The Manchester System of Intracavitary Brachytherapy for Carcinoma Cervix

A Primer for Radiation Oncology Students

Dr Santam Chakraborty

Acknowledgements

This Kindle Book is derived from a series of notes I had made during my post graduation. The Manchester System of Intracavitary Brachytherapy is the most commonly used system in the world and for a good reason. It was designed with simplicity in mind. However over the last 2 decades with the advent of HDR brachytherapy and treatment planning systems the need for such systems has diminished. However the principles on which the system was designed remain true till date as they were based on basic physics. Paterson and Parker devised this system at a time when Roentgen was the unit for measuring radiation and it is a testament to their brilliance that it stood the test of time for so long. The books I have borrowed heavily from are - 'The treatment of malignant disease by radiotherapy' by Paterson and 'Manchester System' by Paterson and Parker. Of these while the first one is available in old bookshops but the second one which had the physics behind the system is much harder to find. I would also like to acknowledge the contributions of Professor Suresh S Sharma and Professor Firuza D Patel who taught me about this system during my residency days.

The Manchester system of cervical brachytherapy was one of the most commonly used methods of cervical brachytherapy, till the arrival of computer-based dosimetry. Before a look into the reason why this system was so popular we must look into the history of cervical brachytherapy and dosimetric systems as a whole.

Dosimetric systems

Any dosimetric system is a set of rules for arrangement of a specific set of radio isotopes in a specialised applicator to deliver a designated dose to a designated point.

Each system that specifies the following:

- Type of radioisotope to be used.
- The geometrical arrangement of radioisotope.
- Specification of the treatment in terms of the dose, time and administration.
- A specified set of tables to allow, reproducible and easy calculation in most of the encountered clinical scenarios.

Older dosimetric systems

Before the advent of the Manchester system, to other systems were commonly used: the Paris system and the Stockholm system.a brief description of these systems is given below:

Paris system:

In the Paris system of cervical brachytherapy, a single application of radium was specified.the system incorporated two cork colpostats in the form of a cylinder and an intrauterine tube.

The system was designed to deliver a dose of 7000- 8000 mg-hrs of radium over a period of five days.in this system, almost an equal amount of radium was used in the uterus and the vagina.

The intrauterine sources contained three radioactive sources, with source strengths in the ratio of 1:1:0.5. the colpostats harbored sources with the same strength as the topmost uterine source

Stockholm system:

The Stockholm system of cervical brachytherapy was the predecessor of modern-day cervical brachytherapy dosimetric systems. In this system of fractionated course of radiotherapy was delivered and the total course of radiation therapy was delivered over a period of one month. Usually 2-3 applications were used, with each application lasting for a period of 20 to 30 hours.

In this system, intravaginal boxes were used, made up of lead or gold. The intrauterine tube was made up of flexible rubber. Unlike the Paris system, the Stockholm system advocated an unequal loading or of the uterine and the vaginal radium. 30 to 90 mg of radium was placed inside the

uterus, while 60 - 80 mg were placed inside the vagina. A total dose of 6500-7100 mg Ra was prescribed and 4500 mg Ra was contributed by the vaginal box.

Common features

Both the Paris and the Stockholm Systems used intrauterine tubes, which were separate from the vaginal colpostats. Thus these systems had a loose geometry. in addition, the uterine sources in both the systems were arranged from the top of the uterine cavity, down below to the external os. In addition, the longest possible uterine tubes were preferred to allow the highest dose to the paracervical tissue and the pelvic lymph nodes.

Problems with older dosimetric systems

Two basic problems with the dose specification methods of the older dosimetric systems were as follows:

- With the use of external-beam radiotherapy with the dose is specified in terms of the absorbed dose, the use of Milligram-hours Radium as a unit in brachytherapy was no longer acceptable.
- In addition, dose prescription in this unit ignored the importance of tolerance of different critical organs to radiation. This was because the dose to important anatomical targets could not be quantified adequately with the use of this dose prescription method.

Principles of the Manchester system of cervical brachytherapy

When Todd and Meredith designed the Manchester system of cervical brachytherapy, they had three points in mind:

- To define the treatment in terms of dose to a **point**. According to the authors, this point should have met the following criteria to be acceptable:
    - It should have been anatomically comparable from patient to patient.
    - Should have been in a region where the dosage is not highly sensitive to small alteration in applicator position.
    - Should have been in position, so that it allowed correlation of the dose levels with the clinical effects
- To design a **set of applicators and their loading** (with a given amount of radium), which would give the same dose rate irrespective of the combination of applicators used.
- To formulate a set of rules regarding the **activity, relationship and positioning** of the radium sources in the uterine tumors and the vaginal ovoids, which will give rise to the desired dose rate.

Actual design of the system

Designation of point A:

When Todd and Meredith, started planning this system they wanted a point, which would satisfy the criteria as stated above. External loss and the mucosa of the vagina vault although being attractive options clinically, where not considered because they were not comparable from patient to patient and because the dose in these regions was highly sensitive to small changes in applicator positions. In addition, in 1938, Todd F showed that the initial lesion of radiation necrosis was not due to the direct effects of radiation on the rectum or the bladder, but due to the high dose effects in the area in the medial edge of the broad ligament, where the uterine vessels cross the ureter. This area is also known as the paracervical triangle. Keeping this triangle in mind, the authors defined a point, which was 2 cm lateral to the center of the uterine canal and 2 cm superior to the mucosa of the lateral fornix, ***in the plane of the uterus***.
The value of this point for this dosage purpose was illustrated in a study of over 500 cases, which showed a clear relationship between the tolerance of normal tissues and the dose received to this area.

Design of applicators:

The design of the applicators used in the Manchester system was very similar to that used in the Paris system. Thus a pair of ovoids were used along with a thin rubber tube, which served as the intrauterine tube.

The ovoids

The name ovoid is an approximation, and it is actually an ellipsoid of revolution. The shape is mathematically also known as the prolate spheroid. The word spheroid means a sphere, where the two axes are of *"almost"* equal length. In the prolate spheroid, one of the major axes is pointy and this shape is obtained by rotating a ellipse around it's major axis.
The sizes of ovoids that were selected, were on the basis of measurements done by Sandler et al on the pelvis of 100 patients with malignant disease, while the shape was selected on the basis of the shape of isodose curves around a Radium tube with the "**active length" of 1.5 cm**.

Thus the three ovoids selected had a diameter of

- 2 cm
- 2.5 cm
- 3 cm

The three different diameters were selected in order to ensure that the largest ovoid could be placed in the roomiest vagina in order to achieve the **best lateral dose throw off**.

The intrauterine tube

The intrauterine tube was made up of the thinnest of the rubber in order to prevent excessive dilatation of the cervical canal. This was considered important in those days, because effective antibiotics were not available so risk of sepsis was very high. In addition, the authors felt that any additional trauma, resulted in a pathway for spread of malignancy.

The rubber tubes were also available in three separate lengths in order to accommodate 1, 2 or three Radium tubes (**2 cm long**) in line. The tubes were closed at one end, and at the other end had a flange so that when it was packed into position, the uterine tube did not slip out during the treatment. In addition there was a thread attached to the tube at the flange to help in the fixation after application.

Other equipment

in addition to the above-mentioned equipments, and other set of equipments were also used in order to maintain the distance between the ovoids and to help in their fixation.these are known as the "spacer" and the "washer".

As the name indicate the spacer was used, in order to give the largest possible separation

between the ovoids so that the dose could be carried out as far laterally as possible. The washer was only used when it was not possible to accommodate the spacer.

The distance between the ovoids, when the washer was used, was 1 cm.

Definition of rules

The system also specified a set of rules that was to be used for the loading of radium in these ovoids and intrauterine tubes. as previously specified. The system was based on the premise that point, the point A should receive the *same dose rate*, irrespective of the combination of applicators used. In addition to this the system also ensured that the dose did not exceed the tolerance of the vagina mucosa.

In order to achieve these rules, it was decided that not more than one third of the total dose to point A should be delivered by the vaginal ovoids. Paterson had given the dictum that the vaginal mucosa can't tolerate doses more than 140% of the doses given to point A (11,200 R)

At that time, the following doses were delivered for the treatment of cervical cancer at Manchester.

- **Total Dose to point A**: 8000 R
- **Total number of applications**: 2
- **Total Time for each application**: 72 hrs
- **Total time**: 144 hrs
- **Dose rate desired**: 55.5 R per hour to point A

The authors defined the total amount of radium to be used in terms of **units**. Each **unit** was equivalent to 2.5 mg of radium filtered by 1 mm platinum. the loading of all the applicators there specified in terms of integral multiples of this **unit**.

The loading was done as follows

Intrauterine Tube	Length	Tubes used	Mg Ra loaded	Units loaded from fundus to cervix	Tubes (mg) used for loading
Large	6	3	35	6-4-4	15-10-10
Medium	4	2	25	6-4	15-10
Small	2	1	20	8	20

Ovoid	Tubes used	Mg Ra loaded	Units loaded	Tubes (mg) used for loading

Large	3	22.5	9	10-10-5 or 20/25*
Medium	2	20	8	20
Small	1	17.5	7	10-5-5 or 20/15**

** 20 mg tube loaded in 1st application and 25 mg in the 2nd giving a total of 45 mg which is equivalent to 2 applications of 22.5 mg.*
*** 20 mg tube inserted in 1st application followed by 15 mg tube in the 2nd which gives a total of 35 mg (again equivalent to two sessions of 17.5 mg)*

Each tube would have an active length of 1.5 cm and a total length of 2 cm.
The dose rates with the use of the ideal system at the point A was remarkably good and approximated the ideal dose rate of 55.5 R per hour.

Standard Treatment:

- **Long tube** : 37.1 R
- **Medium tube** : 36.9 R
- **Ovoids**:
    - *Large ovoid*
        - with washer 20.4 R
        - with spacer 19.8 R
    - *Medium ovoid*
        - with washer 20.5 R
        - with spacer 20.3 R
    - *Small ovoid*
        - with washer 20.5 R
        - with spacer 20.4 R

Total dose at point A in various scenarios:

- Large tube with large ovoid and washer : 57.5 R
- Large tube with large ovoid and spacer: 56.9 R
- Large tube with small ovoid and washer: 57.6 R
- Medium tube with small ovoids and spacer: 57.3 R

The variations were thus within **1.5% range**.

The highest dose rate was obtained with the long tube with the medium / small ovoid (2 cm) with a washer (57.6 R)
The lowest dose rate was obtained with the use of a medium tube with large ovoid with a spacer (56.7 R)

When a short intrauterine tube was used the dose rate at the point A was 29.5 R
The use of ovoids "in tandem" resulted in dose rates falling as below:

- Large ovoid 15.8 R
- Medium ovoid 16.1 R
- Small ovoid 16.0 R

The dose at point A with the use of a short IU tube and a standard ovoid pair was around 50 -49.3 R which was approximately **10% less** than the desired.
Similarly with the use of a standard IU tube and the ovoid loading in tandem the dose rate obtained was around **4% less** than the desired.

Important points:

1. The ideal loading of the IU tube is ~ 1.8 times that of the ovoids (55% of the dose was given by the ovoids).
1. With the use of the smaller ovoids the lesser radium is required as the diameter of the ovoid is smaller so the tube comes closer to the point A.
2. What this implies by proxy is that due to the inverse square effect a greater reduction in the ratio of point B dose to the point A dose will be seen with a smaller ovoid.
3. As the diameter of the ovoid increases from 2 to 3 centimeter the dose to the vaginal mucosa by falls by almost 35 per cent. This is one of the most important implications of use of a larger diameter ovoid in cervical brachytherapy.
4. Similarly with the use of washers the ovoids are brought closer so the dose to periphery falls off.
5. Use of the longest IU tube is recommended as it gives the highest dose to the point A and also a greater dose to the paracervical tissues with respect to the mucosa of the uterus and cervix.
6. The ends of the longer tube make little contribution to the dose at the mucosa, while the dose to distant points is contributed equally by all segments of the tube due to the operation of the inverse square law.
7. Use of nonstandard applications like short tube and ovoid in tandem loading makes the point A dose lesser.
8. Due to the inverse square effect the use of a smaller ovoid will result in a higher dose to the point A when loaded in tandem.

Special Considerations:

1. Use of tubes in a **bunched fashion** results in reduction in the dose rate to point A. This is one of the problems of loading of ovoids, where three tubes are needed in order to give the exact dose. This can be circumvented by using different loading at different times, as the use of this bunch to arrangement leads to a reduction in dose by approximately 10% to point A. For example, loading of the large ovoid can be done with the help of a 25 mg radium tube in the first session followed by a 20 mg radium tube in the second session.
2. **Dose to the point B** as defined by the system, is more or less the equivalent irrespective of the type of applicator used. It instead depends upon the total amount of radium used, and 4000 mg hours of radium are required to give a dose of 1000 R at point B (In other words, 4000 mg of radium will give a dose of 1000 R to the point B in one hour.)
3. In the Manchester system, the **point B** corresponds to location of the obturator nodes. This point is defined around the same level as point A, but 5 cm from the midline. Unlike point A which can change with the geometry of the uterus, the location of the point B does not change.
4. The **amount of packing** that should be done behind ovoids should be such that at least 1.5 cm separation should be given between the ovoid and the vaginal mucosa.
5. When treating a patient whose cervix is just present in the form of a stump, for example after subtotal hysterectomy, a **short tube** is preferred because in this circumstance we do not want to contribute the same dose rate to point A as a medium or long applicator does. therefore a short applicator is purposeful in under-loaded.
6. When treating a patient with a narrow vagina, **ovoids are often used in tandem**. In this circumstance, by necessity, the dose to the point A is **reduced** and therefore, it is tempting to increase the treatment time in order to compensate for the reduced dose rate. What must be remembered over here is that, because of the nature of this arrangement, a higher dose is given proportionately to the vagina mucosa, and therefore tolerance may be exceeded with the use of this arrangement for a longer period of time.
7. In addition to point B which corresponds to the obturator nodes, two other points which are of critical importance in this system are:
    1. **The recto-vaginal septum**: The dose to this point should be around 80 per cent of the dose received by point A.
    2. **The vaginal mucosa**: Not more than 40% of the total dose to the point A can be delivered safely without exceeding the mucosal tolerance.
8. In a patient where the **uterus is tilted to one side**, the location of the point A is found by measuring 2 cm along the intrauterine tube from the lower end and then going 2 centimeters on either side perpendicular to the line of the tube. In this system, the location of the point B is 5 cm laterally from a point 2 cm above the mid-line from the end of the radium tube.

Important points that are neglected in the design of the system are:

1. The effect of oblique filtration, due to the use of platinum filtration.
2. Effect of attenuation and scattering of gamma rays by different tissues.
3. Impact of tissue heterogeneity.
4. Based upon the assumption that gamma radiation from a point strictly obeys the inverse square law.
5. Intensity of gamma radiation (exposure rate constant) from Radium is calculated to be 8.4 R per hour at one centimeters from a point source of 1 mg filtered by 0.5 mg of platinum. According to calculations of Parker et al this value is now taken to be 8.25 R per hour.

Corrections proposed for Manchester system:

1. Exposure rate constant should be 8.25 $Rcm^2/mg\text{-}hr$
2. Roentgen to rad conversion factor of 0.957 should be used to get the absorbed dose.
3. Because the effect of organ infiltration of sources is neglected to 2-4% reduction in value of the dose obtained from the Paterson Parker table is expected.
4. As the exposure rate constant of these tables are obtained from measurements in air corrections for tissue induced attenuation need to be made.

Multiplying the amount of mg-hr radium required to give a dose of 1000 R by 0.9 corrects for these deficiencies in the original system.

Use of a different radioisotope in this system can be done with the help of the following formula:

1. Find out the exposure rate constant of the given radioisotope
2. The mass of the given radioisotopes needed to deliver the same dose at a point at one hour will be called to the mass of the radium in mg-hour multiplied by 8.25 and divided by the exposure rate constant of the given radioisotope.
3. The mass of the radioisotope is given in terms mCi-hr and to convert it into the mCi divided by the total treatment time.

Other definitions of point A:

1. Point A_o (1953): Defined as a point 2 cm above the external os of uterus and 2 cm lateral to the uterine tandem in the plane of the uterus.
2. Point A_v (1987): defined by Potish as a point, 2 cm lateral to the midpoint of the cervical collar and 2 cm above the top of the colpostats when measured at the point of their intersection with the tandem midpoint in a lateral radiograph.
3. Point A_f (): given by the American brachytherapy society, where they defined the point as a point 2 cm lateral to the central tandem and 2 cm plus the radius of the colpostats above

the line joining the midpoint of the sources in the colpostats in an AP view. in case of arrangement with the help of the vaginal cylinder point a was defined as to lie point 2 cm above the flange of the central tandem and 2 cm lateral to it.

4. Point M (1993): it was defined specifically for a new system of radiotherapy known as the Madison system. In this system a tenaculum is used to lower the cervix and to spare the small intestinal from the radiation dose. here the defined the point as lying 2 cm superior to a line joining the midpoint of the vaginal ovoids, and 2 cm perpendicular to the tandem when using ovoids with radius of 1 centimeter.

Fallacies of point A:

Several fallacies have been pointed out regarding dose prescription at point A. The important ones, among them are:

- The location of the point A is at a point where significant cranio-caudal dose gradients exist, and therefore use of this point for prescription and reporting of doses can lead to substantial inaccuracies.
- Dose point A does not correlate significantly with the complications or the control rates in various forms of cervical brachytherapy.
- Prescription to this point, without regarding cervical anatomy can lead to substantial under dosing of a large cervix.
- The location of the point A is determined based upon the applicator geometry instead of the anatomy of the patient.
- The original concept or the dose-limiting paracervical triangle is now considered invalid in light of recent clinical data, which show that the tolerance of this area far exceeds that of the bladder or the rectum.
- Dose calculated to point A use in the Manchester system rules can be significantly inaccurate with the use of modern-day radioisotopes and new applicator design, where the arrangement of the applicator and the radioactive source do not follow the recommendations of the Manchester system.
- The use of point A as a prescription point is not recommended in applicators where the vaginal sources are parallel to the uterine sources.
- The use of point A is not recommended for interstitial cervical brachytherapy, because of significant dose gradients that may exist in this system to do the placement of interstitial needles.
- Over the period of time, different centres have used different definitions of point A and calculation of the time of application according to these different definitions result in different treatment times, which makes comparison of data between different centres difficult.