Example for HDR intracavitary Cervix brachytherapy – per fraction

<table>
<thead>
<tr>
<th>Category</th>
<th>Optimum level</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source strength</td>
<td></td>
<td>PSDL traceable calibrations</td>
</tr>
<tr>
<td>Treatment planning</td>
<td></td>
<td>Reference data with the appropriate bin width is used</td>
</tr>
<tr>
<td>Medium dosimetric corrections</td>
<td></td>
<td>Applicator without shielding and CTV inside pelvis (concerning for scatter)</td>
</tr>
<tr>
<td>Dose delivery including registration of applicator geometry to anatomy</td>
<td></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></td>
<td>For one treatment plan per applicator insertion but several subsequent fractions – check for major deviations in subsequent fractions</td>
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</table>

Total dosimetric uncertainty for one single fraction
## Example for HDR intracavitary Cervix brachytherapy – per fraction

<table>
<thead>
<tr>
<th>Category</th>
<th>Optimum level</th>
<th>Assumptions</th>
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<tbody>
<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>
</tr>
<tr>
<td>Dose delivery including registration of applicator</td>
<td></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>geometry to anatomy</td>
<td>4%</td>
<td></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>
</tbody>
</table>

**Total dosimetric uncertainty 13% for one single fraction**
### Example for HDR intracavitary Cervix brachytherapy – total dose 4 fractions

<table>
<thead>
<tr>
<th>Category</th>
<th>Optimum level</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<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>
</tr>
<tr>
<td>Dose delivery including registration of applicator geometry to anatomy</td>
<td>1 / √N</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% → 6%</td>
<td>For one treatment plan per applicator insertion but several subsequent fractions –</td>
</tr>
</tbody>
</table>

**Total dosimetric uncertainty for entire BT**

7%

*We would need interfraction value < 3% to have total uncertainty < 5%*
Example for LDR prostate brachytherapy

<table>
<thead>
<tr>
<th>Category</th>
<th>Optimum level</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source strength</td>
<td>3%</td>
<td>PSDL traceable calibrations</td>
</tr>
<tr>
<td>Treatment planning</td>
<td>4%</td>
<td>Reference data with the appropriate bin width is used</td>
</tr>
<tr>
<td>Medium dosimetric Corrections</td>
<td>5%</td>
<td>A general prostate tissue is considered, but no consideration is given for calcifications (or their composition) in the patient</td>
</tr>
<tr>
<td>Inter-seed attenuation</td>
<td>4%</td>
<td>An advanced dose calculation formalism may indicate source models and orientations cause the largest effects</td>
</tr>
<tr>
<td>Treatment delivery imaging</td>
<td>2%</td>
<td>US QA performed according to AAPM TG-128</td>
</tr>
<tr>
<td>Anatomy changes between dose delivery and post-implant imaging</td>
<td>7%</td>
<td>Post-implant (day 0) imaging using CT, with a scalar correction factor for edema correction</td>
</tr>
<tr>
<td>Total dosimetric uncertainty</td>
<td>11%</td>
<td></td>
</tr>
</tbody>
</table>
Applicator reconstruction

- Reason for various systematic and random uncertainties

X-ray marker pos. 1, 16, 26
T.Hellebust et al., PMB, 2007

Source position 16

CT
MRI

Tanderup et al.
Direct reconstruction - challenge

Ring in one slice

Ring in several slices

By T.Hellebust
Library plans
Library plans
Library plans
~3% dose deviation per mm

20 mm

~ 5-6 mm

Point A
Stability of DVH

Uncertainty of cranio-caudal applicator positioning
Mean DVH shifts (%)
Direct Reconstruction Applicator on MR Images

The Solution

Medical University of Vienna, Department of Radiotherapy
Exclusive MRI-based tandem and colpostats reconstruction in gynaecological brachytherapy treatment planning

Applicator reconstruction and applicator shifts in 3D MR-based PDR brachytherapy of cervical cancer.

Direct-reconstruction of the Vienna applicator on MR images

Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group: considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy.
The problem: no visible source channel

How to reconstruct the tandem ring applicator directly on MR Images?

How to identify the 1st source position of the ring?

Do we need MR markers to identify the whole source channel (path)?
The problem: no visible source channel

How to reconstruct the tandem ovoids applicator directly on MR Images?

How to identify the 1st source position of the ring?

Do we need MR markers to identify the whole source channel (path)?
The problem: no visible source channel

How to reconstruct the *mould* applicator directly on MR Images?

How to identify the 1\textsuperscript{st} source position of the ring?

Do we need MR markers to identify the whole source channel (path)?

MR markers in Mould provided by I. Dumas and Ch. Haie-Meder IGR-Paris
The problem: no visible source channel

How to reconstruct the tandem ring applicator directly on MR Images?
• The holes/needles can be used to determine the exact ring rotation and position

How to identify the 1st source position of the ring?
• Applicator geometry in relation to outer shape/dimension must be known

Do we need MR markers to identify the whole source channel (path)?
• Not necessarily when using the Vienna ring, it helps to provide additional information during the reconstruction process

MR markers (Nucletron) Phantom scan at open MR 0.2T
A. De Leeuw et al. *Tandem- Ovoids applicator reconstruction on MRI*

**Radiographs**

**Auto-Radiography**

**Template for Reconstruction**

**Ovoids:**
- Tip-1$^\text{st}$ dwell position 6 mm
- 1$^\text{st}$ dwell position intersection 19 mm
- Angle 120°

**Intrauterine Tandem:**
- Tip-1$^\text{st}$ dwell position 7 mm

**MR Imaging**

**Template in place**

**Reconstruction of source path**
What do you see on MR images when using the tandem ring applicator?
What do you see on MR images when using the Vienna ring applicator?
If the relation between applicator shape and the source path is defined once, the reconstruction process can be performed by directly placing the applicator in the MRI dataset.
Geometry and dimensions of the applicator

<table>
<thead>
<tr>
<th>Ring Diameter</th>
<th>nominal</th>
<th>outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>47</td>
<td></td>
</tr>
</tbody>
</table>

Nominal Tandem Length – 2mm

Level of ring center plane

Nominal Tandem Length – 2mm

7.5mm
QA is needed to verify the reconstruction
- Acceptance tests and commissioning of TPS and applicators -

Source to tip distance
example:
- 26 mm ring: 6.8 mm (~28°)
- 30 mm ring: 7.7 mm (~34°)
- 34 mm ring: 7.5 mm (~35°)
Applicator surface
Applicator + Source path
Reconstruction
Reconstruction

Better accuracy
less time to reconstruct
Know the tool you are using!

Interstitial Applicator

**Material**

- Plastic
  - flexible
- Titanium
  - rigid
- Steel
  - rigid

**field strength**

- (0.2T, 1.5T, 3T)

**Ultrasound**

- Plastic needles
- Titanium needles

**Different materials scanned in 0.2 T open MRI**

**different materials in 3T MRI**
Interstitial Applicator

Know the tool you are using!

- **Material**
  - Plastic (flexible)
  - Titanium (rigid)
  - Steel (rigid)

- **Tip-end**
  - Tumour border
  - Avoidance structure
  - Needle insertion depth

- **Field strength**
  - CT: 0.2T, 1.5T, 3T
  - MRI: 0.2T, 1.5T, 3T
  - US: 0.2T, 1.5T, 3T
• end
Applicator Reconstruction
Registration/Fusion or Direct Reconstruction

- X-ray
- CT
- MRI (T1)
- special MRI
- MRI (T2)

Minimized or No Registration Error when using “direct” MRI (T2) applicator reconstruction

Working Package II of the European 3D GYN Network: 7 centers – 7 different methods
www.embracestudy.dk
Image registration between MRIs (using DICOM coordinates)
VIENNA II

Applicator design for distal parametrial disease in cervical cancer

D. Berger et al. 2010 Brachytherapy