The Role of Radiation Oncology in Cancer Care

Goals of this Lecture:

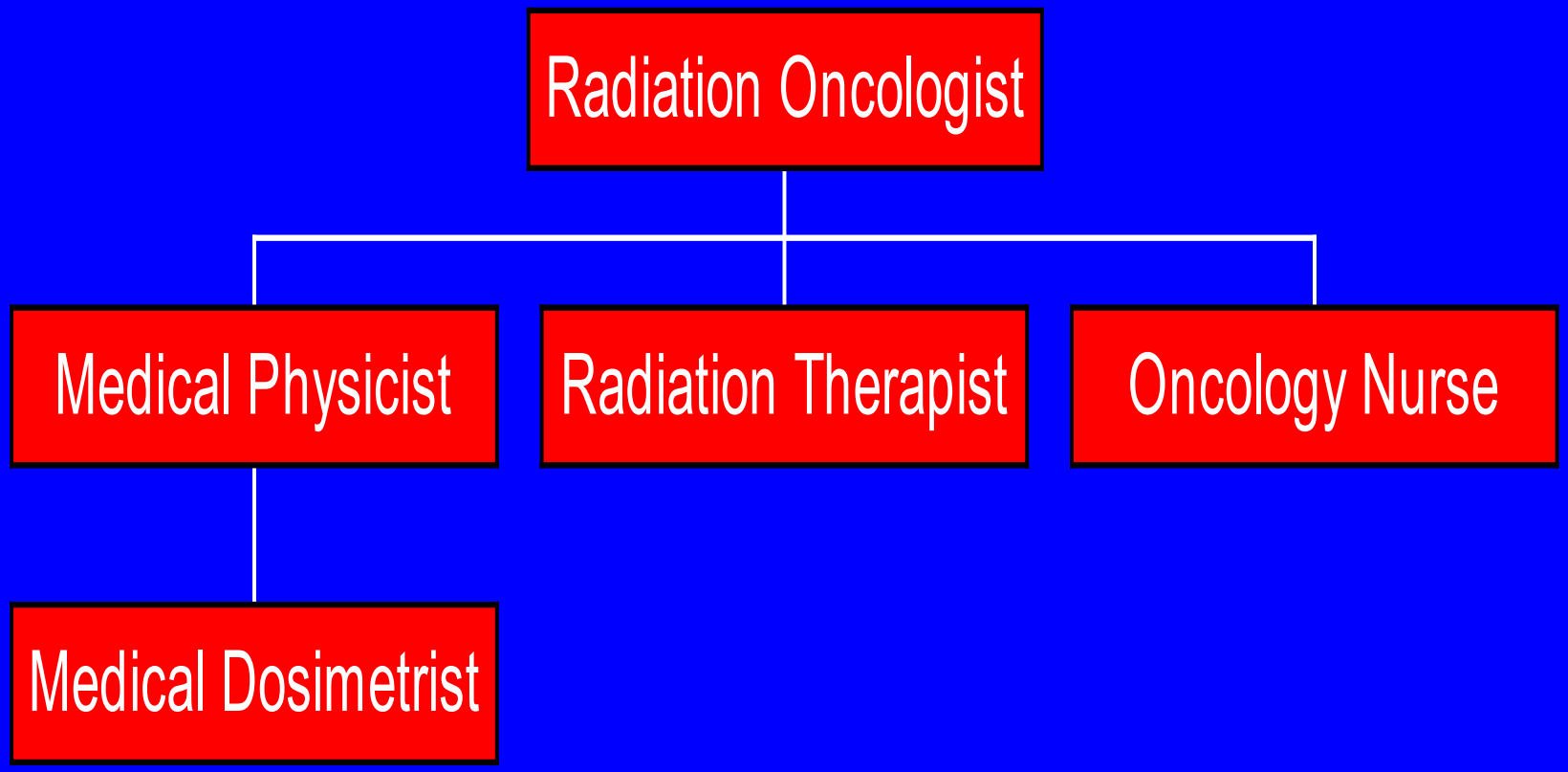
- What is therapeutic radiation
- How is it used in medicine
- What patients are candidates for radiation
- How is radiation planned and delivered
- What is a Radiation Oncologist

The Role of Radiation Oncology in Cancer Care

Lecture Outline

- The radiation oncology team
- Goals of radiation therapy
- The radiobiology of cancer
- Planning & delivering radiation treatment
- Case presentations
- Side-effects of radiation therapy

Radiation Therapy Team



Medical Physicist

Goals of Radiation Therapy

- Curative intent
  - Radiotherapy alone
  - Chemoradiation
  - Adjuvant radiation following surgery
  - Trimodality therapy
- Palliation

Curative: Radiotherapy Alone

- Prostate cancer
- Head & neck cancer
- Skin cancer
- Lung cancer
- Hodgkin's disease
- Benign disease: keloid, desmoid,heterotopic bone

Curative: Chemoradiation

- Organ preservation
  - Esophagus
  - Bladder cancer
  - Head & neck
- Stage III non small cell lung cancer
- Small cell lung cancer
- Cervical cancer
- Hodgkin's and NonHodgkin's lymphoma

Curative:adjuvant Radiotherapy (Microscopic Residual Disease)

- CNS malignancies
- Sarcoma
- Head & neck malignancies
- Endometrial cancer
- Cervical cancer
- Non small cell lung cancer

Curative: Trimodality Therapy

- Breast
- CNS: anaplastic oligodendrogliomas, GBM
- Lung: Pancoast tumors
- Stage III lung cancer: under investigation
- Esophagus: under investigation
- Pancreas, colon
- Rectal cancer

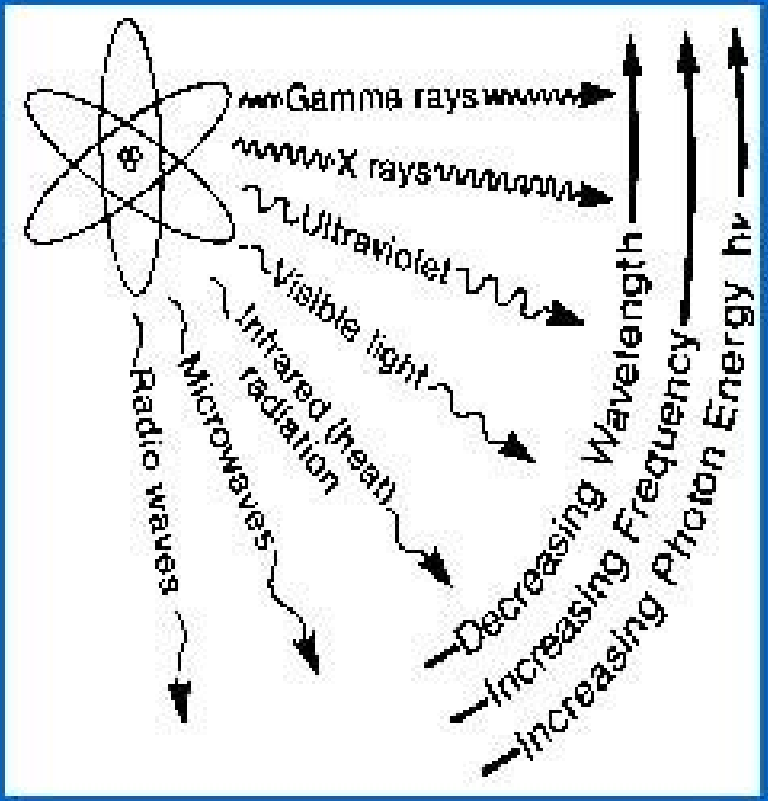
Palliation

- Goals:
  - Relieve pain
  - Prevent fracture
  - Change the manner of death to that which is more acceptable to the patient and her family
- All metastatic sites
- High dose palliation; Unresectable disease
- Retreatment

What is Radiation?

The emission and propagation of energy through space or a material medium by electromagnetic waves or particles.

The Electromagnetic Spectrum

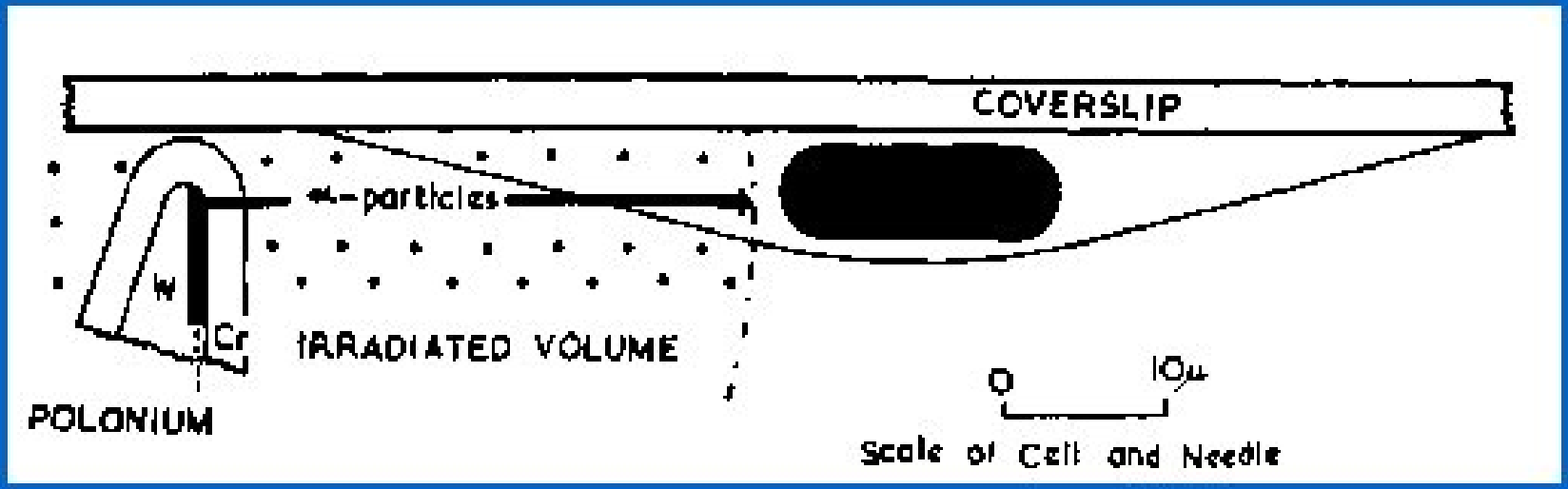


- Frequency X Wave Length = Speed of light
- Higher frequency means higher energy photons
- The higher the energy photon the more penetrating is the radiation

Radiobiology of Cancer

- DNA double strand breaks (DSB) are most important lesions caused by radiation
- Two DSB may result in cell kill at the time of cell division, mutation or carcinogenesis
- 6.9 Gy to kill 1 log of cells, therefore tumor with 10^9 cells would require 10 logs of cell kill to = 90% chance control = 69 Gy

DNA as THE Target



Irradiation of Chinese hamster cells by α particles from a polonium-tipped microneedle

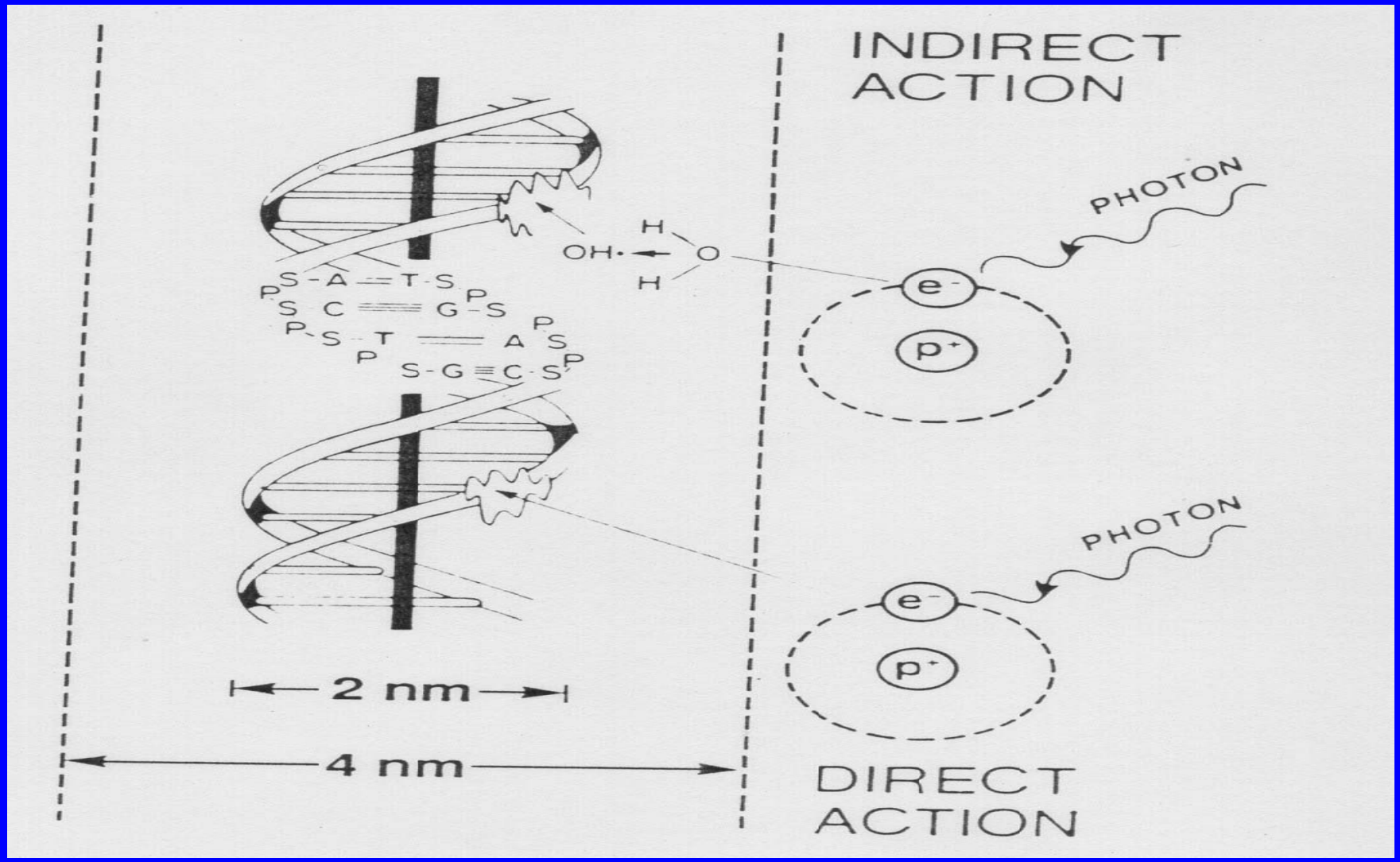
How Do the Cells Die?

Apoptotic Death

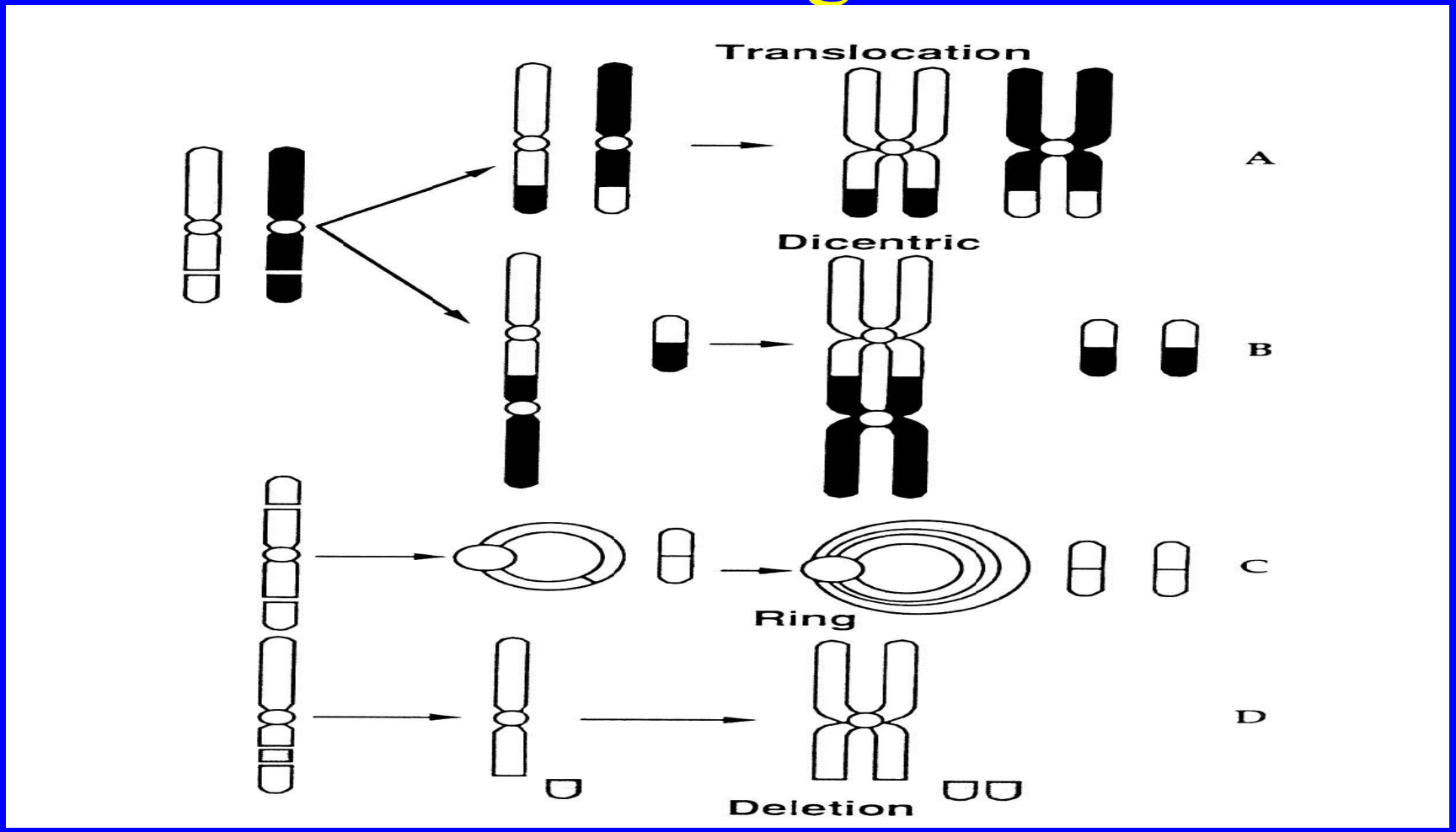
Vs.

Mitiotic Death

Radiation Inflicts DNA Damage



Radiation Induced Chromosome Damage



The "4 R's" of Radiation Biology

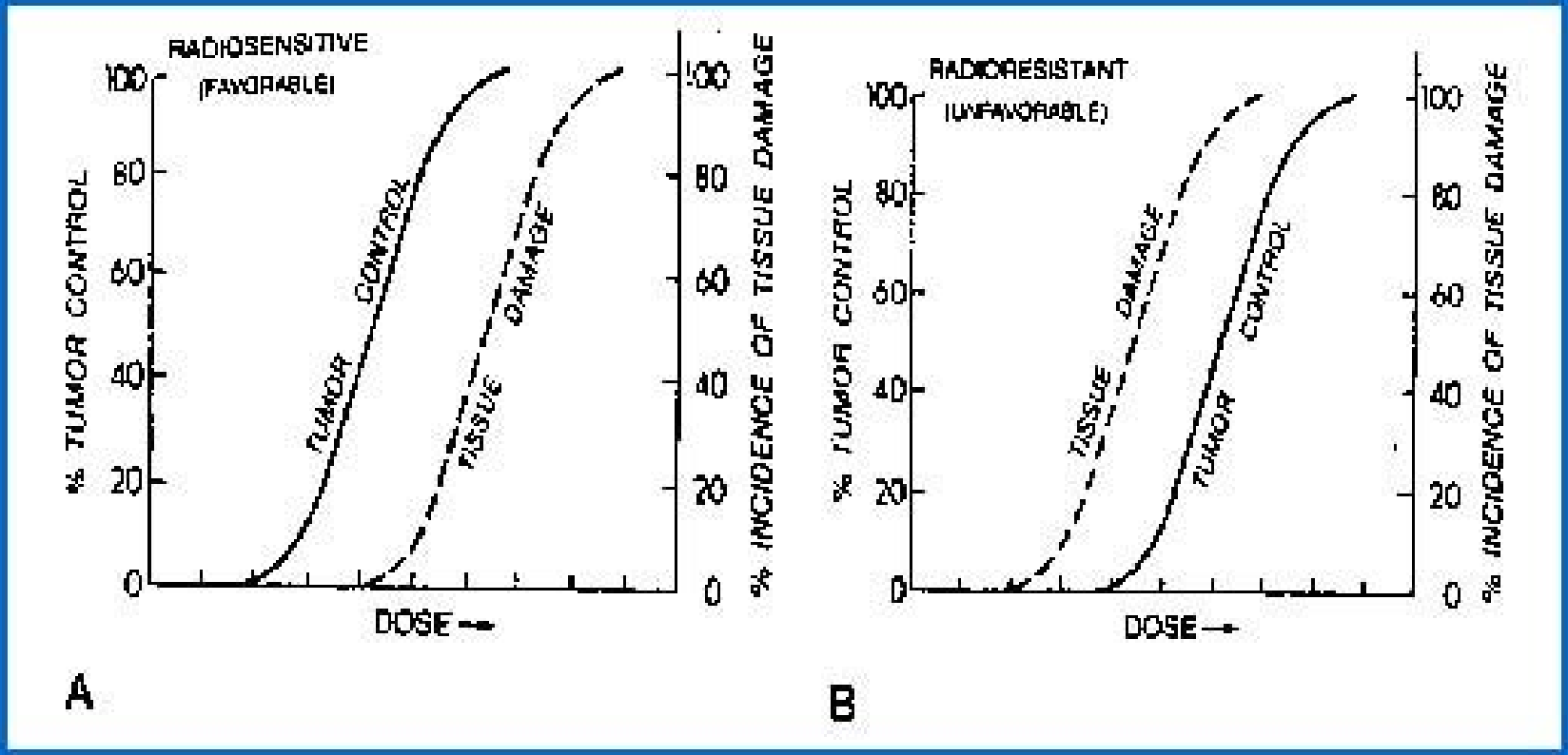
Repair

Reassortment

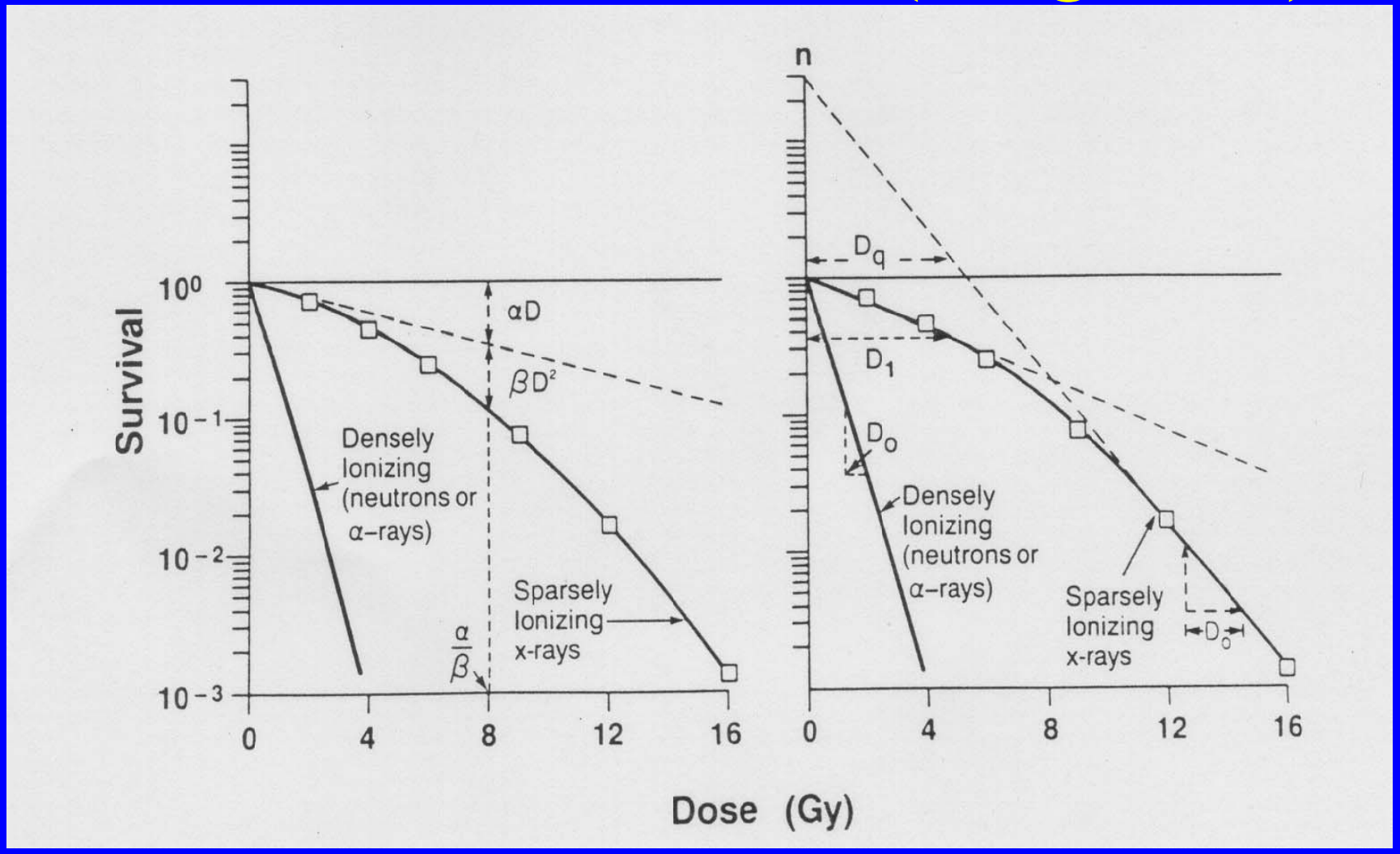
Repopulation

Reoxygenation

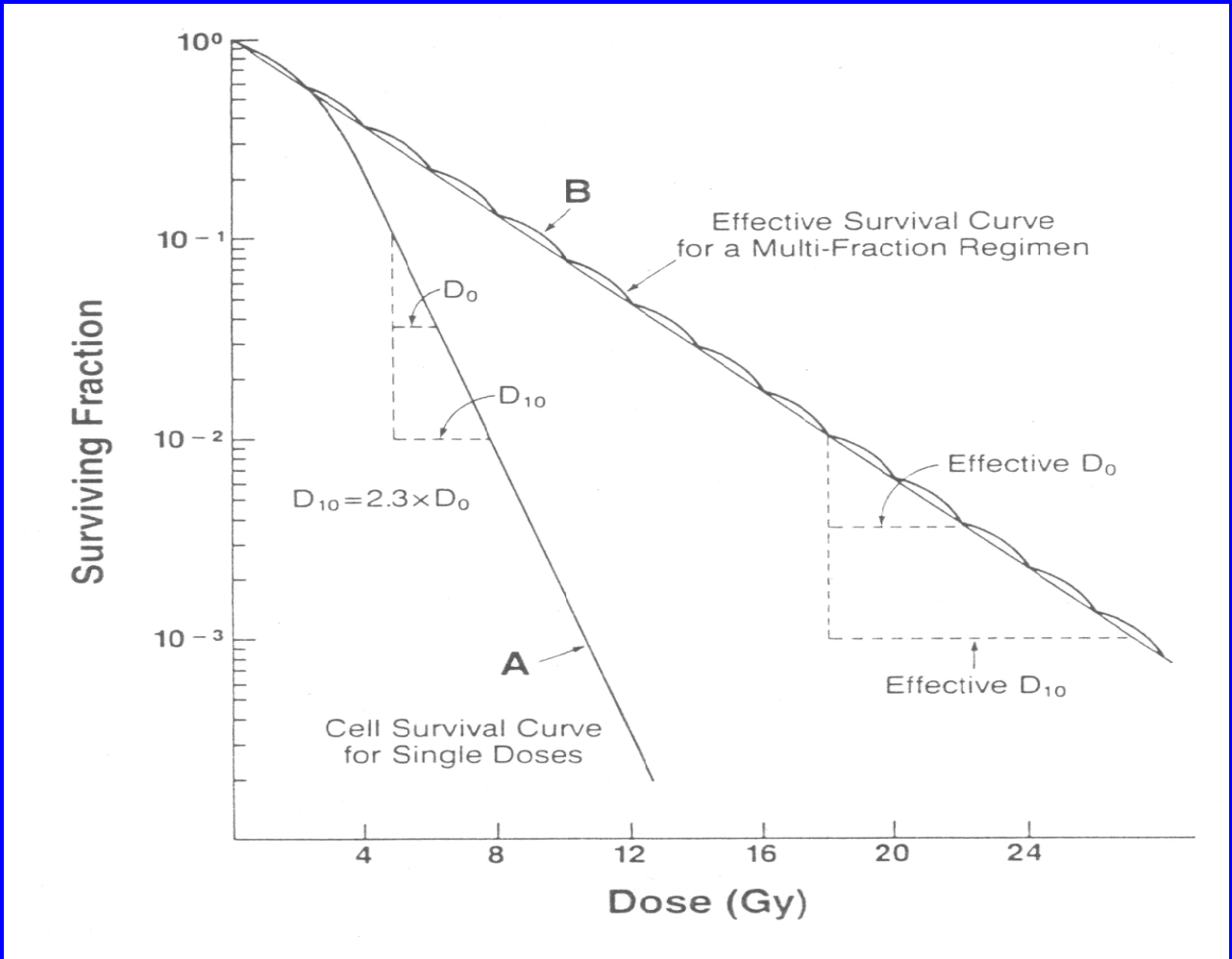
Therapeutic Ratio



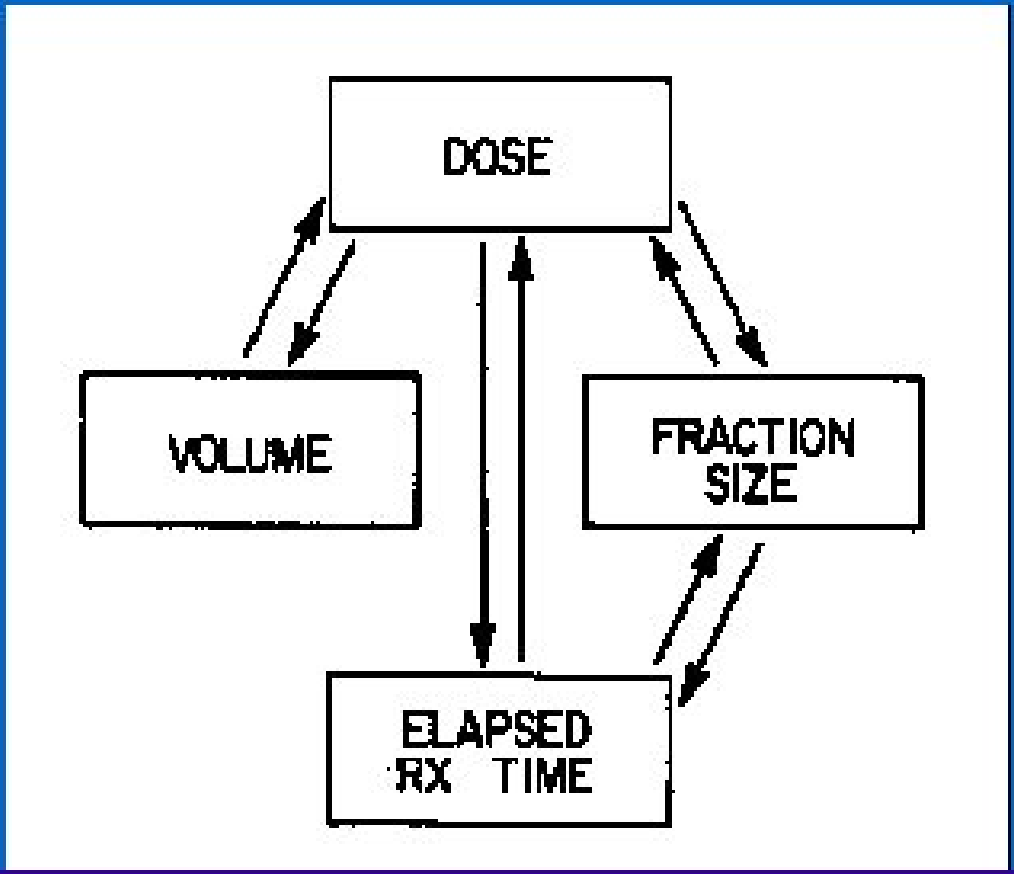
Cell Survival Curves (Single Fx)



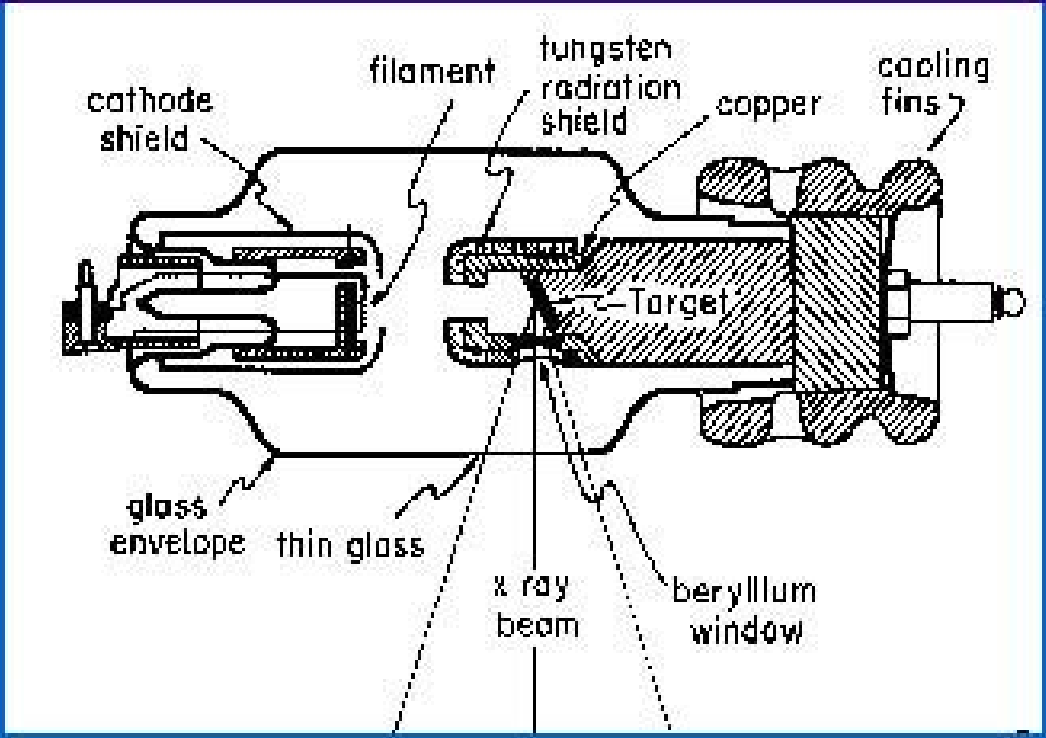
Survival Curve Multiple Fraction



Predicting Normal Tissue Reactions

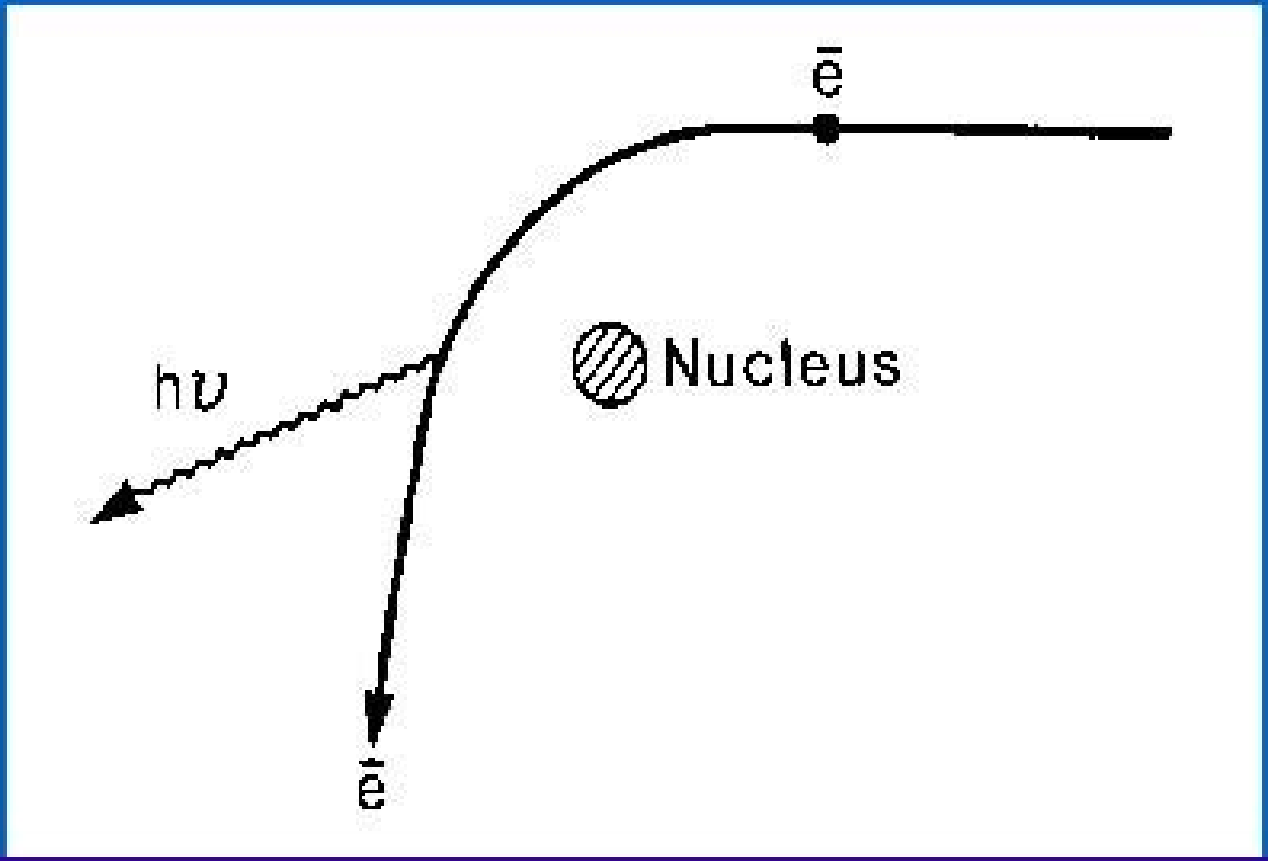


How X-Rays Are Made

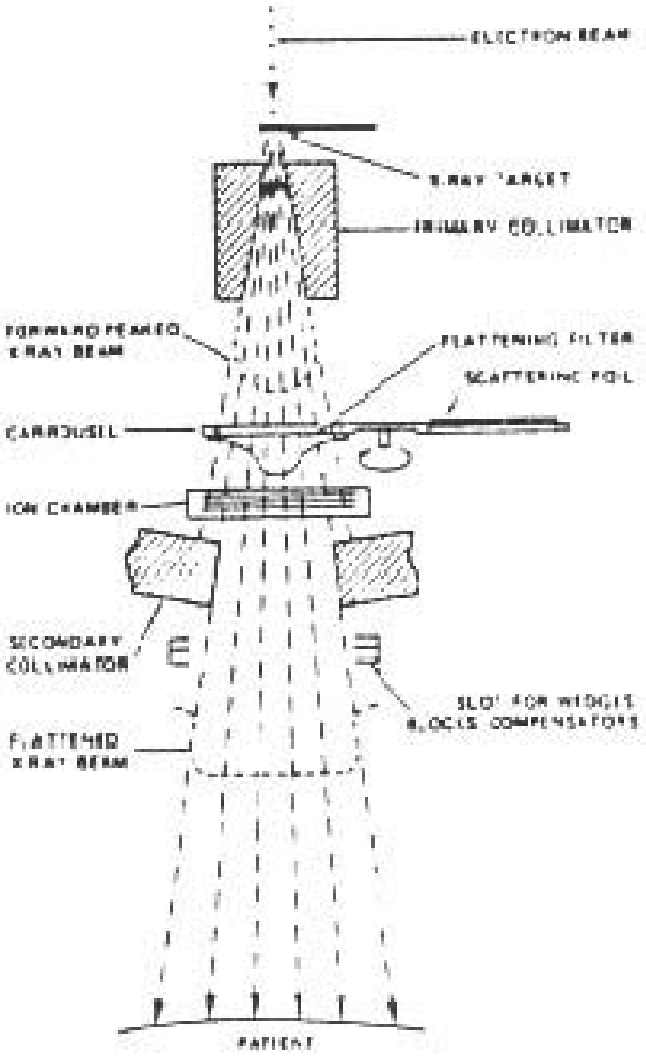


Example of a Hooded Anode therapy tube

Bremsstrahlung X-Rays

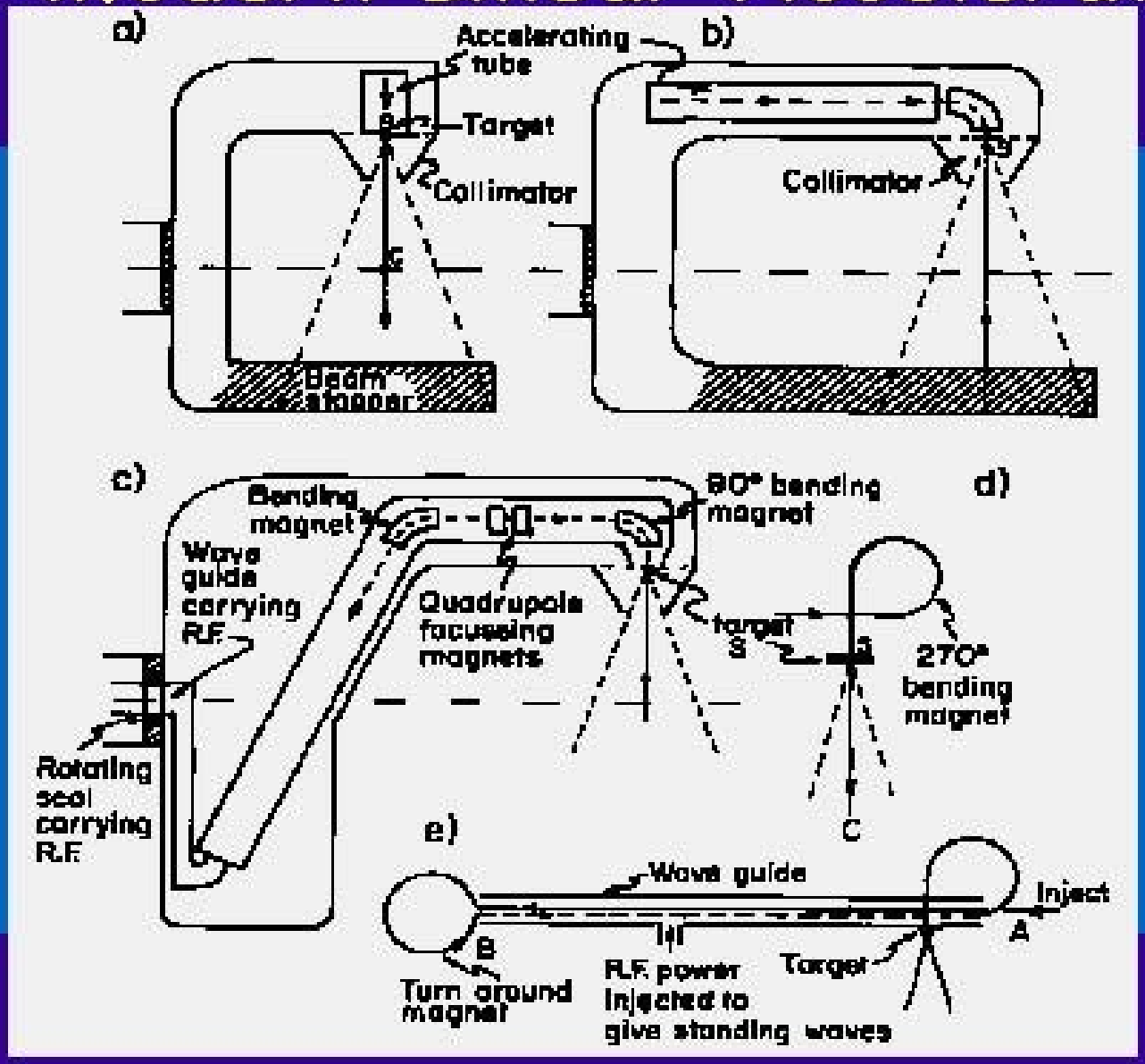


Therapeutic X-ray Production

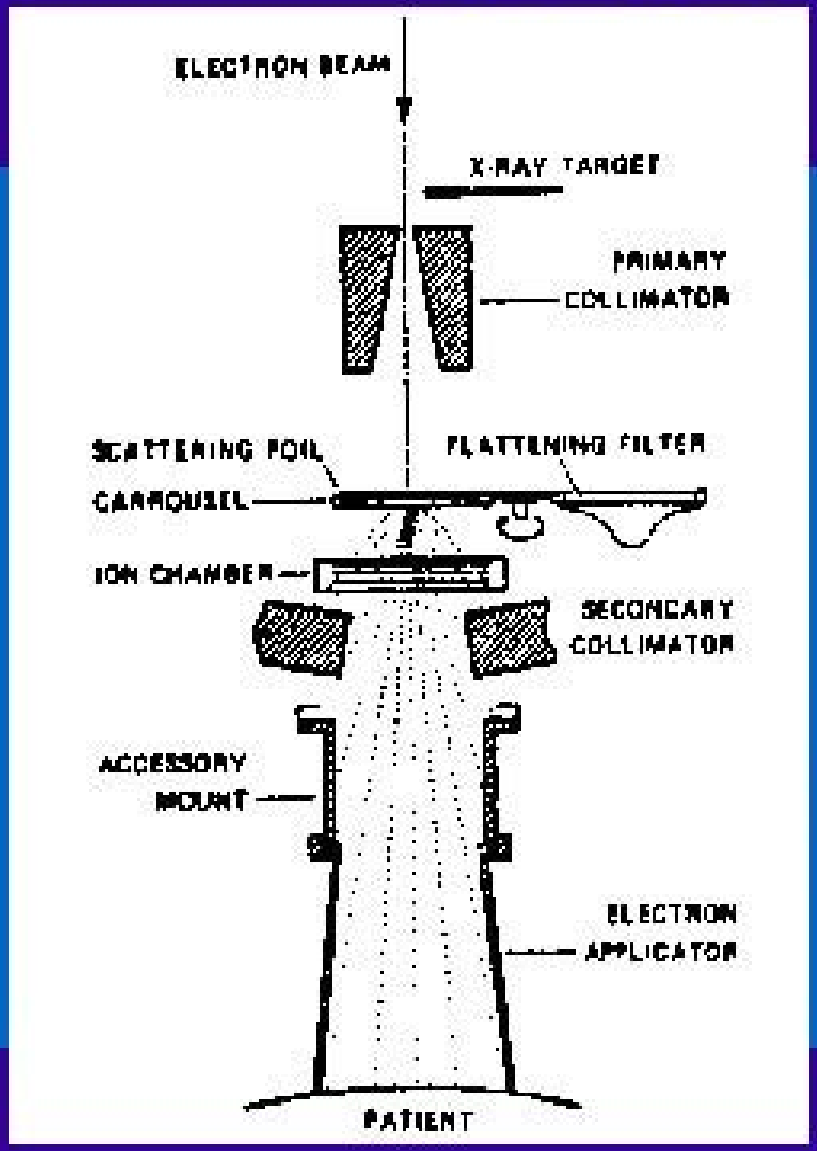


- The forward traveling X-rays are first shaped by 2 sets of very thick tungsten collimators
- The second set of mobile jaws establishes the size of the field projected and have a transmission factor of ~ 1%

The Modern Linear Accelerator

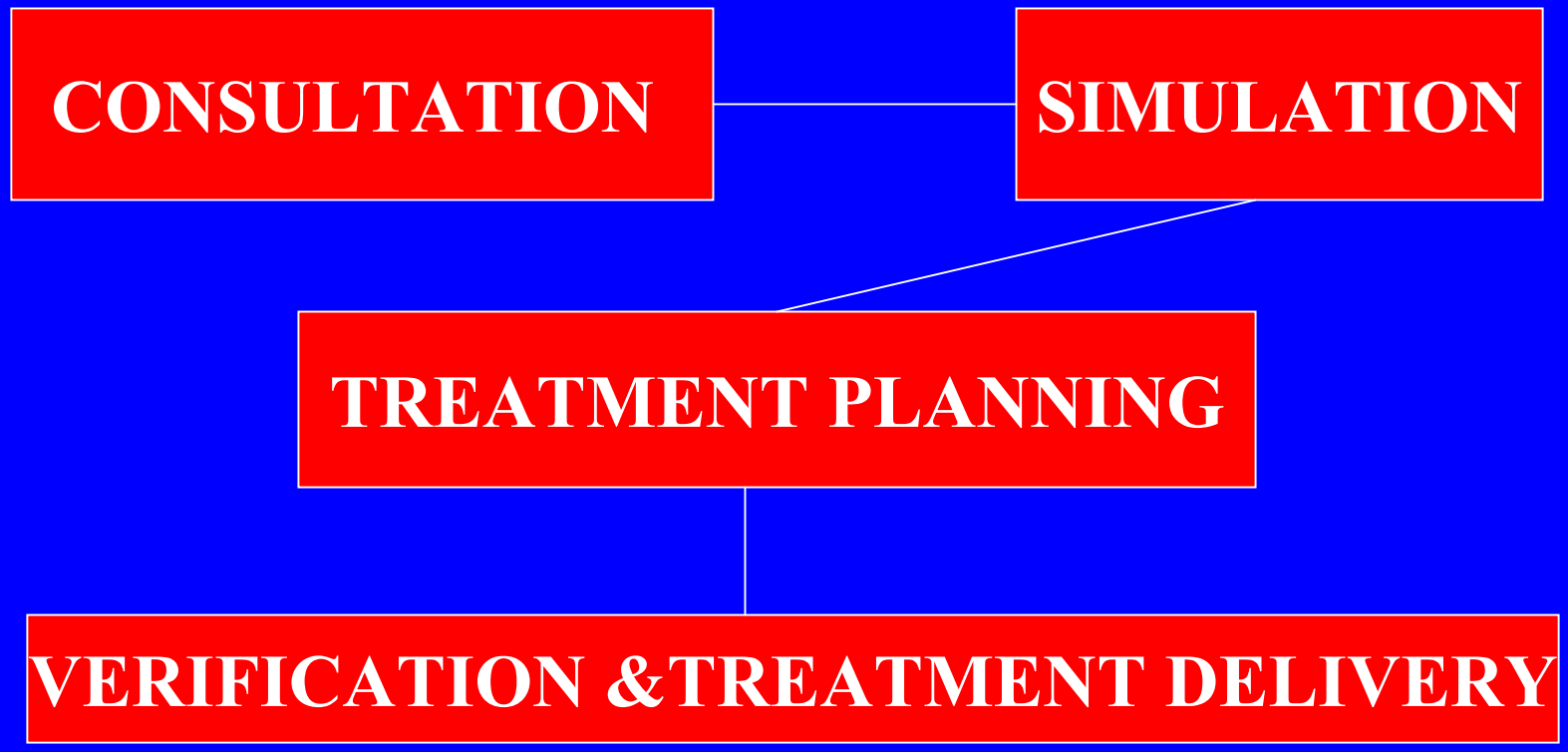


Electron Beam



- The electron beam is created by removing the target from the path of the accelerated electrons
- A scattering foil is used to "spread out" the very narrow electron stream

Planning and Delivering Treatment

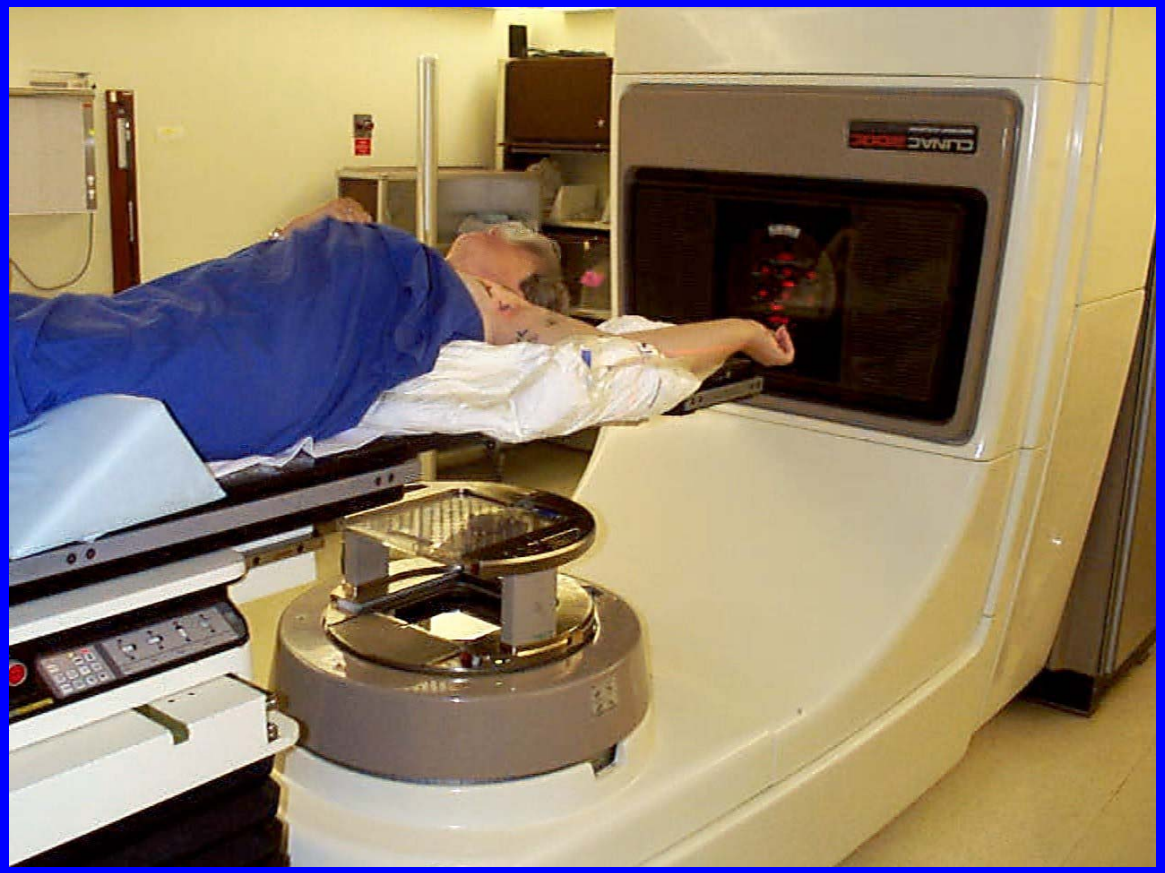


Simulation (60-120 Minutes)

- Immobilization
- Field definition
- Obtain films of ports to be used
- CT scan if 3-D treatment planning
- Mark patient
- Obtain dosimetric information/ contour

Simulator

Immobilization



Field Definition

Treatment Planning (Minutes to Hours)

- Define the target volume
- Identify critical structures
- Design blocks
- Prescribe dose
- Plan beam arrangement and energies to best cover target and avoid critical structures
- Calculate dose

Treatment Planning

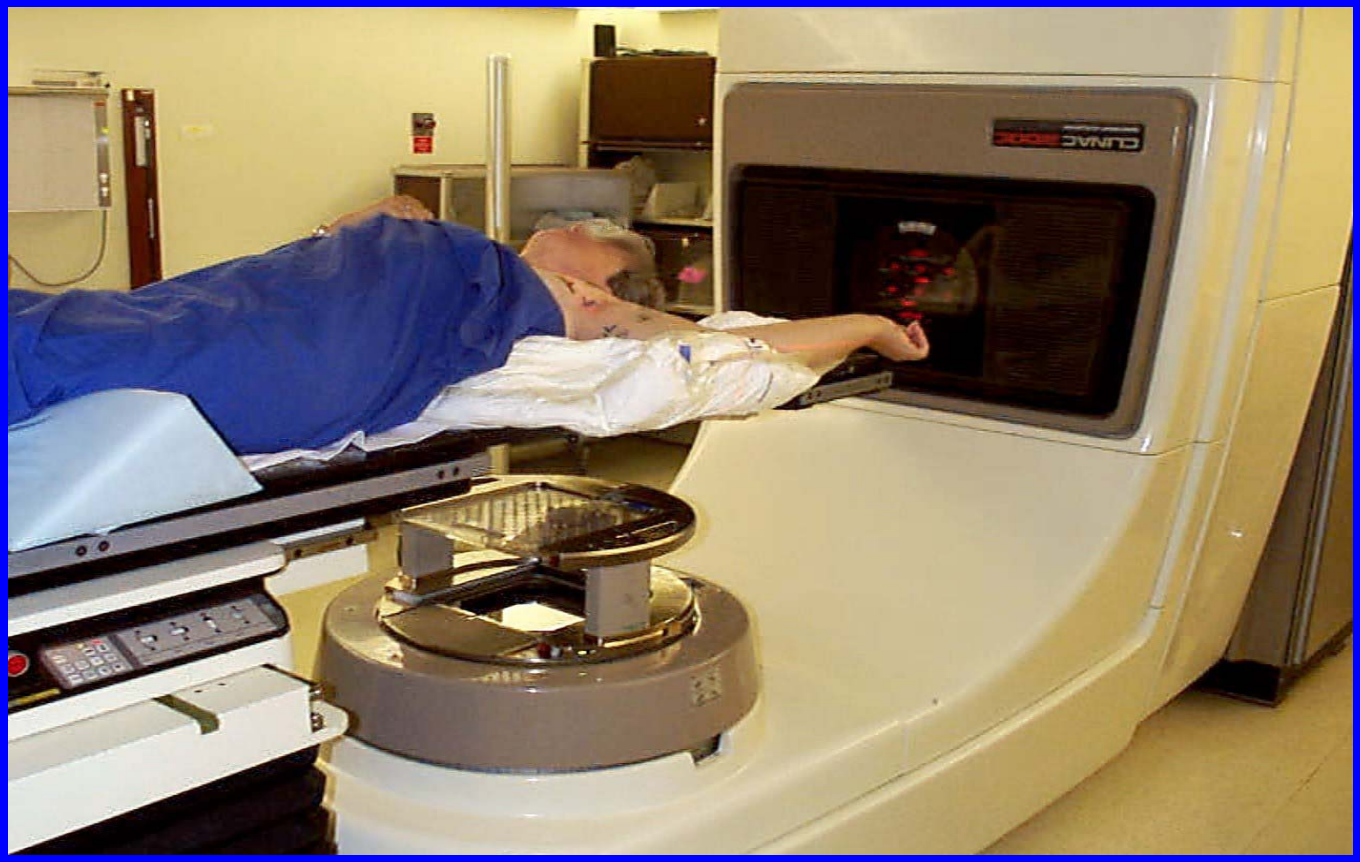
Designer Blocks

Verification & Delivery (10 Minutes)

- Reproduce set up
- Verify treatment plan and parameters
- Obtain port films to document treatment area
- Deliver treatment

Verify Set Up

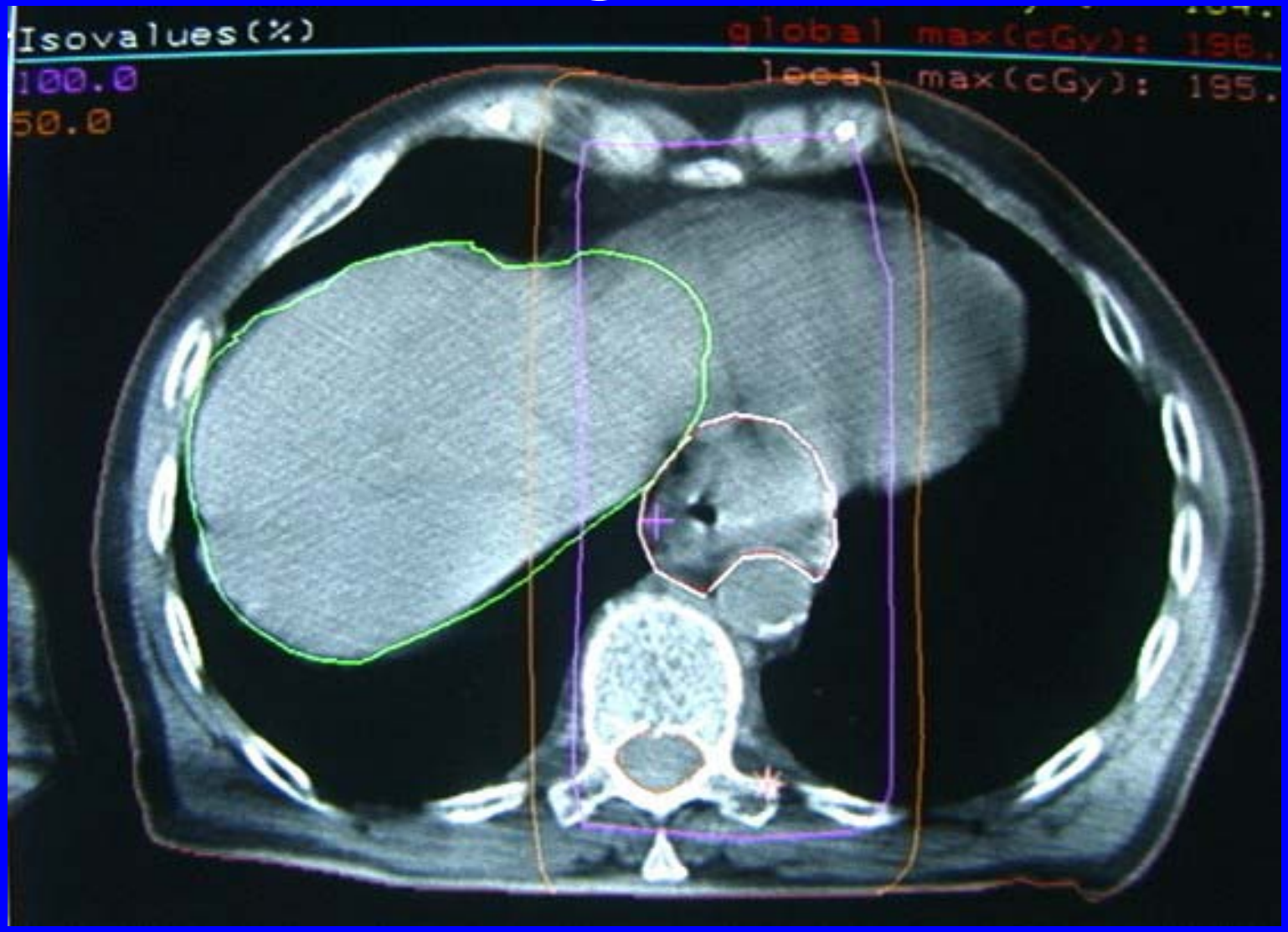
Deliver Treatment



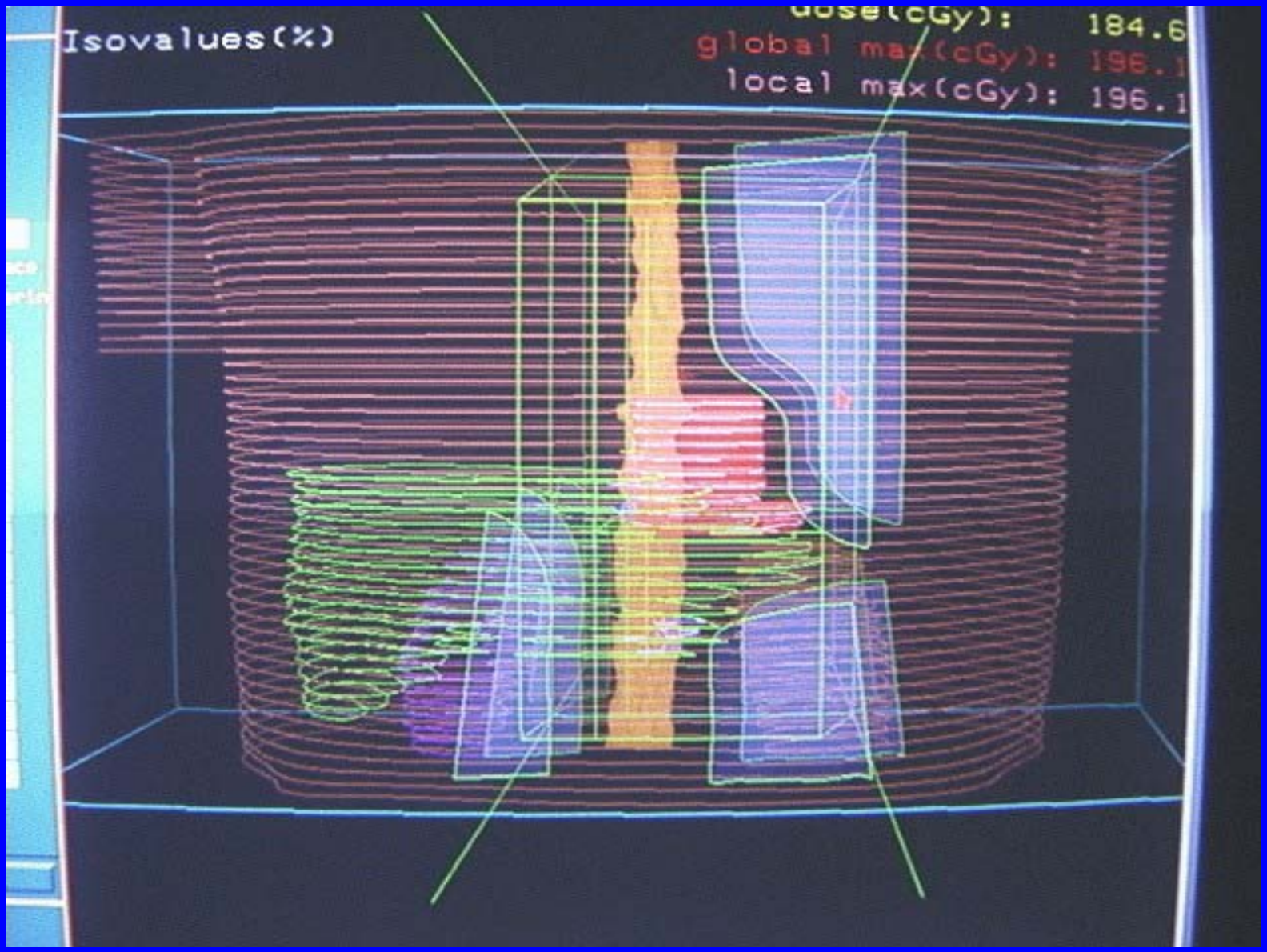
Case: Esophageal Carcinoma

- 71 y.O. Male with 3 month hx of dysphagia. Evaluation with esophagoscopy, CT scan, barium swallow and esophageal ultrasound revealed a T3N1 adenocarcinoma of the esophagus.
- Plan: chemoradiation perhaps followed by surgery. Taxol/carboplatin/5fu + 50 Gy.

Esophageal Adenocarcinoma: Planning CT Scan

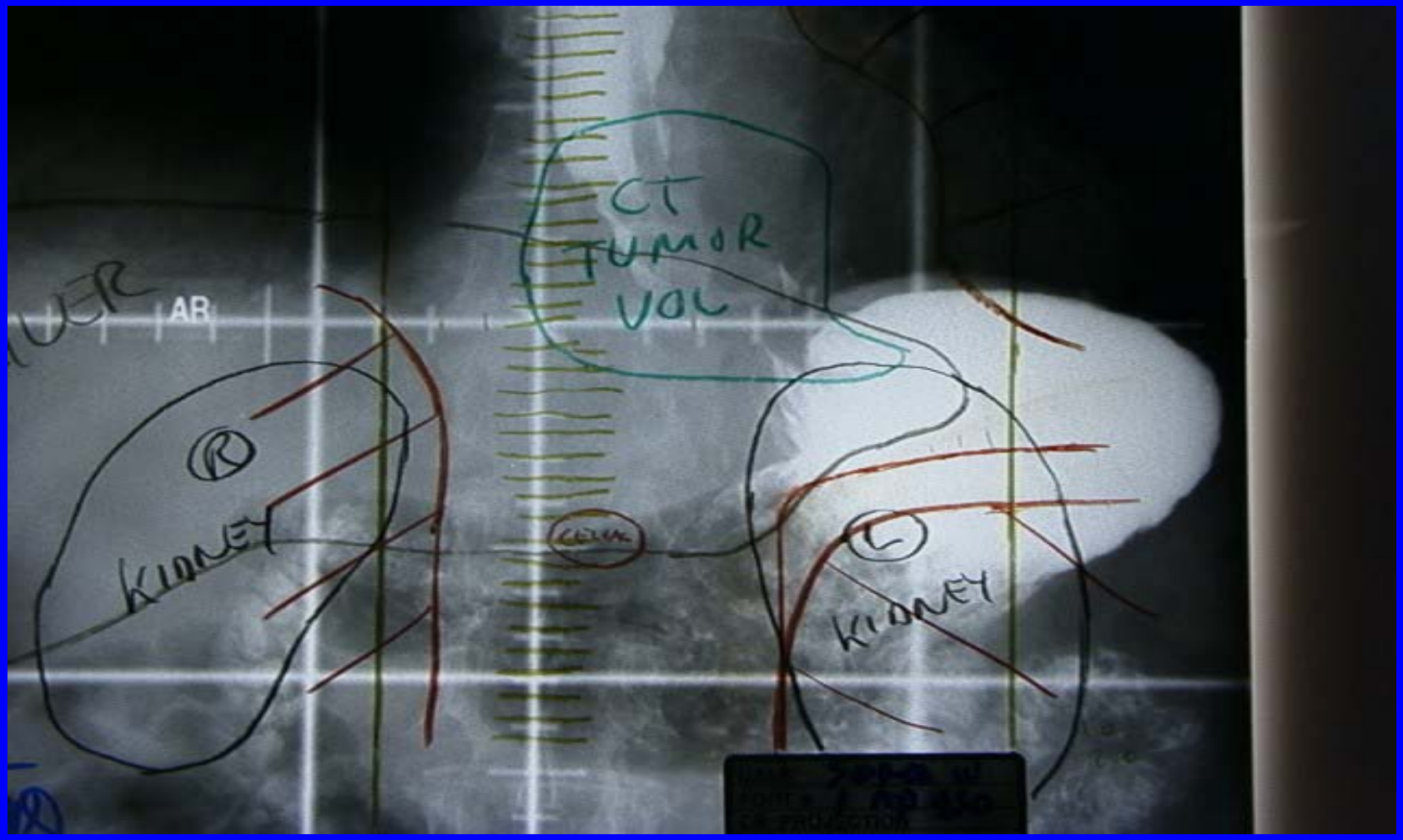


Esophagus – Multiple Plane View

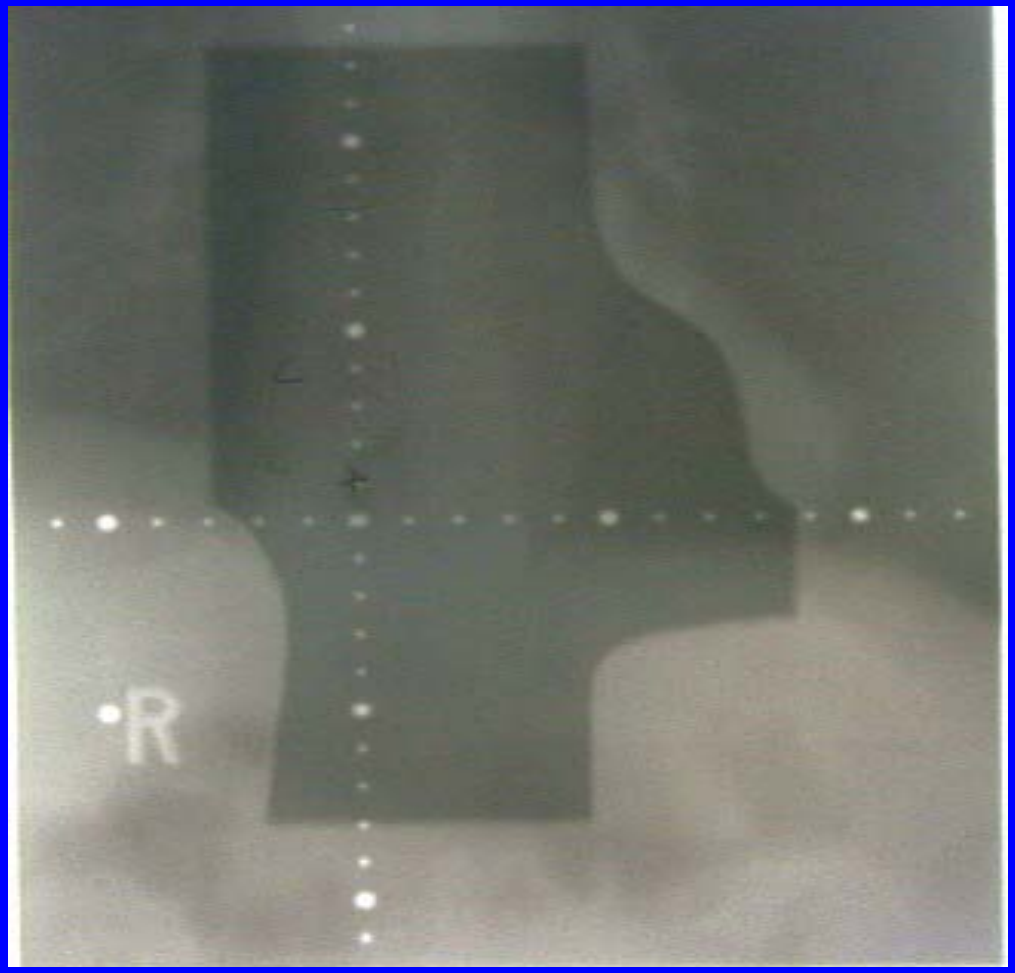


Esophageal Cancer: Dose Volume Histogram for Liver

Simulation Film for Esophageal Cancer



Port Film
Treatment of Esophageal Cancer

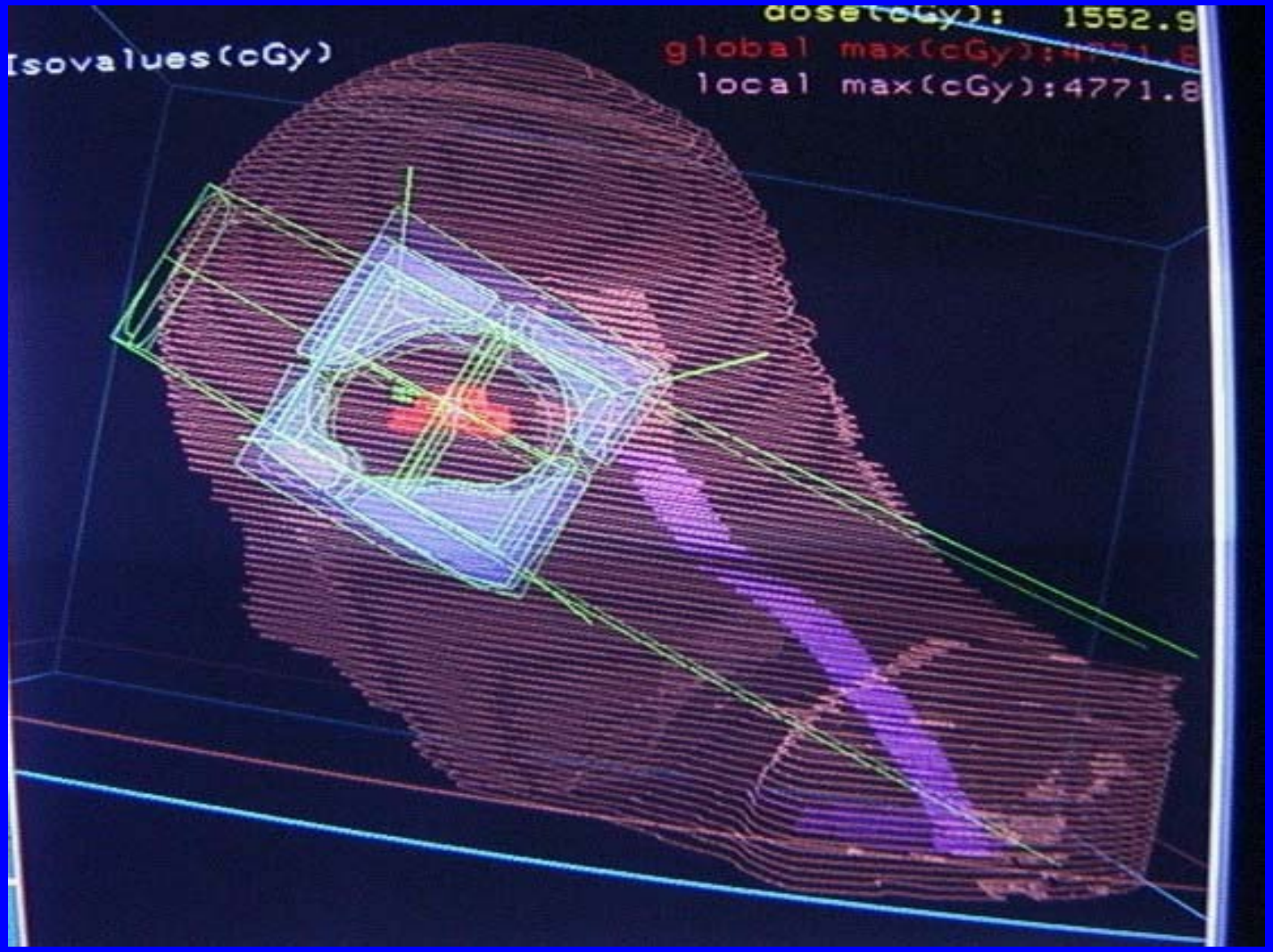


Case: Pituitary Macroadenoma

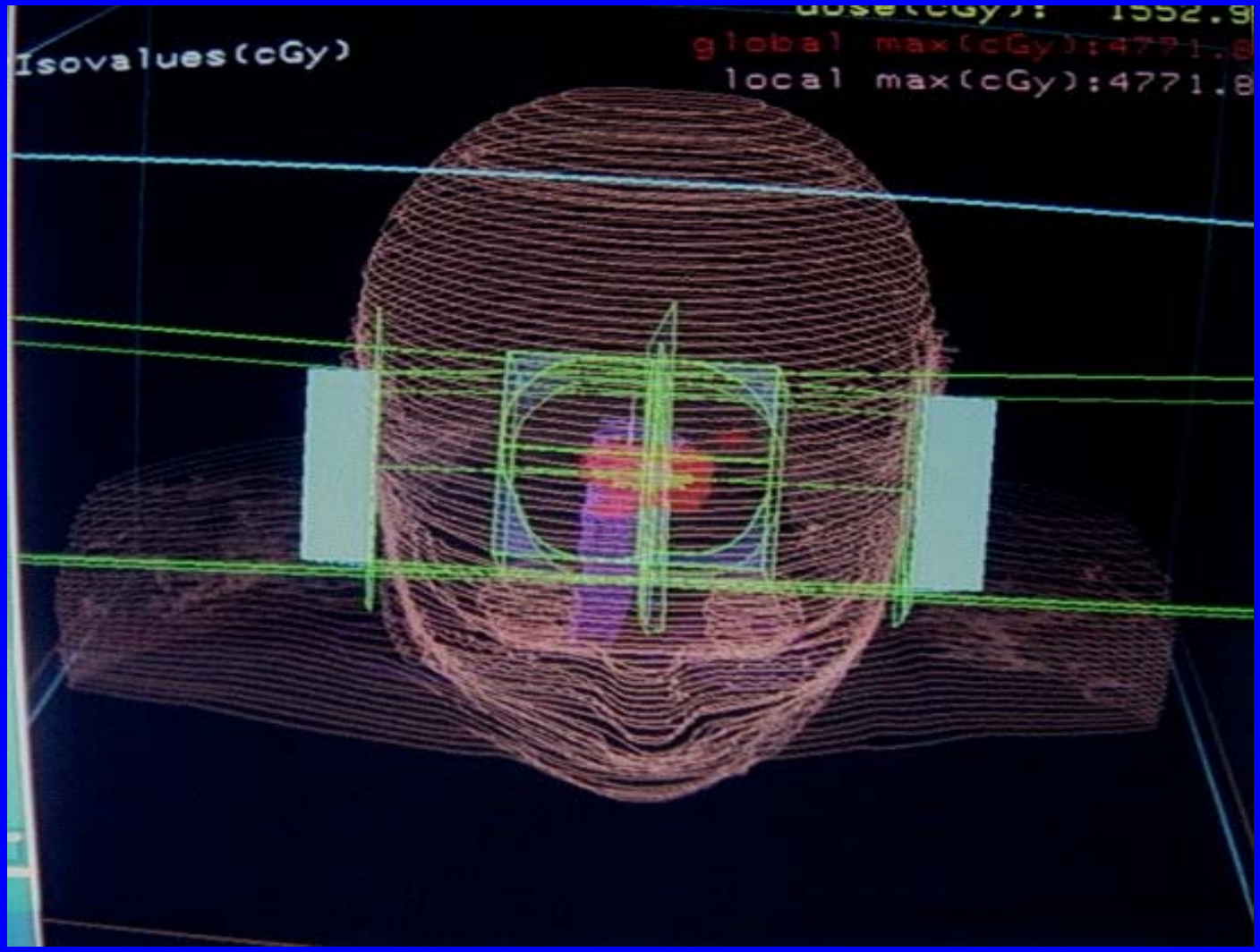
- 81 y.O. Male s/p partial resection of pituitary tumor in 1991. Vision stable. Regular CT follow up of tumor revealed progression and patient developed new onset headaches.
- Referred for definitive treatment of tumor, too large for complete surgical resection.
- Plan: 45 Gy to region over 5 weeks.

Pituitary Macroadenoma: Axial CT Scan

Pituitary Adenoma – 3 Field Technique



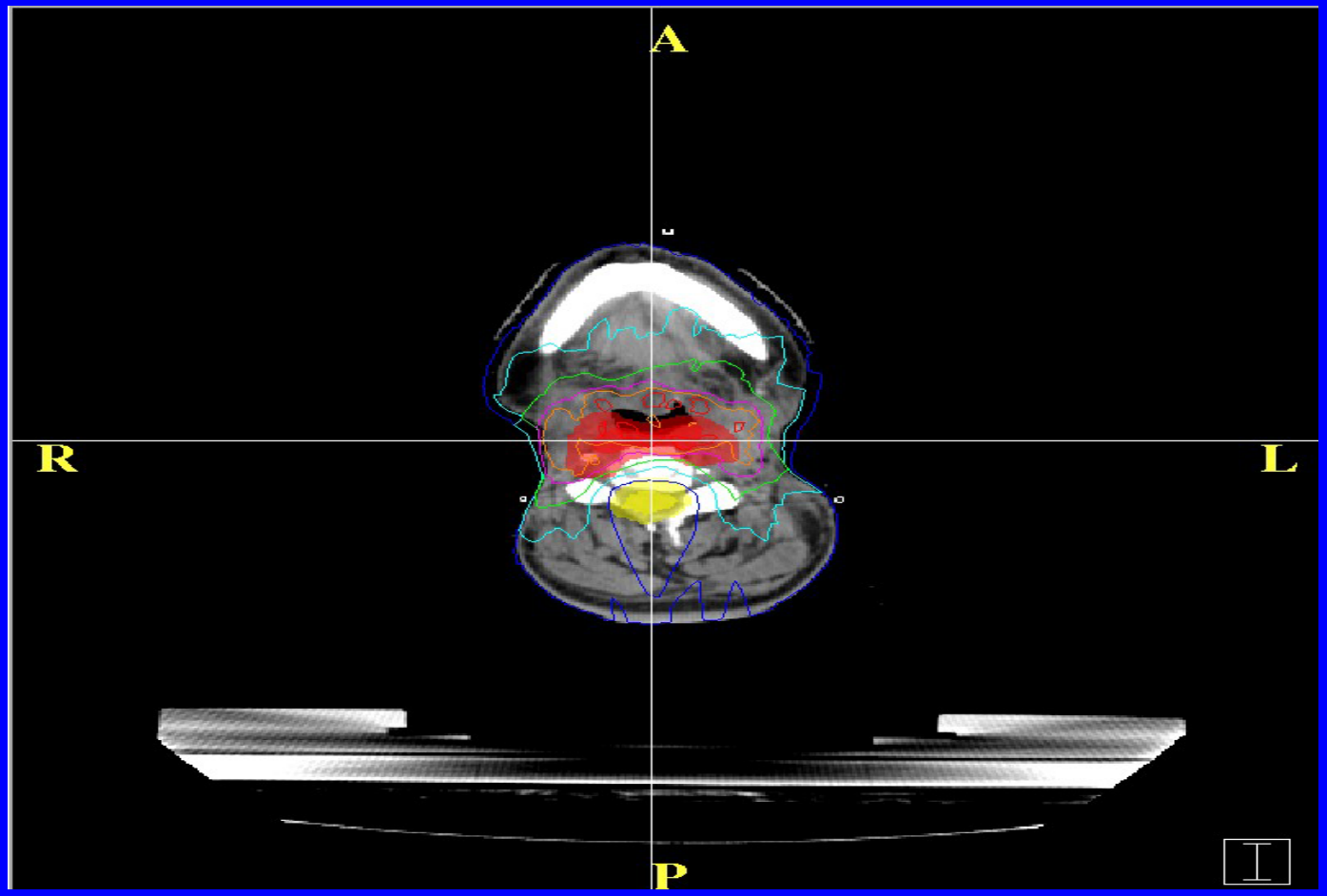
Pituitary Adenoma – 3 Field Technique



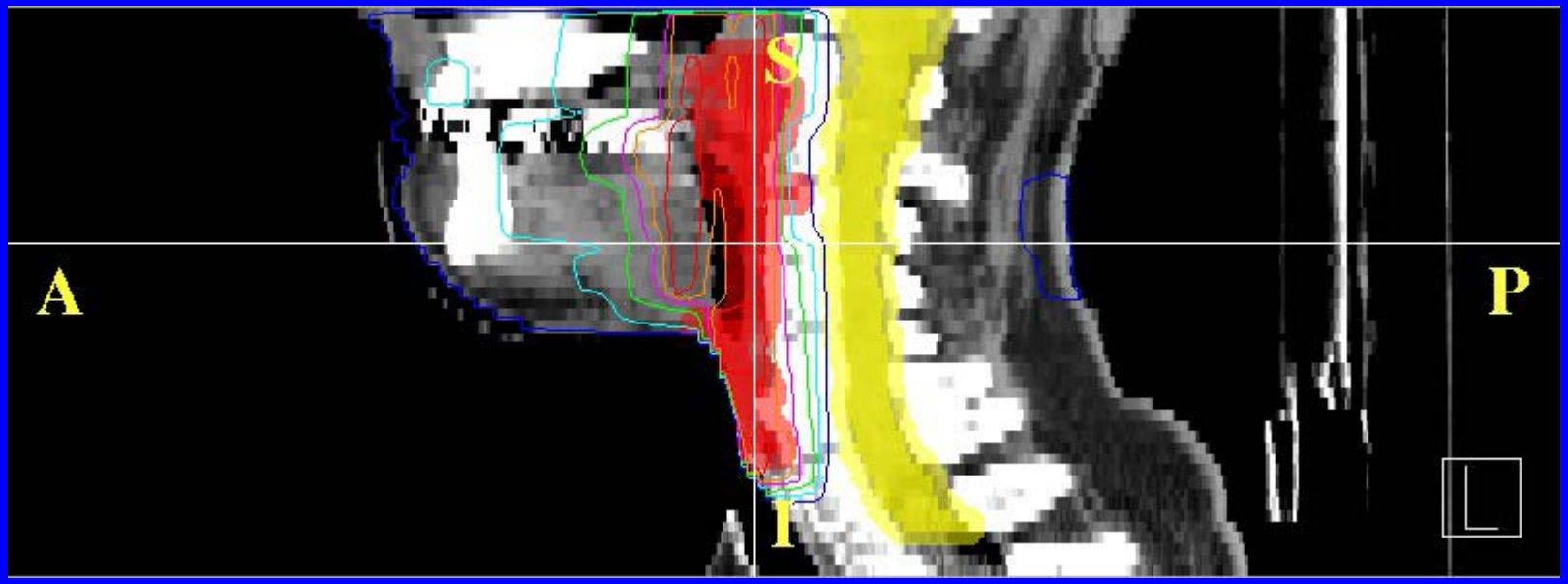
Case: Recurrent Oropharyngeal Cancer

- 62 y.O. Male s/p XRT to hypopharyngeal tumor in 1961. Recurred in mid 80s and underwent laryngectomy and bilateral radical neck dissections.
- Now with recurrence on posterior pharyngeal wall, extensive.
- Plan: concurrent chemoradiation 40 Gy with 5FU and cisplatin.

Recurrent Oropharyngeal Cancer: Treatment With IMRT



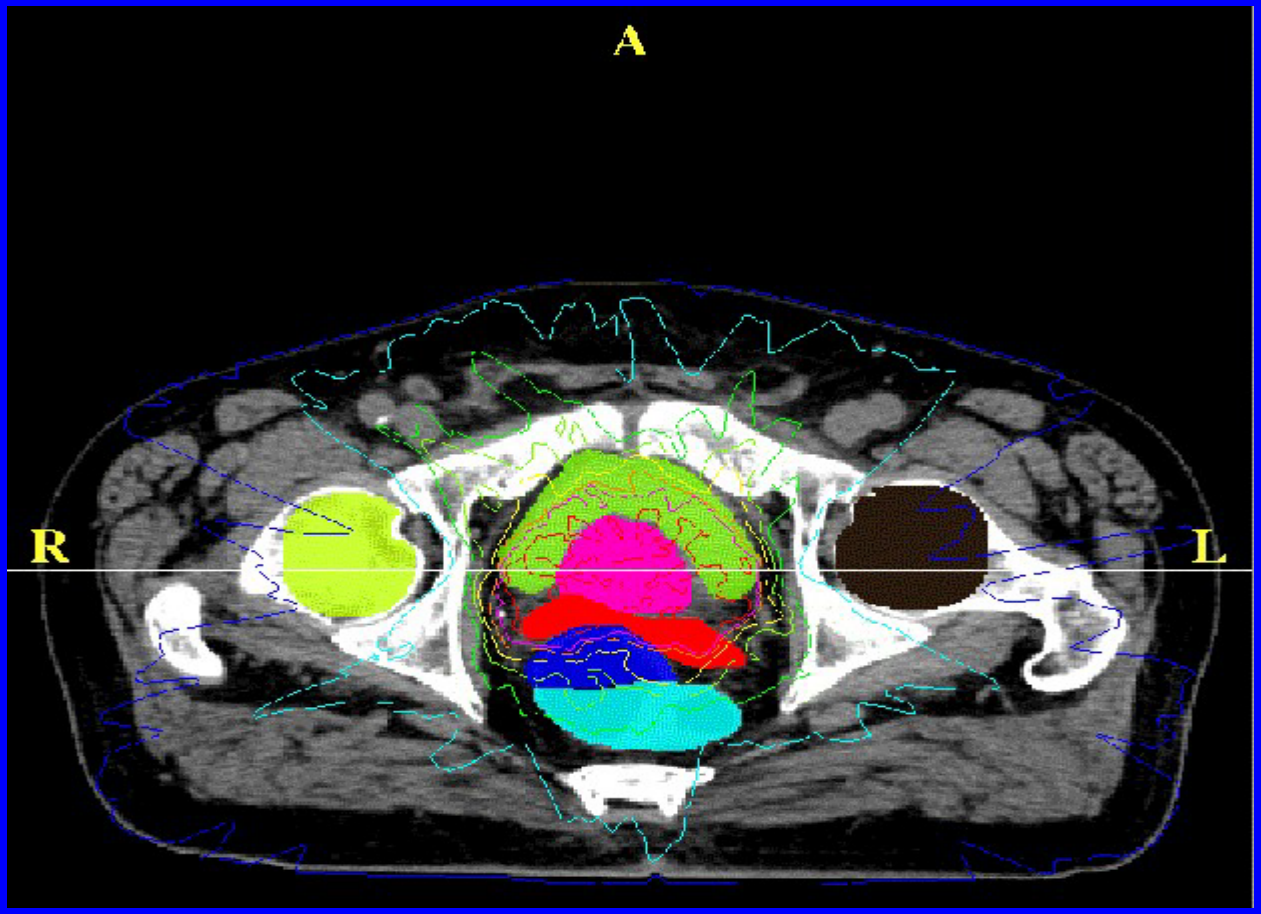
Recurrent Oropharyngeal Cancer: Treatment With IMRT



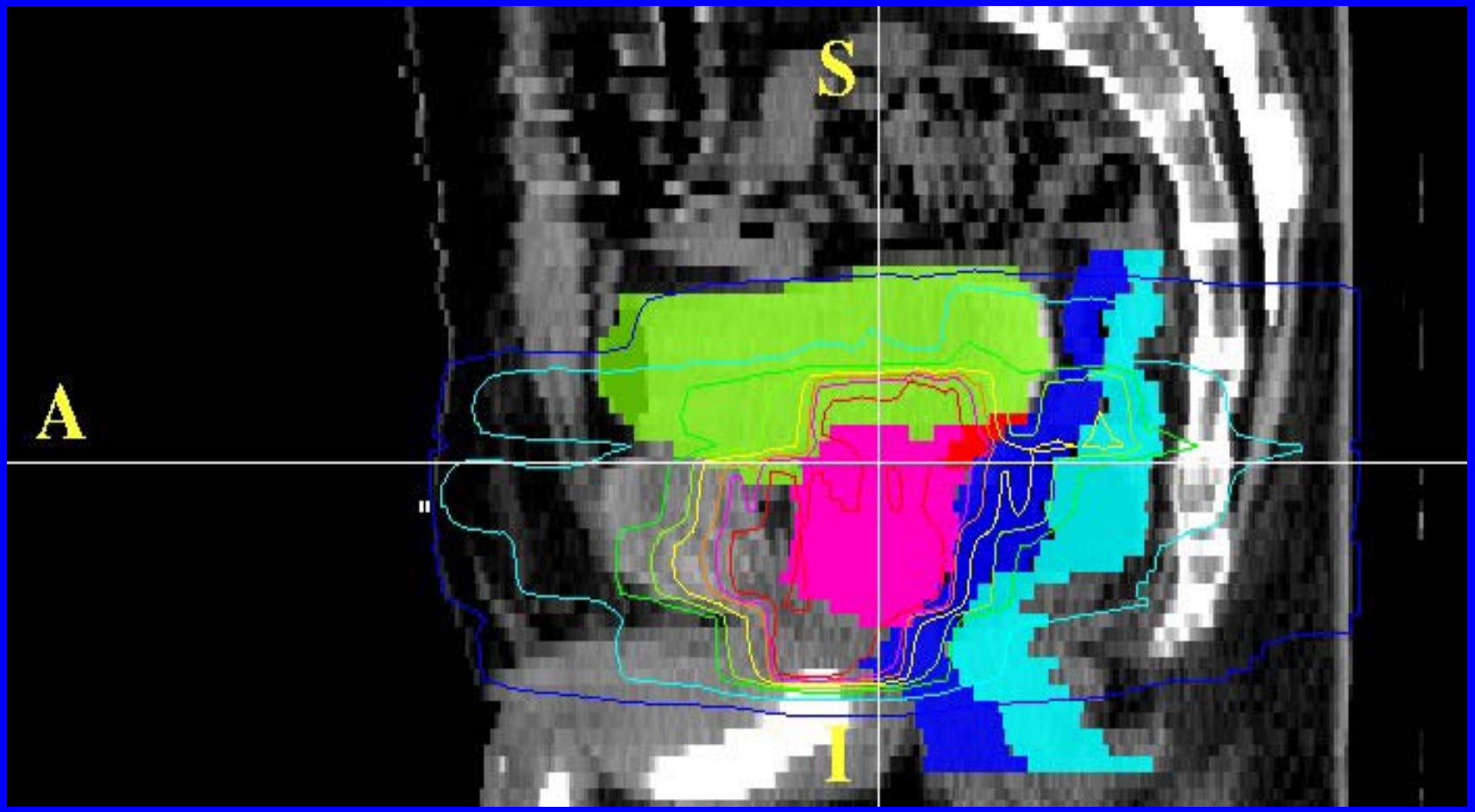
Case: Prostate Cancer

- 63 y.O. Male with t1cn0m0 adenocarcinoma of the prostate, present in 1 of 6 cores, Gleason sum 5 (3+2) with presenting PSA of 4.3.
- Options of surgery and radiation discussed.
- Radiation options: EBRT, IMRT, brachytherapy.

IMRT Treatment Plan for Prostate Cancer



IMRT Treatment Plan for Prostate Cancer: Sagital Image



Statistics for IMRT Prostate Cancer Treatment Plan

Desired Target Dose

Deliver 22 fractions over 22 days (inclusive)

Minimum dose to	Seminal vesicles -	26.00	Gy,	1.18	Gy per fraction
Minimum dose to	Prostate bed - target	44.00	Gy,	2.00	Gy per fraction

Planning Parameters: Dr. Pollock: Male Prostate

Total Delivered Dose

Deliver Prostate bed - target 44.00 Gy total 2.00 Gy per fraction

CTV PTV

Total Accumulated Dose

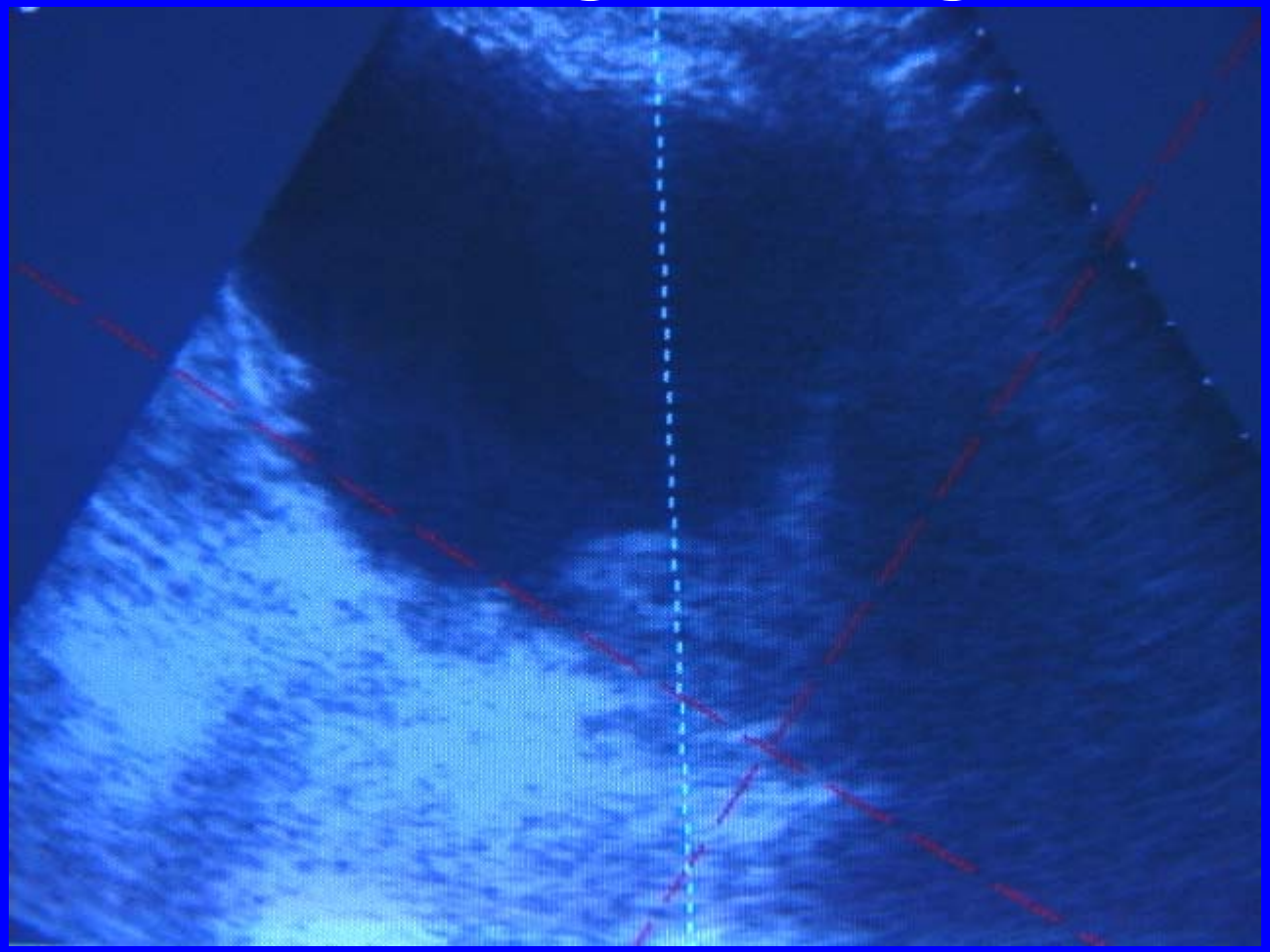
Deliver 44.00 Gy at 83.8 % of maximum

(minimum dose to Prostate bed - target PTV, 32.83 Gy, is 62.5% of maximum)

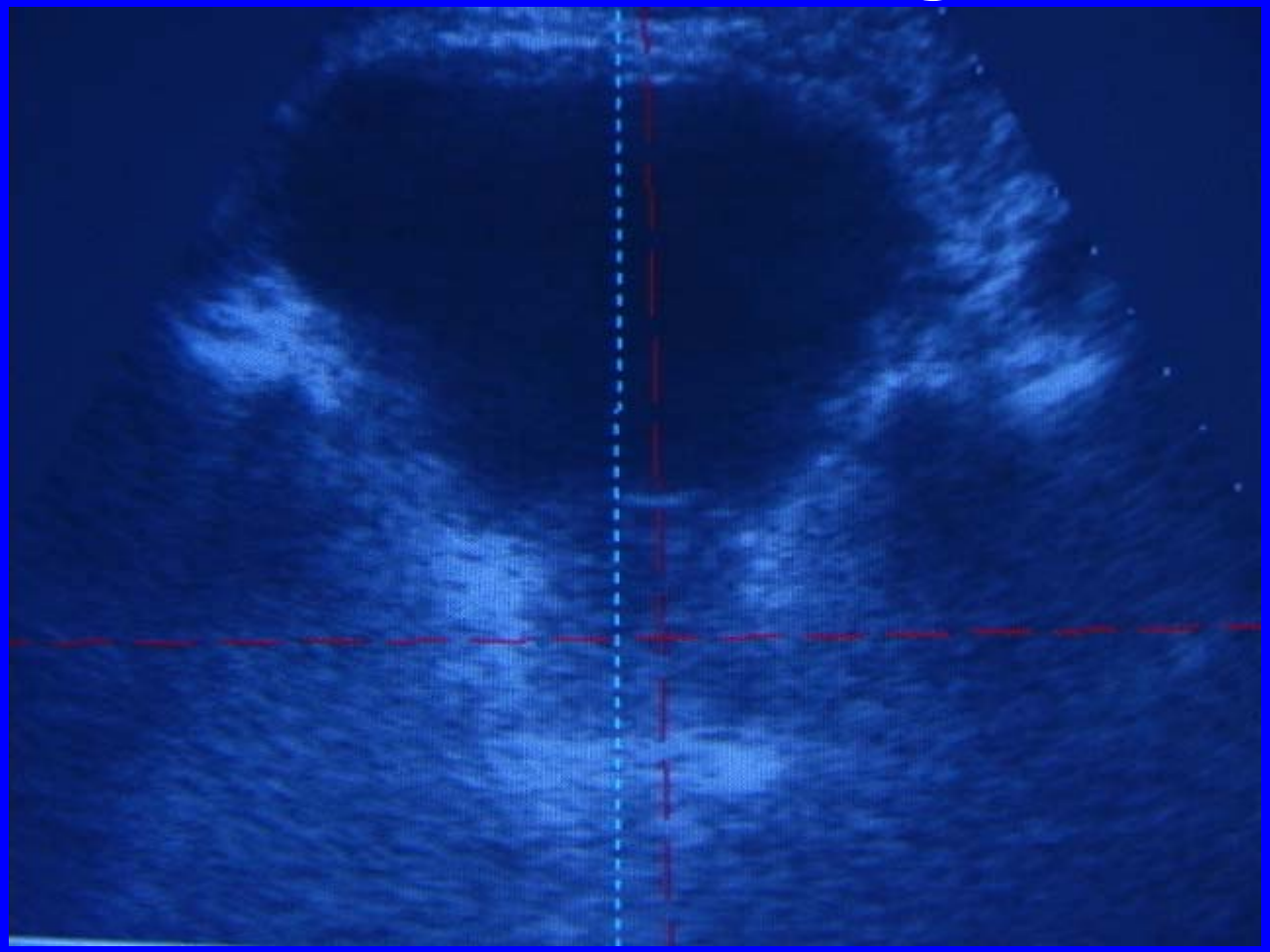
Target Name	Goal (Gy)	Vol Below Goal (%)	Vol Below Goal (cc)	Min (Gy)	Max (Gy)	Mean (Gy)	S.D. (Gy)	Vol. (cc)
Seminal vesicles -	26.00			27.84	51.99	37.42	7.51	14.82
Prostate bed - target	44.00	0.63	0.31	40.18	52.52	48.16	1.31	48.38

Structure Name	Limit (Gy)	Vol Above Limit (%)	Vol Above Limit (cc)	Min (Gy)	Max (Gy)	Mean (Gy)	S.D. (Gy)	Vol. (cc)
Non-target Tissue	48.00	0.31	33.45	0.00	52.26	6.74	8.60	*******
Tissue	48.00	0.59	63.44	0.00	52.52	6.96	9.09	*******
Bladder	29.00	37.77	73.31	2.63	51.99	25.40	12.50	194.10
Femoral Head (Lt)	10.00	7.89	4.40	2.63	13.92	7.21	1.89	55.82
Femoral Head (Rt)	10.00	8.75	4.54	2.89	13.13	7.50	1.88	51.84
Ant Rectum	46.00	3.41	2.06	2.36	49.63	28.51	12.97	60.29
Post. Rectum	30.00	14.29	8.92	1.84	38.86	19.78	9.54	62.42

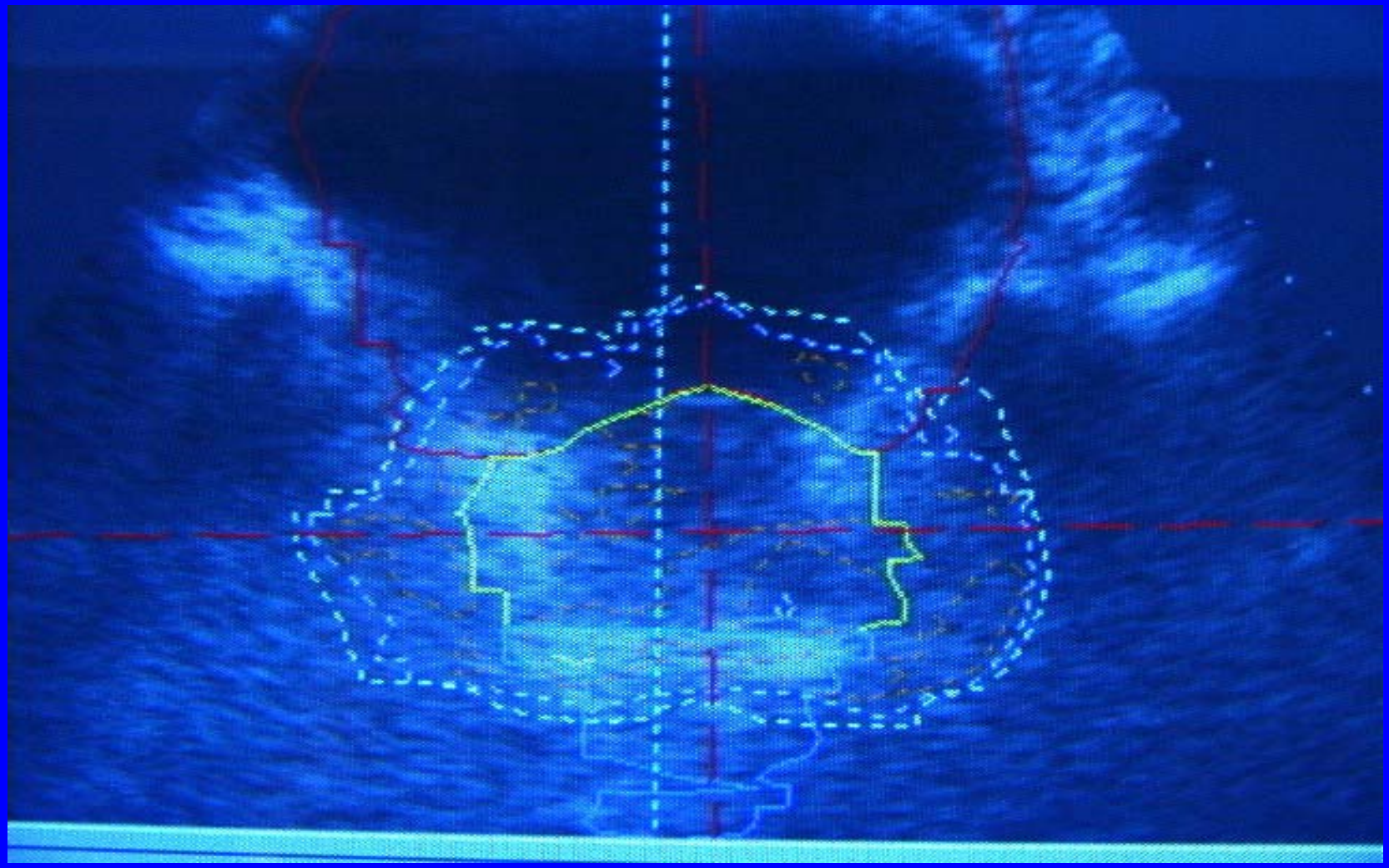
BAT Sagital Image



BAT Axial Image



BAT Axial Image With Structures and Isodoses



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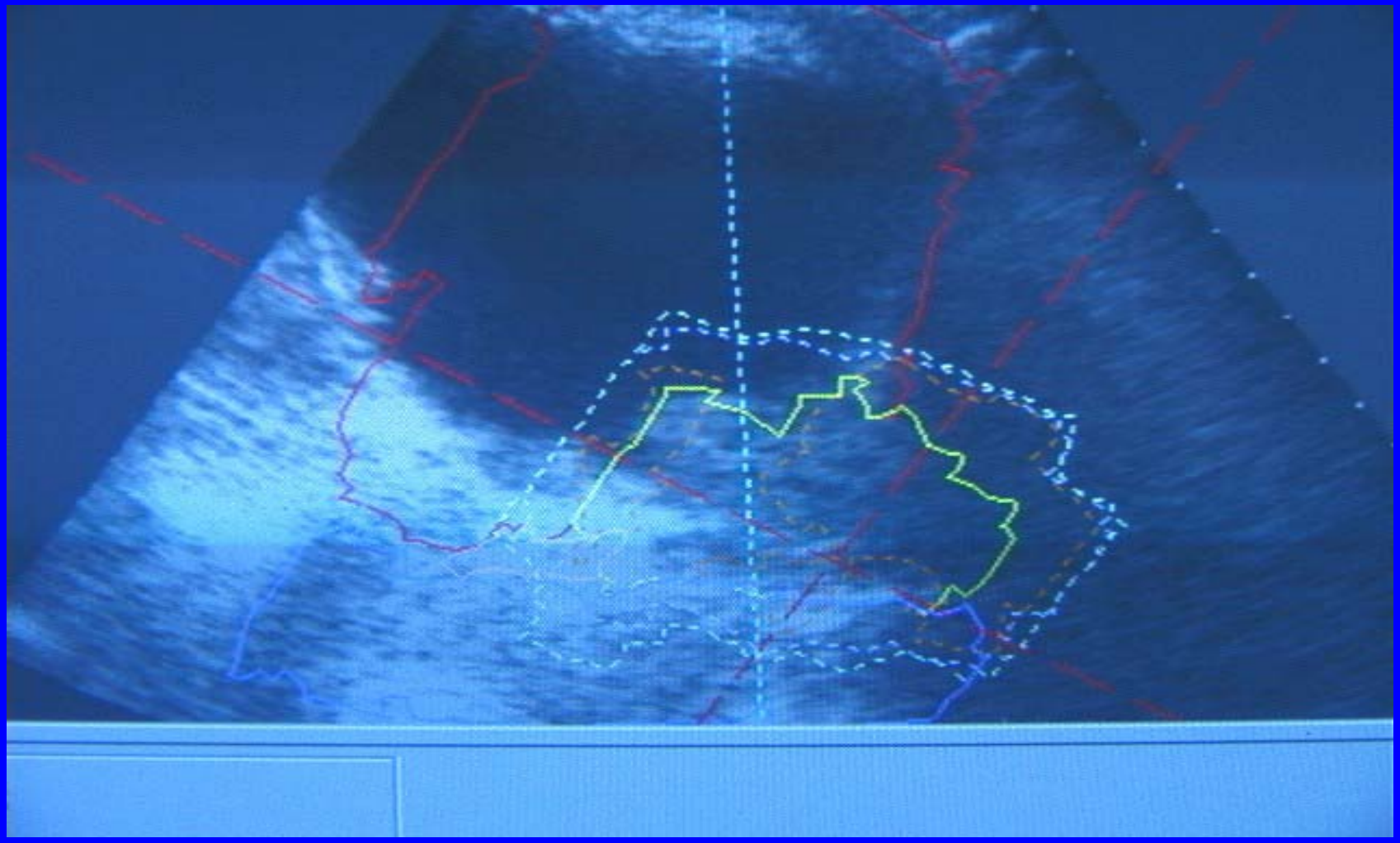
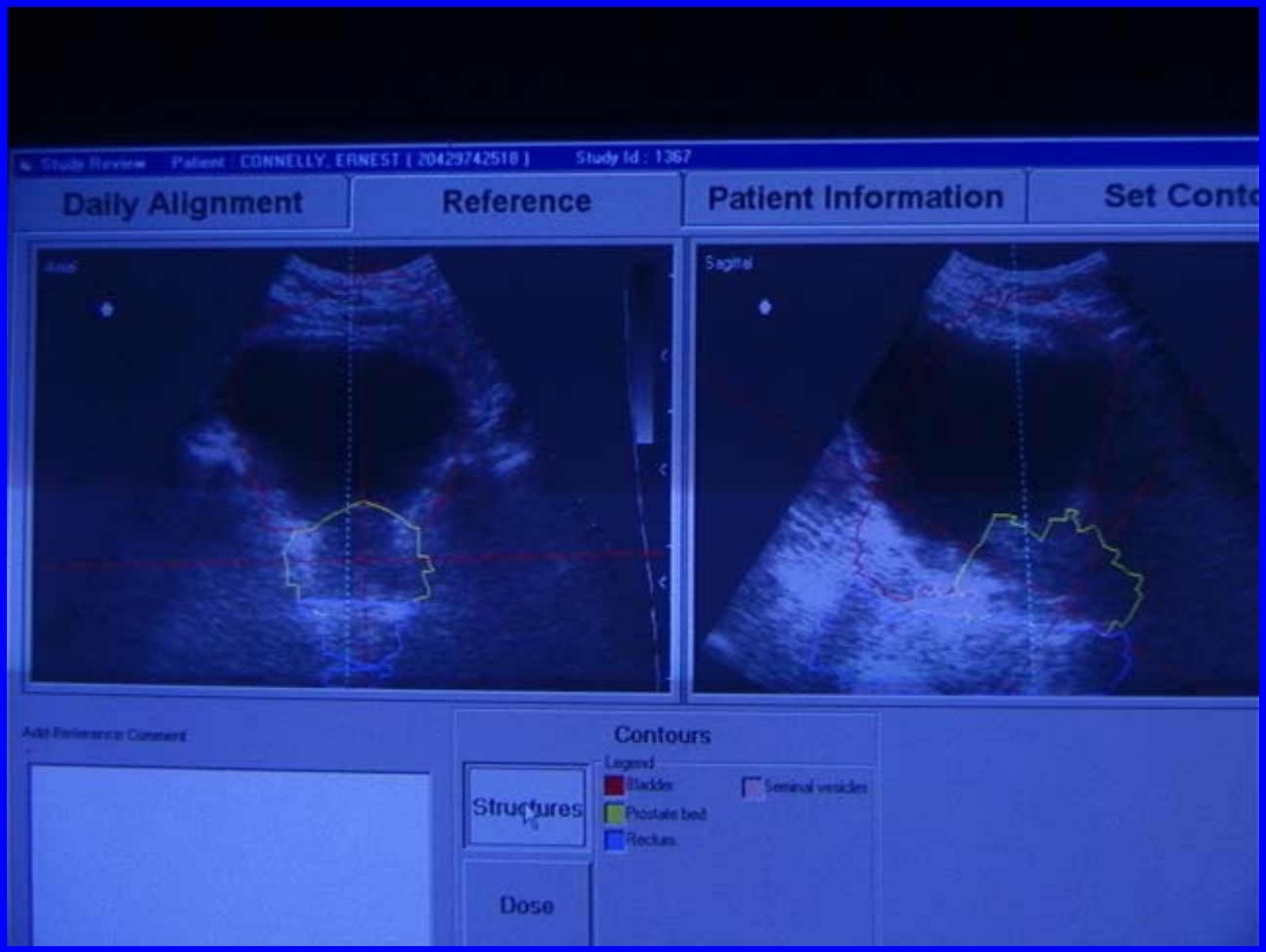
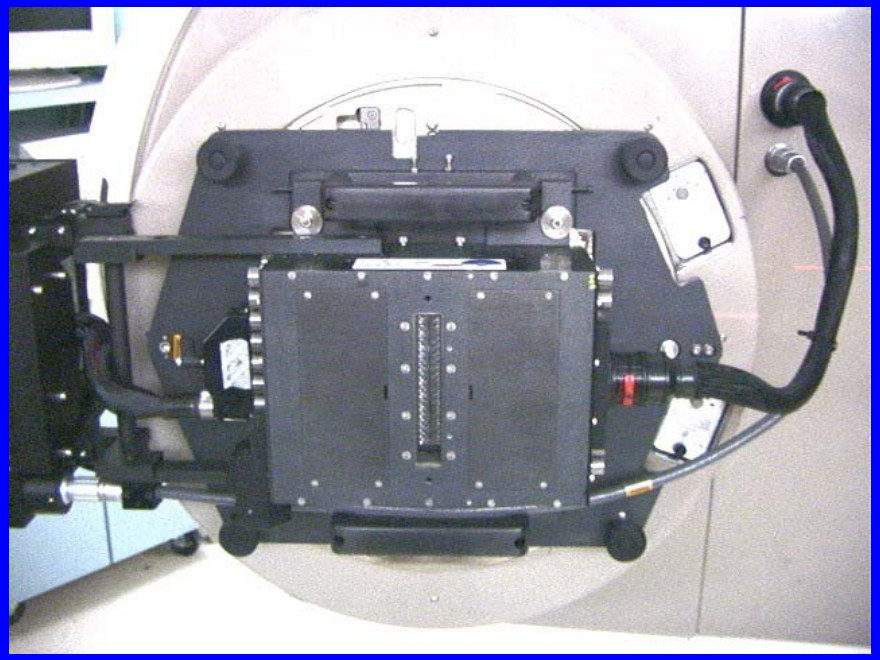


BAT Sagital and Axial Images

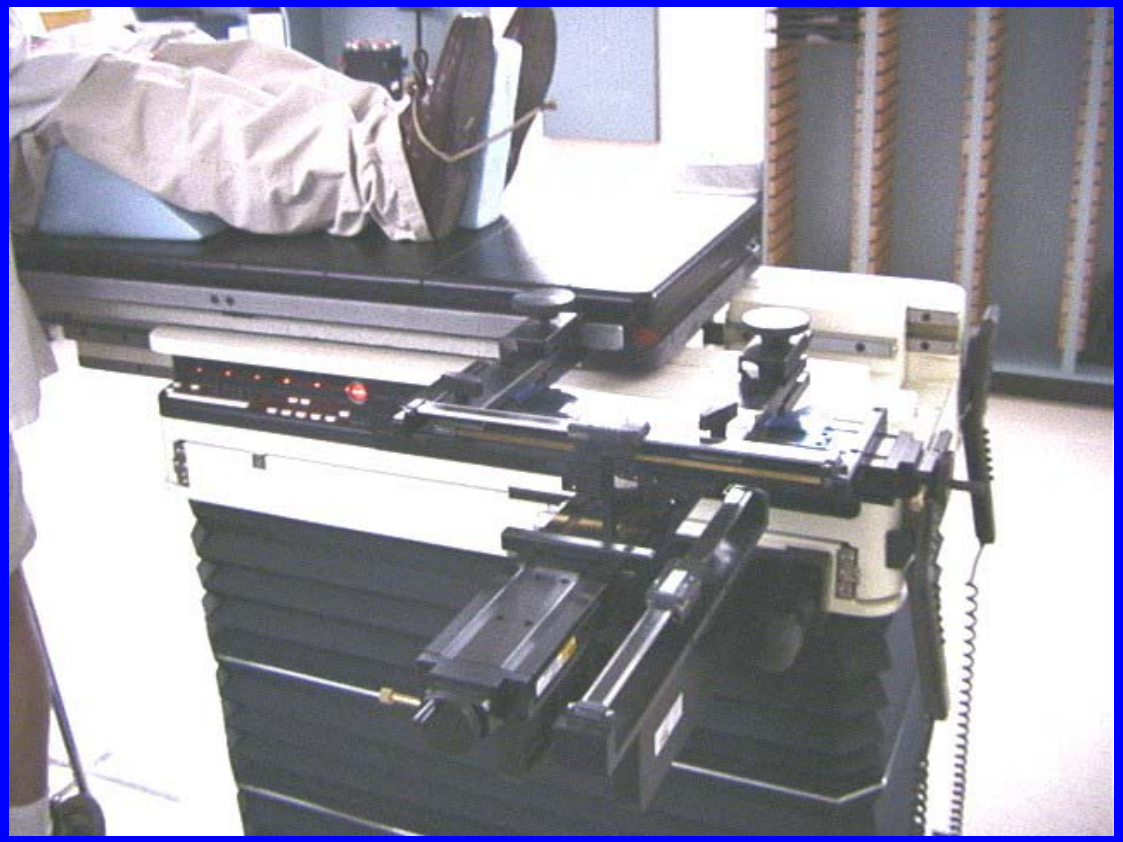


Acquiring BAT Image

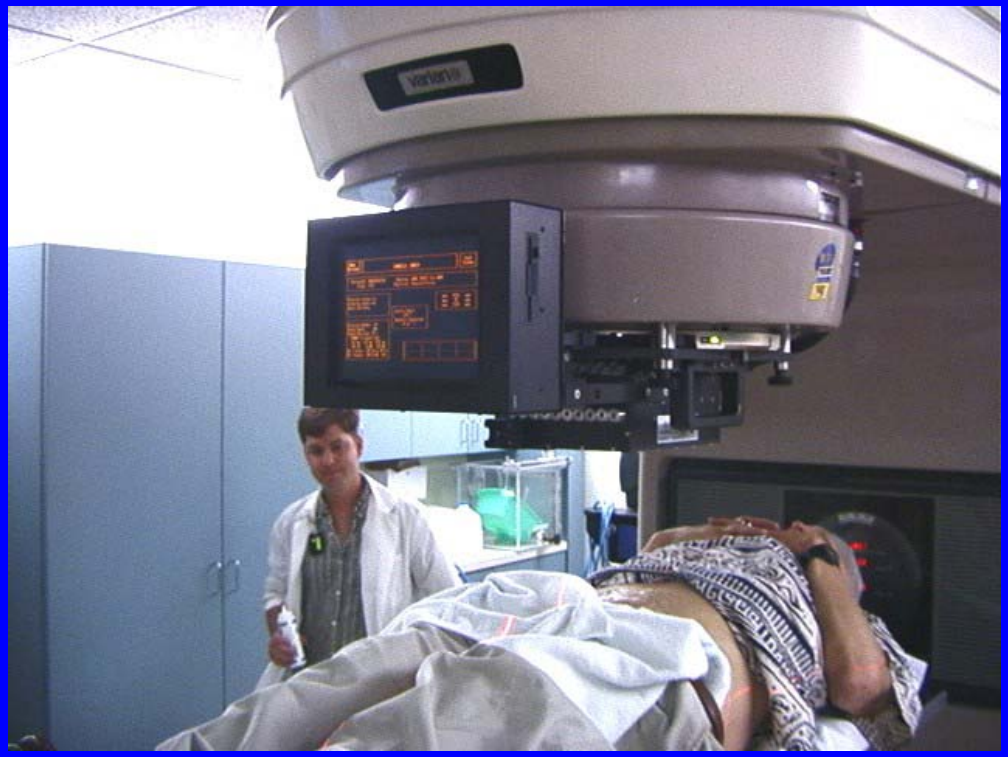
Treatment Head of IMRT



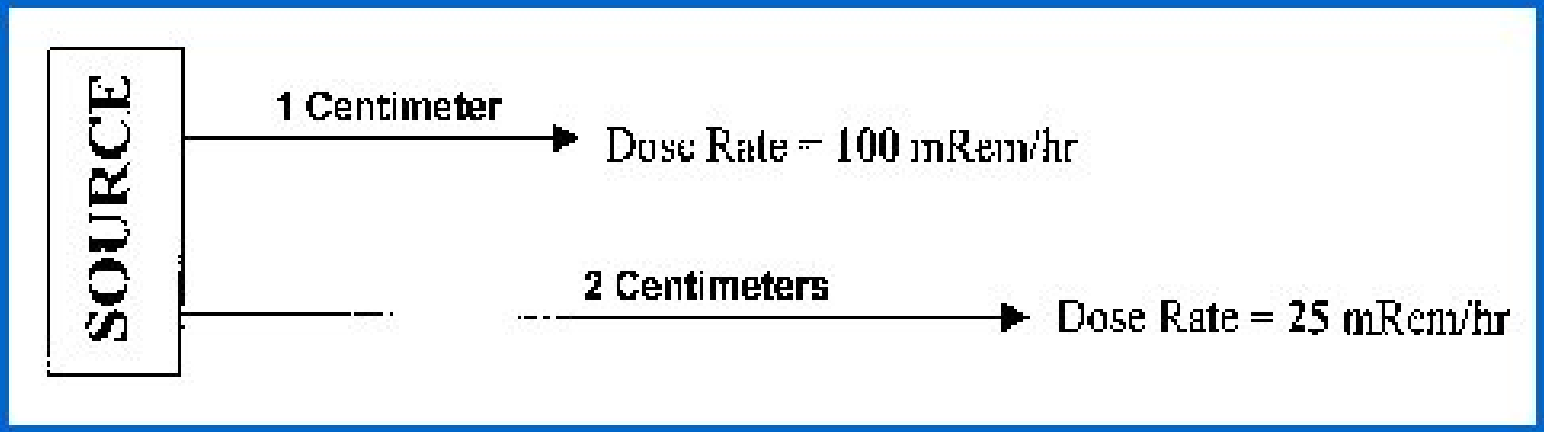
Small Adjustments to Table Position



Computer Program Drives Leaves



Why Not Use External Beam Alone?



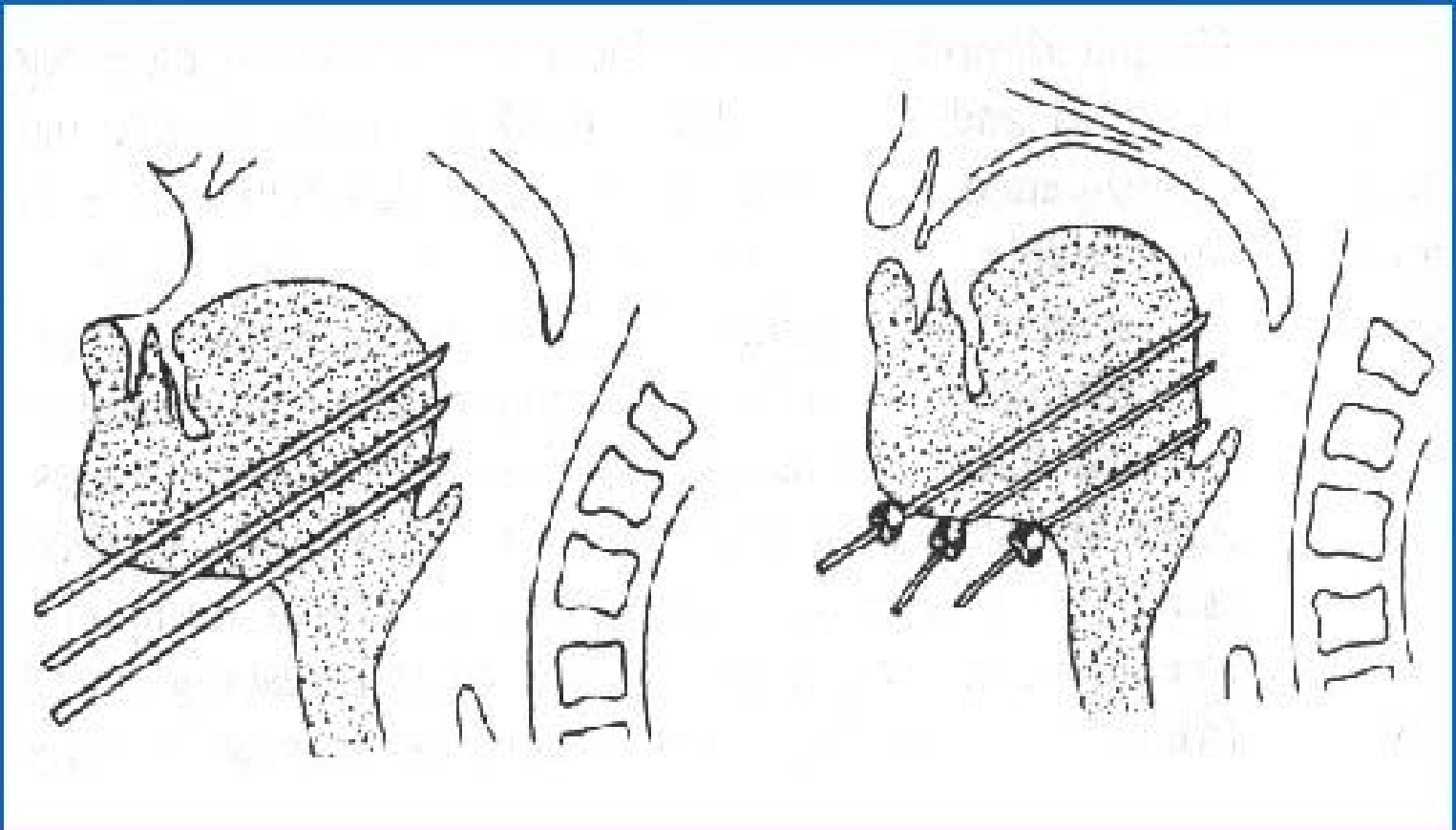
- Using brachytherapy takes advantage of the inverse square law:

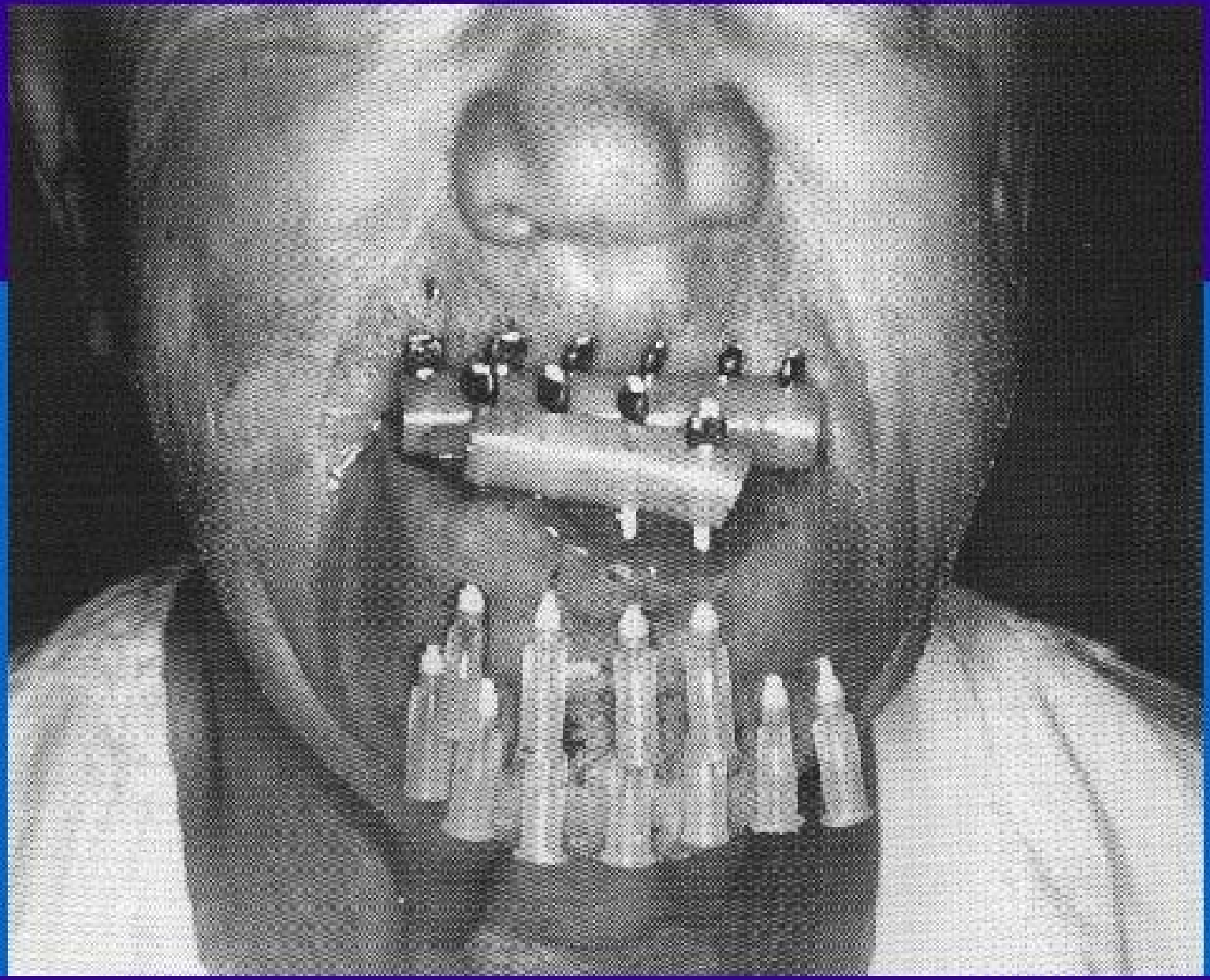
$$\text{Exposure} \sim 1 / R^2$$

- In this way, the therapeutic ratio is maximized by delivering high doses to the target tissue while respecting normal tissue tolerances

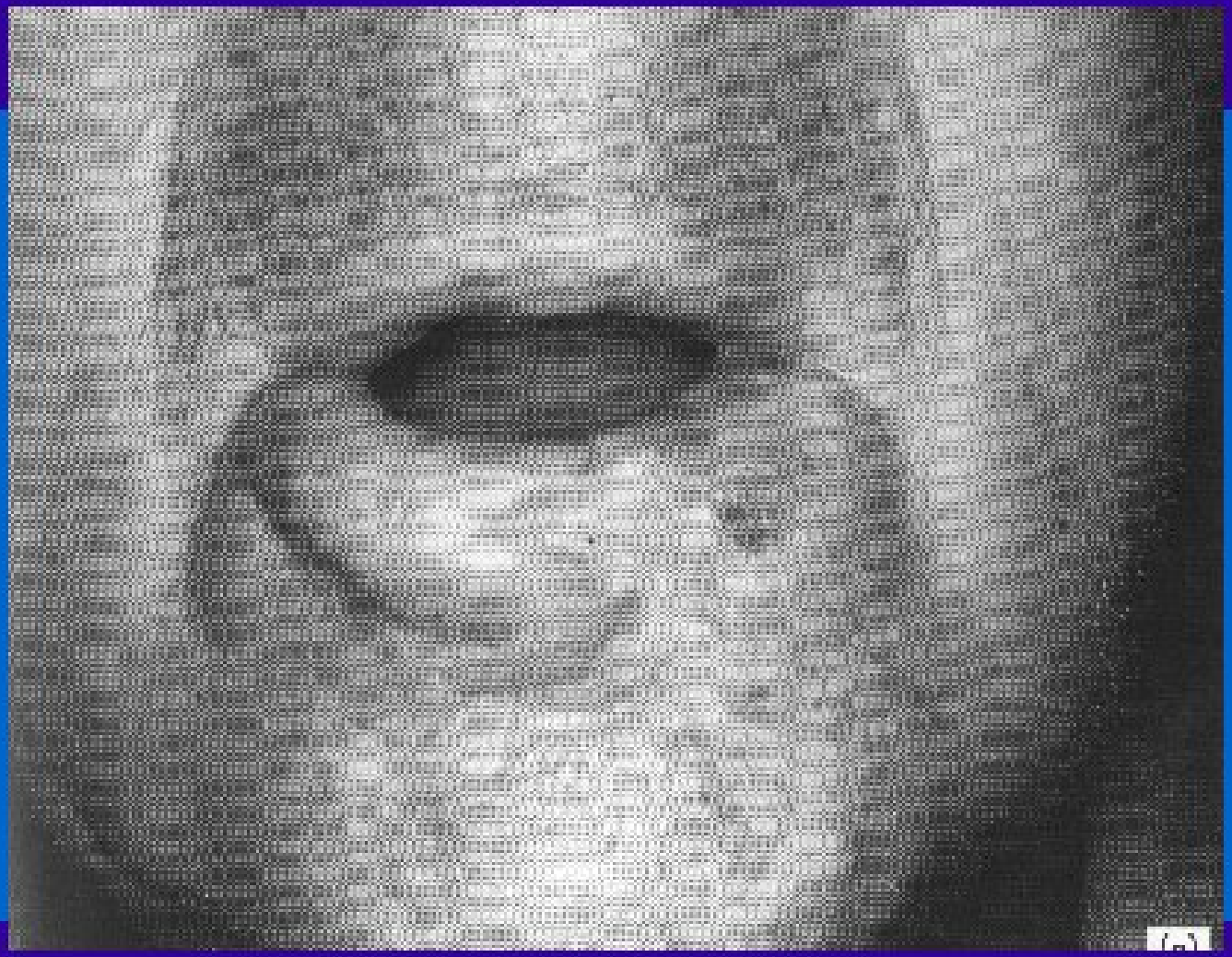
Brachytherapy Seed Implant for Prostate Cancer

Base of Tongue Implants





7 Years Later



Effects of Radiation on Normal Tissues

- Acute: bone marrow, ovary, testis, salivary gland, small bowel, stomach, colon, oral mucosa, larynx, esophagus, skin, bladder, vagina
- Late: lung, liver, kidney, heart, spinal cord, brain, thyroid, lymph vessels pituitary, breast, bone, cartilage, pancreas (endocrine)

Who Should Schedule a Rotation in Radiation Oncology?

Anyone considering one of the following specialties:

ENT
GYN (esp. Gyn Onc)
General Surgery
Thoracic Surgery

Pediatric Oncology
Hematology Oncology
Urology
Neurosurgery

Question #1

If given the job of loading 10 radioactive Ir-192 seeds into a tube, which would be better?

Doing the job in 30 seconds at a distance of 1 foot

or

Doing the job in 60 seconds at a distance of 2 feet

Question #2

- Clinical case: 57 y.o. male undergoes a low anterior resection of a T3 N1 rectal cancer. Margins of the resection were negative, but the tumor had gone through the bowel wall and 3 out of 18 lymph nodes were involved with cancer. A course of radiation therapy is recommended to treat the pelvic lymph node regions an the tumor bed.

Is this an example of DEFINITIVE or ADJUVANT treatment?

Question #3

Who gets more on the job exposure to ionizing radiation?

Radiation Oncologist

Cardiologist

Urologist