Basic Concepts in Image Based Brachytherapy
(GEC-ESTRO Target Concept & Contouring)

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GYN GEC – ESTRO NETWORK MEMBER AND FACULTY

ACKNOWLEDGEMENTS: GYN GEC – ESTRO Teaching Faculty, ESTRO & IAEA Teaching Material
Two Dimensional (2D) Brachytherapy Planning in Cancer Cervix

- Orthogonal X-ray Based
- Target: Point A Prescription
- OAR’s: ICRU Rectal & Bladder point based (ICRU 38)

Local control rates
2D + CRT : additional 5 - 10%

Morbidity rates after radiotherapy (EBRT + BT)

<table>
<thead>
<tr>
<th>STAGE</th>
<th>Total no. of patients</th>
<th>G2 complications</th>
<th>G3 complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB</td>
<td>415</td>
<td>51 (12%)</td>
<td>26 (6%)</td>
</tr>
<tr>
<td>IIA</td>
<td>137</td>
<td>14 (10%)</td>
<td>23 (17%)</td>
</tr>
<tr>
<td>IIIB</td>
<td>391</td>
<td>65 (17%)</td>
<td>57 (15%)</td>
</tr>
<tr>
<td>IIIB</td>
<td>326</td>
<td>38 (12%)</td>
<td>45 (14%)</td>
</tr>
<tr>
<td>IVA</td>
<td>23</td>
<td>3 (13%)</td>
<td>2 (9%)</td>
</tr>
</tbody>
</table>

"Refinements in brachytherapy techniques are necessary to improve the present results."

Perez CA in Perez/Brady 1998
Limitations in Conventional 2D Brachytherapy Planning

- Limitations of Point A Based Dosimetry: Small & large tumors
- OAR Dose Assessment: Relative and Indirect
- Several Studies: No correlation with toxicities
- Tumor related Target Volume Assessment: Not possible
- Delineation of Target and Organs at Risk
  - Residual tumor at brachytherapy
  - Rectum, bladder, sigmoid,
  - Small intestine, vagina etc....
- Advances in Brachytherapy: Although slow
ADVANCES IN GYNAECOLOGICAL BRACHYTHERAPY

- Applicator development: *Intracavitary (IC), Interstitial (IS) & IC+IS*

- In corporation of Newer Imaging Modalities: *CT, MR, PET, etc.*

- Advances in Treatment Planning Systems

- **Image / Volume Based Brachytherapy**
RADIOTHERAPY TREATMENT SCHEDULE for MR - IGABT

Option 1.

- blue bar represents a fraction of EBRT 1.8 Gy
- black bar represents a course of cisplatin 40 mg/m²,
- orange bar represents a fraction of HDR brachytherapy 7 Gy (2 fractions within one application) X 2 applications one week apart

overall treatment time 46 days

Option 2.

overall treatment time 56 days
Imaging protocols MRI and CT

Key issues for image-guided radiotherapy

Quantitative tumor regression

EBRT: tumor regression 75%
Brachytherapy: tumor regression 10%

Prior to therapy
1. brachytherapy
2. brachytherapy
3. brachytherapy
4. brachytherapy

Absolute Vol (cm³)

Dimopoulos et al. Strahlenther Onkol 2009

Courtesy: Johannes Dimopoulos
**2D BT**
- SS, IC, Fletcher
- Orthogonal, X-rays
- Markers: Foley, Rectum
- X-ray markers
  - Point A, ICRU points, 60Gy Vol
  - Std loading, manual optim
  - Dose to point A, OAR points

**3D BT**
- CT/MR compatible Applicators
- CT / MR Contrast, Bladder protocol
- Target / OARs
- Applicator commissioning
  - Point A, ICRU points
  - STD loading Manual, GrO, IP
- GEC ESTRO DVH parameters

**Work flow**

**Brachy procedure**
**Applicators**
**Imaging**
**Contouring**
- Definition of dose points
  - Planning
  - Plan evaluation
- Dose delivery
Dose of EBRT

Gy

III B

w = 9.0 cm
h = 6.0 cm
t = 5.0 cm

Vagina: 5 cm

Note: vagina and parametria not included in h

dd/mm/yy

Signature

At Diagnosis  X

At Brachytherapy

Dose of EBRT Gy
At Brachytherapy

Dose of EBRT  50.4 Gy

Note: parametria not included in h.

Signature
GEC-ESTRO Volume Concept (Rad. Oncol. 2005)

• 2000: GYN GEC-ESTRO Working Group formulated

• 2001 /2: Initial Protocol Development

• Within GEC-ESTRO, 3 teams coming from different traditions:
  - Paris: mould / LDR / PDR / Reference volume (60 Gy)
  - Leuven: ovoid / mould PDR / point A
  - Vienna: ring / HDR / point A

• 2003/4: Protocol Development: 2 workshops / training

Principles for MRI based Cervix BT

Delineation of GTV, CTV and OAR in relation to the applicator

- MRI compatible applicators
- Specific investigation protocols
  - Quality of images
- Image acquisition: orientation
- Accuracy of Images (QA)
- Planning details: DVH parameters (CTV / OAR‘s)
Pre-Workshop : 2002/3

Fig. 1. Examples of delineation variations for GTV (left), HD CTV (middle) and ID CTV (right) from three different experts from GYN GEC-ESTRO GTV and CTV delineation workshop I (7/2003): FIGO stage IIIB patient with involvement of right pelvic wall and left distal parametrium; partial remission after radio-chemotherapy with high signal intensity mass in cervix and pathologic residual mass in right proximal parametrium at brachytherapy.

Post - Workshop + Consensus : 2003/4

Fig. 2. Example of delineation for GTV (left), HR CTV (middle) and IR CTV (right) based on final version of GYN GEC-ESTRO protocol 12/2003 presented at GYN GEC-ESTRO GTV and CTV delineation workshop II (12/2003) with full description of all different terms.
Gyn GEC ESTRO Recommendations
Target Concept

Bringing different traditions together

“Point A” tradition


Moving from 2D to 3D

“60 Gy reference volume” tradition

CTV according to GTV at time of BT?

CTV according to GTV at Diagnosis?
Gyn GEC ESTRO Recommendations

Bringing different traditions together

“point A - based”

CTV according to GTV at time of BT?

“ref. V - based”

CTV according to GTV at Diagnosis?

Historical difficulties in communicating results

We need a common language!
GYN GEC ESTRO Recommendations: 4 papers

Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy—3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology

Richard Pötter1,*, Christine Haie-Meder1, Erik Van Limbergen1, Isabelle Barillot1, Marisol De Brabandere1, Johannes Dimopoulos1, Isabelle Dumas1, Beth Erickson1, Stefan Lang1, An Nulens1, Peter Petrow1, Jason Rownd1, Christian Kirisits2

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.


Department of Medical Physics, Division of Cancer and Surgery, Oslo University Hospital, Norway. Taran.Paulsen.Hellebust@ousp.no
GEC ESTRO RECOMMENDATIONS – I & II

- **GTV:** macroscopic tumour extension at time of brachytherapy...

  *High signal intensity mass(es)* (FSE, T2) in cervix/corpus, parametria, vagina, bladder and rectum

- **HR-CTV:**
  includes *gtv, whole cervix,* and *presumed extracervical tumour extension.* Pathologic residual tissue(s) as defined by palpable indurations and/or *grey zones* in parametria, uterine corpus, vagina or rectum and bladder are included in HR-CTV. **No safety margin are added.**

- **IR-CTV:**
  encompasses the **HR-CTV** different **safety margins** are added according to the treatment strategy, tumour size and tumour regression. *In any case a minimal safety margin of 5 to 15 mm have to be added.*

D90, D98, V100 for GTV, HR-CTV, IR-CTV
D0.1cc, D1cc, D2cc for OAR’s : RECTUM, SIGMOID, BLADDER, SBR,…….

Radiother & Oncol. 2005; 2006;
Target Volume Concepts

Target definition

2 CTVs

A first target related to the extent of GTV at time of BT: taking into account tumour extent at diagnosis with a high dose prescribed to this target (80-90 Gy)

*High risk CTV*

A second target related to the extent of GTV at diagnosis: with an intermediate dose prescribed to this target (60 Gy)

*Intermediate risk CTV*
GTV and Three CTVs
according to cancer cell density & risk of recurrence

Different dose levels required to sterilize the GTV & three CTVs

Haie-Meder et al. Radiother Oncol 2005
Target volume concepts

HR CTV:

- GTV at the time of BT
- CTV defined for brachytherapy if major response:
  - limited to cervix and adjacent structures with presumed residual disease (~30-60 cc)
- Intent: 80 to 90+ Gy total dose to CTV in definitive radiotherapy in advanced disease
- Dose comparable with dose to point A
Target volume concepts

High Risk CTV:

GTV at time of brachytherapy

In all cases includes:

- Whole cervix
- Presumed tumour extension
  - Clinical assessment
  - Residual grey zones on MRI

NO SAFETY MARGINS

AIM: DOSE HIGH ENOUGH TO STERILIZE MACROSCOPIC TUMOUR
Target volume concepts

IR CTV:

- Integrates GTV at the time of diagnosis
- Always includes HR-CTV
- In case of major response:
  - Includes safety margins with regard to GTV initial size
- Intent: 60 + Gy total dose to CTV in definitive radiotherapy in advanced disease
- Dose comparable with dose to the 60Gy isodose (ICRU 38 recommendations)
Target volume concepts

Intermediate Risk CTV:

GTV at time of diagnosis

In all cases includes:

- HR-CTV
- Integrates initial CTV

SAFETY MARGINS:
1-1.5 cm cranially
0.5cm antero-posteriorly
1cm laterally

AIM: TO STERILIZE MICROSCOPIC TUMOUR
Delineation of BT target volumes

Practical requirements for contouring

Treatment schedule example (Institute of Oncology Ljubljana example; Treatment schedules vary across institutions!!!)

Clinical findings at DG
MRI at DG
Clinical findings at BT
Application technique
3D imaging at BT

EBRT

Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7

Cisplatin Cht

BT
Definition of BT target volumes

GTV

Macroscopic cancer cell density

Significant microscopic

Potential microscopic

Pelvic regions

Pelvic wall

Cervix

Different dose levels required to sterilize the three CTVs

Haie-Meder et al. Radiother Oncol 2005

Pelvic wall
Definition of BT target volumes

**Limited Disease**

Gross Tumor Volume = $\text{GTV}_{BT1}$, $\text{GTV}_{BT2}$...

Clinical Findings at BT:

Macroscopic - palpable and visible residual tumor

MRI Findings at BT:

Residual high signal intensity mass

Initial tumour extension (clinical, MRI) taken into account!
Definition of BT target volumes

**Limited Disease**: $\text{GTV}_{BT,1,2,...}$

**Initial MRI findings**

**MRI findings at BT**

- No grey zones and palpable indurations at BT
- $\text{GTV}_{BT} = \text{Gross residual disease after EBRT}$
Definition of BT target volumes

**Advanced Disease**

**Gross Tumor Volume = GTV_{BT1,2...}**

Initial MRI findings

MRI findings at BT

Grey zones and palpable inductions in parametria and uterus at BT

$$HR \ CTV = GTV_{BT} + cervix + grey \ zones$$
Definition of BT target volumes

HR CTV

Macroscopic cancer cell density

Potential microscopic

Significant microscopic

Cancer cell density

Pelvic regions

Different dose levels required to sterilize the three CTVs

GTV (visible/palpable tumor)

Pelvic wall

Cervix

LR CTV

IR CTV

Haie-Meder et al. Radiother Oncol 2005
Definition of BT target volumes

High Risk Clinical Target Volume = HR CTV_{BT1,2}...

HR-CTV Includes:

- $\text{GTV}_{BT}$
- Whole cervix
- Presumed extracervical tumour extension at BT:
  - Clinically palpable indurations
  - MRI: residual “grey zones”

Clinical Findings at BT:

- [Diagrams showing clinical findings]

MRI Findings at BT:

- [MRI image showing HR-CTV and GTV]

Initial tumour extension (clinical, MRI) taken into account!
Definition of BT target volumes

**Limited Disease**

High Risk Clinical Target Volume = $HR\ CTV_{BT1,2...}$

Initial MRI findings

EBRT + ChT

MRI findings at BT

No grey zones and palpable indurations at BT

$HR\ CTV = GTV_{BT} + cervix$
Definition of BT target volumes

**Advanced Disease**

High Risk Clinical Target Volume = HR CTV_{BT1,2...}

Initial MRI findings

MRI findings at BT

Grey zones and palpable indurations in parametria and uterus at BT

HR CTV

= \( GTV_{BT} + \text{cervix} + \text{grey zones} \)
Definition of BT target volumes

IR CTV

Macroscopic cancer cell density

Potential microscopic

Significant microscopic

Cancer cell density

Pelvic regions

Pelvic wall

Cervix

GTV

Visible/palpable tumor

Different dose levels required to sterilize the three CTVs

Haie-Meder et al. Radiother Oncol 2005
Definition of BT target volumes

Intermediate Risk Clinical Target Volume = IR CTV_{BT1,2...}

**IR-CTV Includes:** HR-CTV + presumed adjacent significant microscopic disease → Safety margin

Confined by anatomical borders: bladder, rectum, pelvic wall
In case of invasion of bladder/rectum at DG, wall included, no lumen

**Limited disease** (BT alone or preop.):
- HR-CTV + margin 5-15 mm

**Extensive disease** (EBRT + BT):
- Initial macroscopic tumor (GTV_Dg)
- Margins depend on:
  - Extent at diagnosis
  - Regression after EBRT

Initial tumour extension (clinical, MRI) taken into account!
IR-CTV depends on initial tumor extent and degree of remission

Haie-Meder et al. Radiother Oncol 2005
Definition of BT target volumes

**Limited Disease**

Intermediate Risk Clinical Target Volume = IR CTV_{BT1,2...}

**Initial MRI findings**

**EBRT + ChT**

**MRI findings at BT**

- **1 cm around HR CTV**
- **Confined by anatomical borders**

**Good remission**

- **IR CTV ≈ initial tumor extent**
**Definition of BT target volumes**

**Advanced Disease**

Intermediate Risk Clinical Target Volume = IR CTV_{BT1,2...}

**Initial MRI findings**

**MRI findings at BT**

Poor remission

IR CTV > initial tumor extent

Confined by anatomical borders

1 cm around HR CTV
Original article

Uncertainties of target volume delineation in MRI guided adaptive brachytherapy of cervix cancer: A multi-institutional study

Primož Petrič, Robert Hudej, Peter Rogelj, Mateja Blas, Kari Tanderup, Elena Fidarova, Christian Kirisits, Daniel Berger, Johannes Carl Athanasios Dimopoulos, Richard Pötter, Taran Paulsen Hellebust

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SciVerse ScienceDirect

Radiotherapy and Oncology
journal homepage: www.thegreenjournal.com

Radiotherapy & Oncology 2013, April issue: UNCERTAINTIES in gynae IGABT
Which organs at risk?

OTHER?

- Rectum
- Bladder
- Sigmoid c.
- Small bowel
- Vagina
- Anus
- Urethra
Can we contour *organs* instead of *organ walls*?

Yes, if doses to 2 cm$^3$ are evaluated.

DVH – dose volume histogram
DWH – dose wall histogram

Wachter-Gerstner N. Radiother Oncol 2003;68:269-276  
Olszewska AM. Radiother Oncol 2001
2D BT

- SS, IC, Fletcher
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- Markers: Foley, Rectum
- X-ray markers
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3D BT

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