PLAN EVALUATION & REPORTING

Dr Umesh Mahantshetty,
Professor, Radiation Oncology
GYN & Urology Disease Management Group (DMG) Member
Tata Memorial Hospital,
Mumbai, India

GYN GEC – ESTRO NETWORK MEMBER AND FACULTY

ACKNOWLEDGEMENTS: GYN GEC – ESTRO Teaching Faculty, ESTRO & IAEA Teaching Material
Challenges (combining EXRT + BT)

USE EQD2 formula to combine and report (treatment) dose parameters
1. EBRT + Chemotherapy + BRT

**EBRT Technique:** 3D, CT based CRT; box technique  
**TD:** 45 - 50 Gy / 25#  
**Dose per fraction:** 1.8 Gy  
**Boost:** no  
**Concomitant CT:** Cisplatin 40 mg/m2 weekly, 5 cycles  
**Brachytherapy:** 7 Gy x 4# HDR : Point A / HR-CTV

CTVs for Brachytherapy receives the prescribed dose of EBRT

80-90% of the Rectum receives 90% of the prescribed dose

<80% of the Bladder receives 90% of the prescribed dose

The high and medium dose regions of brachytherapy in OAR rectum, sigmoid, bladder, vagina receive the prescribed dose of EBRT
Major issues for dose volume assessment
Integrating EBRT and Brachytherapy (II)

- Physical doses of EBT and Brachytherapy may be added at the CTV for BT and/or specific points (A) : 45+4x7

- Physical doses of EBT and Brachytherapy may be added at high dose regions in OAR and/or specific points (ICRU) : 45+4x4

- Biologically weighted doses must be generated and added in case of dose per fraction different from 2 Gy/fraction or dose rate different from 50 cGy/hour
Radiobiological Considerations

Linear - Quadratic model for incomplete monoexponential sublethal (DNA) damage repair

- **Biologically Effective Dose:**

  \[
  \text{BED} = nd \left[ 1 + g \frac{d}{(\alpha/\beta)} \right]
  \]

  tissue dependent

- **BED** ... *virtual dose value* that produces the same biological effect as the physical dose with an infinite low dose rate

  - \(n\) ... number of equal fractions
  - \(d\) ... dose per fraction

  **parameters:**

  - \(\alpha/\beta\) ... parameter describing lethal / sublethal lesions
  - \(g\) ... repair function depending on - half time for cell repair \(T_{1/2}\)
  - fractionation
**Mathematical Description /Normalization - EQD2**

- LQ model gives biological equivalence for
  1. classical LDR brachytherapy (50 cGy/h) and
  2. conventional external beam therapy (2 Gy / fraction) with $T_{1/2} = 1.5$ hours (clinical experience, ICRU 38)

- Calculated BED values are normalized to conventional EBRT with 2 Gy / fraction (reference schedule):

\[
\text{BED} = D\text{IsoE} \left[ 1 + \frac{2}{(\alpha/\beta)} \right]
\]

\[
D\text{IsoE} = \frac{\text{BED}}{\left[ 1 + \frac{2}{(\alpha/\beta)} \right]} = \text{EQD}_2
\]

**“isoeffective dose” = “equivalent dose in 2 Gy fractions”**

- To calculate the total isoeffective dose $D\text{IsoE}$ of a combined treatment, all isoeffective doses $D\text{IsoE}$ are added up:

\[
D\text{IsoE,TOTAL} = D\text{IsoE,EXTERNAL} + D\text{IsoE,BRACHY}
\]

\[
D\text{IsoE} = \frac{nd \cdot (1 + \frac{d}{(\alpha/\beta)})}{1 + \frac{2}{(\alpha/\beta)}}
\]
Cumulative Dose Volume Histograms for GTV, HR CTV, IR CTV

for 45 Gy EBT (1.8 Gy/f) and 4x7 Gy HDR BT in HR CTV*

*D90
D98
D100
D50
Vol [%]

Dose per fraction [Gy]

GTV
HR CTV
IR CTV

Total dose $\alpha/\beta=10$ Gy

59 Gy
69 Gy
82 Gy
70 Gy
87 Gy
125 Gy
132 Gy

*GYN GEC ESTRO Recommendations (II) Radioth. Oncol. 2006 (modified)
Challenges (combining EXRT + BT)

- Dose gradient
ICRU 38

- Point A
- TRAK
- Reference Volume (h, w, t)
- Pelvic wall point
- Lymphatic trapezoid

OAR

- Bladder point
- Rectal point

Target

- Point A
- TRAK

GEC ESTRO

- HR CTV D98, D90, D50
- IR CTV D98, D90
- GTV D98, D90
- Lymph node D98, D50

- D0.1cc, D2cc of Rectum, bladder, sigmoid, Bowel
- Vaginal points

HDR/PDR/LDR
- Dose
- Fraction size
- # of fractions
- Time interval between fractions
- Total Rx time
- RAKR
- Dose calculation algorithm

International Commission of Units and Measures report 38, Bethesda, MD, 1985

Point A

• Related to dose to the target.
• Robust – not dependent on contouring, fractionation schedules, dose rate etc
• The total dose at point A delivered through EXRT and BT can be calculated using the EQD2 concept
• Recommended by GEC ESTRO.
Target Dose: 2D and 3D

Correlating tumour effect(s) with doses: correlate effects with doses to volumes, instead of points

TUMOR EFFECT: Tumour regression

D to point A = planning aim Dose

90% of CTV

D90: Dose to 90% of CTV

100% of CTV

D98: Dose to 98% of CTV

Prescribed dose

These correlations enabled by 3D imaging

Dose to organs at risk 2D→3D→4D

Correlating tissue effect(s) with doses
More appropriate to correlate tissue effects with doses to tissue volumes (at different times-4D), rather than points...

Proctoscopy findings

Most exposed V of OAR

Minimum dose to this V

D, V of clinical relevance?

0.1 cm$^3$  D0.1cc
1 cm$^3$    D1cc
2 cm$^3$    D2cc
5 cm$^3$    D5cc

TISSUE EFFECT: damage to OAR

OAR Point (i.e. ICRU-R)

Dose to OAR Point

Dose reporting in 3D BT

HR CTV $D_{90}, D_{98}$

- Minimum dose delivered to 98% and 90% of the most exposed part of the target volume

<table>
<thead>
<tr>
<th>$D_{90}$</th>
<th>$D_{98}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Stable with respect to contouring uncertainties</td>
<td>- Sensitive to contouring uncertainties</td>
</tr>
<tr>
<td>- May look favorable even though a small portion of the target receives less dose.</td>
<td>- More robust indication for near minimum dose, where 2% target volume is outside the isodose line</td>
</tr>
</tbody>
</table>

Potter et al, Radiother Oncol. 2006 :67-77
Dose volume histogram - Target

- GTV
- HR CTV
- IR CTV
- OARs

Minimum (prescription) dose region

High dose region

Very High dose region
HR CTV D90 & D98
HR CTV D90 – 7.1 Gy

10% of HR CTV is not covered by prescription isodose line
HR CTV D50 – High dose region

Dose gradient: 5 to 25% per mm

- Very high dose rate
- Large fraction size
- Biological dose??
GTV & IR CTV – D98, D90
ICRU 38 rectum and bladder points
Correlation of ICRU reference point and $D_{2cc}$

- **Rectum:** ICRU rectal reference point correlates with the $D_{2cc}$ dose of the organ rectum.

- **Bladder:** ICRU bladder reference point, does not correlate well with bladder complications (ICRU 38 bladder point underestimates the bladder dose).

Barillot et al, Perez et al, George P et al, Koom Wset et al.
Upper rectal and sigmoid points on 2D radiographs

- 27 Patients treated with CT image based dosimetry
- Upper rectal and sigmoid points were marked on CT images
- Searched for a reproducible point with respect to applicator and other points
- No point was found that was reproducible that can act as a surrogate for upper rectal and sigmoid

Mahantshetty et al, J Cancer Res Ther. 2011 :298-303
Dose volume histogram - OAR

- Intermediate dose region
- High dose region ($D_{2cc}$, $D_{0.1cc}$)
3D-based Dose Volume Parameters for OAR

**FIXED VOLUME:** tolerance dose (total dose) - “minimum dose to the most exposed tissue”*

- 1cc/2cc: teleangiectasia (20 mm x 20 mm x 5 mm)
- 0.1 cc: 3D “maximum dose”: ulceration (fistula)

Slide Courtesy: Prof: R Potter, MUW, Vienna
Bladder

\[ D_{2\text{cc}} \quad D_{1\text{cc}} \quad D_{0.1\text{cc}} \]

\( w \times h: \)

40mm x 20mm  20mm x 10mm

Slide Courtesy: Prof: R Pötter, MUW, Vienna
Rectum

$D_{2\text{cc}}$

$D_{1\text{cc}}$

$D_{0.1\text{cc}}$

Slide Courtesy: Prof: R Pötter, MUW, Vienna
Sigmoid

$D_{2cc}$

$D_{1cc}$

$D_{0.1cc}$

w x h: 25mm x 20mm

10mm x 10mm

Slide Courtesy: Prof: R Pötter, MUW, Vienna
Limitations of fixed parameters of DVH

Rectum DVH (EQD2)

EBRT: 3D CRT 45 Gy       45 + 15 Gy Boost to Tumour region
BT:   2 x 17.5 Gy BT       2 x 12 Gy
Limitations of adding doses according to „ICRU point-3D model“ both for CTV and OAR

• Non-homogenous dose distribution EBRT e.g. IMRT, VMAT...
• Parametrial boost
• Lymph node boost
• Limitations of the linear-quadratic model
• Future solution for complex adding doses....
Intermediate and larger volumes

- Global organ side effects,
  - stricture,
  - stenosis,
  - functional impairments
    - continence,
    - urgency

Dose tolerance: 45 – 65 Gy more
ACKNOWLEDGMENTS

• Tata Memorial Centre
• GYN GEC-ESTRO Faculty & Teaching Material
• IAEA Teaching Material
• Patients
Case Capsule