Implantation Techniques and Methods of Dose Specifications

- Brachytherapy Course – Lecture V

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Brachytherapy in treatment of cancer

- GYN
  - Cervical cancer
  - Endometrial cancer
  - Other rare tumors (vaginal cancer, etc)
- GU
  - Prostate seed implant
- Breast
  - Balloon brachytherapy to deliver RT to lumpectomy bed
- Other rare situations (endoluminal obstruction, etc.)

Importance of Brachytherapy in GYN Cancers

- Patterns of Care studies
  - Improved local control/outcomes correlate with increasing use of bachytherapy over time
  - recurrences and complications are decreased when brachytherapy is used in addition to EBRT
- ABS recommends brachytherapy must be included as a component of definitive RT for cervical carcinoma

Definitions

- Brachytherapy – placing radioactive material directly in or near the target
  - Intracavitary – placed w/i pre-existing body cavity
  - Interstitial – placed w/i interstices/spaces in an organ
- High dose rate – temporary radioactive source utilizing rate of > 0.2 Gy/min
- Low dose rate – source left in place for duration of treatment
  - usually rate of 40 – 200 cGy/hr
  - May be temporary (removed after days) or permanent

ICRU 38 and ICRU 58

- 1985: ICRU Report 38 was written regarding the Dose and volume specification as well as reporting intracavitary Brachytherapy in GYN.
- 1997: ICRU Report 58 was written to generate a guideline about the dose specification and reporting for interstitial Brachytherapy
- The aim of the report 58 was to develop a common language that was based on the presently existing concepts.

More Definitions

- Temporary Implants
  - The radioactive sources are removed from the tissue after the treatment is completed.
  - Radionuclide used have typically longer half life.
- Permanent Implants
  - The brachytherapy sources remain in the patient indefinitely, and they will not be removed.
  - Radionuclide used have typically shorter half life.

Source Delivery

- HDR remote afterloadering using Ir-192 (outpatient setting)
- PDR remote afterloadering using Ir-192 in an (inpatient setting)
- LDR manually loaded or remote afterloading using Cs-137 and/or Ir-192 (inpatient setting)

Advantages of HDR vs LDR

- Eliminates radiation exposure to caregivers/visitors
- Shorter treatment times
  - Prolonged bed rest is eliminated
  - Makes it possible to treat pts who may not tolerate long periods of isolation, and those at risk for cardiopulmonary toxicity w/ prolonged bed rest
  - Less risk of applicator movement during therapy
  - Allows greater displacement of nearby normal tissues (by packing) → potentially reduces rectal/bladder morbidity
  - Possible to treat larger # of pts in institutions that have a high volume but insufficient inpatient facilities (developing countries)

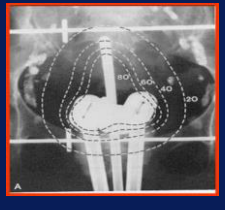
Advantages of HDR vs LDR

- Smaller diameter sources
  - Reduces need for dilatation of cervix
  - Physically easier to insert applicator
- Makes dose distribution optimization possible
  - Variation of dwell time w/ single stepping source allows infinite variation of effective source strength /positions → potentially less morbidity

Planning basics

- Planning temporary implants
  - The total time of implantation depends on
    - Number of sources
    - Strengths (activity) of each source
    - Pattern of distribution of sources
- Planning permanent implants,
  - The number of sources depends on
    - Their initial strength
    - Type of the radioisotope

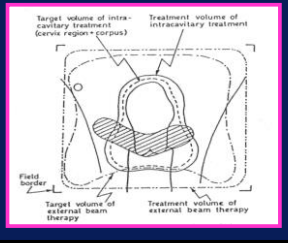
Computerized treatment planning (more to come…)



- Allows the calculation of isodose lines
- Point doses can be calculated easily
- Real-time "Volume based planning"

ICRU 38: Guidance on combination of brachytherapy and external beam doses

- Often brachytherapy is given as a boost to external beam radiotherapy
- If both are planned from CT scans the dose can also be overlaid in many treatment planning systems
- Composite dose to normal tissues must be carefully tracked



Combination of dose distributions

- Watch radiobiological differences!
- 1Gy EBT is not necessarily equal to 1Gy Brachytherapy
  - dose rate dependence
  - fraction size
  - interfraction interval

Commissioning of brachytherapy treatment planning

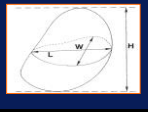
- Source entry methods (*e.g.* orthogonal films) - check geometry
- Source library
- Source strength (apparent activity?)
- Decay corrections (automatic?)
- Dose calculation - check also multiple sources

Prescription and reporting

- There are several historic systems of prescribing brachytherapy
  - Manchester system
  - Paris system
- Relevant reports of the ICRU
  - Report 38 (Gynaecological brachytherapy) - 1985
  - Report 58 (Dose and volume specification for reporting interstitial brachytherapy) - 1998

Dose prescription and reporting in interstitial brachytherapy

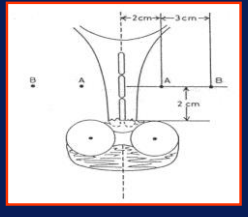
- ICRU report 58 (1995)
- Recommendations based on the so called 'Paris' system
- 3D nature of the implant considered



Prescription and reporting

- While prescription may vary slightly depending on the specific clinical situation, it is always guided by current standard of care (best practice) and current protocols (i.e., RTOG)

Importance of prescription systems



- Prior to availability of computerized dose calculation, the dose was prescribed according to systems which were linked to particular applicator design
- Clinical experience has been gained using these systems
- Modern recommendations are rooted in these systems
- *e.g.* Manchester system

Intraoperative Procedure

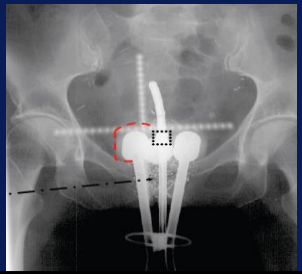
- Good applicator placement must be achieved to obtain increased local control, survival and lower morbidity
  - Consider interstitial brachytherapy for pts with disease that cannot be optimally encompassed by intracavitary appproach (vaginal narrowing, absent fornices, vaginal extension of disease)
  - Largest ovoid diameter that can be accommodated in the fornices without displacement should be inserted
- Conscious sedation/MAC
  - Pt discomfort

Optimum Placement - lateral

- Tandem – 1/3 of the way between S1/S2 and symphysis pubis
- Tandem – midway between bladder and S1/S2
  - Best achieved w/ greatest curvature tandem
- Ovoids should be against cervix
  - Use largest ovoids possible
- Tandem should bisect the ovoids
- Ant and post packing to displace bladder and rectum
  - Seeds @ 12 & 6 o'clock to verify adequate packing

Optimum Placement – AP View

- Ovoids should fill the vaginal fornices
- Ovoids should be separated by 0.5 to 1 cm, admitting the flange of the tandem
  - Flange flush against cervix
- Axis of the tandem should be CENTRAL between the ovoids

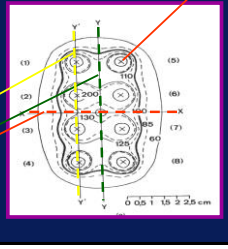


Some Basics of Dose Calculations (ICRU)

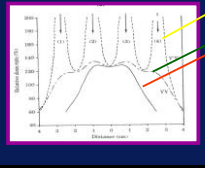
In radiotherapy practice:

- Volumes vary significantly from patient to patient
- No homogenous dose distribution

Line sources

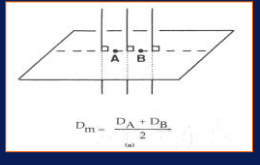


Dose profiles



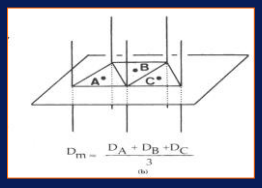
ICRU 58: Dose prescription

- Assume implant of line sources in parallel - this could also be the catheters for a stepping HDR source
- Calculate dose distribution in plane orthogonal to the source lines
- Calculate dose between lines
- Dm = Mean Central Dose



ICRU 58: Dose prescription

- The calculation points are always in the 'geometrical' center between line sources
- Prescribe to 85% of the mean of these point doses
- This works only if the differences between the dose at different points is not too large

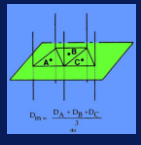


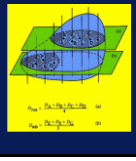
Prescription Dose

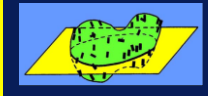
- Minimum Target Dose (MTD):
  - The minimum dose at the periphery of the CTV = Minimum dose decided upon by the clinician as adequate to treat the CTV (minimum peripheral dose).
- MTD ≅ 90% of the prescribed dose in the Manchester system for interstitial brachytherapy

Prescription Dose (cont..)

- **Mean Central Dose (MCD) : Dm**
  - The minimum dose at the periphery of the CTV = Arithmetic mean of the local minimum doses between sources, in the central planes.





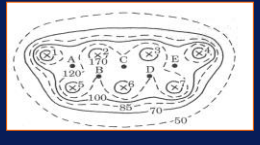


Prescription Dose (cont..)

- Dose Uniformity Parameters
  - ICRU defines the following two methods for the dose uniformity
    1. The spread of the individual minimum doses used to calculate the mean central dose in the central plane (expressed as a percentage of the mean central dose).
    2. The dose homogeneity index; defined as the ratio of minimum target dose to the mean central dose.

ICRU 58: dose prescription

- System can be extended to any number of sources



Dose Distribution in one or more planes through the implant

- The minimum information needed for the dose distribution of an implant is:
  - The isodose curves in at least one plane either in tabular form or by graphical presentation
  - The central plane of the implant should be used, if only one plane is chosen

In practice one needs to report at a minimum:

- Dose to target and possible critical structure
- Description of implant (sources, techniques)
- Dose time pattern

Levels of priority for reporting **temporary interstitial implants**

Parameters for reporting temporary interstitial implants	Priority[a]	Level[b] of computation
Description of Volume (3.A.i):		
Gross Tumor Volume	1	1
Clinical Target Volume	1	1
Treated Volume (2.6.4)	1	3
Description of Source and Technique (3.A.ii, 3.A.iii)	1	1
Radionuclide, type of sourc		
Source size and shape, source pattern		
Reference air Kerma rate		
Inactivity vector (applicator), if any		
Description of Time Pattern (3.A.iv)	1	1
Total Reference Air Kerma (3.A.v)	1	1

SOME BASICS OF APPLICATOR PLACEMENT (IMPLANTATION) for CERVICAL BRACHYTHERAPY

Intraoperative Procedure

- Good applicator placement must be achieved to obtain increased local control, survival and lower morbidity
  - Consider interstitial brachytherapy for pts with disease that cannot be optimally encompassed by intracavitary appproach (vaginal narrowing, absent fornices, vaginal extension of disease)
  - Largest ovoid diameter that can be accommodated in the fornices without displacement should be inserted
- Conscious sedation/MAC
  - Pt discomfort

Optimum Placement - lateral

- Tandem – 1/3 of the way between S1/S2 and symphysis pubis
- Tandem – midway between bladder and S1/S2
  - Best achieved w/ greatest curvature tandem
- Ovoids should be against cervix
  - Use largest ovoids possible
- Tandem should bisect the ovoids
- Ant and post packing to displace bladder and rectum
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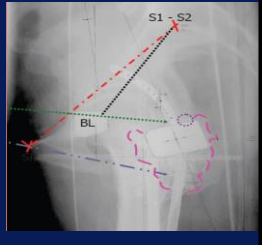

Optimum Placement – AP View

- Ovoids should fill the vaginal fornices
- Ovoids should be separated by 0.5 to 1 cm, admitting the flange of the tandem
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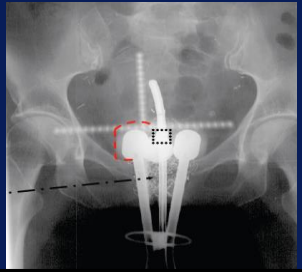
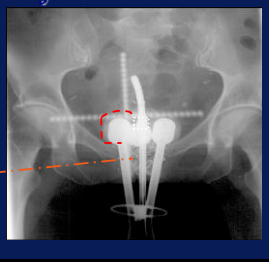


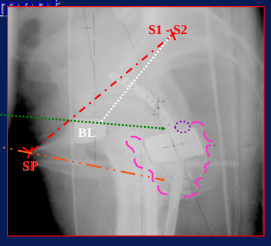
AP View of Optimized System Placement

- 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



Lateral View of Optimized System Placement

- Tandem is 1/3 of the way between S1 – S2 and the symphysis pubis.
- The tandem is mid – positioned between the bladder and sacrum.
- Marker seeds should be placed in the cervix.
- Ovoids should be against the cervix (see marker seeds).
- Tandem should bisect the ovoids.
- The bladder and rectum should be packed away from the implant.

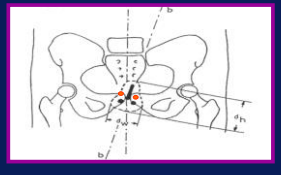


- Pt A
  - 2 cm along the intrauterine tandem from the cervical os or flange of the tandem and 2 cm laterally in the plane of the intracavitary system
- Pt B
  - 5 cm lateral from a point 2 cm vertically superior to the cervical os or flange of the central tandem along the patients' midline = 3 cm lat to pt A if in midline = parametrial dose = 30-40% of pt A dose
- Pt C
  - 4cm lat to Pt A = side wall = 20% dose to pt A
- Bladder point
  - posterior surface on lateral, center of AP film w/ foley w/ 7 cc radiopaque fluid pulled down against urethra.
- Rectal point
  - 5mm behind posterior vaginal wall between ovoids at inferior point of last intrauterine tandem source, or mid vaginal source
- Vaginal Surface
  - Lateral edge of ovoid on AP film & mid-ovoid on lat film. If no ovoids are used (tandem only), the vaginal surface point will be placed just lateral to the packing at the level of the cervical os (cervical flange marking the os or marker seeds)

Point A (ICRU 38)

- Defined as 2 cm along the intrauterine tandem in
- the superior direction from the flange, and 2 cm
- perpendicular to the tandem in the lateral
- direction.

Gynecological brachytherapy

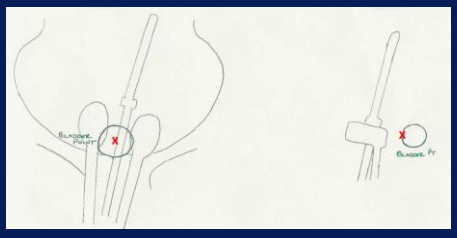


- System accounts for shift of applicator in all directions

Point B (ICRU 38)

- Defined as 2 cm along the intrauterine tandem
- in the superior direction from the flange, and 5
- cm lateral from the midline of the patient.

Diagram of Bladder Point



Prescription

- Treat Point A to at least a total LDR equivalent of
  - 80–85 Gy for early stage disease
- Pelvic sidewall dose recommendations
  - 50–55 Gy for early lesions
- LDR
  - Following 45-50 Gy EBRT + 40-60 cGy/hr to a cumulative dose of 40-45 Gy.
- HDR
  - typically prescribed in one of the following fractionation regimens - 5.5 Gy x 5; 6 Gy x 5;7 Gy x 4

Prescription

- HDR 600 x 5
  - Rectum <4.1 Gy / fraction
    - <70% of prescription dose
  - Bladder <4.6 Gy / fraction
    - <75% of prescription dose
- EBRT + LDR Brachy, total dmax for
  - Small intestine 50 Gy
  - Rectum <70 Gy
  - Bladder <75 Gy
  - Vaginal surface <120 Gy (<140% of pt A dose)
    - Upper Vaginal Mucosa-120 Gy
    - Mid Vagina 80-90 Gy
    - Lower Vagina 60-70 Gy

- Moving forward…

Clinical Target Volume Definition

- Per GYN GEC ESTRO Working Group (2005)
  - High Risk CTV (HR CTV)
    - Major risk of local recurrence due to residual macroscopic disease
    - GTV_{B1} + entire cervix
    - Deliver total dose of 80-90 Gy
  - Intermediate Risk CTV (IR CTV)
    - Correspond to initial macroscopic extent of disease, with, at most, residual microscopic disease at time of brachytherapy
    - "CTV according to GTV at diagnosis"
    - IR CTV = HR CTV + margin 0.5 to 1.5 cm

Clinical Target Volume Definition

- Low Risk CTV (LR CTV)
  - Potential microscopic spread
  - LR CTV = primary tumor CTV + regional LN CTV
  - Includes GTV, entire uterus, parametrial tissues to the pelvic sidewall, at least 2 cm of normal vagina beyond any gross tumor, minimum of 1.5 cm around the iliac vessels (surrogate for iliac LNs), any normal or enlarged pelvic LNs
  - Volume covered by EBRT

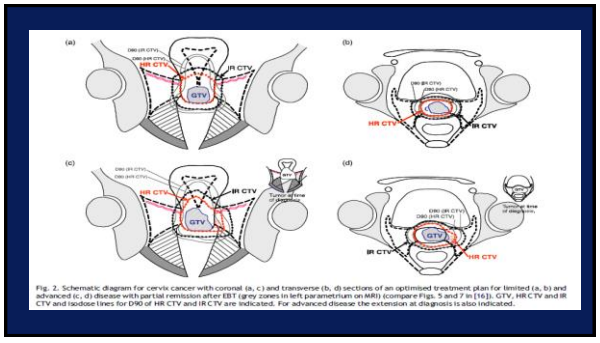
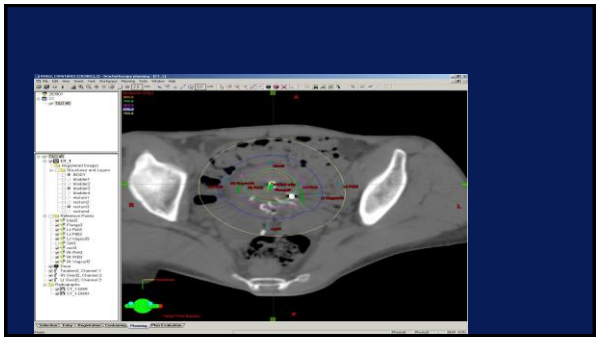
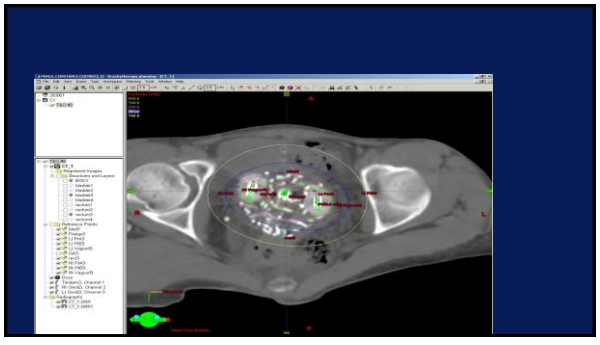
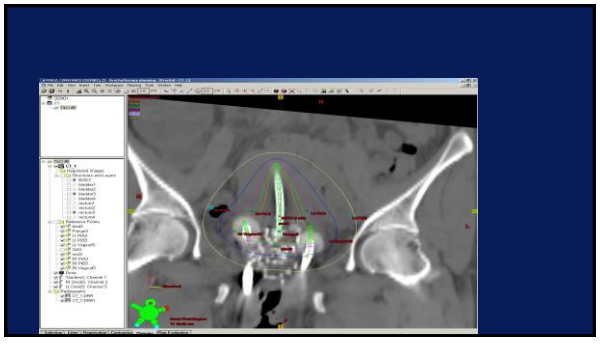
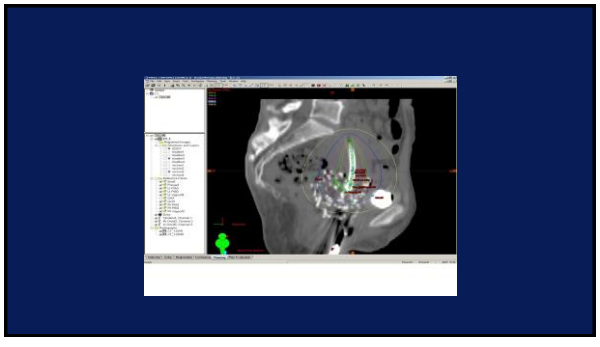


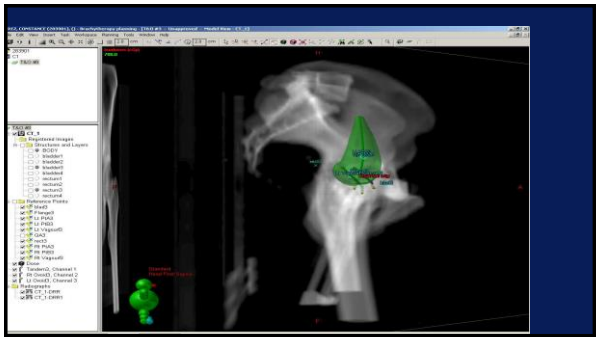
Fig. 2. Schematic diagram for cervix cancer with coronal (a, c) and transverse (b, d) sections of an optimised treatment plan for limited (a, b) and advanced (c, d) disease with partial remission after EBT (grey zones in left parametrium on MRI) (compare Figs. 5 and 7 in [16]). GTV, HR CTV and IR CTV and isodose lines for D90 of HR CTV and IR CTV are indicated. For advanced disease the extension at diagnosis is also indicated.

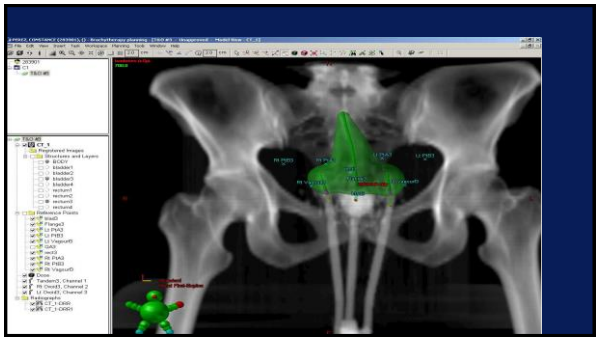


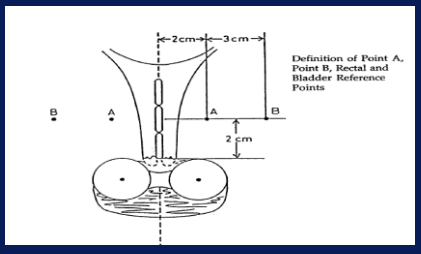






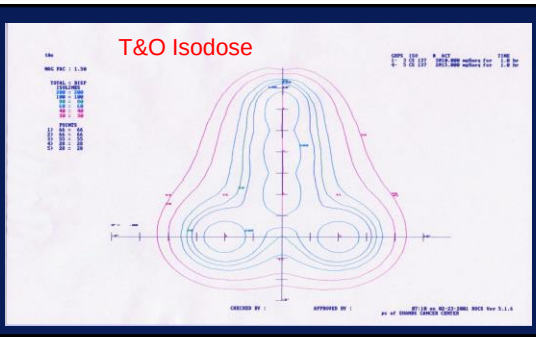




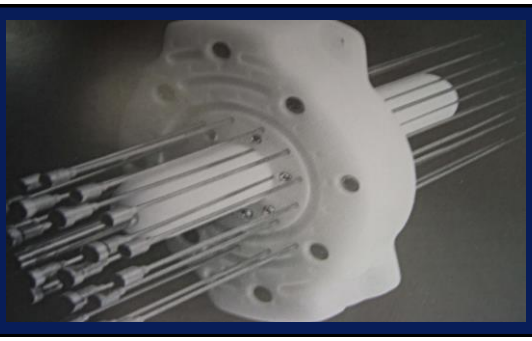


Points A and B

T&O Isodose



- Syed Template used for Interstitial Brachytherapy for GYN cases



- QUESTIONS?