Image guided Adaptive Brachytherapy for Cervical Cancer

Christian Kirisits

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Point A
Point A / target dose

84 Gy

D90 = 65 Gy EQD2

Point A / target dose

84 Gy

D90 = 75 Gy EQD2

Point A / target dose

84 Gy

D90 = 90 Gy EQD2
**Point A / target dose**

- D90 = 85 Gy EQD2

**Recommendations**

- GYN GEC ESTRO recommendations I (Haie-Meder et al.) - contouring
- GYN GEC ESTRO recommendations II (Pötter et al.) - dose parameters
- GYN GEC ESTRO recommendations III (Hellebust et al.) - reconstruction
- GYN GEC ESTRO recommendations IV (Dimopoulos et al.) - imaging
- ABS recommendations on GYN general (Viswanathan and Thomadsen, ABS Cervical Cancer Recommendations Committee) - general
- ABS recommendations on GYN HDR (Viswanathan et al.)
- ABS recommendations on GYN PDR (Lee et al.)

**DOSE AND VOLUME PARAMETERS FOR PRESCRIBING, RECORDING, AND REPORTING TARGET VOLUMES AND ORGANS AT RISK**

**Target parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAK, point A</td>
<td>D98, D90, D50 for HR CTV, IR CTV* (*if used for prescription)</td>
</tr>
<tr>
<td>D98, D50 for GTV</td>
<td></td>
</tr>
<tr>
<td>D90, D50 for PTV (if applicable, only for research!!)</td>
<td></td>
</tr>
<tr>
<td>D98?</td>
<td>D50?</td>
</tr>
</tbody>
</table>

(state of the art parameters in bold)
DOSE AND VOLUME PARAMETERS FOR PRESCRIBING, RECORDING, AND REPORTING TARGET VOLUMES AND ORGANS AT RISK

**OAR parameters**

- $D_{2\text{cm}^3}$, $D_{0.1\text{cm}^3}$ for high doses to bladder, rectum, sigmoid and bowel (if applicable)

- Vaginal points at level of vaginal sources

  Intermediate dose by e.g. $V_{50\text{Gy}}$, $D_{50}$, and points and lengths
An increase of TRAK will result in an increase of the dose to the OAR. The shape of the new curve is stretched, the ratio of the two upper points on the DVH curve becomes larger. The impact on the low dose regions is smaller. The same ratio applies. The blue symbols are from the previous figure with lower dose to the OAR. The third point in the low dose region is not needed necessarily to describe the shape.

The orange curve could be the result of different external beam component or other treatment technique. The shape of the curve is completely changed. All three points on the DVH curve are needed to describe the difference to the two curves shown below.
FROM PLANNING AIMS TO PRESCRIPTION

Traditional concepts:
“when prescribing to a target, the prescription dose is the planned dose to cover this target as completely as possible.”
or
prescription to a 100% isodose which is “to cover” the target volume

Need for common terminology according to ICRU reports on proton treatment and IMRT

- Planning aim dose
  - Set of dose and dose/volume constraints for a treatment

- Prescribed dose
  - Finally accepted treatment plan (which is assumed to be delivered to an individual patient)

- Delivered dose
  - Actually delivered dose to the individual patient

Example:
Previously: 4×7 Gy = 84 Gy EQD2 prescribed, D90 was mean 93 Gy

Planning aim was to deliver 4×7 Gy = 84 Gy, D90 for rectum, sigmoid < 70 Gy EQD2, bladder < 90 Gy EQD2

Prescribed dose was mean 93 Gy ± 13 Gy (1SD) EQD2 to D90 HR CTV

Delivered dose? Depending on variations and uncertainties – on average no systematic deviation from prescribed dose
LINKING DVH PARAMETERS TO CLINICAL OUTCOME for TARGET/TUMOUR

- Entire population (n=141)
- Tumours > 5cm (n=76)

20% less D90 per fraction — 10 Gy less for total dose

D90 (HR CTV)

- Entire population (n=141)
- Tumours > 5cm (n=76)

20% less D90 per fraction — 10 Gy less for total dose

D90 (HR CTV)

Rectum dose

N=141
Clinical Symptoms

N=35
Changes visible with rectoscopy

www.embracestudy.dk
> 650 patients enrolled!
**HR CTV D90 by Center**

*Preliminary - 3D QA pending!*

![Box plot graph showing HR CTV D90 by center with mean values marked.](graph)

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**HR-CTV dose and technique**

- **Large tumours (≥30cc):**
  - IC/IS increases target dose by 6 Gy
  - OAR doses not increased
- **Small tumours (<30cc):**
  - No difference for target or OARs

<table>
<thead>
<tr>
<th>HR CTV &gt;30cc</th>
<th>IC</th>
<th>IC/IS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D90</td>
<td>81.9 ± 9.5 Gy</td>
<td>88.2 ± 7.7 Gy</td>
</tr>
<tr>
<td>Bladder D2cc</td>
<td>78.1 ± 11.3 Gy</td>
<td>78.7 ± 11.6 Gy</td>
</tr>
<tr>
<td>Rectum D2cc</td>
<td>65.4 ± 8.2 Gy</td>
<td>64.6 ± 8.1 Gy</td>
</tr>
<tr>
<td>Sigmoid D2cc</td>
<td>64.4 ± 8.4 Gy</td>
<td>63.7 ± 7.6 Gy</td>
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**Application technique and patterns of tumor regression**

![Diagram showing application technique and tumor regression patterns.](diagram)
IIIB, 8 cm width, insufficient response (11/99)
o no adaptation of application technique
intracavitary approach only

Optimization with Tandem/ring only
HR CTV
D90: 69 Gy

Brachytherapy
9 months after treatment

Diagnosis

Improvement of local control
MRI based brachytherapy Vienna 98-03

Local control treatment period and tumor size

Late side effects at 3 years
Total G3/4: 96-00: 7/144; 01-03: 1/72

D90: 81 Gy (98-00) – 90 Gy (01-03)

Pötter et al. Radiother Oncol 2007

Current local control rates (Vienna experience)

- tumor size 2-5cm (01-08) 1 event: 98%
- tumor size >5cm (01-08) 7 events: 92%
Uncertainties? Where to improve?

Example for HDR intracavitary Cervix brachytherapy – per fraction

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<thead>
<tr>
<th>Category</th>
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<tr>
<td>Source strength</td>
<td>2%</td>
<td>PSDL traceable calibrations</td>
</tr>
<tr>
<td>Treatment planning</td>
<td>3%</td>
<td>Reference data with the appropriate bin width is used</td>
</tr>
<tr>
<td>Medium dosimetric corrections</td>
<td>1%</td>
<td>Applicator without shielding and CTV inside pelvis (concerning for scatter)</td>
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<tr>
<td>Dose delivery including registration of applicator geometry to anatomy</td>
<td>4%</td>
<td>Accurate QA concept for commissioning and constancy checks, especially for source positioning and applicator/source path geometry, appropriate imaging techniques, applicator libraries</td>
</tr>
<tr>
<td>Interfraction/Intrafraction changes</td>
<td>12%</td>
<td>For one treatment plan per applicator insertion but several subsequent fractions – check for major deviations in subsequent fractions</td>
</tr>
<tr>
<td>Total dosimetric uncertainty</td>
<td></td>
<td>13% for one single fraction</td>
</tr>
</tbody>
</table>

Example for HDR intracavitary Cervix brachytherapy – total dose 4 fractions

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<td>For one treatment plan per applicator insertion but several subsequent fractions –</td>
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<tr>
<td>Total dosimetric uncertainty for entire BT</td>
<td>7%</td>
<td>We would need interfraction value &lt; 3% to have total uncertainty &lt; 5%</td>
</tr>
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Visualization of the "real" source positions in relation to the outer dimensions and holes of the Vienna ring applicator.

Applicator surface

Source path
MRI for each fraction?
2nd application: CT

3D applicator reconstruction

Target transfer from first application MRI

Target transfer from MRI to CT with applicator as reference system
Contouring OAR on CT

Target contours from 1st application MRI

OAR contours from 2nd application CT

Dose planning and optimization based on copied target and individual OAR contours. All dose constraints for targets and OAR have to be achieved.
Levels

- X-ray
- CT-based for one application
- CT-based for all applications
- MRI for first, CT for subsequent applications
- MRI for each application
- MRI for each fraction

Ultrasound technology

Outlook

- ICRU 38 revision
- EMBRACE studies to increase insight into dose-effect relationships
- New cost effective methods keeping accuracy reasonable