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

Value of MR → Treatment workflows → QA
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
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

Value of MR → Treatment Workflows → QA

Scanner away from OR

Registration Algorithms

Scanner in OR

Patient Transfers
MR + CT hybrid process with rigid registration
Contour based deformable registration

Quantitative measures of image registration accuracy – TG132


<table>
<thead>
<tr>
<th>Structure</th>
<th>DIL</th>
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<tbody>
<tr>
<td>Metric</td>
<td>ROs</td>
</tr>
<tr>
<td>DSC</td>
<td>0.80 ± 0.10</td>
</tr>
<tr>
<td>MDA (mm)</td>
<td>1.24 ± 0.73</td>
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<tr>
<td>Distance between centroids (mm)</td>
<td>6 ± 2</td>
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<tr>
<td>Registration time (sec)</td>
<td>227 ± 27</td>
</tr>
<tr>
<td>Volume (cc)</td>
<td>3.52 ± 2.00</td>
</tr>
<tr>
<td>Difference between volumes (cc)</td>
<td>0.86 ± 0.50</td>
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CT-Based Technique and Catheter Displacement

Planned

Delivered
Patient Transfer System

• Q-fix Symphony

• Diacor – Zephyr HDR
MRI in clinical workflow

- Diagnosis
  - Scanner away from OR
    - Registration Algorithms
    - Patient Transfers
  - Scanner in OR
    - Suite Design
- Treatment
- QA
- Resources
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

Princess Margaret Cancer Centre (MR on rails)

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

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

- Diagnosis
  - Scanner away from OR
    - Registration Algorithms
    - Patient Transfers
  - Scanner in OR
    - Suite Design
- Treatment
- QA
- Resources
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

2D Brachytherapy at OCC

2D Planning
1 hour

- Applicator Insertion (30 mins)
- 2D image acquisition (10 mins)
- 2D Planning (10 mins)
- QA & Treatment (15 mins)

Total Duration for 20 Consecutive 2D cervix cases:
Start of the OCC program

MR Planning
6 hours

- Applicator Insertion (30 mins)
- Recovery (1-2 hours)
- Image acquisition (1 hour)
- Contouring (1 hour)
- 3D Planning (45 mins)
- QA & Treatment (15 mins)

Total Duration
20 consecutive MR guided cases
20 consecutive intraoperative cases

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

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

- Diagnosis
  - Scanner away from OR
    - Registration Algorithms
    - Patient Transfers
  - Scanner in OR
    - Suite Design
    - Resources
- Treatment
- QA
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

Reconstruction aids
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
Thank you