Basic Principles of ICA

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Basic Principles of ICA

• The basic principles of brachytherapy have not changed much during the past 100 years of radiotherapy

• Recent advances has made brachytherapy
  – Much more efficient for the patient
  – Much safer for the staff from radiation protection point of view
Basic Principles of ICA

• **Brachytherapy Definitions**
  – Interstitial Brachytherapy –
    • sources are implanted in the tumor
  
  – Contact Brachytherapy – Plesiobrachytherapy
    • Sources are close to the tumor

• **Intracavitary**
• **Intraluminal**
• **Endovascular**
• **Surface brachytherapy**
Basic Principles of ICA

• In intracavitary application, radioactive sources are placed in the uterine cavity and vagina, usually inside a predefined applicator with special geometry.

• It is the oldest form of “conformal treatment” without heavy technological involvement & cost
Radiotherapy for Carcinoma Cervix

• Of vital importance to the development of brachytherapy was the establishment of the early specialist radiation centres
  
  – 1908 : Radiumforschung in Vienna
  – 1910 : Radiumhemmet in Stockholm
  – 1912 : Curie Foundation in Paris
  – 1930’s : Holt Radium Inst. In Manchester
  – 1950’s : Fletcher System
Radiotherapy for Carcinoma Cervix

- **Stockholm Technique**
  - Based on clinical experience
  - 2 to 3 applications of 20 hrs given over total time of 3 weeks
  - Intra-vaginal boxes - silver or gold
  - Intrauterine tube - flexible rubber
  - Total prescribed dose 6500-7100 mgh Ra
  - Dose rate-110R/hr or 2500mg/hr/
Radiotherapy for Carcinoma Cervix

Paris System

Radiobiological work of Regaud
Single application of radium for 120 hours.
Semiflexible silk intrauterine tube
Vaginal colpostst – cork cylinders joined by a spring
Dose of 5500 mgh Ra over a period of five days
Dose rate of 45R/h.
Manchester System

Based on Paris technique.

Designed a set of applicators and their loading which would give the same dose rate irrespective of the combination of applicators used.

- It replaced vaginal colpostats with vaginal ovoids separated by spacer or washer.
Radiotherapy for Carcinoma Cervix

Manchester System

Standard dose rate at point A = 53 cGy/h

Two applications of 72 hours each are given with 7-10 days period between two applications.

Dose of 8000 R is delivered at point A

Present day brachytherapy practice is based on Manchester System
Basic Principles of ICA

• The uterine cervix is ideally suited for Intracavitary application because

1. The endocervical canal and vaginal vault form a suitable vehicle to carry radioactive sources

2. The normal cervical tissues and vaginal vault epithelium are relatively radioresistant and tolerate high doses of irradiation

3. The intensity of irradiation rapidly falls off with distance from the intracavitary sources. This restricts the amount of irradiation received by normal tissues beyond the cervix region.
Basic Principles of ICA

Advantages:

1. High dose in short time.
   - Cervix: 20,000-25,000 cGys.
   - Uterus: 20,000-30,000 cGys.
   - Vagina: 10,000 – cGys.

2. Control rate higher.
3. Sharp fall of dose, less normal tissue damage.
4. Less late radiation morbidity.
5. Preservation of normal anatomy.
Basic Principles of ICA

• Effect of ICBT on survival

<table>
<thead>
<tr>
<th>Treatment</th>
<th>%age Survival at 5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ext. RT alone</td>
<td>36%</td>
</tr>
<tr>
<td>2. Ext. RT + ICBT</td>
<td>67%</td>
</tr>
<tr>
<td>3. Single ICBT</td>
<td>60%</td>
</tr>
<tr>
<td>4. 2 or more ICBT</td>
<td>73%</td>
</tr>
</tbody>
</table>

• In the management of carcinoma cervix intracavitary application plays a sheet anchor role and is responsible for most of the cures.
Basic Principles of ICA

• Radiotherapy treatment

• Proportion of Ext RT increases with tumour bulk and stage.
• Except for small tumours, Ext RT precedes ICRT.

• All treatment should be completed in 50 days

• Para-central dose should be 80-90 Gy.
• Pelvic sidewall dose should be 45-60 Gy.
Applicators
Radiotherapy for Carcinoma Cervix

Loose pre-laoded Manchester System

Loose system and therefore, chances of slipping of ovoids and hence disturbed geometry and creation of cold and hot spots leading to high failure or increased morbidity.
Radiotherapy for Carcinoma Cervix

Loose pre-loader-Manchester  Fixed  PGI pre-loader

Radiation hazard: being a preloaded system.
Radiotherapy for Carcinoma Cervix

After loaders
Radiotherapy for Carcinoma Cervix

Drawback:

Unilateral tumor extension exceeding:

- 3.5 cm at the level of the ring
- 2.5 cm at the level of point A
- 2.2 cm at a distance 3-4 cm cranial to the ring surface

Tumor extension cannot be covered by the symmetrical dose distribution of the tandem alone without exceeding dose limits for OAR

CT/MR Compatible Ring & Tandem Applicator
Clinical situations requiring a combined intracavitary/interstitial technique
Intracavitary + interstitial
Brachytherapy, if D90 < 85 Gy
Basic Principles of ICA

- **Applicators**
- All applications must be done under sedation

Standardised

Personalised
Basic Principles of ICA

• **Tandem Loading**

• To optimize the lateral dose to parametrium, the tandem should be as long as anatomy permits but not more than 6 cm.

• As the tandem size increases, the penetration or "lateral throw-off" of the dose distribution increases.

• Increase in tandem length increases the point “B” contribution relative to the uterine cavity surface dose.
Basic Principles of ICA

- **Ovoid Loading**
  - The largest ovoids that permits adequate separation to admit the flange on the tandem between them without causing downward displacement of the ovoids should be used.

- In order to optimize the ratio between the dose at depth and the vaginal mucosal dose.

- As colpostat diameter increases from 2cm to 3cm the vaginal surface dose decreases by 35% relative to the point “A” dose.
Basic Principles of ICA

Lateral View of Applicator Placement

- Tandem - 1/3 of the way between S1 – S2 and the symphysis pubis
- The tandem - midway between the bladder and S1 - S2
- Marker seeds should be placed in the cervix
- Ovoids should be against the cervix (marker seeds)
- Tandem should bisect the ovoids
- The bladder and rectum should be packed away from the implant
Basic Principles of ICA

Anterior – Posterior View of Applicator Placement

- The ovoids should fill the vaginal fornices, add caps to increase the size of the ovoids if necessary.
- The ovoids should be separated by 0.5 – 1.0 cm, admitting the flange on the tandem.
- The axis of the tandem should be central between the ovoids.
Basic Principles of ICA

- Conditions to be met for successful ICBT

  - An adequate dose has to be delivered to the para-cervical areas.
  - Geometry of the radioactive sources must prevent under dosed regions on and around the cervix.
  - Mucosal tolerance has to be respected.
  - Optimal placement “Pear-Shaped” distribution delivering a high dose to the cervix and para-cervical tissues and a reduced dose to rectum and bladder “Banana-Shaped”
Basic Principles of ICA

• **Mucosal Tolerance**

• **Local dose to cervix should be** $2^{1/2} - 3$ times the paracervical dose

• **Surface dose to vaginal mucosa should be** $<150$ Gy to proximal & $<90$ Gy to distal vagina

• **Rectal dose should be** $<75$ Gy

• **Bladder dose should be** $<80$ Gy
Basic Principles of ICA

- **Manchester System**
  - Developed by Todd & Meredith in 1930
  - Defined the treatment in terms of dose to a point.
  - Defined two points – A & B
  - Abandoned previous dosage system of mg./hrs. in favour of roentgen unit.
  - Designed a set of applicators and their loading which would give the same dose rate irrespective of the combination of applicators used
Basic Principles of ICA

• Loading of applicators

• In order that point A receives same dose rate, no matter which ovoid combination is used, it is necessary to have different radium loadings for each applicator size

• Dose rate 57.5 R/hr to point A

• Not more than 1/3 dose to point A must be delivered from vaginal radium
## Basic Principles of ICA

### Manchester Loading

**Table 4.12** Dose rates at point A for standard Manchester loadings

<table>
<thead>
<tr>
<th>Applicator</th>
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<th>Configuration</th>
<th>Dose rate at point A (cGy h⁻¹)</th>
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<tbody>
<tr>
<td>6-cm uterine tube</td>
<td>6, 4, 4 units</td>
<td></td>
<td>34.4</td>
</tr>
<tr>
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<td>6, 4 units</td>
<td></td>
<td>34.2</td>
</tr>
<tr>
<td>2-cm uterine tube</td>
<td>8 units</td>
<td></td>
<td>27.3</td>
</tr>
<tr>
<td>Large ovoids</td>
<td>9 units</td>
<td>1-cm spacer</td>
<td>18.3</td>
</tr>
<tr>
<td>Medium ovoids</td>
<td>8 units</td>
<td>1-cm spacer</td>
<td>18.8</td>
</tr>
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<td>7 units</td>
<td>1-cm spacer</td>
<td>18.9</td>
</tr>
<tr>
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<td>In tandem</td>
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</tr>
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The unit of source activity is 18 μGy h⁻¹ (2.5 mg radium equivalent).
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The unit of source activity is 18 μGy h⁻¹ (2.5 mg radium equivalent).
Basic Principles of ICA

- Rectal dose is mainly affected by vaginal source weightings.
- To lower the rectal doses the dwell times for the vaginal sources must be decreased.
- Width of the reference volume will also decrease.
- Hence attention must be paid to the inclusion of the tumor volume into the reference volume.
Dose Reporting
Basic Principles of ICA

Historical Systems / Techniques

- Paris
- Manchester
- Fletcher
- Stockholm

Sets of rules:
- certain activity (mg of 226Ra)
- for a certain time (hours)
- in certain spatial relations

FOR A GIVEN TUMOUR VOLUME

Manchester system: point A introduction
Radiotherapy for Carcinoma Cervix

• Treatment prescription

• Milligram- hours (today equivalent is TRAK)
• Dose to point ‘A’ part of reporting even today
• ICRU - 60 Gy Reference Volume

• Dose to organs at risk
Basic Principles of ICA

Definition of Point A
Pt A was originally defined as 2cm superior to the vaginal fornix & 2cm lateral to the cervical canal

Later it was redefined to be 2cm superior to the external cervical os (or lower end of tandem) & 2 cm lateral to the cervical canal
Basic Principles of ICA

• In the revised definition Point A is now fixed to the tandem

• Since the distance from the caudal most intrauterine source tip to the colpostat centre (tandem to colpostat displacement) varies from patient to patient the vaginal contribution to revised Pt A is highly variable

• Hence dose delivered to the tumor will be incorrect
Point A:

- Current practice is to prescribe dose to Point A
- Empiric point, does not reflect dose to tumor
- Reference is with applicator

It is located where dose gradient is high i.e. about 10% per mm.
Target Dose: 2D

- Inter & intra institutional inconsistencies in definition

Small inaccuracies in determination of distance

large difference in reported dose
Target Dose: 2D

Reference volume

ICRU 38 recommended:
“...description of volume encompassed by reference isodose when reporting intracavitary BT...”

“...60 Gy accepted as reference level for LDR brachytherapy (equivalent dose in HDR, PDR).”

Dose to Organs at risk: 2D

Dose to bladder and rectum: ICRU Points
Dose to Organs at risk: 2D

Dose to bladder and rectum: ICRU Points

Dose to Organs at risk: 2D

Do ICRU point-doses represent true D-max?

Looking for D-max: orthogonal radiographs

Dose to Organs at risk: 2D

Do ICRU point-doses represent true D-max?

Looking for D-max: orthogonal radiographs

It may not be sufficient to record only the dose at one specific rectal point (ICRU-R)

<table>
<thead>
<tr>
<th></th>
<th>Rectum 1</th>
<th>Rectum 2</th>
<th>Rectum 3</th>
<th>Rectum 4</th>
<th>Rectum 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-max-R</td>
<td>-0.58</td>
<td>3.49</td>
<td>-3.19</td>
<td>10.632</td>
<td></td>
</tr>
<tr>
<td>ICRU-R</td>
<td>-1.01</td>
<td>3.65</td>
<td>-2.47</td>
<td>14.115</td>
<td></td>
</tr>
<tr>
<td>D-max-B</td>
<td>-1.21</td>
<td>3.68</td>
<td>-0.69</td>
<td>23.415</td>
<td></td>
</tr>
<tr>
<td>D-max-B</td>
<td>-1.22</td>
<td>4.08</td>
<td>0.03</td>
<td>21.741</td>
<td></td>
</tr>
</tbody>
</table>

D-max-R: within 1 cm from D-ICRU-R in ≈ 90%
D-max-B: 1.5-2 cm above D-ICRU-B

Image Based Brachytherapy
Image Based Brachytherapy

Image based brachytherapy:

- Technique where advanced imaging modalities are used to gain information regarding the volumetric dose distribution.

- The primary advantage of 3D Image Based brachytherapy is the possibility to adapt and conform the dose given by BT to the anatomy of each individual patient taking into account both tumor regression and the position of OARs.
Target Dose: 2D

- **Point A:**
  - Current practice is to prescribe dose to Point A
  - **Empiric point, does not reflect dose to tumor**
  - **Reference is with applicator**
  - **It is located where dose gradient is high i.e. about 10% per mm.**
Target Dose: 2D

- Main limitation of 2D approaches:
  - Absence of visual information on spatial relations between tumour and applicator
    - Where is the target volume (GTV? CTV?)
    - Where are the organs at risk?
  - Clinical findings + Sectional imaging (MRI) help in visualising
    - Target, organs & applicator
    - Assess inter-relations
Recently

- 3D & 4D image–based brachytherapy treatment planning & dosimetry has been used for Cancer Cervix.

- Prescribed dose is always related to the target while the actual coverage can be evaluated with the use of DVH parameters

- Shape the spatial dose to conform to the target volume
  - Escalate dose to the tumor to produce greater rates of local control
  - Reduce dose to normal tissues & hence reduce the normal tissue toxicity.
Image Based Brachytherapy

- Tumor volume assessment
  - First based on Clinical Examination
  - Appropriate documentation in three dimensions
  - Sectional imaging gives information on tumor extension & configuration & its topography
Image Based Brachytherapy

TUMOUR EXTENSION AND PARAMETERS AT DIAGNOSIS

axial

sagittal

coronal
Target volume definitions

- **GTV**
  - Includes macroscopic tumor extension as detected by clinical examination (visualisation & palpation) & as visualised on MRI

- Change of GTVs during treatment –
  - At diagnosis \( \text{GTV}_D \)
  - At brachytherapy \( \text{GTV}_B \)
Target volume definitions

2 CTVs

A first target related to the extent of GTV at time of BT: taking into account tumour extent at diagnosis.

- High risk CTV
  - Major risk of recurrence because of residual macroscopic tumor
  - Intent is to deliver a total dose as high as possible to eradicate all residual macroscopic tumor
  - High dose prescribed to this target (80-90+Gy)=dose to point A
Target volume definitions

- **HR CTV includes**
  - GTV, whole of the cervix, & presumed extracervical tumor extension.
  - Pathologic residual tissue(s) as defined by palpable indurations &/or grey zones in parametria, uterine corpus, vagina, bladder or rectum are included in HR CTV
  - No safety margins are added
Target volume definitions

2 CTVs

A second target related to the extent of GTV at diagnosis:

- **Intermediate risk CTV**

  - Major risk of recurrence in areas that initially had macroscopic extent of disease with *residual microscopic disease* at time of BT

  - Intent is to deliver dose appropriate to cure microscopic disease in cervix cancer, which corresponds to a dose of 60Gy

  - It includes the HR CTV plus the initial tumor extension at diagnosis
Target volume definitions

- **IR CTV includes**
  - HR CTV plus the initial tumor extension at diagnosis
  - IR CTV encompasses the HR CTV with a safety margin of 5-15 mm margin
  - Safety margin is chosen according to the tumor site & location, & the amount of tumor regression
Target volume definitions

Haie-Meder, Radiot & Oncol, 74, 2005
Dose prescription

- The prescribed dose is always related to the target.
- The prescription dose is the planned dose to cover this target as completely as possible.
- The actual coverage can be evaluated with the use of DVH parameters.
- Coverage of the target can be improved starting from the standard dose prescription & careful adaptation of the loading pattern & dwell times.
- Finally dose can be prescribed to an image-based target.
- For comparison, dose reporting should refer to the prescribed dose to the image-based target & to the traditional system.
Image Based Brachytherapy

- **Dose volume parameters**
  - **D100 & D90** – minimum dose delivered to 100 & 90% of the volume of interest respectively
  - **D100** is extremely dependent on target delineation. Due to steep dose gradients, small spikes in the contour cause large deviations in D100
  - **D90** is less sensitive to these influences & is therefore considered a more ‘stable’ parameter

- **V(60 Gy_{EQD2})** plays a role for evaluating the **IR CTV**
- **V(85 Gy_{EQD2})** represents more closely the prescription dose to the **HR CTV**
OARs

- As there is a rapid dose fall-off near the sources, in particular in adjacent small organ (wall) volumes, dose assessment has to refer to one (or more) defined dose points in these limited volumes.

- The minimum dose in the most irradiated tissue volume adjacent to the applicator (0.1, 1, 2, 5 cm³) is recommended for recording & reporting.

- It is assumed that these volumes are contiguous.

- This is wrongly called as the ‘maximum dose’ to a 2 cm³ tissue.
Image Based Brachytherapy

Potter, Radiat & Oncol, 78, 2006
Dose volume constraints

- 2 cm³ of rectum & sigmoid < 75 Gy₃
- 2 cm³ of bladder < 90 Gy₃
- High risk CTV & D₉₀ greater than the PD V₁₀₀ > 90%
Optimisation of treatment plans

PRESCRIPTION TO POINT A

100% isodose

OPTIMIZATION FOR TARGET COVERAGE

100% isodose
Conclusions

- Image based brachytherapy is feasible in our setup.

- Patients who present with bulky disease are the ones who benefit the most and this is relevant to the Indian scenario.

- The mean D90 of the GTV\textsubscript{BT} was 120.9 Gy EQD2 – which no form of IMRT or any conformal EBRT technique can achieve.

- It is very labour intensive & needs a good team work.

- During optimisation, basic principles must be remembered & followed.
Basic Principles of ICA

Thank you