Image guided brachytherapy: HDR treatments in the MR room

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UMC Utrecht: HDR treatments in the MR room, or an MR scanner in the Brachy suite

- Since 2010
- 1.5 T MR system at department Radiotherapy
- MR guided intervention
  - Brachytherapy
  - HIFU
Contents

• Why MR and why MR in Brachy treatment room

• MR safety

• MRI guided brachytherapy in
  – Focal HDR prostate brachytherapy
  – Robotic prostate brachytherapy
  – oesophagus, head & neck
  – Gynaecology

• Workflow HDR for cervical cancer
IGABT for cervical cancer: GEC-ESTRO recommendations:

**Target definition**

MR based

- GTV (macroscopic tumor)
- **HR-CTV** (GTV + suspected microscopic tumor)
- IR-CTV (pre-treatment extension)

**Reporting Dose Volume parameters**

DVH: aims and constraints on total dose: EBRT + Brachytherapy

DVH analysis based on EQD2 with: $\alpha/\beta$(target) = 10 Gy

$\alpha/\beta$(OAR) = 3 Gy

$T_{1/2}$ = 1.5 h

Dose volume parameters:

- **target:** D90 and D98
- **OAR:** D2cc

**Common Language!!**

Haie-Meder et al. Radiother Oncol 2005
Pötter et al. Radiother Oncol 2006
**UMC Utrecht: since 2006 MR guided treatment**

PDR in two applications, 2* 31 hours
MR scans with applicator in situ
MR at department radiology
Optimization, combination Intracavitary/interstitial

### Clinical results 2006-2008 RETRO-Embrace

<table>
<thead>
<tr>
<th>3 yrs outcome</th>
<th>All n=46</th>
<th>Node positive n=20</th>
<th>Node negative n=26</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall survival</td>
<td>65</td>
<td>50</td>
<td>77</td>
<td>0.032</td>
</tr>
<tr>
<td>Local Control</td>
<td>93</td>
<td>94</td>
<td>92</td>
<td>0.799</td>
</tr>
<tr>
<td>Pelvic control</td>
<td>84</td>
<td>78</td>
<td>88</td>
<td>0.370</td>
</tr>
</tbody>
</table>

![Graph showing survival probabilities](image)

- **LC**: Local Control
- **PFS**: Progression-Free Survival
- **OS**: Overall Survival

**Notes:**
- Utrecht applicator
- Optimization, combination Intracavitary/interstitial
- MR scans with applicator in situ
>1100 patients, from >24 centers  
Preliminary Dose Effect analysis OAR

**Bladder**  
Dose effect grade 2-4 morbidity

**Vagina**  
Dose effect grade ≥ 2 morbidity

**Strong rationale to decrease OAR dose**

*Fokdal et al. 2013*  
*Kirchheiner et al 2013*
Brachy treatment suite
With 1.5 T MR scanner and HDR afterloader

Radiation Shielded treatment room with MR scanner 1.5 T

**non** MR compatible HDR afterloader

MR compatible applicators, needles, tubes

MR compatible instruments/robotics
MR safety issues

All equipment on the MRI unit must have
One of these symbols,

MR SAFE
MR UNSAFE
MR CONDITIONAL

Need for:
MR compatible instruments and applicators

Effort: Once before start
MR safety issues

5 Gauss marking on the floor for MR conditional equipment

Securing non MRI compatible equipment: HDR afterloader with double ropes.
MR safety issues: Training

Most experienced RTT’s are trained/educated in operating MR scanner as well.

MR Safety procedures and -training developed

**MR Safety training**: conform hospital protocol:
- yearly for all staff,
- as well for anesthesia staff!!

**HDR emergency procedure in MR**: regularly trained: RTT’s, physicians
- 5 minutes movie available

**Combination training**

Continuous effort!!
MRI guided brachytherapy: HDR prostate

Focal HDR brachytherapy for localized cancer

- 19 Gy on focal tumors in single fraction (GTV+5mm margin)
- **ONLY IF:** Dose plan meets stringent constraints: Rectum and bladder: D1cc < 12 Gy, Urethra: D10% < 21 Gy

Procedure

- Pre brachy multi parametric MRI
- US guided insertion of catheters
  - Fusion with pre brachy MRI
- MRI
- Reconstruction
- Contouring Fusion with pre brachy MRI
- (Inverse) dose planning
- MRI (position verification)
- Irradiation

Groenendaal et al. IJROBP 2012;82:537-44
Development of robot and MR compatible afterloader

Setup with treatment length 1500 mm at 50 mm beyond isocenter MR; position test with film: source position within spec (error <0.5 mm)

The aim is to treat the patient in imaging position. This is feasible, with longer treatment cable and breaking the RF waves.

Courtesy Moerland 2013
MRI guided brachytherapy: Studies

Esophageal cancer

a) Delineation of the esophageal tumor on a T2 MR image
b) Markers indicate the tumour borders as determined with standard X-ray guided endoscopic procedure

Applicator tube with inner MR marker tube

Head & Neck

Potential benefit of MRI-guided brachytherapy for nasopharynx, lip, vestibulum nasi tumours
MRI guided brachytherapy: Gynecology

- Vaginal cylinders, endometrium cancer

Application, MR scan, visual inspection, irradiation standard plan, dose calculation

- Advanced cervical cancer
MRI guided brachytherapy: Advanced Cervical cancer

MRI guidance

- Accurate delineation of target volumes
- Additional needles help to increase target dose
- Adequate organ sparing
- Moderate morbidity rates
- Improvement of local control and cancer specific survival

Need for: MR scans with applicator and needles in situ
Direct reconstruction on MR using models in TPS
Direct delineation on MR
Uncertainties in image guided adaptive cervix cancer brachytherapy: Impact on planning and prescription

Kari Tanderup, Nicole Nesvacil, Richard Pötter, Christian Kirisits

*Dept. of Oncology, Aarhus University Hospital, Denmark; †Dept. of Radiotherapy and Oncology, Comprehensive Cancer Center & Christian Doppler Laboratory for Medical Research for Radiation Oncology, Medical University of Vienna, Austria

Intra- inter fraction dose variation

A multicentre comparison of the dosimetric impact of inter- and intra-fractional anatomical variations in fractionated cervix cancer brachytherapy

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Intra-fraction dose variation UMC Utrecht:

**PDR**
- One fraction: ~30 hours treatment, one pulse every hour
- Dose variation during fraction due to OAR changes
- Systematic increase of rectum D2cc dose

Therefore change to:

**HDR** 2*2 fractions of 7 Gy (since brachy suite with MR)
Imaging workflow  HDR patients (study: n=15)

Brachytherapy schedule HDR : 4*7Gy: 2 applications, with 2 fractions each

<table>
<thead>
<tr>
<th>Application1</th>
<th>Application2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BT1</strong></td>
<td><strong>BT4</strong></td>
</tr>
<tr>
<td>Fraction1</td>
<td>Fraction2</td>
</tr>
<tr>
<td><strong>BT2</strong></td>
<td><strong>BT3</strong></td>
</tr>
<tr>
<td>Fraction1</td>
<td>Fraction1</td>
</tr>
<tr>
<td></td>
<td>Fraction2</td>
</tr>
</tbody>
</table>

- **MRplan**
  - Contouring
  - Optimised plan

- **MRpreRad**
  - Match on applicator
  - Contours of MRplan on MRpreRad
  - OK?
  - Irradiation opt planBT1

- **MRpostRad**

- **MRplan**

- **MRpreRad**
  - Match (appl) with MRplanBT1
  - Contours of MRplanBT1 on MRBT2
  - OK?
  - Irradiation opt planBT1

- **MRpostRad**

- ~4 hr
- ~22 hr
- ~50 min
HDR workflow: image registration and calculation of DVH parameters on ‘real’ contours

MRplan

MRpre-/postfraction

match on applicator

adapting contours

contours re-sampled

DVH parameters on new contours

D2cc rectum 4.2 → 5.8 Gy
Treatment planning system: Oncentra/Elekta
Results: dose differences for 3 time intervals

Planning (~4 hours)

irrad=radiation+MR (50 minutes)

day (~22 hours)

Important: detect outliers

Christel Nomden et al 2014
Example from first patients

- Difference in rectal filling: Increase of gas!
- Therefore:
  - Rectum catheter in all HDR patients
- Adapt when necessary (de-gassing)
Comparison intra-fraction dose variation
PDR versus HDR

Unfavourable systematic increase during PDR

Christel Nomden et al. 2014
Imaging workflow HDR patients: clinical practise

Brachytherapy schedule HDR: 4*7Gy: 2 applications, with 2 fractions each.
## Clinical practise: workflow first application

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>MR scan</strong></td>
<td>MR scan immediately before start application (T2 TSE sagital, transversal, coronal):</td>
</tr>
<tr>
<td>(MRpreApp)</td>
<td>replacement of MR in week 4</td>
</tr>
<tr>
<td></td>
<td>• Tumor regression?</td>
</tr>
<tr>
<td></td>
<td>• Needles necessary?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>• MR scan</td>
<td></td>
</tr>
<tr>
<td>• Planning</td>
<td></td>
</tr>
<tr>
<td>• MR scan</td>
<td></td>
</tr>
<tr>
<td>• Irradiation</td>
<td></td>
</tr>
</tbody>
</table>
Clinical practise: workflow first application

Application in MR room
- If needles necessary:
  - MR guided placement
  - short sagital/transversal sequence (~2*1min)

After application:
- MR scan: T2 TSE sagital, transversal, coronal, DWI (~13 min)

- MR scan
- Application
- MR scan
- (MRplan)
- Planning
- MR scan
- Irradiation

BT1 preApp  BT1 nld  BT1 plan
Clinical practise: workflow first application

- MR scan
- Application
- MR scan

**Planning**

- MR scan
- Irradiation

**Contouring** by radiation oncologist

- DVH analysis standard plan
- Optimization of plan (with needles)
- DVH analysis optimized plan

**Applicator reconstruction** by RTT

- if approved by doctor and physicist:
  - next step:

**Workflow first application**

MR scan → Application → MR scan → Planning → MR scan → Irradiation
Clinical practise: workflow first application

Patient on MR trolley

MR scan: sagittal scan, visual inspection, adaptation?
and transversal and coronal scan

Registration of transversal scan with MRplan
(Mutual Information on box around applicator)

• MR scan
• Application
• MR scan
• Planning

• MR scan (MRprefract)
• Irradiation

Visual inspection
Needle location?
OAR position?
OK?

yes
irradiation
adapt contours
DVH analysis on new contours
adapt constraints for 2nd application

no
adapt contours
DVH analysis on new contours
acceptable?

yes
irradiation
adapt constraints for 2nd application

no
adapt plan
Example 1 No special adaptation

<table>
<thead>
<tr>
<th></th>
<th>BT1 plan</th>
<th>BT1 prerad</th>
<th>BT2 prerad</th>
<th>BT3 plan</th>
<th>BT3 prerad</th>
<th>BT4 prerad</th>
</tr>
</thead>
<tbody>
<tr>
<td>bladder EQD2 Gy</td>
<td>77.1</td>
<td>79.0</td>
<td>77.1</td>
<td>79.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rectum EQD2 Gy</td>
<td>57.6</td>
<td>55.4</td>
<td>57.6</td>
<td>55.4</td>
<td></td>
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<tr>
<td>bowel EQD2 Gy</td>
<td>70.1</td>
<td></td>
<td>70.1</td>
<td></td>
<td>66.0</td>
<td></td>
</tr>
</tbody>
</table>
Example 2 changing bladder filling

‘wrong’ (not empty) bladder filling at first MR

→ lower bladder, higher bowel dose for first fraction

→ Next fraction 100 cc bladder filling

→ adaptive

See, manipulate, adapt dose!
Controlling total dose, using spreadsheet

- Adaptive workflow, adaptation rectum/bladder filling
- Better estimation delivered OAR dose
Conclusions

MR Imaging directly before HDR dose delivery:
- results in a more accurate estimate of delivered dose
- helps identifying situations that ask for individual adaptations
  (e.g. rectal de-gassing)

But .....MR safety training is essential
Thanks to UMCU Team

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