Brachytherapy Applicators Cervical Cancer



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RADIOTHERAPY IN CARCINOMA CERVIX

• EXTERNAL BEAM RADIATION THERAPY - 3D CRT, IMRT, IGRT etc..

• BRACHYTHERAPY (INTERNAL RADIATION)

> INTRACAVITARY LDR / HDR
> INTERSTITIAL LDR / HDR
> MOULD LDR / PDR/HDR

Brachytherapy forms the corner stone for local control and toxicities

History....



- Henri Becquerel discovered radioactivity in 1896
- Marie Curie discovered radium in Paris in 1898
- Curie discovered radioactive ore pitchblende in Joachimthal mines in Bohemia-Po in 1898
- Becquerel and Marie and Pierre curie got Nobel prize in 1903.
- ✤ 1901-Danlos and Bloch of St Lewis Hospital, Paris borrowed Radium from Pierre curie → treated cutaneous Lupus and started the era of brachytherapy
- **Wickham** (1904) initiated treatment of Ca Cervix with Radium.
- Wickham can be properly referred to as Father of Radium treatment of uterine cancer
- Discovery of artificial radioactivity (1934) by Irene and Frederic Joliot Curie

St. Joachimstal mines, Bohemia

•1523+ Silver coin (Thaler = \$),

16+: Ni, Bi, Uranium1873: Great Fire

19+: Ra & Radon SpaWW2: Germans to Czechs

•Uranium mining ceased 1964

•Radioactive thermal springs Rheum.

•Average life expectancy 42 years



Need of System

- Dose prescription was entirely empirical due to lack of
- 1. Knowledge about the biological effects of radiation on the normal tissues and tumor.
- 2. Understanding about dose ,dose distribution and duration of treatment
- There were few schools trying to develop system of Brachytherapy with practically usable applicator and dosage schedule
 - **STOLKHOLM SYSTEM**—Forsell (1914)
 - PARIS SYSTEM Regaud (1926)
 - MANCHESTER—Todd (1938)



STOCKHOLM SYSTEM- 1914

- Gosta Forsell in 1910 started radium treatment of ca of cervix, Stockholm, Sweden
- It consist of Tandem + vaginal box
- Intravaginal boxes -lead or gold,
- Intrauterine tube -flexible rubber
- Application reported in terms of mg-hr
- Fractionated course-over a period of one month.
- Usually 2-3 applications, each of 20- 30 hours (repeated 2-3weekly)
- Vaginal and uterine applicators were **not fixed** together





Figure 7. Manchester technique vaginal ovoids and Stockholm technique boxes.

Stockholm System

- The amount of Radiumunequal in uterus and in vagina
- Unequal loading
 - 53 80 mg of radium in uterus
 - 60 80 mg in vagina
- Total prescribed dose -6500-7100 mghrs
 - 4500 mghrs contributed by the vaginal box



Stockholm System

ADVANTAGE-

- Simple method
- Fractionated scheduleshort period of treatment

PROBLEM -

- N0 dose reference point
- No specific volume distribution
- Parametrium receives lesser dosage
- Need for repeated insertions
- Dose in mg-hrs- unreliable method of prescription
- Flexible applicatorspositions not fixed
- Pre -loaded

PARIS SYSTEM- Regaud (1926)

- Intrauterine tube- semi-fexible silk rubber
- Vaginal radium were introduced in cork colpostat
- Single application of radium
- Delivers a dose of 7000- 8000 mg-hrs of radium period of tive days (120hrs)
- Equal amounts of Radium in uterus and vagina strength between 10 -15 mg of radium
- 1 intrauterine source made of 3 radium tubes **containing 33.3 mg of radium** in the ratio of 1:1:0.5
- 3 individualised vaginal sources (cork colpostats) 1 in each lateral fornix and 1 centrally
- Two cork colpostats (cylinder) with 13.3 mg radium in each
- Radiobiologically- prolonged low intensity radiation caused greater tumor destruction than high intensity short treatment



Figure 6. Paris technique cork applicators.

Paris System

ADVANTAGE----

- •Ovoids provide additional dose to parametrium
- Single insertion
- Rigid applicators

PROBLEM ---

- •Cork position not fixed
- •Flexible implants- position of applicators depends upon anatomy of uterus
- •Long duration of confinement
- Pre-loaded

Drawbacks

- Did not apply any fixed distance between vaginal sources
- No fixed connection between vaginal and uterine sources.
- Dose prescription in terms of mg-hr ignored the importance of tolerance of different critical organs(anatomical targets and organs at risk)
- There was limited use of **EBRT** in Stockholm technique while Paris system use EBRT before intracavitary application.
- Intracavitary therapy in mg-hr with EBRT in absorbed doseoverall radiation treatment can not be adequately defined.

Manchester System

- Todd and Meredith (1930).
- Modification : the Paris system (source loading) and Stockholm system (fractionated delivery of dose).
- Calculate dose in Roentgen to various points in pelvic region where dose variation was not rapid and at which exposure dose should be stated and measured.



Principles of Manchester System

- The problem of the dose received in the treatment of carcinoma cervix presents special difficulties because of the variable size and shape of the parts to be treated and of the tumours found
- Define treatment in terms of dose to a point-
 - ✓ anatomically comparable
 - ✓ in region where dose is not highly sensitive to small alteration in applicator position
 - ✓ in position which allowed correlation of the dose levels with the clinical effects
- Design set of applicators and their loading to give same dose rate irrespective of the combination
- Set of rules regarding activity, relationship and positioning of Ra sources to produce desire dose rate.

Main Features

- I. Selection and definition of two points A and B for dosage specifications.
- II. Introduction of new vaginal and uterine applicators.
- III. Use of system of loadings in terms of simple number of units of radium such that dose rate at point A was fairly constant whichever combination of applicator used





PARACERVICAL TRIANGLE

- Initial lesion of radiation necrosis occurs here.
- Area in the medial edge of broad ligament where the uterine vessel cross over the ureter

POINT A

Fixed point 2cm lateral to the center of uterine canal and 2 cm from the mucosa of the lateral fornix

Dose rate at this point is not too sensitive to small variations in applicator position

Radiation tolerance of this point was the limiting factor for Rx Represents average dose where initial lesion of radiation necrosis

occurs

Area in the medial edge of broad ligament where the uterine vessel cross over the ureter

POINT B

- Defined to be 5 cm from the mid-line and 2 cm up from the mucus membrane of the lateral fornix
- Rate of dose fall-off laterally
- Imp- Calculating total dose-Combined with EBRT
- Proximity to important OBTURATOR LNs
- Dose ~20-25 % of the dose at point



F16. 1.—Diagram showing paracervical triangle points A and B.



Design of Applicators

1) Ovoids-

- Similar to that of Paris- Ovoids (hard rubber)
- Shape based on isodose lines around Ra tubes with active length-1.5cm- ensured homogenous dose over whole surface of ovoids.
- Sizes Measurements by Sandlers et al on pelvis of 100 patients
- Various sizes 2, 2.5, 3 cm Take one or more radium tubes of actual length 2.2 cm., active length 1.5 cm.
- Largest ovoid in roomiest vagina for best lateral dose throw off i;e dose to point B
- But as so many mghrs were used- high vaginal doses with small ovoids and low doses with large ovoids – so diff quantity of Ra was used for diff sizes of ovoids - same dose could be achieved to pt 'A'.

FIG. 2.—Isodose curves round tube of radium to show corresponding shape of ovoids.



2) Intrauterine tube

- Thinnest rubber tube-avoid dilatation (risk of sepsis and trauma)
- Closed at one end and have flange at another end for aiding fixation.
- Three separate lengths- 2 cm, 4 cm and 6 cm, meant for one, two and three radium tubes resp.
- Threads were attached to flange

 helped in fixation after
 application



Radium sources and their loading

- 1 Unit of radium was defined as 2.5 mg of radium with 1 mm platinum filtration.
- All loadings in intrauterine tubes and vaginal ovoids were made integral multiples of this unit.



LOADINGS IN TERMS OF "UNITS" OF THE ORIGINAL SYSTEM (NOW OBSOLETE)

Intra-uterine	e appl	ica	tor	s (figure	s from	left	to	right,	fundus
Long applic	ator	23	3	radium	tubes		2 -	2 – 1	units
Medium	,,		2	,,	,,	••		2 - 1	,,
Short	**	• •	1	,,	,,	••		2	,,
Vaginal ovo	ids (in	pa ove	air Did	s across	the var 5 unit	gina s ea	ı). ch		

variation in dose rate when different combinations of loadings are used could be as much as 15 % on either side of mean

Prescription

- Optimal total dose to point "A': 7200 R
- Number of sessions: 2
- Duration of each session: 48 hours
- Interval in between sessions: 4 7 days
- Calculated dose in Roentgens.
- Ratio of dose to pt A from uterine and vaginal applicators was 1:1
 - Thinnest intrauterine applicator was used to avoid risk of tearing open the uterus.
 - Largest size ovoid was used to have increase dose to pt 'B'.
 - Different content of radium was used so that whichever combination of applicator used ,same dose could be achieved to pt 'A'.

Drawbacks of

Manchester

- Dose tolerance of point A region far exceeds the tolerance of other critical organs in proximity to the cervix such as the bladder& rectum, and therefore cannot be used as a limiting factor
- Point A relates to the position of the sources and not to a specified anatomic structure.
- Dose to point A is very sensitive to the position of the ovoid sources relative to the tandem sources.
- Depending on the size of the cervix, point A may lie inside the tumor or outside the tumor.
- By prescribing to point A one could risk underdosage of large cervical tumors or overdosage of small tumors
- Point A- cannot be simulated



Figure 1. AP and lateral x-rays of the pelvis of a cervical cancer patient treated by the Manchester technique. The ovoids, which are kept in the lateral fornices and separated by a washer, are seen lying in the upper part of the vagina in line with the tandem.

Afterloading Era

First after loading cervix applicator was introduced by U. Henschke in 1960.







Remote Afterloading Endocurie Therapy for Carcinoma of The Cervix

P. Pradeep Kumar, MD, Feraydoon Bahrassa, MD, Maria C. Espinoza, MD, and J. Rao Nibhanupudy, MS Washington, DC

Since October 1975, 41 cancer patients were treated with a remote afterloading device using fractionated high dose-rate intracavitary radiation. Nineteen of these 41 patients were treated for carcinoma of the cervix. Remote afterloading high dose-rate fractionated intracavitary radiation was given in combination with external irradiation. The dose fractionation and rad equivalent therapeutic (RET) values and various points of interest are discussed.

Historical Background

Intraoperative intracavitary radium has been used for the treatment of carcinoma of the cervix since the beginning of the century.¹ There are three major problems with the widely used Paris,²⁻⁴ Stockholm,⁵ and Manchester⁶ techniques which use radium: protection, position, and contamination. wear and tear, the capsule holding the radium cracks or breaks allowing the radon gas, which is a daughter product of radium, to leak out.

The Afterloading Technique

Although the intraoperative intracavitary radium technique is still used in many centers all over the world,

A further development to totally eliminate problems associated with protection and position led to the development of remote afterloading techniques, first reported by Walstam7 in 1954 from Radiumhemmet. In this method, the afterloading applicator is placed in position and the applicator is connected to a high-intensity afterloading source device (Figure 3). Then the patient is isolated and the desired radiation dose is delivered in a short period of time (four to five minutes) by remotely driving the high-intensity source into the applicator. Because of the short treatment time, the patient can be totally isolated, thus, protecting everyone. The position of the applicator remains undisturbed be-

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Brachytherapy Applicator

- Pre-loaded / After-loading
- Loose / Fixed / Semi fixed
- Material: Rubber / Plastic / metallic (Steel/Titanium) Full / Partial
- Fixity: Screws / joint
- Manual After Loading / Remote After-Loading
- LDR / MDR / PDR / HDR

Flexible



Manchester Type



Fig 14.6: Modern Manchester applicator set (A) which is available for a Cesium source (LDR, MDR) or - with a smaller tube diameter – for an Iridium source (HDR, PDR).

The different angles and lengths of the intrauterine tubes are demonstrated as well as the shape and size of the different ovoids (B,C). There is a clamp to fix the position of the ovoids and the intrauterine tube to each other (Nucletron \mathbb{R}).



Manchester distribution



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Fletcher Applicators Evolution of FSD Ovoids





Delclos, et al., Cancer 41, 970-979, 1978



Fletcher Type



Fletcher distribution









Moulage



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



CT Vienna System with Titanium Needles

CT MAC. Interstitial GYN Template

MUPIT IMPLANT IN CA CERVIX



In corporation of Newer Imaging Modalities

- 2D Planning : Orthogonal X-ray Based (STD)
- 3D Planning :
 - CT Scan: Interstitial Brachytherapy
 - MRI: TMH Experience
 - US: TMH Experience (Reverse ICRETT)
 - PET etc.

ADVANCES IN GYN BRACHYTHERAPY PLANNING

T2 REFORMAT

CONVENTIONAL PLANNING

.790 MRI BASED PLANNIN

25 Nox 12325 Alag FI RD



CT- BASED MUPIT PLANNING



SYED-NEBLETT TEMPLATE

- Two Plastic / Silicone plates 1.2 cm thick
- 2 cm central hole for vaginal obturator,
- 34 holes with rubber rings (O-rings) drilled 1 cm apart in incomplete concentric circles to accommodate the guide needles.
- Vaginal obturator
 - ✓ 2 cm diameter
 - ✓ Three different lengths of 12, 15 and 18 cm
 - Central tunnel to accommodate tandem
 - \checkmark Six longitudinal grooves on the surface for guide needles
 - ✓ Embedded screw at it's distal end to secure the tandem.
- 17 Gauge hollow needles 20 cm long.
- Long axis held perpendicular to sagittal plane to treat parametria.





HAMMERSMITH PERINEAL HEDGEHOG

Modified Syed-Neblett template.

Held with long axis parallel to sagital plane.

Three or four complete concentric rings of holes produced as compared to laterally deficient Syed-Neblett (for treatment of lower vagina and vulval cases)





Outer tubing with lead washers at needle ends, with decreasing length $P \rightarrow A$

Allows ease while loading and helps fix Ir192 Wires.

Cs source can be inserted through the central needle to substitute for the central ring of needles.

Br J R 1985, Branson et al

Brachytherapy Applicators











Various BT Techniques



An example: Perineal Interstitial HDR Brachytherapy Boost Using Martinez Universal Perineal Interstitial Template (MUPIT)

- EUA : Residual disease, pelvic anatomy etc. assessed
- 18 G stainless needles: Multiple plane implant (Straight +/- Divergent planes)
- CT Scan images with 3-5 mm slice thickness
- Image acquisition and Delineation
- Treatment planning :
 - Catheter reconstruction and Source loading (6-6.5 cm)
 - Basal dose points (Paris Dosimetry system)
 - Dose prescription (HDR) : 3.4 4 Gy per fraction @ 2# per day 6 hrs apart x 4-5 #
 - Optimization : Geometric +/- graphical
 - Plan evaluation (DVH) : Target and OAR's



Epidural anesthesia

Procedure Details















PRINCIPLES OF PERINEAL INTERSTITIAL IMPLANTS

• Evolution from Manchester system with Radium to Paris System for present generation Afterloading techniques.

Principles

- Radioactive lines must be rectilinear, parallel with centers in the same plane (central plane), perpendicular to the direction of the lines.
- Equidistant adjacent radioactive lines
- Separation between planes is 0.7 distance between two needles in triangular geometry and equal to the distance of needles in a square geometry.
- Reference linear kerma rate or the linear activity along each radioactive line must be uniform and identical for all lines.

