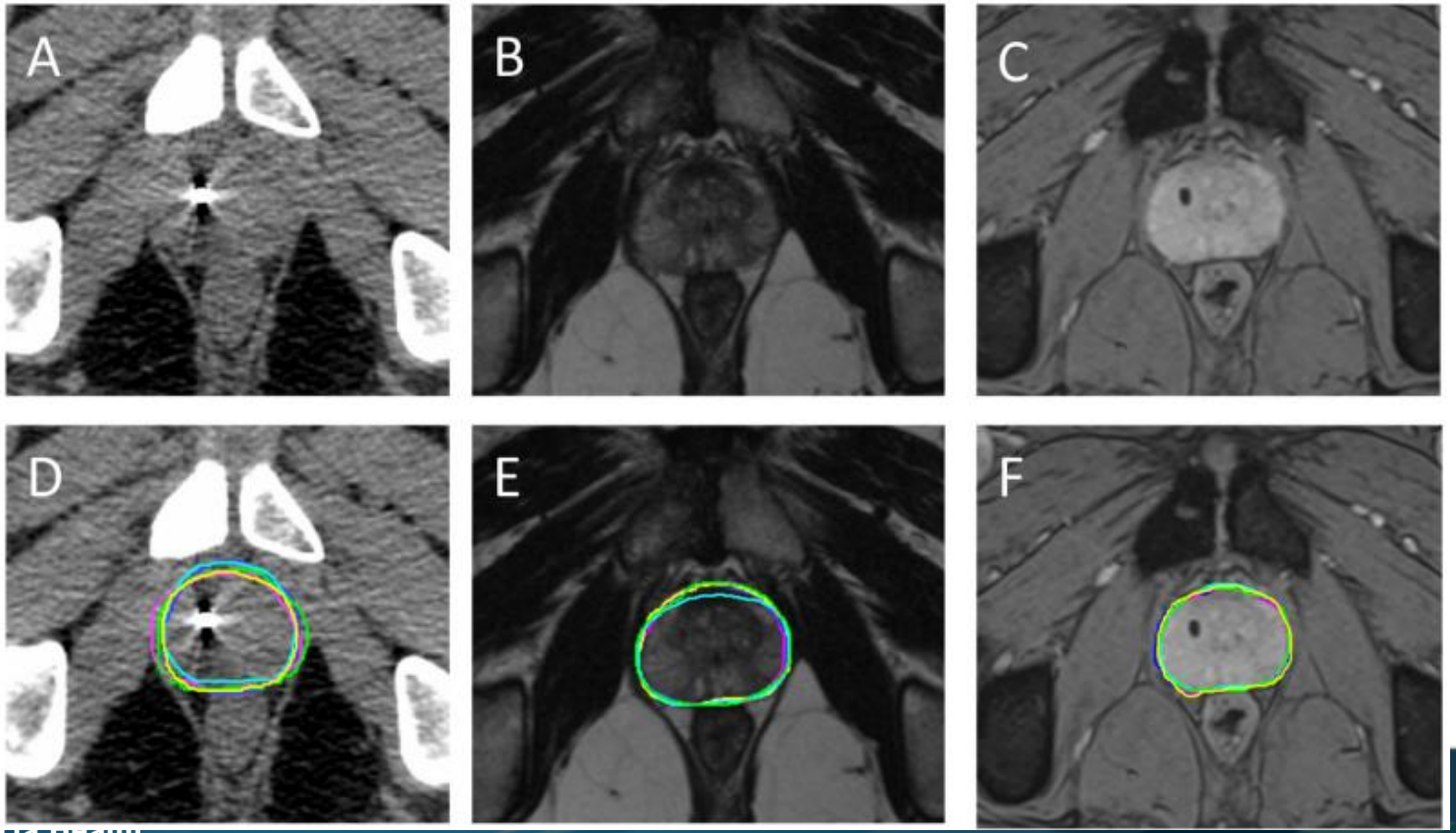
Simulation / Planning	Delivery
	

Simulation / Planning



CT vs MRI

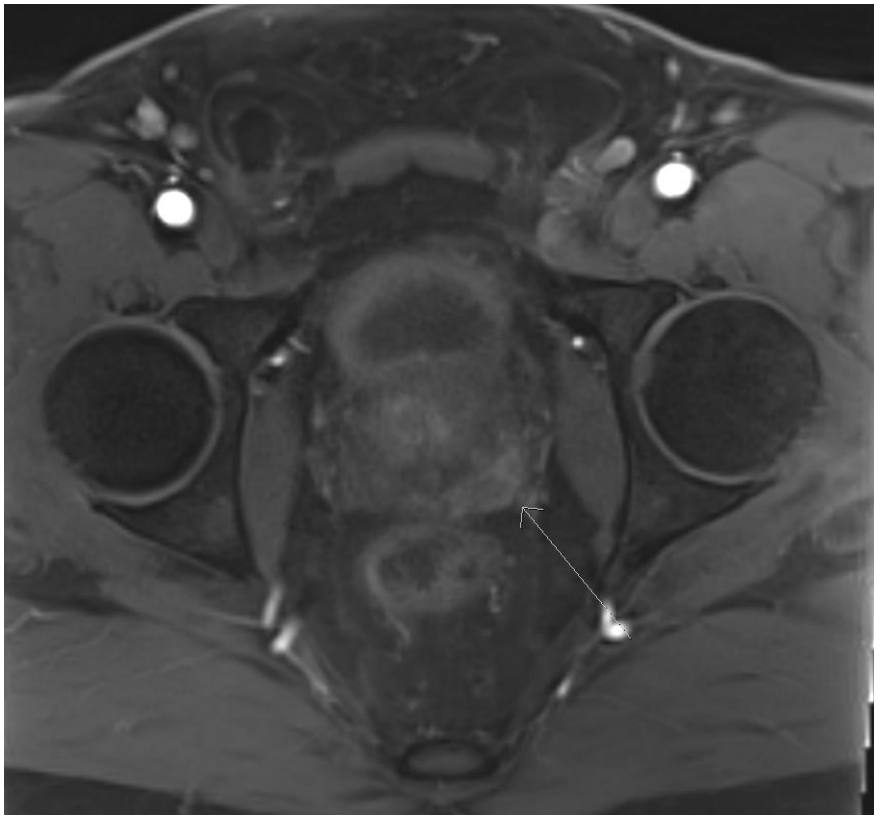
- MRI has superior soft tissue visualization vs CT
- Prostate contouring is more accurate, with smaller volumes and less variability between physicians when using MRI compared to CT



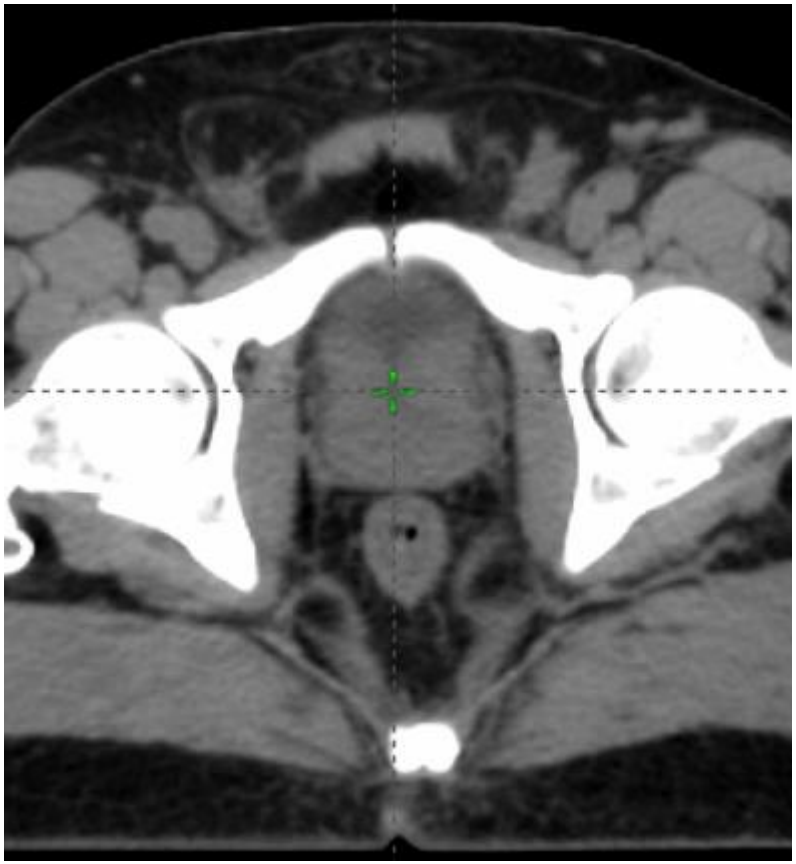
Pathmanathan, Br J Radiol 2019

Dominant Intraprostatic Nodules

MRI



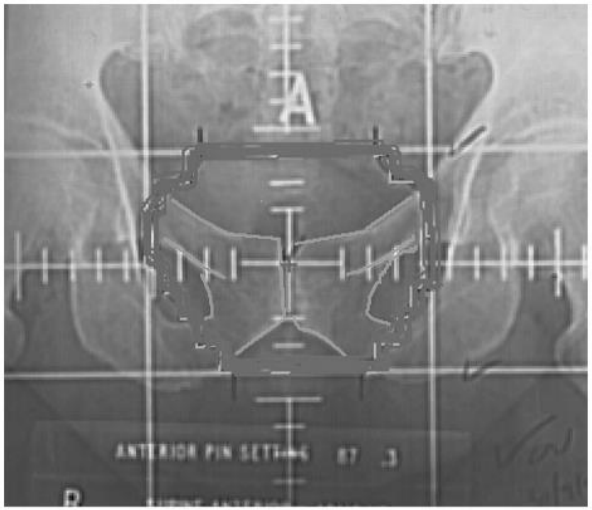
CT



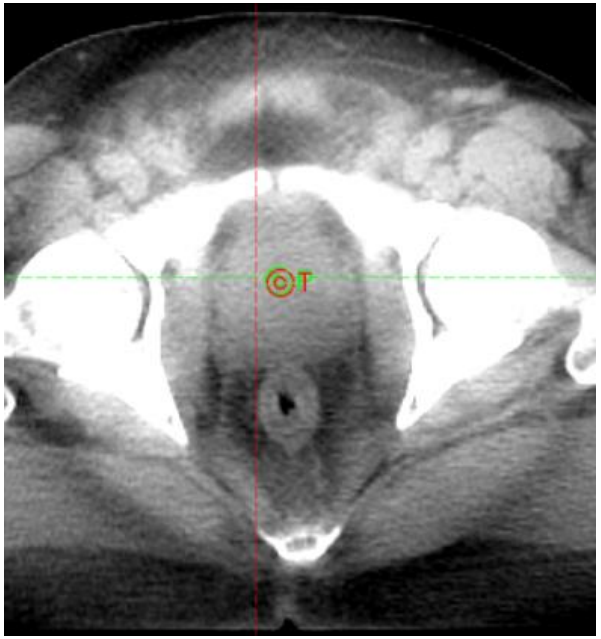
Treatment Delivery

- Daily image guidance allows an image (x-ray, CBCT, MRI) to be taken just prior to each RT fraction

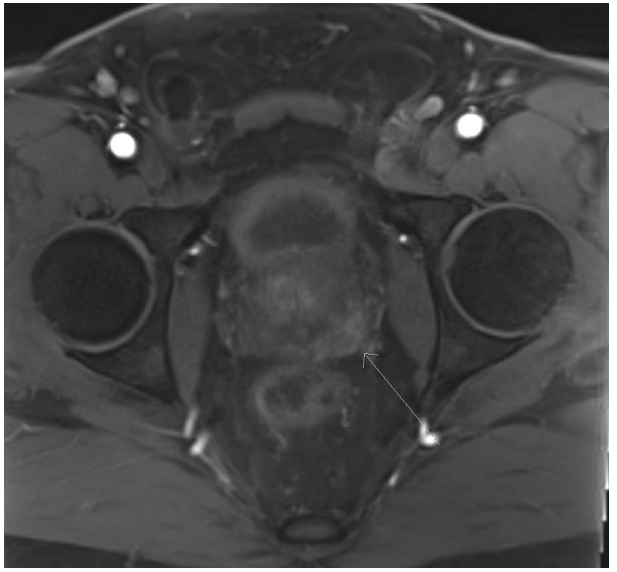
X-ray



CBCT

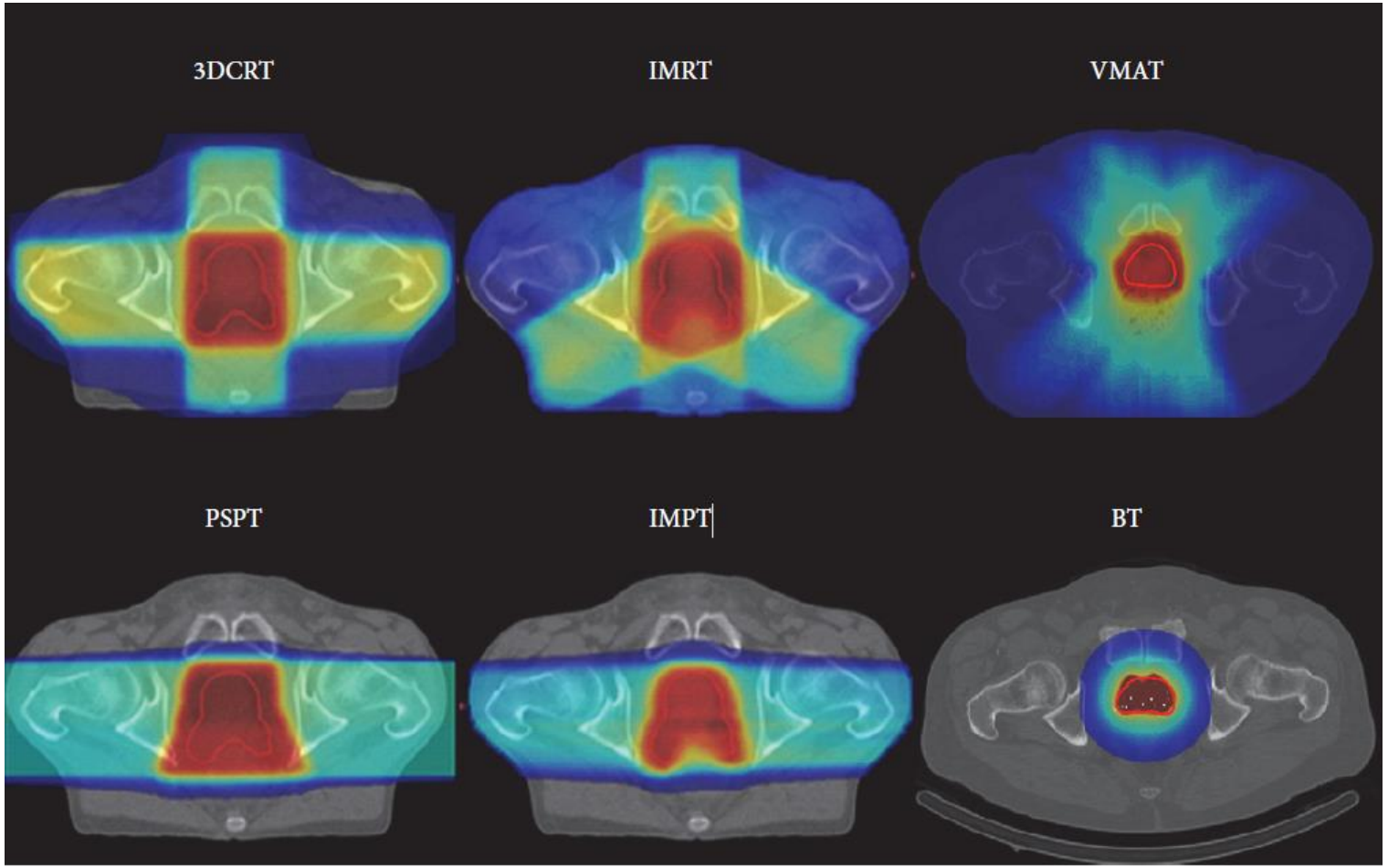


MRI



Mubata, IJROBP 1998

Delivery Techniques

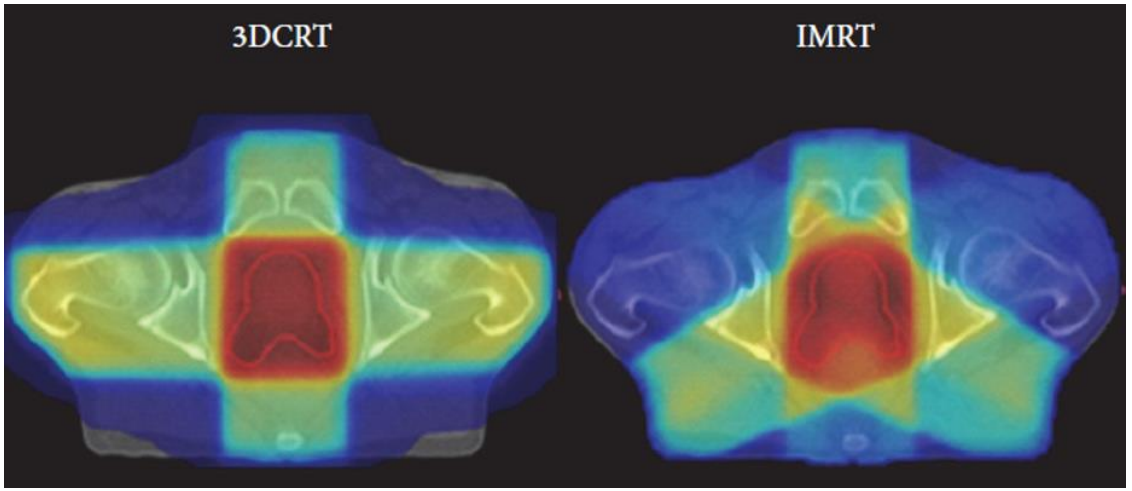


Vanneste, BioMed Res Int 2016

Treatment Delivery

- Combined with image guidance, improved radiation delivery techniques (3DCRT, IMRT, VMAT) have allowed the delivery of increased doses with comparable side effects and improved cancer control

68 Gy (1990s) → 78 Gy (mid 2000)



Vanneste, BioMed Res Int 2016

Trend towards fewer fractions

78 Gy in 39 fractions Over 8 weeks 2 Gy per day ~2005	→
60 Gy in 20 fractions Over 4 weeks 3 Gy per day ~2015	

- Trend led by effort to reduce costs and to improve patient convenience
- Larger doses in fewer fractions = hypofractionation

Biological basis for hypofractionation

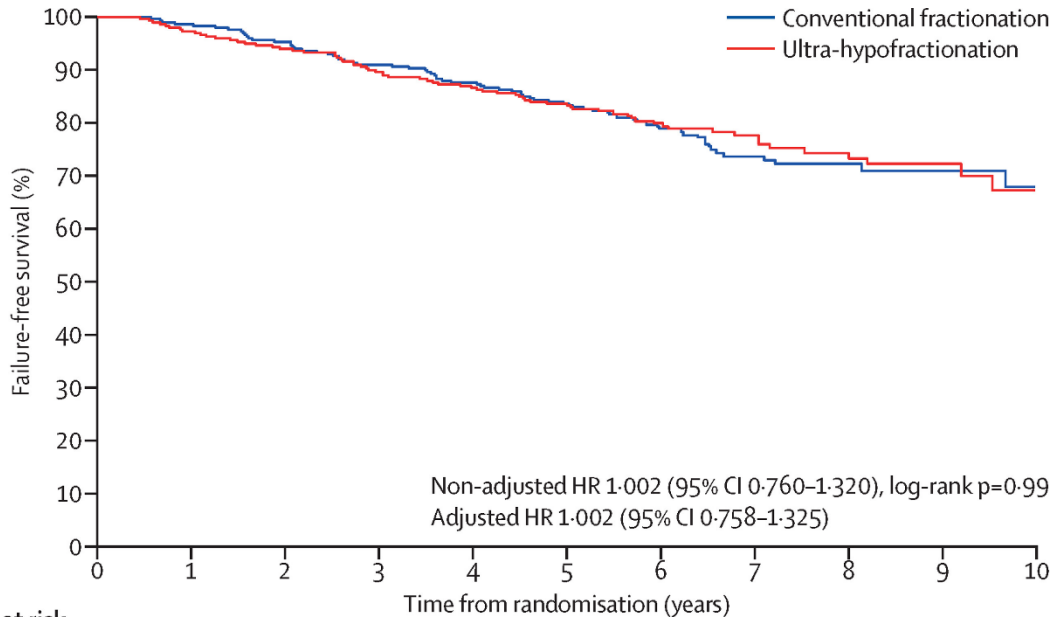
	Head and Neck Squamous cell carcinoma	Prostate adenocarcinoma
	BED if α/β ratio = 10 Gy	**BED if α/β ratio = 1.5 Gy**
78 Gy in 39 fractions	94 Gy	182 Gy
42.7 Gy in 7 fractions	69 Gy	216 Gy
36.25 Gy in 5 fractions	63 Gy	211 Gy

- Higher doses per fraction results in higher overall biological equivalent dose (BED) in prostate cancer

Universitätsspital Zürich, 5x5 – Will 5 fractions of precision radiotherapy suffice? 5 Fraction Radiotherapy in Prostate Cancer, (Jun. 04, 2021). Accessed: Jan. 08, 2022. [Online Video]. Available: https://www.youtube.com/watch?v=K3aDOYy9e94

Ultra-hypofractionation

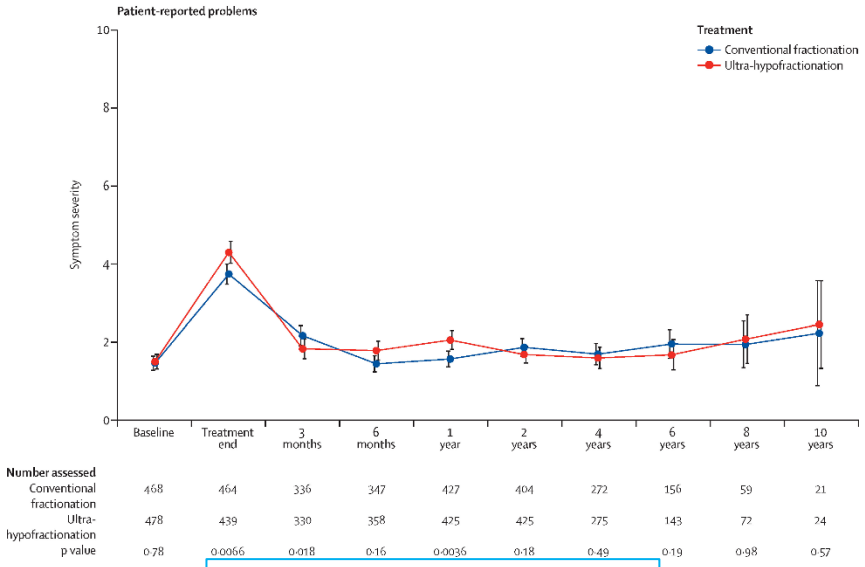
- Ultra-hypofractionation = less than 5-7 fractions
- Ultra-hypofractionation (5-7 fractions) shown to be safe and effective compared to convetional fractionation (39 fractions)



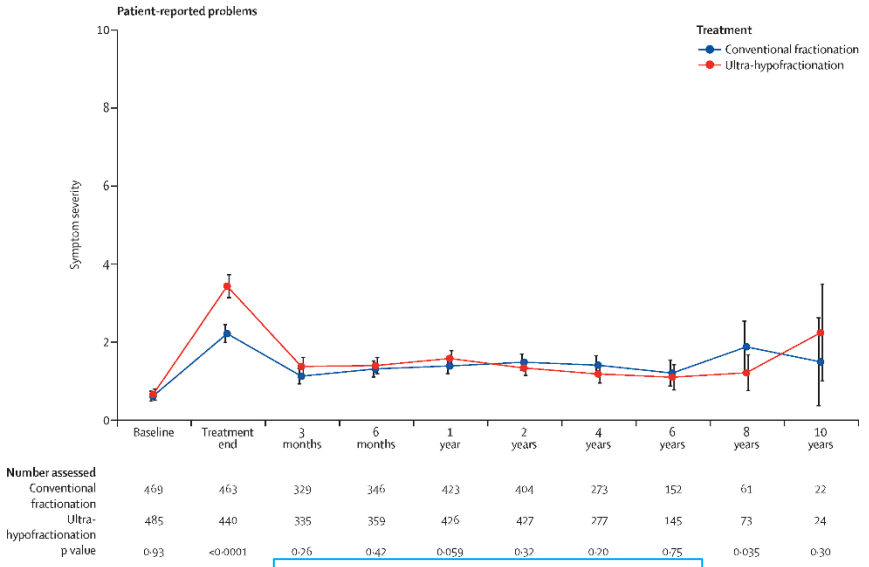
Widmark A, Gunnlaugsson A, Beckman L, Thellenberg-Karlsson C, Hoyer M, Lagerlund M, et al. Ultra-hypofractionated versus conventionally fractionated radiotherapy for prostate cancer: 5-year outcomes of the HYPO-RT-PC randomised, non-inferiority, phase 3 trial. The Lancet 2019;394:385–95. https://doi.org/10.1016/S0140-6736(19)31131-6.

Ultra-hypofractionation

- Rates of urinary and bowel side effects equivalent between ultra-hypofractionation and conventional fractionation in Widmark 2019 study
- Other studies have shown worse toxicity



Urinary side effects



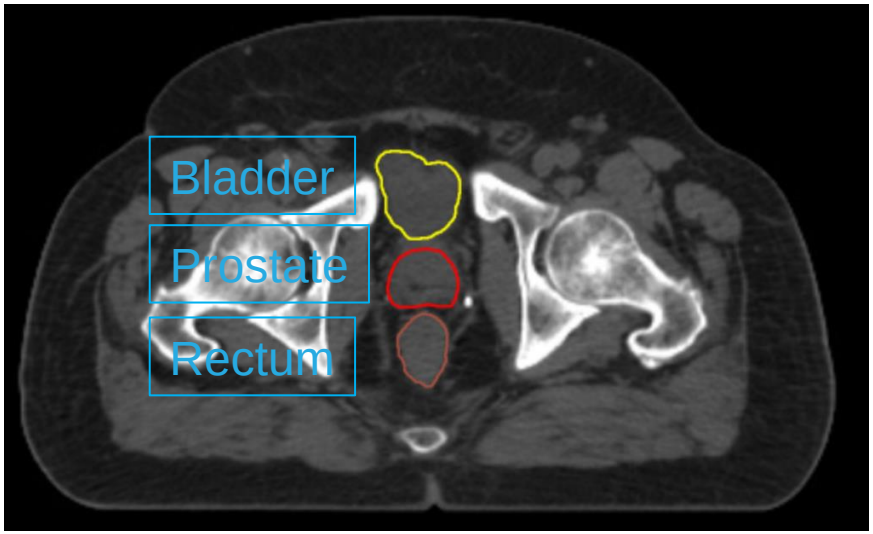
Bowel side effects

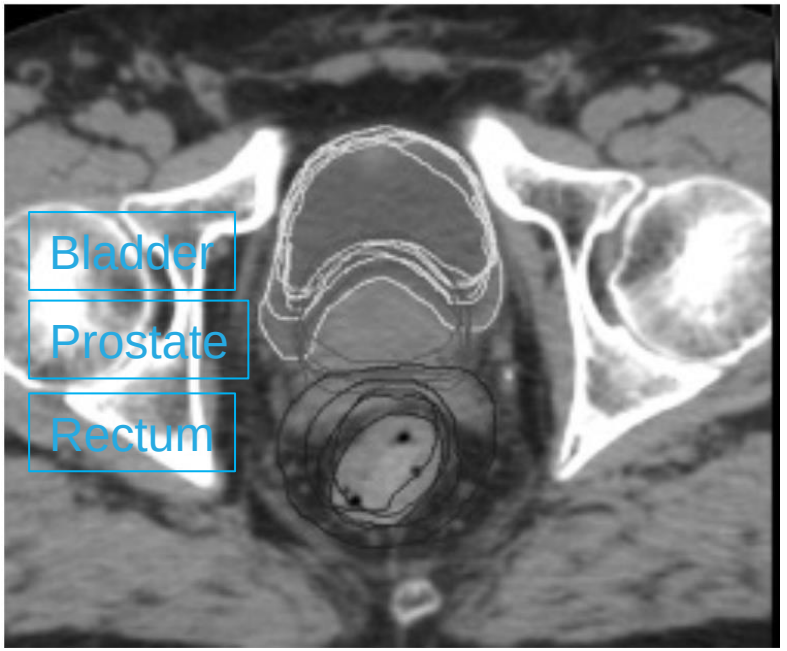
Widmark A, Gunnlaugsson A, Beckman L, Thellenberg-Karlsson C, Hoyer M, Lagerlund M, et al. Ultra-hypofractionated versus conventionally fractionated radiotherapy for prostate cancer: 5-year outcomes of the HYPO-RT-PC randomised, non-inferiority, phase 3 trial. The Lancet 2019;394:385–95. https://doi.org/10.1016/S0140-6736(19)31131-6.

Alberta Health Services

Organs at risk

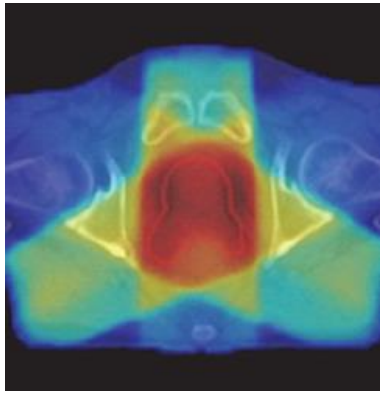
- Prostate sandwiched between bladder and rectum



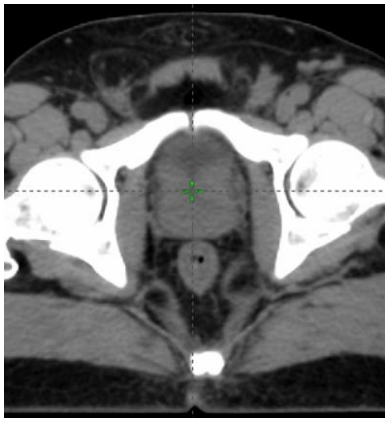


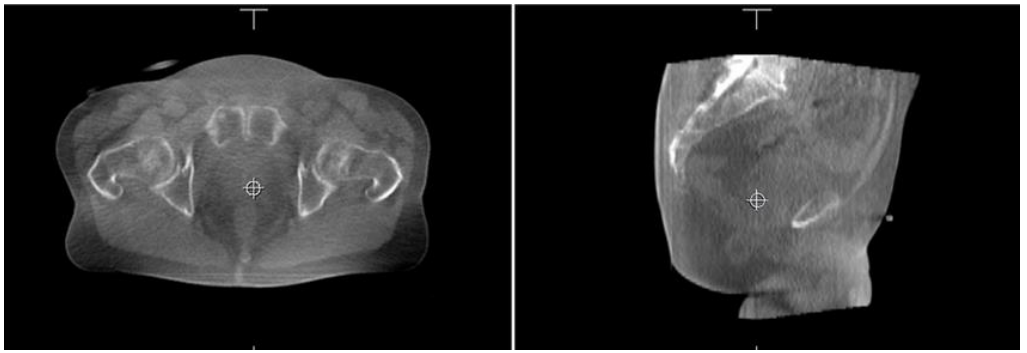
https://econtour.org/cases/109.
McPartlin, A. J. et al. MRI-guided prostate adaptive radiotherapy – A systematic review. Radiotherapy and Oncology 119, 371–380 (2016).

Conventional work flow



CT Simulation → Radiation Planning → Daily Cone beam CT → Radiation Delivery

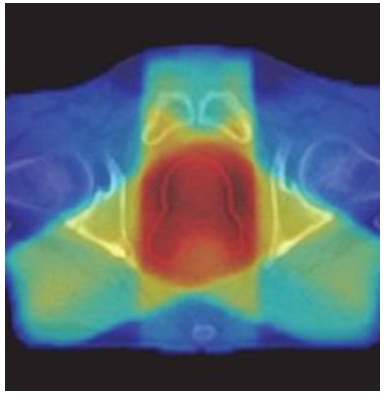




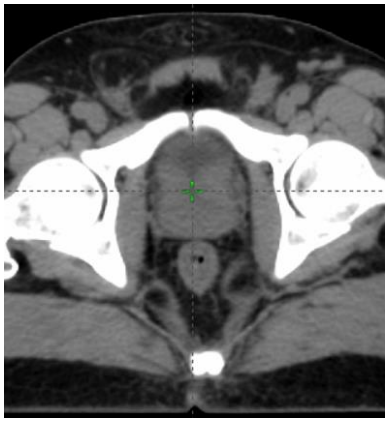
Cone beam CT used for patient positioning

Corradini, S. et al. X-change symposium: status and future of modern radiation oncology—from technology to biology. Radiat Oncol 16, 27 (2021).

MRI guided work flow



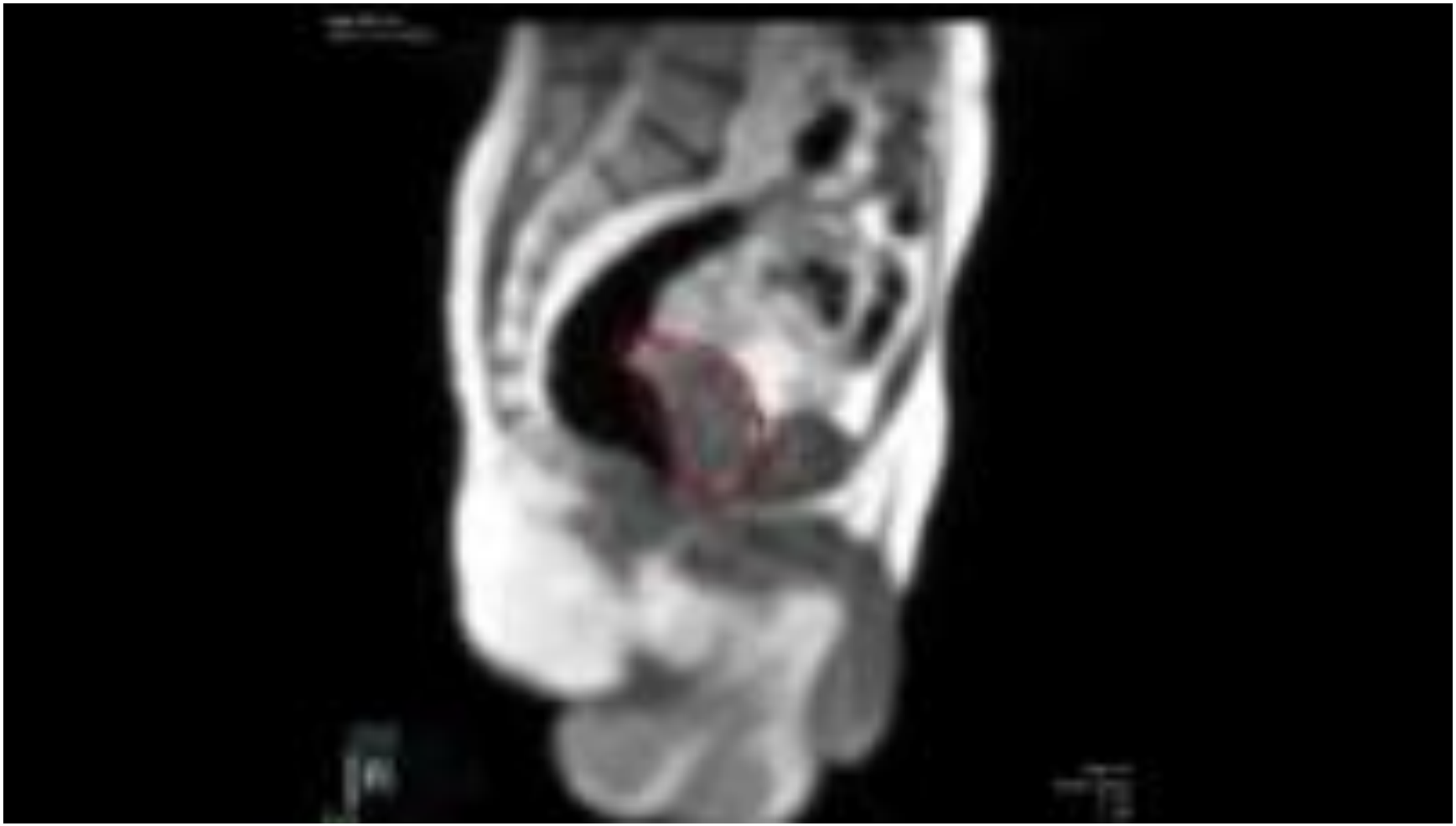
CT and MRI Simulation → Radiation Planning → Daily MRI → Radiation Delivery



MRI used for:
- patient positioning
- Adapting plan according to changes in bladder and rectal position

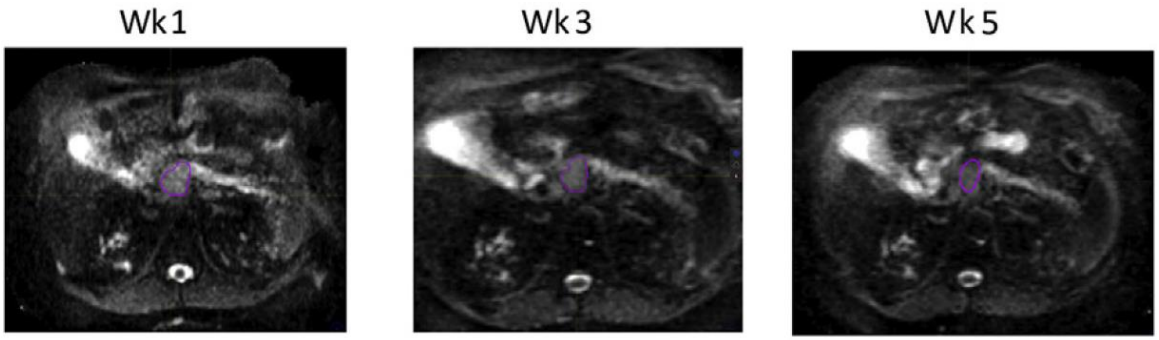
Corradini, S. et al. X-change symposium: status and future of modern radiation oncology—from technology to biology. Radiat Oncol 16, 27 (2021).

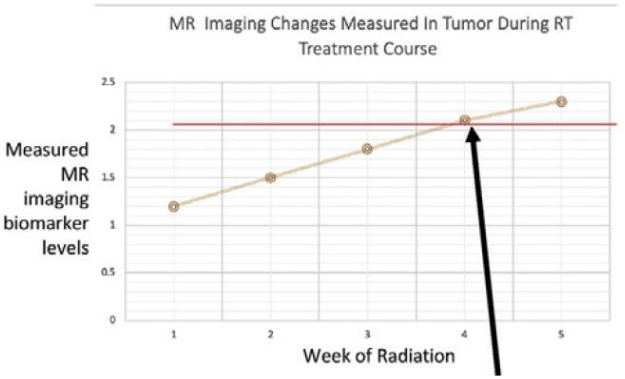
Real time gating



Hegde JV, Cao M, Yu VY, Kishan AU, Shaverdian N, Lamb J, et al. Magnetic Resonance Imaging Guidance Mitigates the Effects of Intrafraction Prostate Motion During Stereotactic Body Radiotherapy for Prostate Cancer. Cureus 2018;10. https://doi.org/10.7759/cureus.2442.

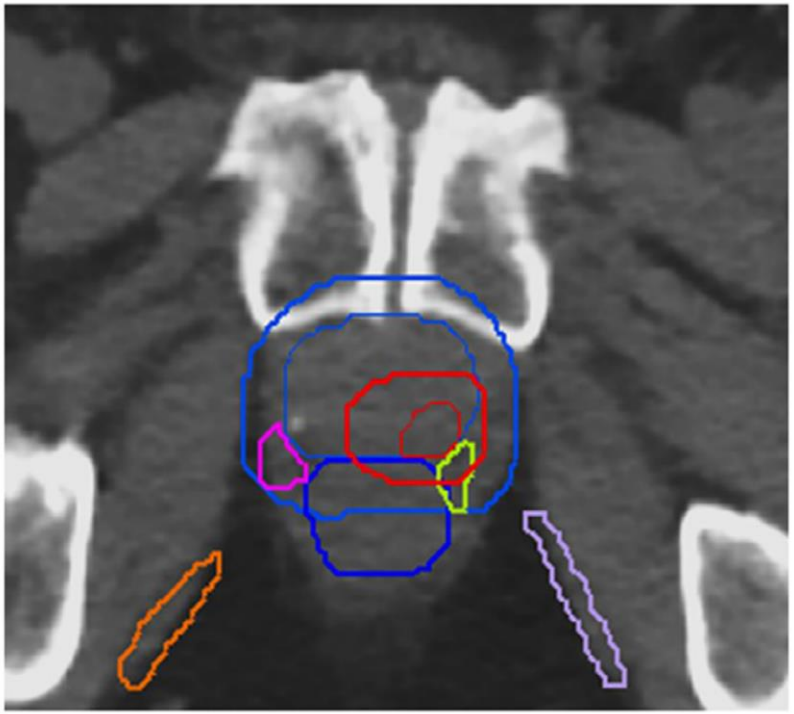
Adaption based on biology

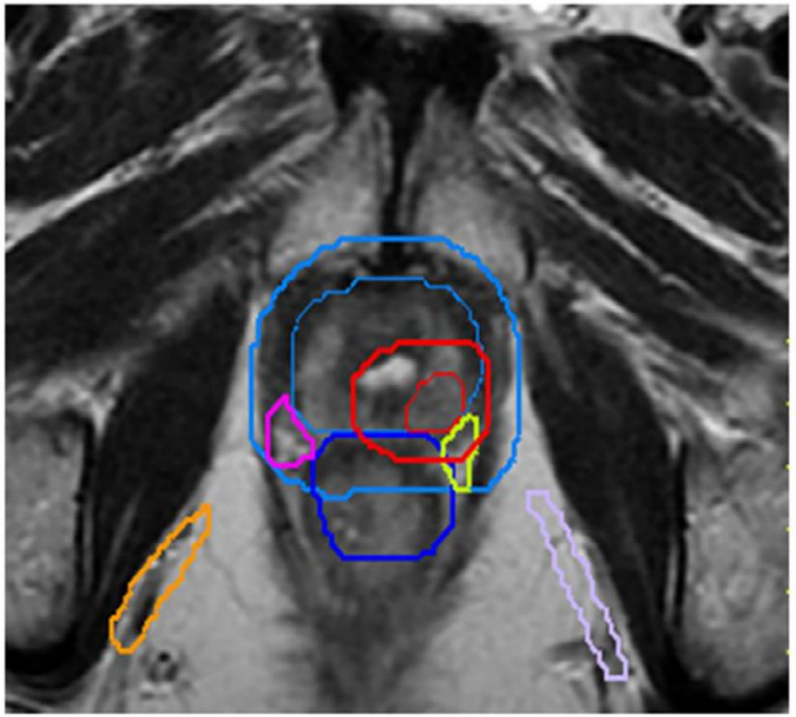




Lee, S. L., Hall, W. A., Morris, Z. S., Christensen, L. & Bassetti, M. MRI-Guided Radiation Therapy. Advances in Oncology 1, 29–39 (2021).

Precision targeting

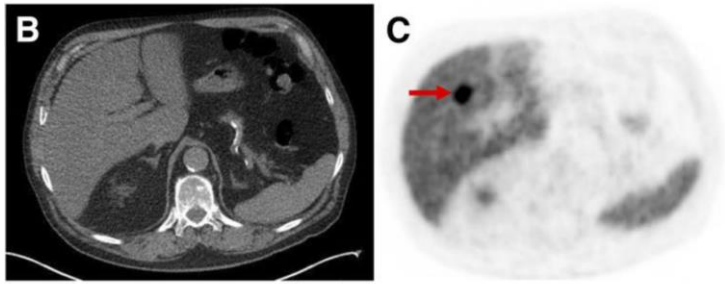




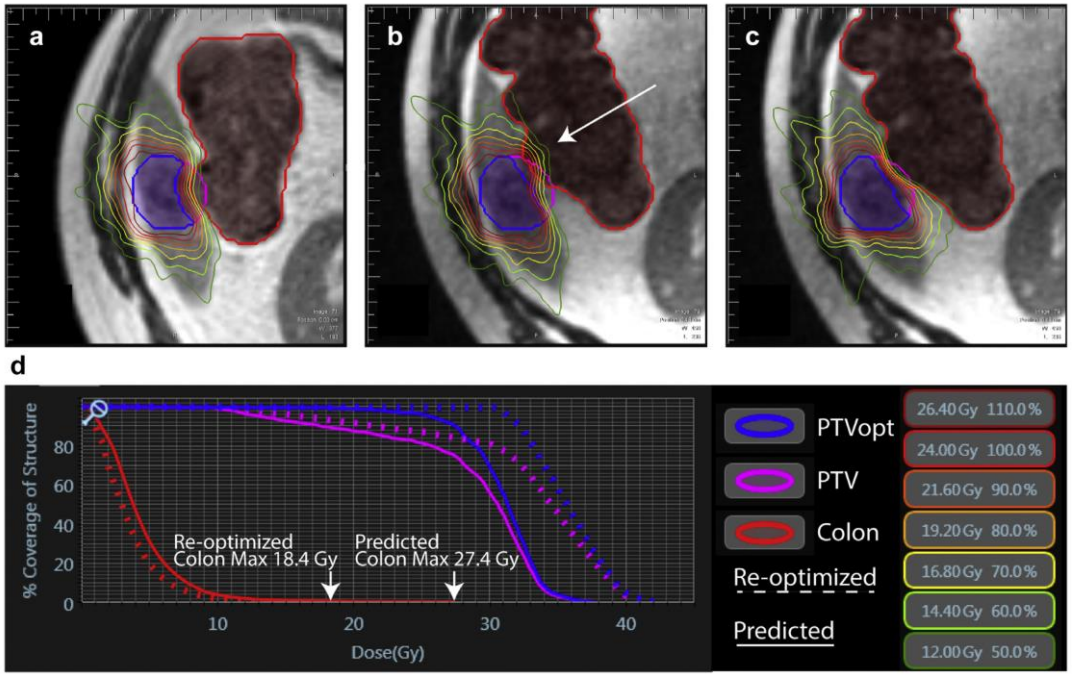
- Increase dose to dominant prostate lesion (red)
- Decrease dose to sensitive structures to maintain sexual function (nerves: pink and lime, blood vessels: orange and purple)

Ciabatti, S. et al. Dominant intraprostatic lesion boosting in sexual-sparing radiotherapy of prostate cancer: A planning feasibility study. Medical Dosimetry 44, 356–364 (2019).

Treatment of limited metastases



Prostate-Specific Membrane Antigen–Targeted PET Imaging



Safe treatment of metastatic lesions

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Rowe, S. P., Pienta, K. J., Pomper, M. G. & Gorin, M. A. Proposal for a Structured Reporting System for Prostate-Specific Membrane Antigen–Targeted PET Imaging: PSMA-RADS Version 1.0. Journal of Nuclear Medicine 59, 479–485 (2018).
Lee, S., Yadav, P., Kogel, A. J. van der, Bayouth, J. & Bassetti, M. F. In Silico Single-Fraction Stereotactic Ablative Radiation Therapy for the Treatment of Thoracic and Abdominal Oligometastatic Disease With Online Adaptive Magnetic Resonance Guidance. Advances in Radiation Oncology 6, (2021).

New Calgary Cancer Centre

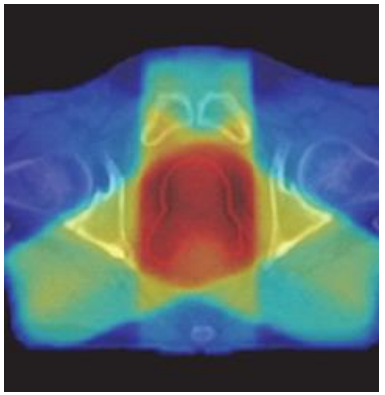
Operational in 2023

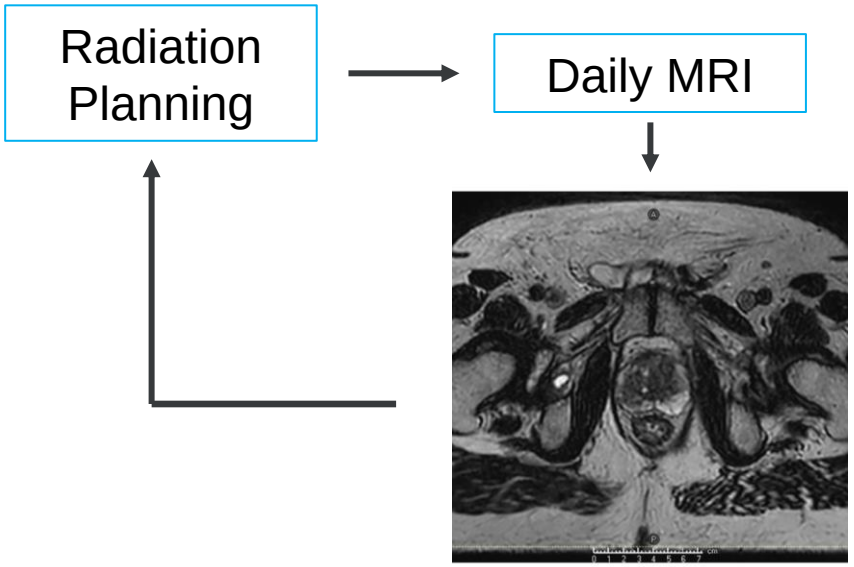
Alberta Health Services

AHS_CancerCare. 'The delivery of 2 MR-Linacs represent a big milestone. This new tech will allow us to better track tumours & adapt #radiotherapy on a daily basis, personalizing treatment when the #calgarycancercentre opens.' @albertacancer @ahs_media -Lisa Barbera, Head of Radiation Oncology https://t.co/QFoHTSDRMc. @AHS_CancerCare https://twitter.com/AHS_CancerCare/status/1448369028183982087 (2021).

Challenges in real-time MRI guided prostate radiotherapy

- Limited availability
- Time consuming treatments
  - Applications of artificial intelligence
    - To delineate tumor and surrounding organs
    - To register different images
    - To convert MRI to CT
- Collection and pooling of data between institutions to demonstrate statistical and clinical improvements





Your support needed

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https://owncancer.ca/