Dosage Systems & Treatment Planning

Principles of Brachytherapy Dosage Systems & Treatment Planning

The following discussion refers only to the use of "sealed sources" radioactive materials sealed in a metal container.

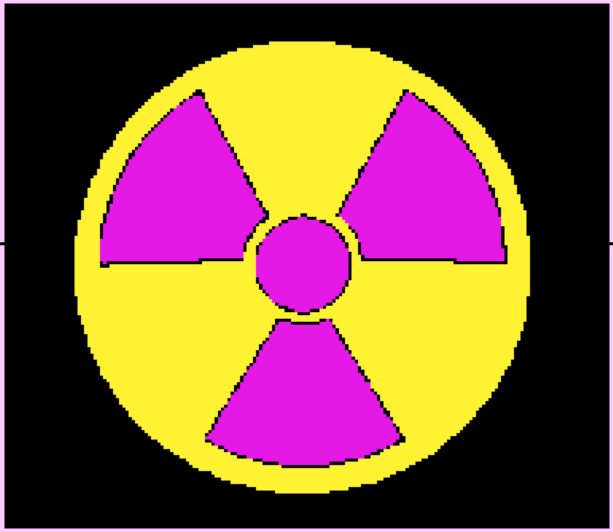
Advantages of Brachytherapy

- Can deliver a very high dose to a small volume of tissue.

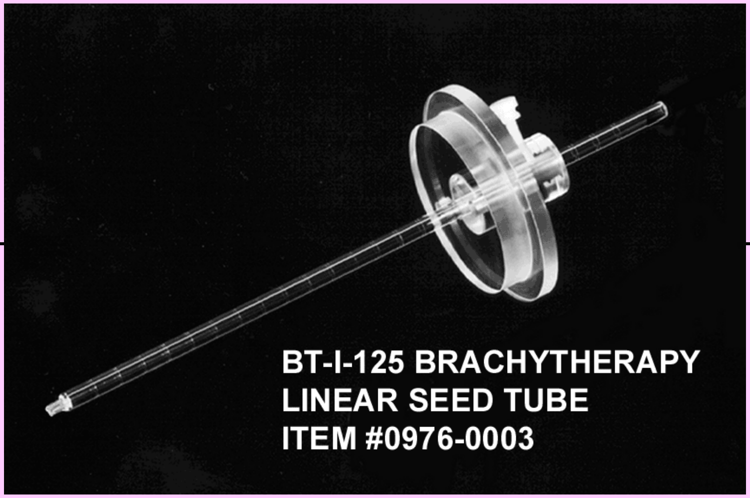
- Radiation distribution can be made to conform to the shape of the tumor / mass.

Types of Radioactive Sources Used in Brachytherapy

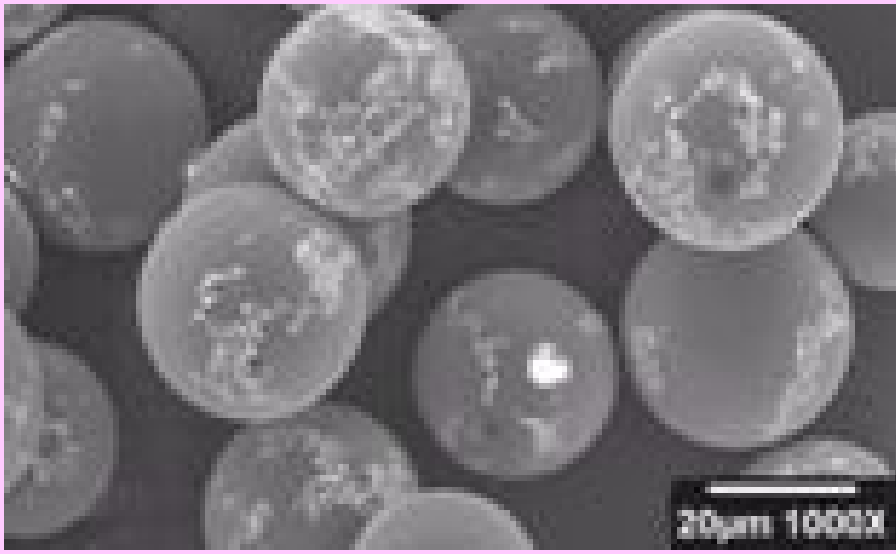
Type	Usage	Activity
SEEDS	Often Permanently implanted	0.1 - 1.0 mCi
NEEDLES	Inserted directly into tissue temporarily (reusable)	2-3 mg Ra/eq
TUBES	Usually inserted into an applicator (reusable)	5-20 mg Ra/eq
MICROSPHERES	Permanently implanted	1-5 - 2.5 Gbq
LIQUID SOURCES	Usually contained in a balloon catheter	



Radioactive sources are divided into several "cells" of equal size. These cells are filled with radioactive material. This is termed cell loading. An advantage of cell loading, is that the radioactive material is distributed equally over the length of the tube or needle. A second advantage is that in case the needle or tube becomes broken the amount of "spillage" is minimized.



In brachytherapy tubes and needles the term **active length** refers to the length of the radioactive material in the needle or tube. The overall length of a brachytherapy source refers to its physical length.



In brachytherapy, microspheres are suspended in pyrogen free water for injection which allows the activity required implantation to be measured as a volume. Microspheres are intended for use on the day of calibration within 24 hours

GliaSite® Radiation System

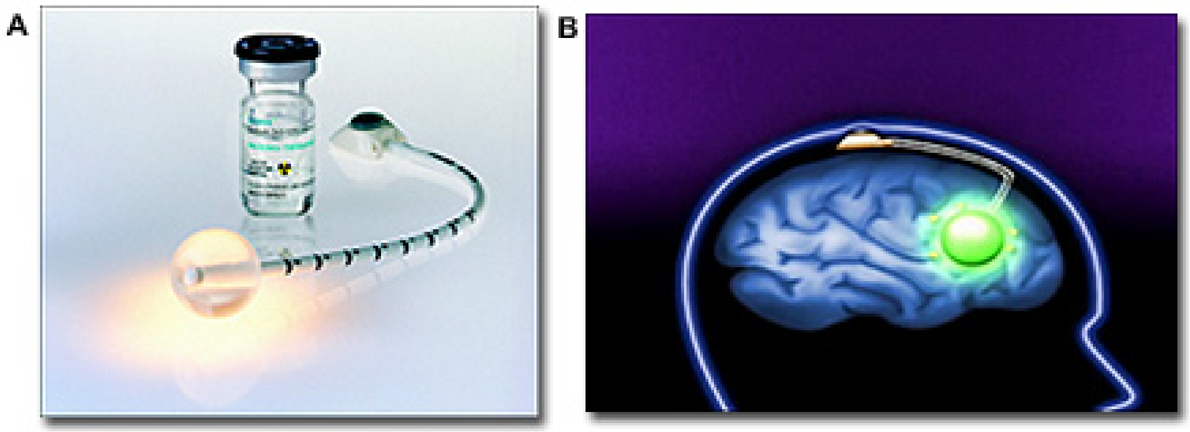


Figure A,B. A. Gliasite® Radiation System. B. Gliasite Catheter within the brain.

In GliaSite brachytherapy, a liquid radiation source and saline solution are injected into a balloon catheter which has been placed inside the tumor cavity during surgery. Once the patient has recovered from the surgery, the tumor may be treated directly inside the cavity with this method.

Dosage Systems in Brachytherapy

- Quimby/ Memorial System
- Patterson Parker System (Manchester System)
- Paris System
- Computer Calculation methods (Sievert integral)

The Quimby /Memorial system

1. Radioactive sources of equal intensity

2. Sources spaced equally over the treatment volume (Simple geometric arrangements)

3. Resulting dosage distribution that is greater in the center of the treatment volume (unequal dosage distribution)

Patterson Parker System (Manchester System)

1. Radioactive sources of unequal intensity

2. Spaced unequally over the treatment volume (Complex geometric arrangements)

3. Resulting dosage distribution that is uniform (equal dosage)

physical grounds, that for areas which are large relative to the " distance " the rectangular distributions may be preferable to the circular.

In the treatment of skin lesions such regular arrangements can usually be employed, but within the mouth limitations of space are much greater and here the rules for irregular areas find frequent use for intra-oral moulds (as in Example C).

The rules for curvature allow these general principles to be applied fairly extensively, but they are not applicable with safety to very marked degrees

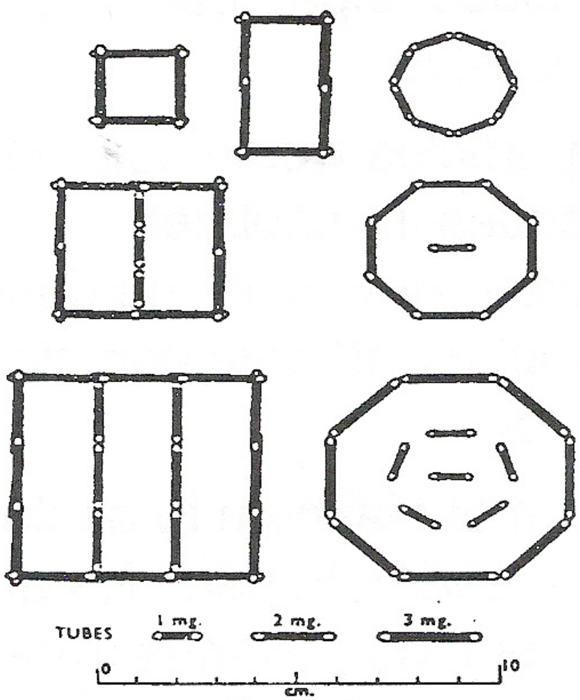


FIG. 2

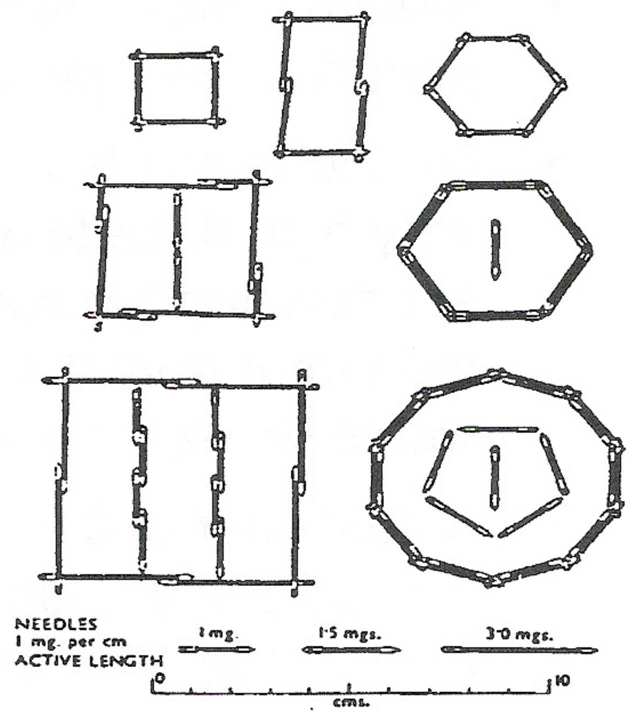


FIG. 3

of curvature such as are found, for example, with applicators enclosing the lip. (This type of case is best calculated on the basis of the sandwich applicator (Example F).)

The Paris System

1. Radioactive sources of equal intensity

2. Dose is defined and calculated in central plane

3. Wider spacing of sources and typically in parallel lines

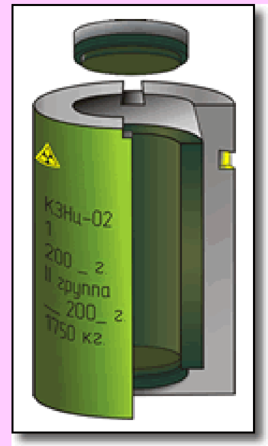
Computer Calculation methods (Sievert integral)

1. Breaks linear source into smaller components and calculates the dose at every point in the patient from every component and adds values to get total

2. Produces individual isodose curve for each patient

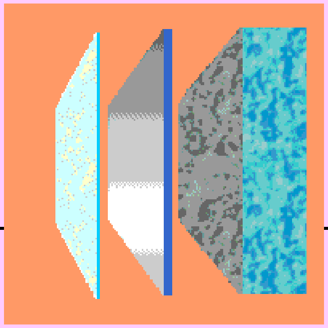
3. Must be checked periodically by manual calculations for accuracy

Filtration



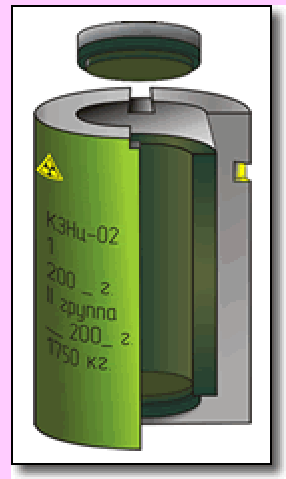
The metal container that contains the radioactive substance may serve two purposes: to contain the radioactive substance, and to remove (filter) undesirable emissions. Radium sources are a good example of filtration.

Filtration



In the decay process of Radium, alpha particles, beta particles and gamma rays are emitted. The alpha and beta particles, if allowed to escape, would deposit a very high dose to tissues immediately surrounding the source. However, the dose to the tumor from the alpha and beta particles would be extremely low. By using a container of 0.5 mm of platinum to enclose the radium, the alpha and beta particles are removed or filtered from the patient's treatment.

Filtration



In general, as the thickness of the metal container increases, a correction factor is used to account for the fact that the radiation must pass through more metal before it reaches the patient.

Source Strength

Historically, source strength was specified in curies (Ci) or millicuries (mCi). The curie was defined as the activity generated by 1 gram of Radium. Treatment times were specified in terms of milligram (of Radium) hours. As different radioisotopes were introduced their strengths were defined in terms of (having the same exposure rate as) so many milligrams of Radium (mgRaeq). This is because all the clinical experience (what worked and what didn't) was with Radium.

Source Strength

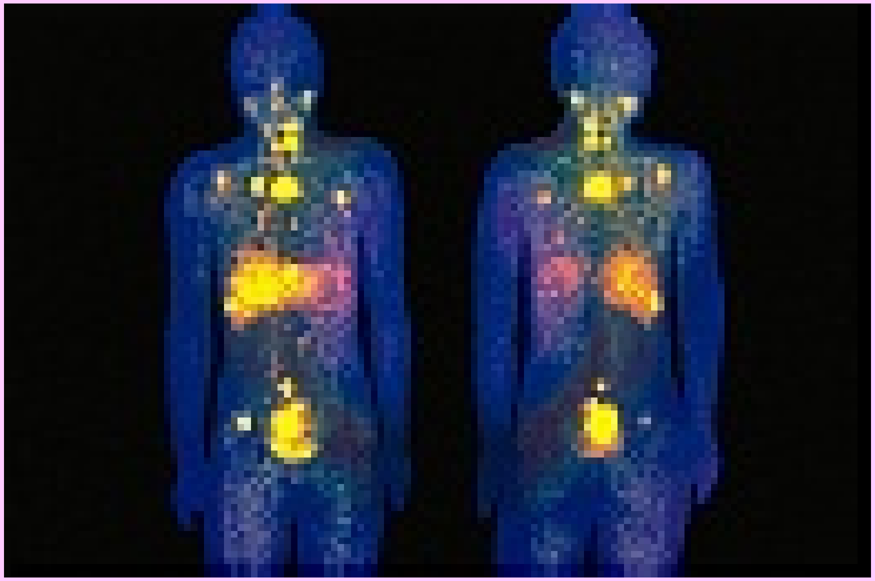
- Currently Radium is seldom used because of its high exposure rate and the predominance of alpha particles in its decay. Instead of using mCi to define the activity of a source (or mgRaeq) we use the Becquerel, which is the number of disintegrations per second. The conversion between the two is

- 1 Curie = $3.7x\ 10^{10}$ disintegrations per second = $3.7x\ 10^{10}$ Becquerel

Exposure vs. Dose vs. Dose Equivalent (Roentgens vs. rads vs. rems)

Exposure in air is a measurable quantity. The unit is Roentgens (2.58×10^{-4} Coul/kg of air). The exposure equation tells us that as the activity of a source increases, so will the exposure. Similarly, if we substitute another radioisotope with a different Gamma constant the exposure will change. Most importantly, the equation tells us that the exposure is very dependent on the distance since distance is squared in the equation. Finally, we can see that the total exposure received depends on the time.

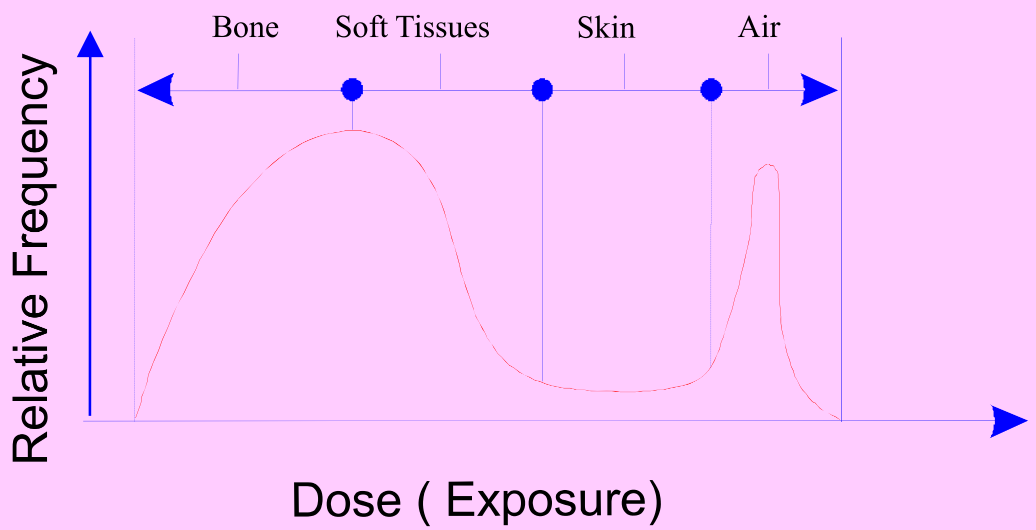
In therapy we need to know the dose to tissue rather than the exposure to air from a radioisotope.



Dose is measured in centiGray (rads). A Roentgen-to-cGy conversion factor will change the exposure rate in air to a dose rate in tissue.

fmed

This factor (fmed) is slightly energy dependent and also depends on the media (water, muscle, bone) where we want to measure the dose.

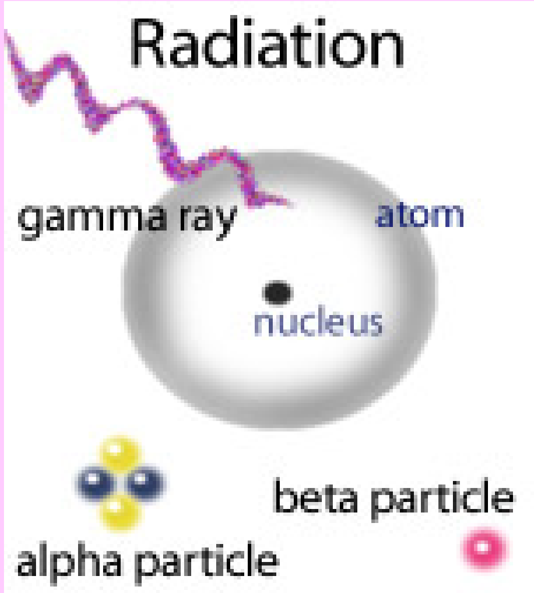


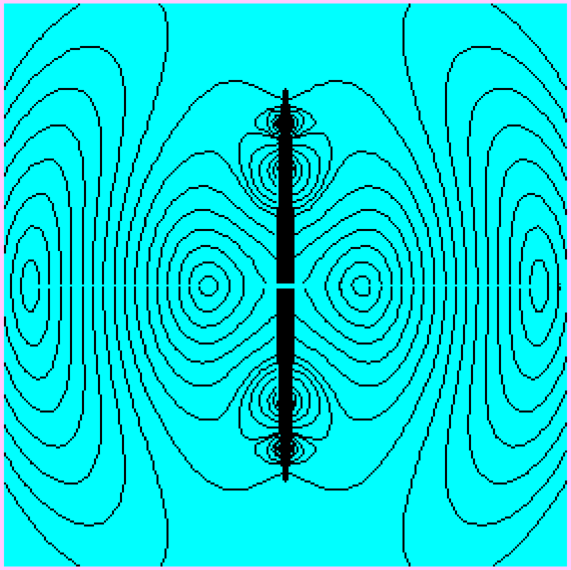
One factor not included in the exposure equation is the type of radiation emitted by the source. Heavy particles, such as neutrons, can deposit much more dose than photons. Therefore, the best way to measure the dose to tissue is to consider the effective dose equivalent (to photons) of the radiation source. Effective Dose Equivalent (H) is:

H (rems) = Dose (rads) Q

Where Q is one for photons but can be as high as 20 for neutrons. If dose is expressed in Grays (1 Gy = 100 rads), then:

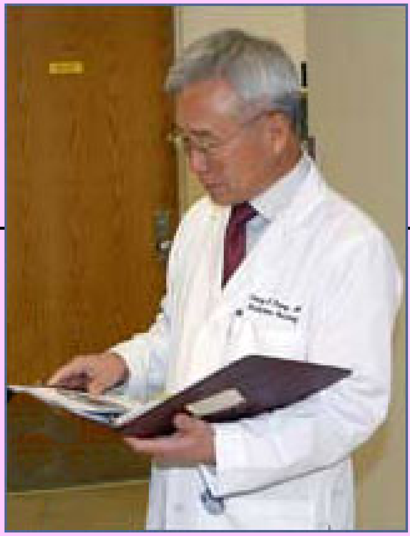
H(Sievert) = Dose (Gy) Q = 100 rems





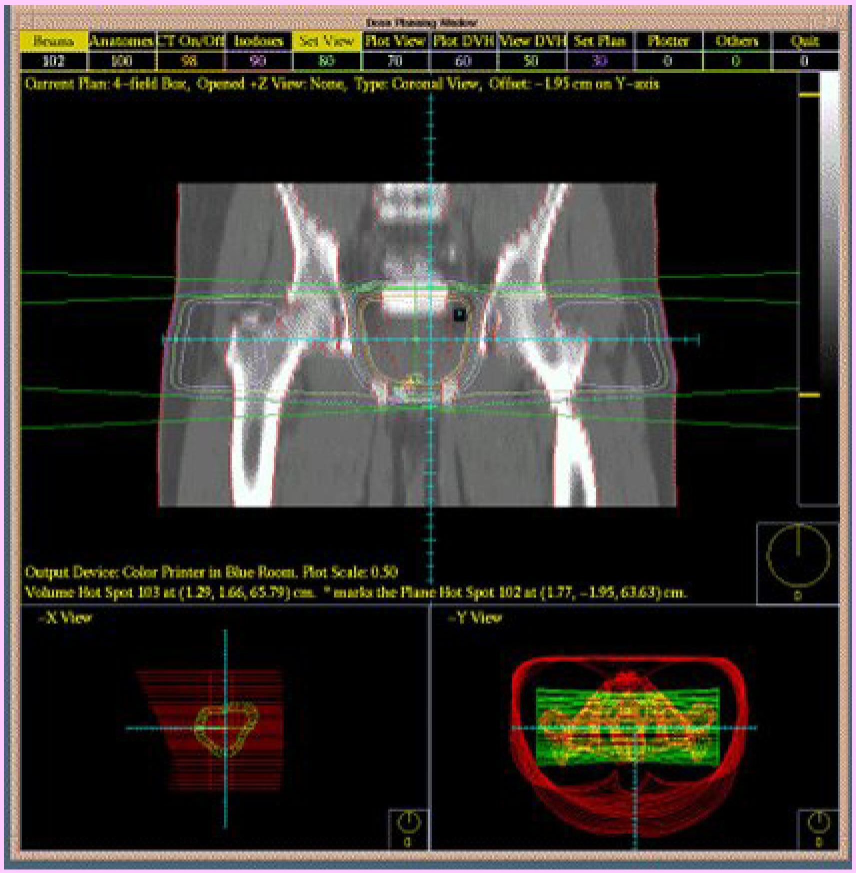
The standard definition of source strength is the air kerma rate (AKR). The units are (uGy/h)m^2.

Manufacturers typically measure the air kerma strength (AKR)at a distance of 1 meter from the source. At this distance, the geometry and design of the sources has a much smaller effect. This requires that measurements be taken in a very large room so that the charged particles do not bounce off the wall and hit the meter a second time. Likewise a very sensitive (large) chamber is required because at this distance the signal measured from the source is weak and lots of charges must be accumulated to get an accurate reading.



Reality is often different from recommendations issued by scientific bodies Currently most physicians still specify sources in terms of mCi and mgRaeq. Medical physicists must convert these values to AKS so that it can be documented on the chart.

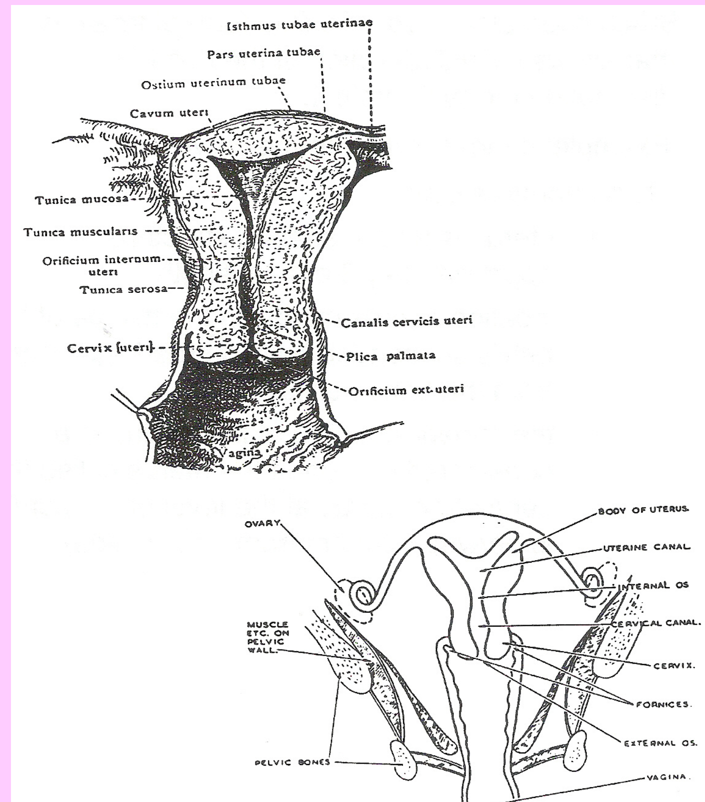
Brachytherapy Treatment Planning



Brachytherapy is a very flexible form of treatment that allows for individualization of the dosage distribution for each patient.

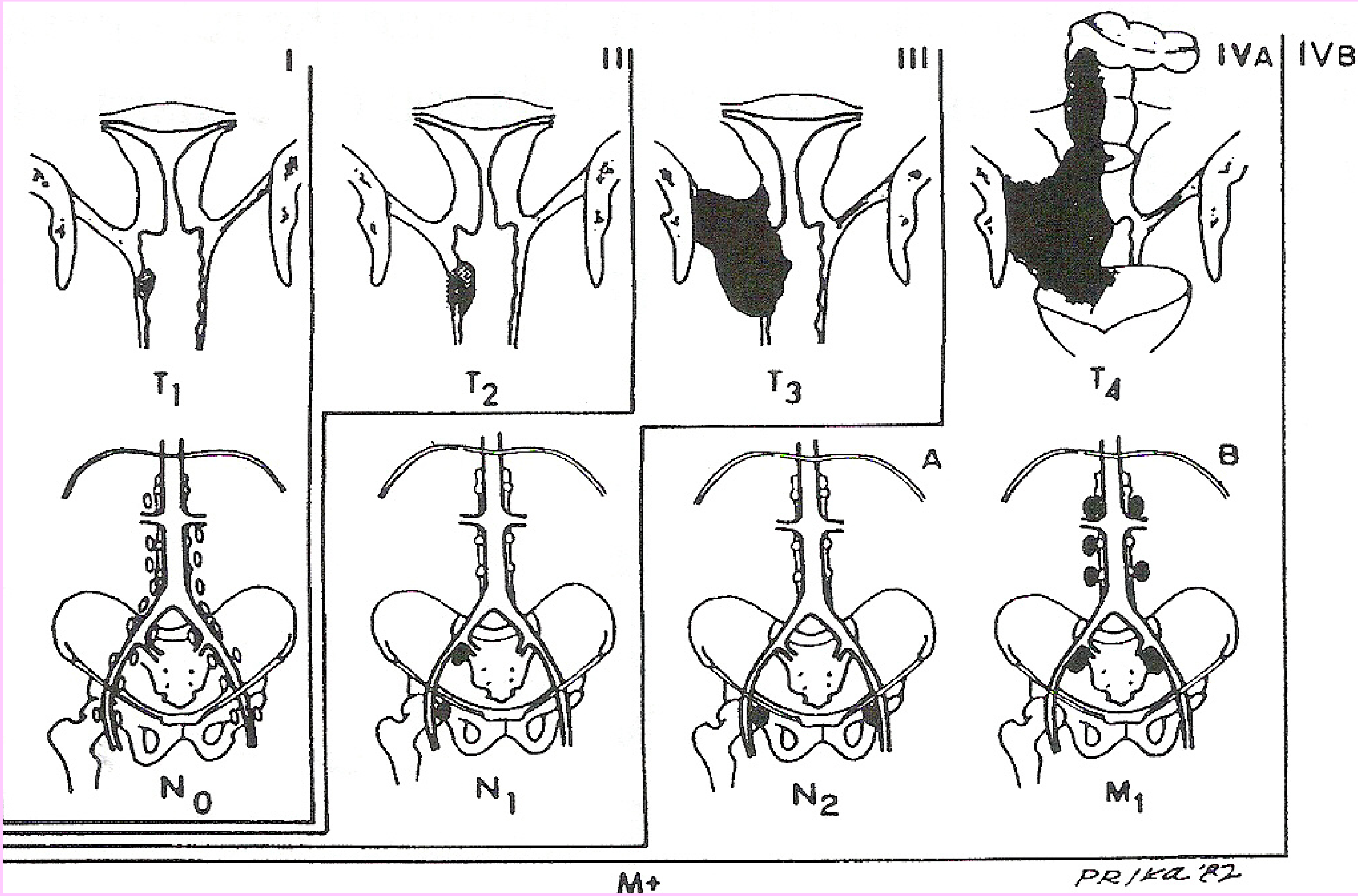
Brachytherapy Treatment Planning

Brachytherapy is a very flexible form of treatment that allows individualization of the dosage distribution for each patient.
Example: cancer of the uterine cervix
1 . Anatomy review
. uterus is a pear shaped structure
approximately 3 cm. In length
-. location approximately in the middle of the pelvis suspended by two broad ligaments from the bony pelvis
. the superior portion of the vagina is a constricted portion of the uterus called the cervix (the uterus at the level of the cervix is between 2-3 cm from side to side)

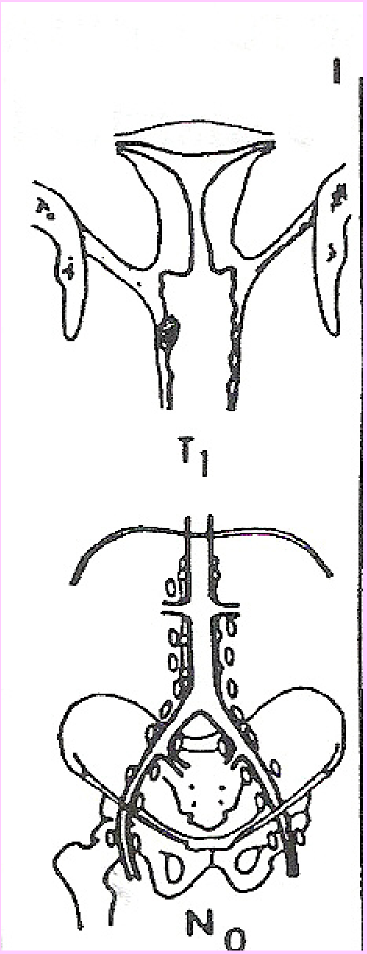


The female pelvis—side to side.

Brachytherapy Treatment Planning

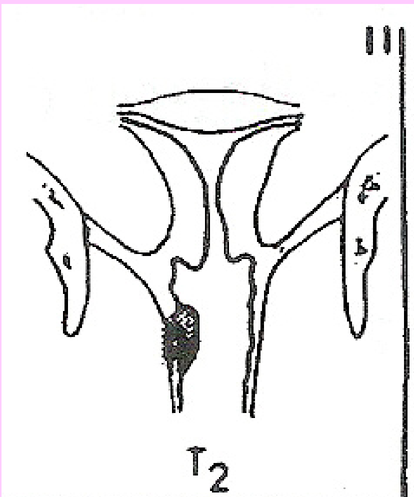


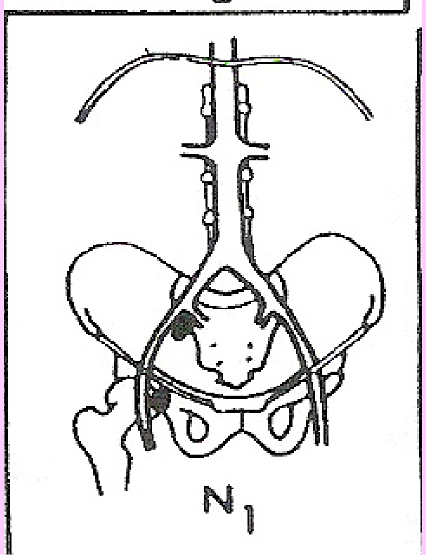
Comparison of FIGO and AJC Stagings of Carcinoma of the Vagina



FIGO	SITE	AJC
Stage I	Confined to vaginal mucosa	T1

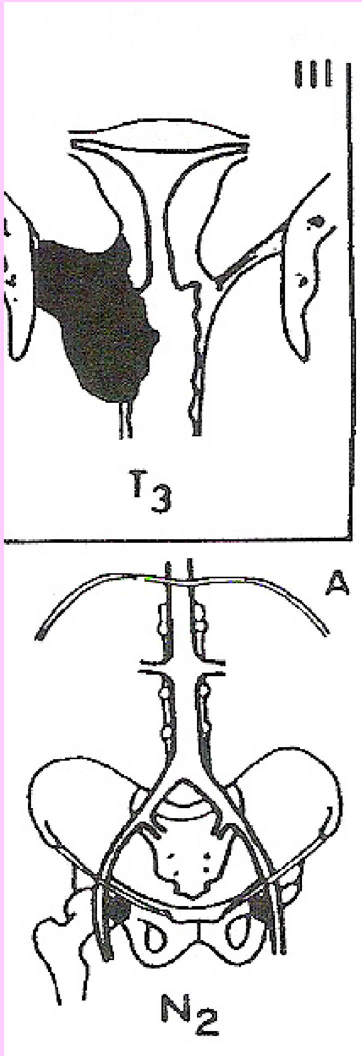
Comparison of FIGO and AJC Stagings of Carcinoma of the Vagina





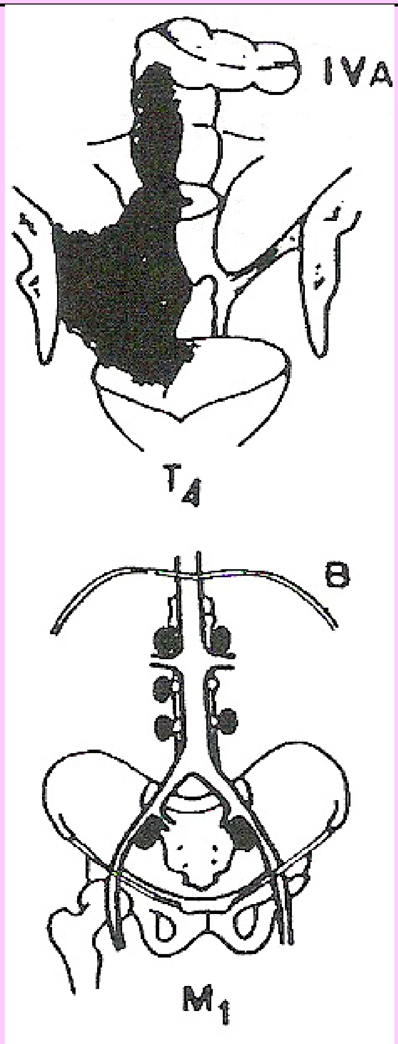
FIGO	SITE	AJC
Stage II	Submucosal infiltration into parametrium, not extending to pelvic wall	T2

Comparison of FIGO and AJC Stagings of Carcinoma of the Vagina



FIGO	SITE	AJC
Stage III	Tumor Extending to Pelvic Wall	T3

Comparison of FIGO and AJC Stagings of Carcinoma of the Vagina



FIGO	SITE	AJC
Stage IV	Tumor extension to bladder or rectum metastasis outside true pelvis	T4

Diagrammatic representation to illustrate the relationship between tumor stage, size, and radiation dose distribution.
(not to scale)

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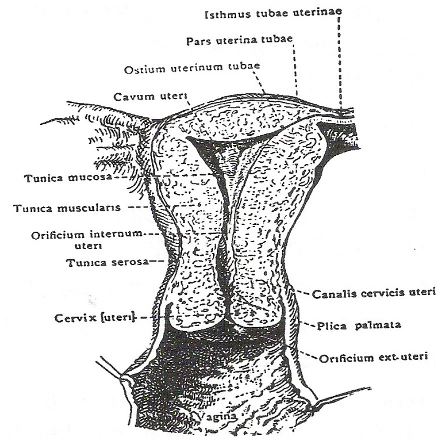

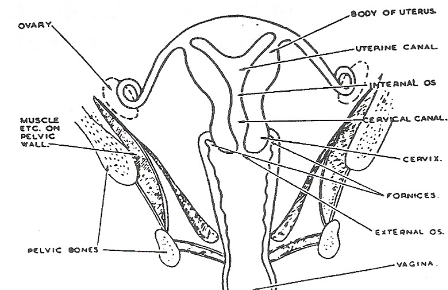

The female pelvis—side to side.

Pelvic Brim	5 cm	2 cm	Cervix	2 cm	5 cm	Pelvic Brim
Stage III		Stage II	Stage I	Stage II		Stage III
30%		100%	200%	100%		30%

The brachytherapy treatment planning of cancer of the cervix is related to the extent of the disease. Often to provide effective treatment, combinations of external beam therapy and brachytherapy must be utilized.

Examples:

Stage I & IIa (lla tumor has not invaded the muscle of the uterus)

. Treatment is surgery in younger patients or intracavitary treatment in a few select cases.

Stage II B (tumors that have invaded the muscle of the uterus)

. Treatment is combined external beam radiation and brachytherapy.