Technological Advances in Gynaecological brachytherapy

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2D BT

- SS, IC, Fletcher
- Orthogonal, Foley, R marker
- X ray markers
- Point A, ICRU points, 60Gy Vol
- Std loading, m optimization
- Dose to point A, OAR points

3D BT

- CT/MR compatible IC+IS
- CT / MR Contrast, B protocol
- Target / OARs
- Applicator commissioning
- Point A, ICRU points
- Std loading, MO, GrO, IP
- GEC ESTRO DVH

Application in OT

Applicators

Imaging

Contouring

Applicator reconstruction

Definition of dose points

Planning

Plan evaluation

Dose delivery
Imaging
Imaging 2D vs 3D

- Great view of the applicator and the source positions
- Can locate some cardinal points on some OARs which act as surrogates
  - Bladder neck - by inserting foley catheter with contrast
  - Vaginal mucosa through radio-opaque gauze
  - Rectum when radio-opaque marker is inserted or by rectal separator inserted in the vagina.
- Target / disease at the Cervix and parametrium
- Uterus
- Rectum
- Bladder
- Sigmoid
- Small bowel
Advances in Imaging leads to the online Tumour regression

Dimopoulos et al. Radiother & Oncol Suppl 2004
Applicator material

- Metal (SS applicators), produces streak artifacts in CT images
- CT/MR compatible applicators made of plastic/titanium-zirconium alloy (non ferromagnetic materials) produce less artifacts
Application technique
Systematic adaptation
Adaptation of the tumor using the applicator

IC

(IC+IS)

IC +IS
(WITH additional NEEDLES)
Contouring

- The Most New concept in the technical advances
- Associated with learning curve
- Largest uncertainty in the whole chain of 3D BT
- **Training / Hands on workshop** is mandatory to remain consistent with the definitions
- Encouraging **Inter observer consistency**.
  - Dimopoulos et al, Lang et al, Nulens et al, Petric et al, Tanderup et al.
Contouring
Treatment planning – point A-STD loading
Point A / target dose

D90 = 65 Gy EQD2

Slide courtesy: C Kirisits/Prof Potter
Point A / target dose

Point A:
- 84 Gy

Point B:
- 93 Gy

D90 = 75 Gy EQD2

Slide courtesy: C Kirisits/Prof Potter
Point A / target dose

D90 = 90 Gy EQD2

Slide courtesy: C Kirisits/Prof. Potter
2D standard plans

K Tanderup et al, Radiother Oncol 2010

10/57 pts
3D optimised plans

K Tanderup et al, Radiother Oncol 2010
Benefit of 3D optimization – Volume

Median volume: 32cc

Violation of OAR constraint

K Tanderup et al, Radiother Oncol 2010
Benefit of 3D optimization – Volume

Optimised

11% needles

64% needles

Violation of OAR constraint

Application of needles
Improvement of local control
MRI based brachytherapy Vienna 98-03

Depending on treatment period
(experience, modification of application)

D90: 81 Gy (98-00) – 90 Gy (01-03)

Late side effects at 3 years

Total G3/4:
98-03: 7/145; 98-00: 6/73;
[93-97: 14/189] 01-03: 1/72

Pötter et al. Radiother Oncol 2007
## DOSIMETRIC COMPARISON: Retrospective Vs Prospective Data

<table>
<thead>
<tr>
<th></th>
<th>TMH: RD</th>
<th>TMH: PD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HRCTV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol in cc</td>
<td>45.2 ± 15.8</td>
<td>42.5 ± 19.5</td>
</tr>
<tr>
<td>D100</td>
<td>54.1 ± 6.5</td>
<td>65.7 ± 4.6</td>
</tr>
<tr>
<td>D90</td>
<td><strong>70.9 ± 10.6</strong></td>
<td><strong>87.2 ± 4.4</strong></td>
</tr>
<tr>
<td>Avg. Pt A</td>
<td>73.4 ± 4.5</td>
<td>93.1 ± 24.8</td>
</tr>
<tr>
<td><strong>Bladder</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICRU Bladder</td>
<td>80.4 ± 34.4</td>
<td>76.4 ± 15.5</td>
</tr>
<tr>
<td>D0.1cc</td>
<td>139.1 ± 54.7</td>
<td>109.6 ± 19.7</td>
</tr>
<tr>
<td>D2cc</td>
<td><strong>93.4 ± 24.6</strong></td>
<td>74.8 ± 7.1</td>
</tr>
<tr>
<td><strong>Rectum</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICRU Rectum</td>
<td>63.5 ± 8.1</td>
<td>68 ± 7.9</td>
</tr>
<tr>
<td>D0.1cc</td>
<td>66 ± 9.9</td>
<td>71.5 ± 7.5</td>
</tr>
<tr>
<td>D2cc</td>
<td><strong>57.8 ± 7.7</strong></td>
<td><strong>64.5 ± 5.5</strong></td>
</tr>
<tr>
<td><strong>Sigmoid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D0.1cc</td>
<td>109.4 ± 45.2</td>
<td>74 ± 8.6</td>
</tr>
<tr>
<td>D2cc</td>
<td><strong>74.6 ± 19.6</strong></td>
<td><strong>65.2 ± 5.4</strong></td>
</tr>
</tbody>
</table>

Mahantshetty et al, ESTRO 2013; Geneva
Linking of DVH parameter with toxicities

N=141
Clinical Symptoms

N=35
Changes visible with rectoscopy

Georg et al. 2009
## Uncertainty budget

<table>
<thead>
<tr>
<th></th>
<th>Geometric variation (mm)</th>
<th>Mean dose variation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contouring</strong></td>
<td>SD 4 mm experienced*</td>
<td>5-10%**</td>
</tr>
<tr>
<td></td>
<td>? mm in-experienced</td>
<td></td>
</tr>
<tr>
<td><strong>Reconstruction</strong></td>
<td>SD 0.5-2mm***</td>
<td>4-5%****</td>
</tr>
<tr>
<td><strong>Image fusion</strong></td>
<td>? (~1-2mm)</td>
<td>? (~5%)</td>
</tr>
<tr>
<td><strong>DVH calculation</strong></td>
<td></td>
<td>3%‡</td>
</tr>
<tr>
<td><strong>Worst case assumption</strong></td>
<td></td>
<td>Bladder: 5%‖□□□□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rectum, Sigmoid: ?</td>
</tr>
<tr>
<td><strong>Organ motion</strong></td>
<td></td>
<td>20-25%□□□□□□□□</td>
</tr>
</tbody>
</table>

*Petric et al, RO 2013  
**Hellebust et al, RO 2013  
***Haack et al, RO, 2009  
****K.Tanderup et al, RO, 2008  
‖Kirisits et al, RO, 2007  
‖‖K.Tanderup et al, RO 2013  
‖‖‖N.Nesvacil et al, RO 2013
EMBRACE - International study on MRI-based 3D brachytherapy in locally advanced cervical cancer

A prospective observational multi-centre trial (> 1000 pts)

Vienna
Aarhus
Utrecht
Leiden
Ljubljana
London
Arnhem
Paris (Europe)
Kaposvar
Maastricht
Trondheim
Leeds
Oslo
Amsterdam
Kuopio
Cambridge

(P.N.America)
Pittsburgh
Milwaukee
Edmonton
Iowa
BCU

(Asia)
Mumbai
Chandigarh
ChangMai
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Dose delivery

GEC ESTRO DVH

Workflow
Intra-application and inter-application variation

<table>
<thead>
<tr>
<th>Center</th>
<th>Bladder Mean</th>
<th>SD</th>
<th>Rectum Mean</th>
<th>SD</th>
<th>Sigmoid Mean</th>
<th>SD</th>
<th>HR CTV Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>21.9</td>
<td>6.1</td>
<td>21.6</td>
<td>-2.7</td>
<td>22.8</td>
<td>-3.1</td>
<td>11.6</td>
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<tr>
<td>2</td>
<td>-0.1</td>
<td>14.7</td>
<td>0.6</td>
<td>17.4</td>
<td>1.8</td>
<td>24.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>3.7</td>
<td>12.0</td>
<td>3.6</td>
<td>23.4</td>
<td>-</td>
<td>-</td>
<td>-1.1</td>
<td>9.0</td>
</tr>
<tr>
<td>4</td>
<td>6.4</td>
<td>24.7</td>
<td>8.6</td>
<td>24.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>0.9</td>
<td>13.1</td>
<td>0.6</td>
<td>15.1</td>
<td>11.9</td>
<td>37.5</td>
<td>-0.9</td>
<td>19.4</td>
</tr>
<tr>
<td>6</td>
<td>2.1</td>
<td>24.3</td>
<td>5.2</td>
<td>26.0</td>
<td>2.3</td>
<td>21.3</td>
<td>1.6</td>
<td>10.4</td>
</tr>
<tr>
<td>total</td>
<td>3%</td>
<td>20%</td>
<td>5%</td>
<td>22%</td>
<td>2%</td>
<td>27%</td>
<td>-1%</td>
<td>13%</td>
</tr>
<tr>
<td>Intra-application</td>
<td>1%</td>
<td>18%</td>
<td>4%</td>
<td>21%</td>
<td>-2%</td>
<td>24%</td>
<td>-3%</td>
<td>11%</td>
</tr>
<tr>
<td>Inter-application</td>
<td>4%</td>
<td>22%</td>
<td>6%</td>
<td>23%</td>
<td>7%</td>
<td>30%</td>
<td>0%</td>
<td>15%</td>
</tr>
</tbody>
</table>

N.Nesvacil et al, Radiother Oncol 2013
Inter application variation of high dose region
Uncertainties of dose accumulation
Direct addition Vs Deformed addition
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Dose to point A, OAR points

3D BT

Point A, ICRU points

Std loading, m optimization

Dose to point A, OAR points

Work flow
Thank You