Importance of Conventional RT in 2010

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Introduction

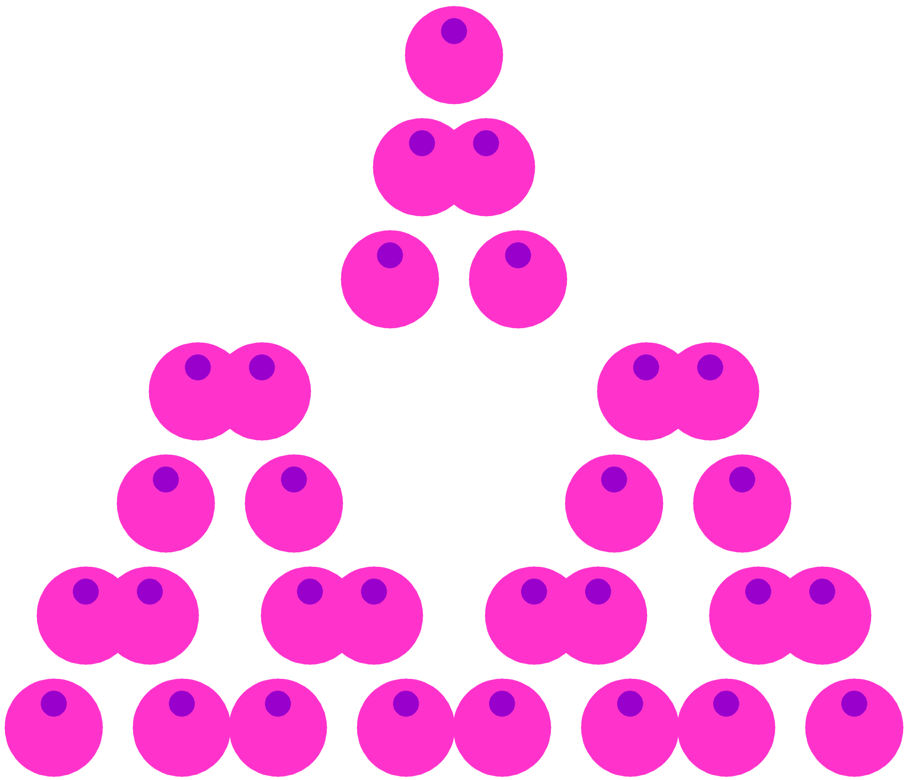
- **Conventional-** established practice, accepted standards or traditional.

- **Conformal-** latin word ‘conformalis’: same shape; maintaining true shape of a small area and scale in every direction.

Oxford English Dictionary

What is Cancer?

Cancer is a group of diseases characterized by uncontrolled cell division leading to growth of abnormal tissue.

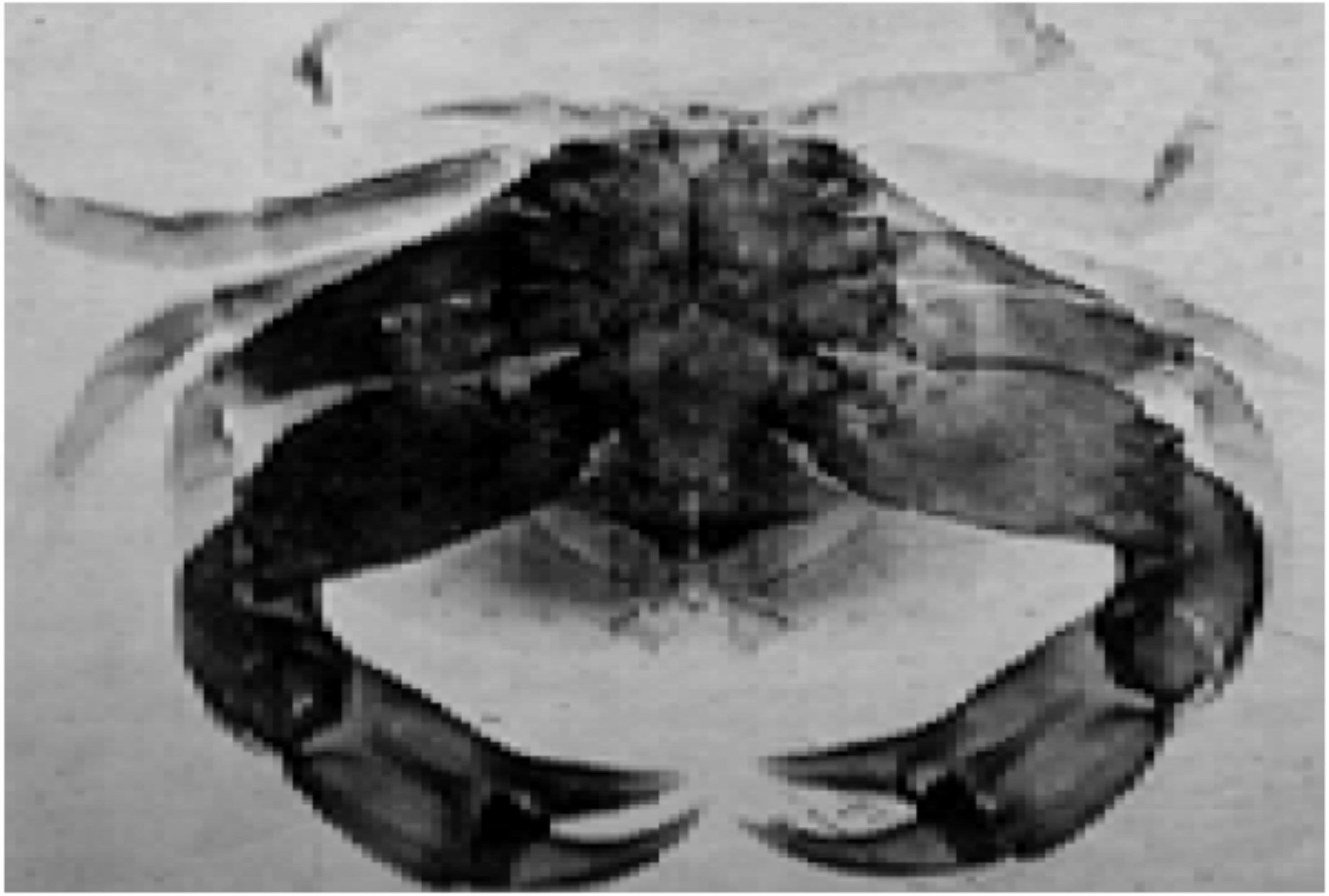


Treatment of Cancer

Cancer can be treated using the following main methods: ‘***Multimodality approach***’

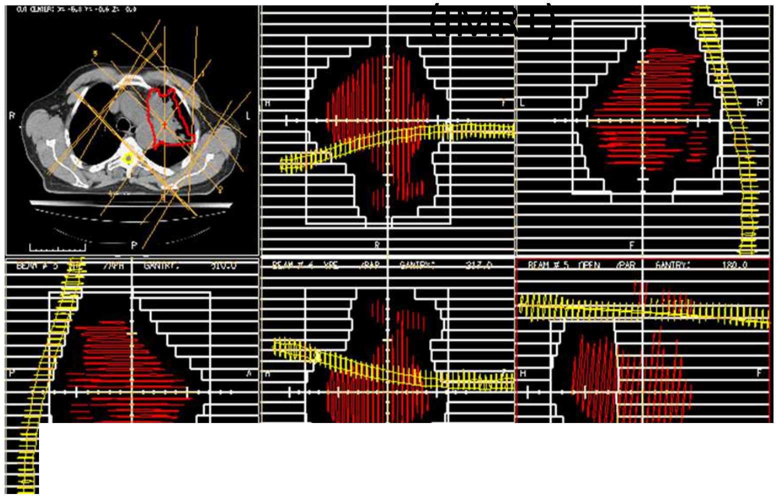
- Surgery.
- Radiation therapy (radiotherapy and brachytherapy).
- Chemotherapy (drugs).

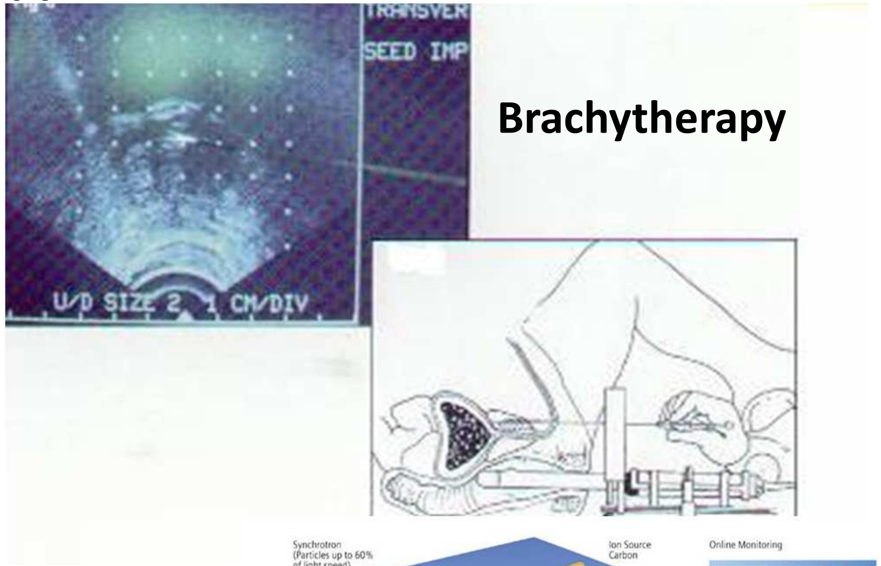
99% of Radiation Therapy Procedures are to Treat Cancer



The treatment of cancer with ionising radiation is called Radiotherapy (RT) or Radiation Oncology.

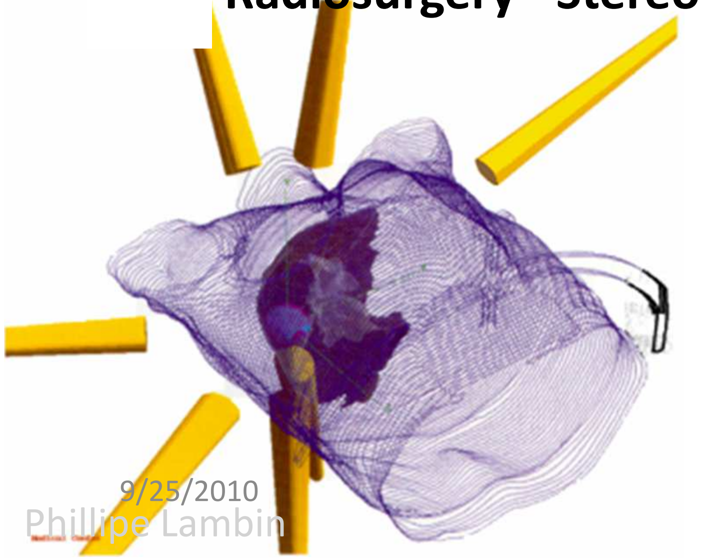
External RT ± Intensity Modulated Radiotherapy (IMRT)

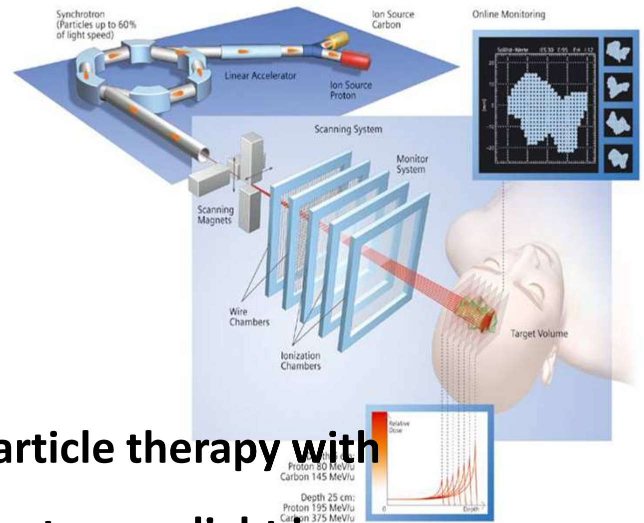




Brachytherapy

Radiosurgery - Stereotactic RT





Particle therapy with

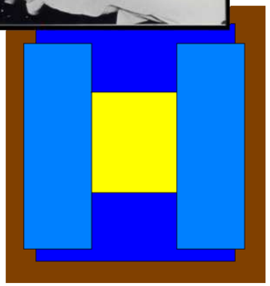
Protons or light ions

The Evolution of Radiation Therapy

1ST Telecobalt machine in August 1951 in Sasaktoon Cancer Clinic, Canada

1960's

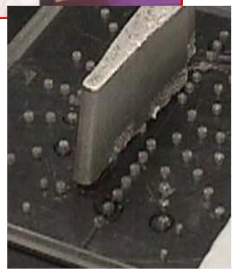
The First Clinac



Standard Collimator

The linac reduced complications compared to Co60

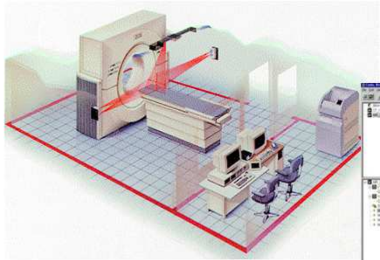
1970's



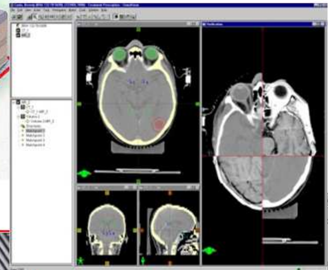
Cerrobend Blocking
Electron Blocking

Blocks were used to reduce the dose to normal tissues

1980's



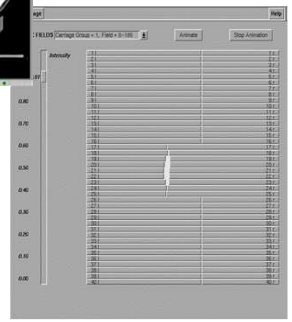
Computerized 3D CT Treatment Planning



Multileaf Collimator

MLC leads to 3D conformal therapy which allows the first dose escalation trials

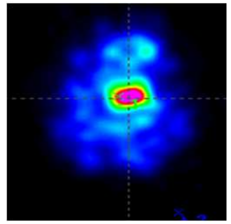
1990's



Dynamic MLC and IMRT

Computerized IMRT introduced which allowed escalation of dose and reduced compilations

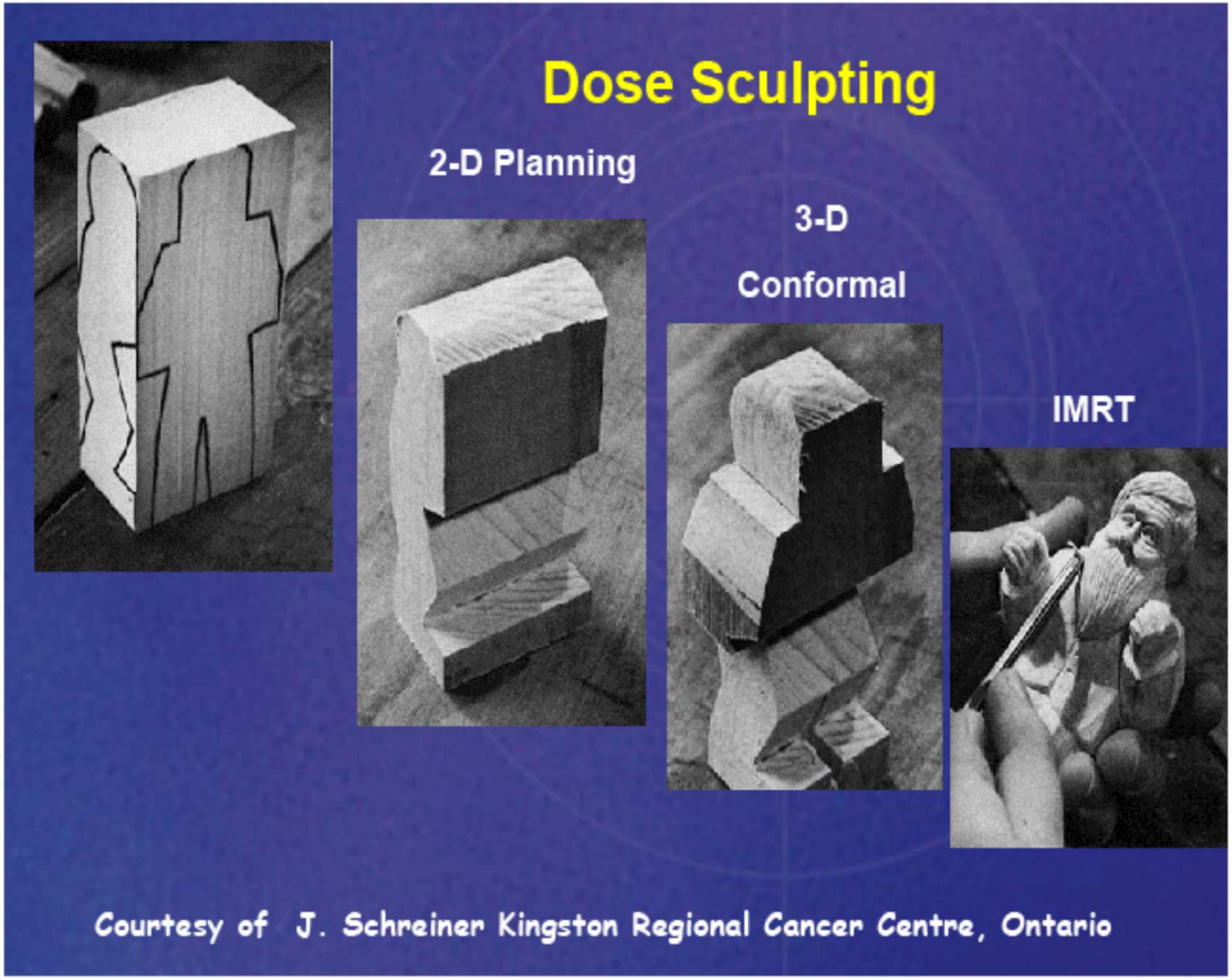
2000's



Functional Imaging

High resolution IMRT

IMRT Evolution evolves to smaller and smaller subfields and high resolution IMRT along with the introduction of new imaging technologies


Dose Sculpting
2-D Planning
3-D
Conformal
IMRT
Courtesy of J. Schreiner Kingston Regional Cancer Centre, Ontario

Radiotherapy /Radiation therapy is the use of ionizing radiation to treat cancer.

There are two ways:

1. Teletherapy.

2. Brachytherapy.

RADIOTHERAPY

Radiation Therapy

- Aims
- Intent
- Rationale

Why is necessary to improve local tumor control ?

- **Local control is a prerequisite for cure**
- **Local failure may affect quality of life**
- **Local failure is associated with an increase in metastatic disease**

Therapeutic Ratio

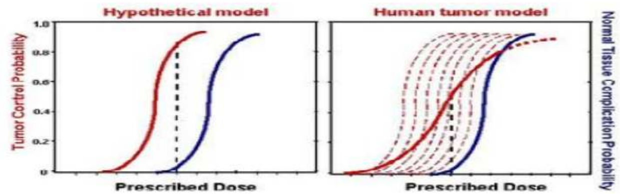
- Tumor Control Probability is a function of:
  - Total Dose
  - dose /fraction
  - Target definition to include all tumor
  - Reproducibility (set up, motion, etc.)

Therapeutic Ratio

- Normal Tissue Complication Probability (NTCP) is a function of:
  - Total Dose
  - dose /fraction
  - volume of tissue irradiated

- The greatest challenge for radiation therapy is to attain the highest probability of cure with the least morbidity.

TCP/NTCP Model of Radiotherapy



Intent of Radiotherapy:

1.***Curative-***

(i)Radical radiotherapy

(ii)Adjuvant (post operative)

(iii)Neoadjuvant

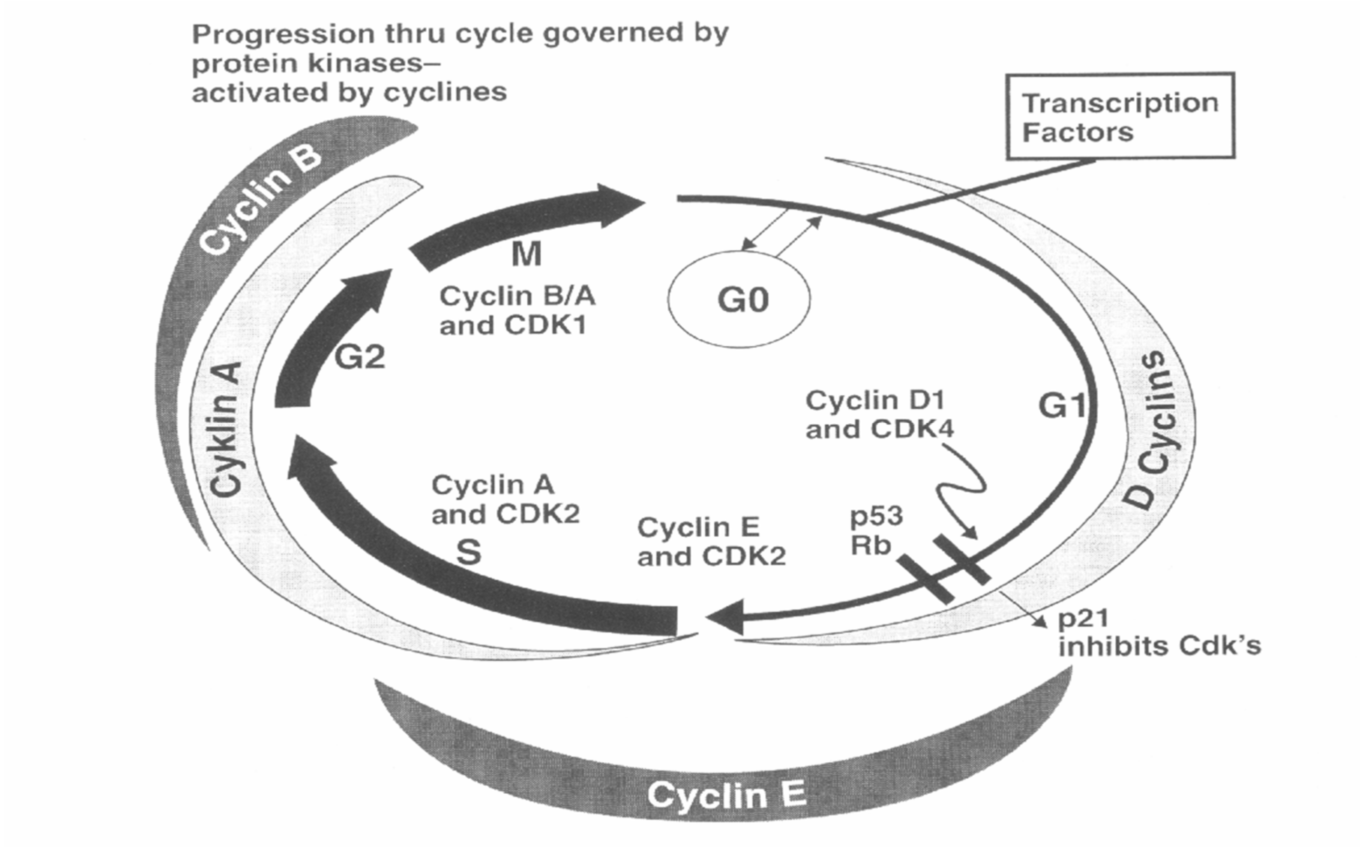
(iv)Concurrent with chemotherapy

2.***Palliative-***

(i)Pain

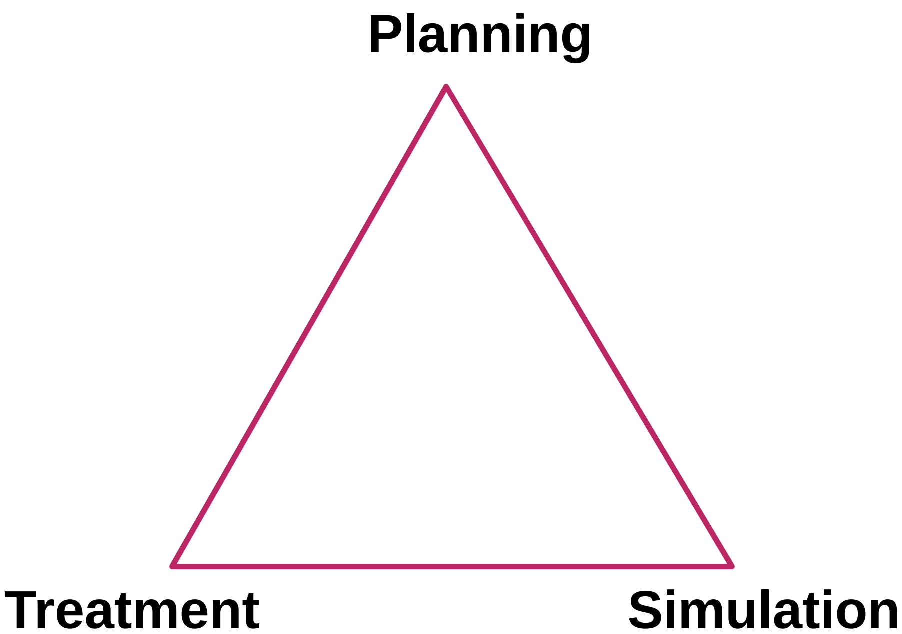
(ii)Functional

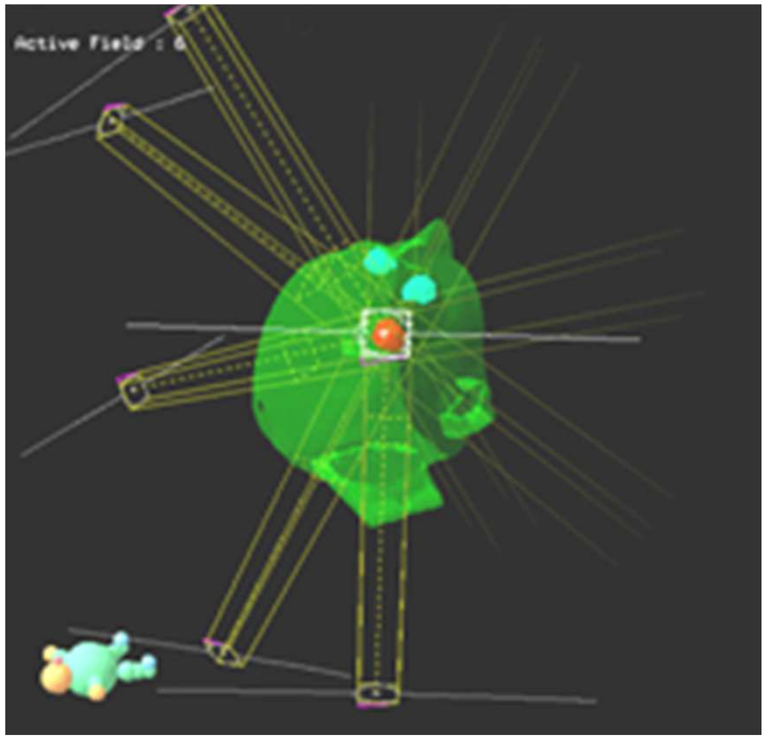
Cell Cycle


Progression thru cycle governed by
protein kinases–
activated by cyclines
Transcription
Factors
Cyclin B
Cyklin A
M
Cyclin B/A
and CDK1
G2
G0
G1
D Cyclins
Cyclin D1
and CDK4
Cyclin A
and CDK2
S
Cyclin E
and CDK2
p53
Rb
p21
inhibits Cdk's
Cyclin E

Radiotherapy Treatment Planning

Every treatment using radiotherapy has to be rigorously planned. The planning process consists of ***three phases:***

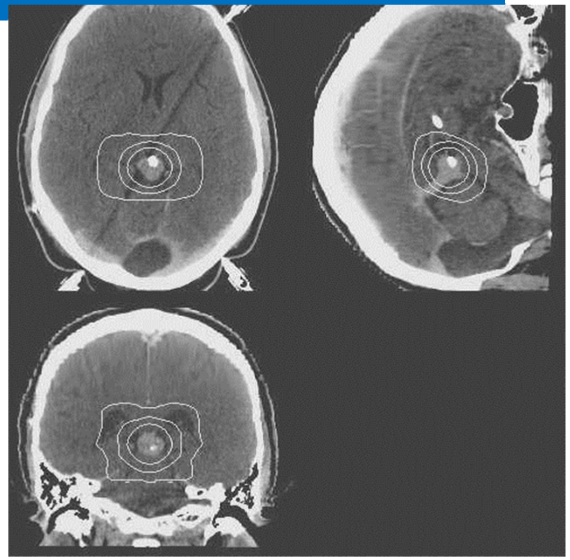




Radiotherapy Treatment Planning

Planning

The tumour has to be located so that its size and position can be analysed. This information can be obtained from:



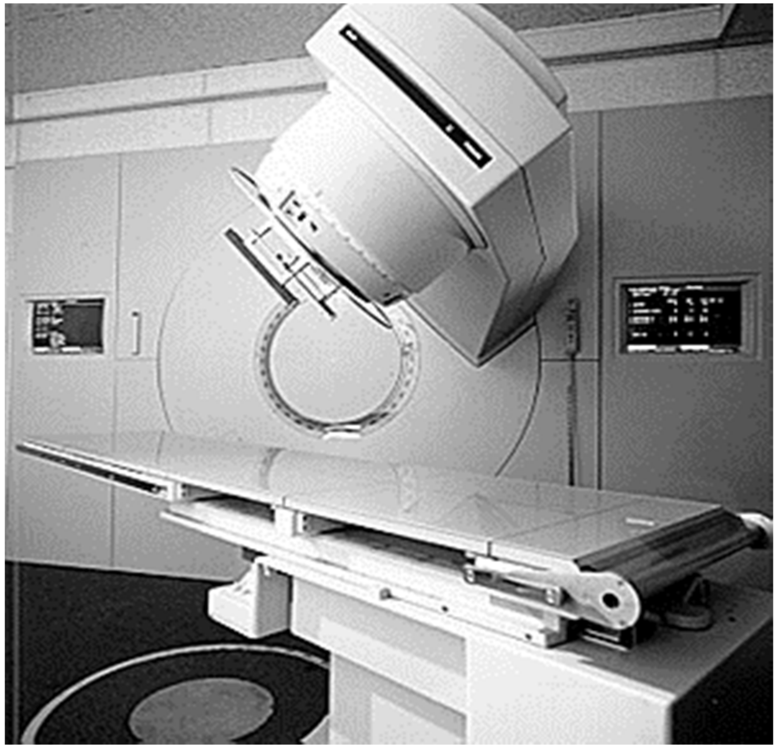
- X-rays
- CT scans
- MRI scans
- Ultrasound images
- pet scan

Radiotherapy Treatment Planning

Treatment

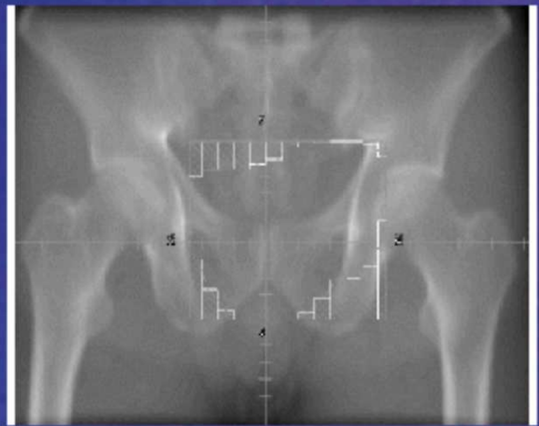
Cancer can be treated using radiotherapy as follows:

- Irradiation using high energy gamma rays.
- Irradiation using high energy x-rays.



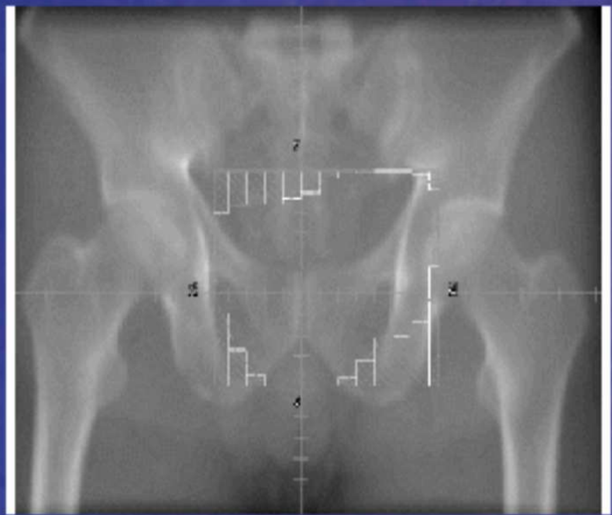
2D Treatment Planning

2D Treatment Planning

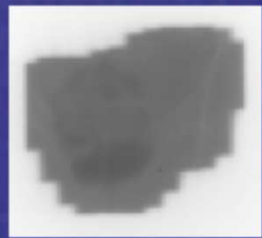


2D **simulation films** or
computer-generated **"DRRs"**

2D Treatment Planning



Tumors are hard to see in 2D images, especially port films, and you must rely on "landmarks."



2D **simulation films** or computer-generated **"DRRs"**

Treatment machine **port films**

Treatment planning

- Patient positioning
- Immobilization
- Target volumes
- Beam arrangement/alignment
- Treatment portals
- Dose & fractionation schedules
- Treatment delivery

Patient positioning & immobilization

- Supine/Prone
- Lateral
- Hands overhead
- Arms over hips (akimbo)
- Frog leg position

- **Head rest**
- **Orfit/Thermoplastic moulds**
- **Bite block**
- **Shoulder traction**
- **Vacloc**
- **Knee rest/ ankle rest**
- **Breast board**


13/02/2003


24 Hr


C·GHOSH
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C·GHOSH
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THIS SIDE UP
THIS SIDE UP

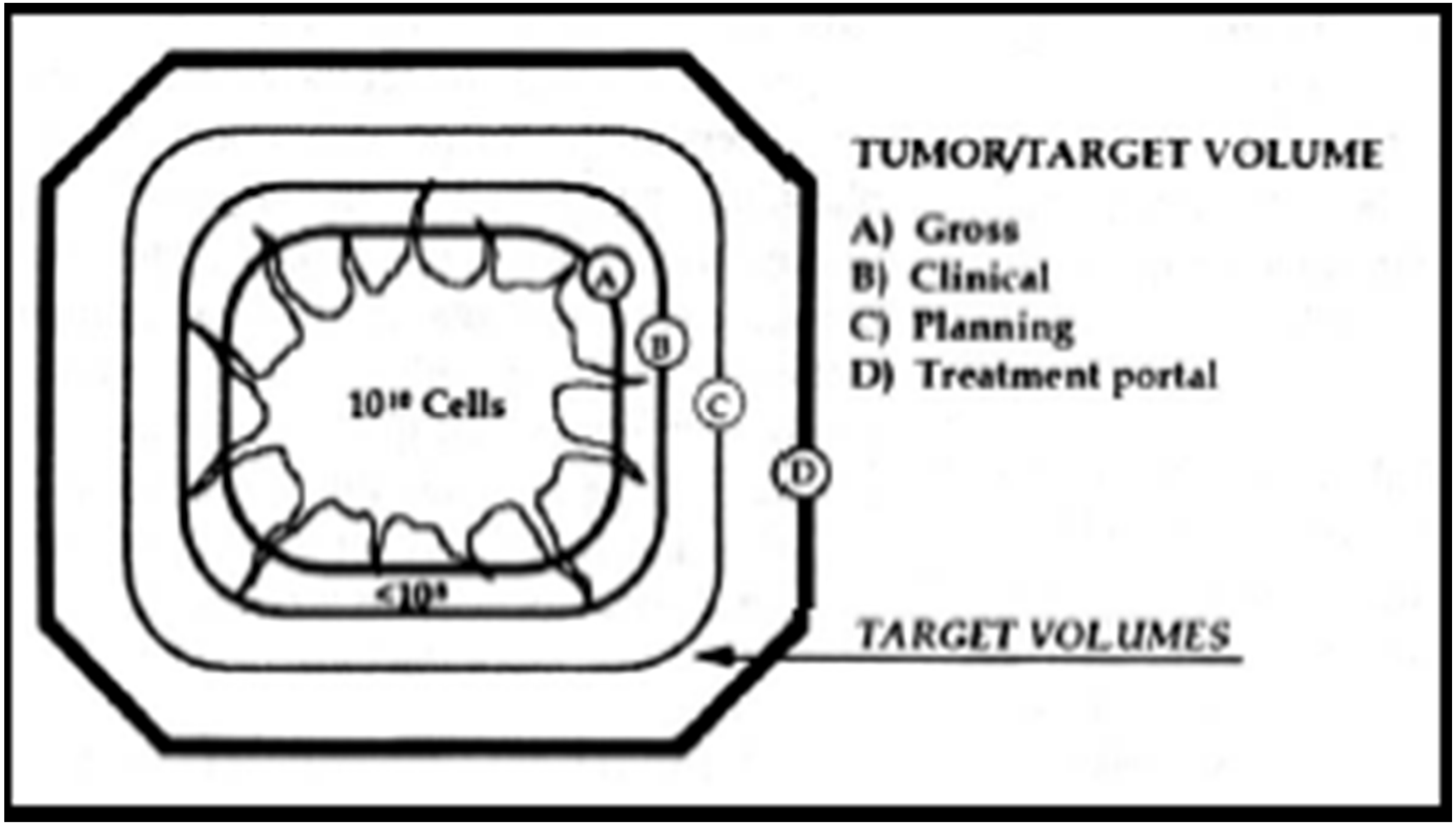

3/1/06
F2
F1
0
H1
H2
13/02/2003

ICRU 50 & 62

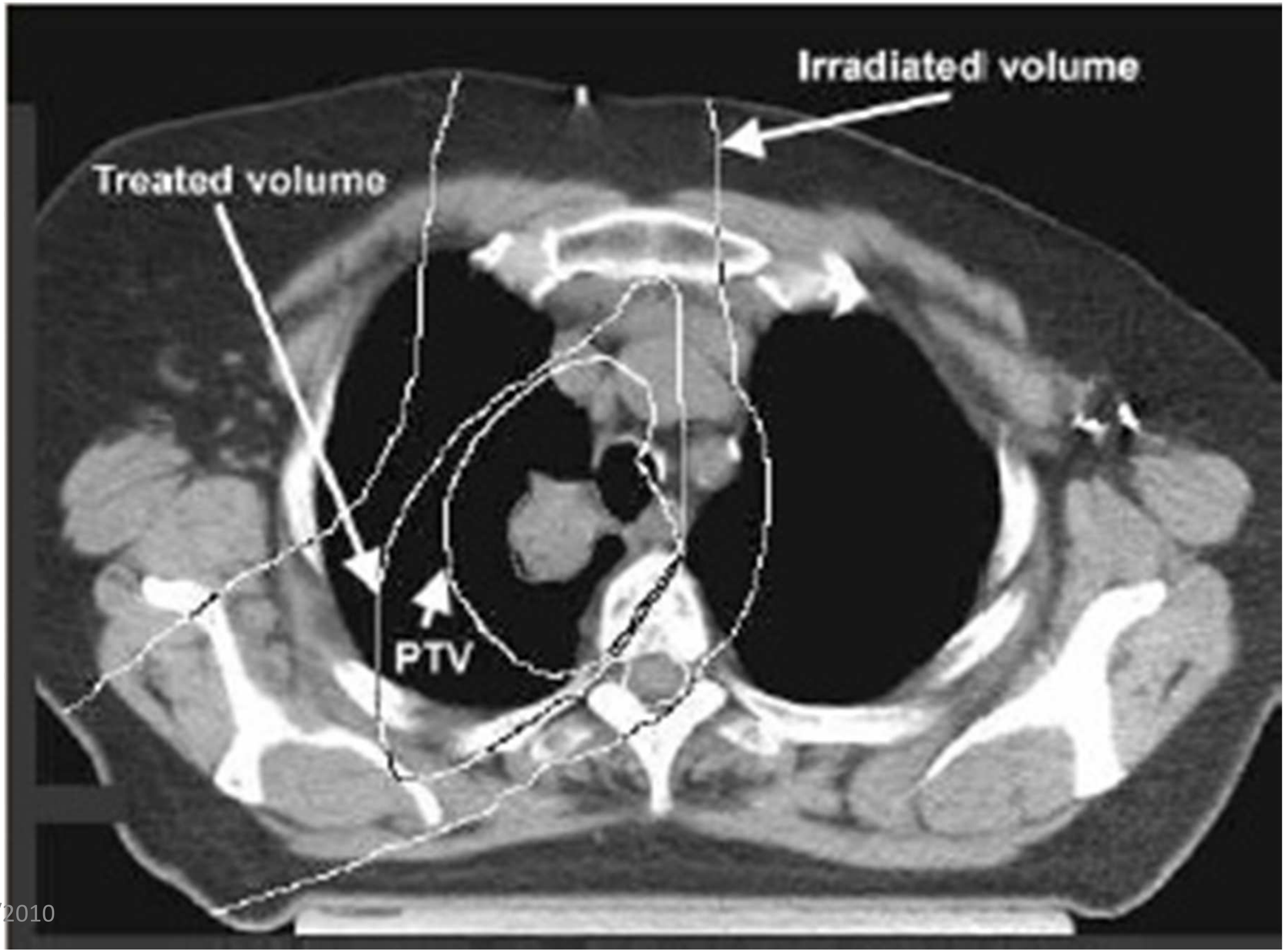
- **When delivering Radiotherapy treatment, parameters such as volume & dose have to be specified for:**
  - **Prescription**
  - **Recording**
  - **Reporting**
- **Such specifications serve a number of purposes**
  - **To enable the Radiation Oncologist to maintain a consistent treatment policy and improve it in the light of experience.**
  - **To compare the results of treatment and benefit from other departmental treatments.**
  - **It is particularly important in multi-center studies in order to keep treatment parameters well defined, constant & reproducible.**
- **It is expected that rapid development of new techniques would increase the complexity of radiotherapy and emphasize the need for general strict guidelines.**

Volumes

- Two volumes should be defined prior to treatment planning, these volumes are:
  - **Gross tumor volume (GTV).**
  - **Clinical target volume (CTV).**
- During the treatment planning process, other volumes have to be defined.
  - **Planning target volume (PTV).**
  - **Organs at risk.**
- As a result of treatment planning, further volumes can be described. These are:
  - **Treated volume (TV).**
  - **Irradiated volume (IRV).**


TUMOR/TARGET VOLUME
A) Gross
B) Clinical
C) Planning
D) Treatment portal
TARGET VOLUMES
A
B
C
D

- **The GTV** is the gross (palpable, visible or demonstrable) extent and location of malignant growth.
- This may consist of primary tumor, metastatic lymphadenopathy or other metastases.
- No GTV can be defined if the tumor has been removed. Eg. By previous surgery.
- **The CTV** is GTV + sub clinical microscopic disease.
- Additional volumes with presumed sub clinical spread may also be considered for therapy and may be designated as CTV II, CTV III etc. (ICRU 62)
- **The PTV** is a geometrical concept defined to select appropriate beam sizes and beam arrangements.
- It considers the net effect of the geometrical variations to ensure that the prescribed dose is actually absorbed in the CTV.
- These variations may be intra-fractional or inter-fractional due to number of factors like
  - Movement of tissues/patient.
  - Variations in size & shape of tissues.
  - Variations in beam characteristics.
  - The uncertainties may be random or systematic.


Irradiated volume
Treated volume
PTV

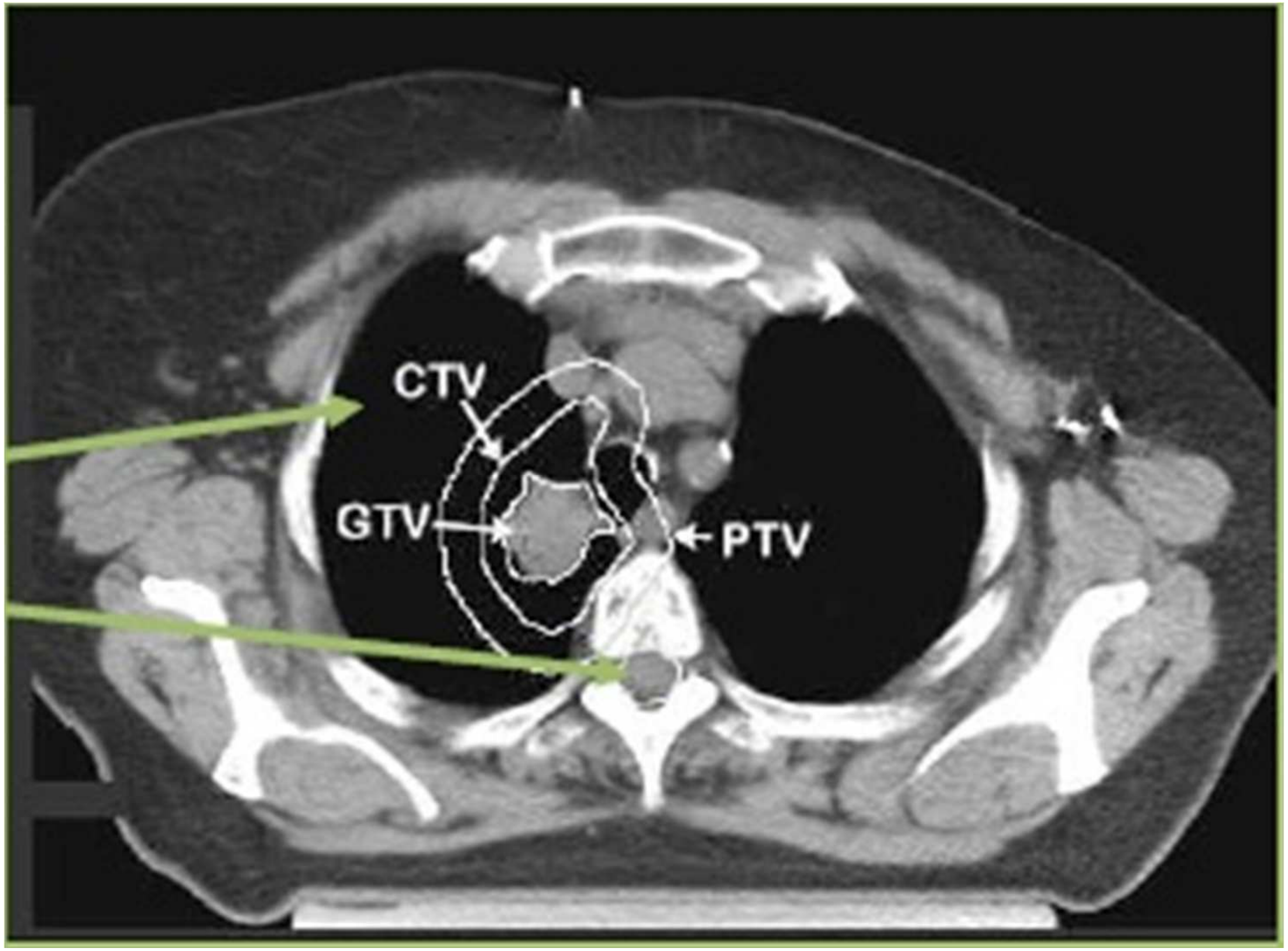
Organs at Risk

- **Organs at risk are normal tissues, whose radiation sensitivity may significantly reduce the treatment planning and/or prescribed dose.**
- **Any possible movement of the organ at risk as well as uncertainties in the setup during the whole treatment course must be considered.**
- **Organs at risk may be divided into three different classes:**
  - **Class I (Radiation lesions are fatal & result in severe morbidity.)**
  - **Class II (Result in moderate to mild morbidity.)**
  - **Class III (Radiation lesions are mild, transient and reversible or result in no significant morbidity.)**

Organs at Risk

OARs

- **Lungs**
- **Spinal Cord**



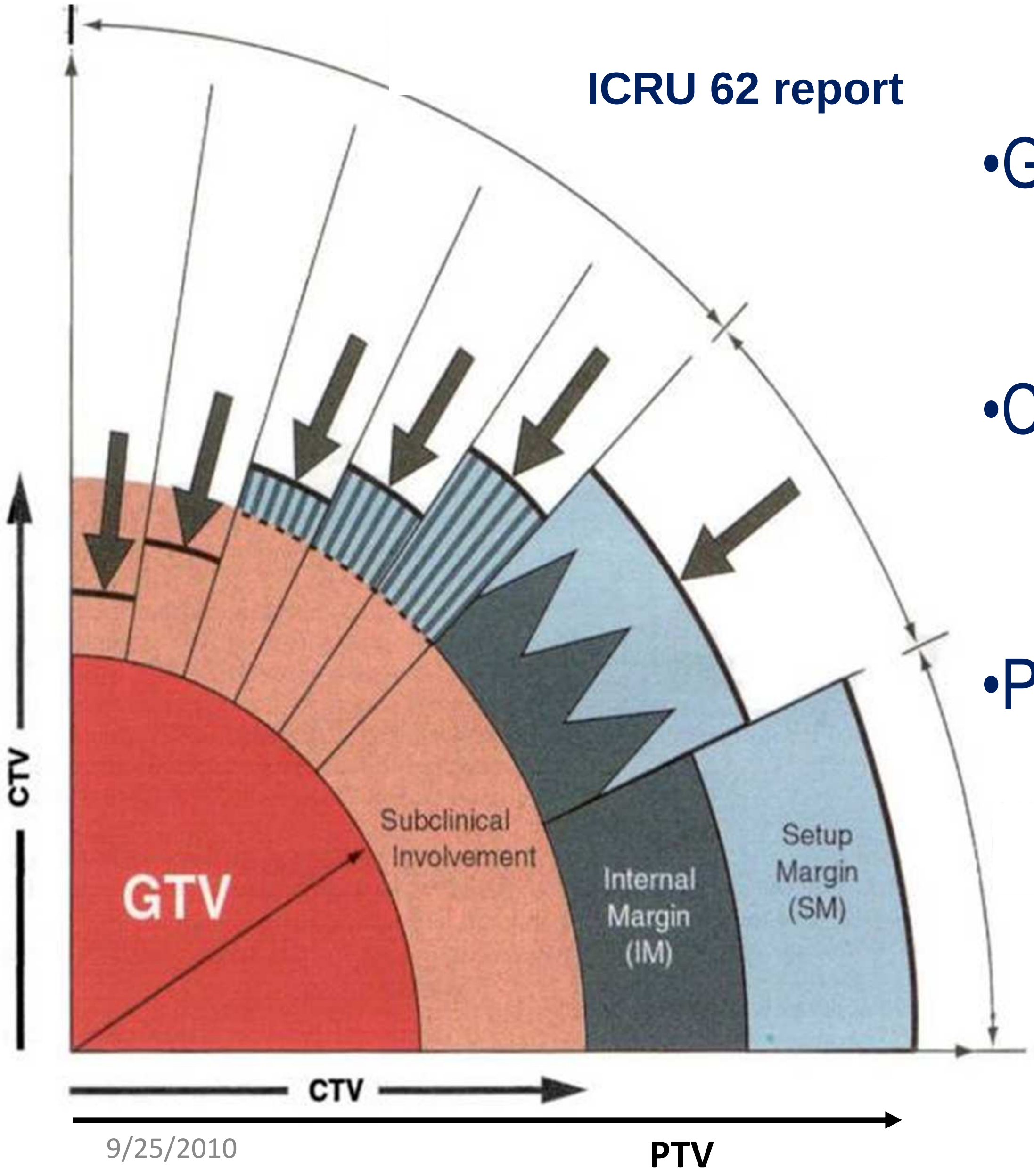
ICRU 62, 1999

- **Gives more detailed recommendations on different margins that must be considered to account for Anatomical & Geometrical uncertainties.**
- **Introduces concept of reference points & coordinate systems.**
- **Introduces the concept of conformity index.**
- **Classifies Organs at Risk.**
- **Introduces planning organ at risk volume.**
- **Gives recommendations on graphic.**
- **Gives additional recommendations on reporting doses, not only in a single patient but also in a series of patients.**
- **Of all, *Reporting is Emphasized*.**

Internal Margin (*IM*) & Internal Target Volume (*ITV*)

- **A margin must be added to the CTV to compensate for expected physiological movements & expected variations in size, shape & position of the CTV during therapy.**
- **It is in relation to an internal reference point and its corresponding coordinate systems.**
- **This margin is now denoted as the Internal Margin *(IM).***
- **They do not depend on external uncertainties of beam geometry.**
- **They cannot be easily controlled.**

Target volumes



- GTV = Gross Tumour Volume

  = Macroscopic tumour

- CTV = Clinical Target Volume

  = Microscopic tumour

- PTV = Planning target Volume

Advice: Always use the ICRU reports to specify and record dose and volume

Baumert et al. IJROBP 2006 Sep 1;66(1):187-94

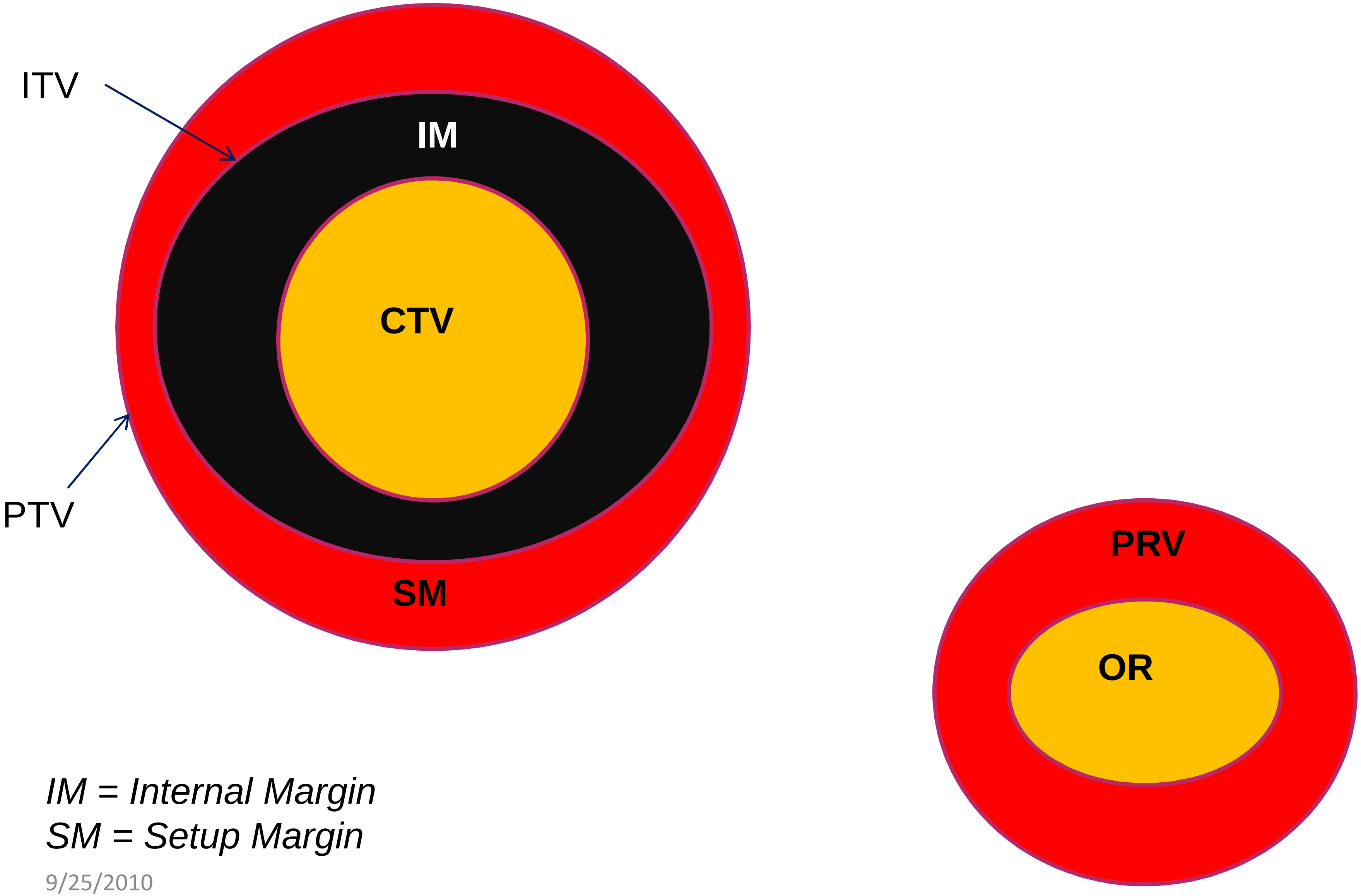
Set up Margin (SM):

- It accounts for the uncertainties in patient positioning and aligning of therapeutic beams.
- It includes the treatment planning session as well as all the treatment sessions.

Planning organ at risk volume (PRV):

- An integrated margin must be added to the *OR* to compensate for variations including the movement of organ as well as setup uncertainties.
- In particular the internal margin & the setup margin for the *OR* must be identified. This leads to the concept of *PRV.*

ICRU 62 – Volume definitions



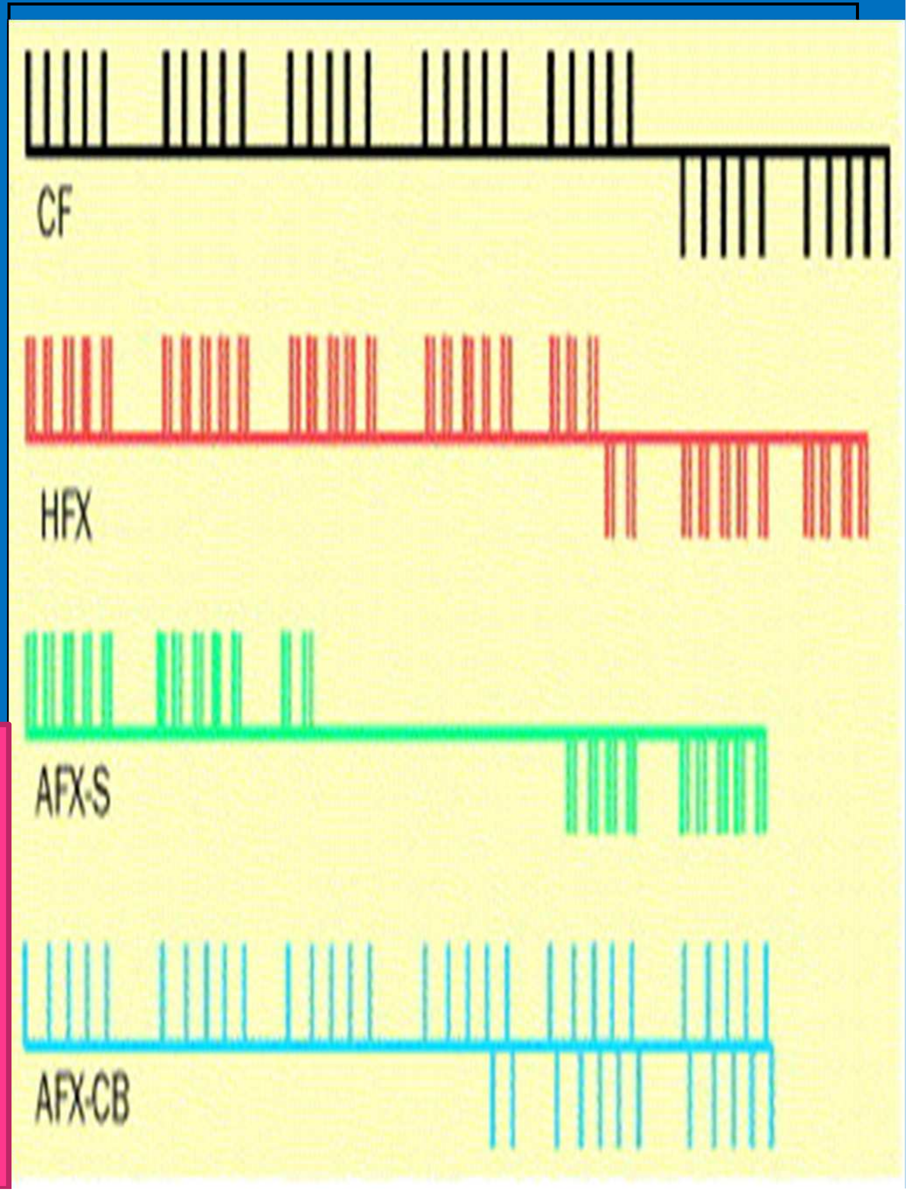
IM = Internal Margin
SM = Setup Margin

Beam arrangement/alignment

- AP/PA (parallel opposed)
- Bilateral opposing
- Bilateral tangential
- PA alone/AP alone
- 3 field technique
- 4 field box technique
- Wedge technique

Dose & fractionation schedules:

- *Total dose*
- *Overall treatment duration*
- *Size of dose /fraction*
- *Frequency of dose fractions*



Standard fractionation
Altered fractionation

Radiotherapy Treatment Planning

Simulation

Once the amount of radiation to be given has been accurately calculated, the patient then goes to the simulator to determine what settings are to be selected for the actual treatment using a linear accelerator.

The settings are determined by taking a series of x-rays to make sure that the tumour is in the correct position ready to receive the ionising radiation.

Simulation:

- Conventional simulation
- CT-Sim
- Sim-CT
- Virtual simulation

Conventional Simulator

- **Advantages**

1. Convenient and cost effective.
2. Fluoroscopic verification of isocenter.

- **Disadvantages**

1. Limited soft tissue contrast.
2. Tumour mostly not visible.
3. Requires knowledge of tumor .
4. Restricted to setting field limits with respect to bony landmarks.

CT Simulator

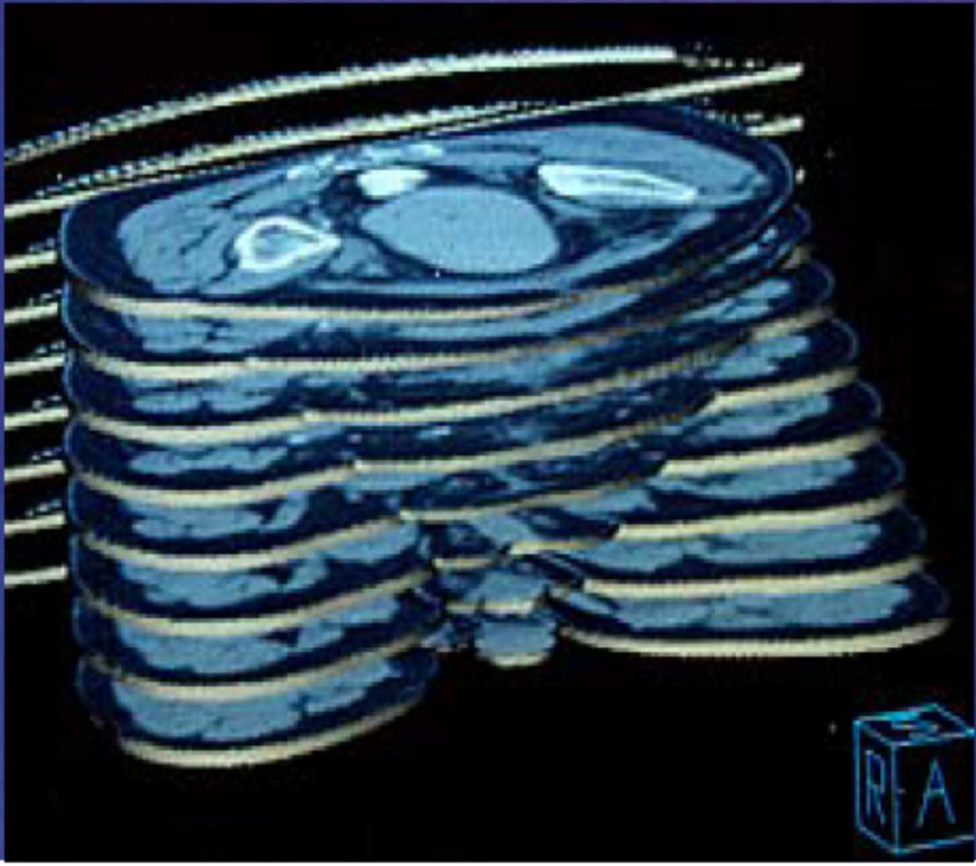
Advantages

1. Increased soft tissue contrast.
2. Axial anatomical information available.
3. Delineation of target and OARs directly on CT slices.
4. Allows DRRs.
5. Allows BEVs.
6. The patient is not required to stay after the CT-scanning has taken place

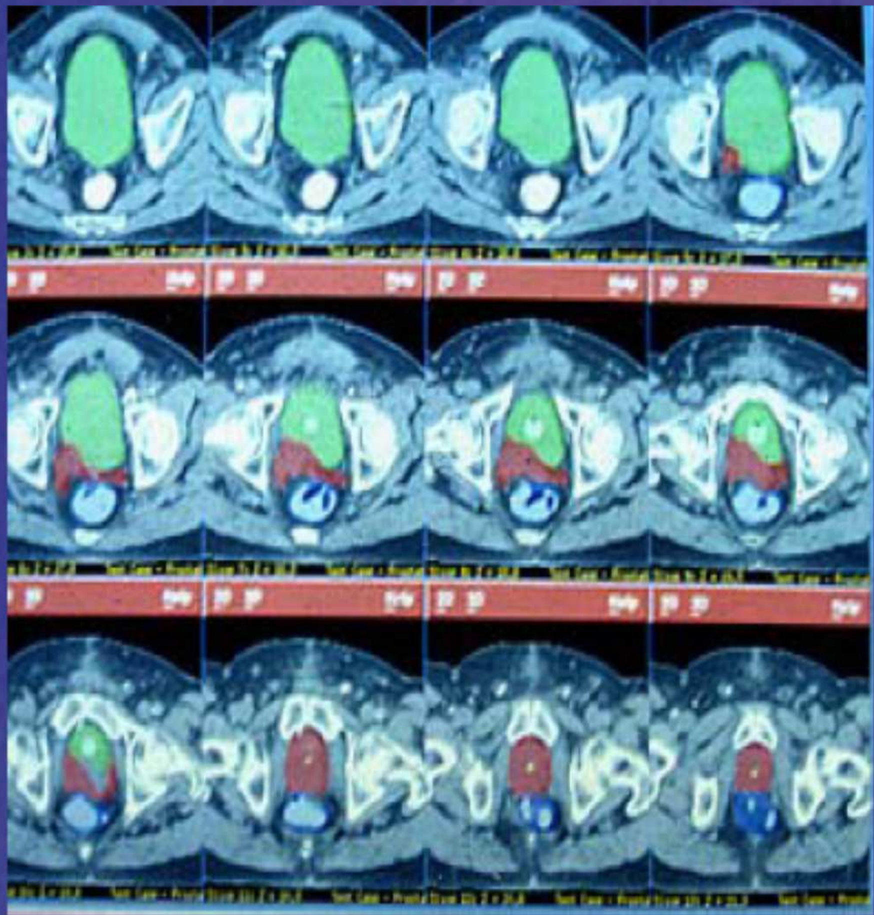
Disadvantages

1. Limitation in use for some treatment setups where patient motion effects are involved
2. Requires additional training and qualification in 3D planning

CT Slices Forming a Patient Representation is the Modern Basis for Radiotherapy



The Tumor and Sensitive Structures are Outlined



Portals

Head and neck cancers

- Oral cavity
- Oropharynx
- Hypopharynx
- Larynx
- Nasopharynx

Breast

Cervix

Rectum and anal canal

Oral Cavity

Superior-1 to 1.5 cm superior to the dorsum of tongue or 2 cm superior to the scar.

Inferior-just cephalad to the arytenoids.

Anterior-just in front of the mandible.

Posterior-just behind the spinous process.

FR/cord off-mid vertebral body.

Oropharynx

Superior-at the base of the skull to cover parapharyngeal lymphatics.

Inferior-just above the arytenoids.

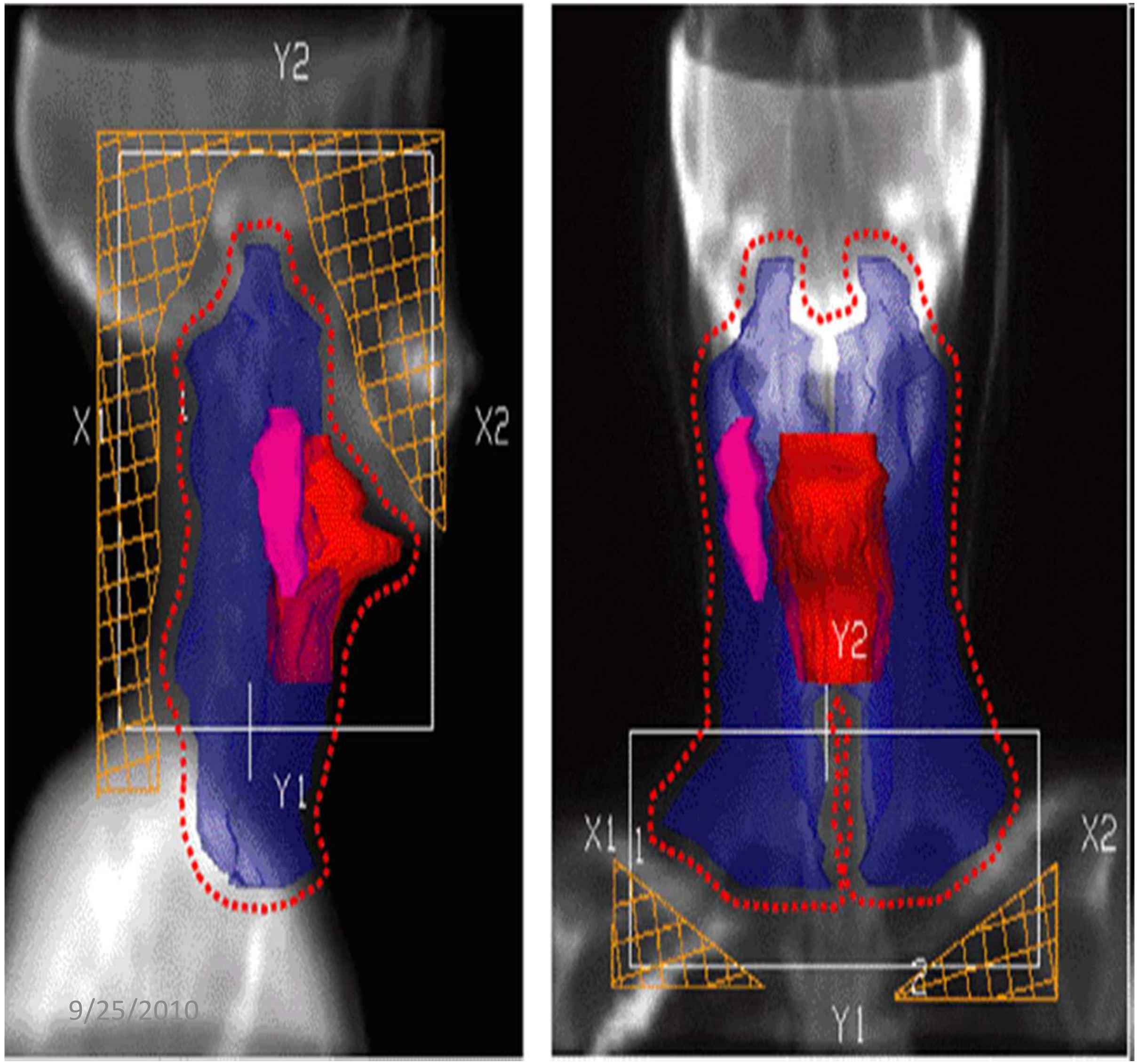
Anterior-along the anterior border of the masseter or 2 cm anterior to the known extent of the tumour.

Posterior-just behind the spinous process.

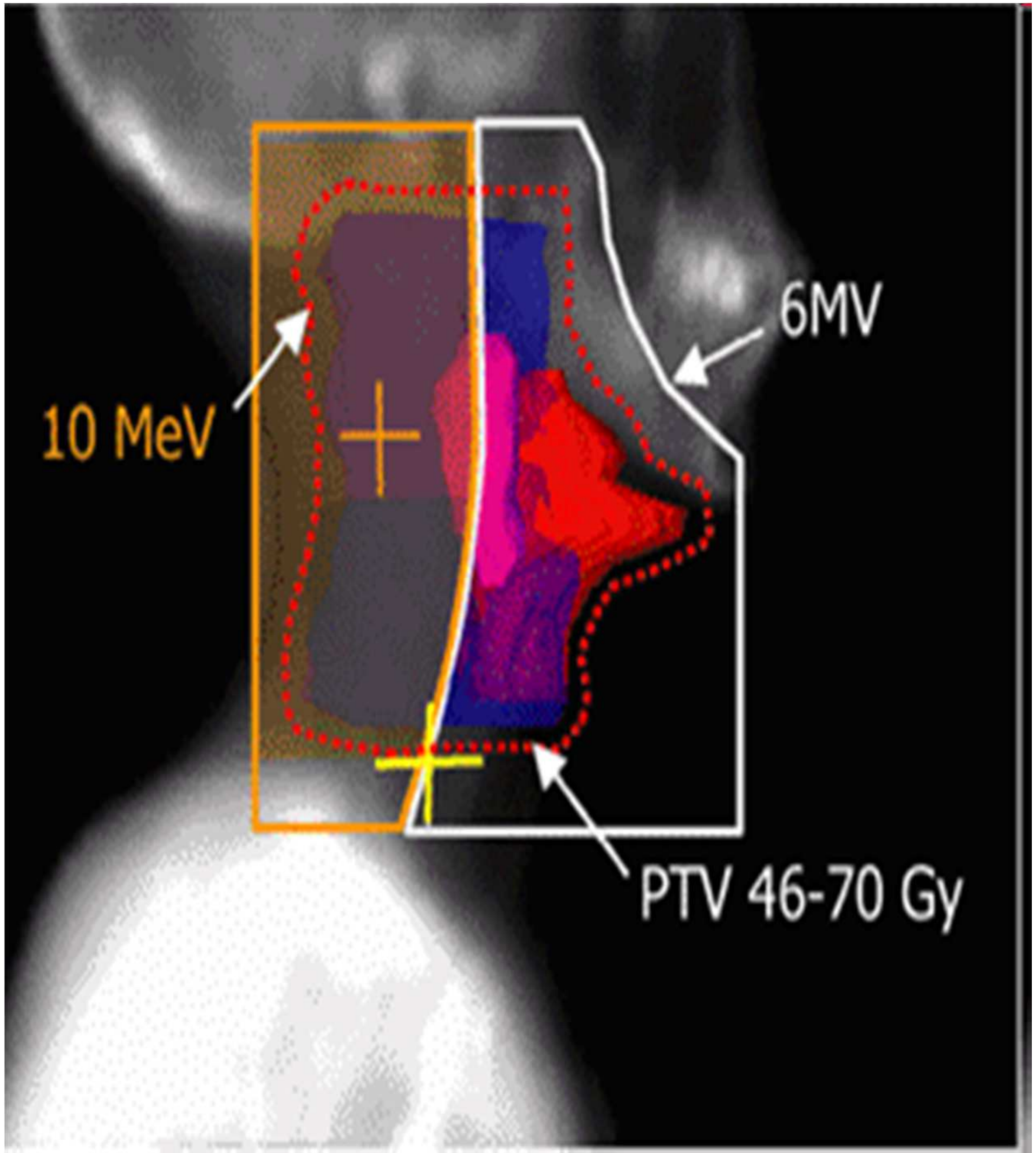
FR/cord off- mid vertebral body.

Anterior neck for treating lower neck nodes.

Oropharynx

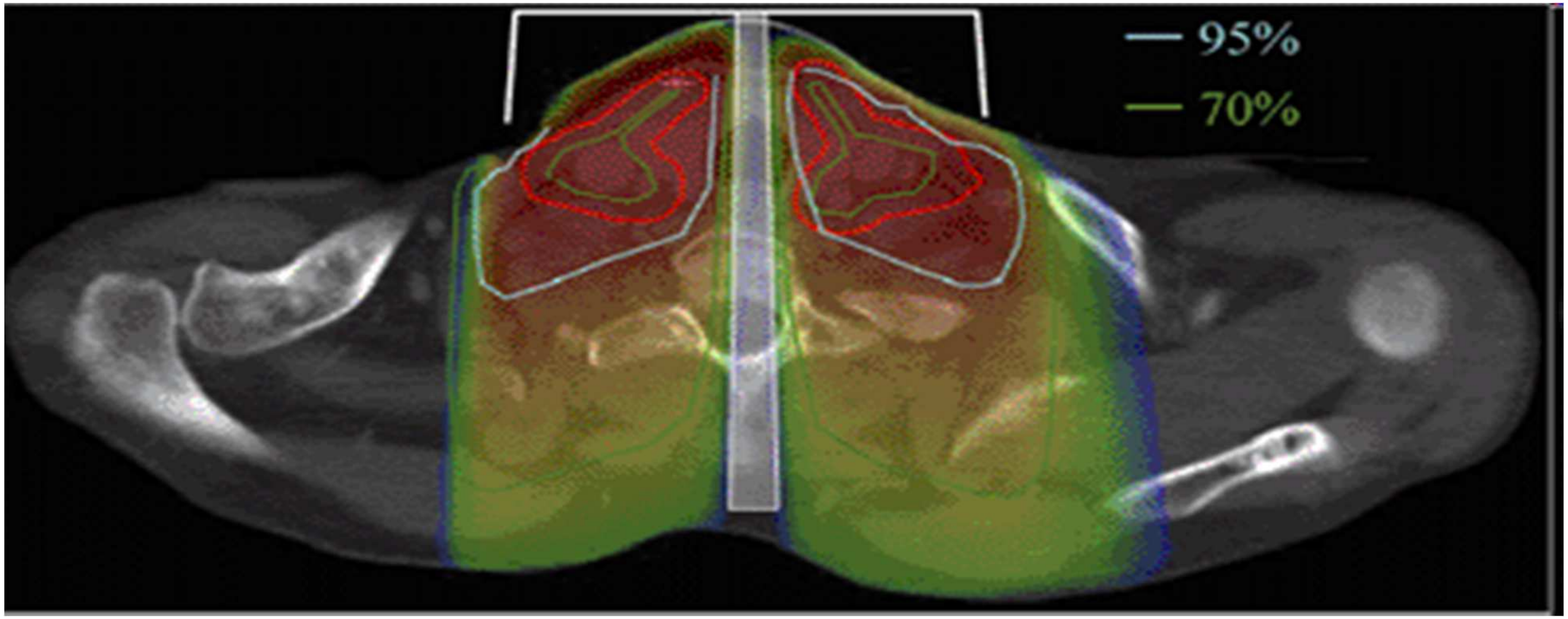


Base of tongue tumor, staged T2N2b. Beam's-eye view of conventional parallel-opposed fields of the upper neck.



9/25/2010

Cumulative dose volume histograms of base of tongue tumor treated to a cumulative dose of 70/2 Gy.



Anterior Neck portals

Hypopharynx

Superior-at base of the skull.

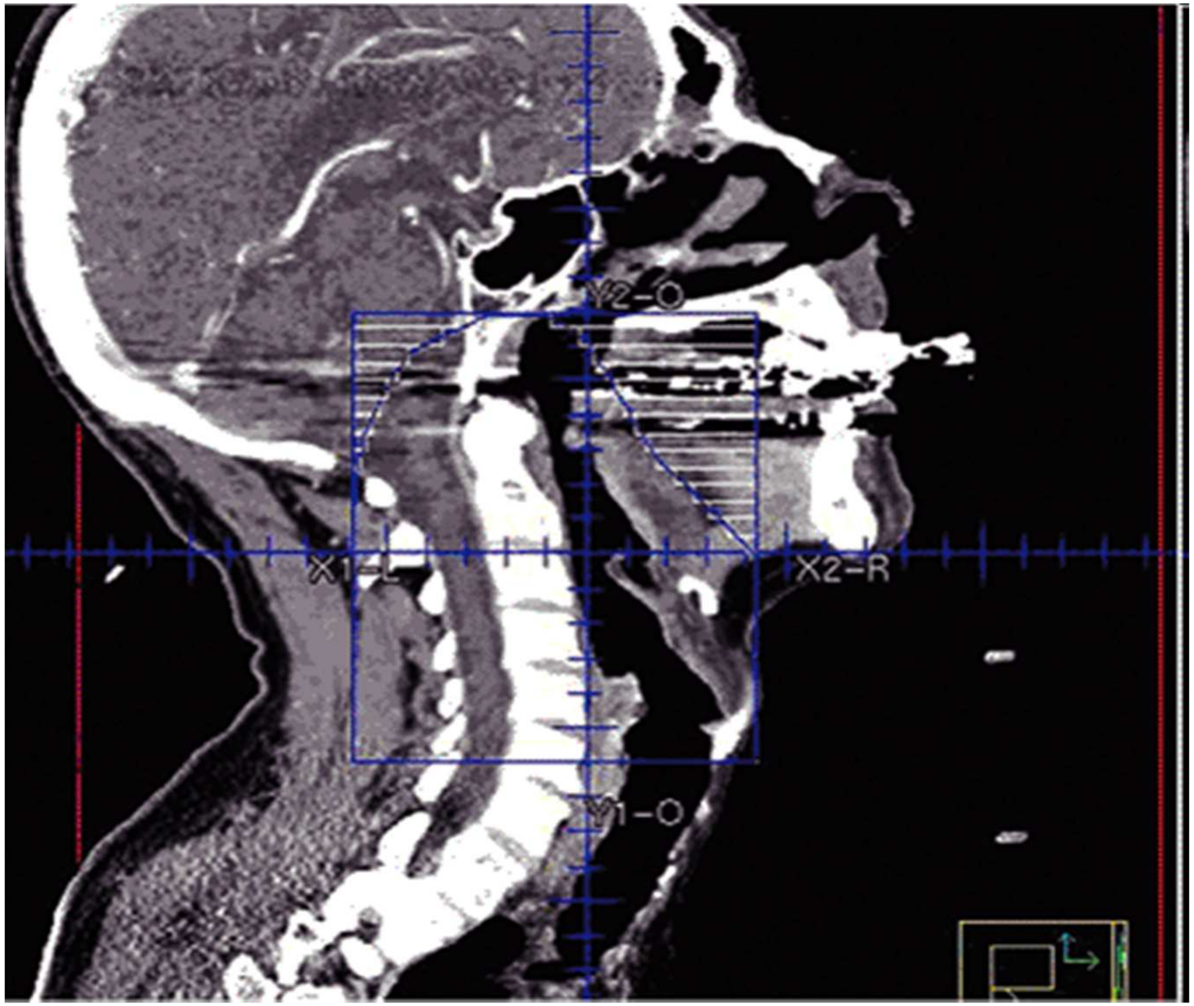
Inferior- as low as possible while avoiding the shoulders, encompasses the primary tumor with margin.

Anterior-short of fall off.

Posterior-just behind the spinous processes

Anterior portal to treat lower neck nodes.

Hypopharynx



Larynx

Superior- 2cm above the angle of mandible.

Inferior-middle or bottom of cricoid cartilage

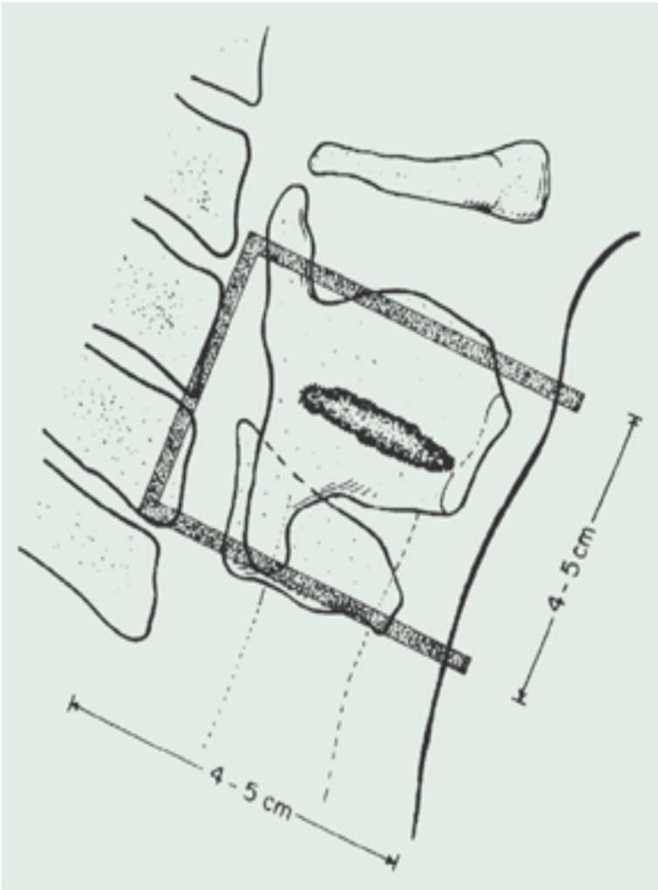
Anterior-fall off anteriorly.

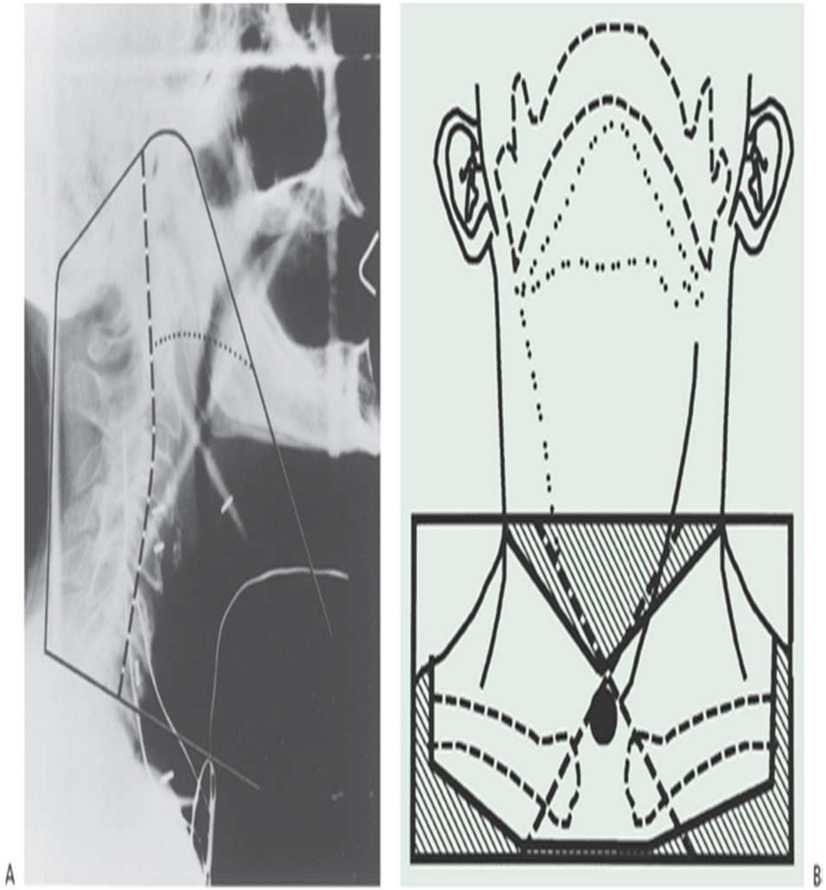
Posterior- behind the mastoid process/spinous process depending on N0 or N+ status.

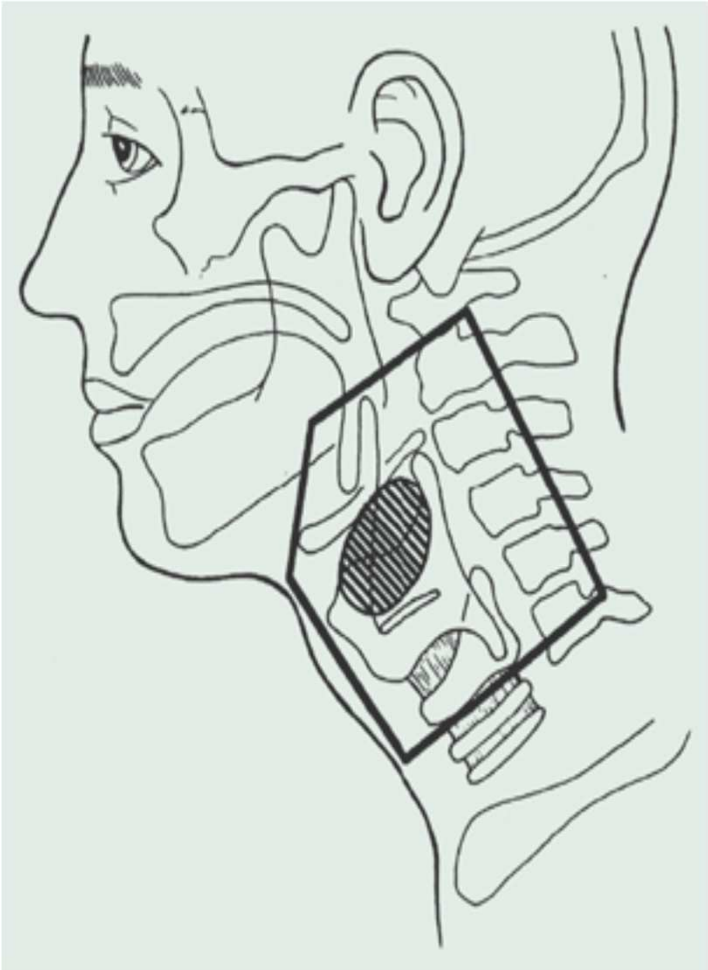
FR/cord off- antr 1/3rd of vertebral body.

Anterior neck to treat lower neck.

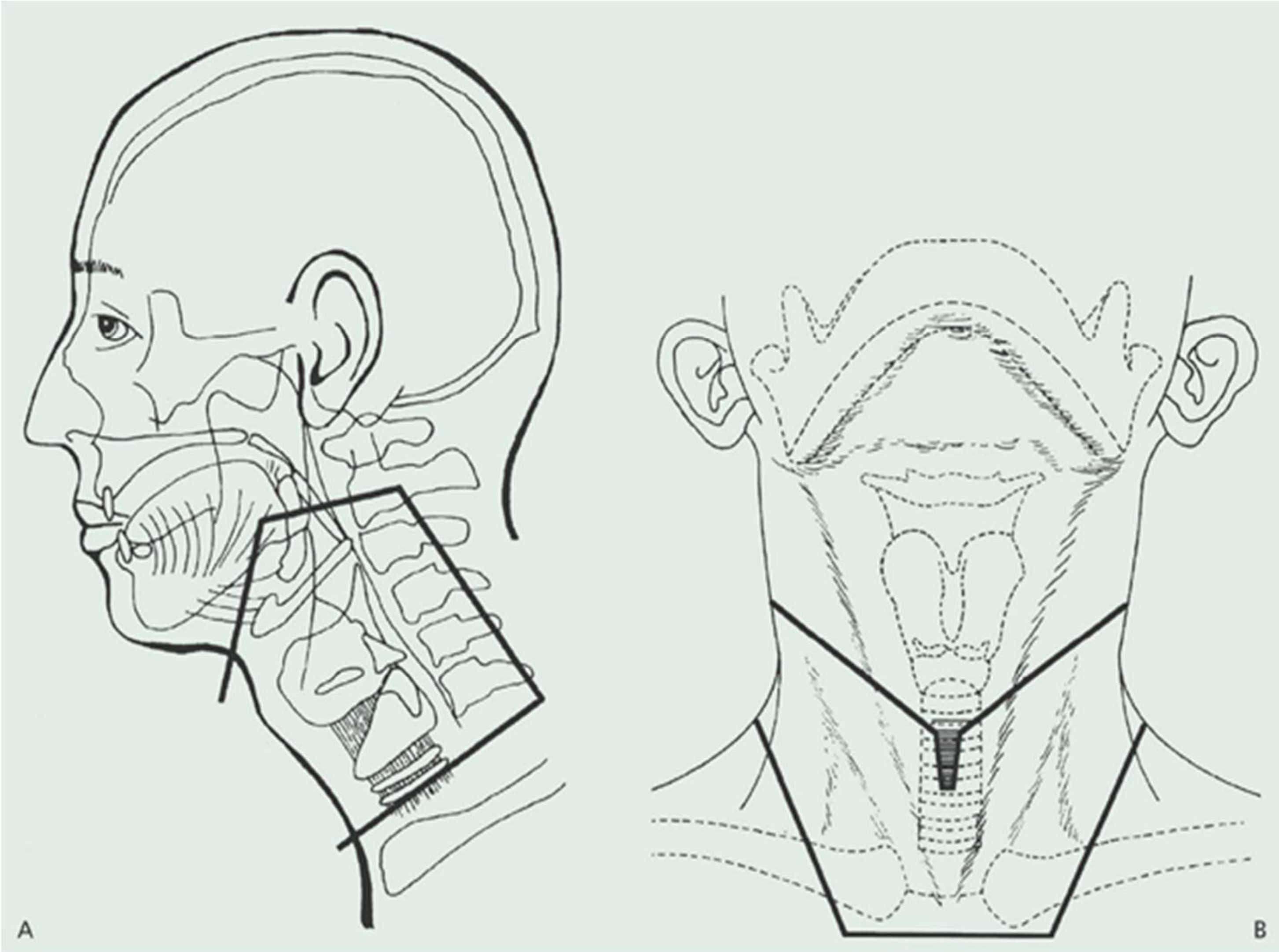
Larynx







Example of the portal for a lesion of the lower epiglottis or false vocal cord and a neck with clinically negative findings. The subdigastric nodes are included but not the junctional nodes. Depending on the anatomy and tumor extent, the anterior border may fall off (i.e., "flash") or a small strip of skin may be shielded.


A
B

Nasopharynx

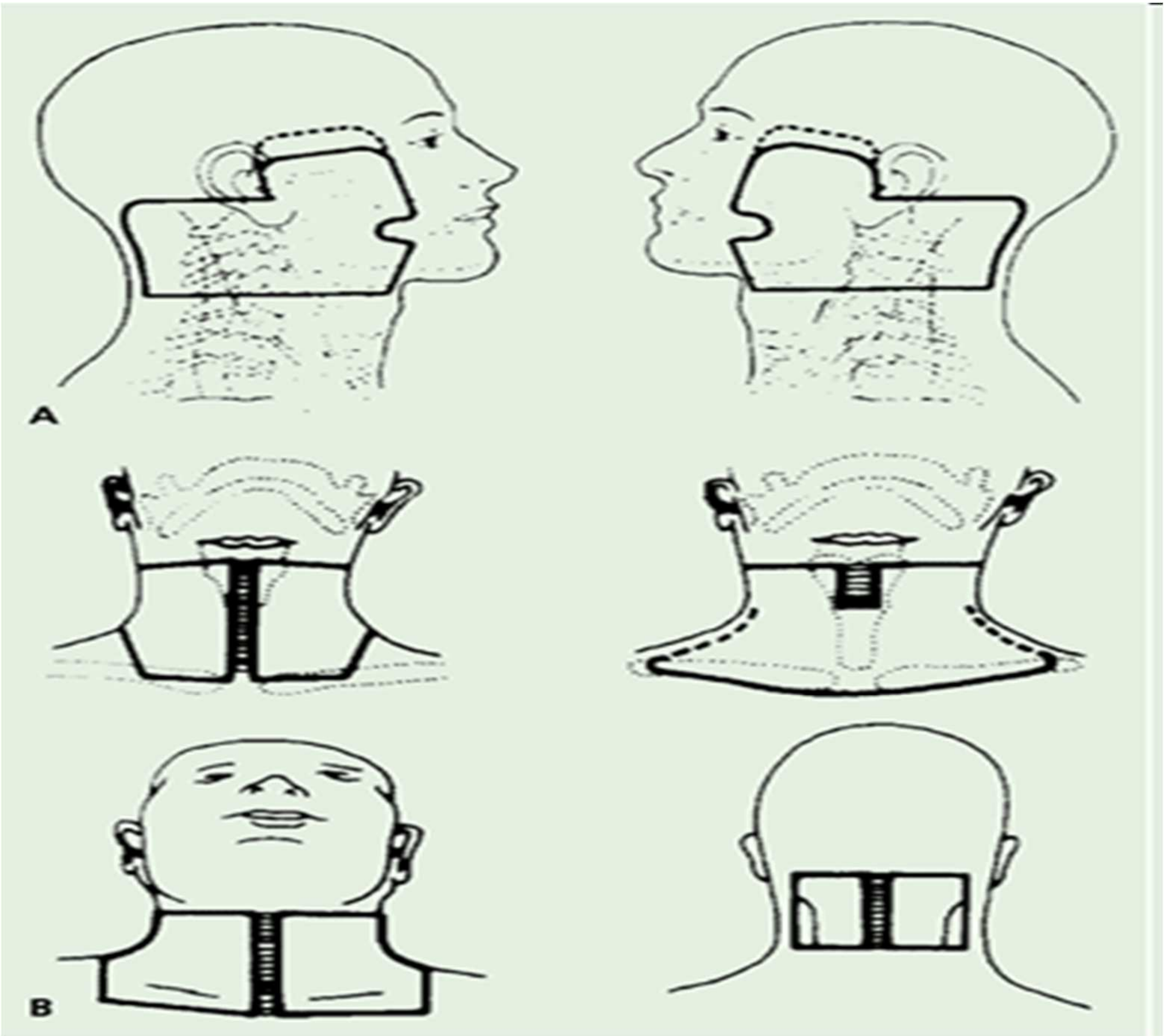
Superior- at bottom of the pituitary fossa.

Inferior-just above the arytenoids.

Anterior-postr 1/3 rd to ½ of nasal cavities are included.

Posterior-just behind the spinous process or more posterior to include large nodes.

FR/cord off- postr 1/3rd of vertebral bodies.


A
B

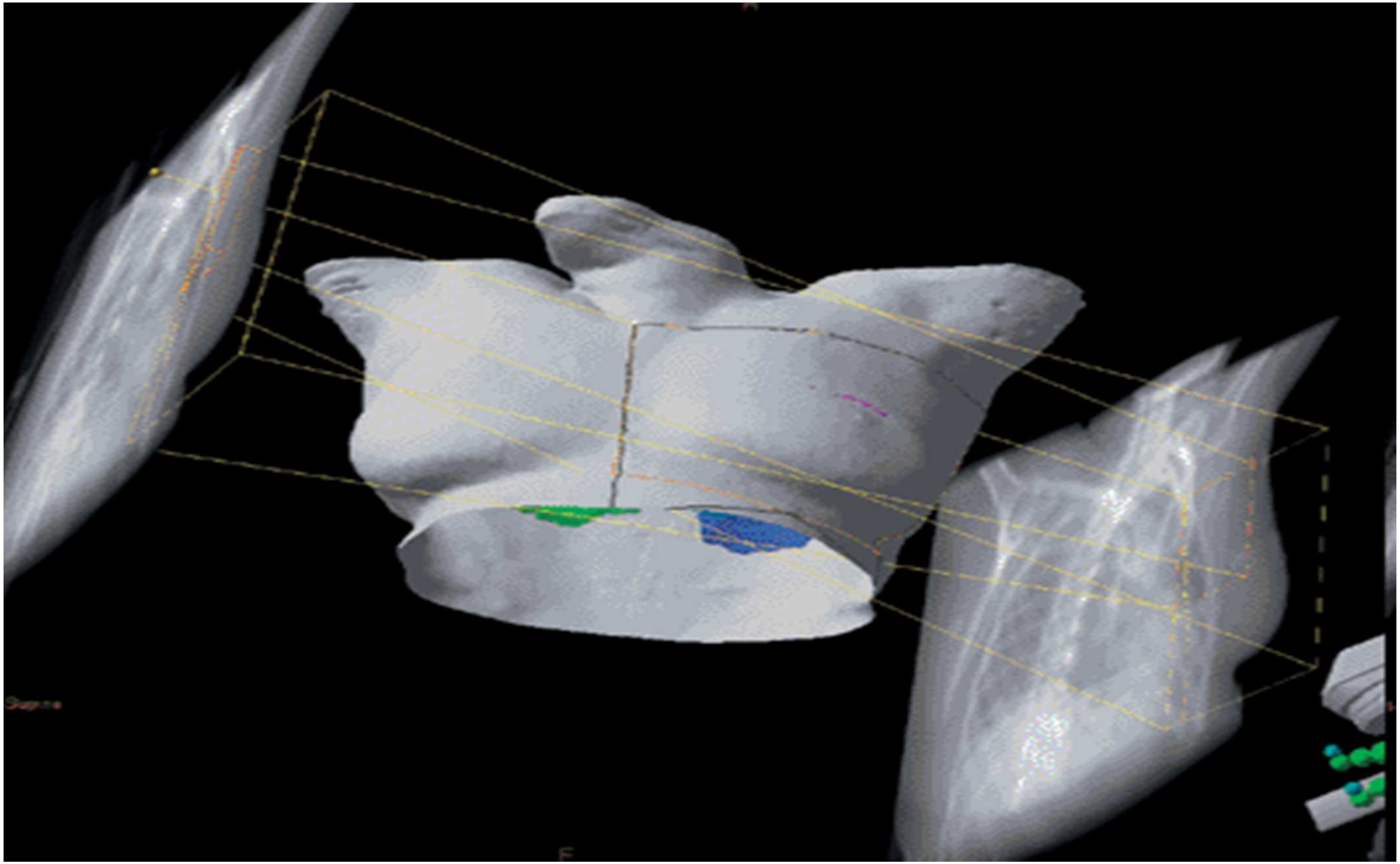
Breast

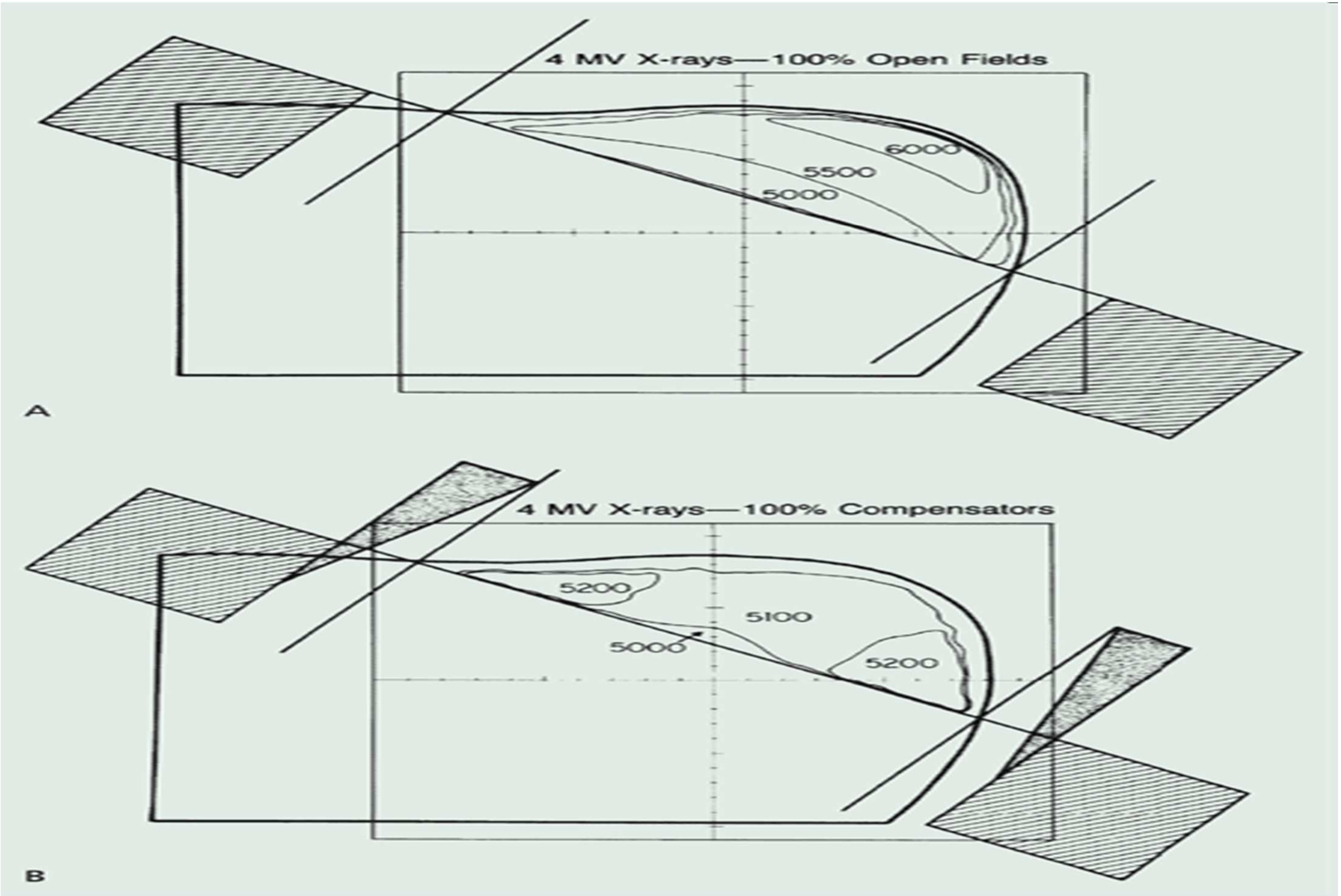
Chest wall:

- Superior-along the 2nd intercostal space
- Inferior-2cm below CL inframammary fold
- Medial-1cm over the midline.
- Lateral-2cm beyond all palpable breast tissue usually midaxillary line.

Supraclavicular region:

- Inferior-along the 2nd intercostal space.
- Medial-1cm across the midline along the medial border of the sternocleidomastoid.
- Lateral-along the anterior axillary fold or the insertion of deltoid.





4 MV X-rays—100% Open Fields
6000
5500
5000
A
4 MV X-rays—100% Compensators
5200
5100
5000
5200
B

Cervix

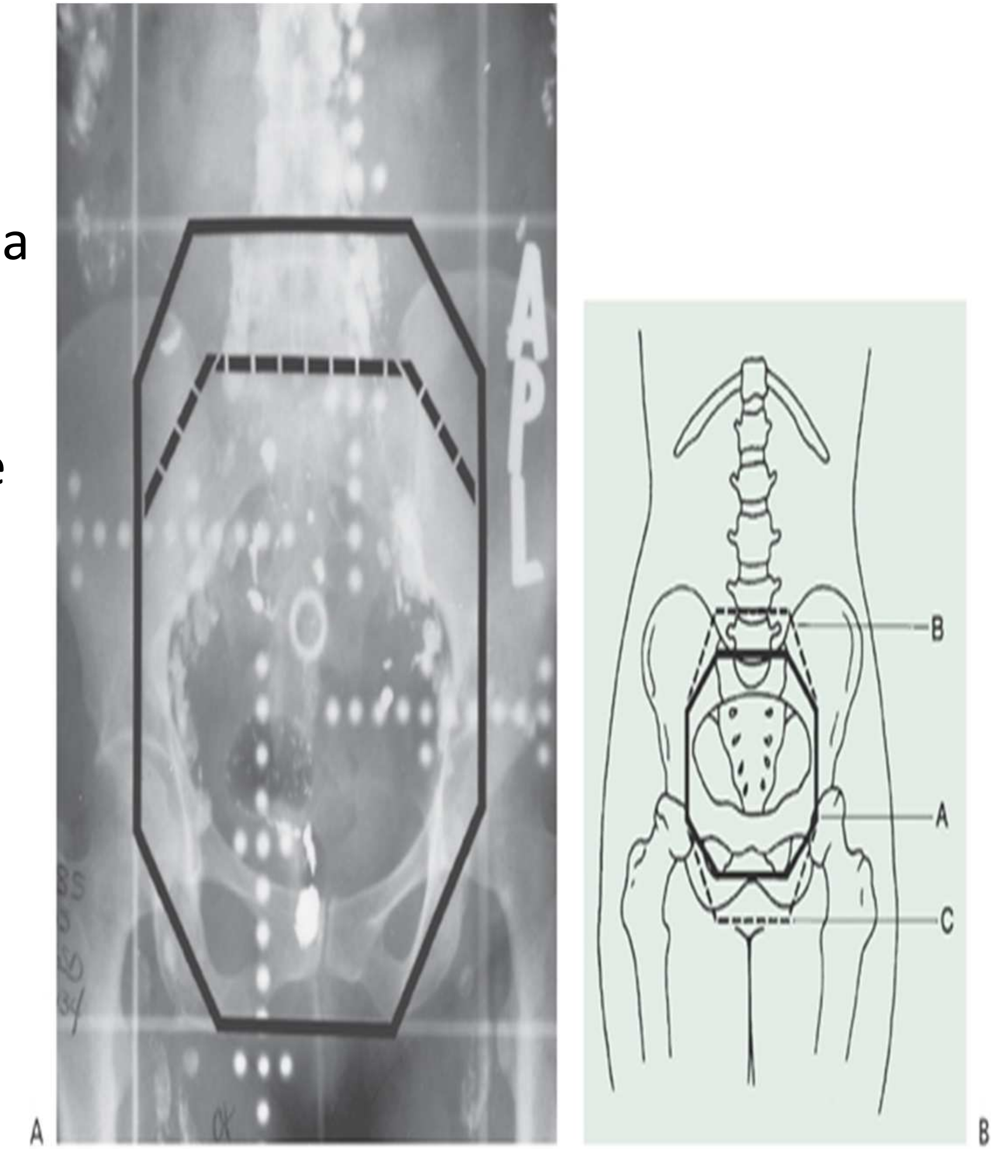
2 field technique:

- Superior –L4/L5 junction, along highest point of iliac crest.
- Inferior-IIB- just below the ischia tuberosities, IIIB-upto the introitus.
- Lateral-1.5 to 2 cm beyond true pelvis.

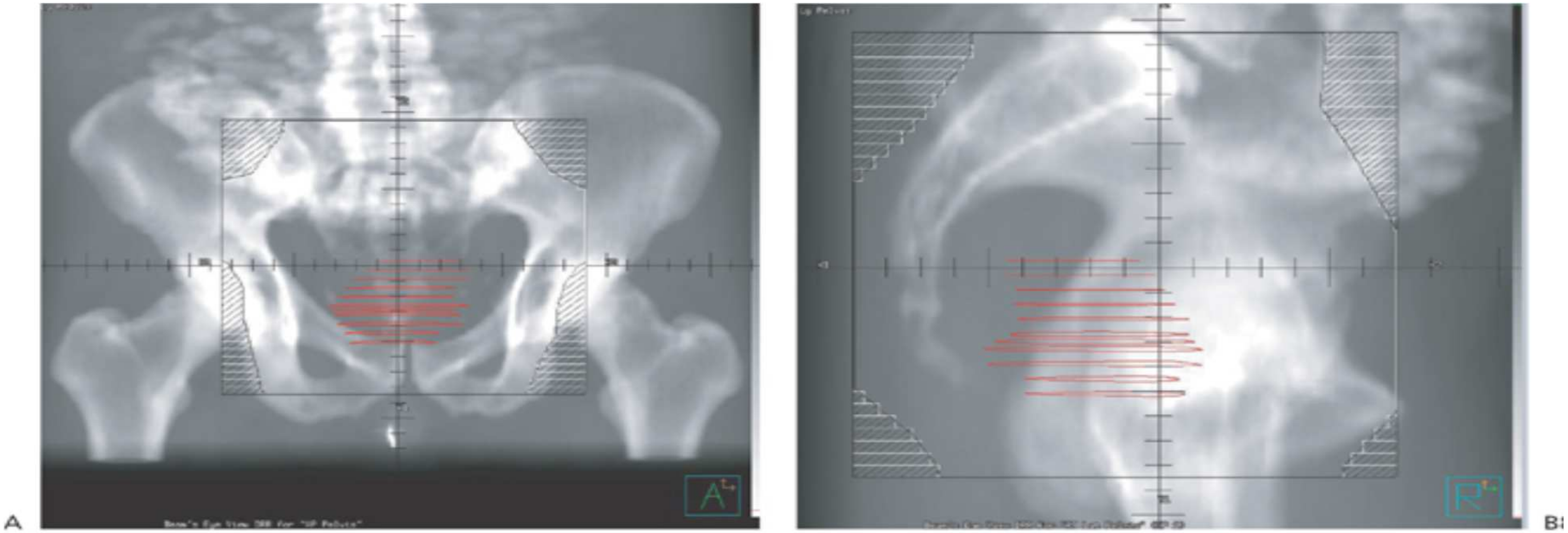
4 field technique:

Lateral fields-

- Superior –L4/L5 junction
- Inferior –same as above.
- Anterior- anterior cortex of symphysis pubis.
- Posterior-S2/S3 vertebrae.



Rectum



Superior-L5/S1 vertebra.

Inferior-2cm margin beyond distal extent of lesion.

Lateral-1.5 to 2 cm beyond true pelvis.

Lateral portals:

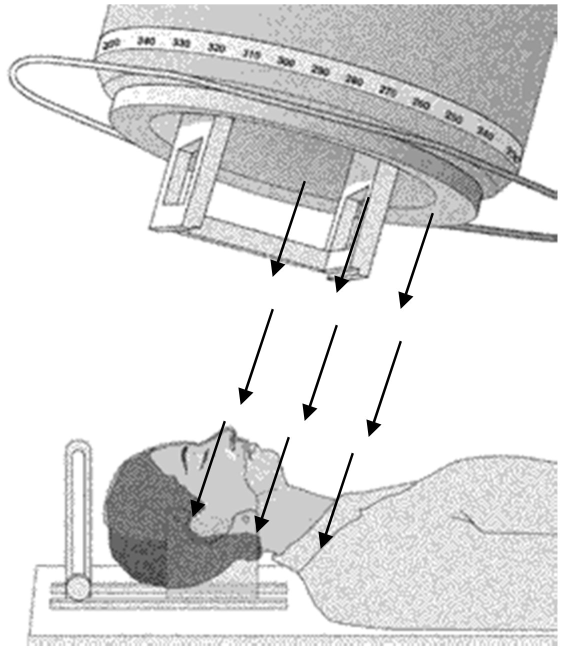
Anterior-anterior or posterior to pubic symphysis depending on N0 / N+ status.

Posterior- entire sacral hollow.

Radiotherapy Treatment

Irradiation Using High Energy Gamma Rays

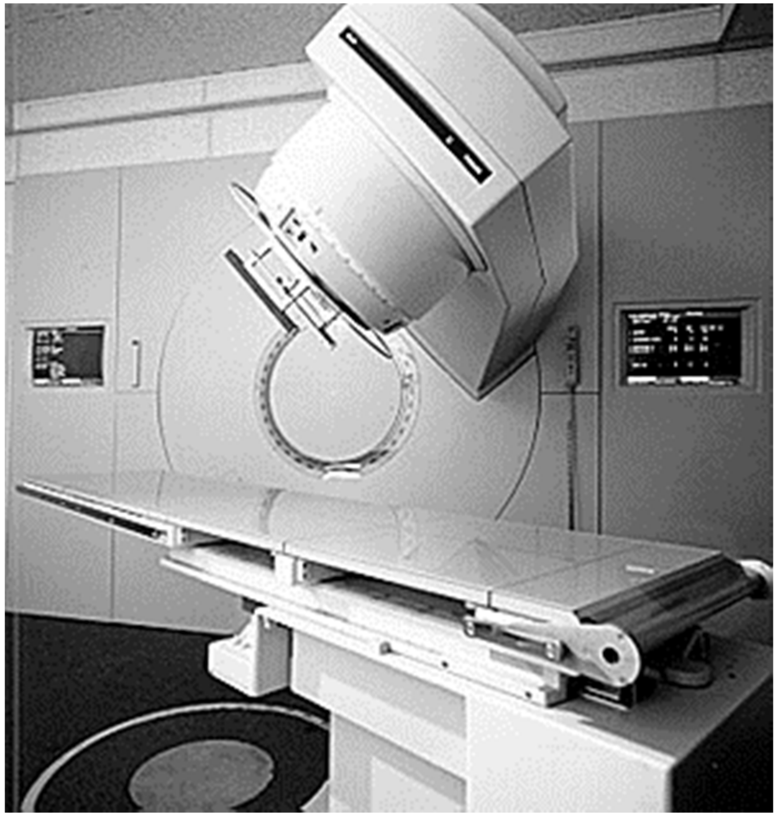
- Gamma rays are emitted from a cobalt-60 source – a radioactive form of cobalt.
- The cobalt source is kept within a thick, heavy metal container.
- This container has a slit in it to allow a narrow beam of gamma rays to emerge.



Treatment of Cancer

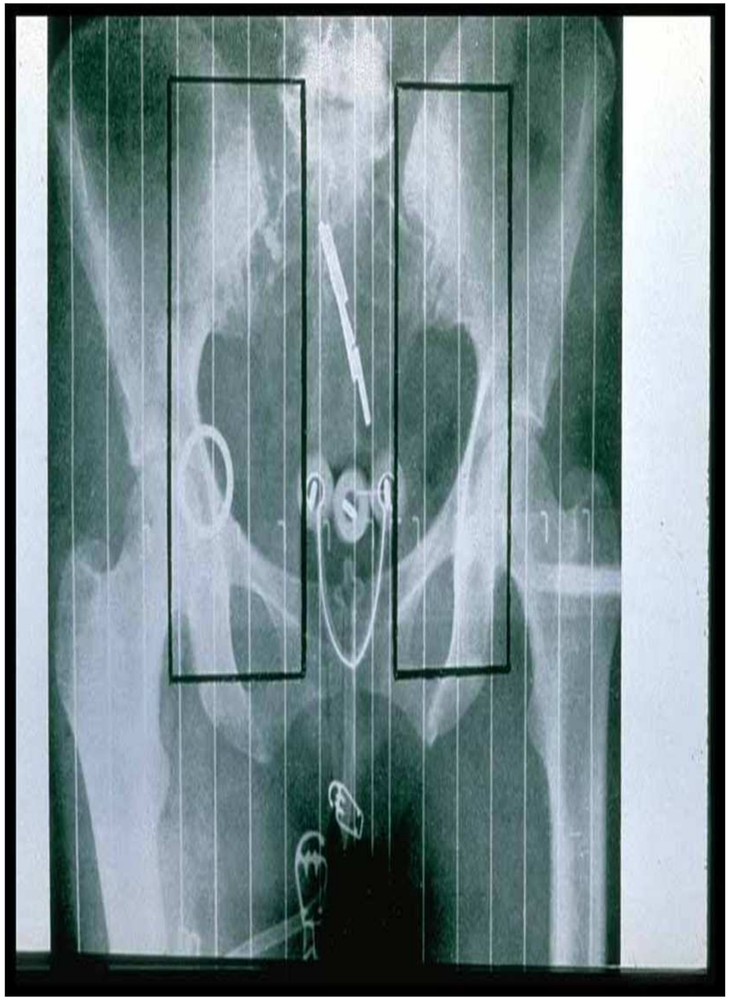
Radiotherapy

- The apparatus is arranged so that it can rotate around the couch on which the patient lies.
- This allows the patient to receive radiation from different directions.
- The diseased tissue receives radiation all of the time but the healthy tissue receives the minimum amount of radiation possible.
- Treatments are given as a series of small doses because cancerous cells are killed more easily when they are dividing, and not all cells divide at the same time – this reduces some of the side effects which come with radiotherapy.



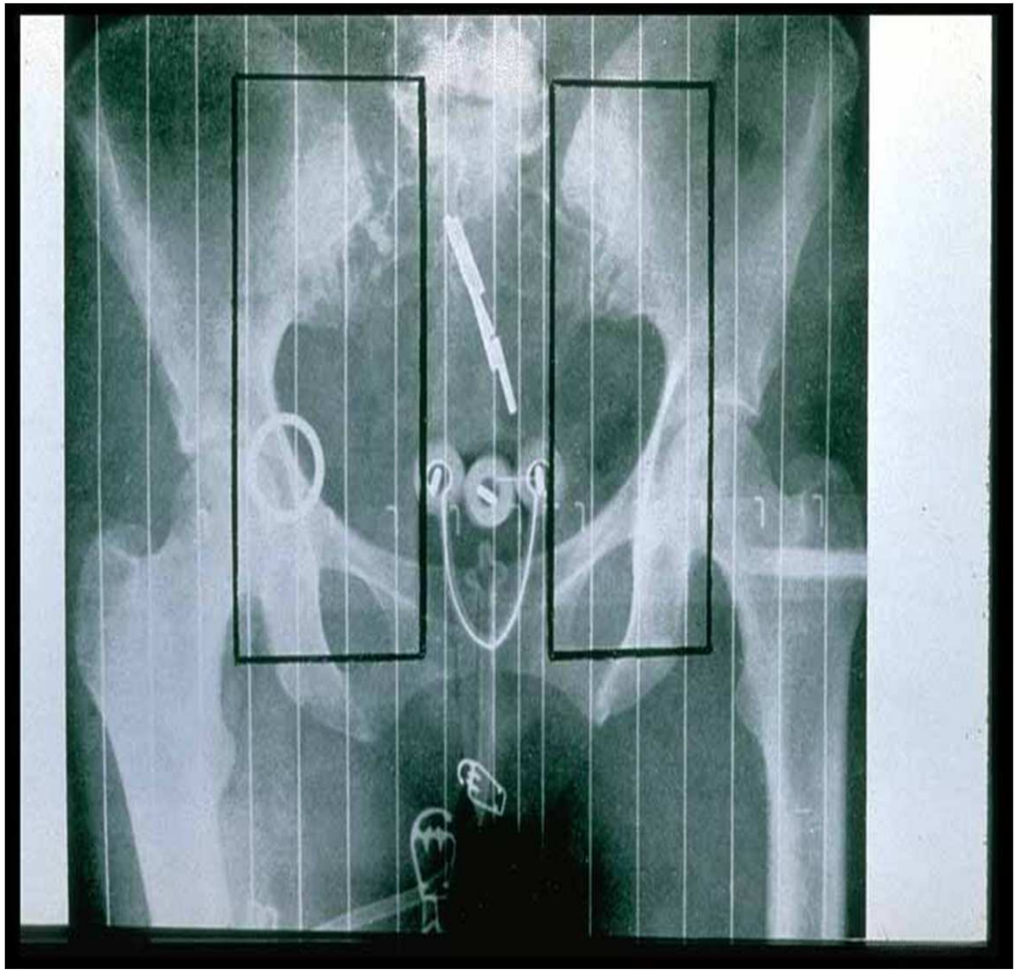
Brachytherapy

- **This involves placing implants in the form of seeds, wires or pellets directly into the tumour.**
- **Such implants may be temporary or permanant depending on the implant and the tumour itself.**
- **The benefit of such a method is that the tumour receives nearly all of the dose whilst healthy tissue hardly receives any.**

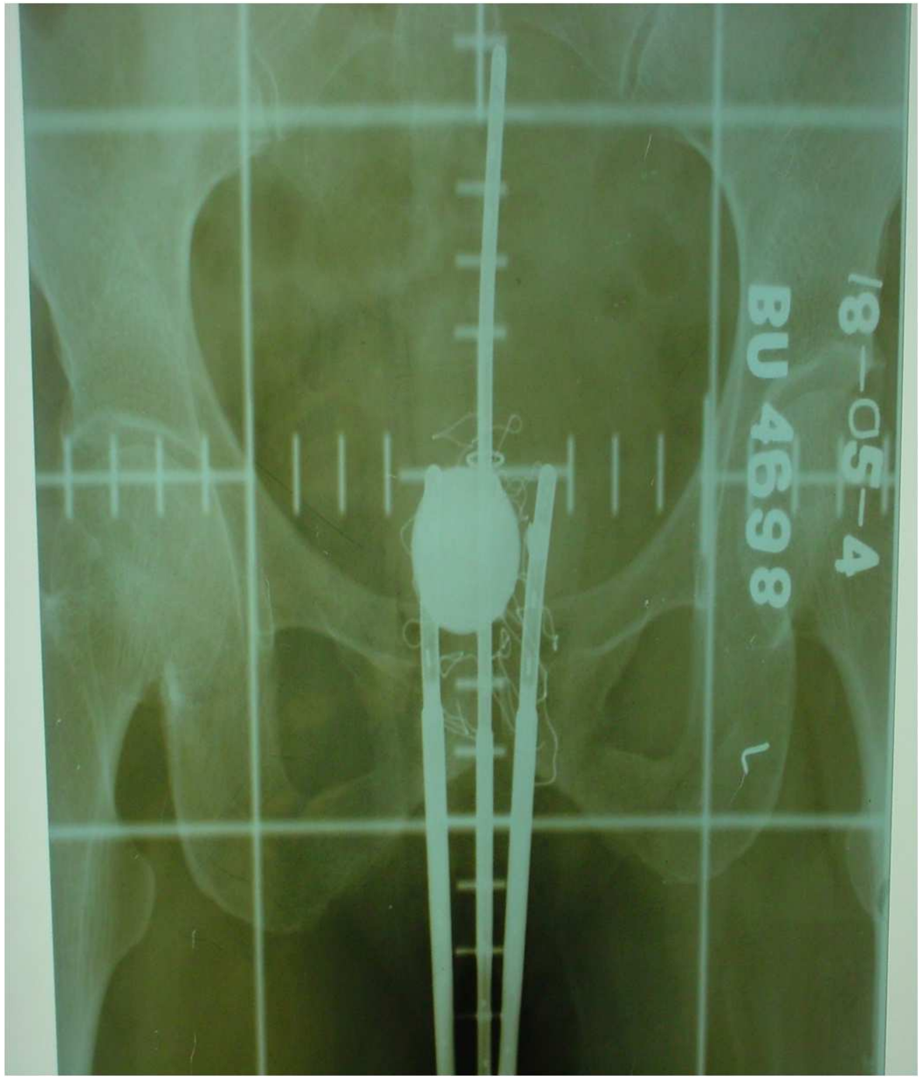


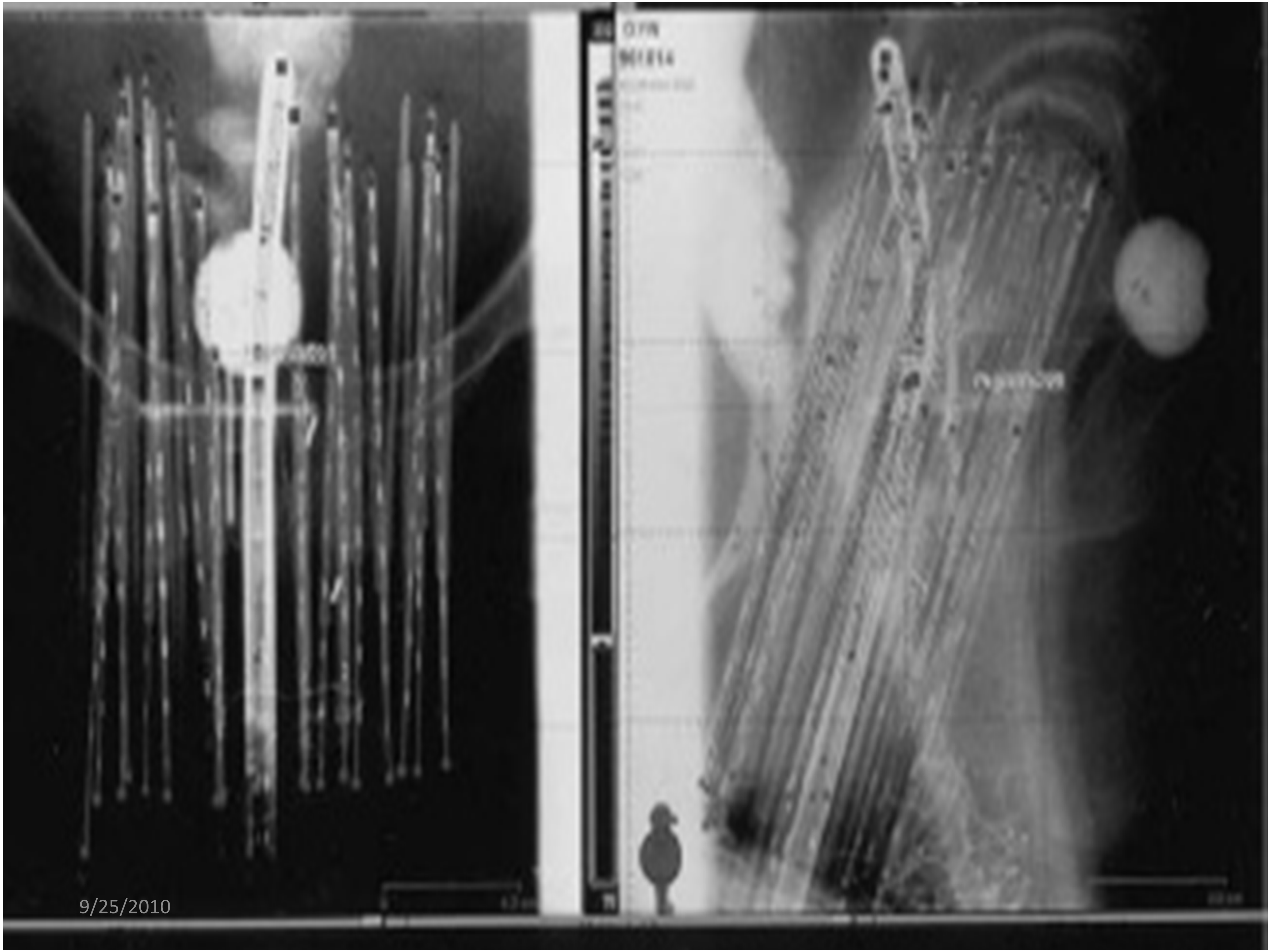
Brachytherapy
Indications/Sites:

- *Uterus*
- *Cervix*
- *Prostate*
- *Intraocular*
- *Skin*
- *Thyroid*
- *Bone*



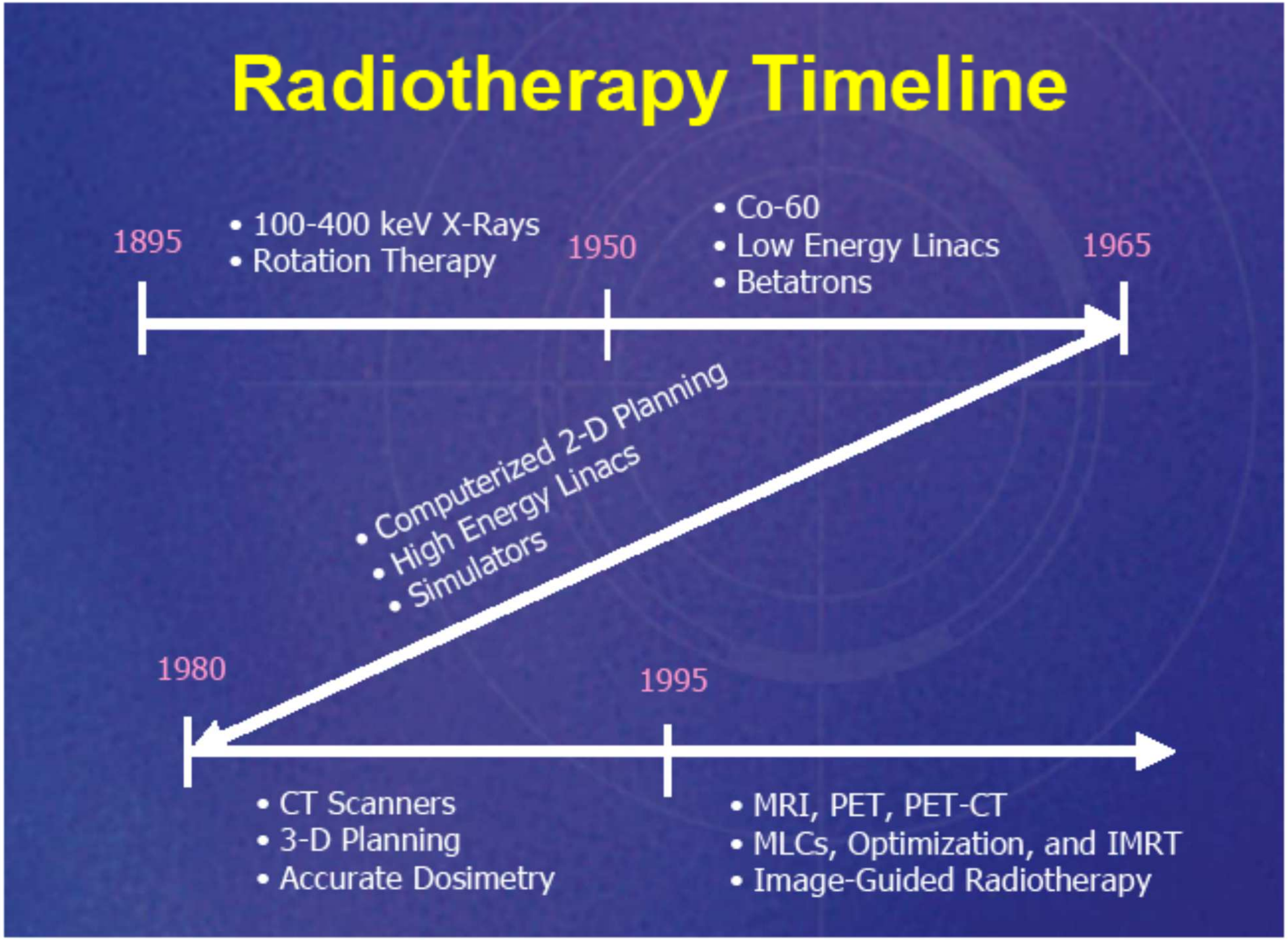
Orthogonal Xrays

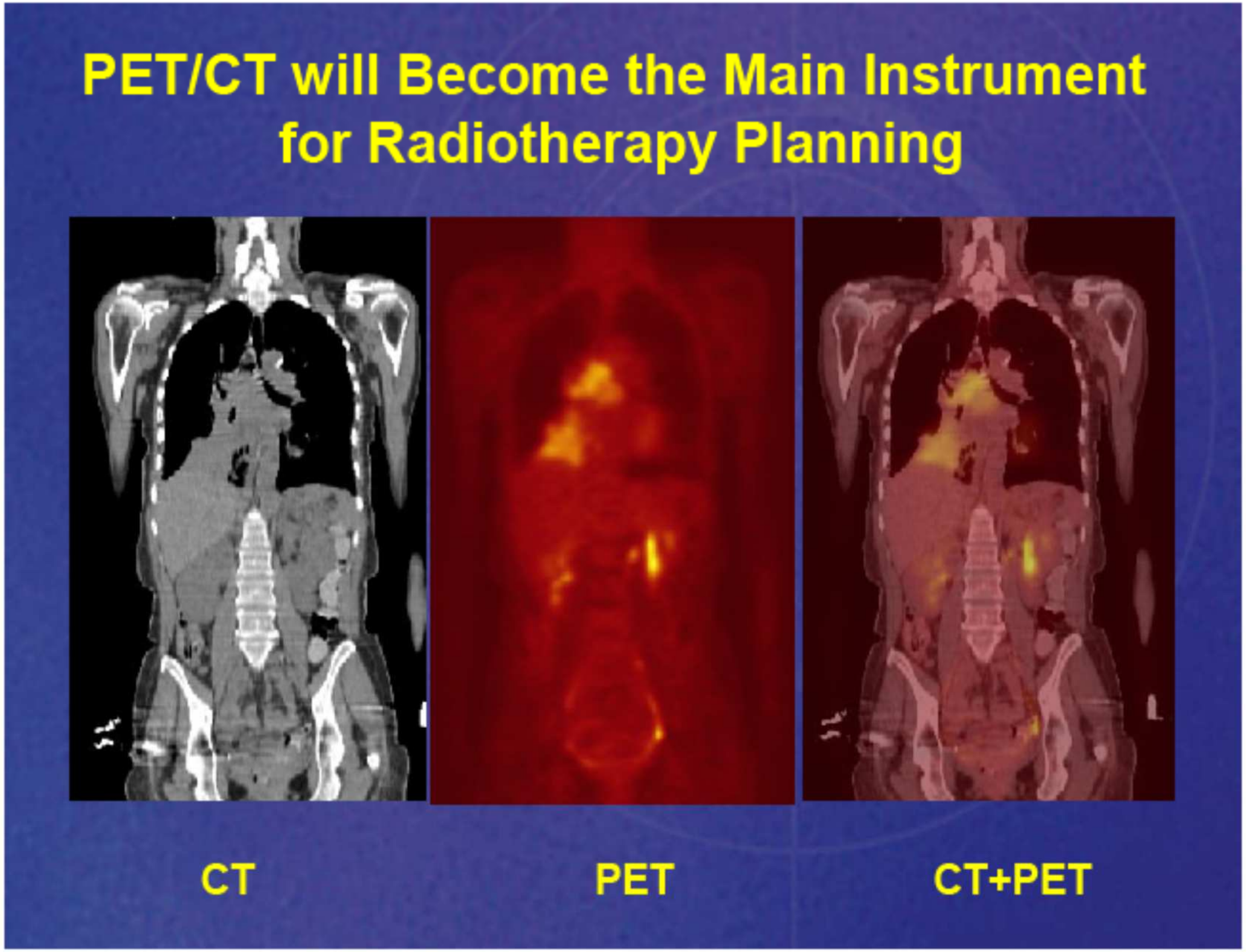




9/25/2010

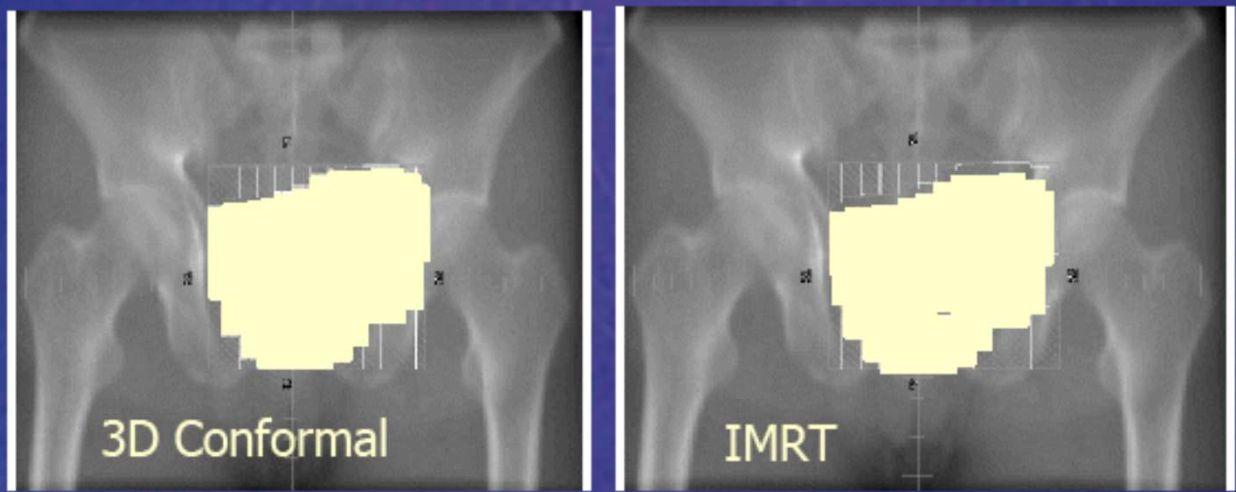

TATE BRITAIN
ST. JOHN'S SMITH SQUARE
LONDON AQUARIUM
ST. THOMAS'S HOSPITAL
THAMES PATH
WHITEHALL
THAMES PATH
Lambeth Bridge


Radiotherapy Timeline
1895
• 100-400 keV X-Rays
• Rotation Therapy
1950
• Co-60
• Low Energy Linacs
• Betatrons
1965
• Computerized 2-D Planning
• High Energy Linacs
• Simulators
1980
1995
• CT Scanners
• 3-D Planning
• Accurate Dosimetry
• MRI, PET, PET-CT
• MLCs, Optimization, and IMRT
• Image-Guided Radiotherapy


PET/CT will Become the Main Instrument for Radiotherapy Planning
CT
PET
CT+PET

Optimization and Intensity-Modulated Radiotherapy (IMRT)

- *Let the computer do the work…*



Let the computer optimize the plan, varying the intensity within each beam, to "conform" and "spare" even more.

Image-Guided Radiotherapy of the Future

- Image-based staging of the primary and regional field.
  - Determine hypoxic and highly proliferative regions using bioimaging and paint in higher dose.
  - Conformally avoid sensitive structures in the regional field.
- IMRT with 3-D image verification.
  - Less fraction quantity – greater fraction quality.
  - Adaptive radiotherapy to provide patient-specific QA of the whole course of therapy.

Image-Guided Radiotherapy of the Future (Cont.)

- Image-based monitoring of outcome.
  - e.g., PET scans for regional or metastatic development using a priori information.
- Aggressive treatment of recurrences or distant metastases using conformal avoidance to spare critical structures.
  - Better QA of first treatment will allow safer retreatments.
  - "Weeding the garden" with image-guided radiotherapy and prevent spread with chemotherapy and immunotherapy.

Conclusion

- **Conventional RT means standard/ traditional.**
- **Patient positioning, immobilization, treatment portals ,dose and fractionation are of paramount importance.**
- **ICRU recommendations of target volumes to be strictly followed.**
- **Basic education on standard treatment is a prerequisite for conformal techniques.**
- **3D CRT, IMRT, IGRT, Tomotherapy, Rapid arc have become the state of the art of Radiation Oncology.**
- ***However , in search of the tree we should not forget the forest!***


9/25/2010
PHOTOS BY