Brachytherapy, Gamma Tiles, Part 1

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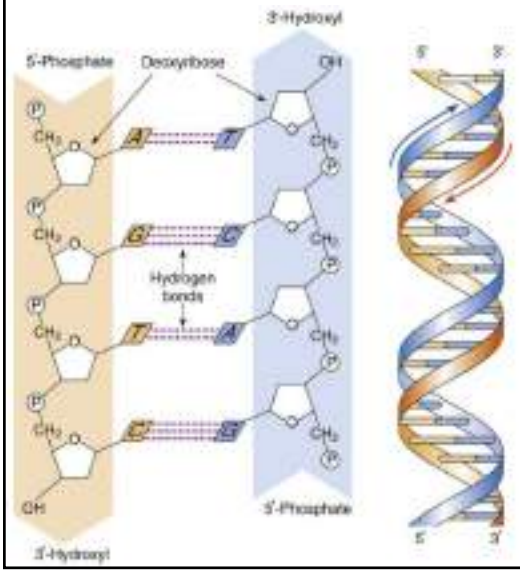
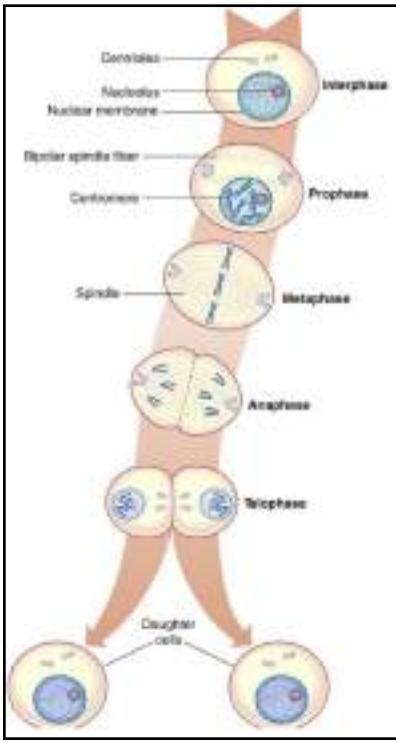
Objectives

- Upon completion of this lecture, participants should be able to:
  - List the methods we use to deliver radiation therapy so tumor cells are damaged more than normal cells.
  - List some of the advantages, as well as the challenges, of giving radiation therapy in the form of brachytherapy.

Radiation Therapy



- One of our most important weapons against growing tumors.
- The use of high energy ionizing radiation to kill growing tumors / cancers.
- The radiation damages the DNA of targeted cells.



Radiation Therapy

- The DNA damage causes the cells to *die* when they attempt cell division or *mitosis*.
- Radiation causes a “mitotic cell death.”

Two Ways of Delivering Radiation

- There are two ways of delivering radiation:
- (1) **External Beam Radiation**." Beams of radiation generated *outside* the patient are aimed at the tumor inside the patient.
  - This is how we usually deliver radiation therapy.
- (2) **Brachytherapy** or **Internal Radiation**. Radiation-emitting ("radioactive") seeds are placed inside the patient, placing them inside or next to the tumor.
  - Seeds can be placed in a body *cavity adjacent* the tumor: **Intracavitary Brachytherapy**, or
  - Seeds can be inserted *directly into* the tumor itself: **Interstitial Brachytherapy**.

Two Ways of Delivering Radiation: Brachytherapy

Radioactive seeds

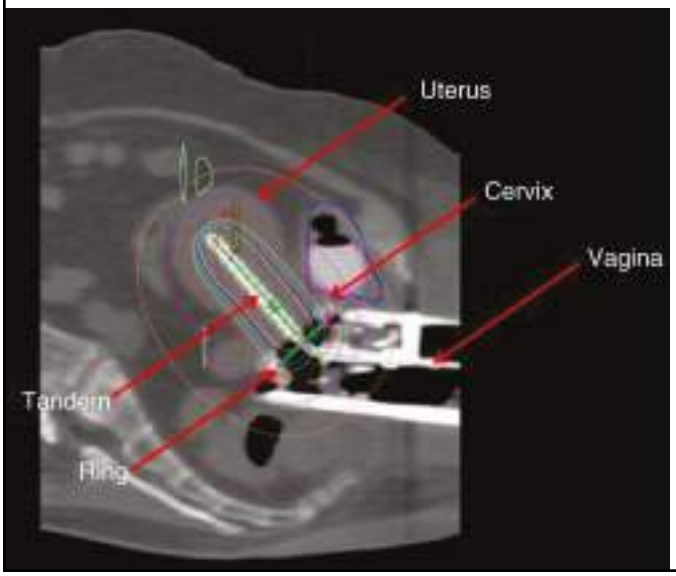
- In brachytherapy or internal radiation:
  - The radiation-emitting ("radioactive") seeds are placed either *temporarily* or *permanently.*
  - The rate of radiation delivery can be either *"low dose rate"* (LDR) or *"high dose rate"* (HDR).
- "Low dose rate" (LDR) brachytherapy: seeds placed for days, or permanently.
- "High dose rate" (= HDR) brachytherapy: seeds placed for sessions lasting minutes, then removed.
  - These sessions are repeated, typically 3 to 5 times.

Two Ways of Delivering Radiation: Brachytherapy

- A common example of brachytherapy or internal radiation:
  - Permanent (low dose rate, LDR) iodine 131 prostate seed interstitial brachytherapy for treatment of prostate cancer.

X-ray of prostate radioactive seed implant

Two Ways of Delivering Radiation: Brachytherapy



- A common example of brachytherapy or internal radiation:
  - Temporary (high dose rate, HDR) iridium 192 intracavitary brachytherapy for treatment of cervix cancer.

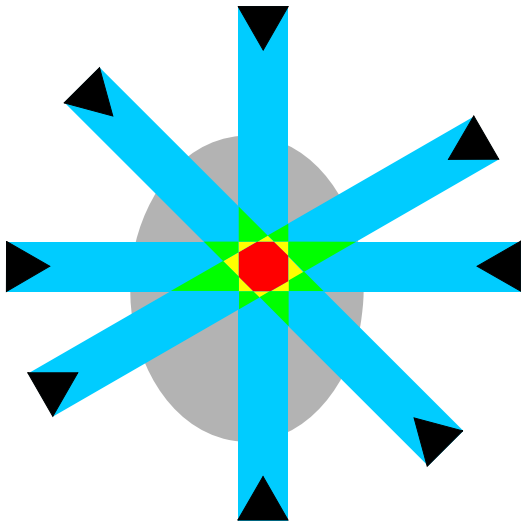
CT of tandem and ring temporary iridium 192 implant for cervix cancer.

Radiation Cell Damage

- How do we give radiation therapy so we damage *tumor* cells *more* than *normal* cells?
- (1) *Focus* or *concentrate* the radiation *only* to the tumor area.
- (2) Take advantage of the ability of *normal* cells to *repair* some damage from radiation, and deliver the radiation *slowly enough* that the normal cells can repair their damage.
  - One of *defects* in tumor cells / cancer cells is the *loss* of the ability to do such repairs*.

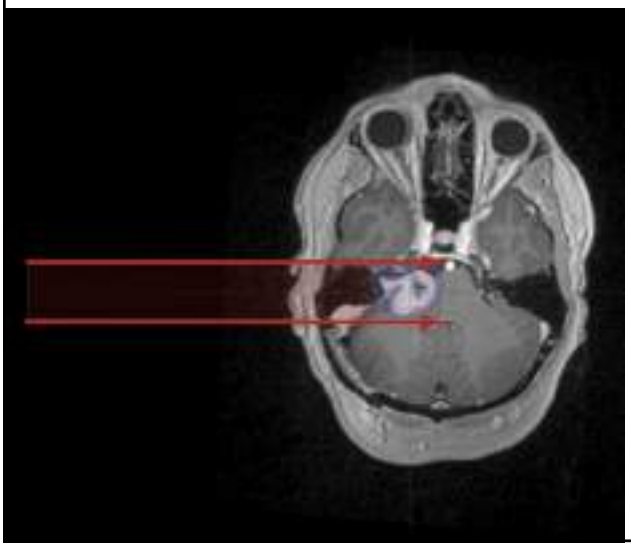
* Normal cell populations also have other advantages over cancer cell populations in recovering from radiation damage, such as a better ability to replace (*repopulate)* damaged cells.

External Beam Radiation: Focusing



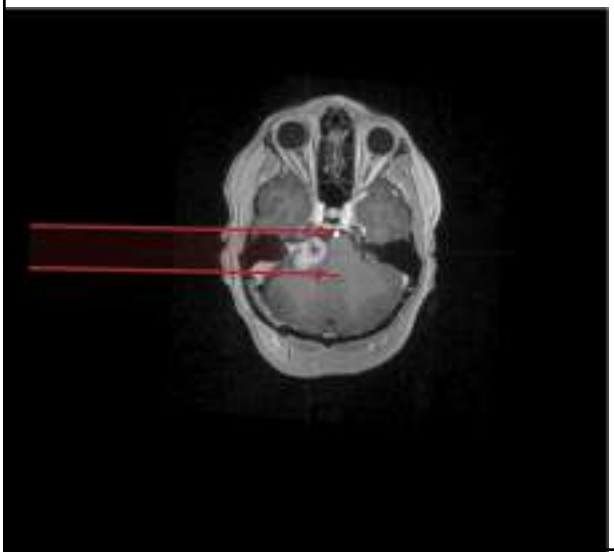
- To *focus* external beam radiation, we use *multiple intersecting beams*.

External Beam Radiation: Focusing



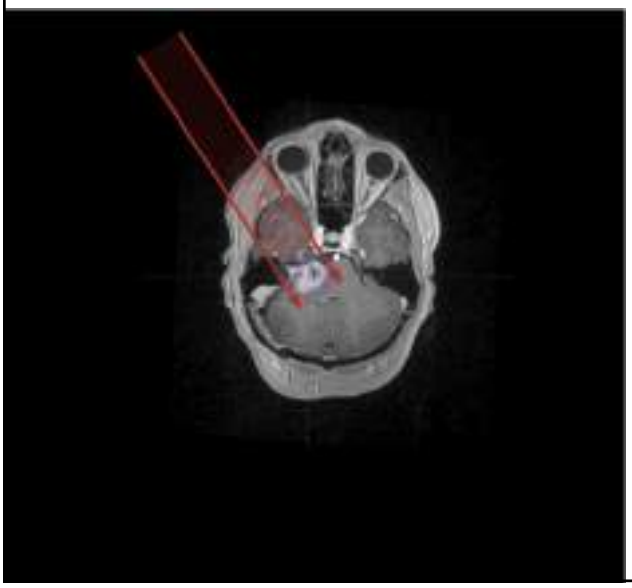
- A single external radiation beam entering a patient from one side will exit the other side, 75% to 80% unabsorbed.
- If we treated using a single beam, we would have *no* problem reaching a deep tumor, but we would end up treating to *high dose* the *entire* swath of tissue from where the beam entered to where it exited.

External Beam Radiation: Focusing



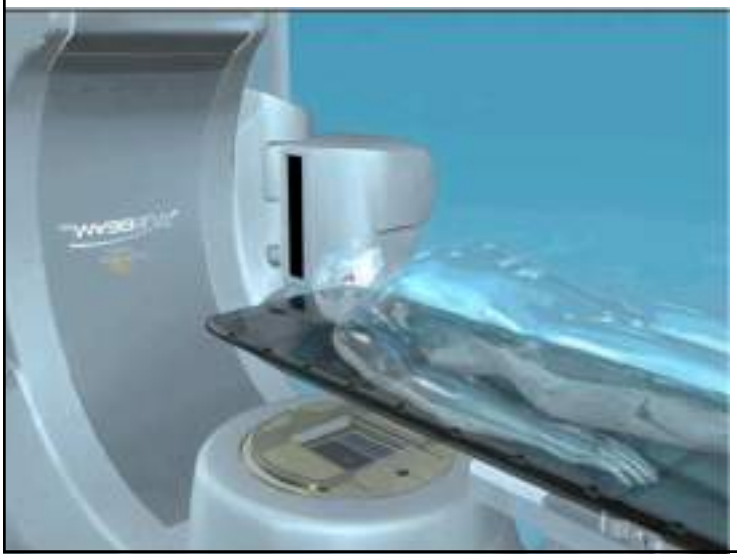
- The primary way we have of concentrating, focusing x-rays is to use *multiple intersecting* beams.
- The *more* beams we use, the *more* we can *concentrate*, *focus* the radiation on the tumor target, delivering *less* radiation to the surrounding normal tissues.

External Beam Radiation: Focusing



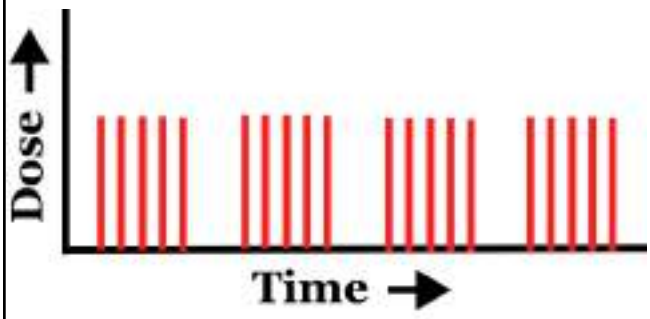
- We now commonly use an “arc” technique, where the radiation machine rotates or arcs around the target.
- During the arc, the shape of the radiation beam changes to correspond to the projected 2-D shape of the target at that angle of rotation.

External Beam Radiation: Focusing



- Modern external beam radiation machines can deliver such arc therapy in all 3 dimensions.

External Beam Radiation: Sufficiently Slow Delivery

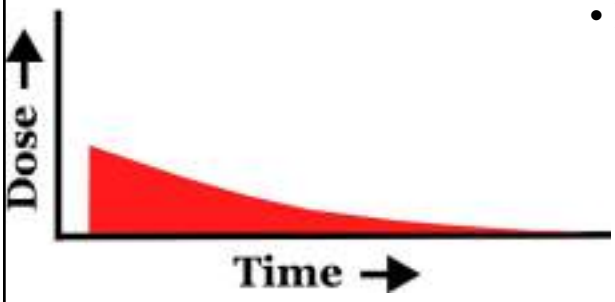


- To deliver external beam radiation *slowly* enough that normal cells can repair their damage, we give *multiple small daily treatments*, Monday through Friday, for several weeks.
  - The daily dose (the daily "spike" of radiation) is kept *low enough* that the normal cells can *repair* their daily damage from the daily "spike" of radiation *before* the next day's treatment.

Brachytherapy: Focusing

- To *focus* brachytherapy or internal radiation, we simply place the radiation seeds – the very *source* of radiation – right in the tumor area.
- It is the ultimate way of "focusing" radiation.

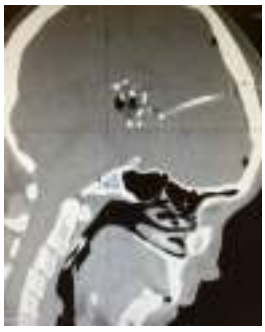
Brachytherapy: Sufficiently Slow Delivery

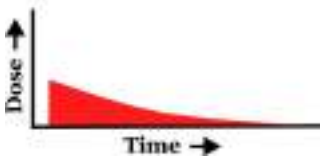


- How do we deliver brachytherapy or internal radiation *slowly* enough that normal cells can repair their damage?
- In "low dose rate" / LDR brachytherapy*:
  - The radiation seeds emit radiation *continuously* at a slowly decreasing rate.
  - The *continuous, slow* rate of radiation emission from the seeds* – rather than a daily "spike" of radiation – is perhaps the *most gentle* way of delivering radiation for normal cells, allowing them to most readily repair their damage.

* "high dose rate" / HDR brachytherapy is more akin to external beam radiation, with delivery of several "spikes" of radiation.

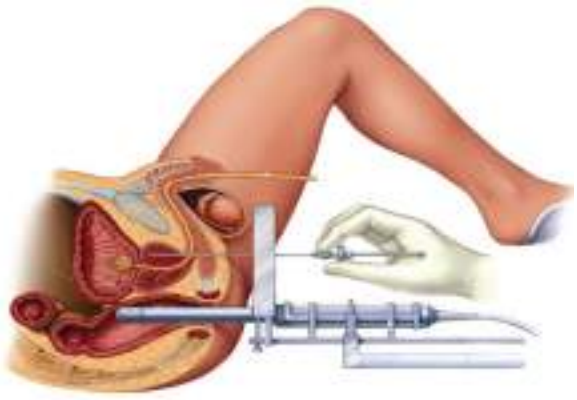
Challenges of Doing Good Brachytherapy





- Brachytherapy or Internal Radiation has a lot of advantages:
- Very elegant way of "focusing" radiation.
  - Puts the generating *source* of the radiation right in the tumor area itself.
- If low dose rate (LDR), it is very *gentle* for the normal cells:
  - Delivers a *continuous low dose* of radiation (rather than a daily "spike" of radiation as we do in external beam radiation or high dose rate (HDR) brachytherapy).

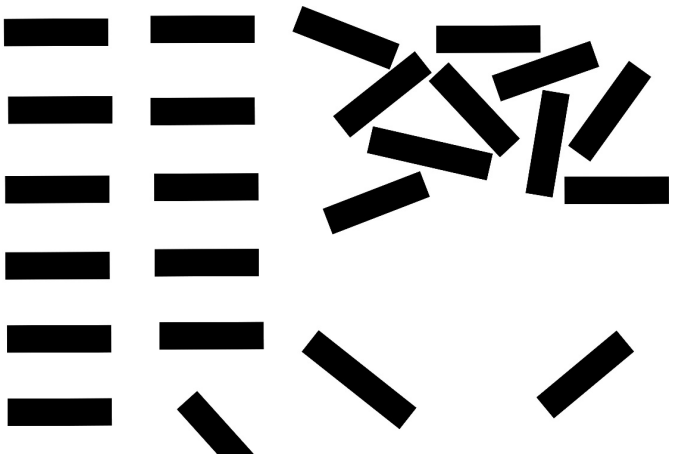
Challenges of Doing Good Brachytherapy



Implantation of iodine 131 radioactive seeds for prostate cancer.

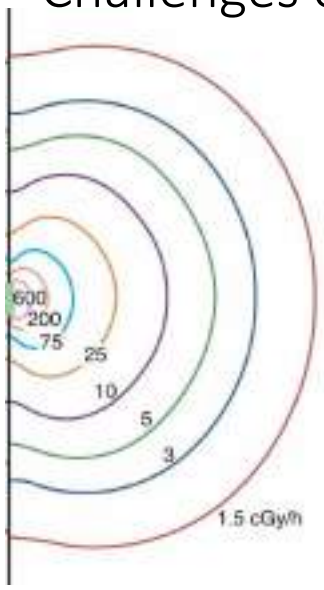
- But there are some major *challenges* of doing good brachytherapy or internal radiation:
- (1) Implanting the radioactive seeds in the tumor area is an *invasive* procedure.
- That's why external beam radiation is the most common way of delivering radiation.

Challenges of Doing Good Brachytherapy



- (2) The seeds must be placed *uniformly* in or around the tumor.
- If the seeds get bunched up, you get "hot" spots of radiation where the seeds are bunched together, and "cold" spots where the seeds are too sparse.

Challenges of Doing Good Brachytherapy



- (3) The radiation emitted by the seeds is *extremely high* right next to the seed, and falls off *rapidly* as you get further from the seeds.
- The dose at the *surface* of a seed is so high that *no* cells can repair the damage:
- Any normal tissue touching a seed will be damaged.

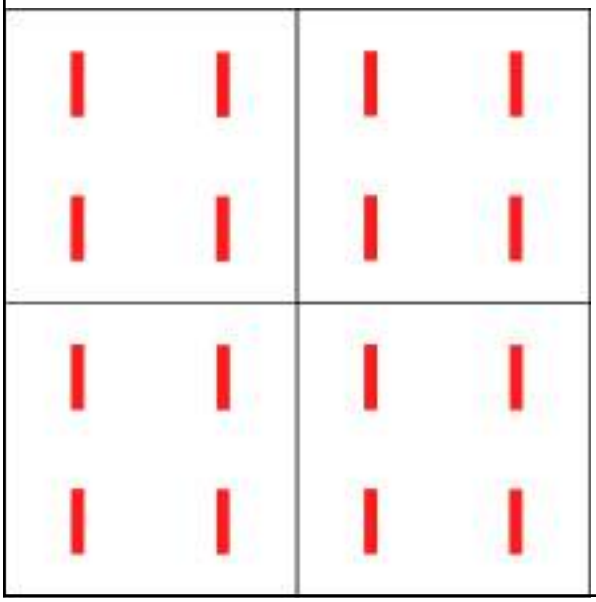
What is a GammaTile?

- A GammaTile is a product for doing permanent, low dose rate (LDR) brachytherapy in the brain, that solves these latter 2 challenges:
- (2) The need to *keep* the radiation seeds *uniform* when they are implanted near a tumor area.
- (3) The need to *keep* normal tissues *from touching* the *surface* of an implanted radioactive seed.

What is a GammaTile?

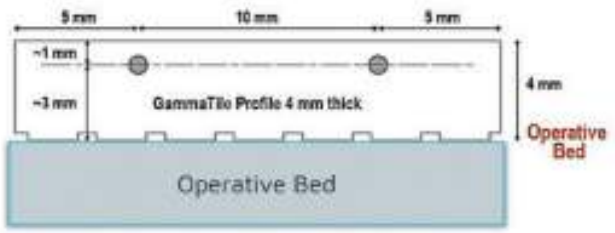
- A GammaTile consists of 4 radioactive cesium 131 seeds uniformly embedded inside a square collagen wafer or “tile.”
- The tile measures 20 x 20 x 4 millimeters thick (0.79” x 0.79” x 0.16” thick).

What is a GammaTile?



- When the tiles are laid edge to edge, all the radioactive seeds are spaced *uniformly*, minimizing hot spots or cold spots.

End View

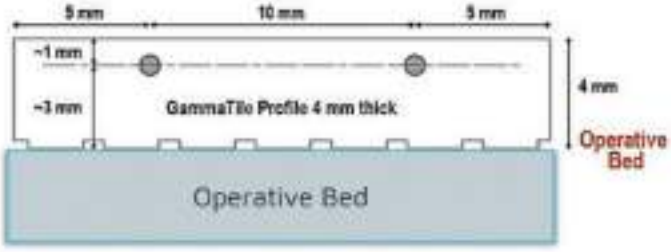


What is a GammaTile?

- To *prevent* the extremely high, damaging radiation dose of a seed *touching* normal tissue, 3 mm of wafer material separates a seed from any normal tissue.

Use of a GammaTile

End View



- GammaTiles are designed to deliver brachytherapy to the "operative bed" (the "bed" where a tumor used to lie) after a neurosurgeon has grossly removed a tumor.
- The purpose of the brachytherapy is to kill any microscopic or residual tumor cells at the edges of the operative bed.

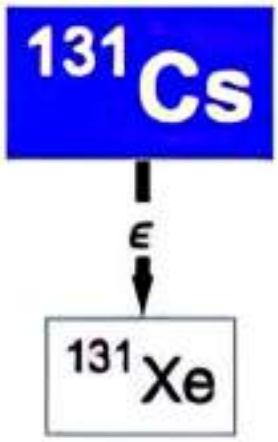
Use of a GammaTile

- At the time of surgery, after removing the visible tumor, the neurosurgeon lines (or "tiles") the edges of the "operative bed" with the GammaTiles.
- The collagen matrix of the tiles:
  - maintains the uniform spacing of the radioactive seeds.
  - adheres to the "operative bed" edges, preventing the seeds from migrating.
- The seeds stay in place permanently, becoming "scarred down" to the operative bed as the body absorbs the collagen matrix material.

Radiation from a GammaTile

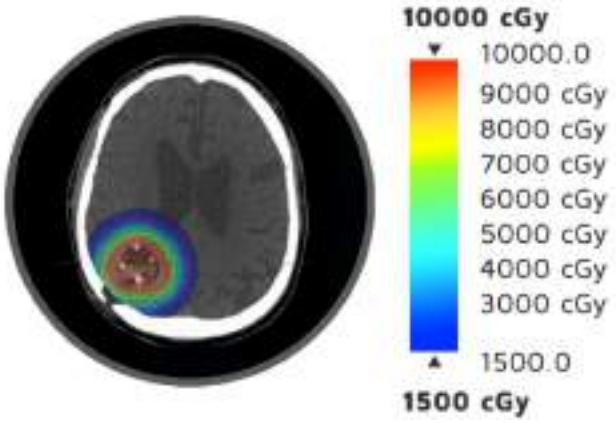
- Each radioactive seed in a GammaTile consists of the radioactive element Cesium 131 enclosed in a titanium capsule.
- "half life" of cesium 131 is 9.7 days:
  - Every 9.7 days, the strength of the radioactive seeds goes down by half.
  - After 100 days, the strength of the radioactive seeds is so low they are considered inert.

Radiation from a GammaTile



- The cesium 131 seeds emit ionizing radiation in the form of an x-ray (or "gamma ray") of energy 30.4 keV.
- The emitted gamma rays are absorbed as they pass through the tissues.
- Half of the gamma rays are absorbed as they pass through each 18 mm of tissue (that is, the amount of radiation falls off by half every 18 mm of tissue).

Radiation from a GammaTile



- GammaTiles are designed to deliver a total radiation dose of 6000 cGy at 5 mm from the surface of the implanted tiles.
  - >50% of dose delivered within 10 days.
  - 88% of dose delivered within 30 days.
- For comparison: when delivering external beam radiation to a resected glioma brain tumor bed, we give a total dose of 6000 cGy of radiation in 30 daily treatments (daily "spikes") of 200 cGy per day over 6 weeks.

Radiation from a GammaTile

- Radiation "exposure" from a typical GammaTile brachytherapy right after surgery:
  - One hour at 1 meter from a GammaTile patient's head: 1.5 mrem.
- For comparison:
  - One day of environmental background radiation: 0.85 mrem.
  - Dental x-ray series: 1.5 mrem.
  - Transatlantic flight: 2.5 mrem.
  - AP & lateral chest x-ray: 6.0 mrem.