Commissioning and clinical implementation of an MRI brachytherapy suite

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Disclosure

I am a consultant to MOLLI Surgical

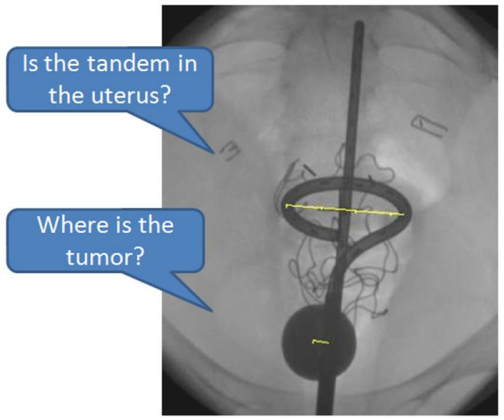
Outline

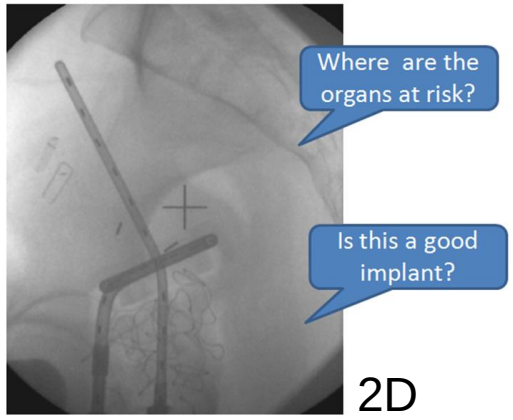
- Value of MR imaging in Brachytherapy
- MR brachytherapy workflows and considerations
  - MR imaging + registration
  - Intraoperative MR imaging
- Resource requirements
- Commissioning/QA

MRI in Brachytherapy

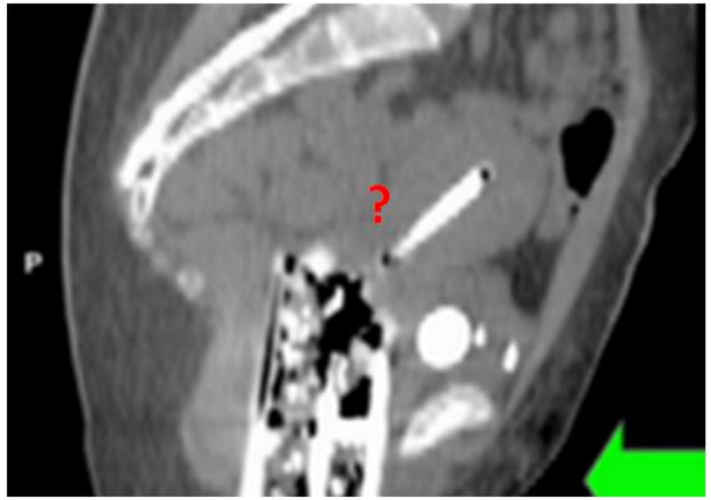
MRI-based Brachytherapy

- MRI allows us to see applicators, OAR and tumor
  - Safe dose escalation and OAR avoidance is now possible
  - Dose is patient specific and not applicator specific

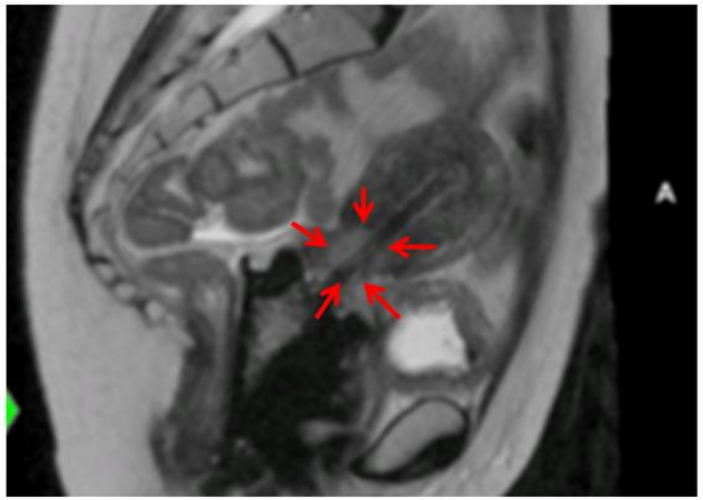




2D



CT



MRI

Impact of including MR in brachytherapy

Gyne

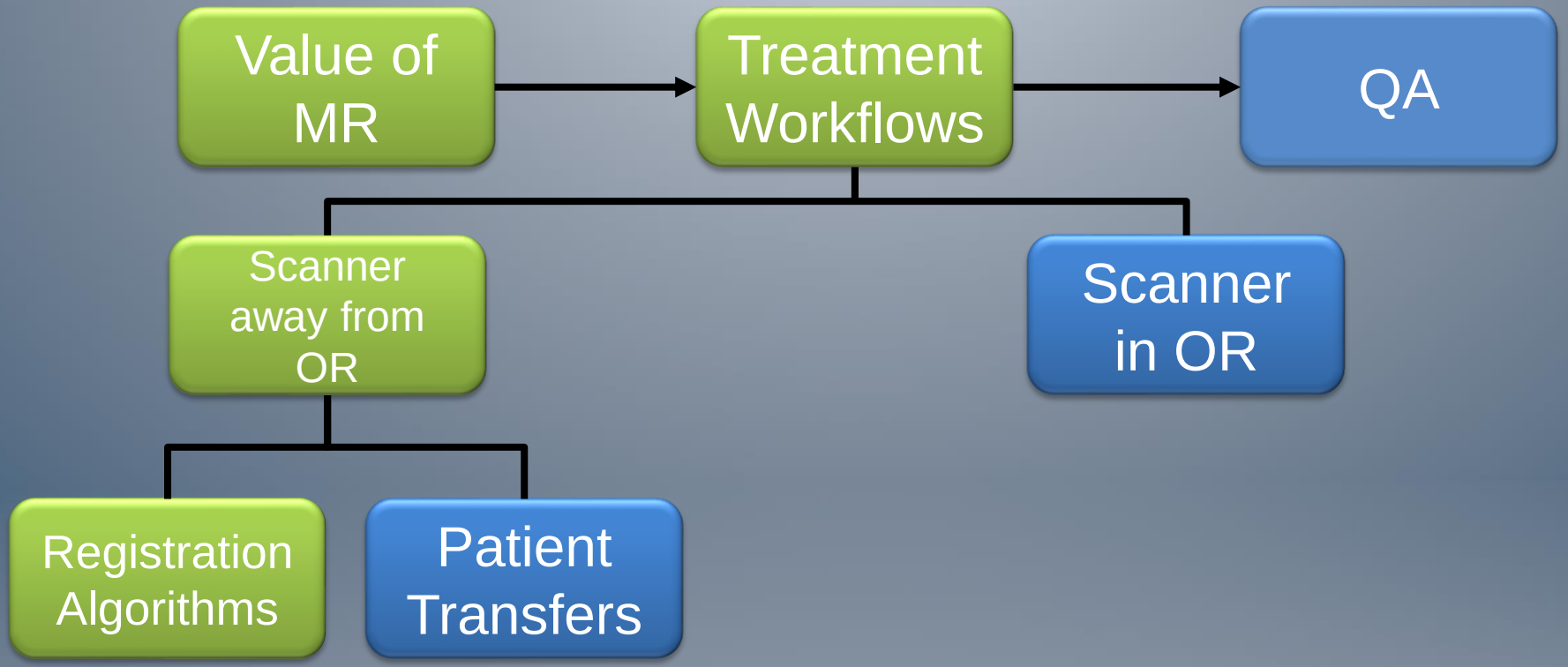
- **Overall Survival**
  - **Benefit of 10% OS**
    - retroEMBRACE compared with historical controls
- **Toxicities**
  - **Reduction in 3 – 6 % per organ**

Prostate

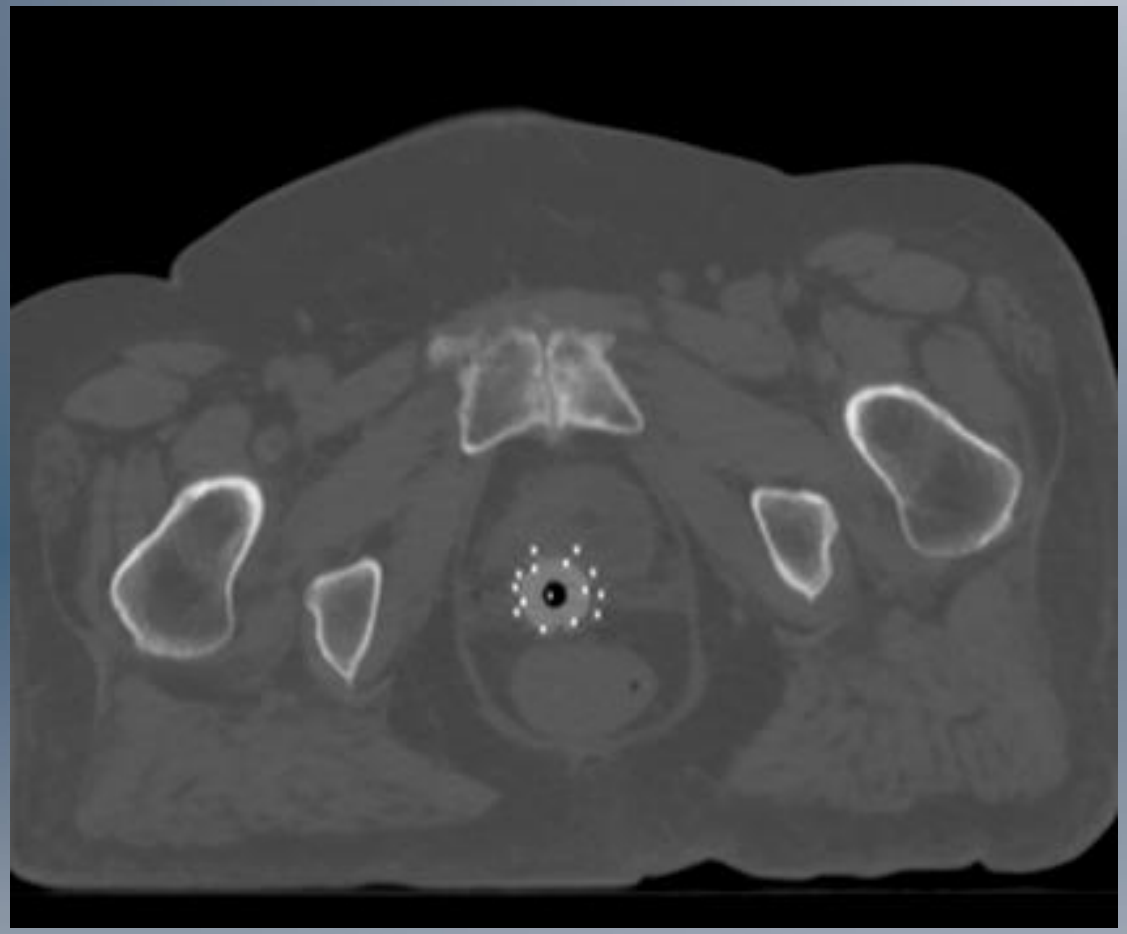
- **Volume**
  - **CT volumes are 16% larger than MR**
  - **TRUS volumes are 10% smaller than MR**
- **Dosimetry**
  - **MR limits dose spill at Apex and Base**
  - **Can control dose to urinary sphincter**

Potter/Tanderup et al, EMBRACE Review, ctRO 75 (2018)
Sturdza et al, retroEMBRACE, Radiother Oncol 120 (2016) 428-433
Smith et al, IJROBP 64 (2007) 1238-1247
Takiar et al, Brachytherapy, 13 (2014) 68-74

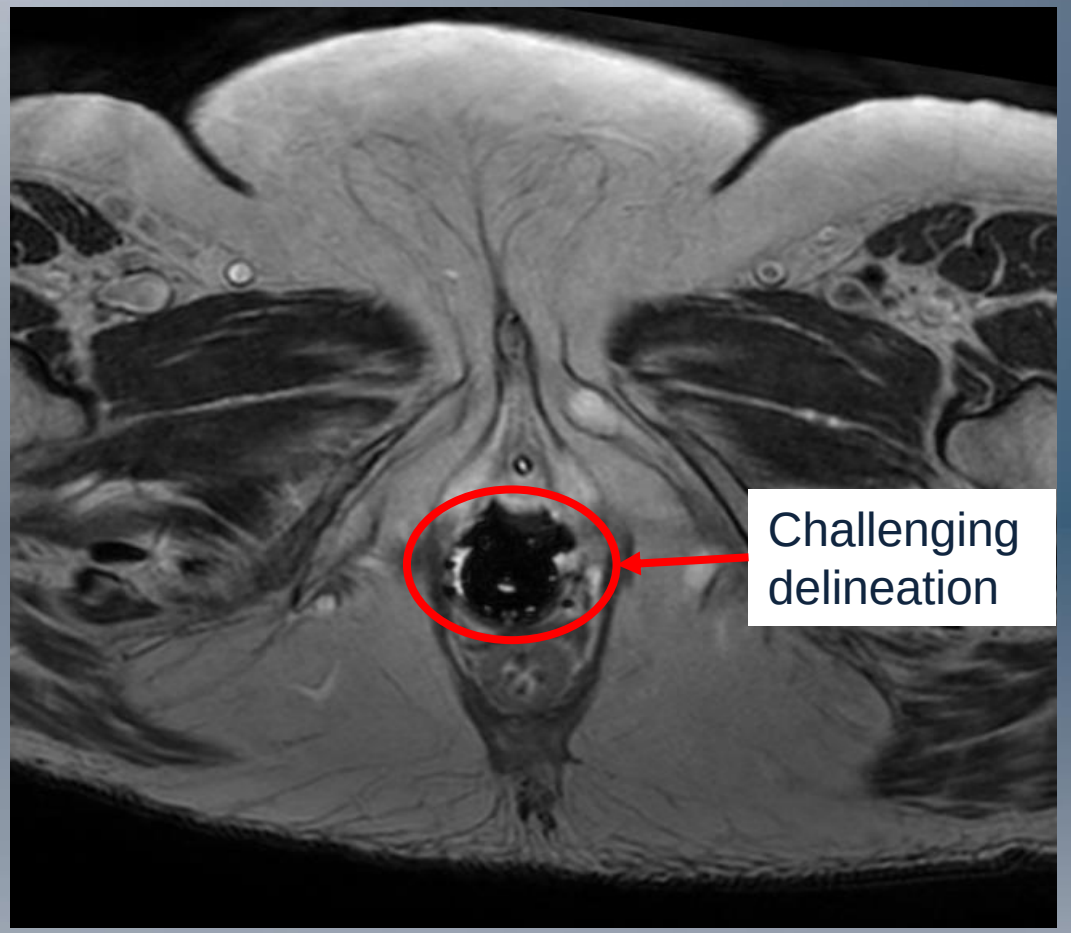
MRI in clinical workflow



MR + CT hybrid process with rigid registration

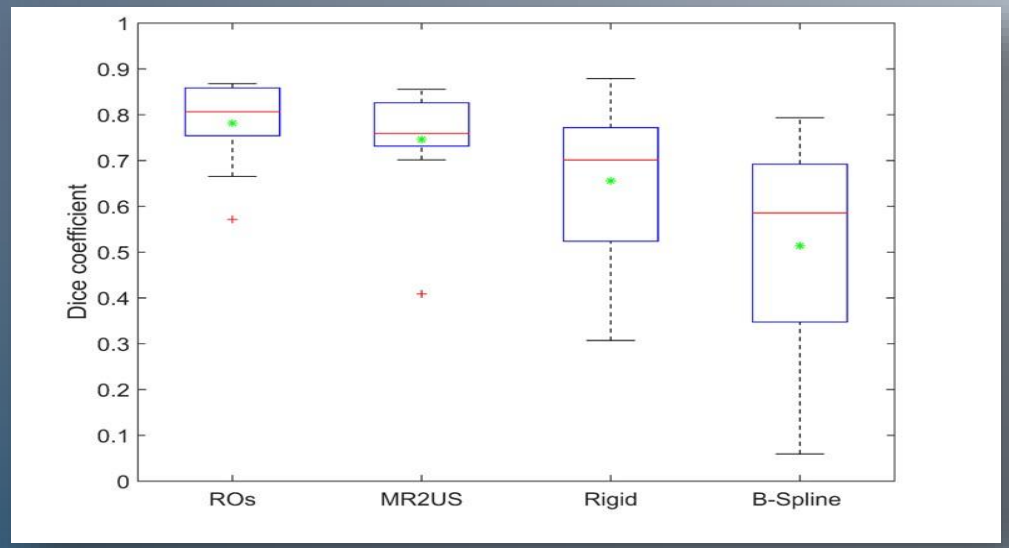


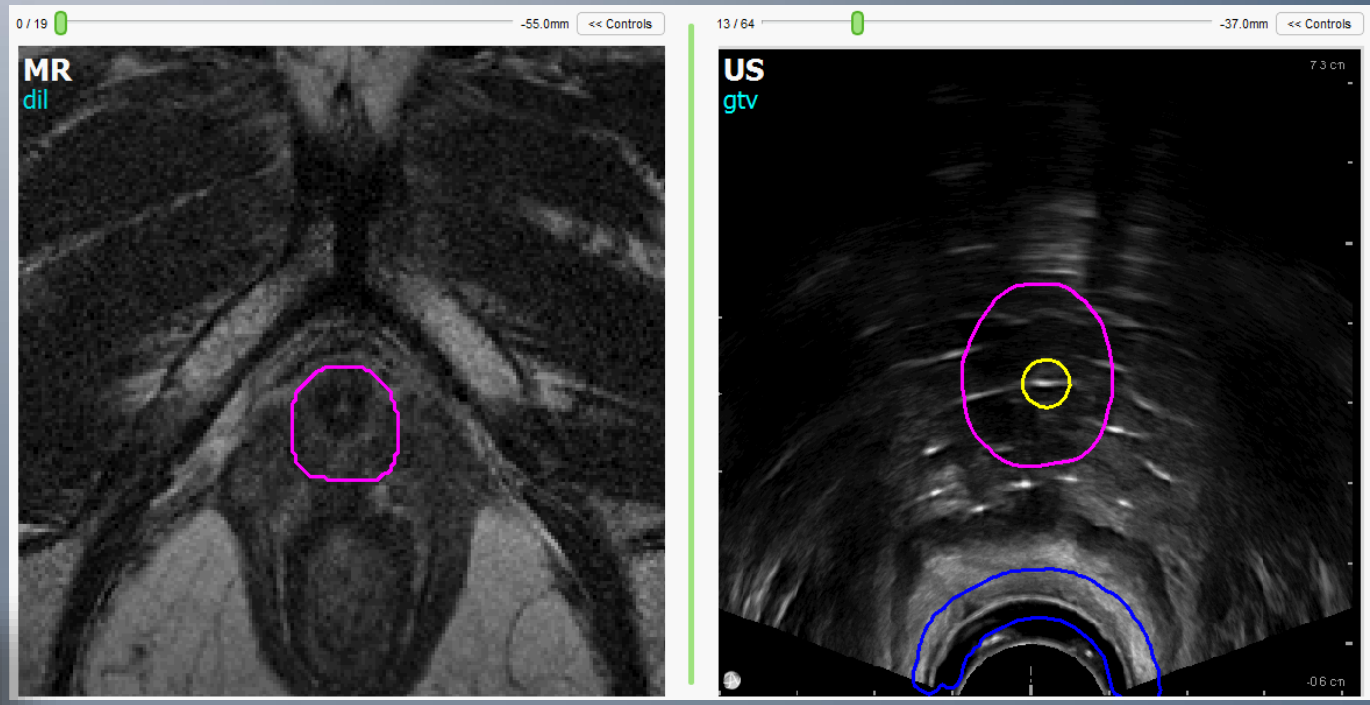
CT



MR

Contour based deformable registration



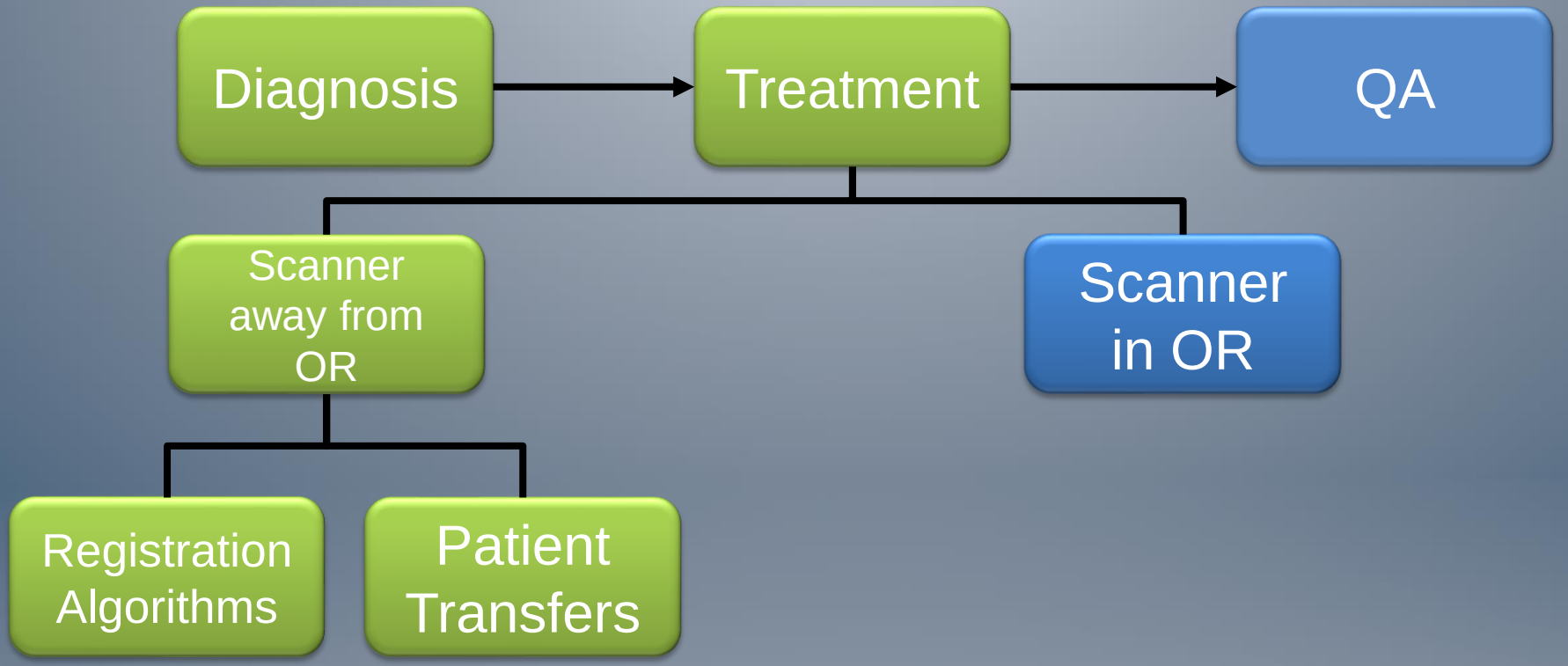


Structure	DIL			
Metric	ROs	MR2US	Rigid	B-Spline
DSC	0.80 ± 0.10	0.80 ± 0.13	0.65 ± 0.20	0.51 ± 0.30
MDA (mm)	1.24 ± 0.73	1.30 ± 0.53	1.71 ± 0.80	3.10 ± 2.00
Distance between centroids (mm)	6 ± 2	5 ± 2	7 ± 5	18 ± 11
Registration time (sec)	227 ± 27	11 ± 2	7 ± 1	199 ± 38
Volume (cc)	3.52 ± 2.00	3.31 ± 2.00	2.83 ± 1.74	2.30 ± 1.64
Difference between volumes (cc)[a]	0.86 ± 0.50	1.10 ± 0.50	1.50 ± 1.00	2.10 ± 1.20

Quantitative measures of image registration accuracy – TG132

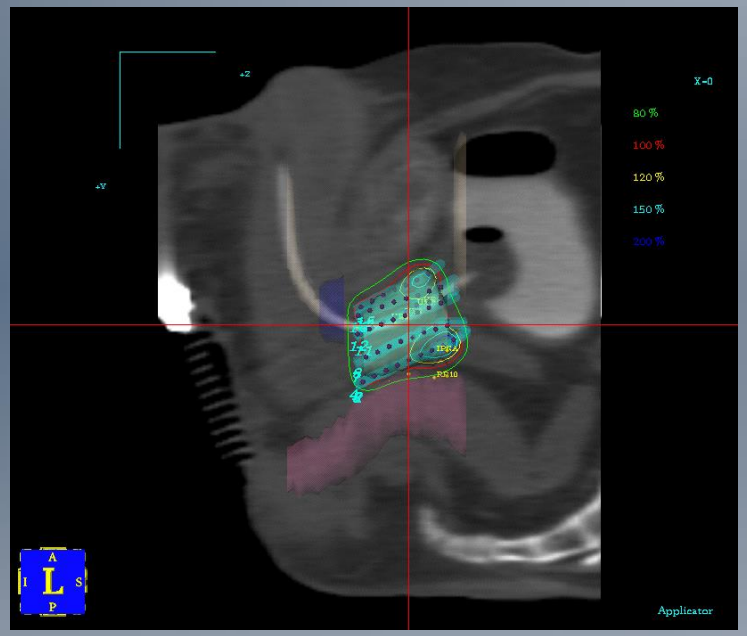
Shaaer, A., et al. (2018). *Brachytherapy* 18.1 (2019): 95-102.
Brock, Kristy K., et al. TG132. *Medical physics* 44.7 (2017): e43-e76.

MRI in clinical workflow

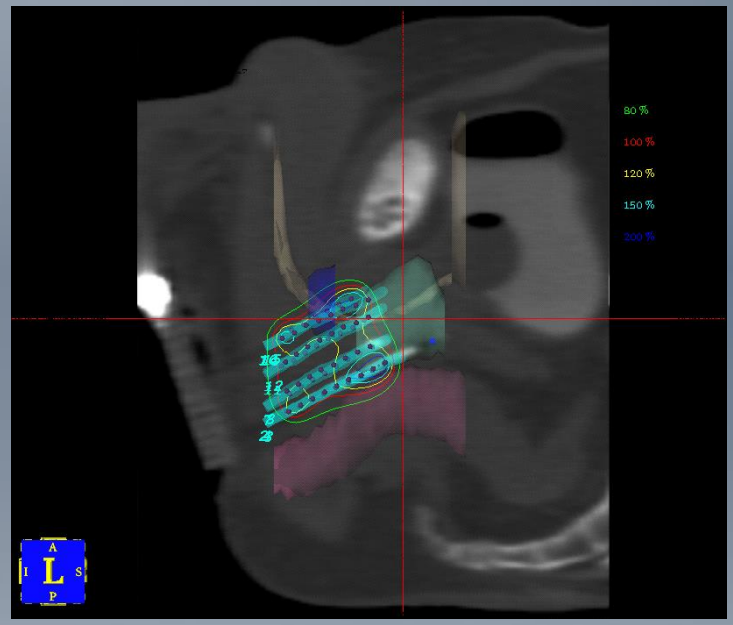


CT-Based Technique and Catheter Displacement

Planned



Delivered



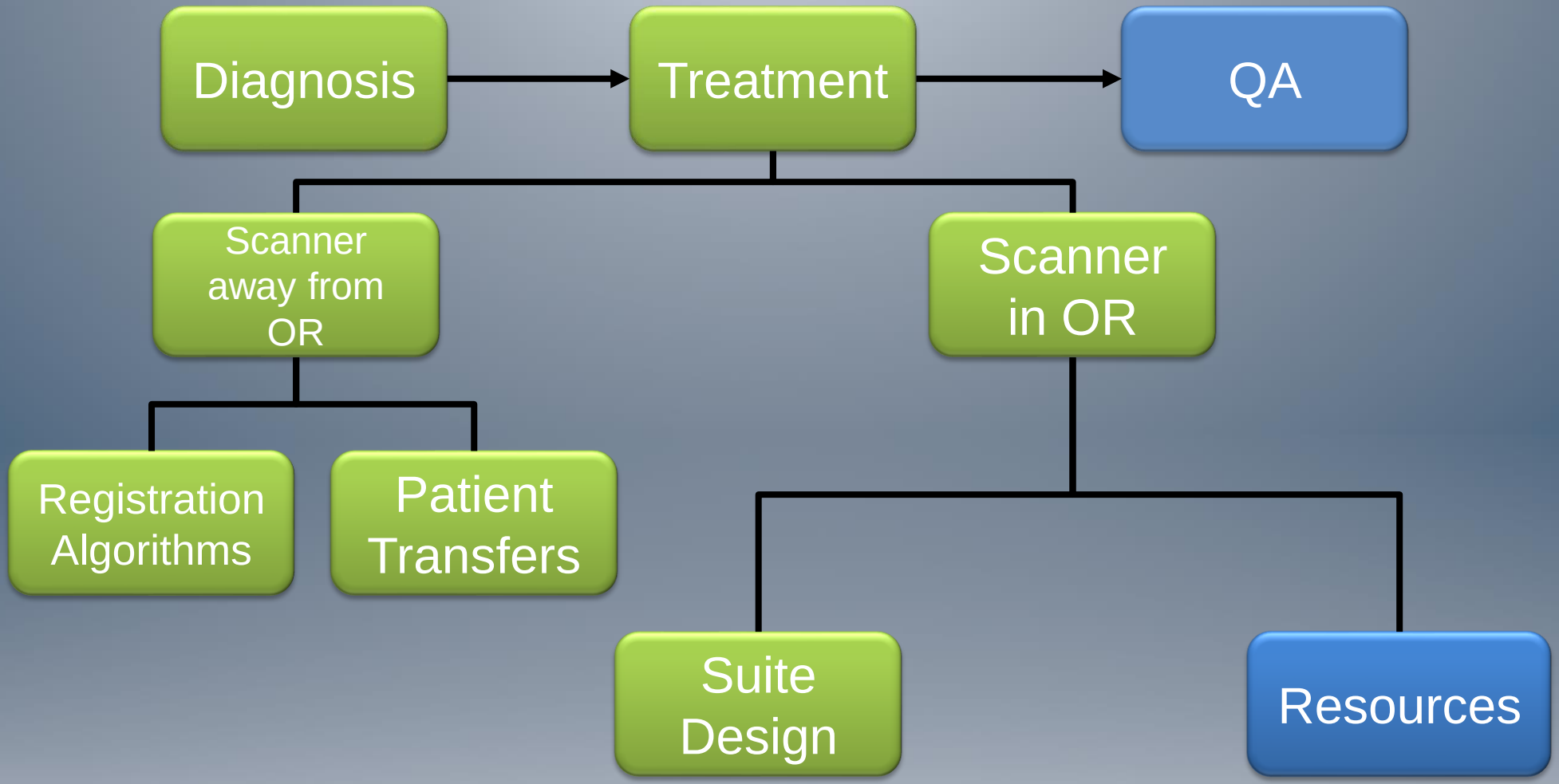
R. Holly et al. / Brachytherapy 10 (2011) 299-305

Patient Transfer System

- Q-fix Symphony

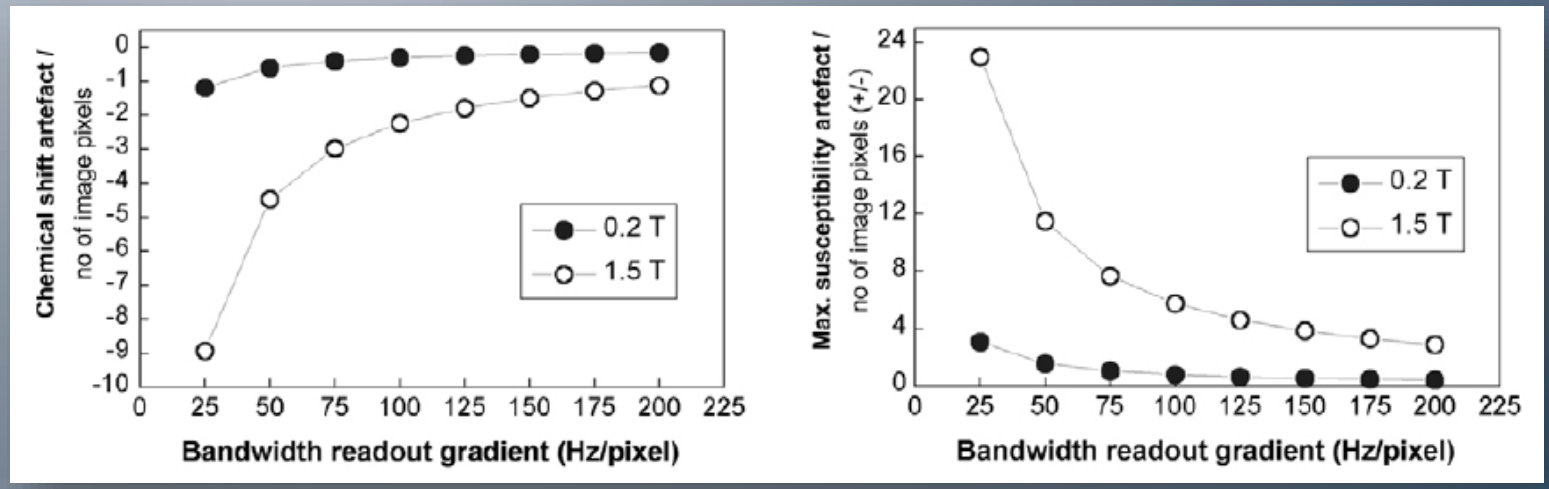
- Diacor – Zephyr HDR

MRI in clinical workflow



Medical University of Vienna (Low Field - Open Bore)

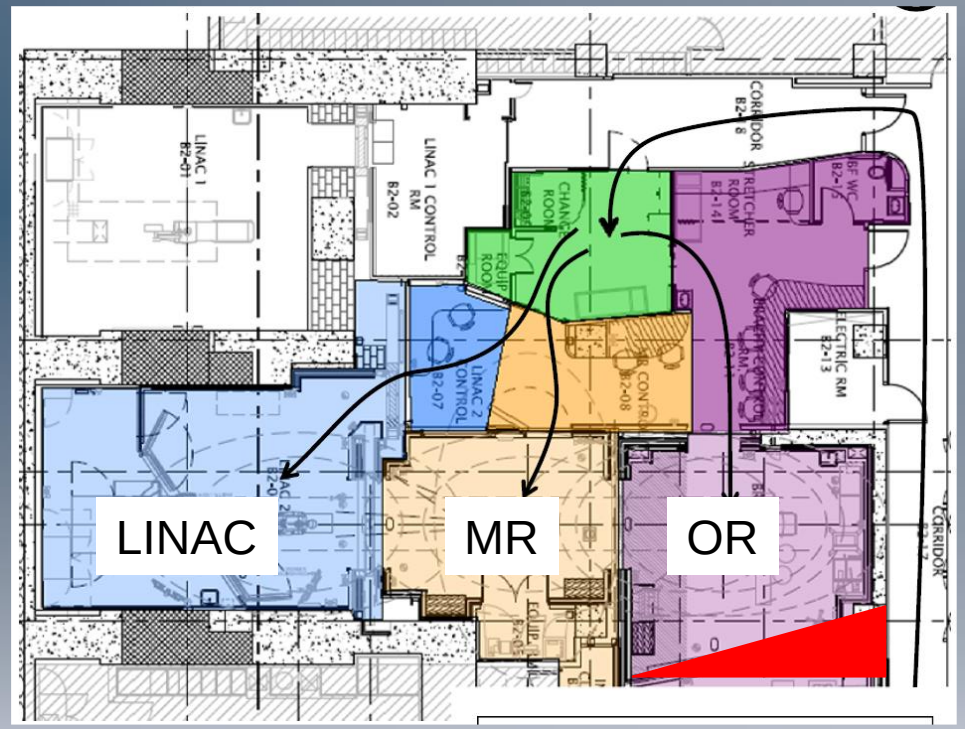
- Low Field (0.35T MRI)
- Open bore
- Improved field homogeneity
- Low susceptibility artifact
- Reduced chemical shift artefact



Fransson et al. *Strahlentherapie und Onkologie* 177.2 (2001): 59-73.

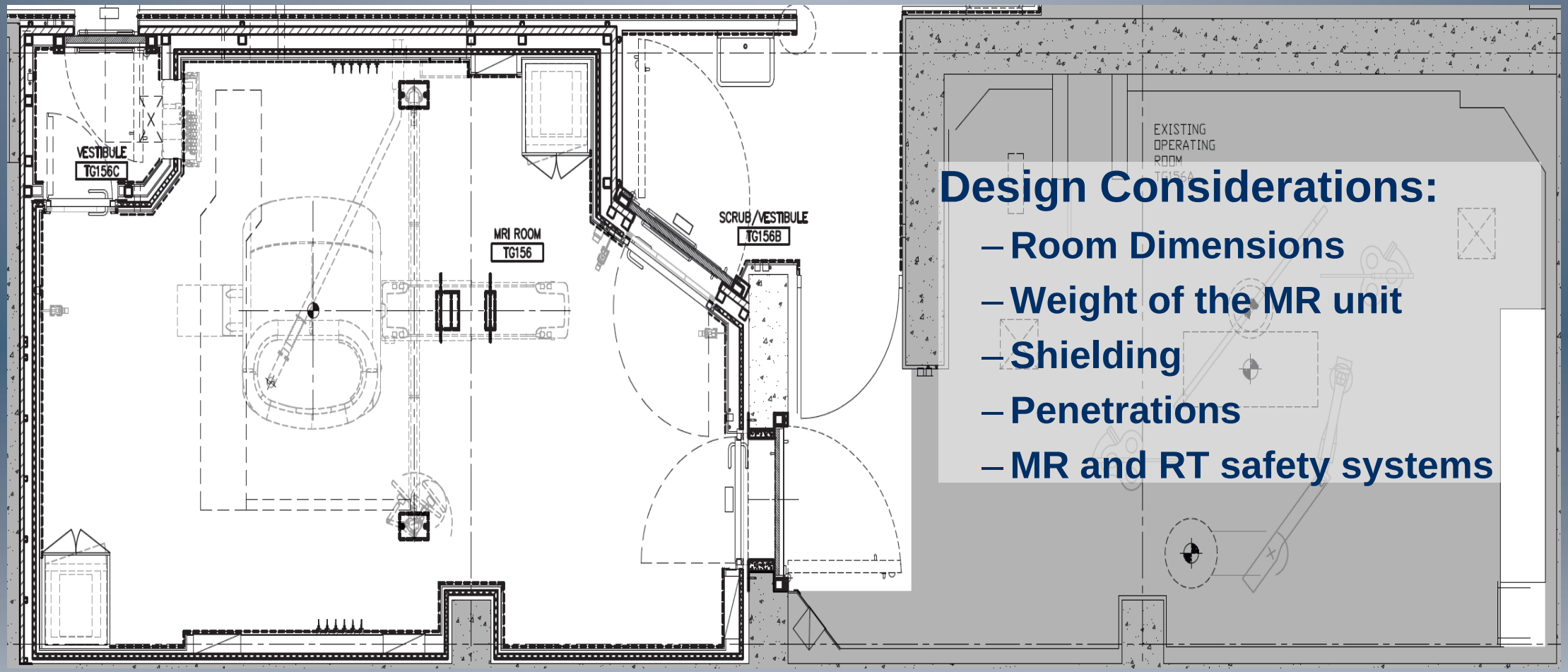
Princess Margaret Cancer Centre (MR on rails)

- **1.5T MR on rails**
  - **MR sim**
  - **Linac bunker**
  - **Brachy suite**



Ménard, C. et al. *Brachytherapy* 16.4 (2017): 754-760.

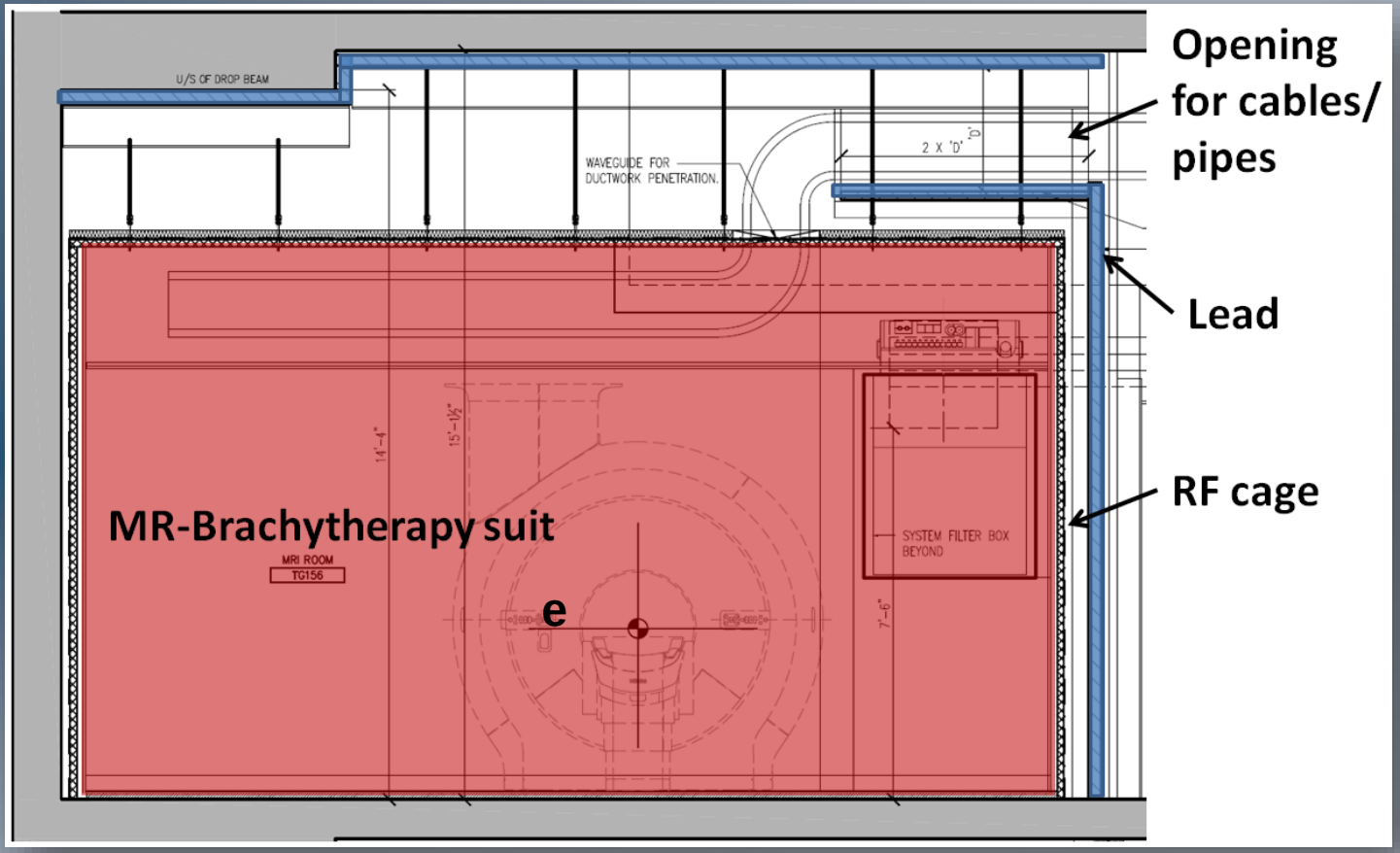
OCC MR image guided brachytherapy suite



Design Considerations:

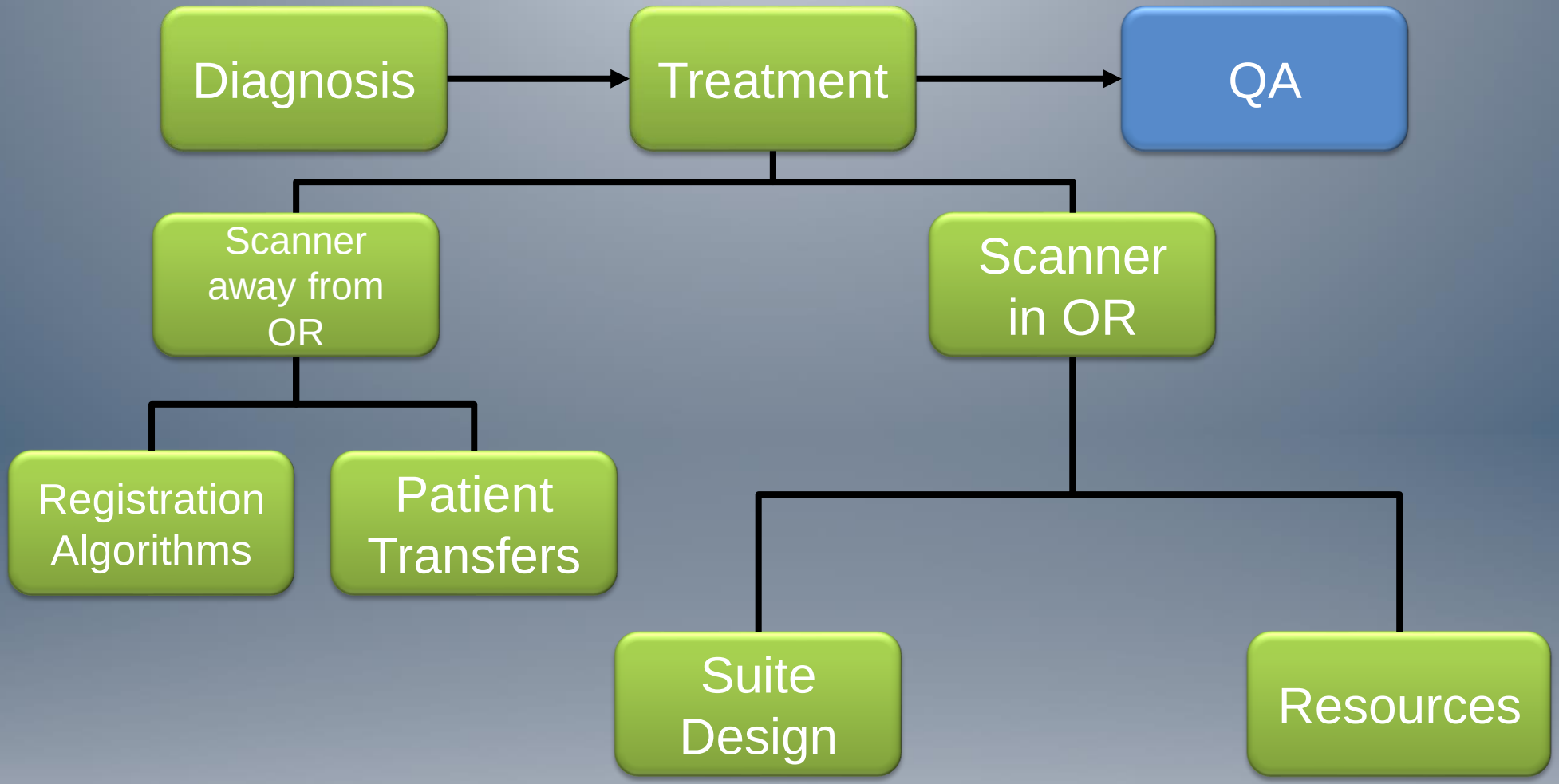
- Room Dimensions
- Weight of the MR unit
- Shielding
- Penetrations
- MR and RT safety systems

Shielding for RF and radiation



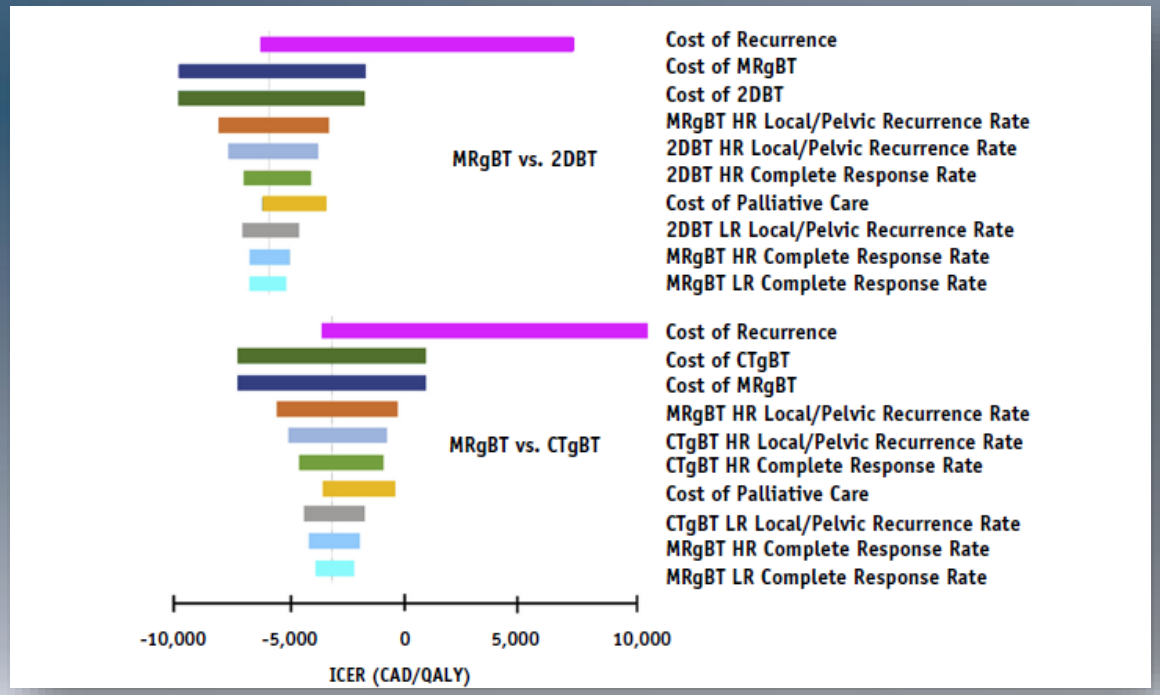
- RT safety systems:
  - Interlocks
  - Emergency Stops
  - Indicators
  - Radiation Monitoring & Source stuck kit
- MR safety:
  - Appropriate Zoning
  - Ferromagnetic detectors at the door
  - Quench button
  - Evacuation fans

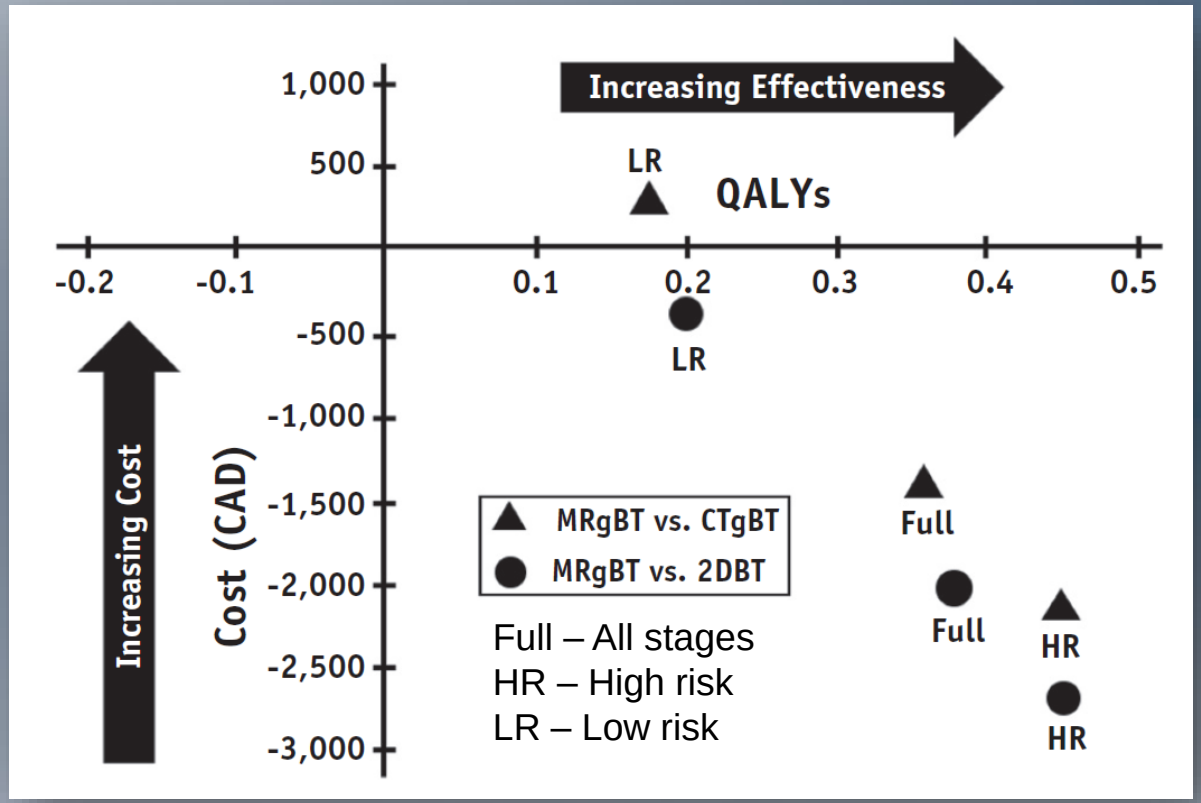
MRI in clinical workflow



Cost-Utility of MR guided brachy vs. CT or 2D

- Public health single payer perspective
- For all stages MRgBT provides systemic savings over CT and 2D
- Driven by cost of recurrence

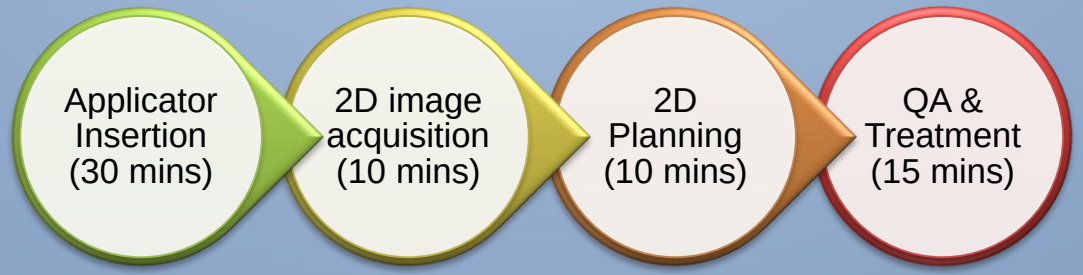


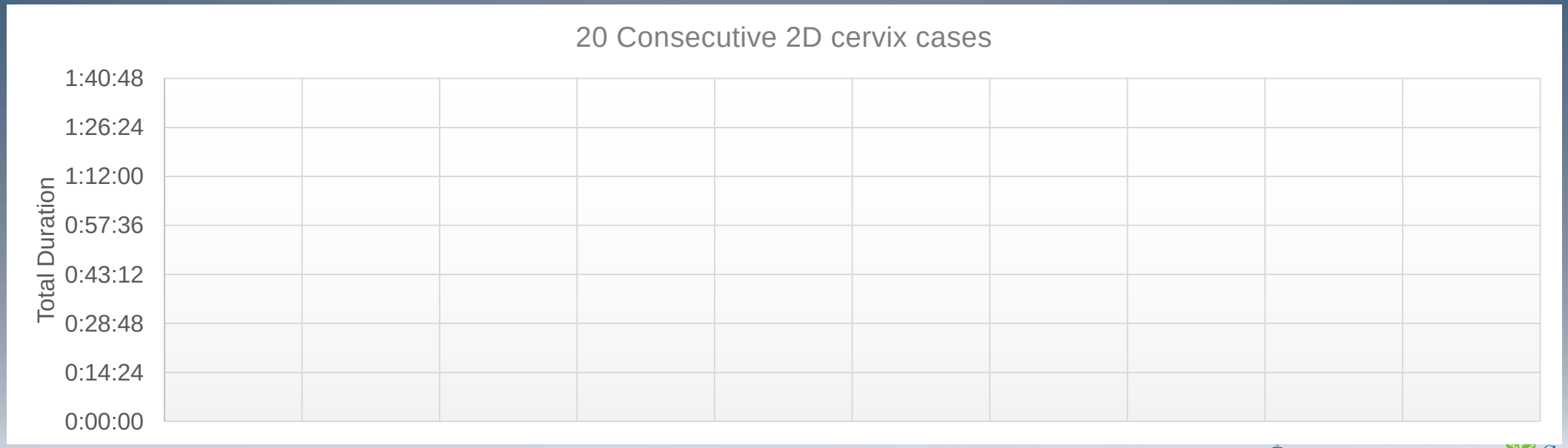


Perdrizet, Johnna, et al. *IJROBP* (2020).

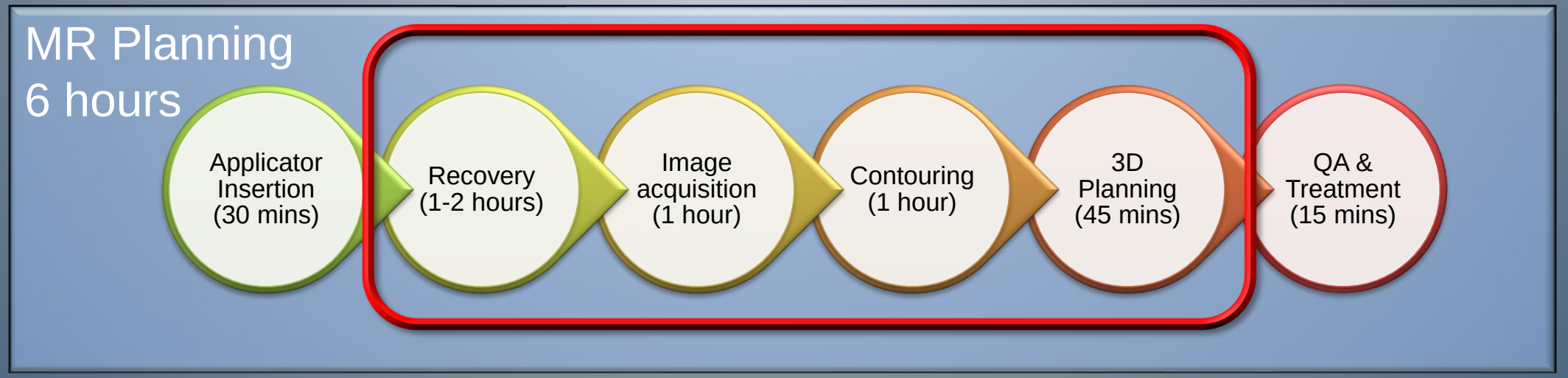
2D Brachytherapy at OCC

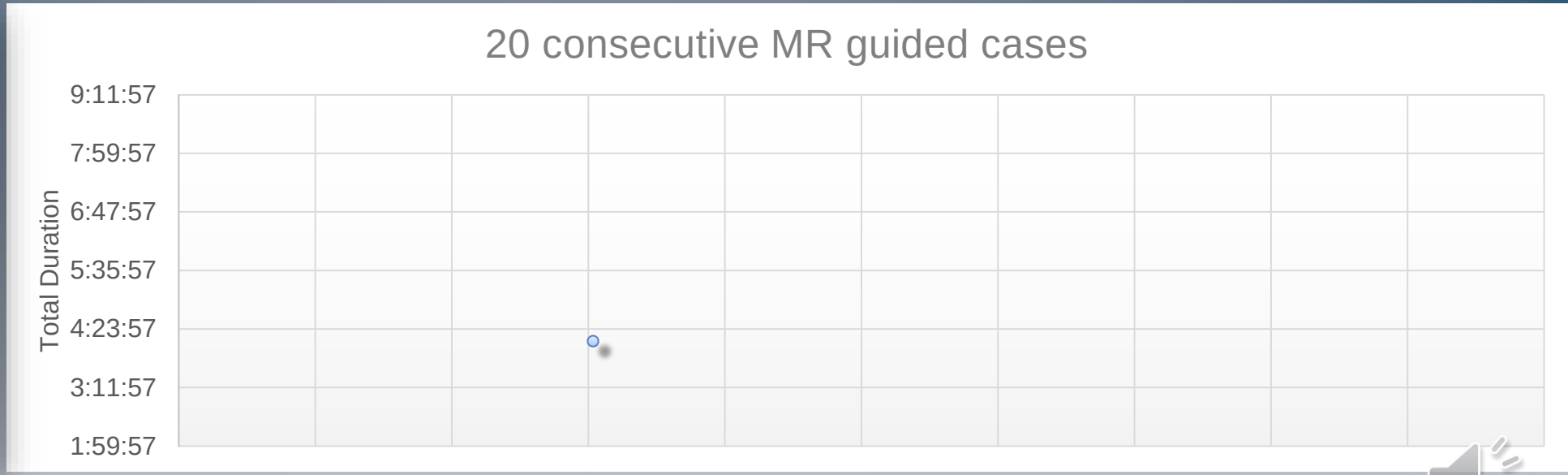
2D Planning
1 hour





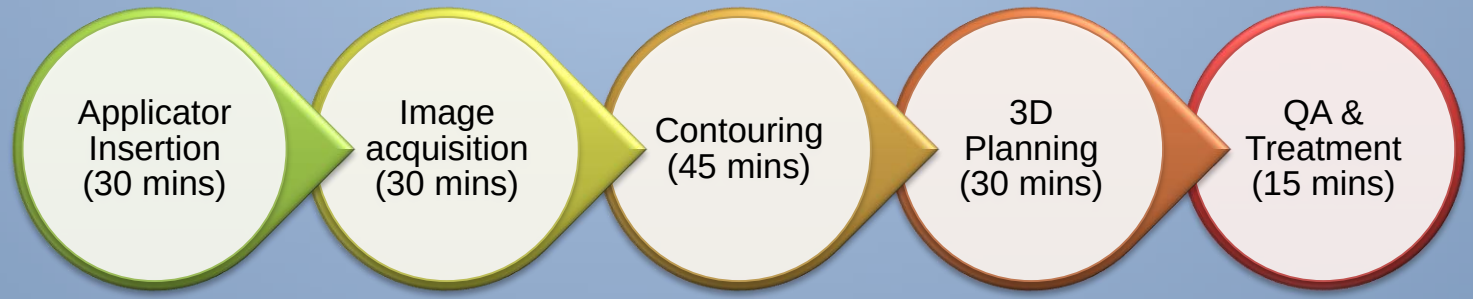
Start of the OCC program

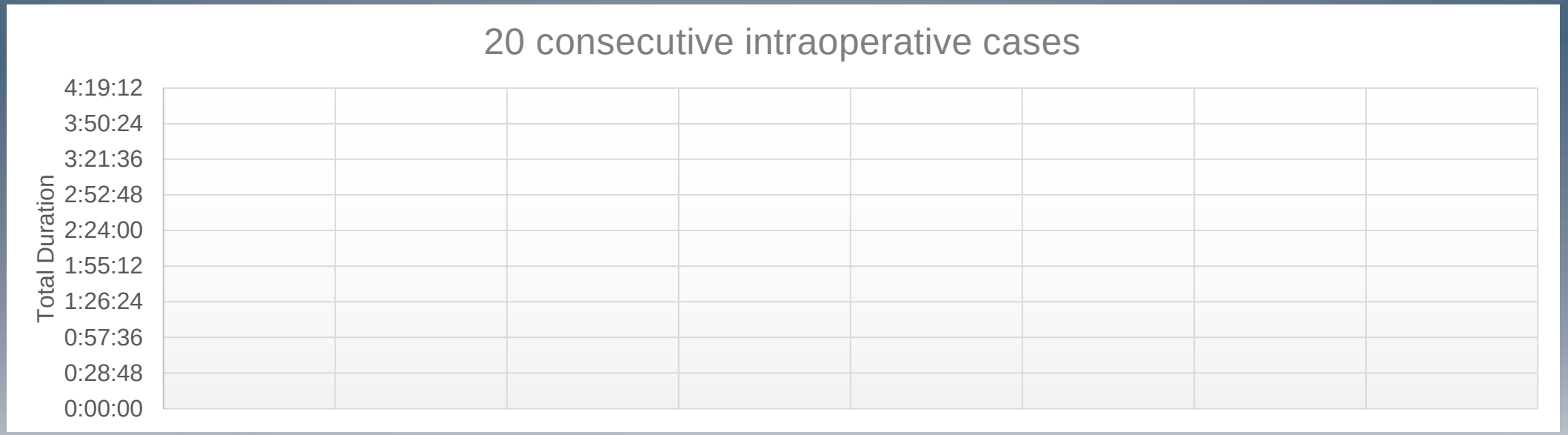




Intraoperative Brachytherapy Experience

MR-only Planning
2.5 hours





Ezezika, Jacqueline, et al. "Going Lean to Improve the Patient Experience in a High-Throughput Brachytherapy Program." Journal of Medical Imaging and Radiation Sciences 49.2 (2018): 130-135.

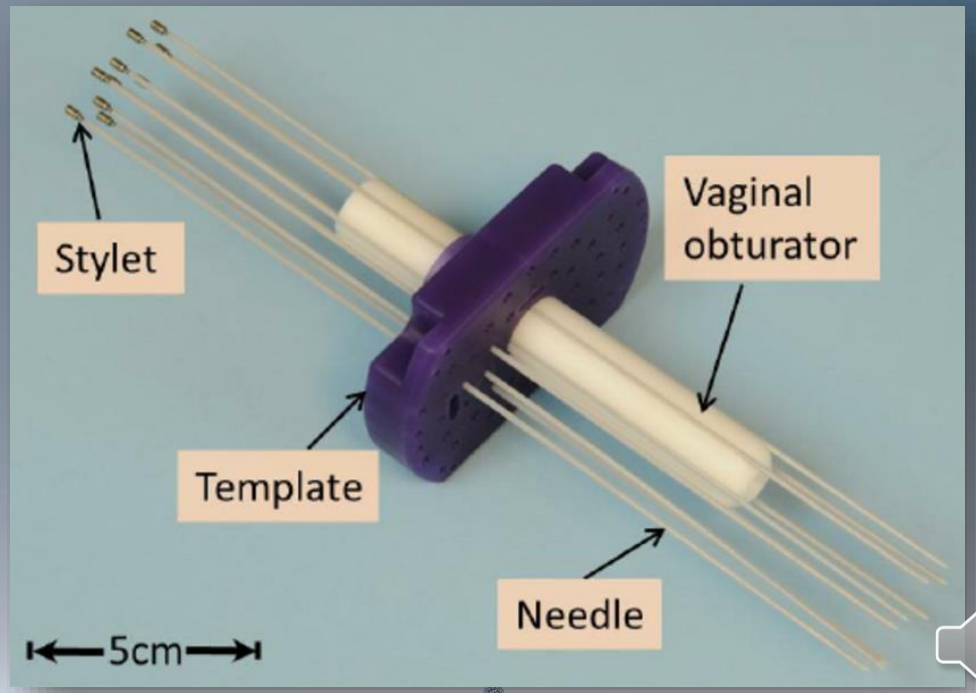
MR safe brachytherapy equipment

- MR safe anesthetic cart
  - Compatible with Anesthesia supplies
- MR safe patient monitor
  - Remote display capability
- MR Conditional Afterloader
  - Plastic cables
  - RF shielded afterloader
  - Shielded data cable

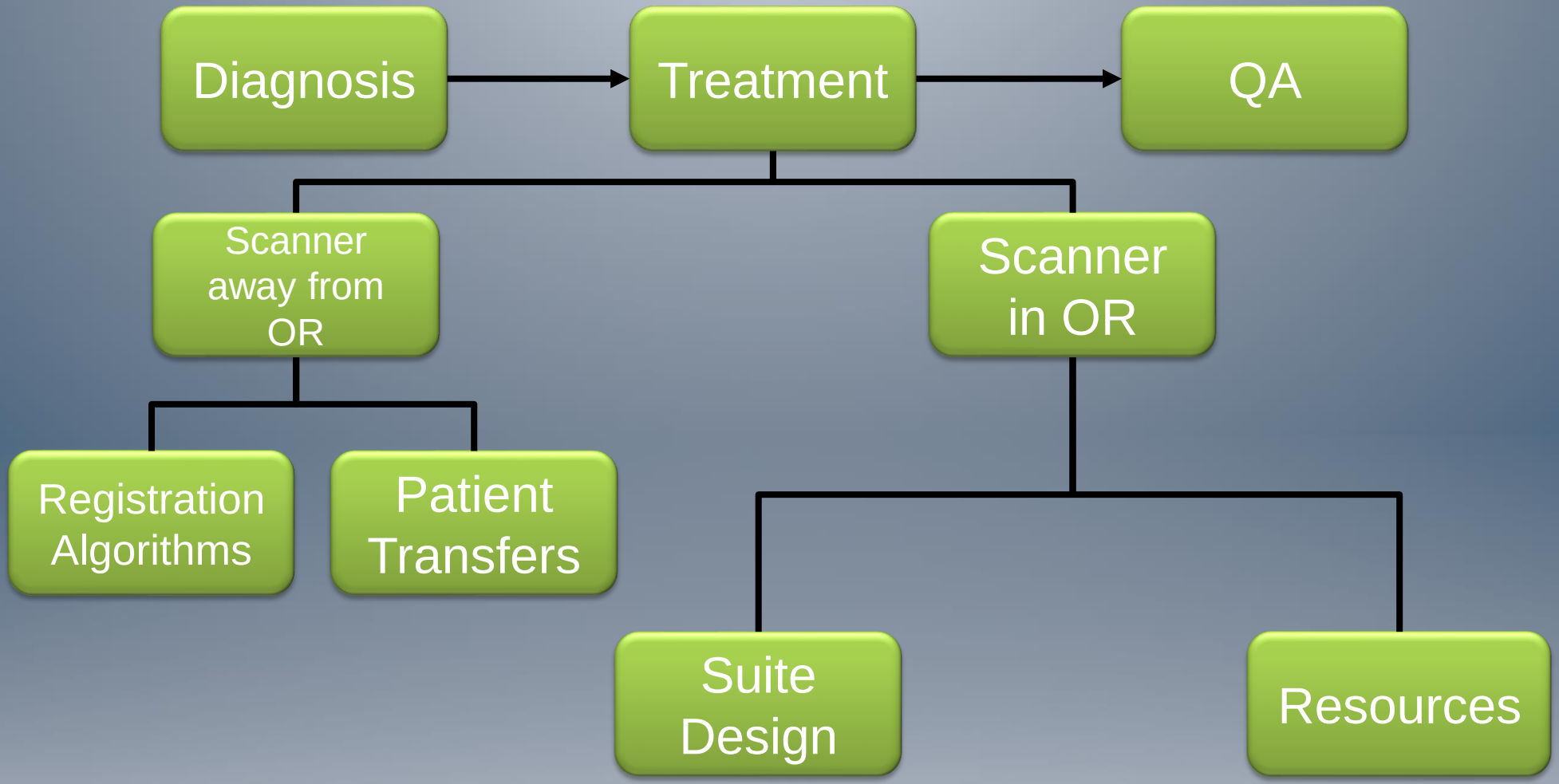
Beld, Ellis, et al. IJROBP. 102.4 (2018): 960-968.

Selection of MR Safe Applicators

- Plastic applicators create signal voids
  - No local distortions
  - MR markers/Model based reconstruction may aid reproducibility
- Metal Applicators
  - Distortion and artefacts need to be quantified
  - Vendor must provide MR safety information

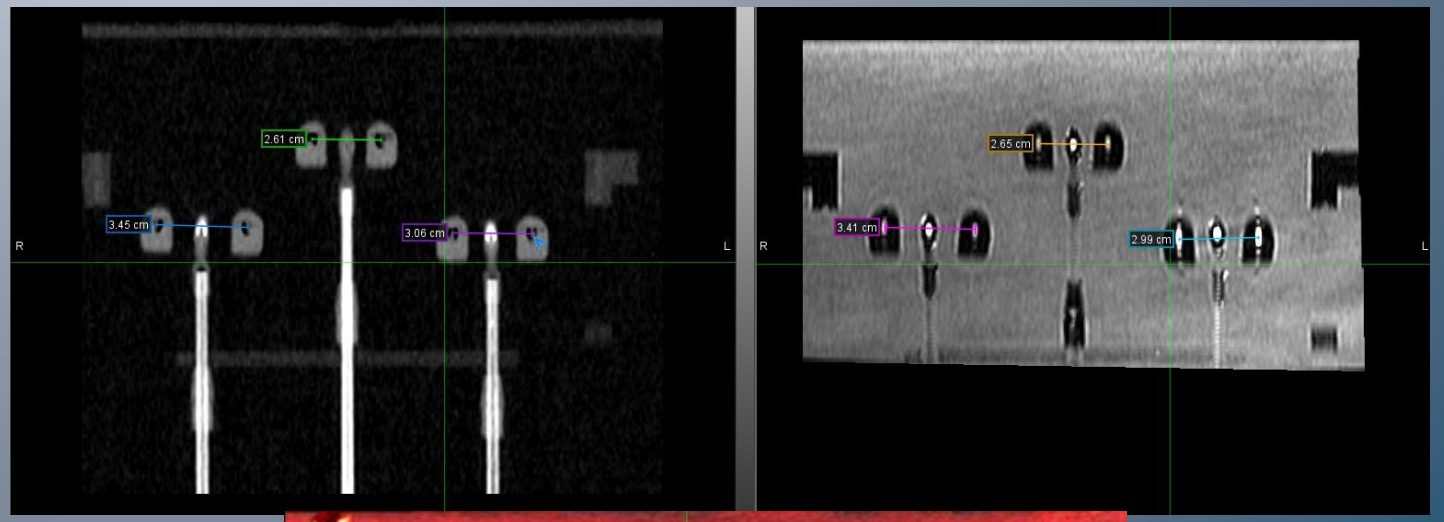


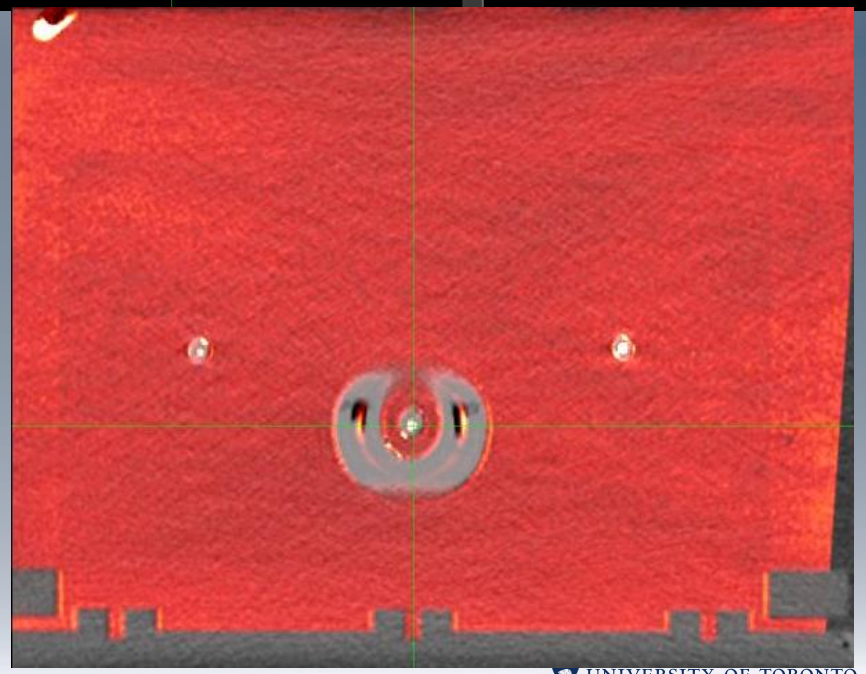
MRI in clinical workflow



Commissioning

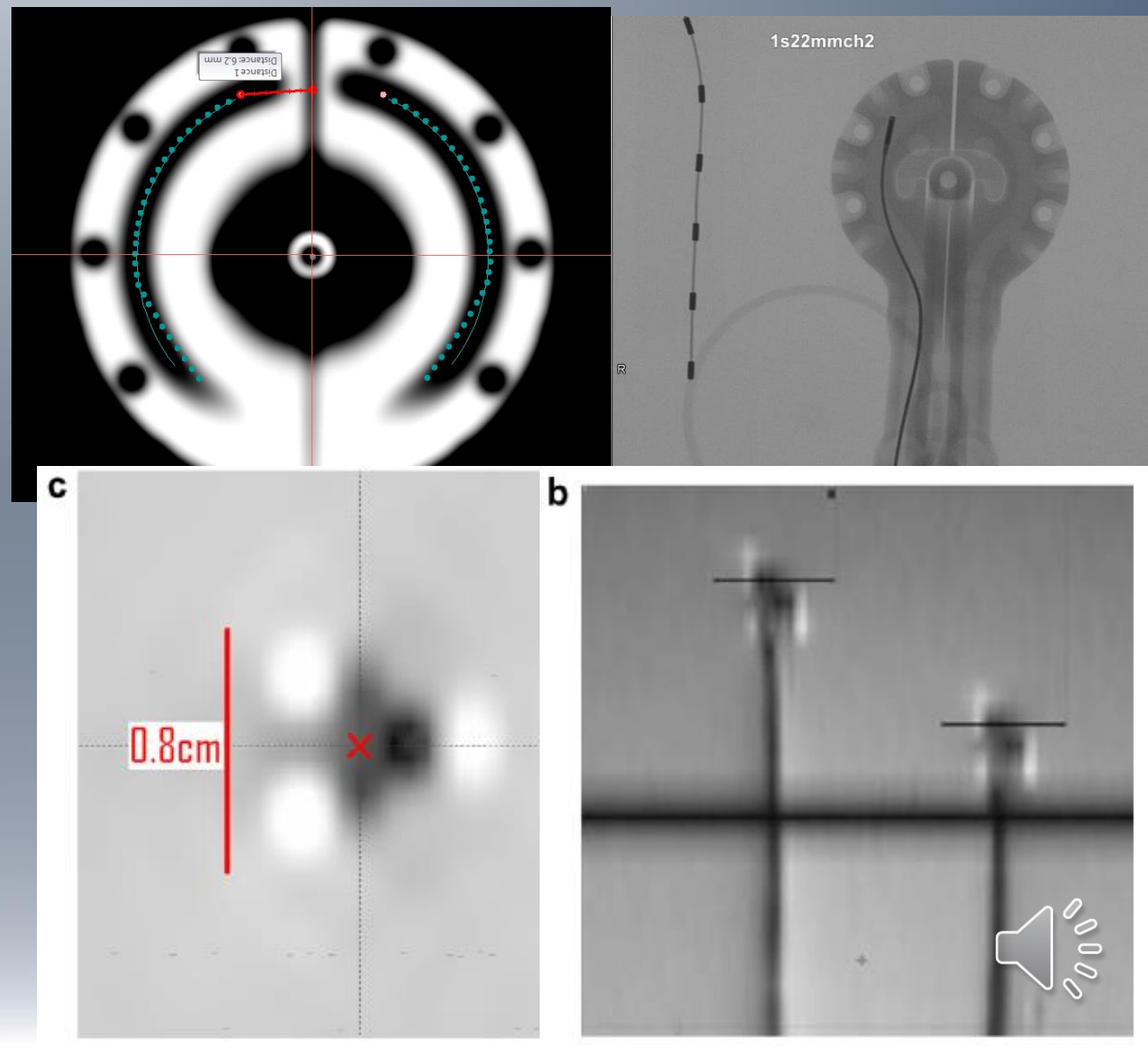
- Geometric fidelity checks of MR sequences
- Data transfer integrity
- Source path characterization
- Applicator model validation





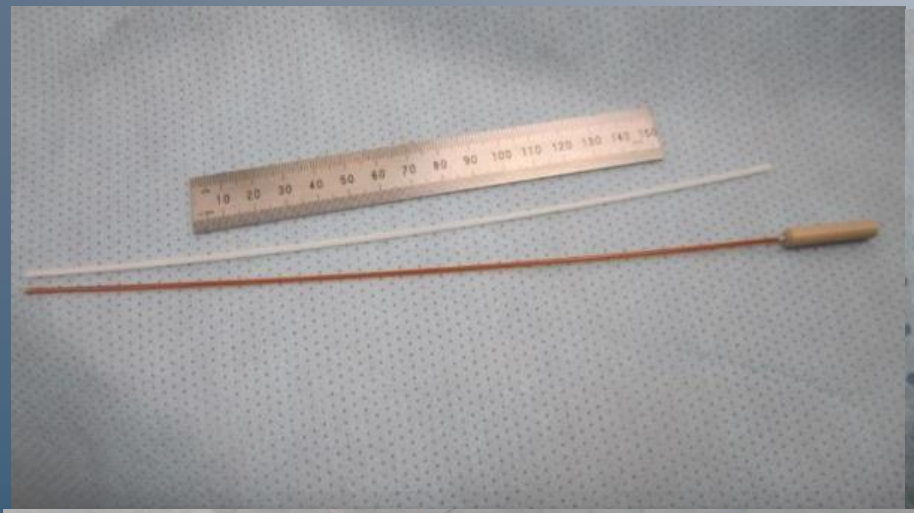
Applicator Commissioning

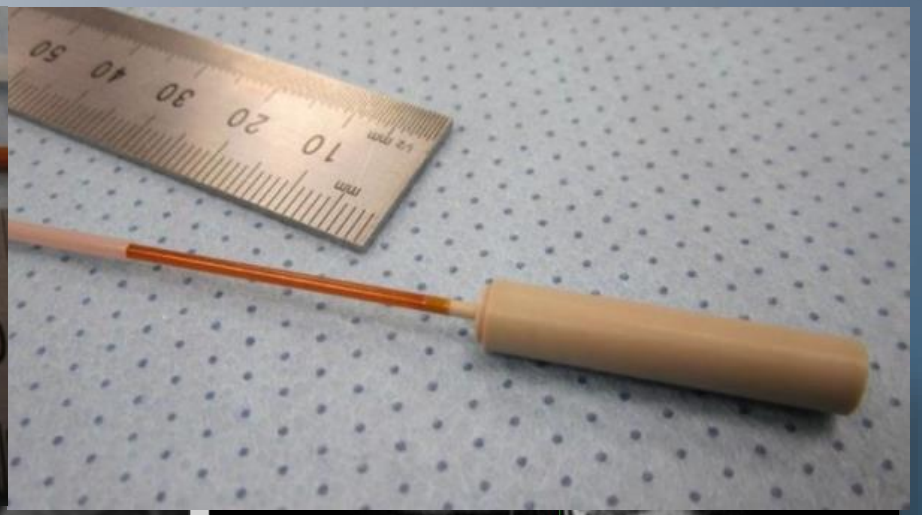
- Index position of first Dwell position
- Distance of dwell to outer surface of applicator
- Spot checks of source path for curved applicators
- Imaging artefacts introduced by metallic applicators

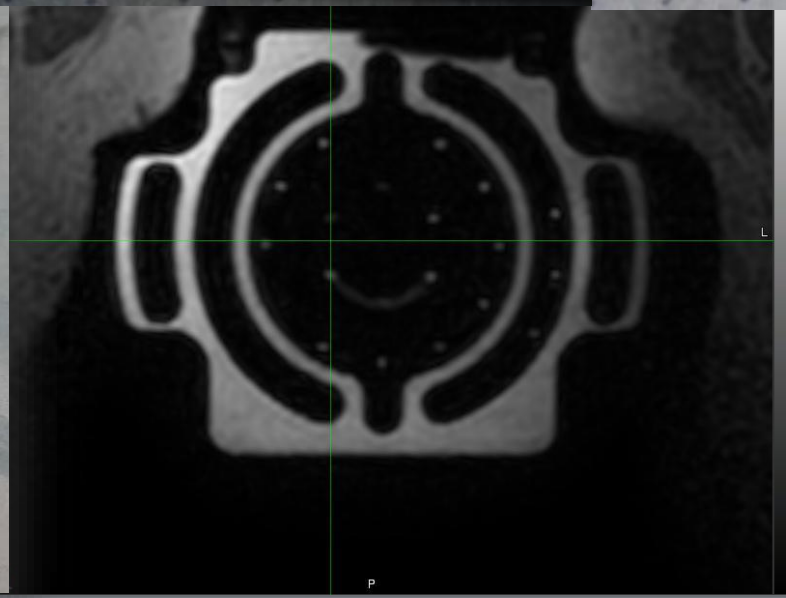


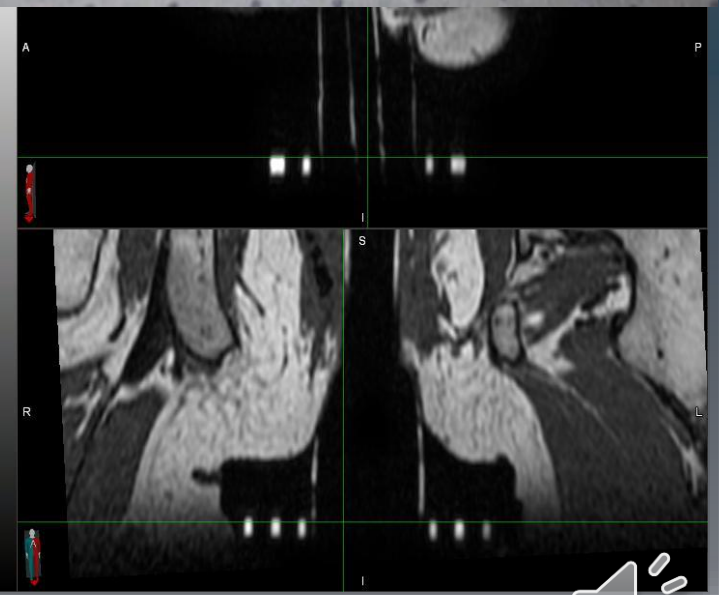
Hellebust et al. *Radiotherapy and Oncology* 96.2 (2010): 153-160.

Reconstruction aids









AAPM report No. 100

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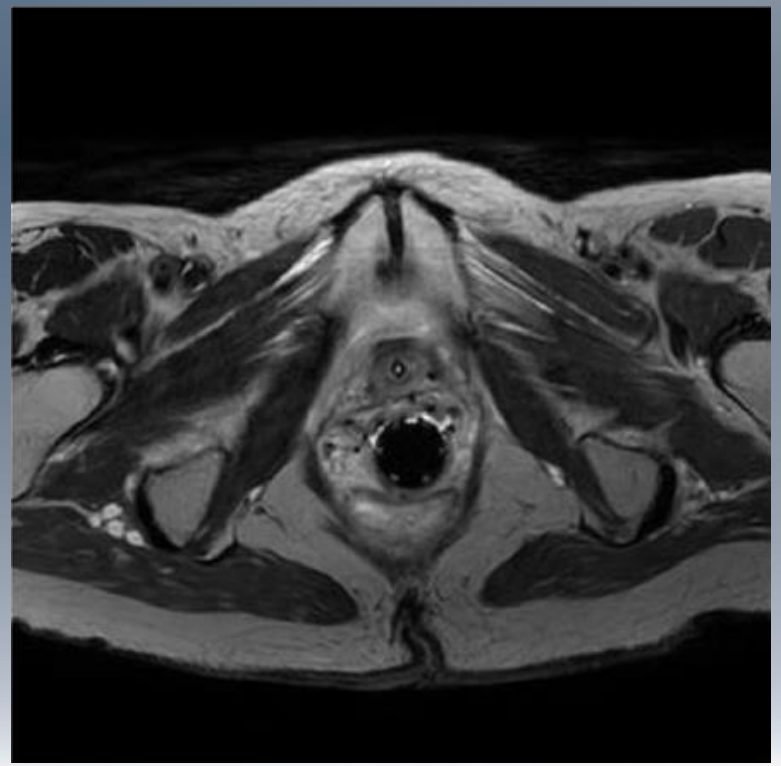
MR sequences for catheter delineation

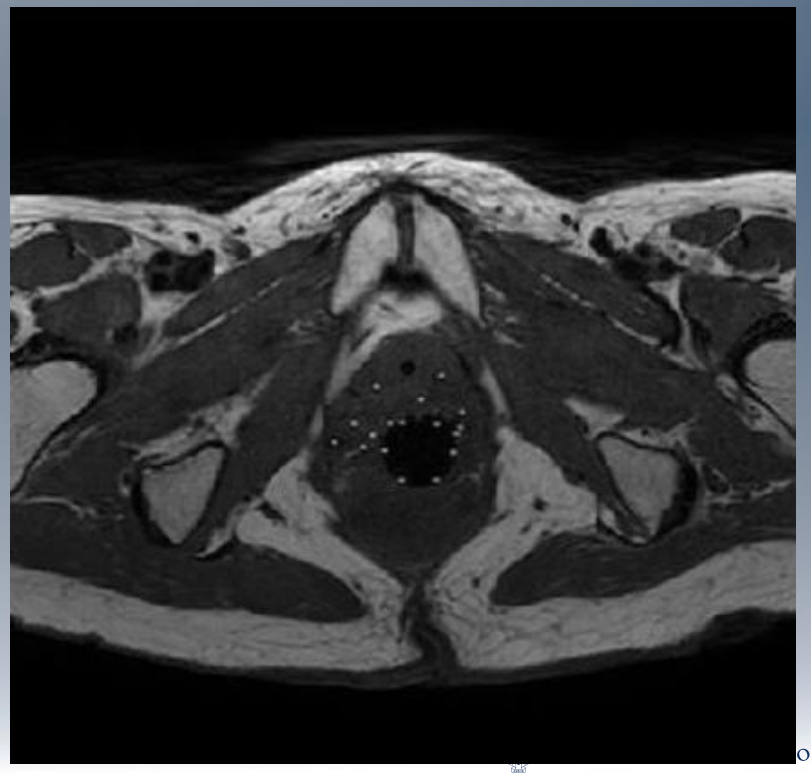
T2W 3D coarse – (1 mm isotropic)

- Catheters appear as voids
- Negative contrast
- ~3 mins



T1W 3D coarse – (1 mm isotropic)

- Catheters appears as bright
- Positive Contrast
- ~ 3 mins



QA for MR-guided brachy program

Patient specific QA

- Real-time peer review of contours
- Free length verification
- Automated second checks

Programmatic QA

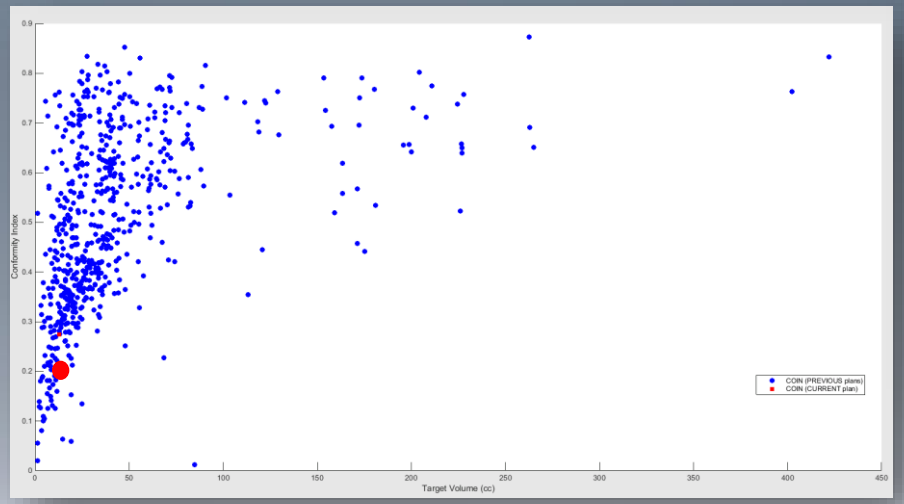
- CPQR QA program
- Monthly QA of MR markers

Interstitial Free length Calculator

CLINICAL VERSION

Channel number	Last Dwell	Tandem (Y/N)	Measured Free Length/mm	Estimated Last dwell	Error
1				-2	2
2				-2	2
3				-2	2
4				-2	2
5				-2	2
6				-2	2
7				-2	2
8				-2	2
9				-2	2
10				-2	2
11				-2	2
12				-2	2
13				-2	2
14				-2	2
15				-2	2
16				-2	2
17				-2	2
18				-2	2
19				-2	2
20				-2	2
21				-2	2
22				-2	2
23				-2	2

CLINICAL VERSION



HFN: 3357022
Fraction number: 2
Plan type: SN Transperineal - WITH tandem
Plan name: fx2
Plan date: 20200210
Plan time: 104257

QA STATUS: SEE WARNINGS IN REPORT

QA REPORT

PASS - Channel length check: All channels have correct indexer length and 1 tandem in channel 5 has a 1300 mm indexer length
PASS - Plan approval status
PASS - Flexitron HDR 192-Ir afterloader is being used

WARNING - Treament position check: Most distal dwell in channel 1 is 21 mm from the channel end
WARNING - Treament position check: Most distal dwell in channel 4 is 28 mm from the channel end
WARNING - Treament position check: Most distal dwell in channel 7 is 31 mm from the channel end
WARNING - Treament position check: Most distal dwell in channel 12 is 51 mm from the channel end!
WARNING - Same treatment position warning as above affects other channels... Please check!
PASS - Channel directionality check: All channels have proper directionality assuming head first scan orientation.
PASS - Channel offset check: All channels have zero offset and 1 tandem in channel 5 has a -6 mm offset
PASS - Transperineal channel free length checks
PASS - Dose calculation based on TG-43 formalism
PASS - Channel mapping check: All channels have correct mapping.
PASS - Activity check

All checks completed. Treatment plan pdf and QA map copied to UN IMPAC HDR

Thank you

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